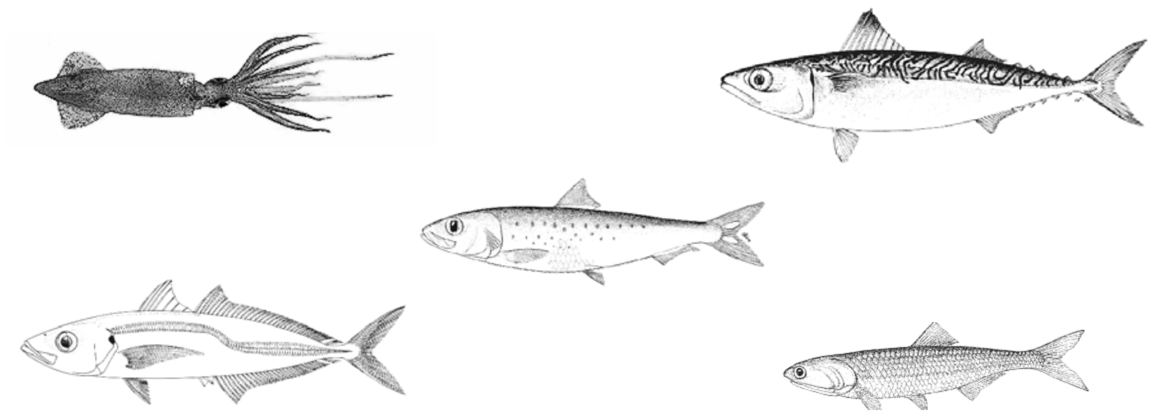
STATUS OF THE PACIFIC COAST COASTAL PELAGIC SPECIES FISHERY AND RECOMMENDED ACCEPTABLE BIOLOGICAL CATCHES

STOCK ASSESSMENT AND FISHERY EVALUATION 2016



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LIST OF ACRONYMS AND ABBREVIATIONS

ABC	acceptable biological catch
ACL	annual catch limit
ACT	annual catch target
ADEPT	a population analysis model
APA	Administrative Procedures Act
ASAP	Age-structured Assessment Program
BO	Biological Opinion
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CANSAR-TAM	Catch-at-age Analysis for Sardine - Two Area Model
CC	California Current
CCLME	California Current Large Marine Ecosystem
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CFGC	California Fish and Game Commission
CONAPESCA	National Commission of Aquaculture and Fisheries (Mexico)
Council	Pacific Fishery Management Council
CPFV	commercial passenger fishing vessel
CPS	coastal pelagic species
CPSAS	Coastal Pelagic Species Advisory Subpanel
CPSMT	Coastal Pelagic Species Management Team
CPSPDT	Coastal Pelagic Species Plan Development Team
CPUE	catch per unit effort
CS	catch shares
CUTOFF	The lowest estimate of biomass at which directed harvest is allowed
EBFM	ecosystem based fishery conservation and management
EEZ	exclusive economic zone
EFH	essential fish habitat
EFMP	ecosystem fishery management plan
EIS	environmental impact statement
ENSO	El Niño southern oscillation
ESA	Endangered Species Act
FMP	fishery management plan
GT	gross tonnage
HCR	harvest control rule
HG	harvest guideline
INP	Instituto Nacional de la Pesca (Mexico)
LE	limited entry
LME	large marine ecosystem
Magnuson Act	Magnuson-Stevens Fishery Conservation and Management Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MAXCAT	maximum harvest level parameter
MEI	Multivariate El Niño Index
MSFMP	Market Squid Fishery Management Plan
MSST	Minimum Stock Size Threshold
MSY	maximum sustainable yield

mt	metric ton
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	notice of intent
NSNA	Northern subpopulation of northern anchovy
NWFSC	Northwest Fisheries Science Center (NMFS)
NWR	National Marine Fisheries Service (NMFS) Northwest Region
ODFW	Oregon Department of Fish and Wildlife
OFL	overfishing limit
OFWC	Oregon Fish and Wildlife Commission
OMB	Office of Management and Budget
OY	optimum yield
PacFIN	Pacific Coast Fisheries Information Network
PDO	Pacific Decadal Oscillation
PFAU	Pelagic Fisheries Assessment Unit
PRD	Protected Resource Division
RecFIN	Recreational Fishery Information Network
RIR	regulatory impact review
ROV	remotely operated vehicle
SAFE	stock assessment and fishery evaluation
Secretary	U.S. Secretary of Commerce
SFD	Sustainable Fisheries Division
SS2	Stock Synthesis 2
SSC	Scientific and Statistical Committee
SST	sea surface temperature
st	short ton
STAR	Stock Assessment Review (Panel)
STAT	Stock Assessment Team
SWFSC	Southwest Fisheries Science Center (NMFS)
SWR	Southwest Region (NMFS)
TF	transformation frontier
USFWS	U.S. Fish and Wildlife Service
VPA	virtual population analysis
WCR	NMFS West Coast Region
WDFW	Washington Department of Fish and Wildlife

1.0 INTRODUCTION

The purpose of this report is to briefly summarize aspects of the coastal pelagic species (CPS) Fishery Management Plan (FMP) and to describe the history of the fishery and its management. This report includes information generally through calendar year 2015, although some sections include more recent information. The guidelines for FMPs published by the National Marine Fisheries Service (NMFS) require that a stock assessment and fishery evaluation (SAFE) report be prepared and reviewed annually for each species managed under this FMP: Pacific sardine (*Sardinops sagax*), Pacific mackerel (*Scomber japonicus*), northern anchovy (*Engraulis mordax*), jack mackerel (*Trachurus symmetricus*), market squid (*Doryteuthis opalescens*), and krill (*euphausiid spp.)*. Pacific herring (*Clupea pallasi*) and jacksmelt (*Atherinopsis californiensis*) were added as Ecosystem Component species, concurrent with Council approval of Amendment 13 to the CPS FMP. Shared ecosystem component species were subsequently added with Amendment 15. The SAFE report for Pacific Coast CPS fisheries was developed by the Council's Coastal Pelagic Species Management Team (CPSMT) from information contributed by scientists at NMFS, the Southwest and Northwest Fisheries Science Centers (SWFSC, NWFSC), California Department of Fish and Wildlife (CDFW), Oregon Department of Fish and Wildlife (ODFW), and Washington Department of Fish and Wildlife (WDFW). Included in this report are descriptions of landings, fishing patterns, estimates of the status of stocks, and acceptable biological catches (ABCs). Stock assessments for Pacific sardine and Pacific mackerel are typically published in briefing book materials in April and June, respectively. In addition, they may be included as appendices to the SAFE report, when there is a new full or updated assessment, or a projection estimate available. The ABC recommendations, together with social and economic factors, are considered by the Council in determining annual harvest guidelines and other measures for actively managed fisheries (i.e., Pacific mackerel and Pacific sardine).

2.0 THE CPS FISHERY

2.1 Management History

The CPS FMP builds on the *Northern Anchovy Fishery Management Plan*, which was implemented in September 1978. The Council began to consider expanding the scope of the northern anchovy FMP in 1990, with development of the seventh amendment to the FMP. The intent was to develop a greatly modified FMP, which included a wider range of coastal pelagic finfish and market squid. A complete draft was finished in November of 1993, but the Council suspended further work because NMFS withdrew support due to budget constraints. In July 1994, the Council decided to proceed with public review of the draft FMP. NMFS agreed with the decision on the condition that the Council also consider the options of dropping or amending the northern anchovy FMP. Four principal options were considered for managing CPS fisheries:

1. Drop the anchovy FMP (results in no Federal or Council involvement in CPS).
2. Continue with the existing FMP for anchovy (status quo).
3. Amend the FMP for northern anchovy.
4. Implement an FMP for the entire CPS fishery.

In March 1995, after considering the four options, the Council decided to proceed with option four, developing an FMP for the entire CPS fishery. Final action was postponed until June 1995 when the Council adopted a draft plan that had been revised to address comments provided by NMFS and the Council's Scientific and Statistical Committee (SSC). Amendment 7 was submitted to the U.S. Secretary of Commerce (Secretary), but rejected by NMFS Southwest Region (SWR) as being inconsistent with National Standard 7. NMFS announced its intention to drop the FMP for northern anchovy in a proposed rule published in the *Federal Register* on March 26, 1996 (61*FR*13148). The proposed rule was withdrawn on November 26, 1996 (61*FR*60254). Upon implementation of Amendment 8 (see below), the northern anchovy FMP was renamed the Coastal Pelagic Species Fishery Management Plan.

2.2 Recent Management

For a complete listing of formal Council actions and NMFS regulatory actions since implementation of the CPS FMP see Tables 2-1 and 2-2, respectively.

2.2.1 Amendment 8

Development of Amendment 8 to the northern anchovy FMP began during June 1997 when the Council directed the Coastal Pelagic Species Plan Development Team (CPSMT) to amend the FMP for northern anchovy to conform to the recently revised Magnuson-Stevens Fishery Conservation and Management Act (MSA) and to expand the scope of the FMP to include other species harvested by the CPS fishery.

In June 1999, NMFS partially approved the CPS FMP. Approved FMP elements included: (1) the management unit species; (2) CPS fishery management areas, consisting of a limited entry (LE) zone and two subareas; (3) a procedure for setting annual specifications including harvest guidelines (HG), quotas, and allocations; (4) provisions for closing directed fisheries when the directed portion of an HG or quota is taken; (5) fishing seasons for Pacific sardine and Pacific mackerel; (6) catch restrictions in the LE zone and, when the directed fishery for a CPS is closed, limited harvest of that species to an incidental limit; (7) an LE program; (8) authorization for NMFS to issue exempted fishing permits for the harvest of CPS that otherwise would be prohibited; and (9) a framework process to make management decisions without amending the FMP.

At that time, NMFS disapproved the optimum yield (OY) designation for market squid, because there was no estimate of maximum sustainable yield (MSY). Bycatch provisions were disapproved for lack of standardized reporting methodology to assess the amount and type of bycatch and because there was no explanation of whether additional management measures to minimize bycatch and the mortality of unavoidable bycatch were practicable.

On December 15, 1999, final regulations implementing the CPS FMP were published in the *Federal Register* (64*FR*69888). Provisions pertaining to issuance of LE permits were effective immediately. Other provisions, such as harvest guidelines, were effective January 1, 2000.

2.2.2 Amendment 9 – Bycatch Provisions; Treaty Indian Fishing Rights

During 1999 and 2000, the CPSMT developed Amendment 9 to the CPS FMP. Originally, Amendment 9 addressed the disapproved provisions of the FMP – bycatch and market squid MSY. The amendment also included provisions to ensure that treaty Indian fishing rights are implemented according to treaties between the U.S. and specific Pacific Northwest tribes.

The Council distributed Amendment 9 for public review on July 27, 2000. At its September 2000 meeting, the Council reviewed written public comments, received comments from its advisory bodies, and heard public comments. Based on advice about market squid MSY determination, the Council decided to include in Amendment 9 only the provisions for bycatch and treaty Indian fishing rights. The Council decided to conduct further analysis of the squid resource and prepare a separate amendment to address OY and MSY for squid. The Secretary approved Amendment 9 on March 22, 2001, and the final rule implementing Amendment 9 was published August 27, 2001 (66*FR*44986).

2.2.3 Amendment 10 – Limited Entry Capacity Goal; Permit Transfers; Market Squid OY/MSY

In April 2001, the Council adopted a capacity goal for the CPS LE finfish fishery and asked the CPSMT to begin work on a 10th amendment to the FMP. Amendment 10 included the capacity goal, provisions for permit transferability, a process for monitoring fleet capacity relative to the goal, and a framework for modifying transferability provisions as warranted by increases or decreases in fleet capacity. The amendment also addressed determination of OY and MSY for market squid.

In June 2002, the Council adopted Amendment 10 to the CPS FMP. Relative to the LE fishery, the amendment established a capacity goal, provided for LE permit transferability to achieve and maintain the capacity goal, and established a process for considering new LE permits. The purpose of this action was to ensure fishing capacity in the CPS LE fishery is in balance with resource availability. Relative to market squid, Amendment 10 established an MSY (or proxy) for market squid to bring the FMP into compliance with the MSA. The purpose of this action was to minimize the likelihood of overfishing the market squid resource. On December 30, 2002, the Secretary approved Amendment 10. On January 27, 2003, NMFS issued the final rule and regulations implementing Amendment 10 (68*FR*3819).

2.2.4 Sardine Allocation Regulatory Amendment

In September 2002, a majority of the Coastal Pelagic Species Advisory Subpanel (CPSAS) recommended the Council initiate a regulatory or FMP amendment and direct the CPSMT to prepare management alternatives for revising the sardine allocation framework. The Council directed the CPSMT to review CPSAS recommendations for revising the allocation framework. At the March 2003 Council meeting, the SSC and CPSAS reviewed analyses of the proposed management alternatives for sardine allocation. Based on the advisory body recommendations and public comment, the Council adopted five allocation management alternatives for public review. In April 2003, the Council took final action on the regulatory amendment. This change was implemented by NMFS on September 4, 2003 (68*FR*52523).

The new allocation system: (1) changed the definition of Subarea A and Subarea B by moving the geographic boundary between the two areas from 35° 40' N. latitude (Point Piedras Blancas, California) to 39° N. latitude (Point Arena, California); (2) moved the date when Pacific sardine that remains unharvested is reallocated to Subarea A and Subarea B from October 1 to September 1; (3) changed the percentage of the unharvested sardine that is reallocated to Subarea A and Subarea B from 50 percent to both subareas, to 20 percent to Subarea A and 80 percent to Subarea B; and (4) provided for coastwide reallocation of all unharvested sardine that remains on December 1. This revised allocation framework was in place for the 2003 and 2004 fishing seasons. It was also used in 2005 because the 2005 HG was at least 90 percent of the 2003 harvest guideline.

2.2.5 Amendment 11 - Allocation

The Council began developing options for a new allocation framework for the coastwide Pacific sardine fishery in 2003 while the fishery operated under the regulatory amendment described in the previous section. This revision to the sardine allocation framework occurred through Amendment 11 to the CPS FMP in 2006. The FMP amendment was intended to achieve optimal utilization of the resource and equitable allocation of harvest opportunity.

The Council tasked the CPSAS with initial development of a range of allocation alternatives. At the November 2004 meeting, the CPSAS presented several program objectives and a suite of alternative allocation formulae. The Council adopted for preliminary analysis a range of alternatives, including the CPSAS recommendations, as well as the following program objectives:

- Strive for simplicity and flexibility in developing an allocation scheme.
- Transfer quota as needed.
- Utilize OY.
- Implement a plan that balances maximizing value and historic dependence on sardine.
- Implement a plan that shares the pain equally at reduced HG levels.
- Implement a plan that produces a high probability of predictability and stability in the fishery.

For the analysis of the alternatives, the Council gave specific direction to the CPSMT, including:

- Analyze each alternative in a consistent manner.

- Review differential impacts on northern and southern sectors for each alternative.
- Review effects of high and low catch years by sector for each alternative.
- Review resulting effects at various HG levels ranging from 25,000 metric tons (mt) 200,000 mt (at appropriate intervals) for each alternative.
- At the discretion of the CPSMT, combine aspects of the various alternatives to create new alternatives that meet program objectives.

At the April 2004 Council meeting, the CPSMT presented preliminary economic analyses of these alternatives to the Council and its advisory bodies. The economic analysis of alternative allocation schemes included five-year projections of the incremental change in producer surplus and landings projections for each fishing sector and subarea. Monthly landings projections were based on 2004 landings and were inflated by 10 percent annually to account for expected growth in the regional fishery sectors over the next five years. These projections identified months in which there would be a shortfall in landings, and months which would start out with no available allocation. These landings projections were conducted under three HG scenarios: (1) low HG = 72,000 mt, (2) Base case HG = 136,000 mt, and (3) high HG = 200,000 mt.

The Council reviewed the preliminary results and public testimony before following the advice of both the CPSAS and CPSMT when adopting the remaining range of alternatives for further analysis and public review. The Council directed the CPSMT to take into account the advice of the SSC as they proceeded with the analysis. Specifically, the Council requested a sensitivity analysis of the effects of future fishery growth where varying growth assumptions by subarea are applied, rather than the previously assumed 10 percent growth of the fishery coastwide. The Council also recommended that two different provisions for the review of a sardine allocation framework be included in the documentation for public review. The first is based on time, where sardine allocation would be reviewed after three, five, or seven years of implementation; the second is based on the size of the HG, where sardine allocation would be revisited if the HG falls below 75,000 mt or 100,000 mt.

In June 2005, the Council adopted a long-term allocation framework to apportion the annual Pacific sardine harvest guideline among the various non-tribal sectors of the sardine fishery. The Council followed the opinion of the CPSAS when adopting a seasonal allocation scheme, which provides the following allocation formula for the non-tribal share of the HG:

(1) January 1, 35 percent of the harvest guideline to be allocated coastwide;

(2) July 1, 40 percent of the HG, plus any portion not harvested from the initial allocation, to be reallocated coastwide; and

(3) September 15, the remaining 25 percent of the harvest guideline, plus any portion not harvested from earlier allocations, to be reallocated coastwide.

The Council also heeded the advice of the CPSAS, CPSMT, and SSC regarding the dynamic nature of the Pacific sardine resource and uncertainties inherent in long-term projections, and scheduled a formal review of the allocation formula in 2008. The review was intended to provide a comparison of the performance of the fishery to the projections used to evaluate the adopted allocation scheme and will include any new information from Pacific sardine research. The review was postponed and has not been re-scheduled.

2.2.6 Amendment 12 – Krill Fishing Prohibition

At its November 2004 meeting the Council initiated development of a formal prohibition on directed fisheries for krill, and directed staff to begin developing management measures to regulate directed fisheries for krill in Council-managed waters. The proposal for a krill ban was first proposed for West Coast National Marine Sanctuary waters by the National Marine Sanctuary Program.

This Amendment was in recognition of the importance of krill as a fundamental food source for much of the marine life along the West Coast. Moreover, state laws prohibit krill landings by state-licensed fishing vessels into California, Oregon, and Washington. Thus, the action could provide for consistent Federal and state management. There are currently no directed krill fisheries in Council-managed waters.

At the November 2005 Council meeting, the Council recommended that all species of krill be included in the CPS FMP as prohibited harvest species, and approved a range of krill fishing alternatives for public review and additional analysis over the winter. The Council narrowed the range of alternatives to: 1) status quo, 2) a prohibition on krill fishing in all Council-managed waters, and 3) an initial prohibition combined with the establishment of a process for considering future krill fishing opportunities. Of these alternatives, the Council adopted the second, a complete ban on krill fishing as a preliminary preferred alternative.

In March 2006, the Council adopted a complete ban on commercial fishing for all species of krill in West Coast Federal waters and made no provisions to allow future fisheries. They also specified essential fish habitat (EFH) for krill, making it easier to work with other Federal agencies to protect krill. This broad prohibition will apply to all vessels in Council-managed waters.

Amendment 12 was approved by the Secretary and in 2009, NMFS published the implementing regulations in a final rule (74*FR33372*).

2.2.7 Amendment 13 – Annual Catch Limits

The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA) established several new fishery management provisions pertaining to National Standard 1 (NS1) of the MSA. The MSA sought to end overfishing and required rebuilding plans for those stocks considered to be overfished. It also introduced new fishery management concepts including overfishing levels (OFLs), annual catch limits (ACLs), annual catch targets (ACTs), and accountability measures (AMs) that are designed to better account for scientific and management uncertainty. Council action on Amendment 13 also included a recommendation to add Pacific herring and jacksmelt to the FMP, as Ecosystem Component Species.

At its June 2010 meeting, the Council selected preferred alternatives and approved a draft alternatives document that forms the backbone of Amendment 13 to the CPSMP. Draft implementing regulations and Amendment 13 text were released for a 60-day public review on June 3, 2011. The Secretary of Commerce, via NMFS, gave final approval of Amendment 13 in September 2011.

2.2.8 Sardine Start Date Change

At its June 2013 meeting, the Council adopted an annual start date of July 1 for the Pacific sardine fishery. The previous start date was January 1 each year. The change to a different start date was made to allow more time for spring and summer sampling results to be analyzed and organized, and subsequently to become available to the Stock Assessment Team. The new schedule would allow for more confidence in the spring/summer sampling results because there is more time available for analysis, interpretation, and organization. The period allocations were not changed with the new start date. However, with the fishing year ending June 30, there will be no rollover of unused quota into the July 1-September 14 fishing period.

2.2.9 Amendment 14 – Northern Anchovy MSY

In November 2013, in response to a lawsuit by the conservation group Oceana, the Council took final action to establish an MSY value for the northern subpopulation of northern anchovy (NSNA). At its November 2010 meeting, the Council had considered two options that were analyzed by the CPSMT, but ended up not adopting either one. One of those analyzed values was an MSY reference point of Fmsy = 0.30, which was subsequently formally adopted by the Council in November 2013. This reference point was incorporated into the FMP as part of Amendment 14, which was approved by the Secretary of Commerce on March 23, 2015.

2.2.10 Amendment 15 – Unmanaged Forage Fish

Amendment 15 addressed protections for unfished and unmanaged forage fish, and incorporated them as Ecosystem Component species in each of the Council's four FMPs. Amendment 15 prohibits the development of new directed fisheries on forage species that are not currently managed by the Council, or the States, until the Council has had an adequate opportunity to assess the science relating to any proposed fishery and any potential impacts to our existing fisheries and communities. This is not a permanent moratorium on fishing for forage fish. Instead, the Council adopted COP 24, which outlines a review process for any proposed fishery. Amendment 15 was approved by the Secretary of Commerce in March 2016.

2.3 CPS Fisheries – History and Description

During the 1940s and 1950s, approximately 200 vessels participated in the Pacific sardine fishery. In California, some present-day CPS vessels are remnants of that fleet. CPS finfish landed by the roundhaul fleet (fishing primarily with purse seine or lampara nets) are sold around the world in several product forms. For example, Pacific mackerel are typically sold to Asian and European, middle Eastern and Baltic markets for human consumption. Sardines are exported largely for canning for human consumption, high value table consumption products, and long-line bait. Although the percent of CPS sold for tuna feed or bait fluctuates based on demand, product availability, etc., the percent sold in higher value categories is generally growing (Steele, pers comm, 2014). In addition to fishing for CPS finfish, many of these vessels fish for market squid, Pacific bonito, bluefin, and yellowfin tuna (which are fished primarily in California); and Pacific herring (fished primarily in Oregon/Washington but not in California).

Since 1999, a fishery for Pacific sardine has operated off Oregon and Washington. This fishery targets larger sardine, which are typically sold as bait for Asian longline tuna fisheries. Beginning in 2006, this fishery has been expanding into human consumption markets.

2.3.1 Federal Limited Entry Fishery

The CPS LE fleet currently consists of 65 permits and 56 vessels (Table 2-3), operating under a Federal permit program. The LE vessels range in age from 3 to 72 years, with an average age of 34 years (Table 2-4). The capacity goal and transferability provisions established under Amendment 10 are based on calculated gross tonnage (GT) of individual vessels. Calculated GT serves as a proxy for each vessel's physical capacity and is used to track total fleet capacity. Calculated GT incorporates a vessel's length, breadth, and depth, which are consistent measures across vessel registration and U.S. Coast Guard documentation lists. As described at 46 CFR § 69.209, GT is defined as:

GT=0.67(length*breadth*depth)/100

Vessel dimension data were obtained from the U.S. Coast Guard database, and each vessel's calculated GT was attached to the permit under Amendment 10. Original GT endorsements (specified in Table 2-3) remain with the permit, regardless of whether the permit is transferred to a smaller or larger vessel.

GT values for the current fleet range from 23.8 GT to 160.7 GT, with an average of 85.4 GT (Tables 2-3 and 2-4). The fleet capacity goal established through Amendment 10 is 5,650.9 GT, and the trigger for restricting transferability is 5,933.5 GT (Goal + 5 percent). The current LE fleet is 5,122 GT, well within the bounds of the capacity goal.

2.3.2 California Sardine Fishery

California's sardine fishery began in the 1860s as a supplier of fresh whole fish. The fishery shifted to canning from 1889 to the 1920s in response to a growing demand for food during World War I. Peaking in 1936-37, sardine landings in the three west coast states plus British Columbia reached a record 717,896 mt. In the 1930s and 1940s, Pacific sardine supported the largest commercial fishery in the western hemisphere, with sardines accounting for nearly 25 percent of all the fish landed in the United States by weight. In the 1940s, the fishing fleet consisted of 376 vessels and more than 100 canneries and reduction plants, which employed thousands from San Francisco to San Diego, California.

The fishery declined and collapsed in the late 1940s due to extremely high catches and changes in environmental conditions, and remained at low levels for nearly 40 years. The fishery declined southward, with landings ceasing in Canadian waters during the 1947-1948 season, in Oregon and Washington in the 1948-1949 season, and in the San Francisco Bay in the 1951-1952 season. The California Cooperative Fisheries Investigations (CalCOFI), a consortium of state and Federal scientists, emerged to investigate the causes of the sardine decline. Analyses of fish scale deposits in deep ocean sediments off southern California found layers of sardine and anchovy scales, with nine major sardine recoveries and subsequent declines over a 1700-year period (Baumgartner et al. 1992). Sardines and anchovies both vary in abundance over periods of about 60 years. Warm-water oceanic cycles favor sardine recruitment and cold-water cycles favor anchovy recruitment.

The decline of the sardine fishery became a classic example of a "boom and bust" cycle, a characteristic of clupeid stocks.

In 1967, the California Department of Fish and Game implemented a moratorium that lasted nearly 20 years. The remaining vessels diversified into other coastal pelagic "wetfish" fisheries. Sardines began to return to abundance in the late 1970s, when the Pacific Decadal Oscillation shifted to a warm cycle again, but this time fishery managers adopted a highly precautionary management framework. California's sardine fishery reopened in 1986 with a 1,000 short ton quota, authorized by the Legislature when the biomass exceeded 20,000 mt. The sardine resource grew exponentially in the 1980s and early 1990s, with recruitment estimated at 30 percent or greater each year. In 1998, the sardine resource was declared "recovered," with a biomass estimated at slightly more than 1 million mt. The quota set by CDFG had increased to 43,545 mt, and it was virtually completely utilized.

In 1999, the new coastwide harvest guideline (HG) jumped to 186,791 mt, based on a 1999 biomass estimate of 1.58 million mt. In 2000, California harvested 57,935 mt. About 71 percent of the catch was exported, valued at $23.3 million, and approximately 17 percent of the catch went to canneries. However, the last cannery in southern California was sold in December, leaving only one cannery remaining in Monterey, in a fishery that had employed more than 100 canneries and reduction plants statewide during the fishery's heyday in the 1930s and 1940s.

The sardine recovery appeared to level off during 1999-2002. By August 2002, the Northern area sardine fishery attained its allocation and was forced to close early. Northwest sardine interests lobbied the Council for an emergency reopening and revision to the allocation framework because thousands of tons of sardine were available and going unharvested in the Southern fishery.

In the early 2000s, the California fishery encountered an abundance of small sardines on traditional fishing grounds, for which markets were very limited. The larger fish appeared to move offshore in their northern migration, out of the range of California seiners who made most of their catches inside the 3-mile state boundary. The lack of canning-size sardines caused the last cannery in Monterey to sell its canning equipment. Still, sardines ranked among the top fisheries in California for volume and sixth in value with ex-vessel ranging from $4.5 million to more than $5 million. With a main focus now on export markets, California shipped sardines to as many as 22 countries worldwide, and annual export values exceeded $20 million.

From 1998-2006, California sardine landings averaged 46,793 mt. In 2005, Oregon landings surpassed California for the first time since the fishery reopened. California caught nearly 81,000 mt of the 152,564 mt HG in 2007 – the highest landings since the 1960s. Ex-vessel value exceeded $8 million, and 66,896 tons of sardine were exported to 37 countries, with an export value of $40.4 million.

In 2008, the HG declined 42 percent, to 89,093 mt, and the sardine fishery closed early in all three allocation periods, with California catching 57,803 mt of the total. Beginning in 2008, California's sardine fishery was closed more than it was open, and it was closed early, during the peak fall season in all years but 2012 and 2013. In 2009, the annual HG was attained in 77 fishing days. California landings totaled 37,578 mt, with two-thirds of the catch in Monterey. California exported 33,909 mt to 35 countries. In 2010, California landings fell to 33,658 mt of the 72,039 mt quota, and 83 percent of the catch was landed in San Pedro. The summer period closed July 22, the fishery reopened on September 15, and closed for the year on September 24. The 2011 sardine fishery experienced another 30 percent reduction in HG, with only 50,526 mt allowed to be harvested of a 537,173 mt age 1+ biomass. California caught 27,714 mt in 83 total days of fishing opportunity.

In 2012, although the biomass and HG increased substantially (988,385 mt biomass and 109,409 mt HG), California landings continued declining to only 23,037 mt. Fishermen couldn't find sardines early in the year, then focused on a banner squid season during the summer. There was further evidence of a natural sardine decline in 2013 as sardines disappeared from Canadian waters. The 2013 HG decreased 69 percent to 66,495 mt, and California harvested only 7,074 mt. Pacific mackerel landings surpassed sardine for the first time since 1993. In place of sardine, a decadal squid population explosion occupied the California purse seine fleet until 2015, when an El Nino event sharply reduced squid availability. Since Federal management began in 2000, the sardine biomass has declined more than 70 percent since the 2006 high of 1.3 million mt, and harvest limits have fallen from a high of an HG of 186,971 mt in 2000 to an ACT of 23,293 mt for the 2014-2015 season. Both the April 2015 and April 2016 biomass estimates fell below the CUTOFF value of 150,000 mt, thereby precluding a directed commercial fishery for the 2015 – 2016 and the 2016-2017 fishing years (see Section 8).

2.3.3 Oregon State Limited Entry Sardine Fishery

The Pacific sardine fishery off Oregon started in 1935, but there are recorded landings of sardine in Oregon dating back to 1928. The catch dropped off in the 1940s with 1948 being the last year of directed fishery landings until 1999 when the fishery was revived. Pacific sardine was managed as a developmental fishery from 1999 to 2005. In 2004, the sardine industry asked ODFW to remove Pacific sardines from the developmental species list and create a LE system for the fishery.

ODFW began work with the Developmental Fisheries Board and the industry to develop alternatives for the fishery. In December 2005, the Oregon Fish and Wildlife Commission (OFWC) moved the Pacific sardine fishery from a developing fishery into a state-run LE fishery system. Twenty Oregon permits were initially established and made available to qualifying participants for the 2006 fishery. The OFWC amended a LE permit eligibility rule in August 2006, which resulted in an immediate addition of six permits for a total of 26 LE sardine fishery permits. The Oregon Limited Entry fleet does not have capacity restrictions.

In April 2009, the OFWC enacted a number of rule changes for the Pacific sardine fishery. First, the OFWC modified the requirement for minimum landings of sardines into Oregon to qualify for permit renewal that was enacted in 2006. These minimum landing requirements for permit renewal were effective only when the Federal coastwide maximum HG for the fishing year exceeded 100,000 mt. The minimum landing requirements themselves, either a minimum of ten landings of at least five mt each or landings totaling at least $40,000 ex-vessel price, were not changed. Next, the OFWC eliminated a rule that became effective in 2008, which specified that permit holders must either own or operate a vessel that is permitted. The OFWC also established a lottery system for sardine permits. If the number of permits issued falls below 24, a lottery may be held the following year, but the total number issued shall not exceed 26 LE permits. A new rule defined catching vessels and limited catch sharing to catching vessels with state LE sardine permits. In 2012, the OFWC eliminated the landings requirements for permit renewal.

The Pacific sardine fishery in Oregon operates as a day fishery with vessels based primarily in Astoria where processing plants for sardine operate. Many vessels utilize aircraft to assist in locating schools of sardine and setting their nets when weather permits. Weather and tides are major factors in fishing operations and timing of vessels transiting in and out of the Columbia River.

In 2013, the Pacific Fishery Management Council approved shifting the sardine fishery year from a January 1 – December 31 schedule to a July 1 – June 30 schedule, beginning on January 1, 2014. To transition from the calendar year schedule to the new schedule, a 2014 Interim Fishery was specified for January 1 – June 30, 2014. The 2014-2015 sardine fishery began on July 1, 2014.

2014 Interim Fishery

No sardines were landed into Oregon during the 2014 Interim Fishery, January 1 – June 30, 2014.

2014-2015

Of the twenty-five state limited entry vessels permitted in Oregon, 18 (72 percent) participated in the sardine fishery (Table 2-5). Oregon landings totaled 9,919.8 mt, including 9,758.3 mt by the directed purse seine fleet, 160.1 mt in incidental purse seine landings, 0.2 mt by beach seine gear, and 1.2 mt in incidental landings by non-CPS fisheries. The directed fishery in Oregon accounted for 56 percent of the initial 17,793 mt federal directed sardine fishery allocation.

Oregon landings in 2014-2015 were the lowest since 2000. Sardines were landed in all three allocation periods with 39.8 percent landed in the first period, 38.4 percent landed in the second period and 21.8 percent landed in the third period. As in recent years, directed fishing closed early for all three allocation periods. Due to a stock assessment error upon which the sardine harvest guideline was based, Oregon closed directed fishing for the third allocation period effective April 25, 2015, three days earlier than the Federal closure. Sardine landings in Oregon ranged from less than 1 mt to over 100 mt with most being between 40 mt and 70 mt. Sometimes landings during the sardine fishery periods comprised much higher proportions of Pacific mackerel and jack mackerel than sardines. The ex-vessel value of sardine landed in the directed fishery in Oregon totaled $4.3 million. This is about the same as the average ex-vessel revenue since 2000 because the price in 2014-2015 averaged $440/mt, much higher than prices during previous years. Previously, the highest average price was $288/mt in 2011.

After a fishery period closure, up to 45 percent sardines were allowed to be landed in mixed loads with other coastal pelagic species. For each allocation period, up to 500 mt was set aside for incidental landings. Following the closure of the first allocation period on July 23, 2015, purse seine vessels targeted mackerels off Oregon. Sardines were being landed incidentally at a fast pace, potentially very quickly reaching the entire 500 mt set aside for the first period. To slow the incidental landings rate of sardines, Oregon reduced the incidental landings allowance by temporary rule to a maximum of 20 percent sardines in mixed loads of coastal pelagic species, effective July 31 – September 14, 2014. Incidental purse seine landings of sardines in Oregon totaled 160.1 mt for the 2014-2015 fishery, all of it taken between the closure of the first allocation period and the start of the second allocation period.

2015-2016

The directed sardine fishery was closed due to low stock abundance. Estimated biomass was below CUTOFF (150,000 mt), the level at which directed purse seine fishing is prohibited. Incidental landings of sardine during 2015-2016 (July 1 – June 30) totaled 1.44 mt, taken largely during a purse seine fishery for market squid in spring 2016.

2.3.4 Oregon Anchovy Fishery

State developmental fishery permits for harvesting anchovy were issued from 1995 to 2009. All developmental fisheries in Oregon had a limited number of permits available and landing requirements for permit renewal, but the number of permits and landing requirements differed by target species. In 2009, Oregon issued four of the 15 developmental fishery permits available for the anchovy fishery. In December 2009, all developmental fisheries programmatic activities including permitting were suspended due to lack of funding. The OFWC moved the anchovy fishery to a Category C developmental fishery, those that are managed under a state or Federal FMP which has established permit and/or gear limitations. Because the Federal CPS FMP does not have permit restrictions for vessels operating north of 39^{o} N. latitude, the ocean fishery for northern anchovy is now an open access fishery off Oregon limited to legal gear under the CPS FMP and state regulations. In recent years, northern anchovy have been infrequently targeted during open periods for the sardine fishery, although a significant fishery developed in 2015.

2014 - 2015

During 2014, no anchovy were landed in Oregon. During 2015, the fishery landed significantly more anchovy than ever before, 335.2 mt in Astoria, all by the purse seine fishery. During the previous decade, anchovy landings averaged 54 mt annually.

2.3.5 Washington State Limited Entry Sardine Fishery

Pacific sardines are the primary coastal pelagic species harvested in Washington waters. From 2000 through 2009, participation in the sardine fishery was managed under Washington's Emerging Commercial Fishery Act (ECFA), which provides for the harvest of a newly classified species or harvest of a classified species in a new area or by new means. The ECFA offers two choices for fishery-permit designations: trial, which does not limit the number of participants or experimental, which does limit participation and prohibits the transfer or sale of the permit. From 2000 through 2002, WDFW managed the purse seine fishery for sardine under the trial designation. Absent limited participation, the Washington fishery was managed to a state HG of 15,000 mt.

The Pacific Northwest sardine fishery saw a rapid expansion of catch between the years 1999 to 2002 when landings increased from 771 mt to 15,820 mt. In response to this situation, WDFW engaged in an extensive public process to address management needs in the fishery. In 2003, following this public process, a formal Sardine Advisory Board (Board) was created, and the WDFW Director, in collaboration with the Board, advanced the sardine fishery designation from trial to experimental as provided for under the ECFA. The number of experimental fishery permits was capped at 25. The experimental fishery program continued through June 2009. Besides limiting participation, WDFW also restricted the amount of sardines sold for reduction to a 15 percent season cumulative total by weight by individual vessel.

During the 2009 Washington State legislative session, WDFW proposed legislation to establish a commercial license limitation program specifically for the harvest and delivery of Pacific sardines into the state. The legislation was passed into law in July 2009, establishing 16 permanent licenses. In addition, the new law provides criteria for the issuance of temporary annual licenses at the discretion of the WDFW Director. In combination, the number of permanent and temporary annual licenses cannot exceed 25. The law did not set any vessel capacity restrictions for the Washington limited entry fishery.

After the creation of the sardine license in July 2009, licenses could be transferred (sold). To maintain a sardine license, yearly renewal is required and is accomplished by paying an annual fee; the number of permanent licenses remains at 16. In 2010 and 2012, a single temporary annual license was also issued. Table 2-6 lists the vessels designated on Washington sardine fishery licenses for the 2014/2015 fishery year.

Washington State waters (0-3 miles) are closed to directed commercial sardine fishing. Fishing for or possessing sardine taken with any commercial gear is prohibited January 1 through March 31. However, fishing opportunity is typically limited until late spring or early summer, due to adverse weather and/or too few fish. In some years the period (January 1 – June 30) allocation is attained before April 1, in others, sardine abundance offshore is not sufficient to support commercial activity until early or mid-June. Pacific sardines are the targeted catch in the Washington fishery, but anchovy, mackerel, and squid may be incidentally retained and landed.

To document bycatch levels in the Pacific sardine fishery (see Section 4.3.2), WDFW conducted a five-year observer program from 2000 through 2004. Overall observer coverage in this program was in excess of 25 percent and results showed bycatch of non-targeted species in the Washington sardine fishery to be relatively low. A mandatory state logbook program has been in place since the fishery began in 2000. The logbook requires skippers to report incidental catch and bycatch. The logbook data are maintained in electronic format at the WDFW regional office at Montesano, Washington.

All sixteen Washington permanent licenses were renewed for 2014; Table 2-6 lists the associated designated vessel. Of these vessels, two also hold a Federal sardine LE permit, four others hold an Oregon LE permit, and one holds both the Federal and Oregon LE permits. No temporary annual permits were issued consistent with a reduced harvest guideline.

During the 2014 interim period, three vessels participated in the Washington sardine fishery. Landings from January 1 through June 30, 2014 totaled 910 metric tons, or 13 percent of the 6,946 mt allocated coast-wide (California, Oregon and Quinault Tribe) for harvest. The ex-vessel value of sardine landed into Washington from the directed fishery during this period averaged $295/mt and totaled $268,000. Individual landings ranged from approximately 30 mt to a little over 100 mt, and averaged 64 mt. The fishery also landed 43 mt Pacific mackerel and 17 mt jack mackerel.

2014 – 2015 Fishing Year (July 1, 2014 – June 30, 2015)
Washington sardine licenses are issued on the calendar year, thus all 16 licenses renewed during the interim management period remained valid through the end of 2014.

Sardine landings for Washington totaled 6,276 mt, representing 22 percent of the coastwide harvest guideline. All of the sardine catch was landed in July and September 2014. Eight vessels, or half of the licensed fleet, participated in the fishery. Per landing tonnage averaged about 57 mt, and ranged from just under 10 mt to about 110 mt. Total direct value of landings was $2.8 million.

Incidentally landed species in the sardine purse seine fishery included 489 mt Pacific mackerel and 158 mt jackmackerel. These landings represent the second highest total for Pacific mackerel and the highest total for jackmackerel since the directed sardine fishery began in Washington in 2000.

2015 – 2016 Fishing Year (July 1, 2015 – June 30, 2016)
No directed sardine purse seine landings were made into Washington during the 2015-2016 fishing year. Effective April 1, 2016, Washington authorized a trial directed mackerel purse seine fishery creating potential for incidental landings of Pacific sardine by vessels fishing for Pacific mackerel. However, no vessels participated in the Pacific mackerel directed fishery through June 30, 2016.

2.3.6 Washington State Anchovy Fisheries

Anchovy fisheries in Washington are conducted primarily to provide live bait for recreational and commercial fisheries. Smaller amounts of anchovy are packaged and sold as bait to recreational fishermen. In 2010, WDFW adopted permanent rules restricting northern anchovy catch and disposition. These rules were intended to accommodate the traditional bait fishery and discourage the development of high-volume fisheries for anchovy. The rules limit the catch, possession, or landing of anchovy to 5 mt daily and to 10 mt weekly. In addition, the rules limit the amount of anchovy taken for reduction (or the conversion of fish to products such as fish meal or fertilizer) to 15 percent of a landing by weight. See 2.3.11 Washington State Live Bait Fishery.

2.3.7 Market Squid Fishery

2.3.7.1 California Market Squid Fishery

In 2001, legislation transferred the authority for management of the market squid fishery to the California Fish and Game Commission (CFGC). Legislation required that the CFGC adopt a market squid fishery management plan (MSFMP) and regulations to protect and manage the resource. In August and December of 2004, the CFGC adopted the MSFMP, the environmental documentation, and the implementing regulations, which went into effect on March 28, 2005, just prior to the start of the 2005-2006 fishing season on April 1.

The goals of the MSFMP are to provide a framework that will be responsive to environmental and socioeconomic changes and to ensure long-term resource conservation and sustainability. The tools implemented to accomplish these goals include: (1) setting a seasonal catch limit of 107,048 mt (118,000 short tons [st]) to prevent the fishery from over-expanding; (2) maintaining monitoring programs designed to evaluate the impact of the fishery on the resource; (3) continuing weekend closures that provide for periods of uninterrupted spawning; (4) continuing gear regulations regarding light shields and wattage used to attract squid; (5) establishing a restricted access program that includes provisions for initial entry into the fleet, permit types, permit fees, and permit transferability that produces a moderately productive and specialized fleet; and (6) creating a seabird closure restricting the use of attracting lights for commercial purposes in any waters of the Greater Farallones National Marine Sanctuary. Under this framework, the MSFMP provides the CFGC with specific guidelines for making management decisions. The CFGC has the ability to react quickly to changes in the market squid population off California and implement management strategies without the need for a full plan amendment. The MSFMP framework structure was also designed to achieve the goals and objectives of the MLMA and to be consistent with the management outlined in CPS FMP Amendment 10.

Under the restricted access program in the MSFMP, a permit is needed to participate in the fishery. Qualification for different types of permits and transferability options was based on recent participation in the fishery (2000-2003). In 2015, 75 vessel permits, 34 light boat permits, 44 brail (netted scoop) permits, and zero experimental permits were issued. Of the 75 vessel permits issued, 57 vessels made commercial landings in 2015. 45 vessels made 95 percent of the landings (by tonnage) in 2015. Of the 44 brail permits issued, one brail vessel landed squid. Market squid vessel permits allow a vessel to attract squid with lights and use large purse seine nets to capture squid. Brail permits allow a vessel to attract squid with lights and use brail gear to capture squid. Light boat permits only allow a vessel to attract squid with lights (30,000 watts, maximum). In 2014, revised regulations went into effect clarifying the take of squid incidentally after a closure of the directed market squid fishery. These regulations require incidental landings of squid to contain 10 percent or less of squid and 2 tons or less of squid, when landed with another targeted species. CDFW revised commercial squid logbooks in 2016, to improve formatting and instructions as well as improve quality of the logbook data collected.

The California market squid fishery is strongly affected by environmental and atmospheric conditions of the California Current. California market squid are extremely sensitive to the warm water trends of El Niño. Historically, overall catches have decreased during El Niño but then rebounded with the increased upwelling of cooler La Niña phases. During warm water events with nutrient poor water, landings can disappear entirely in some areas. For example, for years 2012-2015, average SST in southern California was highest in 2015, which corresponds to the lowest southern California landings. Conversely, average SST for both northern and southern California waters were lower in 2012, corresponding to higher southern California landings.

With recent El Niño warm waters, overall California landings decreased significantly beginning with the 2015-2016 fishing season (running Apr 1 2015 – Mar 31 2016). The warm blob beginning in 2014, coupled with early El Niño signals, also had an effect of pushing the squid fishery north, as reflected in the geographic distribution of 2014 landings. With the onset of the La Niña phase, squid may be more abundant and available to the fishery throughout their normal range in the near future; however, the odds of an El Niño developing in late 2017 are increasing, and may also continue to cause squid population movements away from traditional grounds. It's also possible squid may be unavailable to the fishery due to movement to deeper colder waters, as the fishery conducts operations in relatively shallow depths.

2.3.7.2 Oregon/Washington Market Squid Fisheries

Squid species in Washington are not targeted or incidentally landed by CPS fisheries.

In Oregon, market squid are occasionally targeted. In 2014, targeted fishing by fewer than three vessels landed less than 0.5 mt. No market squid were landed in 2015.

2.3.8 Treaty Tribe Fisheries

The CPS FMP recognizes the rights of treaty Indian tribes to harvest Pacific sardine and provides a framework for the development of a tribal allocation. An allocation or a regulation specific to the tribes shall be initiated by a written request from a Pacific Coast treaty Indian tribe to the NMFS West Coast Regional Administrator at least 120 days prior to the start of the fishing season.

The Makah Tribe sent a letter to NMFS expressing their intent to attain an allocation and to enter the Pacific sardine fishery in 2006. However, no formal request was subsequently submitted.

In fall 2011 and 2012, the Quinault Indian Nation sent a letter to the NMFS WCR Regional Administrator requesting up to 9,000 mt as a Tribal sardine allocation for the 2012 and 2013 fishing years, respectively. The Quinault Nation submitted similar requests each season since, including a request for 1,000 mt for the six month season of January 1, 2014 – June 30, 2014; and 4,000 mt for the July 1, 2014 – June 30, 2015 sardine fishing year. The Council accounted for the requests when it set harvest specifications and management measures at its November 2011, 2012, 2013, and April 2014 - 2016 meetings. The final tonnage amount is subsequently agreed to between NMFS and the Quinault Nation.

Quinault Indian Nation fishers harvested 1294 mt in 2012, 586 mt in 2013, and zero during the abbreviated January 1 – June 30, 2014 fishing season. Agreements were reached with NMFS to re-allocate unharvested fish to the coast-wide fishery in 2012, 2013, in the six-month season January 1 – June 30, 2014, and also in the 2014 – 2015 fishing year.

2.3.9 California Live Bait Fishery

Through much of the 20th century, CDFW monitored the harvest of CPS finfish in the California live bait fisheries by requiring live bait logs. Northern anchovy and Pacific sardine are the main species in this fishery, with a variety of other nearshore or CPS taken incidentally. An estimated 20 percent of this harvest is sold to private fishing vessels, with the remainder to the CPFV fleet, where payment to the bait haulers is on a percentage basis of the CPFV revenues (Thomson *et al.* 1994). An example of the first Live Bait Log from 1939, termed a "Daily Bait Record" as printed for the State of California, Department of Natural Resources, and Division of Fish and Game can be found in Alpin (1942). The data collected were self-reported daily estimates of the number of "scoops" taken and sold by the fishermen, by species. Although this variety of data does not lend itself readily to rigorous scientific analysis, there are at least 74 years of data available, collected in a reasonably uniform manner that can serve as an index to this low volume, high value fishery.

Studies conducted by CDFW, NMFS, and others have examined this fishery, generally with a focus on the dominant species taken over a given period. As in the directed commercial CPS fisheries, the local availability of each CPS to the bait fleet changes periodically. Problems with the live bait data such as conversion factors for scoops of live fish to weight, the economics of the fishery, the character of the fleet, and compliance rates in submitting logs have been addressed in various agency reports (Maxwell 1974; and Thomson et al. 1991, 1992, 1994).

2.3.9.1 Legislative History

Alpin (1942) describes the earliest implementation of the live bait log program in 1939, which followed a pilot program of verbal interaction with the fishermen that established four categories describing the variation in abundance or availability of CPS to the recreational industry.

Live bait logs have been at different times mandated by state law or submitted to the CDFW on a voluntary basis. In the early 1990s, sardine became more prevalent in the bait fishery, and quotas were imposed on their annual take pursuant to management efforts to recover the sardine population off California. In 1995, CDFW lifted quotas restricting the quantity of sardines that the live bait industry could harvest. The sardine population along the California Coast was increasing toward a "recovered" level, as anchovy showed a decline, and sardines became the preferred live bait over anchovy. With the sardine quota lifted, the level of scrutiny on the harvest of the live bait industry lessened.

2.3.9.2 Species Composition

The ratio of anchovy to sardine in the southern California live bait harvests shifts significantly as the populations of these two fish expand and contract over periods of years or decades. Much of the early reported harvest consisted of anchovy, following the collapse of the sardine fishery in the 1940s. Through the years 1994 to 2015 the proportion of anchovy to sardine in the total reported harvest ranged from a high of 58 percent anchovy to 42 percent sardine in 1994 to 5 percent anchovy to 95 percent sardine in 2004 (Table 4-13).

A new market squid live bait fishery has expanded in southern California in recent years. However, the amount of market squid harvested and the value of the fishery is largely unknown, as there are no permitting and reporting requirements. The live bait fishery is likely a low-volume, high-value endeavor, as recreational anglers targeting mainly white seabass are willing to pay up to $85 for a "scoop" of live squid, approximately 12 pounds.

2.3.9.3 Logbook Information

Until 2000, the CDFW Live Bait Log (Title 14, Section 158, California Code of Regulations: DFG 158, October 1989) required only the estimated scoops taken daily of either anchovy or sardine be reported, and a check mark be made if certain other species are taken, with space for comments related to fishing. Other species noted, but not consistently enumerated in the live bait harvest, include white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), Pacific and jack mackerels, and various small fishes collectively known as "brown bait" that can include juvenile barracuda (*Sphyraena argentea*), Osmerids, Atherinids, and market squid (Table 4-11). Estimates of ancillary catch data has been documented in earlier reports, and in CPS FMP Amendment 9. Beginning in 2000, the live bait logs were no longer mandatory, but submitted on a voluntary basis. In 2015, CFDW met with live bait and CPFV fishery participants to increase participation in the log program and discuss improving the log form to better describe live bait catch. In fall of 2015, a revised log form was issued to bait haulers, and by 2016 was used by all log submitters.

The CDFW Coastal Pelagic Species / Highly Migratory Species Project presently archives the CDFW live bait logs. Preliminary estimates of the reported total live bait harvest in California through 2015 have been appended to previously reported estimates from Thomson *et al.* (1991, 1992, 1994) (Table 4-12). Since 2013, sardine (northern subpopulation) biomass estimates have sharply declined. Consequently, all sources of sardine mortality, including live bait catch, have received renewed attention. The CDFW is in an ongoing effort to evaluate the current logbook structure, reporting requirements, and the information obtained in order to correct the data problems identified above, increase reporting rates, and to better estimate the economics of the fishery.

2.3.10 Oregon Live Bait Fishery

Historically commercial capture of CPS for live bait has primarily occurred in the Umpqua River estuary where Pacific sardine, northern anchovy, and a number of other species not under Federal management may be taken by beach seine and sold as bait, some of which is sold as live bait. In 2009 the Oregon Fish and Wildlife Commission implemented rules to allow capture of northern anchovy in a limited number of Oregon estuaries. All other species must be released unharmed. This harvest of anchovy is limited to commercial vessels that use the anchovy as live bait in commercial fishing operations on the catching vessel. The gear used to capture anchovy is restricted to purse seines with a maximum length of 50 fathoms (300 ft), lampara nets, and hook and line. This live bait fishery is open from July 1 to October 31. Fishers intending to fish for anchovy in this manner must notify Oregon State Police with the vessel name, fishing location and estimated time of the activity 12 hours prior to fishing activity. Information on live bait catch must be recorded in logbooks provided by ODFW.

2014 and 2015

There were no landings of northern anchovy or Pacific herring reported for use as live bait, either in fish tickets or logbooks.

2.3.11 Washington Live Bait Fishery

Northern anchovy support important baitfish fisheries on the Washington Coast (ocean, lower Columbia River, Grays Harbor and Willapa Bay). Distinguished by gear type, fisheries for anchovy include a lampara gear fishery and a seine gear fishery. The lampara-gear fishery is primarily comprised of albacore tuna fishers that catch and hold anchovy in onboard live-wells to meet their own bait needs. The purse-seine fishery harvests and holds live bait in dockside net pens for retail sale to recreational and commercial fishers. The fishery occurs in Federal waters (3-200 miles), inside three miles (state waters) on the southern Washington coast, as well as within the estuaries of Grays Harbor and Willapa Bay, and in the lower Columbia River.

Except for herring which is under a license limitation program, participation in baitfish fisheries is not limited. About two dozen baitfish-lampara gear licenses and two or three baitfish-purse seine licenses are issued annually.

Since 2007 WDFW has required fishers to document all forage fish used for bait in another fishery on the fish receiving ticket for the target species. Although all Washington anchovy landings are reported on fish tickets, no distinction is made between anchovy destined for packaged product versus anchovy destined for use as live bait. Landings from the lampara gear fishery are typically reported by the scoop and converted to weight for data entry.

Incidentally caught species include other forage fish species (e.g. sardine, herring) which have species specific landing limits. Bycatch of non-forage fish species is not documented but includes rare encounters with sturgeon by purse seine gear. Since quality is paramount in the live bait fishery, fishermen avoid encountering non-forage fish species; any that are encountered are released quickly. To protect out-migrating salmon, regulations include seasonal closures of Grays Harbor and Willapa Bay.

<u>2014</u>

In 2014, six vessels (purse seine and lampara) landed 112 mt of anchovy. This is similar to the previous year's total of 116 mt and below the 10 year average of 166 mt which excludes the atypical 2009 catch. Landings spanned from May through October, with the majority (nearly 80 percent) landed in June, July and August. Total direct value of landed anchovy was approximately $57,000.

<u>2015</u>

Preliminary totals for 2015 are up from 2014: 15 vessels (purse seine and lampara) landed 143.7 mt of anchovy. Purse seine landings spanned May through October, with the majority (nearly 86%) landed in July, August and September. Total direct value of landed anchovy was approximately $82,000.

2.3.12 References

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3.0 REFERENCE POINTS AND MANAGEMENT FRAMEWORK

3.1 Optimum Yield

The MSA defines the term "optimum," with respect to the yield from a fishery, as the amount of fish which:

- will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems.
- is prescribed on the basis of the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor.
- in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery [50 C*FR* §600.310(f)(1)(i)].

OY for a CPS stock is defined to be the level of harvest which is less than or equal to ABC estimated using an ABC control rule, consistent with the goals and objectives of this FMP, and used by the Council to manage the stock. In practice, OY is determined with reference to ABC. As necessary, additional OY considerations (economic, social, and ecological) will be used to set ACLs, ACTs, and/or HGs on an annual or multi-year basis. In particular, OY will be set less than OFL/ABC to the degree required to prevent overfishing.

3.2 Definition of Overfishing Limits, MSY, and OFL and ABC Control Rules

The harvest control rules for CPS are defined to be a harvest strategy that provides biomass levels at least as high as the F_{MSY} approach while also providing relatively high and relatively consistent levels of catch. According to Federal regulations (50 CFR ' 600.310(b)(1)(ii)), an MSY control rule is "a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY." Similarly, MSY stock size "means the long-term average size of the stock or stock complex, measured in terms of spawning biomass or other appropriate units that would be achieved under an MSY control rule in which the fishing mortality rate is constant." The CPS harvest control rules are more conservative than MSY-based management strategies, because the focus for CPS is oriented primarily towards stock biomass levels at least as high as the MSY stock size, while reducing harvest as biomass levels approach overfished levels. The primary focus is on biomass, rather than catch, because most CPS (Pacific sardine, northern anchovy, and market squid) are very important in the ecosystem for forage.

3.3 Definition of Overfishing

Overfishing occurs whenever a stock or stock complex is subjected to a level of fishing mortality or annual total catch that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis. In general, overfishing criteria for CPS are based on MSY or MSY proxy harvest rates applied to the best available estimate of biomass. In cases where biomass estimates or stock distributions include portions of the population in foreign waters, a DISTRIBUTION term will be used to estimate the percentage of the population in the U.S. EEZ.

In operational terms, overfishing occurs in the CPS fishery whenever catch exceeds the overfishing limit; an annual amount of catch. This annual amount of catch corresponds to the estimate of MSY fishing mortality on an annual basis. No CPS stocks are currently experiencing overfishing.

3.4 Definition of an Overfished Stock

By definition, an overfished stock in the CPS fishery is a stock at a biomass level low enough to jeopardize the capacity of the stock to produce MSY on a continuing basis. An overfished condition is approached when projections indicate that stock biomass will fall below the overfished level within two years. The Council must take action to rebuild overfished stocks and to avoid overfished conditions in stocks with biomass levels approaching an overfished condition. MSSTs for actively-managed stocks were established in Amendment 8. Pacific sardine MSST is 50,000 met and Pacific mackerel MSST is 18,200 met. MSSTs are unspecified for Monitored CPS stocks.

According to National Standard 1 guidelines of the MSA (50 CFR 600.310(e)(2)(i)-(ii) a minimum stock size threshold (MSST) is the level of biomass below which the stock or stock complex is considered to be overfished. Stock-specific MSSTs have been adopted for Pacific sardine and Pacific mackerel. The CPS FMP (PFMC 1998, 2016) defines an overfished sardine population as one with an age 1+ stock biomass on July 1 of 50,000 mt or less. The CPS-FMP defines an overfished Pacific mackerel stock as one with 18,200 mt or less of age 1+ biomass (PFMC 1998, 2016). The MSST for the northern anchovy central subpopulation is not currently specified in the CPS FMP, given the monitored classification for this species (PFMC 1998, 2016). However, the sixth amendment to the northern anchovy FMP implemented an ‘overfishing’ definition for the stock (PFMC 1990). In Amendment 6, ‘overfishing’ was defined as fishing when the stock drops below 50,000 mt of spawning biomass, so this was a de facto biomass-based ‘overfished’ criterion, which was previously reviewed by the SSC and adopted by the Council. MSSTs have not yet been specified for jack mackerel or the northern subpopulation of northern anchovy because neither of these stocks have been formally assessed for management. No CPS stocks are currently overfished.

3.5 Rebuilding Programs

Management of overfished CPS stocks must include a rebuilding program that can, on average, be expected to result in recovery of the stock to MSY levels in ten years. It is impossible to develop a rebuilding program that would be guaranteed to restore a stock to the MSY level in ten years, because CPS stocks may remain at low biomass levels for more than ten years even with no fishing. The focus for CPS is, therefore, on the average or expected time to recovery based on realistic projections. If the expected time to stock recovery is associated with unfavorable ecosystem conditions and is greater than ten years, then the Council and the Secretary may consider extending the time period as described at 50 CFR § 600.310(e).

Rebuilding programs for CPS are an integral part of general control rule for actively managed stocks but may be developed or refined further in the event that biomass of a CPS stock reaches the overfished level.

3.6 Harvest Control Rules

Harvest control rules in the CPS fishery may vary depending on the nature of the fishery, management goals, assessment and monitoring capabilities, and available information. Under the framework management approach used for CPS.

The use of harvest control rules for actively managed stocks is to provide managers with a tool for setting and adjusting harvest levels on a periodic basis while preventing overfishing and overfished stock conditions. All actively managed stocks must have stock-specific harvest control rules, a definition of overfishing and a definition of an overfished stock.

Along with preventing overfishing, the main use of control rules for the monitored stocks is to help gauge the need for active management. Harvest control rules and harvest policies for monitored CPS stocks may be more generic and simple than those for actively managed stocks with significant fisheries. Any stock supporting catches approaching the ABC levels should be actively managed unless there is too little information available or other practical problems.

In 2011, Amendment 13 to the CPS FMP was adopted to ensure the FMP was consistent with new aspects of the advisory guidelines published at 50 CFR 600.310 with respect to a process for setting ACLs and accountability measures (AMs). Amendment 13 modified management measures to include the specification of new reference points such as ACLs. This included the process for annually setting ACLs and associated AMs, as well as other provisions for preventing overfishing, such as the potential of setting ACTs.

The formulas established by Amendment 13 for actively managed species such as Pacific sardine and Pacific mackerel are shown below.

OFL	BIOMASS * F_{MSY} * DISTRIBUTION
ABC	BIOMASS * BUFFER * F_{MSY} * DISTRIBUTION
ACL	LESS THAN OR EQUAL TO ABC
HG	(BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION
ACT	EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS

The OFL is an annual catch amount that corresponds to the estimate of (annual) MSY fishing mortality. The OFL is expressed in terms of numbers or weight of fish; overfishing occurs if catch exceeds the OFL. For Pacific sardine, the OFL is based on a MSY proxy harvest rate, determined by the best available scientific information, and applied to the best available estimate of biomass. Additionally, because a portion of the sardine population is in foreign waters, the OFL is adjusted using a DISTRIBUTION to estimate the percentage of the population in the U.S. EEZ.

The ABC is a harvest specification set below the OFL and is a threshold that incorporates a scientific uncertainty buffer against overfishing (i.e., exceeding the OFL). The ABC is decided by the Council based on its preferred level of overfishing risk aversion. The ABC incorporates a percentage reduction of the OFL selected according to an SSC determination on scientific uncertainty and a risk policy determined by the Council. In cases where scientific uncertainty (σ) associated with estimating an OFL is quantified by the SSC, the percentage reduction that defines the scientific uncertainty buffer and the ABC can be determined by translating the estimated σ to a range of probability of overfishing (Pstar) values. After the Council decides on its level of preferred risk (Pstar), that value is matched to its corresponding BUFFER fraction. The BUFFER fraction then is applied to the OFL according to the ABC control rule.

An ACL is the level of annual catch of a population or population complex that is set to help prevent overfishing from occurring and, if met or exceeded, that triggers accountability measures such as a closure of the fishery or a review the management strategy of the fishery. The Pacific sardine fishery is managed to keep total catch from all sources below the ACL. ACLs are set no higher than ABC, and the HG cannot exceed the ACL or ABC. In cases where the result of the HG formula exceeds the ABC value, the Council will set a lower ACL, HG, or ACT in response. Along with optimum yield (OY) considerations, an HG or ACT may be utilized below an ACL or sector-specific ACL to account for management uncertainty, discard or bycatch mortality and research take. These provisions will be considered on an annual basis in response to changing resource status and fishery dynamics.

Along with the setting of HGs or ACTs below the ACL, accountability measures (AMs) are in place, such as inseason management controls and post-season review processes, to prevent ACLs from being exceeded and to correct or mitigate overages of the ACL if they occur.

To some extent, the previously existing HG control rules for actively managed species also merge scientific uncertainty and OY considerations thereby providing additional reductions from OFL levels. Therefore, HG control rules are considered in conjunction with ABC control rules to prevent overfishing (see Section 4.6).

For monitored stocks, Amendment 13 maintained the previously existing harvest control rules but modified them so as to specify the new necessary management reference points. Amendment 13 stated that for the monitored finfish stocks (Northern anchovy [northern and central subpopulations] and jack mackerel) the OFL would be based on existing species-specific MSYs, if previously specified, or other MSY proxies. The existing 75 percent reduction buffer in the ABC control rule (ABC equals 25 percent of MSY) would remain in use until recommended for modification by the Council's Scientific and Statistical Committee (SSC) based on best available science and approved by the Council (below). ABCs are further reduced based on estimated resident stock size in U.S. waters. ACLs would be specified for multiple years until such time as the species becomes actively managed or new scientific information becomes available.

Default control rules for CPS Finfish Monitored Stocks:

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

Reference points for monitored CPS stocks are difficult to determine due to limited data to estimate biomass and productivity, however current landings of CPS finfish monitored stocks are extremely low. While landings remain low, the stock remains in the monitored category, ACLs are specified for multiple years, and stock status is assessed infrequently; any stock supporting catches approaching or exceeding the ACL levels will be reviewed to see if they should be moved to active management.

The default control rules and overfishing specifications are generally used for these monitored stocks. Stock specific MSY proxies, ABC, and ACLs can be revised based on the best available science as recommended by the SSC and as adopted through the annual harvest specification process, and will be reported in the CPS SAFE.

3.6.1 General Harvest Guideline/Harvest Control Rule for Actively Managed Species

The general form of the harvest control rule used for actively managed CPS fisheries was designed to continuously reduce the exploitation rate as biomass declines. The general formula used is:

HG = (BIOMASS-CUTOFF) x FRACTION x DISTRIBUTION

where HG is the harvest target level, CUTOFF is the lowest level of estimated biomass at which directed harvest is allowed, and FRACTION is the fraction of the biomass above CUTOFF that can be taken by the fishery. The BIOMASS is generally the estimated biomass of fish age 1+ at the beginning of the fishing season. The purpose of CUTOFF is to protect the stock when biomass is low. The purpose of FRACTION is to specify how much of the stock is available to the fishery when BIOMASS exceeds CUTOFF. DISTRIBUTION is the prorated proportion of a stock's biomass estimated to be in U.S. waters. It may be useful to define any of the parameters in this general harvest control rule, so they depend on environmental conditions or stock biomass. Thus, the harvest control rule could depend explicitly on the condition of the stock or environment.

The formula generally uses the estimated biomass for the whole stock in one year (BIOMASS) to set harvest for the entire stock in the following year (HG), although projections or estimates of BIOMASS, index of abundance values, or other data may be relied upon as well. The BIOMASS represents an estimate and thus is subject to some amount of uncertainty. For example, recent CPS stock assessments resulted in coefficients of variation associated with terminal biomass estimates of roughly 30 percent. It is important to note that scientific uncertainty around biomass estimates (stock assessment error) was accounted for in the current Pacific sardine harvest guideline rule.

The general harvest control rule for CPS (depending on parameter values) is compatible with the MSA and useful for related species that are important as forage. If the CUTOFF is greater than zero, then the harvest rate (HG/BIOMASS) declines as biomass declines. By the time BIOMASS falls as low as CUTOFF, the harvest rate is reduced to zero. The CUTOFF provides a buffer of spawning stock that is protected from fishing and available for use in rebuilding if a stock becomes overfished. The combination of a spawning biomass buffer equal to CUTOFF and reduced harvest rates at low biomass levels means that a rebuilding program for overfished stocks may be defined implicitly. Moreover, the harvest rate never increases above the FRACTION. If the FRACTION is approximately equal to F_{MSY}, then the harvest control rule harvest rate will not exceed F_{MSY}. In addition to the CUTOFF and FRACTION parameters, a maximum harvest level parameter (MAXCAT) was established so that total harvest specified by the general formula never exceeds the 200,000 mt. The MAXCAT is used to protect against extremely high catch levels due to errors in estimating biomass, to reduce year-to-year variation in catch levels, and to avoid overcapitalization during short periods of high biomass and high harvest. Also, the MAXCAT distributes the catch from strong year classes across a wider range of fishing seasons.

Other general types of control rules may be useful for CPS and this FMP does not preclude their use as long as they are compatible with National Standards and the MSFCMA.

3.6.2 Harvest Guideline Control Rule for Pacific Sardine

The harvest control rule for Pacific sardine sets an HG for the U.S. fishery based on an estimate of biomass for the whole sardine stock, a minimum biomass threshold (CUTOFF) equal to 150,000 mt, a harvest FRACTION between 5 percent and 20 percent (depending on oceanographic conditions as described below), and maximum allowable catch (MAXCAT) of 200,000 mt (PFMC 1998). The U.S. HG is calculated from the target harvest for the whole stock by prorating the total HG based on 87 percent DISTRIBUTION of total biomass in U.S. waters, e.g.:

$$HG = (BIOMASS - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION$$

Harvest FRACTION depends on recent ocean temperatures, because sardine stock productivity is typically higher under ocean conditions associated with warm water temperatures. An estimate of the relationship between F_{MSY} for sardine and ocean temperatures is:

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

where T is the average three-season sea surface temperature (SST) (C°) at Scripps Pier (La Jolla, California) during the three preceding seasons. Thus, the control rule for Pacific sardine sets the control rule parameter FRACTION equal to F_{MSY} over a narrow range of temperatures, such that FRACTION is never allowed to be higher than 20 percent or lower than 5 percent.

Although F_{MSY} may be lesser or greater, FRACTION can never be less than 5 percent or greater than 20 percent unless the control rule for sardine is revised, because the 5 percent and 20 percent bounds are policy decisions based on social, economic, and biological criteria. In contrast, relationships between FRACTION, F_{MSY} and environmental conditions are technical questions and estimates or approaches may be revised by technical teams (e.g., the CPSMT) to accommodate new ideas and data.

In February 2013, the Council and the NOAA Southwest Fisheries Science Center convened a workshop of experts to re-visit parameters of Pacific sardine harvest control rule. The workshop participants found that the California Cooperative Oceanic Fisheries Investigations (CalCOFI) temperature series provides a better relationship to sardine productivity than the SIO temperature series. Subsequently, the council initiated a process to use the CalCOFI temperature index in sardine management, eventually adopting the revised F_{MSY} relationship, the new CalCOFI temperature index, and a revised harvest FRACTION range bounded by 5 percent and 20 percent[1].

[1] The Council used the revised F_{MSY} relationship beginning with the April 2014 meeting, and adopted the new temperature index and harvest FRACTION range at its November 2014 meeting. Annual calculations of the OFL and ABC, recommended by the Council and approved by NMFS since that time have subsequently used this new relationship. However, unlike for the OFL and ABC control rules, the formula for the HG control rule must be changed under the framework mechanism of the FMP.

3.6.3 Harvest Control Rule (Harvest Guideline (HG) rule) for Pacific Mackerel

The HG control rule for Pacific mackerel sets the CUTOFF and the definition of an overfished stock at 18,200 mt and the FRACTION at 30 percent. Overfishing is defined as any fishing in excess of the OFL calculated using the OFL control rule. No MAXCAT is defined, given the U.S. fishery appears to be limited by markets and resource availability to about 40,000 mt per year; however, in the event landings increase substantially, then the need for such a cap should be revisited. The target harvest level is defined for the entire stock in Mexico, Canada, and U.S. waters (i.e., not just the U.S. portion), and the U.S. target harvest level is prorated based on 70 percent relative abundance (i.e., DISTRIBUTION) in U.S. waters.

3.6.4 Default CPS Control rule and Monitored Stocks

Northern anchovy (northern and central subpopulations), jack mackerel and market squid are currently classified under monitored status in CPS FMP. The Council may use the default harvest control rule (ABC = OFL*0.25) for setting ABC for Monitored species unless a better species-specific rule is available, as is the case for market squid. The default harvest control rule can be modified under framework management procedures.

3.6.4.1 Northern Anchovy-Central Subpopulation

The central subpopulation of northern anchovy ranges from approximately San Francisco, California, to Punta Baja, Mexico. The OFL or ABC is prorated by the DISTRIBUTION of the stock in U.S. waters to arrive at ABC in U.S. waters. In November 2010, the Council adopted an ABC and ACL both equal to 25,000 mt.

3.6.4.2 Northern Anchovy-Northern Subpopulation

The northern subpopulation of northern anchovy ranges from San Francisco north to British Columbia, with a major spawning center off Oregon and Washington that is associated with the Columbia River plume. The northern subpopulation supports small but locally important bait and human consumption fisheries. Northern anchovy is an important source of forage to local predators, including depleted and endangered salmonid stocks.

Additionally the portion of the northern subpopulation of northern anchovy resident in U.S. waters is unknown. It is likely that some biomass occurs in Canadian waters off British Columbia. In November 2010, the Council adopted an ABC and ACL both equal to 9,750 mt. The Council also adopted an ACT of 1,500 mt, which serves as a check-in point for the states of Oregon and Washington.

3.6.4.3 Jack Mackerel

The MSY level for jack mackerel is calculated by age/area from mid-range potential yield values. OFL or ABC in U.S. waters is prorated according to the DISTRIBUTION of the stock in U.S. waters (65 percent). In November 2010, the Council established an ABC and an ACL both equal to 31,000 mt.

3.6.4.4 Market Squid

The MSY Control Rule for market squid is founded generally on conventional "eggs per recruit" model theory. Specifically, the MSY Control Rule for market squid is based on evaluating (throughout a fishing season) levels of egg escapement associated with the exploited population. The estimates of egg escapement are evaluated in the context of a "threshold" that is believed to represent a minimum level that is considered necessary to allow the population to maintain its level of abundance into the future (i.e., allow for "sustainable" reproduction year after year). In practical terms, the Egg Escapement approach can be used to evaluate the effects of fishing mortality (F) on the spawning potential of the stock, and in particular, to examine the relation between the stock's reproductive output and candidate proxies for fishing mortality rates that would result in MSY (F_{MSY}).

The fishing mortality (F_{MSY}) that results in a threshold level of egg escapement of at least 30 percent is used as a proxy for MSY. However, it is important to note that the level of egg escapement is reviewed periodically, as new information becomes available concerning the dynamics of the stock and fishery, to ensure that the threshold meets its objective as a long-term, sustainable biological reference point for this marine resource. This is not a trivial exercise, given the need for ongoing research regarding the biology of this species, which may result in revised recommendations in the future. Current studies include developing an ageing program, sampling reproductive status of squid landed in the fishery, assessing the quality of spawning habitats, estimating mortality rates and modeling squid movement from paralarval to adult stages, and a collaboration with industry to develop a long-term index of paralarval abundance. Note that in an experiment conducted by McDaniel et al. (2015) new methods were developed for drying mantle punches to derive "the mantle condition index", which is a critical parameter of the egg escapement model. These newer procedures allow CDFW staff to processes mantles punches at a rate that is approximately 100 times faster than the rate of processing established in the original method by Macewicz et al. (2004). Since 2010, CDFW has also been measuring fresh instead of formalin preserved gonad weight of market squid, which is another important parameter of the egg escapement model. Likewise, a new equation has been developed by McDaniel et al. (2015) to convert fresh gonad weight into formalin preserved weight, and thus allowing the continuity of the time series of gonad weight data from 1999-2006 (developed by Dorval et al., 2013) based on preserved gonad weight) to 2007-2014. These new mantle and gonad data will be used to update the egg escapement model and provide estimates of proportional egg escapement and fishing mortality rates from 1999 to 2014.

The market squid fishery operates within the constraints of currently adopted regulations of the MSFMP (e.g., annual landings cap, weekend closures, closed areas, limited entry), and also monitored by NMFS, as long as egg escapement on average is equal to, or greater than, the threshold value. In the event that egg escapement is determined to be below the 30 percent threshold for two successive years, then a point-of-concern would be triggered under the FMP's management framework, and the Council could consider moving market squid from Monitored to Active management status. Current state regulations for squid are not anticipated to change in the near future. However, should existing laws limiting effort or harvest be rescinded, further management actions by the Council could also be considered. In November 2010, the Council adopted an ABC proxy of F_{MSY} resulting in egg escapement ≥ 30 percent. Recent research has provided new information regarding squid egg escapement (see Dorval et al 2013).

3.7 Annual Specifications and Announcement of Harvest Levels

Each year, the Secretary will publish in the *Federal Register* the final specifications for all CPS Actively managed by the Council. The total U.S. harvest will be allocated to the various fisheries as ACLs, HGs or ACTs, or as quotas.

In calculating ACLs, ACTs, HGs and quotas for each species, an estimate of the incidental catch of each species caught while fishermen are targeting other species will be taken into account. Therefore, the total HG will consist of an incidental catch portion and a directed fishery portion. In general, HGs or ACTs will be used to describe direct and incidental commercial fishery take, will be set in accordance with harvest control rules, and may be below the ACL to take into account management uncertainty and additional known sources of mortality such as recreational harvest, discards, bycatch, research take, and live bait fisheries. This will be done to minimize the chances of exceeding the target harvest levels and the ACL.

If the HG, ACL, or ACT for the directed fishery is reached, the directed fishery will be closed by an automatic action and incidental catch will continue to be allowed under the incidental catch allowance, which is expressed in an amount of fish or a percentage of a load (Section 5.1). If the estimated incidental catch portion of the HG, ACL, or ACT has been set too high, resulting in the probability of not attaining the target harvest level by the end of the fishing season, the remaining incidental catch portion may be allocated to the directed fishery through the "routine" management procedures. This reallocation of the remaining incidental catch portion of the HG to the directed fishery is not likely to be necessary unless substantial errors are discovered in calculations or estimates.

3.7.1 General Procedure for Setting Annual Specifications

The intent of the management approach under the FMP is to reassess the status of each actively managed species at frequent intervals and preferably every year (although a full analytic stock assessment may not be necessary or possible in some cases). The general procedure for making the annual specifications for CPS is as follows:

1. The CPSMT will produce a SAFE report that documents the current estimates of biomass for each CPS assessed and status of the fishery. In the report, the CPSMT will include the most recent harvest specifications and the stock assessment used to inform harvest specifications.

2. The Council will review all information compiled for the annual specifications, consider recommendations of the SSC, CPSMT, CPSAS, and will hear public comments. The Council also will review any important social and economic information at that time, then make a recommendation to the NMFS Regional Administrator on the final specifications, including OFL, ABC, OY levels, ACLs, ACTs, HGs, quotas, allocations, and other management measures for the fishing season.

3. Following the Council meeting, the NMFS Regional Administrator will make a determination of the final specifications. This determination will be published in the *Federal Register* with a request for additional public comment.

4. Alternate Procedure: If assessment and season schedules warrant, the NMFS Regional Administrator may make preliminary harvest specifications quickly (without prior discussion

at a Council meeting) to allow fishing to begin without delay. As soon as practicable, the Council will review all background documents contributing to the determination of the biomass estimates and make a final recommendation for the resulting target harvest level, HGs, and quotas. Following the meeting of the Council, the NMFS Regional Administrator will consider all comments and make a determination of whether any changes in the final specifications are necessary. If such changes are warranted, they will be published in the *Federal Register*.

The intention of the proposed regulations is to have public review of and a Council recommendation on the estimated biomass and HGs before the fishing season begins; however, the NMFS Regional Administrator is not precluded from announcing the HGs in the *Federal Register* before the process is completed so that fishermen can plan their activities and begin harvesting when the fishing season begins.

If assembling the data and producing a report would require enough time that permitting a complete public review before the beginning of the fishing season could reduce the season, then this alternate procedure should be used.

5. NMFS and the west coast states will monitor the fishery throughout the year, tracking incidental catch, ACTs, and HGs and quotas. If an HG or quota for any species is or is likely to be reached prematurely, a "point of concern" may occur, triggering a possible review of the status of the stock. If the directed harvest portion of an ACT or ACL, HG, or quota is reached, then directed fishing will be prohibited and the pre-specified incidental trip limit will be imposed as an automatic action through publication of a notice in the *Federal Register*.

3.8 Section References:

California Department of Fish and Game (CDFG). 2005. Final market squid fishery management plan. Document can be obtained from State of California Resources Agency, Department of Fish and Game, Marine Region, 4665 Lampson Avenue (Suite C), Los Alamitos, CA 90720. 124 p.

Dorval, E., J. McDaniel, and P. Crone. 2008. Squid population modeling and assessment (January 2008). Final report submitted to the California Department of Fish and Game (Marine Region) and the Southwest Fisheries Science Center. 30 p.

Dorval, E., Crone, P.R., and McDaniel, J.D. 2013. Variability of egg escapement, fishing mortality and spawning population in the market squid fishery in the California Current Ecosystem. Marine and Freshwater Research. 64(1): 80-90.

Macewicz, B.J.; J.R. Hunter; N.C.H. Lo; and E.L. LaCasella. 2004. Fecundity, egg deposition, and mortality of market squid (*Loligo opalescens*). Fish. Bull. 102: 306-327.

Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). 1990. Public Law 94-265.

Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA). 2006. Public Law 109-479.

McDaniel, J.M., E. Dorval, J. Taylor, and D. Porzio. 2015. Optimizing biological parameterization in the egg escapement model of the market squid, (*Doryteuthis opalescens*), population off California. NOAA-TM-NMFS-SWFSC-551. doi:10.7289/V5/TM-SWFSC-551.

Restrepo, V. R., and ten co-authors. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31.

Pacific Fishery Management Council (PFMC). 1998. Amendment 8 (To the northern anchovy fishery management plan) incorporating a name change to: the coastal pelagic species fishery management plan. Document can be obtained from Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220.

Pacific Fishery Management Council (PFMC). 2002. Status of the Pacific Coast coastal pelagic species fishery and recommended acceptable biological catches: stock assessment and fishery evaluation (2002). Appendix 3: market squid MSY. Document can be obtained from Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220.

4.0 Bycatch and Discard Mortality

Fishery management plans prepared by a fishery management council or by the Secretary must, among other things, establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures to the extent practicable and in the following priority:

1. Minimize bycatch.
2. Minimize the mortality of bycatch that cannot be avoided.

The MSA defines bycatch as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. Such term does not include fish released alive under a recreational catch and release fishery management program" (16USC1802).

CPS vessels fish with roundhaul gear (purse seine or lampara nets). These are encircling type nets, which are deployed by a skiff around a school of fish or part of a school. The end of the float line is then attached back to the vessel. With purse seines, the bottom of the net (the lead line) is then pulled closed. Lampara nets do not purse the bottom. The area including the free-swimming fish is diminished by bringing one end of the net aboard the vessel. When the fish are crowded near the fishing vessel, pumps are lowered into the water to pump fish and water into the ship's hold. Another technique is to lift the fish out of the net with netted scoops (e.g., stocking brails). Roundhaul fishing results in little unintentionally caught fish, primarily because the fishermen target specific schools, which usually consists of one species. CPS typically school with similarly sized fish. The most common incidental catch in the CPS fishery is another coastal pelagic species (e.g., Pacific mackerel incidental to the Pacific sardine fishery). If larger fish are in the net, they can be released alive before pumping or brailing by lowering a section of the cork-line or by using a dip-net. The load is pumped out of the hold at the dock, where the catch is weighed and incidentally-caught fish can be observed and sorted. Because pumping at sea is so common, any incidental catch of small fish would not be sorted at sea. Grates can be used to sort larger non-CPS from the catch. Grates are mandatory in Oregon to sort larger non-CPS from the catch. At-sea observers have recorded discard at one time or another since the year 2000 off the states of Oregon, Washington, and California. Incidental harvest of non-prohibited larger fish are often taken home for personal use or processed.

Historically, market squid have been fished at night with the use of powerful lights, which cause squid to aggregate, allowing fishermen to pump squid directly from the sea or to encircle them with a net. California actively manages the market squid fishery in waters off California and has developed an FMP for the state-managed fishery. Management measures pertinent to bycatch include

Establishing a prohibition on use of lights in the Greater Farallones National Marine Sanctuary to eliminate the potential of future negative interactions with seabirds.

Additionally, several circumstances in the fishery tend to reduce bycatch:

1. Most of what would be called bycatch under the MSA is caught when roundhaul nets fish in shallow water over rocky bottom. Fishermen try to avoid these areas to protect their gear. Also, they may be specifically prohibited to fish these areas because of closures.

2. South of Pt. Buchon, California, many areas are closed to roundhaul nets under California law and the FMP, which reduces the chance for bycatch.
3. In California, a portion of the sardine caught incidentally by squid or anchovy harvesters can be sold.
4. A provision in the CPS FMP allowing landings of less than five tons without a LE permit should reduce regulatory discard, because those fish can be landed without penalty. LE permits otherwise are required south of Point Arena, California.
5. From 1996 to 2003, bycatch from the live bait logs was reported with an incidence of 10 percent. The primary species taken as incidental catch was barracuda. Virtually all fish caught incidentally in this fishery are either used for bait, for personal use, or released alive. (See Table 4-11).
6. CDFW's logbook program for the squid fishery collects data including bycatch.

4.1 Federal Protection Measures

NMFS regularly conducts Endangered Species Act (ESA) section 7 consultations to ensure that federally threatened or endangered species are not adversely affected by federally managed fisheries. Since 1999, the NMFS WCR Sustainable Fisheries Division (SFD) has conducted numerous formal and informal consultations with Federal agencies, including the NMFS Protected Resource Division (PRD) and U.S. Fish and Wildlife Service (USFWS) regarding CPS fisheries. In all informal consultations the PRD concurred with the SFD, that the CPS fishery is not likely to adversely affect protected resources. In all formal consultations on the Pacific sardine fishery specifically, no jeopardy determinations were made.

The NMFS WCR Sustainable Fisheries Division initiated a Section 7 consultation with NMFS WCR Protected Resources Division (PRD) on the continued management and prosecution of the Pacific sardine fishery. PRD completed a formal Section 7 consultation on this action and in a biological opinion (BO) dated December 21, 2010, determined that fishing activities conducted under the CPS FMP and its implementing regulations are not likely to jeopardize the continued existence of any endangered or threatened species under the jurisdiction of NMFS or result in the destruction or adverse modification of critical habitat of any such species. Specifically, the current status of the Lower Columbia River Chinook, Snake River Fall Chinook, Upper Willamette Chinook, Puget Sound Chinook, Lower Columbia River coho and Oregon coast coho, were deemed not likely to be jeopardized by the Pacific sardine fishery. Additionally, NMFS determined that the potential for direct incidental take of other ESA-listed salmon, marine mammals, sea turtles, green sturgeon, abalone, or steelhead, through the harvest of sardines in the purse seine fishery was discountable, and the potential indirect adverse effects of sardine harvest on ESA-listed species were insignificant.

NMFS also initiated an ESA Section 7 consultation with USFWS regarding the possible effects of implementing Amendment 11 to the CPS FMP. USFWS concurred with NMFS and determined that implementing Amendment 11 may affect, but was not likely to adversely affect: the endangered tidewater goby, the threatened western snowy plover, the Santa Ana sucker, the endangered short tailed albatross, the endangered California brown pelican, the endangered California least-tern, the threatened marbled murrelet, the threatened bald eagle, the threatened bull trout, and the candidate Xantus's murrelet. Formal consultation, however, was deemed necessary on the possible effects to the southern sea otter. The resulting BO signed June 16, 2006, concluded that fishing activities conducted under Amendment 11 and its implementing regulations were not likely to jeopardize the continued existence of the otter. As a result of this BO new reporting requirements and conservation measures were implemented within the CPS FMP to provide further protection for southern sea otters.

These reporting requirements and conservation measures require all CPS fishermen and vessel operators to employ avoidance measures when sea otters are present in the fishing area and to report any interactions that may occur between their vessel and/or fishing gear and otters. Specifically, these new measures and regulations are:

1. CPS fishing boat operators and crew are prohibited from deploying their nets if a southern sea otter is observed within the area that would be encircled by the purse seine.
2. If a southern sea otter is entangled in a net, regardless of whether the animal is injured or killed, such an occurrence must be reported within 24 hours to the Regional Administrator, NMFS West Coast Region.
3. While fishing for CPS, vessel operators must record all observations of otter interactions (defined as otters within encircled nets or coming into contact with nets or vessels, including but not limited to entanglement) with their purse seine net(s) or vessel(s). With the exception of an entanglement, which will be initially reported as described in #2 above, all other observations must be reported within 20 days to the Regional Administrator.

4.1.1 California Coastal Pelagic Species Pilot Observer Program

NMFS SWR (prior to merging with the NMFS NWR) initiated a pilot observer program for California-based commercial purse seine fishing vessels targeting CPS in July 2004 with hopes of augmenting and confirming bycatch rates derived from CDFW dockside sampling. SWR personnel trained the first group of CPS observers in mid-July in Long Beach, California. Frank Orth and Associates, a private contractor, hired and provided observers for training and subsequent deployment. Six observers who had previous experience in other SWR-observed fisheries attended and completed the course. The training course emphasized a review of ongoing observer programs (drift gillnet, pelagic longline) and introduction to the soon-to-be observed fisheries (purse seine, albacore hook-and-line). The training curriculum included vessel safety, fishing operations, species identification, and data collection.

In late July 2004, observers began going to sea aboard CPS vessels. Observers used ODFW's Sardine Bycatch Observations form to record data on fishing gear characteristics, fishing operations, and target/non-target species catch and disposition. Observers also recorded data on trip specifics and protected species sightings/interactions. Observers had access to data field definitions in their SWR observer program Field Manuals. Most data detailing length, volume, or weight of the catch were obtained verbally from the vessel operator. Position and time data were recorded by the observer directly from hand-held or on-board electronics.

Data from this program have been compiled though 2008 (Tables 6-1 through 6-4). A total of 107 trips by vessels targeting CPS (228 sets) were observed from July 2004 to January 2006. Tables 6-1 through 6-4 show how incidental catch and bycatch data collected during this time and are categorized by target species of the trip (i.e., Pacific sardine, Pacific mackerel, market squid or anchovy). Additionally, from January 2006 to January 2008 a total of 199 trips (426 sets) were observed.

Potential future needs of any CPS observer program include: standardization of data fields, development of a fishery-specific Observer Field Manual, construction of a relational database for the observer data, and creation of a statistically reliable sampling plan. A review of the protocol and catch data by NMFS Southwest Science Center staff, the CPS Management team and other CPS interested parties is planned in the future to help address some of these needs.

4.2 Fishery South of Pigeon Point

Information from at-sea observations by the CDFW and conversations with CPS fishermen suggest that bycatch south of Pigeon Point is not significant in these fisheries. However, some individuals have expressed concern that game fish and salmon might constitute significant bycatch in this fishery. This is a reasonable concern, because anchovy and sardine can be forage for these predators, but there are no data to confirm significant bycatch of these species. CDFW port samples indicate minimal incidental catch in the California fishery (Tables 4-5). The behavior of predators may help to minimize bycatch, as they tend to dart through a school of prey rather than linger in it, and easily avoid encirclement with a purse seine.

CDFW port samplers collect information from CPS landings in Moss Landing and ports to the south. Biological samples are taken to monitor the fish stocks, and port samplers report incidentally caught fish. Reports of incidental catch by CDFW port samplers confirm small and insignificant landings of bycatch at California off-loading sites (Tables 4-5). These data are likely representatives of actual bycatch, because (as noted) fish are pumped from the sea directly into fish holds aboard the vessel. Fishermen do not sort catch at sea or what passes through the pump. Unloading of fish also occurs with pumps. The fish are either pumped into ice bins and trucked to processing facilities in another location, or to a conveyor belt in a processing facility, where fish are sorted, boxed, and frozen.

From 1985 through 1999, there were 5,306 CDFW port samples taken from the sardine and mackerel landings. From 1992 to 1999, incidental catch was reported on only 179 occasions, representing a 3.4 percent occurrence. Up to 1999 reports of incidental catch were sparse, and prior to 1992 none were reported. Earlier incidents of bycatch may not have been noted, because the harvest of anchovy and sardine was small, and only since 1995 did the harvest of sardine increased substantially (see Table 8-3). The incidental catch reported are primarily marketable species that do not meet the definition of bycatch in the MSA. During this period, unless an incidental species represented a significant portion of the load (at least a whole percentage point) the amount of the incidental catch was not recorded. Of the incidental catch reported from 1992 to 1999, the two most prevalent species were market squid at 79 percent, and northern anchovy at 12 percent incidence within samples (not by load composition). CDFW port samples provide useful information for determining the significance of bycatch in the CPS fishery off California (south of Pigeon Point).

In 2001, California wetfish port samplers began tallying undocumented incidental catch observed during landings in greater detail, and listed the occurrence of species in each sampled landing. The port sampling program records bycatch observed (i.e., presence or absence evaluations), but actual amounts of incidental catch have not been quantified to date. In 2011, bycatch data were recorded by estimates of pounds observed in an offload at northern California ports. Offloading facilities in northern California allow observations and estimates of bycatch amounts compared to southern California ports. These observations are summarized in Table 4-5 for the 5 years between 2011 and 2015. The dynamic of the 2008 sardine fishery changed due to a decrease in the annual harvest guideline. Since then, fishing activity no longer took place year around, but was truncated within each allocation period. This may have affected the types and frequencies of organisms observed during the offloading process of sardine. The most commonly occurring flora and fauna in wetfish landings during 2015 were kelp, Pacific sanddab, butterfish, Pacific electric ray, unspecified shrimp, plainfin midshipman, unspecified crab, California lizardfish, bat ray, California scorpionfish, and eelgrass. . Sixty-six incidental species were observed in total. Since the closure of the directed sardine fishery starting in the 2015-2016 season, opportunistic sampling has occurred whenever sardine is found incidentally to another directed CPS catch.

Larger fish and animals are typically sorted for market, personal consumption, or nutrient recycling in the harbor. To document bycatch more fully at sea, including marine mammal and bird interactions, NOAA Fisheries placed observers on a number of California purse seine vessels beginning in the summer of 2004, under a pilot program that continued until 2008 (see Sec. 4.1.1).

4.2.1 Incidental Catch Associated with the Market Squid Fishery

Because market squid frequently school with CPS finfish, mixed landings of market squid and incidentally caught CPS finfish occur intermittently. In 2014, less than one percent of round haul market squid landings (by tonnage) included reported incidental catch of CPS (Table 4-6).

Although non-target catch in market squid landings is considered minimal, the presence of incidental catch (species that are landed along with market squid that are not recorded through landing receipt processes [i.e., not sold] as is typically done for incidentally-caught species) has been documented through CDFW's port sampling program. During 2015, incidental catch consisted of 36 species (Table 4-7). Similar to previous years, most of this catch was other pelagic species, including Pacific sardine, Pacific mackerel, and jack mackerel. However, kelp and algae were also observed frequently.

In 2015, market squid egg cases were identified in 3.7 percent of observed landings, a decrease from the previous year. The extent that market squid egg beds and bottom substrate are damaged by purse seine operations, which may contribute to mortality of early life stages, is not known at this time. One way to determine if nets are disturbing egg beds is to look for egg cases in market squid landings. When market squid egg cases are observed at offloading sites, there are two potential reasons that egg cases may be in the load: 1) market squid released egg cases in the net after being captured, or 2) egg cases were taken from the ocean floor during fishing activity. A sample of observed egg cases from loads are collected and aged. If egg cases are more than one day old, then egg cases were likely taken from the bottom, but the rate of development of embryos is greatly influenced by environmental conditions, such as temperature. One way to determine if egg cases were laid in the net or on the bottom is noting whether or not they appear fouled (algal growth) or attached to mud, which is noted on CDFW sample forms.

4.3 Fishery North of Point Arena

The Pacific sardine fishery north of Point Arena began again in 1999 after more than a 50 year hiatus. Oregon and Washington closely monitor these fisheries and collect information about landings. Information on bycatch and incidental catch from Oregon and Washington is summarized in Tables 4-8 through 4-10.

4.3.1 Oregon

CPS vessels landing in Oregon primarily target Pacific sardine. Oregon's LE sardine permit rules stipulate that an at sea observer be accommodated aboard vessels when requested by ODFW. ODFW does not have personnel dedicated to observe and document bycatch of non- target species on sardine vessels and available state personnel were unable to conduct onboard observations of any CPS fishery vessels during the 2014 through 2015-2016 fisheries. Also, no Federal observers were placed on the vessels. To reduce bycatch, the state requires the use of a grate over the intake of the hold to sort out larger species of fish, such as salmon or mackerel. The grate size spacing can be no larger than 2-3/8 inches between bars. Oregon rules require seine gear logbooks that record incidental catch including salmonids and other species. Effective May 27, 2015, Oregon extended these requirements for sardine fishing to purse seine fishing for all coastal pelagic species, jacksmelt, and Pacific herring, except the grate is not required for the market squid fishery.

With adoption of CPS FMP Amendment 13 in September 2011, Pacific herring, which occur in waters off all three states, and jacksmelt, which typically occur only in waters off California, were designated as "ecosystem component species", as defined in National Standard 1 guidelines. The incidental catch of these two species are required to be reported in the SAFE document.

<u>2014 Interim Fishery</u>
No sardines were landed in Oregon during this sardine fishery and therefore, there was no bycatch of salmon, ecosystem component species, or other species. There also were no other fisheries targeting CPS during this time.

With adoption of CPS FMP Amendment 15 in March 2016, a suite of lower trophic level species were designated as "shared ecosystem component species" and required to be reported in the SAFE document (Information on shared EC species will be included in the subsequent SAFE document).

<u>2014-2015</u>
Based on logbook records, bycatch of salmonids by the Oregon purse seine fleet was at its lowest since 2000 (Table 4-8). Of the 24 salmon reported incidentally taken in the 2014-2015 sardine fishery, 17 (71percent) were released live. Thus, the incidental catch rate was 0.002 salmon per mt of sardines landed. Both logbook data (Table 4-9) and fish ticket data (Table 4-10) indicate that the catch of other non-target species in the sardine fishery was nearly non-existent, except for Pacific mackerel and jack mackerel. With the low levels of allowed sardine harvest, mackerels also may have been opportunistically targeted during the sardine fishery openings when sardines may not have been as readily accessible; some landings were largely comprised of mackerels. For directed sardine fishery openings, Pacific mackerel landings totaled 1,008.1 mt and jack mackerel landings totaled 245.0 mt (Table 4-10). A trace amount of shad were also landed. Accordingly, non-target species accounted for

12.8 percent (by weight) of the 9758.3 mt of sardines landed in the 2014-2015 sardine fishery. Mackerels were also targeted when the sardine fishery periods were closed.

Three purse seine vessels targeted Pacific mackerel between the first and second sardine allocation periods, landing 196.5 mt of Pacific mackerel and 333.0 mt of jack mackerel. They also landed 160.1 mt of sardines as incidental catch.

For the sardine fishery, no ecosystem component species (herring and jacksmelt) were landed as incidental catch or recorded in logbooks (Tables 4-9 and 4-10). For ecosystem component species in other CPS fisheries, a small amount (0.3 mt) of Pacific herring was landed with sardines by beach seine gear.

<u>2015-2016</u>

The directed sardine fishery was closed and, therefore, there was no bycatch of salmon, ecosystem component species, or other species in this fishery. A total of 1.3 mt of sardines were landed incidentally in fisheries targeting other coastal pelagic species.

However for ecosystem component species landed by other CPS fisheries, 0.7 mt Pacific herring were landed with sardines by beach seine gear and a trace amount of herring was landed with market squid by purse seine gear during 2015-2016.

4.3.2 Washington

From 2000 through 2004, WDFW required fishers to carry at-sea observers, and to provide financial support for this observer effort. Bycatch information was collected in terms of species, amount, and condition; observers noted whether the fish were released or landed, and whether alive, dead, or in poor condition. During the five-year period of the program, overall observer coverage averaged over 25 percent of both total landed catch and number of landings made. Based on observer data, the bycatch of non-targeted species in the Washington sardine fishery was relatively low. Due to low bycatch levels, as well as a WDFW commitment to industry that the observer fee would only be assessed until bycatch in the sardine fishery could be characterized, the mandatory observer program was suspended at the conclusion of the 2004 season.

A comparison of logbook and observer data from 2000 to 2004 indicated that logbook data, in general, tended to under report bycatch by 20 to 80 percent (Culver and Henry, 2006). For this reason, salmon bycatch in the Washington sardine fishery for years subsequent to the observer program is calculated by multiplying total sardine catch and the observed five-year average bycatch rates. Bycatch and mortality estimates of incidentally captured salmon by year and species are shown in Table 4-14.

Incidental species caught and reported on Washington fish tickets are shown in Table 4-14. Mackerel, both Pacific and jack, comprise the majority of incidental catch in the sardine fishery. Until recent years incidental catch, other than mackerel, was minimal.

During the 2014 interim fishing Season (January 1 – June 30, 2014), the total estimated salmon bycatch was 55 fish (Chinook and coho combined). For the 2014 – 2015 fishing year, the total estimated salmon bycatch was 383 fish (Chinook and coho combined). With the closure of the directed Pacific sardine fishery, bycatch was zero during the 2015-2016 fishing year.

4.4 Section References

Culver, M., and C. Henry, 2006. Summary Report of the 2005 Experimental Purse Seine Fishery for Pacific Sardine (*Sardinops sagax*). Washington Department of Fish and Wildlife, Montesano, Washington. 11 pp.

5.0 SAFETY AT SEA CONSIDERATIONS

The safety of fishing activities is an important management concern. Roundhaul fisheries operating off the Pacific Coast are often limited by environmental conditions, most notably inclement weather. Given that the average age of permitted CPS vessels in the LE fishery is 34 years and many older vessels are constructed of wood, concern has been raised regarding their safety and seaworthiness. Implementing time/area closures or restricting transferability could impact safety by making more difficult to replace an older vessel with a newer, safer vessel; or by promoting fishing during hazardous weather conditions. This concern in part is addressed by Amendment 10 to the CPS FMP (January 2003), which allows LE permits to be transferred to another vessel and/or individual.

As discussed in Section 2.2, the Council created a long-term allocation strategy for sardines under Amendment 11 to the CPS FMP. This action was expected to enhance safety at sea by advancing the reallocation date from October 1 to September 15. Waiting until October 1 to reallocate has the potential of inducing fishermen to fish in unsafe weather conditions. However, from 2008 through 2014, the directed Pacific sardine fishery experienced seasonal closures because the period allocation was (in most cases) met prior to the end of that fishing period. The declining trend in HGs, beginning in 2008 led to a “derby style” fishery where vessels compete for a share of the seasonal harvest guideline over a short period of time. Such derby fisheries can create unsafe conditions, as season duration is compressed and competition increases.

The 2015-2016 and 2016-17 directed fisheries were closed because the biomass estimate fell below the cutoff value of 150,000 mt. Although some allowance was made for incidental catch of sardines in other CPS fisheries, Tribal catch, and other minor sources of mortality, the commercial fishery was essentially shut down.

The U.S. Coast Guard reported in March 2015 on U.S. West Coast safety incidents (http://www.pcouncil.org/wp-content/uploads/C1b_USCG_2014Rpt_MAR2015BB.pdf). There were no casualties or safety incidents noted in the report in the CPS fishery during 2014 or 2015. Reflecting year 2014, other highlights from the report include:

- Of 1,156 vessel boardings, 68 percent were engaged in federal fisheries managed by the Council. The rest were participating in either tribal or state-managed fisheries.
- Two lives were lost in 2014, the lowest number in many years. One was a geoduck clam scuba diver, and was from a Tribal fishing vessel.
- The USCG partners with Federal, tribal, and state counterparts in the region, on cooperative enforcement actions and monitoring activities.

6.0 ECONOMIC STATUS OF WASHINGTON, OREGON, AND CALIFORNIA CPS FISHERIES IN 2014

This section[2] summarizes economic data presented in Tables 6-1 through 6-5 in Appendix A, and Figures 6-1 through 6-10 below. Overall landings (all three states, all CPS species) increased substantially between 1998 and 2000, then showed peaks, including a notable increase in 2009, driven primarily by an increase in California market squid landings. Ex-vessel revenues also increased dramatically, beginning in the late 1990s. More recently, Washington, Oregon and California landings of CPS totaled 128,901 mt in 2014, a 30 percent decrease from 2013. Ex-vessel revenues decreased from $91 million to $73 million – a 20 percent decrease. Market squid landings, almost entirely in California, totaled 86,201 mt, with an ex-vessel value of $61 million - decreases of 17 percent in both cases from 2013. Pacific sardine landings and ex-vessel revenues declined substantially, likely in response to significantly reduced allowable harvest. The 2014 HG was less than half of the 2013 HG.

Market squid accounted for 81 percent and Pacific sardine 8 percent of total west coast CPS landings in 2014. Landings of Pacific mackerel decreased 32 percent, and landings of northern anchovy rose 73 percent from 2013 to 2014. Real ex-vessel market squid revenues (2014$) decreased 2 percent from 2013. The decrease in market squid landings was accompanied by a less than1 percent decrease in ex-vessel price from $704 to $702 per mt (2014$). There was an 11 percent increase in aggregate CPS finfish landings from 2013; ex-vessel revenue increased by 17 percent. In 2014, market squid accounted for slightly more than 30 percent of total west coast ex-vessel revenues, and CPS finfish accounted for 2 percent. Washington, Oregon and California shares of total west coast CPS landings in 2014 were 6 percent, 7 percent and 88 percent respectively.

The major west coast processors and buyers of CPS finfish are concentrated in the Los Angeles, Santa Barbara-Ventura, Monterey and the Columbia River port areas of Oregon and Washington. The ex-vessel markets for market squid are mainly in the Los Angeles, Santa Barbara-Ventura and Monterey port areas.

Between 2004 and 2014, market squid landings have ranged from 38,000 mt to 131,000 mt, with exvessel revenues ranging from $20 million to $74 million (Table 6-1). The primary country of export was China, and over 80 percent of market squid exports went to China and five additional countries: Philippines, Spain, Vietnam, Japan, and Hong Kong. Domestic sales were generally made to restaurants, Asian fresh fish markets or for use as bait.

[2] This section will be updated with current economic data in the next SAFE document.

Figure 1. Annual West Coast landings and ex-vessel revenues for all CPS species, 1981-2014.

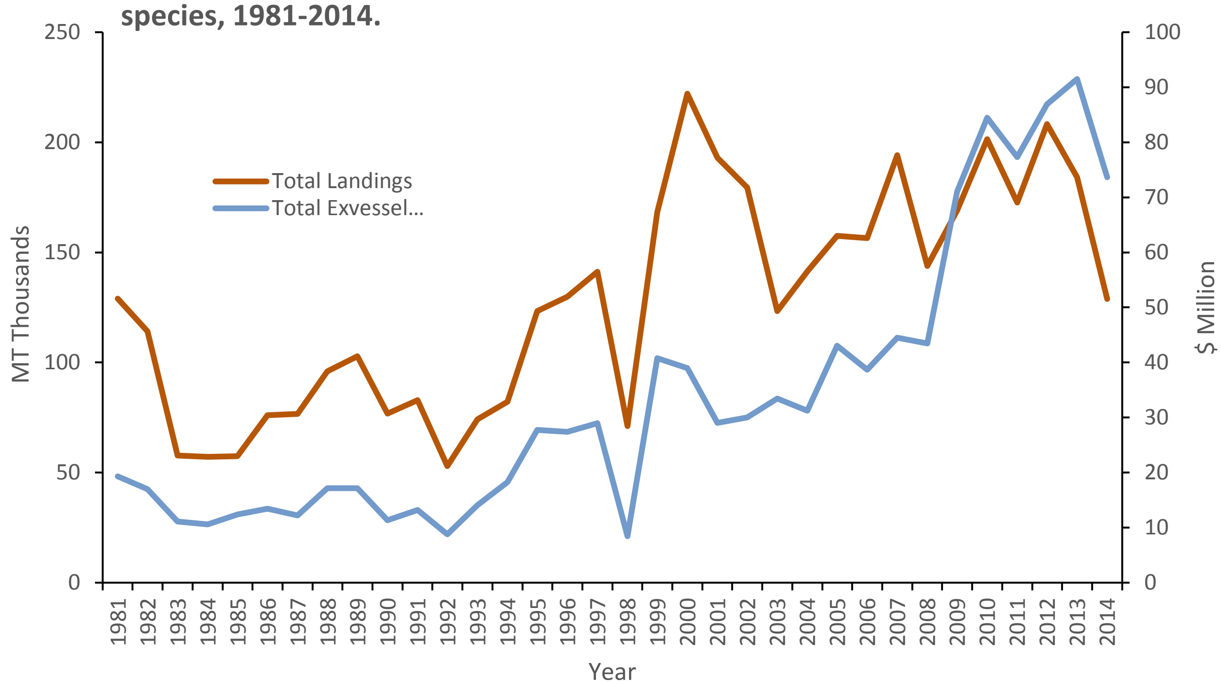
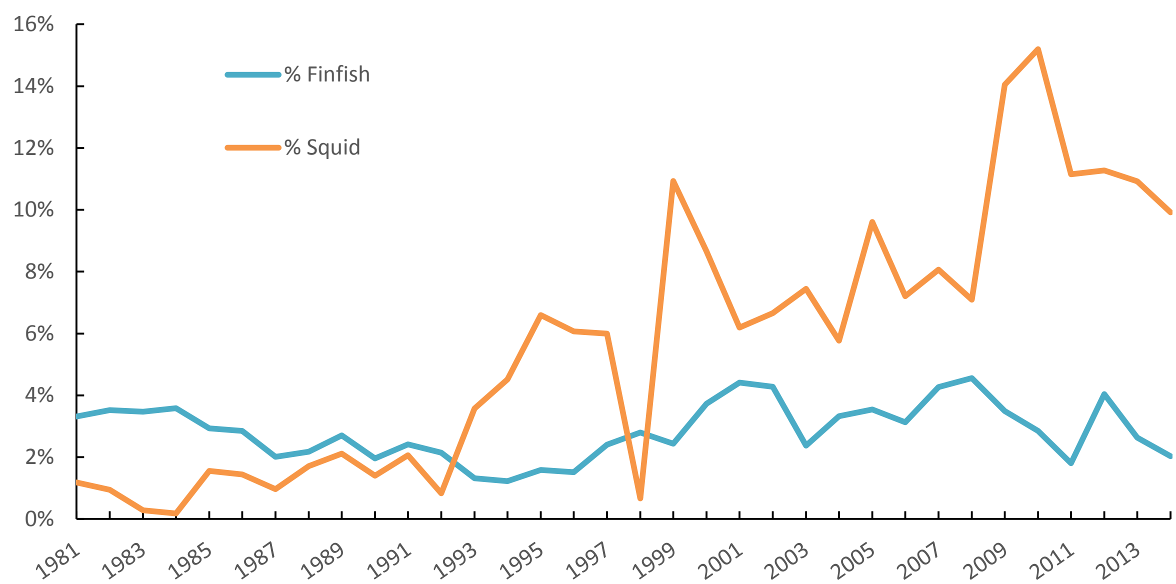


Figure 2. Percentage contribution of west coast CPS finfish and market squid landings to the total ex-vessel value of all Pacific coast landings, 1981-2014.



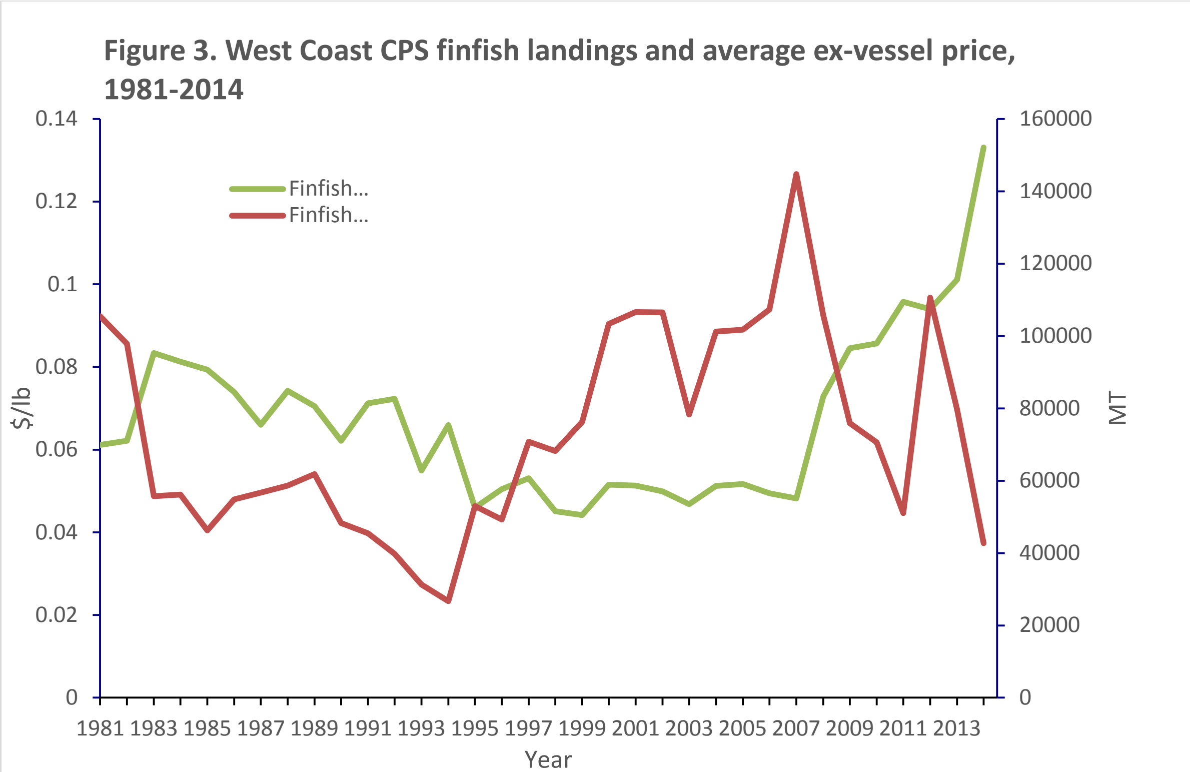


Figure 3. West Coast CPS finfish landings and average ex-vessel price, 1981-2014
$/lb
MT
Finfish...
Finfish...
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0
20000
40000
60000
80000
100000
120000
140000
160000
1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
Year

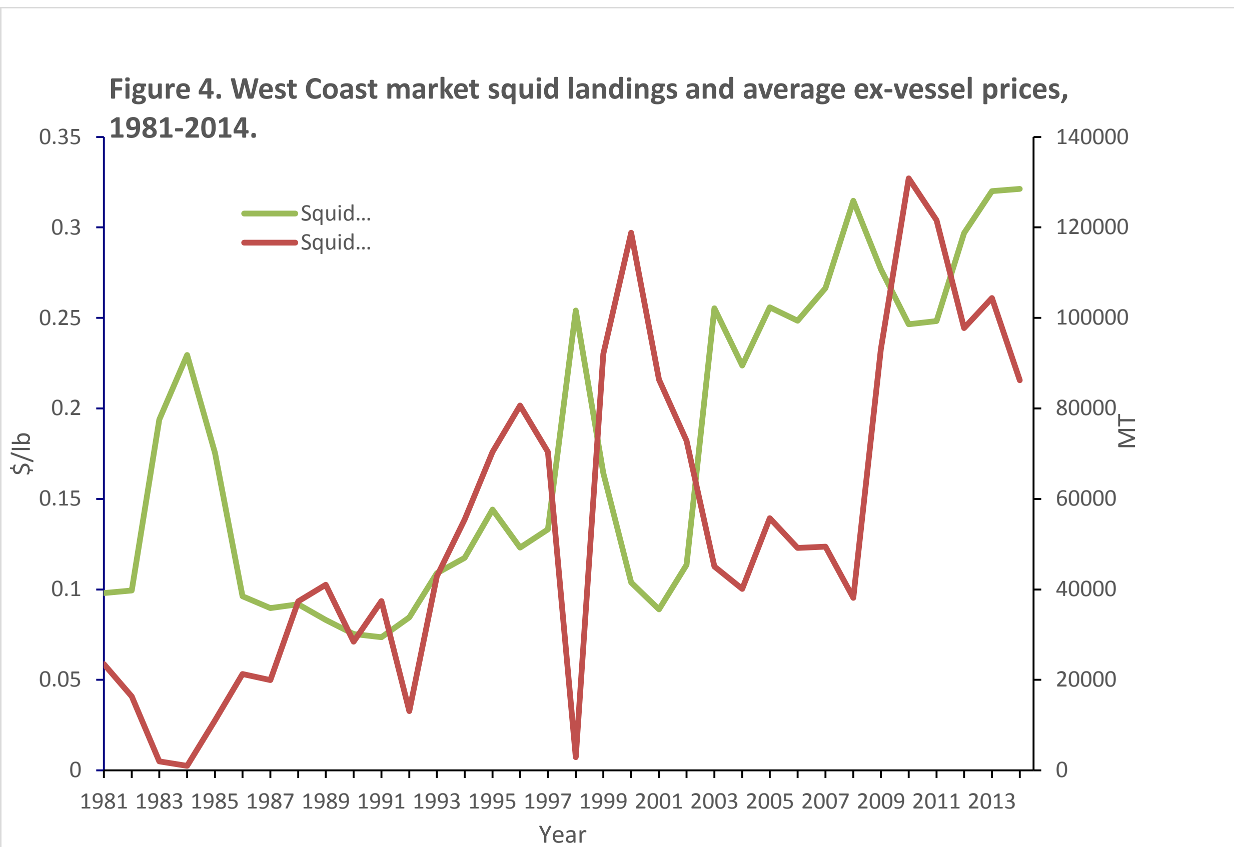


Figure 4. West Coast market squid landings and average ex-vessel prices, 1981-2014.
$/lb
MT
Squid...
Squid...
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0
20000
40000
60000
80000
100000
120000
140000
1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013
Year

Figure 5. Number of vessels with Pacific coast landings of CPS finfish, and number for which CPS finfish was the principle species, 1981-2014.

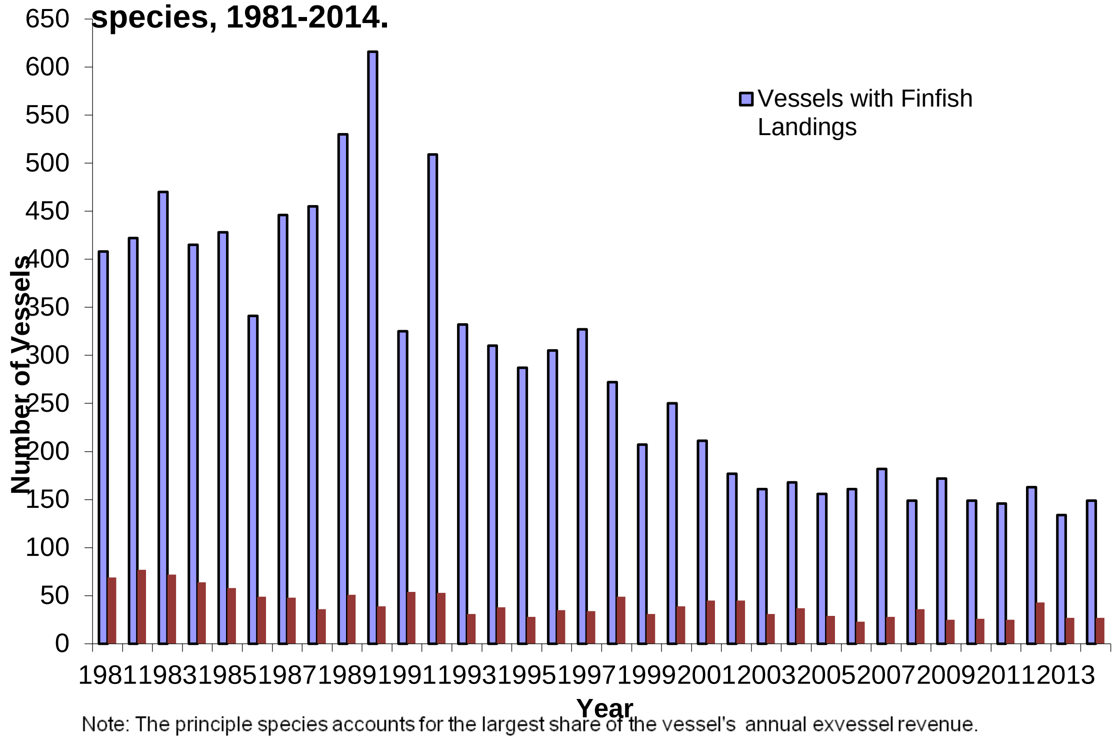
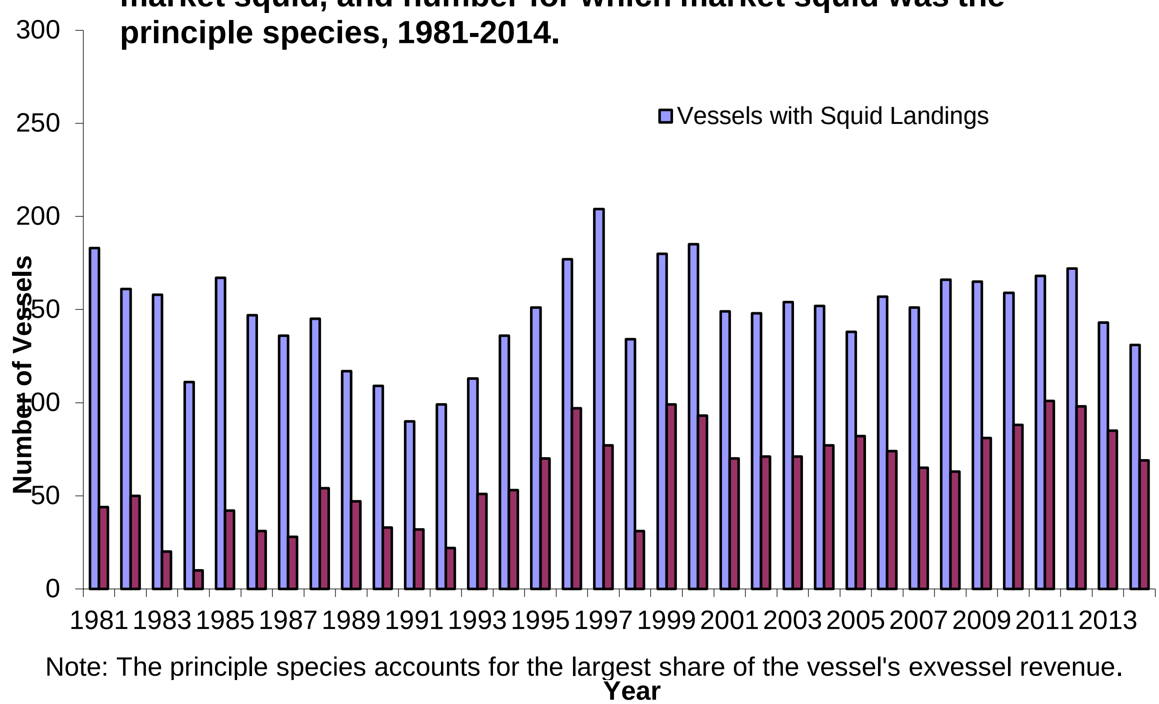


Figure 6. Number of vessels with Pacific coast landings of market squid, and number for which market squid was the principle species, 1981-2014.



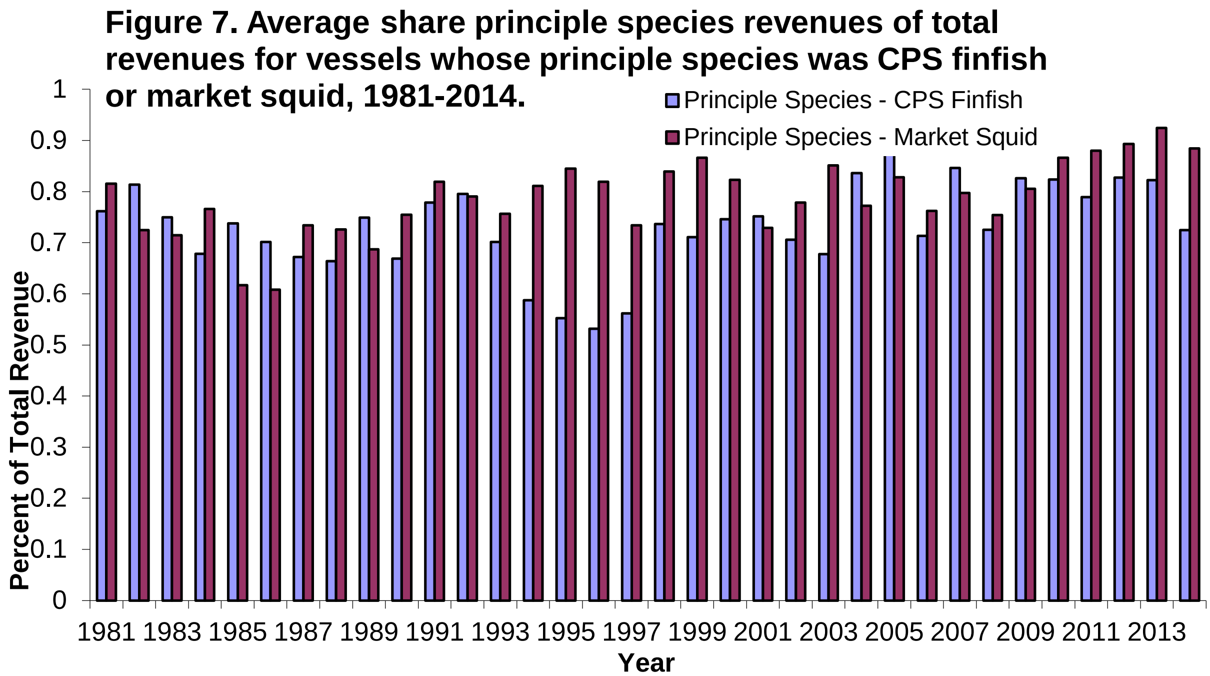


Figure 7. Average share principle species revenues of total revenues for vessels whose principle species was CPS finfish or market squid, 1981-2014.

Note: the principle species accounts for the largest share of the vessel's exvessel

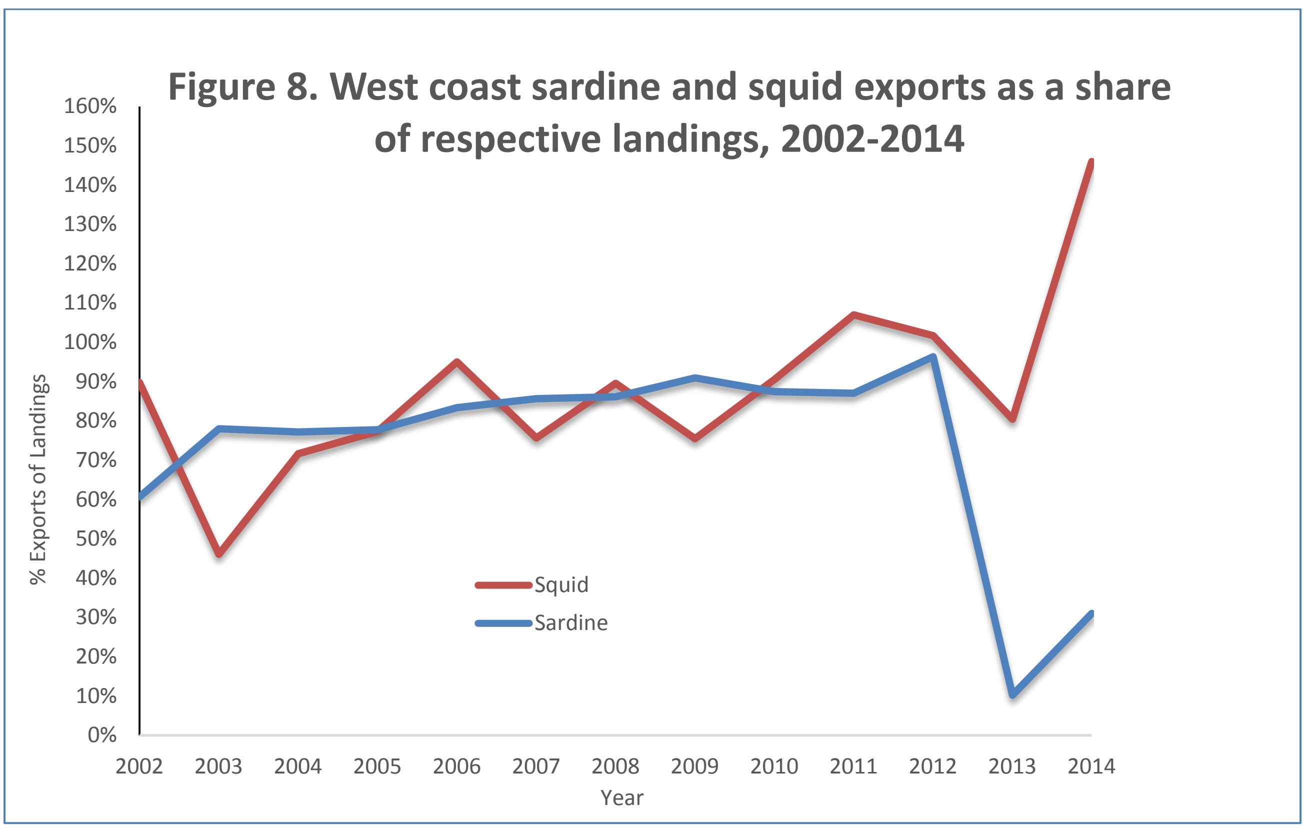


Figure 8. West coast sardine and squid exports as a share of respective landings, 2002-2014

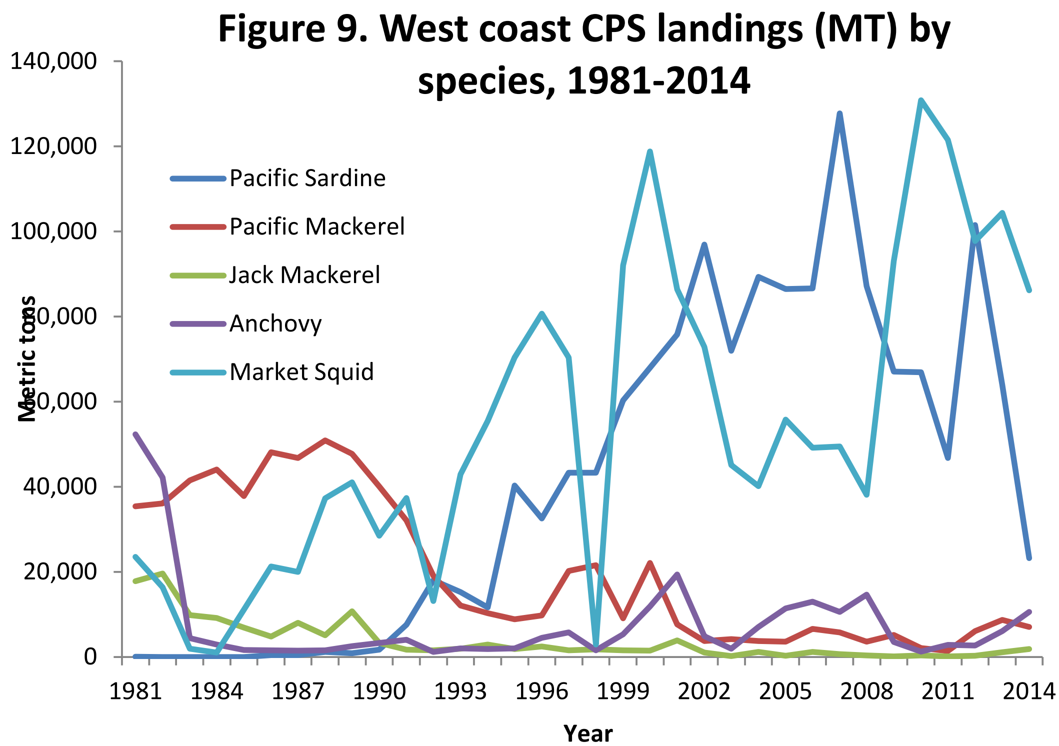


Figure 9. West coast CPS landings (MT) by species, 1981-2014
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Metric tons
Pacific Sardine
Pacific Mackerel
Jack Mackerel
Anchovy
Market Squid
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
Year

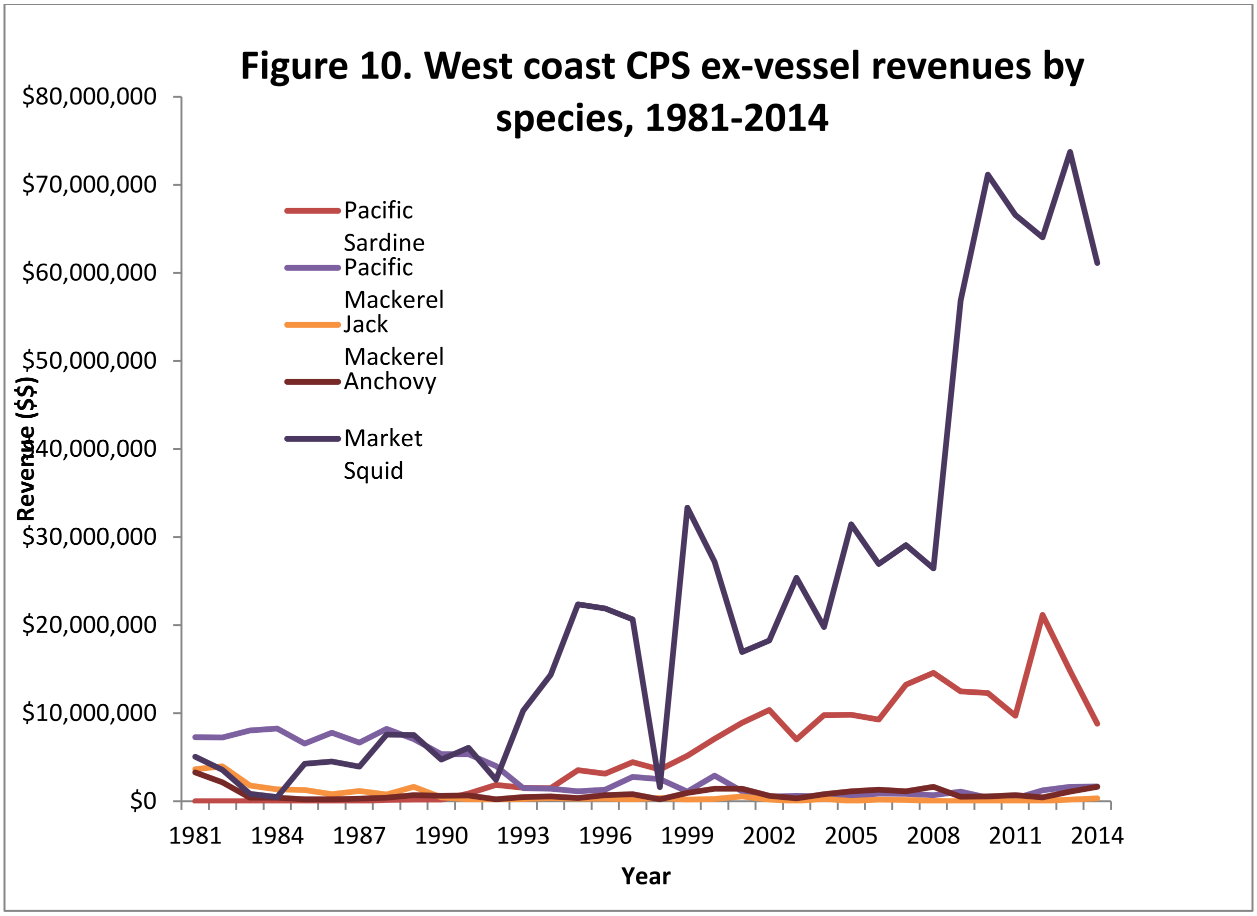


Figure 10. West coast CPS ex-vessel revenues by species, 1981-2014
$80,000,000
$70,000,000
$60,000,000
$50,000,000
$40,000,000
$30,000,000
$20,000,000
$10,000,000
$0
Revenue ($$)
Pacific Sardine
Pacific Mackerel
Jack Mackerel
Anchovy
Market Squid
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
Year

7.0 ECOSYSTEM CONSIDERATIONS

7.1 INTRODUCTION

There is a growing national interest in augmenting existing single-species fisheries management approaches with ecosystem-based fishery management principles that could place fishery management decisions and actions in the context of a broader scope. NOAA/NMFS Science Centers around the country are working to improve the science behind ecosystem-based fishery management including status monitoring and reporting on ecosystem health (Levin et al. 2009). In March 2016, the NWFSC and SWFC presented an "Annual State of the California Current Report" to the PFMC (PFMC 2016). Some of the ecosystem information in that report is also presented here. Additional information has been contributed by J. Field and K. Sakuma (SWFSC) and B. Peterson (NWFSC; www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip).

This section provides a summary of ecosystem trends and indicators being tracked by NOAA and other scientists that are related to CPS. Additionally, Appendix A of Amendment 8 to the CPS FMP (available on the Council's web site) provides a review of the life-cycles, distributions, and population dynamics of CPS and discusses their roles as forage. Appendix D provides a description of CPS essential fish habitat that is closely related to ecosystem health and fluctuation. Research efforts into ecosystem functions and trophic interactions will improve our knowledge base and improved CPS management decisions.

7.2 Description of the California Current Large Marine Ecosystem

The California Current (Figure 1) is formed by the bifurcation of the North Pacific Current. At approximately Vancouver Island, Canada, the southern branch of the North Pacific Current becomes the California Current, and flows southward along the west coast to mid-Baja, Mexico. The California Current flows southward year round off shore from the shelf break to ~200 miles. Coastal currents over the continental shelf flow southward during the summer upwelling season, but northward during the winter downwelling season. The California Undercurrent, flows northward year round, at depths of ~ 200-400 m over the continental slope.

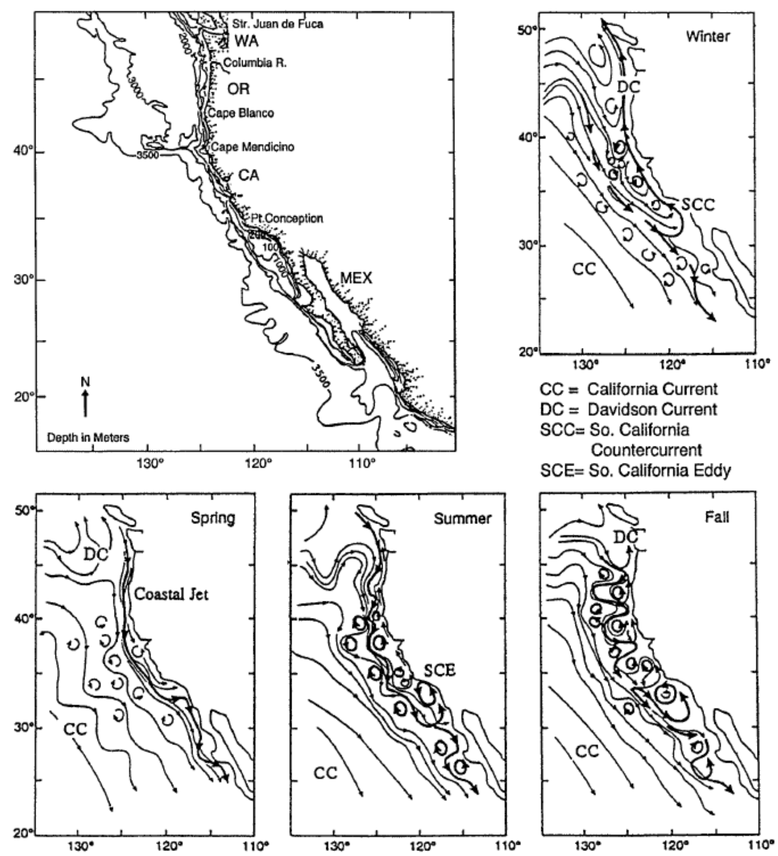


Figure 1. Seasonal variation of large-scale currents along the West Coast with bathymetry illustrating the dynamic conditions in the CCLME. The CC flows southward year round offshore from the shelf break to several hundred kilometers. Along the shelf break, several other currents are found, including the Davidson Current (DC), Southern California Countercurrent, and the Southern California Eddy (SCE). Seasonal panels from Strub and James 2000.

The California Current also defines the outer boundary of the California Current Large Marine Ecosystem (CCLME) that is delineated by bathymetry, productivity and trophic interactions. The LME is an organizational unit to facilitate management of an entire ecosystem and recognizes the complex dynamics between the biological and physical components. NOAA's ecosystem based management approach uses the LME concept to define ecosystem boundaries.

The CCLME is characterized as often having very high biological productivity (>250 mg $C/m^2/day$) that is stimulated by the addition of nutrients that is either upwelled along the shelf break or advected in surface currents from the Gulf of Alaska into the northern region or beginning of the California Current (Ware and Thomson 2005, Hickey and Banas 2008). The biological productivity is reflected in the extensive nearshore kelp beds, large schools of CPS (e.g., sardine, anchovy, squid, etc.) and groundfish (Pacific hake) that, in turn, support large populations of marine mammals, sea birds and highly migratory species (e.g., tuna, sharks, billfish).

The CCLME is heavily influenced by climate at the annual, interannual and decadal time scales. Annually, between winter and spring, the large scale wind fields in the NE Pacific reverse (from southerly to northerly) and the prevailing shelf currents also reverse. The transition in currents and concurrent increase in solar radiation in the spring leads to the dramatic increase in productivity. The date of onset of northerly winds is called the "Spring Transition". The timing and duration of the Spring Transition and their anomalies off Northern California/Oregon/Washington is determined by NMFS' Newport, OR laboratory for 45° N. 125° W. The Spring Transition has been identified as the first day of the year when the value of the 10–day running average for upwelling is positive and the value of the 10–day running average for sea level is negative. Anomalies are calculated as the difference between the observed date and the long-term average date (which is 13 April) (Figure 2). Additional oceanographic data from survey lines off Trinidad Head (Humboldt Co.), CA (NMFS) and Bodega, CA (Sonoma Water Agency-UCD) confirms the Newport prediction.

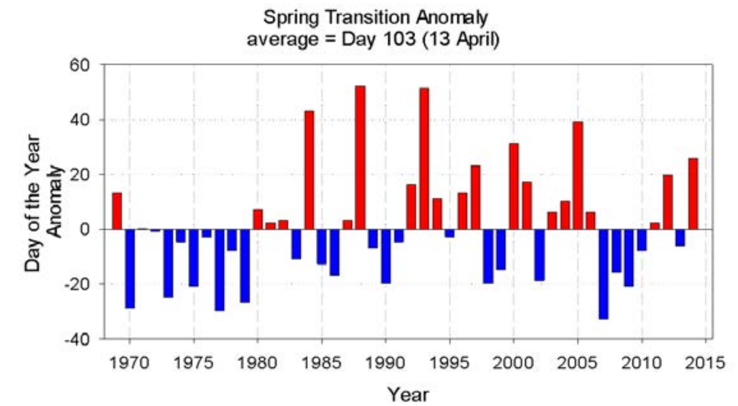


Figure 2. Anomaly of the date of the spring transition off Oregon. William Peterson, NOAA, NMFS, NWFSC.

Along the Oregon coast, the timing and duration of the Spring Transition has been linked to coho salmon abundance in the Columbia River (Peterson et al. 2006). The connection between the Spring Transition and CPS is presently not known but it is suspected to affect recruitment of Pacific herring, smelt, northern anchovy and other coastal pelagic species.

On an interannual time scale of 3-7 years, the CCLME and the entire Pacific Ocean is affected by El Niño/La Niña conditions that are captured by the Oceanic Niño Index (Figure 3). During El Niño events, upwelling is generally ineffective and warm salty surface waters move up from the south increasing water column stratification which in turn reduces primary productivity. During La Niñas, the productivity of the California Current is usually enhanced by the addition of cool, nutrient rich waters from the north, and increased effective upwelling. During El Niños, CPS landings in CA often fluctuate widely, with decreased catches of market squid, anchovy and Pacific herring, while the landings for sardine and mackerel often remain relatively constant.

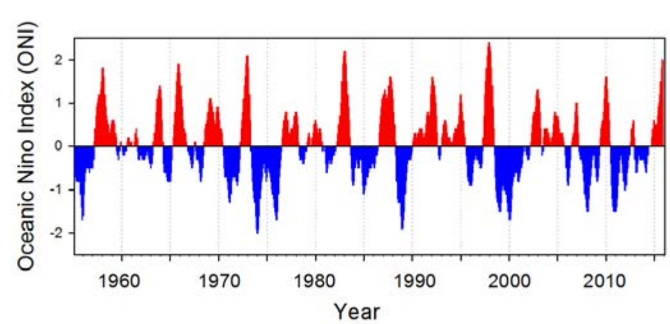


Figure 3. Oceanic Niño Index anomalies. Red indicates warm or El Niño conditions and blue cool La Niña conditions.

At periods between 20 to 30 years, low frequency climatic forcing from the Pacific Decadal Oscillation (PDO) affects the CCLME (Figure 4). The mechanism(s) behind the PDO are still being researched (Beamish et al. 2004) but the work of Bi et al. (2011) demonstrates that advection in the coastal branch of the California Current is enhanced when the PDO is negative and vice versa. The PDO was mostly negative (warm in the central North Pacific Ocean and cool near the west coast of the Americas) from 1946-1976 and mostly positive from 1977-1998. Since 1998, the PDO has fluctuated between positive and negative phases every five years, perhaps indicating an unusual climatic period for the CCLME.

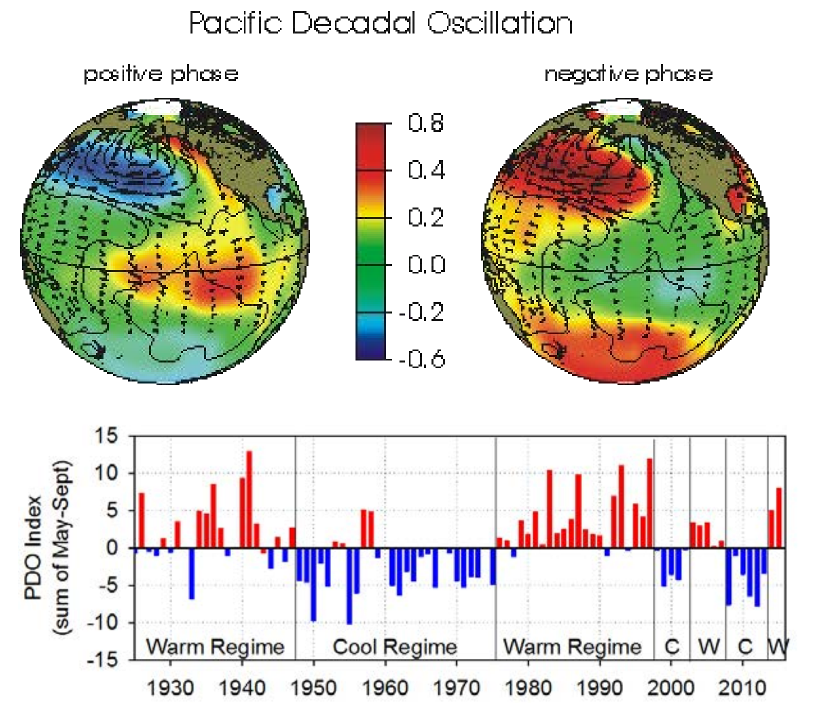


Figure 4. Time series of shifts in sign of the Pacific Decadal Oscillation (PDO) 1925 to 2015. Values are averaged over the months of May through September. Red bars indicate positive (warm) years; blue bars negative (cool) years. The PDO has been in a warm phase since 2014. http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ca-pdo.cfm

The effects of the PDO on fisheries are mixed. In general, the warm phase of the PDO is associated with warm ocean temperatures off the west coast and reduced landings of coho and Chinook salmon while the cool phase is associated with higher salmon landings (Mantua et. 1997). For sardine, positive PDO indices seem to correlate with high landings along the CCLME, while anchovy landings are reduced under positive PDO (Figure 5) (Takasura et al. 2008). Recent work by Zwolinski and Demer (2013) indicate that sardine recruitment is strongly linked to adult condition and the PDO prior to spawning. Others have found that environmental conditions during spawning, such as sea surface temperatures (Lindegren and Checkley 2013) and curl-driven upwelling (Rykaczewski and Checkley 2008) are important for larval sardine survival and recruitment. Until a good understanding of the oceanographic/ecological mechanisms that affect the productivity of sardine and anchovy stocks is achieved, this correlation, which is essentially based on one cycle of the PDO, must be viewed with caution. A recent paper by Zwolinski and Demer (2012) highlighted the similarity between present oceanographic conditions and past condition (1930's) when the CCLME sardine population crashed after a change in the PDO. However, MacCall et al. (2012) noted that management/harvest rates were much different in the 1930's.

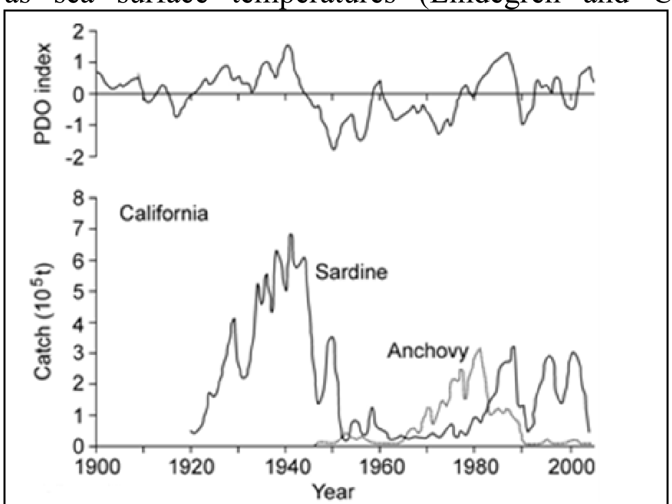


Figure 5. The relationships between Pacific sardine and Northern anchovy landings in California and the PDO. From Takasura et al. 2008.

Like all marine ecosystems, the CCLME is very complex, and despite 65 years of research from the California Cooperative Fisheries Investigation (CalCOFI) surveys, understanding and predicting recruitment success for any fishery including CPS remains elusive. In light of the complexity, ecological indicators have been used as surrogates of ecosystem health and status of fisheries. Preliminary physical indicators and sentinel species are being used to provide information as part of an ongoing Integrated Ecosystem Assessment of the CCLME. As scientists begin to examine and model the effects of changes in the ecology of the CCLME, the value of long term data sets monitoring such things as oceanographic parameters, relative abundance and geographic distribution of various species, and diet studies of higher order predators is becoming apparent.

Finally, climate change is a significant threat to the CCLME. While ocean temperatures had been relatively cool from 2007 to 2013, the PDO changed to a warm phase in early 2014 and has remained anomalously warm since. Furthermore, ocean acidification appears to already be having an effect on CCLME certain plankton and perhaps forage fish feeding and recruitment. For example, recent work by Bednarsek et al. (2014) revealed that ocean acidification in some areas of the CCLME is now great enough to dissolve the shells of the pelagic snail (*Limacina helicina*), an important prey for some forage fish species and pink salmon in some years.

7.3 Current Climate and Oceanographic Conditions

7.3.1 Spring Transition off Oregon and El Niño/Southern Oscillation

In 2015, the date of Spring Transition was the same as the long term average (13 April, 2015) and thus does not show up as an anomaly in Figure 2. The Oceanic Niño Index for the Pacific Ocean reflects a positive La Niña condition for all of 2015 (Figure 3).

7.3.2 Pacific Decadal Oscillation

The PDO was positive for the entire year in 2015 and through the first half of 2016 (Figure 6). A positive PDO is considered favorable for sardine and unfavorable for anchovy (Chavez et al. 2003). The positive PDO indicated unfavorable ocean conditions for juvenile Pacific salmon and anchovy populations, although there were indications of very high anchovy spawning in 2015, and reports of a large abundance of anchovy since then.

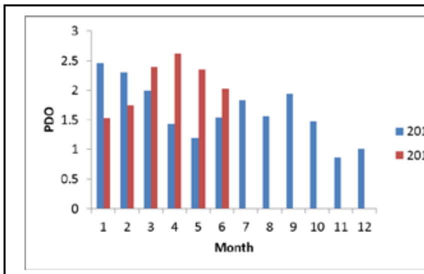


Figure 6. Monthly Pacific Decadal Oscillation index values in 2015-16. http://jisao.washington.edu/pdo/

7.3.3 Columbia River Flows

The Columbia River provides the largest source of freshwater entering the California. As such, it has a large effect on the oceanography and

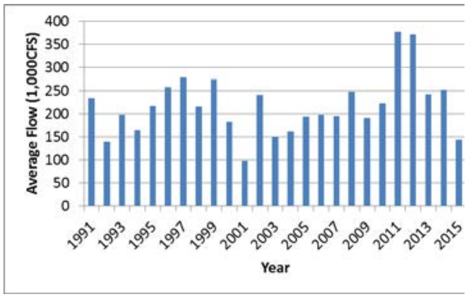


Figure 7. Average Columbia River flows in July.

biological resources on the region (Hickey et al. 2009; Litz et al. 2013). The mouth of the Columbia River is often the center of the sardine fishing off the Pacific Northwest, not only because it is close to processing plants, but because sardines and other CPS actively congregate feed in the biological rich plume habitat (Peterson and Peterson. 2009). In July 2015 flows were well below average, the third lowest since 1991 (Figure 7).

7.4 Trends in Ecosystem Indicators

7.4.1 Sea Surface Temperatures

Sea surface temperatures appear to affect the abundance/productivity of sardine, anchovy and other CPS species abundance (Chavez et al. 2003; Jacobson et al. 2001, 2005). The anomalously warm NE Pacific water ("The Blob") that was advected onto the continental shelf in September of 2014 resulted in a rapid and large increase in SST anomalies of +4°C and persisted on the shelf throughout the most of 2015. It was interrupted only briefly during strong upwelling that occurred in June 2015. Early 2016 exhibited a classic warm-phase PDO pattern (Jan-May), then transitioned back to a "Blob pattern" in Jun-Aug (Figure 8).

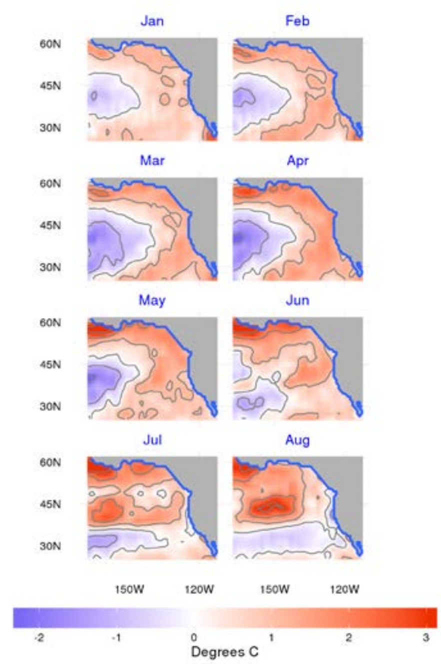


Figure 8. Monthly sea surface temperature anomalies in 2016. NOAA OISST V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/.

7.4.2 Copepods

Copepod species richness is surveyed by the NMFS, NWFSC off Newport, OR and is highly correlated to the PDO. (http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ea-copepod-biodiversity.cfm). Since the Blob came ashore in September 2014, the copepod community became, and has remained, dominated by offshore tropical species (Figure 9).

7.4.3 Coastal pelagic fishes and invertebrates

Night time pelagic forage fish surveys off the Columbia River by NMFS/NWFSC were discontinued in 2012. At this time, only day time pelagic survey data are available. Since daytime surveys typically underestimate forage fish abundance, they are not presented here (Krutzikowsky and Emmett 2005). The Fisheries Ecology Division of the SWFSC has conducted a late spring midwater trawl survey for pelagic juvenile (young-of-the-year, YOY) rockfish (*Sebastes spp.*) and other groundfish off Central California (approximately 36 to 38°N) since 1983, and has enumerated most other epipelagic micronekton encountered in this survey since 1990 (Ralston et al. 2015, Sakuma et al. in prep). The survey expanded the spatial coverage to include waters from the U.S./Mexico border north to Cape Mendocino in 2004. The following results and summary provided by the SWFSC include a time series of anomalies of some of the key species or groups of interest in this region since 1990 (core area) or 2004 (expanded survey area). The data for the 2016 survey are preliminary.

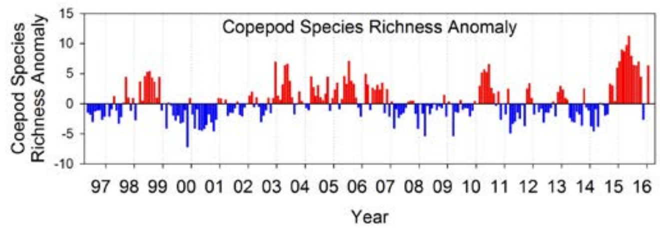


Figure 9. Monthly anomaly of copepod diversity found off Newport, OR: William Peterson, NOAA, NMFS, Newport, OR.

The standardized anomalies from the mean of the log transformed catch rates are shown by year for six key YOY groundfish and forage groups (Figure 10), i.e. YOY rockfish, market squid (Doryteuthis opalescens), krill (primarily Euphausia pacifica and Thysanoessa spinifera), YOY Pacific sanddab (Citharichthys sordidus), Pacific sardine and Northern anchovy. The survey area is broken into five large regions (Sakuma et al. in prep 2016), south (Point Conception south to the U.S./Mexico Border), south central (Point Sur to Point Conception), core (immediately north of Point Reyes through Monterey Bay), north central (Cape Mendocino to Fort Ross), and north (the Oregon border to Cape Mendocino). As the north region has only a limited amount of data (sampling began in 2013 and inclement weather reduced sampling effort in 2016), this region is excluded from this analysis. No sampling was conducted in the south region in 2011 and none in the north central region in 2012 due to weather and vessel constraints. The abundance of krill and market squid in 2016 declined in most areas relative to 2015 and the several years prior, with abundance close to or below average levels. The abundance of adult Pacific sardine and northern anchovy remained very low for most regions as well. Both of these species have been very rarely encountered in these sampling efforts since 2009, with the exception of adult anchovy in the Southern California Bight in 2016, suggesting that the biomass may be too low to be meaningfully indexed by the survey, or that a substantial fraction of the biomass is primarily located in habitats not indexed by the survey (e.g., nearshore or offshore habitat). Catches of YOY anchovy, which are enumerated separately from age 1+ anchovy, were the highest ever observed in the Southern California Bight while in other regions of the California Current their numbers were reduced compared to 2015 (unpublished data).

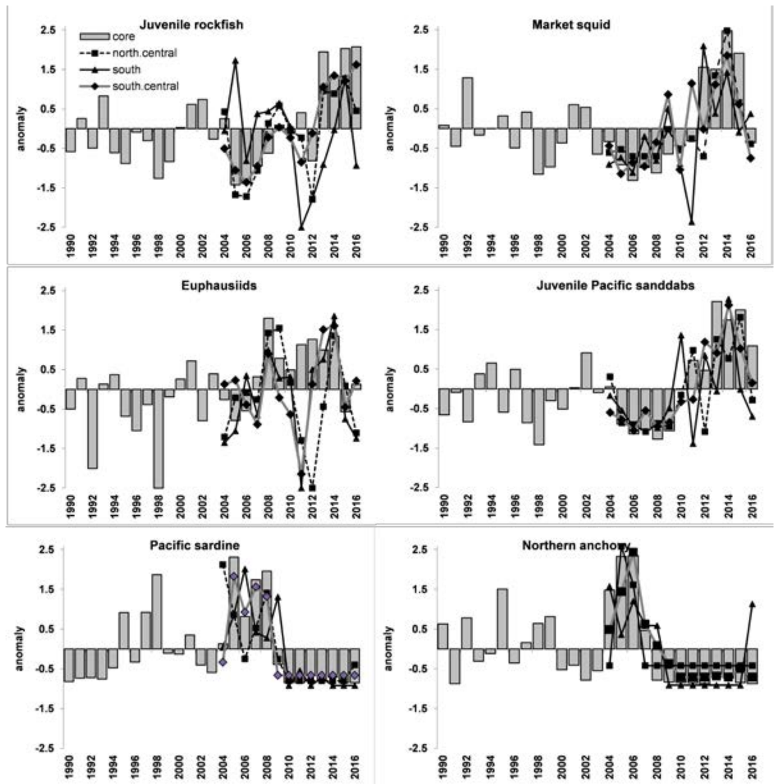


Figure 10. Long-term standardized anomalies of several of the most frequently encountered pelagic forage species from rockfish recruitment survey in the core (Central California) region (1990-2014) and the southern, south-central and north-central survey areas (2004-2015). John Field, NOAA, NMFS, SWFSC.

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Climate Indicators:

PaCOOS Quarterly Update of Climatic and Ecological Conditions in the CA Current Large Marine Ecosystem V4 2010, V1 2010 (http://www.pacoos.org)

El Niño Southern Oscillation (ENSO):
Source: Bill Peterson, NOAA, NWFSC
Source: http://www.cdc.noaa.gov/people/klaus.wolter/MEI/mei.html

Pacific Decadal Oscillation (PDO):
Source: The PDO
Source: http://jisao.washington.edu/pdo/, http://jisao.washington.edu/pdo/PDO.latest

California Current Ecosystem Indicators:
Copepods:
Source: William Peterson, NOAA, NWFSC
Source: http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ea-copepod-biodiversity.cfm

Coastal Pelagic Fishes and Invertebrates:
Ecosystem indicators for the Central California Coast, May-June 2016
Source: John Field, Fisheries Ecology Division, SWFSC

8.0 Stock Assessment Models, Stock Status, and Management Recommendations

The CPS FMP distinguishes between "actively managed," "monitored," "ecosystem component, and "prohibited harvest" species management categories. Actively managed species (Pacific sardine and Pacific mackerel) are formally assessed through Council proceedings annually or biennially. Over the years, seasonal closures and allocations, harvest guidelines, incidental landing allowances, and other management controls have been used for these stocks. Other CPS species (northern anchovy, jack mackerel, and market squid) are monitored to ensure their stocks are stable, but annual stock assessments and Federal fishery controls are not used on an annual basis. Both actively managed and monitored stocks are management unit species, however. Ecosystem component species (Pacific herring and jacksmelt) are not considered part of the CPS fishery, but are categorized in the FMP as EC species. EC species do not require specification of reference points, but incidental catch of EC species should be monitored for indications of change in status of their vulnerability to the fishery. Krill (consisting primarily of two species of euphausiids) are listed under the prohibited harvest species category, and there is no directed take allowed.

On a systematic basis, the CPSMT makes recommendations to the Council and related agencies regarding appropriate management categories for each stock, both short- and long-term. Changes to the appropriate management category for each species can be made annually by the Council, based on all available data, including ABC levels and MSY control rules, and goals as outlined in the CPS FMP (PFMC 2010).

In June 2013, the CPSMT recommended moving Pacific mackerel from actively managed to monitored status starting in the 2014-2015 season, based on very low catches, limited additional sample information, and indications that the population's sustainability is not presently being compromised by fishing pressure. The CPSAS advised keeping mackerel actively managed, and the Council concurred, keeping Pacific mackerel as an actively managed species.

Based on biomass estimates, landings, conservation, socio-economics, and other information, the CPSMT recommends that Pacific sardine and Pacific mackerel remain as an actively managed species, while jack mackerel, northern anchovy, and market squid remain as Monitored stocks.

Finally, while this document focuses on U.S. fisheries, many CPS stocks are characterized by expansive ranges depending on oceanographic conditions and thus, catch information from both Mexico and Canada are of critical interest. See Table 8-4 for Pacific sardine harvest statistics from commercial fisheries operating in the U.S., Mexico, and Canada (2000-2015).

8.1 Actively Managed Species

8.1.1 Pacific sardine

Hill *et al.* (2016) summarized the status of the Pacific sardine northern subpopulation off the U.S. Pacific Coast, British Columbia, and northern Baja California (Ensenada), Mexico. International Pacific sardine landings (Ensenada to British Columbia) totaled 41,301 mt in calendar year 2015, down from 113,140 mt in 2014, and 115,304 mt in 2013 (Table 8-4). The U.S. directed sardine fishery was under a moratorium during the 2015-16 management year. During 2015-16, incidental sardine landings in California totaled 158 mt, Oregon landed one mt, and Washington landed no sardine (Table 8-3). U.S. landings totaled 159 mt during the 2015-16 fishing year.

The U.S. sardine fishery is regulated using a quota-based management approach (see Section 8.1.1.1). From 2000 to 2007, landings were typically lower than the recommended HGs (Table 8-3). Due to a series of lower quotas, the U.S. fishery was subjected to in-season closures during 2008 to 2011, 2013, and 2014-15. The 2015-16 ACL/HG (for incidental, Tribal, and live bait) was 7,000 mt, and the ACT (directed fishery) was set to zero mt.

Harvest of Pacific sardine by the Ensenada (Mexico) fishery is not yet regulated through a quota system, but there is a minimum legal size requirement of 150 mm standard length and measures are in place to control fleet capacity. The Ensenada fleet landed 37,468 mt of sardine in calendar year 2015, down from the record high of 90,396 mt in 2014 (Table 8-4). Sardine landed in Ensenada represent a mixture of fish from the southern and northern subpopulations. Due to prevailing warm oceanic conditions, the vast majority of sardine landed during 2014 and 2015 were likely from the southern subpopulation (Hill et al. 2016). Canadian sardine landings increased substantially after 2007 (1,522 mt), peaking at 22,223 mt in 2010. However, the Canadian fishery found no sardine in 2013, 2014, or 2015 (Table 8-4).

The 2016 stock assessment update (Hill *et al.* 2016) provided a stock biomass (age 1+) estimate of 106,137 mt on July 2016 (Table 8-2), reflecting a continuing trend of low productivity in the northern subpopulation. Although this represents a modest increase in the estimate from the prior year, it still falls below the Cutoff threshold of 150,000 mt. Therefore, directed non-tribal fishing was again closed for the 2016-2017 fishing year.

8.1.1.1 Pacific Sardine Harvest Control Rules for 2016-2017

In March 2014 the PFMC adopted the use of CalCOFI SST data for specifying environmentally-dependent E_{MSY} each year, beginning July 2014. Based on this decision, and given warm oceanic conditions over the past two years, the OFL and ABC for 2016-17 were based on the upper bound of E_{MSY} for the three-year running average of CalCOFI SST for 2013-15 (16.3891 °C). Harvest control rule formulas for the 2016-17 management year were calculated as follows:

OFL = BIOMASS * E_{MSY} * DISTRIBUTION,

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

HG = (BIOMASS – CUTOFF) * E_{MSY} * DISTRIBUTION,

Where: BIOMASS = 106,137 mt; E_{MSY} = 0.25 for OFL and ABC, and E_{MSY} = 0.20 for HG; DISTRIBUTION = 0.87; $BUFFER_{P\text{-star } 0.4 \text{ (Tier 2)}}$ = 0.8333; and CUTOFF = 150,000 mt.

In April 2016, the Council adopted the most recent sardine stock assessment (Hill et al. 2016) to set harvest specifications for the 2016-2017 management year beginning July 1, 2016. Stock biomass from that assessment (106,137 mt, Hill *et al.* 2016) was used to calculate all harvest control rules above. Because the biomass estimates in both 2015 and 2016 fell below the 150,000 mt CUTOFF value, the HG was calculated to be zero, hence no directed commercial fishery was allowed for the 2015-2016 and 2016-2017 fishing years.

Using the control rules for 2016-2017, the Council adopted an OFL of 23,085 mt, an ABC of 19,236 mt, and an ACL of 8,000 mt. The ACL was established to allow for incidental catch, directed tribal harvest (up to 800 mt), live bait, research, and other minor sources of mortality. The Council also adopted the following accountability measures regarding incidental catch:

- An incidental per landing allowance of 40 percent Pacific sardine in non-treaty CPS fisheries until a total of 2,000 mt are landed;
- When a total of 2,000 mt has been landed, the incidental per landing allowance will be reduced to 20 percent;
- When a total of 5,000 mt has been landed, the incidental per landing allowance will be reduced to 10 percent for the remainder of the 2016-2017 fishing year;
- A 2-mt incidental per landing allowance in non-CPS fisheries.

8.1.2 Pacific Mackerel

In June 2015, the Council adopted the most recent full assessment (Crone and Hill 2015) for specifying management measures during the 2015-16 and 2016-17 fishing years. Stock biomass (age-1+ biomass) steadily declined from the mid-1980s to the early 2000s, at which time the population began to increase moderately in size. However, in historical terms, the population remains at a relatively low abundance level, due primarily to oceanographic conditions, given limited fishing pressure over the last decade has likely not compromised this species' biology (i.e., their role in the larger CPS assemblage off the Pacific coast). Recent estimates of stock size are related to assumptions regarding the dynamics of the fish (biology, recruitment, etc) and fishery (operations) over the last several years, which generally confound long-term abundance forecasts for this species (Crone and Hill 2015). It is important to note that exploitation of this stock has changed considerably over the last two decades, i.e., during the 1990s, the directed fisheries off California had average annual landings of roughly 18,000 mt, whereas since 2002, average yearly landings have decreased substantially (Table 8-7). This pattern of declining yields in recent years generally characterized all of the Pacific mackerel fishery sectors, including U.S. commercial and recreational sectors, as well as the commercial fishery of Mexico. U.S. landings in the 2015-16 fishing year were 4,664 mt, still well below the ACT and ABC (Table 8-7).

8.1.2.1 Pacific Mackerel Harvest Specifications for 2015-16 and 2016-17

The Council adopted the 2015 stock assessment (Crone and Hill 2015) to establish an overfishing limit (OFL) and other annual specifications for both the 2015-16 and the 2016-17 fishing years. The Council also adopted the following management measures: for each separate fishing year, should the directed fishery realize the annual catch target (ACT), the Council should recommend that NMFS close the directed fishery and shift to an incidental-catch-only fishery for the remainder of the fishing season, with a 45 percent incidental landing allowance when Pacific mackerel are landed with other coastal pelagic species (CPS), with the exception that up to 3 mt of Pacific mackerel per landing could be landed in non-CPS fisheries.

Harvest control rule formulas for the 2015-16 and 2016-17 management years were calculated as follows:

OFL = BIOMASS * E_{MSY} * DISTRIBUTION,

ABC = BIOMASS * $\text{BUFFER}_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION,

HG = (BIOMASS – CUTOFF) * E_{MSY} * DISTRIBUTION,

Where: E_{MSY} = 0.30; DISTRIBUTION = 0.70; $BUFFER_{P\text{-star } 0.45 \text{ (Tier 2)}}$ = 0.9135; and CUTOFF = 18,200 mt.

Fishing year:	2015-16 (mt)	2016-17 (mt)
Biomass	120,435	118,968
OFL	25,291	24,983
$ABC_{0.45}$	23,104	22,822
ACL	23,104	22,822
HG	21,469	21,161
Incidental	1,000	1,000
ACT	20,469	20,161

8.2 Monitored Species

The monitored species category of the CPS FMP includes the northern subpopulation of northern anchovy, the central subpopulation of northern anchovy, jack mackerel, and market squid. This management category is intended for those species or stocks that do not require intensive harvest management and where monitoring of landings and available abundance indices are considered sufficient to manage the stock. The default control rules and overfishing specifications are used for Monitored stocks unless otherwise specified. OFL, ABC, and ACLs can be revised based on the best available science as recommended by the SSC and as adopted through the annual harvest specification process, and will be reported in the CPS SAFE.

Under the default harvest control rule, the ABC is set to 25 percent of the OFL until the SSC recommends an alternate value based on best available science. ACLs are set for multiple years until new information becomes available, or until the stock is moved to active management. Stocks may be moved between active and Monitored categories on short notice, under the point-of-concern framework.

8.2.1 Northern Anchovy

The most recent complete assessment for northern anchovy was described in Jacobson *et al.* (1995). California landings of northern anchovy began to increase in 1964, peaking in 1975 at 143,799 mt. After 1975, landings declined. From 1983 to 1999, landings did not exceed 6,000 mt per year. There were no reported landings of northern anchovy in Oregon from 1981 through 1999. Washington landings of anchovy were rarely reported before 1967. Landings peaked in the 1970's at 286 mt in 1975 and thereafter declined, not exceeding 100 mt until 1995. From 2000 to 2015, northern anchovy landings averaged 193 mt for Washington and 563 mt for Oregon for years with reported landings, and 8,461mt for California. The greatest northern anchovy landings in California occurred in 2001 (19,277 mt). In Washington, the peak occurred in 2009 (810 mt). In Oregon, the peak in northern anchovy landings occurred in 2008, 2010, and 2015. Anchovy landings in other years were less than 70 mt.

Anchovy (mt)	WA	OR	CA
2000	79	<1	11,753
2001	68	0	19,277
2002	229	3	4,643
2003	214	39	1,676
2004	213	13	6,792
2005	164	68	11,182
2006	161	9	12,791
2007	153	5	10,390
2008	109	260	14,285
2009	810	39	2,668
2010	108	138	1,026
2011	191	21	2,601
2012	218	0	2,488
2013	116	13	6,005
2014	112	0	10,511
2015	144	335	17,286

Through the 1970s and early 1980s, Mexican landings increased, peaking at 258,745 mt in 1981 (Table 8-1). Mexican landings decreased to less than 2,324 mt per year during the early 1990s, with a spike of 17,772 mt in 1995, primarily during the months of September through November. Catches in Ensenada decreased to 4,168 mt in 1996; and remained at less than 5,000 mt through 2014. Landings in 2015 peaked in recent years to 46.850 mt.

With the 2010 reauthorization of the MSA, the Council adopted new management benchmarks for northern anchovy. The OFL values are based on past estimates of biomass and the ABC values account for a 75 percent uncertainty buffer in the OFL. The annual catch limit was set equal to the ABC. An ACT for the northern subpopulation of northern anchovy was established.

Stock	OFL	ABC	ACL	ACT
Northern anchovy, northern subpopulation	39,000 mt	9,750 mt	Equal to ABC	1,500 mt
Northern anchovy, central subpopulation	100,000 mt	25,000 mt	Equal to ABC	N/A

Beginning in 2013, CA anchovy landings began increasing to levels previously seen several years ago. CDFW conducted commercial sampling of anchovy beginning in 2014; however, there remains little biological data for this species in recent decades, from either fishery or survey data collection efforts.

8.2.2 Jack Mackerel

Jack mackerel have not been significantly targeted on the west coast, and regular stock assessments or efforts to collect biological information on jack mackerel have not been a priority. The SWFSC Acoustic-Trawl survey, which began in 2006, could potentially be used to provide abundance estimates in the future, but may need a methodology review prior to use in a jack mackerel stock assessment. Management efforts to collect fishery-dependent age composition data, such as the CDFW Port Sampling Program, are in place for the two actively managed CPS (Pacific sardine and Pacific mackerel), but not for jack mackerel, aside from samples taken prior to 1995.

Landings of jack mackerel in the California pelagic wetfish fishery through the decade of the 1990s reached a maximum of 5,878 mt in 1992, and averaged under 1,900 mt over 1990-2000. During the previous decade, California landings ranged from a high of 25,984 mt in 1982 to a low of 9,210 mt in 1985. Currently, most landings of jack mackerel are incidental to Pacific sardine and Pacific mackerel in California; however, pure landings do occur sporadically. From 2000 to 2014, jack mackerel landings averaged 37 mt for Washington for years with reported landings, with a high of 176 mt in 2014; 116 mt for Oregon, with a high of 800 mt in 2014; and 779 mt for California, with a high of 3,624 mt in 2001. In California and Oregon, jack mackerel landings occurred each year; however, in Washington, jack mackerel were landed in 2002, 2003, 2010, 2012, 2013, and 2014.

Jack mackerel (mt)	WA	WA (unspecified mixed mackerel)	OR	CA
2000	-		161	1,269
2001	-	371	196	3,624
2002	12	238	8	1,006
2003	2	54	74	156
2004	-	22	126	1,027
2005	-	24	70	213
2006	-	41	5	1,167
2007	-	36	14	631
2008	-	6	46	274
2009	-	4	2	119
2010	<1	<1	3	306

2011	-	<1	14	80
2012	14	97	96	133
2013	22	10	123	894
2014	176	-	800	781

Mason (2001) concluded that spawning biomass estimates of the past were inadequate.

Anecdotal evidence suggests that the spawning biomass may be large in California waters, but test fishing found the adult fish too scattered for economical harvest, since portions of the contemporary catch are sometimes found in small aggregations of young fish along rocky shores.

In 2010, in accordance with the reauthorized MSA, the Council adopted new management benchmarks for jack mackerel. The OFL value is based on past studies and the ABC value accounts for a 75 percent uncertainty buffer in the OFL. The ACL was set equal to the ABC:

Stock	OFL	ABC	ACL
Jack mackerel	126,000 mt	31,000 mt	Equal to ABC

Coastwide landings 2010-2014 were as follows:

Jack Mackerel	ACL (mt)	Landings (mt)
2010	31,000	310
2011	31,000	80
2012	31,000	145
2013	31,000	892
2014	31,000	1,757

8.2.3 Market Squid

The CDFW manages the market squid fishery through a state-based management plan including an annual landings cap and various spatial/temporal constraints, such as weekend closures, area and time closures to address seabird issues, and harvest replenishment areas within MPAs (CDFG 2005). In addition, the Egg Escapement Method has been used as an assessment tool, to evaluate population dynamics and biological reference points (MSY related) regarding this species (Section 4.3.4 and Dorval et al. 2008, 2013). The fishery control rules currently in place under the California

MSFMP, are thought to preclude the need for active Federal management. However, if fishery operations change substantially in the future (for example, spatially expands, harvests high amounts of immature squid), additional management measures could be considered.

In 2010, the Council approved benchmarks for market squid, which remain in place until changed by the Council:

Stock	OFL	ABC	ACL
Market squid	Fmsy proxy resulting in egg escapement ≥ 30%	Fmsy proxy resulting in egg escapement ≥ 30%	Exempt

8.2.3.1 California's Market Squid Fishery

In 2001, legislation transferred the authority for management of the market squid fishery to the California Fish and Game Commission (CFGC). Legislation required that the CFGC adopt a Market Squid Fishery Management Plan (MSFMP) and regulations to protect and manage the squid resource. In August and December of 2004, the CFGC adopted the MSFMP, the environmental documentation, and the implementing regulations, which went into effect on March 28, 2005, just prior to the start of the 2005/2006 fishing season, which started April 1.

In 2014, the market squid fishery was California's largest fishery, with landings estimated at 102,516 mt. This is a 2 percent decrease from 2013 (104,404 mt). The total ex-vessel value decreased from $73.7 million in 2013 to $71.8 million in 2014. The median ex-vessel price per metric ton of market squid in 2014 was $716.50. The fishing permit season for market squid extends from April 1 through March 31 of the following year. During the 2013-2014 season (as opposed to the 2014 calendar year), 104,267 mt were landed, an 8 percent increase from the 2012-2013 season (96,239 mt). In addition, the fishery was closed early for the fourth consecutive season as landings were projected to attain the seasonal catch limit of 118,000 st (107,047 mt). In 2014-2015, for the first time in four seasons, the California market squid fishery did not close early. Although landings were once again projected to attain the seasonal catch limit (by November 18, 2014 97.2 percent of the catch limit had been landed), the seine sector of the squid fleet voluntarily stopped fishing so that the remaining portion of the catch limit could be set aside for the brail sector. Neither the brail nor seine sector of the commercial fleet made directed landings of market squid after November 18, and the 2014-2015 season ended without reaching the seasonal catch limit.

8.3 Prohibited Harvest Species

Amendment 12 to the CPS FMP was approved by the Secretary of Commerce in 2009. Amendment 12 prohibits the directed harvest of krill species. The Amendment described EFH for krill, and set an ACL equal to zero.

8.4 Ecosystem Component Species

In June 2010, the Council added Pacific herring (*Clupea pallassi*) and jacksmelt (*Atherinopsis californiensis*), two species not under Federal management, to the Ecosystem Component category of the CPS FMP. Several criteria should be met for a species to be included in the EC category (MSA Section 660.310(d)(5)(i)). These are 1) be a non-target stock/species; 2) not be subject to overfishing, approaching overfished, or overfished and not likely to become subject to overfishing or overfished in the absence of conservation and management measures; and 3) not generally retained for sale or personal use within the CPS fishery, although "occasional" retention is not by itself a reason for excluding a species from the EC category. There is no directed California commercial herring fishery. Identifying and including EC species in an FMP is not mandatory but may be done for a variety of purposes, including data collection, for ecosystem considerations related to specification of OY for the associated fishery, as considerations in the development of conservation and management measures for the associated fishery, and/or to address other ecosystem issues.

A 2010 review of bycatch species in CPS fisheries confirmed that incidental catch and bycatch in CPS fisheries is dominated by other CPS and that bycatch/incidental catch of non-CPS is extremely low. However, jacksmelt and Pacific herring are infrequently caught with CPS gear and were therefore added to the FMP under Amendment 13 to ensure continued monitoring of incidental catch and bycatch of these species through sampling and logbook programs. This information will continue to be reported in the SAFE report. The Council intends to continue and expand its consideration of ecological factors when developing status determination criteria (SDCs) and management measures for CPS management unit species. These considerations will evolve as improved information and modeling of ecological processes become available and will likely include predator/prey relationships and the overall status and role of forage species including these two EC species.

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9.0 Emerging Issues

This section describes current and potential issues that may need to be addressed relative to FMP species and management in general.

9.1 Pacific Sardine

During 2016, the Council considered action that would allow minor directed harvest on CPS finfish when the directed fishery is otherwise closed. This issue became apparent during the 2015 and 2016 closures of the Pacific sardine fishery, when the estimated biomass fell below the 150,000 mt CUTOFF value of 150,000 mt. Although live bait, tribal harvest, and incidental harvest are allowed to continue (up to the ACL) in that case, there are several small operations that harvest sardines as specialty dead bait or for the restaurant market. These small operations were shut down along with the primary directed harvest fishery. However, given the de minimis harvest level, the Council pursued a mechanism to allow for such operations to continue. Final action was scheduled for April 2017.

10.0 Research and Data Needs

Robust assessment procedures are needed to meet the requirements of the FMP, especially for actively managed stocks such as Pacific sardine. Reliable CPS biomass estimates are used in the Council's annual determination of allowable coastal pelagic harvests, as well as appropriate management responses.

In addition to research and data needs presented in this section, refer to the Council's comprehensive research and data needs document last revised in March 2013. The document includes a chapter dedicated to CPS matters and can be obtained by contacting the Council office or by visiting the Council web page. Also, the most recent Pacific sardine and Pacific mackerel assessments and STAR Panel reports include detailed, species-specific, research and data needs.

The 2014 Pacific sardine stock assessment, for the first time, differentiated the northern and southern subpopulations. This is a departure from past stock assessments, which assumed that all landings from Ensenada, Mexico, north were of the northern stock.

Priority research and data needs for CPS are:

- Develop methods for differentiating southern from northern subpopulation of Pacific sardines, and develop an appropriate management approach.
- Gain more information about the status of CPS resources in the north using egg pumps, trawl and sonar surveys, and spotter planes.
- Develop a coastwide (Mexico to British Columbia) synoptic survey of sardine and Pacific mackerel biomass; i.e., coordinate a coastwide sampling effort (during a specified time period) to reduce "double-counting" caused by migration.
- Increase fishery sampling for age structure (Pacific sardine and Pacific mackerel) in the northern and southern end of the range. Establish a program of port sample data exchange with Mexican and Canadian scientists.

- Evaluate the role of CPS resources in the ecosystem, the influence of climatic/oceanographic conditions on CPS, and define predator-prey relationships.
- Routinely, collect detailed cost-earnings data to facilitate analyses for long-term changes to the sardine allocation structure.

10.1 Pacific Sardine

Priority research and data needs for Pacific sardine include:

1) continuing to gain better information about Pacific sardine status through annual coastwide Acoustic-trawl surveys;
2) standardizing fishery-dependent data collection among agencies, and improving exchange of raw data or monthly summaries for stock assessments;
3) obtaining more fishery-dependent and fishery-independent data from northern Baja California, México, and British Columbia, Canada; as well as from nearshore habitats;
4) further refining ageing methods and improved ageing error estimates through a workshop of all production readers from the respective agencies;
5) continuing to develop methods (e.g., otolith microchemistry, genetic, morphometric, temperature-at-catch analyses) to improve our knowledge of sardine stock structure that can ultimately be applied toward more refined management of northern and southern subpopulations;
6) exploring environmental covariates (e.g., SST, wind stress) to inform the assessment model, and to address recent research that brings into question the temperature-recruitment relationship.

10.2 Pacific Mackerel

Given the transboundary status of Pacific mackerel, it is imperative to encourage collaborative research and data exchange between NMFS SWFSC and researchers from both Canada's and in particular, Mexico's academic and Federal fishery bodies. For example, such cooperation is critical to providing a synoptic assessment that considers available sample data across the entire range of this species in any given year.

Fishery-independent survey data for measuring changes in mackerel spawning (or total) biomass are currently lacking. A single index of relative abundance is used in the assessment, which is developed from a marine recreational fishery (CPFV fleet) in California that typically does not (directly) target the species, nor report all catches. Future research funds should focus on improving the current CPFV survey, with a long-term emphasis, which will necessarily rely on cooperative efforts between the industry, research, and management bodies. In addition, further sensitivity analysis related to this index of relative abundance, including issues surrounding catchability (and/or selectivity) and influences regarding time-varying vs. constant parameterization of these fishery time series, should be examined. Other indices may be considered as well, such as incidental catches in the whiting fishery.

Given the importance of age (and length) distribution time series to developing a sound understanding of Pacific mackerel population dynamics, it is critical that data collection programs at the Federal and state levels continue to be supported. In particular, CDFW/NOAA funding should be bolstered to ensure ongoing ageing-related laboratory work is not interrupted, and for related biological research. This applies to the Pacific Northwest fishery as well. For example, maturity-related time series currently relied upon in the assessment model are based on data collected over twenty years ago during a period of high spawning biomass that does not reflect current levels. Also, work is needed to obtain more timely error estimates from production ageing efforts in the laboratory; for example, accurate interpretation of age-distribution data used in the ongoing assessment requires a reliable ageing error time series. Finally, examinations of sex-specific age distributions will allow hypotheses regarding natural mortality/selectivity (i.e., absence of older animals in sex-combined age distributions) to be more fully evaluated.

10.3 Market Squid

Currently, the basics of market squid population dynamics are understood, with market squid rapidly expanding in cool oceanographic conditions and productive ocean environments associated with La Niña events; and contracting in warm and unproductive regimes associated with El Niño events. In light of the wide range (Baja California to Alaska) and short lifespan of market squid, a formal stock assessment has not been attempted, which limits the ability to quantify the abundance of this valuable marine resource found primarily off California. General information concerning important stock- and fishery-related parameters suggests maximum age is less than one year, and the average age of squid harvested is roughly six to seven months. Under the National Standard 1 Guidelines, market squid are exempt from ACLs due to their short lifespan. However, the CPSMT recommends that current monitoring programs continue for this species, including tracking fishery landings, collecting reproduction data from the fishery, and obtaining logbook information.

Although some coastwide squid distribution and abundance has been extracted from fishery-independent midwater and bottom trawl surveys aimed at assessing other finfish species, there is currently no comprehensive measure of annual recruitment success beyond information obtained from the fishery. Since fishing activity generally occurs only on shallow-water spawning aggregations, it is unclear how fluctuations in landings are related to actual population abundance and/or availability to the fishery itself. Landings may be influenced by market conditions, and not resource abundance.

The general consensus from the scientific and fishery management communities is that squid do inhabit, to some degree, greater depths than fished by the fleet; however, species' range suppositions are qualitative at this point in time. Better information on the extent and distribution of spawning grounds along the U.S. Pacific Coast is needed, particularly, in deep water and areas north of central California.

Since 2011, collaborative work between federal, state, and industry sponsored research has produced a relative paralarval abundance index in the two major fishing grounds in southern California and the Monterey Bay area, which has shown a high correlation between ENSO events and paralarval distribution and abundance along the California coast. This collaborative work is also focused on addressing basic life history information, such as trophic ecology and the effects of environmental forcing (ENSO events) on age and growth patterns.

Fecundity and egg survival research is needed from different spawning habitats in nearshore areas and oceanographic conditions associated with the population. Further data on mechanisms and patterns of dispersal of adults, as well as paralarvae, along the coast is necessary to clarify how local impacts might be mitigated by recruitment from other areas inhabited by this short-lived species. See Dorval 2008, Dorval et al 2013, and Van Noord & Dorval 2017 (in press) for additional information.

Although some fishery effort information is now being collected with a logbook program in the State of California, the continuation of this program is essential to provide estimates of relative abundance (e.g., CPUE time series) in the future. Annual collaborative surveys that target market squid paralarvae in shallow waters at the traditional spawning beds in southern and central California using obliquely towed bongo nets have been conducted since 2011. Continuation of this effort and/or the establishment and integration of additional surveys using midwater trawls, bottom trawls, remotely operated vehicles, and satellite and aerial surveys to target abundance data on adult squids would also provide useful information for developing alternative indices of abundance other than those derived from logbook data.

Potential impacts to EFH-related issues could arise in concert with fishing activity by the purse-seine fleet on spawning aggregations in shallow water if gear potentially makes contact with the sea floor. In this regard, there are two areas of potential concern that have not been quantified to date: (1) damage to substrate where eggs may be deposited; and (2) damage or mortality to egg masses from contact with the gear itself. The CDFW is currently working on research methods to evaluate egg stage of squid egg capsules collected in fishery landings to determine how long the egg capsule had been laid before being taken by the fishery or if the egg case was released in the net.

Currently, market squid fecundity estimates, based on the Egg Escapement Method (Dorval et al. 2008 and 2013), are used informally to assess the status of the stock through evaluations of alternative biological reference points related to productivity and MSY. The Egg Escapement Method is based on several assumptions: (1) immature squid are not harvested; (2) potential fecundity and standing stock of eggs are accurately measured; (3) life history parameters are accurately estimated (e.g., natural mortality, egg laying rate); and (4) instantaneous fishing mortality (F) translates into meaningful management units. Given the inherent uncertainty associated with these assumptions, each must receive more scrutiny in the future through continuation of rigorous sampling programs in the field that generate representative data for analysis purposes, as well as further histological evaluations in the laboratory and more detailed assessment-related work. For example, data collected through the CDFW port sampling program will provide information on the age and maturity stages of harvested squid. Further, laboratory work concerning mantle condition, especially the rate of mantle "thinning," will benefit our understanding of squid life history and subsequently help improve the overall assessment of this species. Finally, other poorly-understood biological parameters that relate to spawning and senescence should be studied (for example, life history strategies concerning spawning frequency, the duration of time spent on spawning grounds, and the period of time from maturation to death).

10.4 Live Bait Fishery

The California live bait fishery supplies product for several recreational fisheries, primarily in southern California, but as far north as Eureka. Live bait catch is generally comprised of both

Pacific sardine and northern anchovy. Sardine typically represents a larger portion of the live bait catch, ranging from about 48 percent to 95 percent between 1994 and 2015. Total live bait landings in those years vary between about 2500 mt and 5000 mt, with effort increasing in summer months. However, these estimates are based only on logbooks provided by a limited number of bait haulers, and estimates provided by the CPFV industry. Since the sale of live bait in California is not permitted in a manner similar to that used for the commercial sale of CPS, estimates of tonnage and value are imprecise. Therefore, no estimates of volume or value for the sale of market squid for live bait are available at this time.

10.5 Socioeconomic Data

Economic analyses of management actions affecting coastal pelagic fisheries requires detailed, representative cost and earnings data for the harvesters and processors of sardine and other CPS making up each fishery sector. These data are used to evaluate the economic impacts of proposed management actions. Experience with the long-term allocation of the Pacific sardine HG emphasizes this need, and underscores the necessity for routine data collection. Collecting such data on an irregular basis, or to address an issue at hand, often makes them suspect in terms of strategic bias and validity.

Under Ecosystem-based fishery conservation and management, economic analyses may examine changes in yields from a number of different species, and finding a balance among the variety of ecosystem services CPS can provide. The tradeoffs of interest are between benefits CPS provide as directed harvests, food for higher trophic level commercial predators, food for recreationally important predators, and food for non-commercial but ecologically important predators. The economic data required to evaluate tradeoffs involving recreationally important versus non-commercial but ecologically important species will entail the development of non-market data acquisition and valuation techniques.

10.5.1 Commercial Fisheries

A CPS vessel logbook program for Washington, Oregon, and California vessels that included economic data would greatly contribute to economic analyses of the commercial CPS fishery. Such a program could provide vessel-trip-level fishery economic data (e.g., fuel cost and consumption, number of crew, cost of provisions) across all CPS fishery operations. A logbook program would also need to include other fishery operations in which vessels engage in order to fully evaluate their economic opportunities. To fully understand fleet economics, the at-sea data would need to be supplemented with annual expenditure data, and other data that are not trip-specific, such as interest payments.

A parallel effort should be taken with processors. To fully evaluate the economic impacts of proposed management actions detailed, representative cost and earnings data for west coast sardine processors should be reported on a routine basis. This would entail periodic surveys of CPS processors to collect representative economic data on their processing operations.

10.5.2 Non-market Values

Economic analyses of conservation and management actions affecting the availability of sardines as forage for non-commercial predators will entail developing a framework and compiling the data to estimate the non-market values of recreationally and ecologically important sardine predators. These nonmarket values can then be used to impute the economic value (shadow prices) of Pacific sardine and other CPS as forage for these predators, compared to the economic value in the absence of fishing.

10.6 Northern Anchovy

Concerns about a declining biomass of the central subpopulation of northern anchovy (CSNA) led to several Council agenda items in 2015 and into 2016, as well as a workshop to consider optimal approaches to an anchovy stock assessment, and a general increased impetus to identify adequate survey methodologies. A methodology survey of the SWFSC's acoustic-trawl survey was not approved for northern anchovy. However, there is a need to identify shortcomings, especially related to the proportion of the CSNA biomass that is shoreward of the survey transects.

10.7 References

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11.0 ESSENTIAL FISH HABITAT

Recognizing the importance of fish habitat to the productivity and sustainability of U.S. marine fisheries, in 1996 Congress added new habitat conservation provisions to the Magnuson Fishery Conservation and Management Act of 1976, the Federal law that governs U.S. marine fisheries management. The re-named Magnuson-Stevens Fishery Conservation and Management Act (MSA) mandated the identification of essential fish habitat (EFH) for managed species as well as measures to conserve and enhance the habitat necessary to fish to carry out their life cycles. The MSA requires cooperation among the NMFS, the Councils, fishing participants, Federal and state agencies, and others in achieving EFH protection, conservation, and enhancement. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. 1802(10)). The EFH guidelines under 50 *CFR* 600.10 further interpret the EFH definition as follows:

> *"Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle."*

The Councils and NMFS are expected to periodically review the EFH components of FMPs. Each FMP should include a procedure to review and update EFH provisions if newly-available information warrants revision of EFH. The schedule for this review should be based on an assessment of the quality of both the existing data and expectations when new data will be available. Such a review of information should be conducted at least once every five years (50 *CFR* 600.815).

Process for periodic review of CPS EFH

The review process was initiated at a meeting of the CPSMT in January, 2010, in La Jolla, California, with a discussion of the existing EFH, habitat needs, and new information. The team subsequently compiled publications (see References) relevant to CPS habitat needs and associations. The CPSMT discussed CPS EFH at its April 27-30, 2010 meeting in Portland, Oregon; and during the June 13-14, 2010 Council meeting. In addition, the CPS Subcommittee of the SSC, the CPSMT, and some members of the Coastal Pelagic Species Advisory Subpanel (CPSAS) attended the sardine assessment meeting in October, 2010 in La Jolla, CA, which included discussion of CPS EFH.

The Council's Habitat Committee (HC), Scientific and Statistical Committee (SSC), and the CPSAS considered the issue during the June, 2010 Council meeting in Foster City, California. The full Council also considered CPS EFH at that meeting, and added it to the November, 2010 Council meeting agenda in Costa Mesa, California, scheduled for final action.

In August, 2010, Council staff issued a request for comments on CPS EFH, via an email to the Council's HC, CPSMT, CPSAS, and the CPS subcommittee of the SSC. These advisory and management groups of the Council include representatives from the NMFS Northwest and Southwest Fisheries Science Centers; the NMFS Northwest and Southwest Regions; state agencies of California, Oregon, and Washington; commercial and recreational fishing interests; conservation interests; a port representative; and a tribal representative. No comments were received in response to that request.

The CPSMT considered new information, comments and discussion with Council advisory bodies, and best professional judgment to review CPS EFH in the context of three primary questions:

1. Does new information indicate that existing CPS EFH should be revised?
2. Does new information suggest establishing Habitat Areas of Particular Concern (HAPC)?
3. Are there emerging threats that could adversely affect CPS EFH?

Description of Existing EFH

The CPS fishery includes four finfish species, market squid, and krill:

- Pacific sardine (*Sardinops sagax*)
- Pacific (chub) mackerel (*Scomber japonicus*)
- Northern anchovy (two stocks) (*Engraulis mordax*)
- Jack mackerel (*Trachurus symmetricus*)
- Market squid (*Loligo opalescens*)
- Krill (*Euphasiid spp*.)

CPS finfish inhabit the water column, are not typically associated with bottom substrate, and generally occur above the thermocline in the upper mixed layer. For the purposes of EFH, the four CPS finfish species are treated as a single species complex, because of similarities in their life histories and similarities in the habitat requirements. Market squid inhabit the water column, but are also associated with bottom substrate during spawning events and egg development. Squid are treated in the same complex as CPS finfish because they are similarly fished above spawning aggregations (PFMC 1998).

Unless the Council and NMFS conclude that there are reasons to substantiate a change to the definition of CPS EFH at this time, the description of EFH will remain the same as that identified in Amendment 8 to the FMP (PFMC, 1998). A detailed description of existing EFH for CPS can be found in Appendix D of that document. In determining EFH for CPS, the estuarine and marine habitats necessary to provide sufficient production to support maximum sustainable yield and a healthy ecosystem were considered.

Using presence/absence data, EFH is “based on a thermal range bordered within the geographic area where a managed species occurs at any life stage, where the species has occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by the species” (PFMC 1998). The specific description and identification of EFH for CPS finfish accommodates the fact that the geographic range of all species varies widely over time in response to the temperature of the upper mixed layer of the ocean, particularly in the area north of 39° N latitude. For example, an increase in sea surface temperature since the

1970s has led to a northerly expansion of the Pacific sardine resource. With an environment favorable to Pacific sardine, this species can now be found in significant quantities from Mexico to Canada. Adult CPS finfish are generally not found at temperatures colder than 10° C or warmer than 26° C. Preferred temperatures (including minimum spawning temperatures) are generally above 13° C. Spawning is most common at 14° C to 16° C (PFMC 1998).

Essential fish habitat for west coast CPS species was established in December, 1998, with the issuance of Appendix D to Amendment 8 of the Northern Anchovy Fishery Management Plan. Appendix D contains the identification and description of CPS EFH; information on life history and habitat needs; fishing and non-fishing effects on CPS EFH; and potential conservation and enhancement measures. CPS EFH is linked to ocean temperatures, which shift temporally and spatially, providing a dynamic description of CPS EFH.

This description is as follows:

> *The east-west geographic boundary of EFH for each individual CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone (EEZ) and above the thermocline where sea surface temperatures range between 10^0C to 26^0C. The southern boundary of the geographic range of all CPS finfish is consistently south of the US-Mexico border, indicating a consistency in SSTs below 26^0C, the upper thermal tolerance of CPS finfish. Therefore, the southern extent of EFH for CPS finfish is the US-Mexico maritime boundary. The northern boundary of the range of CPS finfish is more dynamic and variable due to the seasonal cooling of the SST. The northern EFH boundary is, therefore, the position of the 10^0C isotherm which varies both seasonally and annually.*

Krill species were added to the CPS FMP in 2006, and EFH for krill was issued in 2008. The two most prevalent species of krill are *Euphausia pacifica* and *Thysanoessa spinifera,* although six other krill species are also included in the FMP. All are prohibited from harvest on the U.S. West Coast. The two species (*E. pacifica* and *T. spinifera*) form large aggregations of moderate density, while the other species are typically more dispersed. EFH is identified individually for *E. pacifica* and *T. spinifera*, and then collectively for the other krill species. The following descriptions are taken from Amendment 12 to the CPS FMP (PFMC 2006).

Euphausia pacifica EFH
Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.-Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border. Highest concentrations occur within the inner third of the EEZ, but can be advected into offshore waters in phytoplankton-rich upwelling jets that are known to occur seaward to the outer boundary of the EEZ and beyond.

Thysanoessa spinifera EFH
Larvae, juveniles and adults: From the baseline from which the shoreline is measured to the 500 fm (914 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 100 m

deep. Largest concentrations in waters less than 200 m deep, although individuals, especially larvae and juveniles, can be found far seaward of the shelf, probably advected there by upwelling jets.

Other krill species EFH

Larvae, juveniles and adults: From the baseline from which the shoreline is measured seaward to the 1000 fm (1,829 m) isobath, from the U.S.- Mexico north to the U.S.-Canada border, from the surface to 400 m deep, from the U.S.- Mexico north to the U.S.-Canada border. Amendment 12 concluded that no biological, social or economic impacts are expected beyond administrative costs of reviewing federally regulated projects for potential impacts on this habitat, where krill and krill predators concentrate.

New Information

Existing EFH descriptions for CPS are based largely on presence/absence data and upon a thermal range within the broader geographic area in which CPS stocks occur. The 1998 EFH identification and descriptions also base EFH on historical presence or "where environmental conditions do not preclude colonization by the CPS" (PFMC 1998). Although temperature associations among individual species and life stages within the CPS complex exhibit some variation, the temperature range that describes existing EFH is sufficiently representative of habitat associations. This temperature range is between 10°-26° C, although CPS can be found at temperatures outside that range. The CPSMT considered information contained in several recent publications relevant to CPS. The new information continues to support the strong linkage between CPS distribution and sea surface temperature, which varies spatially and temporally, and thus does not present any significant change in existing documented habitat associations. All the new information considered during this process is included in the References section below.

Because krill EFH was only recently established (under Amendment 12, finalized in 2008), the CPSMT did not invest significant effort in reviewing information on which EFH designations for krill are based. However, this periodic review offers an opportunity to synchronize the timing of krill with the other CPS stocks for future EFH reviews.

Amendment 8 cited several research needs related to market squid habitat and potential adverse effects to EFH. More specifically, these research needs centered on spawning distribution, depth, and location; as well as egg and paralarvae production and survival. Dispersal of larvae was also cited as key information that could help to understand how local impacts could be mitigated by recruitment from other areas. There remains a relatively meager volume of literature on market squid habitat. However, there are recent reports and research that are either published or in submission.

A comparison of new and newly-available literature since the last EFH review in 2005, and from when CPS EFH was originally established in 1998, shows that the California Current (CC) and CPS EFH continues to have significant annual and decadal variations in its oceanographic conditions; this includes upwelling, currents, primary and secondary productivity, and plankton and nekton species abundance and distributions (e.g., Humboldt squid in 2009).

Zwoliniski et al. (2011) found that they could identify the pelagic habitat of Pacific sardine using satellite-derived SST and Chlorophyll information. Their information clearly shows the movement of this preferred habitat from southern California in winter/early spring to off the Pacific Northwest in summer. The pelagic habitat off northern Washington appears to have particularly high phytoplankton concentrations during summer (Hickey and Banas 2008; Hickey et al. 2009) and is probably why sardines track this particular habitat.

From 2003-2005 California Current Ecosystem (CCE) ocean temperatures were warmer than average. From 2006 and on, SST were colder – especially in 2008. The PDO also went from positive to negative in 2006. These colder temperatures appear to have had a negative effect on sardine recruitment (Chavez et al. 2005; Jacobson and MacCall 1995; Jacobson et al. 2001, 2005; Takasuka et al. 2008) and may have had a positive effect on squid (Vidal et al 2002; Zeidberg et al. 2006). This may be why the stock size of sardines appears to be lower now.

Climate change has the potential to alter CPS EFH significantly. However, there are still many unknowns regarding how climate change will affect the CCE. At this time it is still uncertain if the CC will actually get colder or warmer in the future. Increasing land temperatures could lead to larger air pressure differentials and cause more upwelling. However, these upwelled waters could be much less productive if ocean acidification affects primary and secondary production (Fabry et al. 2008; Juranek et al. 2009).

Habitat Areas of Particular Concern (HAPCs)

The implementing regulations for the EFH provisions of the MSA (50 CFR part 600) encourage the FMCs to identify specific types or areas of habitat within EFH as "habitat areas of particular concern" (HAPC), based on one or more of the following considerations: (1) the importance of the ecological function provided by the habitat; (2) the extent to which the habitat is sensitive to human-induced environmental degradation; (3) whether, and to what extent, development activities are, or will be, stressing the habitat type; and (4) the rarity of the habitat type. The intended goal of identifying such habitats as HAPCs is to provide additional focus for conservation efforts. While the HAPC designation does not add any specific regulatory process, it highlights certain habitat types as ecologically very important. This designation is manifested in EFH consultations where federally permitted projects with potential adverse impacts to HAPC are more carefully scrutinized during the consultation process.

HAPC were not considered in Appendix D of Amendment 8, for CPS. HAPCs for krill species were considered under Amendment 12, but were not adopted. CPS finfish and market squid are highly mobile, and generally associated with a range of thermal conditions rather than fixed physical habitat. In addition, CPS are somewhat unpredictable and not particularly dependent on any single habitat type or spatially discrete location. Their strong association with a dynamic habitat feature creates a challenge in proposing HAPCs, especially in open ocean waters where CPS stocks are found. This association, combined with the large range of habitats suitable for many CPS, makes it infeasible to provide appropriate justification for designating HAPCs at this time.

For the reasons described above, it was determined that the available information was insufficient to recommend designating HAPCs as part of this review.

Fishing Gear Effects

The MSA requires each FMP to identify fishing activities that may adversely affect EFH and to minimize adverse effects of those activities to the extent practicable. Fishing activities should include those regulated under the CPS FMP that affect EFH identified under any FMPs, as well as those fishing activities regulated under other FMPs that affect EFH designated under the CPS FMP.

Appendix D to Amendment 8 of the CPS FMP describes CPS fishing activities and gear that have the potential to adversely affect EFH, and notes that direct interactions with habitat are unlikely because CPS fisheries typically occur in waters deeper than the height of the net. However, it is important to clarify that while CPS fishing gear does interact with the water (which is EFH), a fishing net passing through the water column is not expected to adversely affect the functioning of that habitat. Direct interactions between gear and CPS EFH may occur when derelict gear comes into contact with the benthos, which could potentially harm squid eggs embedded in the benthos. Even so, Appendix D concludes that habitat impacts resulting from net interactions are rare, minimal, and transitory.

Although some sector shifts and species harvest has changed since Appendix D was written, the gear type, harvest levels, and methods have remained essentially the same over time. In the 1990s, the industry was dominated by roundhaul and lampara gear, which still was true in 2009 (PFMC 2010).

One notable change in fishing activities since 1998 has been a spatial shift in west coast CPS landings. In 1998, the Pacific Northwest sector harvested approximately 1-2% (by weight) of the total west coast CPS landings. More recently, the Pacific Northwest was responsible for harvesting approximately 28% of total CPS landings in 2009 (PFMC 2010). It is important to note that the increase in Pacific Northwest landings represents a shift in where landings are occurring, and not necessarily an overall increase in landings along the west coast. There is no reason to conclude any increase in effects, because methods and gear are essentially the same between California and the Pacific Northwest industry sectors.

This review concludes that based on fishery information and statistics, compared over time, there is no substantial change in gear or activities. Therefore, the description, adverse impacts, and mitigation measures contained in Appendix D are still relevant and valid, and do not suggest that any new evaluation is warranted.

Emerging Threats

Climate Change

Fluctuating oceanographic conditions are known to have significant effects on the abundance of CPS in the Pacific Ocean and worldwide. Ocean temperatures, which are known to have direct effects on CPS recruitment, distribution, and abundance, have increased worldwide (Domingues et al. 2008). The California Current, the dominant large-scale oceanographic feature along the US west coast, is known to fluctuate significantly at annual and longer time scales. At short time scales the El Niño/Southern Oscillation (ENSO) (http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/mei.html) is a short-term cooling or warming of the ocean at the equator caused by altering wind patterns. El Niño periods can produce considerable warming and reductions in primary and secondary production in the CC and reduce some CPS abundances. Many CPS and other fishes show significant alterations in their coastal distributions during strong El Niño or warm ocean periods (Phillips et al. 2007). For example, jellyfish blooms appear to be having significant effects on fisheries all over the world. Recently, Brodeur et al. (2008) indicated that that jellyfish may compete directly with CPS in the CC. The

CC moved from an El Niño condition to a La Niña or cold condition in the summer of 2010. The PACOOS program (http://www.pacoos.org/Default.htm) is presently tracking many oceanographic (physical and biological) indices that are revealing how oceanographic fluctuations affect marine resources, including some CPS. Climate change is expected to alter ENSO frequencies and duration but the levels are still impossible to predict.

Recent research has also shown that the entire North Pacific Ocean oscillates (Pacific Decadal Oscillation, or PDO) between warm and cold states at decadal scales, with significant effects on living marine resources (both benthic and pelagic) (Mantua et al. 1997; Hare et al. 1999; Beamish et al. 2000; Hare and Mantua 2000; Hollowed et al. 2001; Kar et al. 2001; and Brinton and Townsend 2003). Sardines appear to become abundant during warm PDO periods and anchovy during cool PDO periods. However, the time series is short and the mechanisms involved are still uncertain.

The "source water" for the CC appears to fluctuate depending on the status of the PDO and ENSO (DFO. 2010). This has significant effects on CPS and other species in the CC. In 2008, the North Pacific Current was very strong, as was the amount of water that split south from this current to become the CC. When the southern split is strong, much nutrient rich North Pacific waters enter the CC and appear to enhance primary and secondary productivity (DFO 2010; http://www.pac.dfo-mpo.gc.ca/science/oceans-eng.htm). In 2009 and spring 2010 North Pacific flows to the CC were reduced, which decreased overall productivity.

The most significant local feature along the west coast is wind induced upwelling (Bakun 1996). Upwelling is responsible for bringing nutrient rich waters from depth to the surface, thus enhancing primary production. Future climate change scenarios indicate much uncertainty as to whether winds and ocean conditions will be more conducive to upwelling or not, but Bakun (1990) thought that upwelling related winds would intensify because of higher pressure differentials between ocean and land. There is also concern that the phenology (i.e., timing of upwelling relative to the evolved life histories of various species) might be affected by alterations or changes in the seasonality and timing of upwelling periods along the west coast (Bograd et al. 2008).

One of the most significant impacts of climate change comes directly from the increased concentrations of carbon dioxide dissolving into the oceans and leading to decreased pH or ocean acidification. Lower ocean pH levels may have significant consequences on some calcifying organisms, many of which are prey for sardines and other CPS (Feely et al. 2004; 2008; Kerr 2010).

Recently, periods of hypoxia, or very low levels of oxygen, were observed on the continental shelf off Washington and Oregon and are expected to occur more often in the future (Grantham et al. 2004; Chan et al. 2008). Hypoxia could be related to changes in wind and currents directly tied to climate change.

The last few years and particularly in 2009, large numbers of Humboldt squid (*Dosidicus gigas*) were observed in the CC from Canada to Mexico (Field 2008). It is unknown if the unusual abundance of this species in the CC was related to climate change or some other oceanographic condition. However, their occurrence does appear to be related to the recent abundance of the hypoxic area off the west coast (Gilly et al. 2006). Humboldt squid are very efficient predators that have some of the highest growth rates of any species. They can consume significant numbers of CPS and other species and may affect their abundance.

Finally, harmful algal blooms (HABs) have been observed more frequently in recently years and are expected to be more common in the future. The effects of various HAB on CPS are unknown at this time, but related increases in domoic acid can be harmful to marine species, and were responsible for recent closures of west coast the Dungeness crab fishery.

Ocean Energy Development

At this time, there is a lot of interest in developing renewable ocean energy projects in the CC. Possible energy projects include wave, wind, tidal, ocean currents, and thermal gradient. All of these will have structures that may affect benthic and pelagic environments. Unfortunately, the environmental effects of these projects needs study (Boehlert et al. 2008; Boehlert and Gill 2010). Some energy structures may act as fish aggregating devices (FADs) for CPS or their predators. Very few studies have been done to look at the effects of electromagnetic effects on migrations/movements of CPS. As these energy projects become initiated, it will be important to identify how they interact with CPS.

Presently, the nearshore areas that have the highest potential for wave energy development are also areas where many CPS and other fisheries (e.g., Dungeness crab, salmon) are focused. This nearshore habitat has also been identified as EFH for CPS and other fishes (Boehlert et al. 2008). From an ecosystem management position, these habitats (both pelagic and benthic) have not been well studied and their utilization by various species is not well mapped or documented in time or space.

Many coastal pelagic species undertake broad migrations in the coastal region. Wave energy devices may directly affect this migration by their physical structure or by emitting electromagnetic, acoustic, or chemical field that interfere with fish navigation/orientation systems.

Forecasting the effects of wave energy on pelagic species is presently difficult because we have limited information on the effects of large versus small projects and our time series of data from these habitats is also limited. Besides directly altering habitats, these structures could possibly alter food webs and may leach anti-fouling chemicals into the environment which may affect the health and marketability of CPS fishes caught in their vicinity.

Finally, large scale wave energy developments have the potential to conflict with existing or potential CPS fisheries. CPS fish often congregate in very specific areas depending on currents, time of year, predator abundance, etc. If CPS fish are highly congregated in areas that are off-limits to fishing because of wave energy structures, they would significantly affect potential harvest.

Conclusions

After review of recently-published literature, discussion, and presentation at several Council-related meetings, and based on the opportunity provided for public comment, the CPSMT makes the following conclusions:

- New information still supports the strong linkage between CPS habitat utilization and sea surface temperature, which along with other oceanographic conditions like upwelling and primary productivity, is both spatially and temporally variable. Therefore, although this information is likely to help inform EFH consultations, and provides additional background on CPS habitat, it does not warrant changes to the existing description of CPS EFH.
- The fishing impacts and non-fishing impacts sections of Appendix D to Amendment 8 sufficiently describe those adverse impacts as well as conservation measures to mitigate those impacts.
- New information on climate change and ocean energy development should be added to body of information on potential impacts to CPS EFH. This should be published in the 2011 SAFE[3] document, to remain available for use in EFH consultations and for future EFH reviews.
- The timing of the periodic review of krill EFH should be synchronized with the future reviews of CPS EFH.

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APPENDIX A:
SAFE TABLES

Note: Tables are updated through June 2016. Economics tables (6-1 through 6-5) are updated through 2014. Recent economic data will be included in the subsequent SAFE document

TABLE 2-1. HISTORY OF COUNCIL ACTIONS

- The Council initiated development of the FMP for northern anchovy in January of 1977. The FMP was submitted to the Secretary in June of 1978. Regulations implementing the FMP were published in the *Federal Register* on September 13, 1978 (43*FR*40868).

- The first amendment changed the method of specifying the domestic annual harvest for Northern anchovy and added a requirement for an estimate of domestic processing capacity and expected annual level of domestic processing. Approval for this amendment was published in the *Federal Register* on July 18, 1979 (44*FR*41806).

- The second amendment, which became effective on February 5, 1982, was published in the *Federal Register* on January 6, 1982 (47*FR*629). The purpose of this amendment was to increase the domestic fishing fleet's opportunity to harvest the entire OY of northern anchovy from the U.S. EEZ by releasing, inseason, unutilized portions of the northern quota.

- During the spring of 1982, the Council considered a third amendment that divided the quota for northern anchovy into two halves and made release of the second half conditional on the results of a mid-season review of the status of the stock. The methods proposed for the mid-season assessment were considered too complex to implement, and the amendment was not approved.

- The fourth amendment, which had two parts, was published in the *Federal Register* on August 2, 1983 (48*FR*34963) and became effective on August 13, 1983. The first part abolished the five inch size limit in the commercial fishery and established a minimum mesh size of 5/8 inch for northern anchovy. The mesh size requirement did not become effective until April 1986 in order to give the fleet additional time to comply without undue economic hardship. The second part established a mid-season quota evaluation that was simpler in design than the method proposed in Amendment 3.

- The fifth amendment in 1983 incorporated advances in scientific information concerning the size and potential yield of the central subpopulation of northern anchovy. Additionally, the fifth amendment included changes to a variety of other management measures. Two or more alternative actions were considered in each of seven general categories; (1) OY and harvest quotas; (2) season closures; (3) area closures; (4) quota allocation between areas; (5) the reduction quota reserve; (6) minimum fish size or mesh size; and (7) foreign fishing and joint venture regulations. The alternatives for the fifth amendment were reviewed by the Council during 1983. The final rule was published in the *Federal Register* on March 14, 1984 (49*FR*9572).

- In 1990, the sixth amendment implemented a definition of overfishing for northern anchovy consistent with National Standard 7, and addresses vessel safety (56*FR*15299, April 16, 1991).

- The Council began developing the seventh amendment as a new FMP for CPS on a motion from NMFS and California in 1990. A complete draft was available in November of 1993, but the Council suspended further work, because NMFS withdrew support due to budget constraints. In

July of 1994, the Council decided to proceed with the plan through the public comment period. NMFS agreed with the decision on the condition that the Council also consider the options of dropping or amending the anchovy FMP. Thus, four principal options were considered for managing CPS (1) drop the anchovy FMP (no Federal or Council involvement in CPS); (2) continue with the existing FMP for anchovy (status quo); (3) amend the FMP for northern anchovy; and (4) implement an FMP for the entire CPS fishery. In March of 1995, the Council decided to proceed with the FMP for CPS. Final action was postponed until June 1995 when the Council adopted a draft plan that had been revised to address comments provided by NMFS and the SSC. Amendment 7 was submitted to the Secretary, but rejected by NMFS, SWR, as being inconsistent with National Standard 7. NMFS announced its intention to drop the FMP for northern anchovy (in addition to FMP's other species) in the *Federal Register* on March 26, 1996 (61*FR*13148), but the action was never completed.

- Development of Amendment 8 began in June, 1997 when the Council directed the Coastal Pelagic Species Plan Development Team (CPSPDT) to amend the FMP for northern anchovy to conform to the recently revised Magnuson-Stevens Act and to expand the scope of the FMP to include the entire CPS fishery. Amendment 8 was partially approved by the Secretary on June 10, 1999, and final regulations were published on December 15, 1999 (64*FR*69888). The FMP was implemented on January 1, 2000.

- At its meeting in June 1999, the Council directed its CPSMT to recommend appropriate revisions to the FMP and report to the Council the following September. A public meeting of the CPSMT was held in La Jolla, California, on August 3 and 4, 1999, and August 24, 1999, and a meeting was held between the CPSMT and the CPSAS on August 24, 1999. At its September 1999 meeting, the Council gave further direction to the CPSMT regarding MSY for squid. At its March 2000 meeting, the Council asked the CPSMT for a more thorough analysis of the alternatives proposed for establishing MSY for squid and for bycatch. At a public meeting in La Jolla, California, on April 20 and 21, 2000, the CPSMT reviewed comments from the Council, the Council's SSC and prepared additional material for establishing MSY for squid based on spawning area.

- The Council distributed Amendment 9 for public review on July 27, 2000. At its September 2000 meeting, the Council reviewed written comments, received comments from its advisory bodies, and heard public comments, and decided to submit only two provisions for Secretarial review. Based on testimony concerning MSY for squid, the Council decided to include in Amendment 9 only the bycatch provision and a provision providing a framework to ensure that Indian fishing rights are implemented according to treaties between the U.S. and the specific tribes. Since implementation of the FMP, the CPS fishery has expanded to Oregon and Washington. As a result, the FMP must discuss Indian fishing rights in these areas. These rights were not included in the FMP; and the Council decided to address this issue in Amendment 9. The Council decided to conduct further analysis of the squid resource and prepared a separate amendment that addressed OY and MSY for squid.

- The Secretary approved Amendment 9 on March 22, 2001.

- In April 2001, the Council adopted the capacity goal and transferability provisions recommended by the CPSMT for inclusion in Amendment 10. The Council directed the CPSMT to develop an amendment to the CPS FMP that included the capacity goal, provisions for permit transferability, a process for monitoring fleet capacity relative to the goal, and a framework for modifying transferability provisions as warranted by increases or decreases in fleet capacity. The amendment also addressed determination of OY and MSY for market squid.

- In November 2001, the Council reviewed the findings of the market squid STAR workshop and endorsed the egg escapement approach as a proxy for squid MSY, as recommended by the market squid STAR Panel and CPSMT.

- In March 2002, the Council adopted draft Amendment 10 to the CPS FMP for public review.

- In June 2002, the Council adopted Amendment 10 to the CPS FMP.

- December 30, 2002, the Secretary approved Amendment 10. On January 27, 2003 NMFS issued the final rule and regulations for implementing Amendment 10.

- September 2002, the Council requested NMFS take emergency action to reallocate the unharvested portion of the Pacific sardine HG prior to October 1. The Council believed this action would minimize negative economic impacts in the northern fishery without causing market disruptions in the southern fishery. On September 26, 2002, through an emergency rule, NMFS reallocated the remaining Pacific sardine HG and reopened the northern subarea fishery, which had been closed on September 14, 2002.

- September 2002, the CPSAS recommended the Council initiate a regulatory or FMP amendment and direct the CPSMT to prepare management alternatives for revising the sardine allocation framework. The Council directed the CPSMT to review CPSAS recommendations for revising the allocation framework. A public meeting of the CPSMT was held on October 8, 2002. The CPSMT discussed information needs and prospective analyses for developing allocation management alternatives.

- On October 30, 2002, the Council initiated a regulatory amendment to address allocation issues.

- The CPSMT met January 30-31, 2003 to analyze various alternatives for revising the allocation framework and developed recommendations for Council consideration.

- At the March 2003 Council meeting, the SSC and CPSAS reviewed analyses of the proposed management alternatives for sardine allocation. Based on the advisory body recommendations and public comment, the Council adopted five allocation management alternatives for public review.

- At the April 2003 Council meeting, the CPSAS reviewed the five management alternatives and developed recommendations for the Council. The Council took final action on the regulatory amendment. The proposed action adopted by the Council would (1) change the definition of subarea A and subarea B by moving the geographic boundary between the two areas from 35° 40'

N latitude to 39° N latitude, (2) move the date when Pacific sardine that remains unharvested is reallocated to Subarea A and Subarea B from October 1 to September 1, (3) change the percentage of the unharvested sardine that is reallocated to Subarea A and Subarea B from 50 percent to both subareas to 20 percent to Subarea A and 80 percent to Subarea B, and (4) reallocate all unharvested sardine that remains on December 1 coastwide. The Council's intent is for this interim revision to the allocation framework be in effect for the 2003 and 2004 seasons. The allocation regime could be extended to 2005 if the 2005 HG were at least 90 percent of the 2003 HG.

- The regulatory amendment for allocation of the Pacific sardine HG was approved on August 29, 2003. The final rule implementing the regulatory amendment was published September 4, 2003 (68*FR*52523).

- At the November 2003 Council meeting, the Council adopted a HG of 122,747 metric tons (mt) for the 2004 Pacific sardine fishery, within an incidental catch allowance of up to 45 percent. This HG was based on a biomass estimate of 1,090,587 mt. Per the revised allocation framework, on January 1, the HG was allocated 33 percent to the northern subarea and 66 percent to the southern subarea, with a subarea dividing line at Point Arena, CA. The final rule implementing the HG was published December 3, 2003 (68*FR*67638).

- At the June 2004 Council meeting, the Council adopted the following management measures for the July 2004-June 2005 Pacific mackerel fishery: 1) total fishery HG of 13,268 mt; 2) directed fishery guideline of 9,100 mt; and 3) set-aside for incidental catches of 4,168 mt and an incidental catch rate limit of 40 percent when mackerel are landed with other CPS species, except that up to one mt of Pacific mackerel could be landed without landing any other CPS. The Council also requested NMFS track utilization of the directed fishery guideline and advise the Council at the March 2005 meeting if additional action (e.g., a mop-up fishery) was warranted. Additionally, the Council initiated an amendment to the CPS FMP with the primary purpose of allocating the coastwide Pacific sardine HG. The Council discussed a schedule that included final Council action on the FMP amendment by June 2005, which would enable implementation by January 2006. To facilitate development of the amendment, the Council directed the CPSAS to draft a range of alternative sardine allocation scenarios. The Council also directed the CPSMT to formally review the CPS FMP issues raised by NMFS to identify issues that could be addressed through amendment to the CPS FMP and if they could be addressed in the short-term or would require more extensive time to complete.

- At the September 2004 Council meeting, the Council adopted STAR Panel reports for Pacific mackerel and Pacific sardine. New assessment methodologies were used for management of the 2005 sardine fishery and the 2005-2006 Pacific mackerel fishery. Relative to the CPS FMP amendment process, the Council requested the CPSAS to narrow the current broad range of Pacific Sardine allocation alternatives for Council consideration at the November 2004 meeting. The Council received information from the CPSMT about their consideration of several FMP-related issues raised by NMFS, and directed Council staff to communicate to NMFS the Council plans for further review of CPS EFH.

- At the November 2004 Council meeting, the Council adopted a HG of 136,179 mt for the 2005 Pacific sardine fishery. This HG was based on a biomass estimate of 1.2 million mt. Per the FMP allocation framework, on January 1 the HG was allocated 33 percent to the northern subarea and 66 percent to the southern subarea with a subarea dividing line at Point Arena, California. Additionally, the Council directed the CPSMT and staff to begin development of Amendment 11 to the CPS FMP to include alternatives for sardine allocation, as recommended by the CPSAS as well as two additional alternatives. The Council reviewed the draft analyses and considering formal adoption of allocation alternatives at the April 2005 Council meeting.

- At the March 2005 Council meeting, the Council reviewed a progress update from NMFS SWR on a proposed course of action for management of krill in the West Coast EEZ and National Marine Sanctuaries under the auspices of the CPS FMP. The Council approved a draft outline for an alternatives analysis.

- At the April 2005 Council meeting, the Council approved a range of alternatives for the allocation of Pacific sardine for further analysis and public review. After reviewing preliminary results on the range of alternatives approved for analysis in November 2004 and reports of the CPS advisory bodies, the Council eliminated two alternatives (Alternatives 2 and 5) from further consideration. The Council recommended that the CPSMT follow the advice of the SSC as they complete the analysis of allocation alternatives for public review.

- At the June 2005 Council meeting, the Council addressed three CPS matters, pacific mackerel HG and management measures, long-term Pacific sardine allocation, and CPS EFH.

  Regarding Pacific mackerel, the Council adopted the new assessment and the following management measures for the July 2005-June 2006 Pacific mackerel fishery: 1) total fishery HG of 17,419 mt; 2) directed fishery guideline of 13,419 mt; and 3) set-aside for incidental catches of 4,000 mt and an incidental catch rate limit of 40 percent, when mackerel are landed with other CPS, except that up to one mt of Pacific mackerel could be landed without landing any other CPS. The Council requested NMFS track utilization of the directed fishery guideline and advise the Council at the March 2006 meeting if release of the incidental set-aside was warranted.

  Regarding Pacific sardine allocation, the Council took final action on a long-term allocation of the annual Pacific sardine HG. The Council approved a modified version of Alternative 3, which provided the following allocation formula for the non-tribal share of the HG:

  1. A seasonal allocation structure with 35 percent of the HG to be allocated coastwide on January 1.
  2. 40 percent of the HG, plus any portion not harvested from the initial allocation, to be reallocated coastwide on July 1.
  3. On September 15 the remaining 25 percent of the HG, plus any portion not harvested from earlier allocations, to be reallocated coastwide.

  The Council also recommended a review of the allocation formula in 2008.

  The Council adopted the 2005 SAFE document as drafted by the CPSMT including the required review of CPS EFH. The Council recommended no changes to the existing definition of EFH because the CPSMT review identified no new information on which to base EFH modifications. The Council agreed with the research needs identified by the CPSMT in the 2005 SAFE and stressed the importance of coastwide sardine research and harvest policy review.

- At the November 2005 Council meeting, the Council adopted a Pacific sardine HG of 118,937 mt for the 2006 season to be managed under the terms of the allocation arrangements under Amendment 11.

  The Council also approved a range of krill fishing alternatives for public review and additional analysis, including a preliminary preferred alternative to identify krill as a prohibited species in the EEZ. The proposed krill management measures were implemented as Amendment 12 to the CPS FMP. At the June 2005 Council meeting, the Council addressed three CPS matters, pacific mackerel HG and management measures, long-term Pacific sardine allocation, and CPS EFH.

- At the March 2006 Council meeting, the Council took final action adopting CPS FMP Amendment 12 to prohibit harvest of all species of krill in the U.S. EEZ. Additionally, the Council adopted an EFH designation for all species of krill that extends the length of the West Coast from the shoreline to the 1,000 fm isobath and to a depth of 400 meters. No habitat areas of particular concern were identified.

- At the June 2006 meeting, the Council adopted the new assessment model and the following management measures for the July 2006-June 2007 Pacific mackerel fishery: a total fishery HG of 19,845 mt, a directed fishery guideline of 13,845 mt; and a set-aside for incidental catches of 6,000 mt and an incidental catch rate limit of 40 percent when mackerel are landed with other CPS, except that up to one mt of Pacific mackerel could be landed without landing any other CPS.

- At the November 2006 meeting, the Council adopted a HG of 152,654 mt for the 2007 Pacific sardine fishery. This HG was based on a biomass estimate of 1.32 million mt. Per the FMP allocation framework adopted under Amendment 11, the Pacific sardine HG was allocated seasonally with 35 percent of the HG allocated coastwide January 1, 40 percent of the HG, plus any portion not harvested from the initial allocation reallocated coastwide July 1; and the remaining 25 percent of the HG, plus any portion not harvested from earlier allocations, to be reallocated coastwide September 15. The Council also recommended a 45 percent incidental catch rate be allowed for other CPS fisheries in the event that a seasonal allocation be taken before the end of an allocation period or the HG was taken before the end of the year.

  Additionally, the Council reviewed the draft Terms of Reference for the CPS stock assessment process scheduled for 2007 and directed Council staff to revise the document as recommended by the CPSAS, the CPSMT, and the SSC and distribute it for public review. The Council approved a final document in March 2007 for use during the review of full assessments for Pacific mackerel and Pacific sardine in May and September, respectively.

- At the March 2007 Council meeting, the Council approved the final Terms of Reference for the 2007 CPS stock assessment process. The final document was posted on the Council website and distributed for use during the review of full assessments for Pacific mackerel and Pacific sardine May 1-3 and September 18-21 respectively.

- At the June 2007 Council meeting, he Council adopted the new assessment model and the following management measures for the July 2007-June 2008 Pacific mackerel fishery: an acceptable biological catch (ABC) for U.S. fisheries of 71,629 mt, a directed fishery HG of 40,000 mt, and in the event the directed fishery reaches 40,000 mt, the directed fishery will revert to an incidental-catch-only fishery with a 45 percent incidental catch allowance when Pacific mackerel are landed with other CPS, except that up to 1 mt of Pacific mackerel could be landed without landing any other CPS. The Council and NMFS will track the 2007-08 Pacific mackerel fishery and will recommend an in-season review of the mackerel season for the March 2008 Council meeting, if needed, with the possibility of re-opening the directed fishery as a routine action. Additionally, the Council directed Council staff to send a letter to the U.S. State Department requesting increased coordination with Mexico on the exchange of data for the improvement of international management of CPS.

- In November 2007, the Council adopted an ABC or total harvest guideline (HG) of 89,093 mt for the 2008 Pacific sardine fishery. This ABC was based on a biomass estimate of 832,706 mt and the harvest control rule in the CPS FMP. The Council recommended 80,083 mt of the HG for the directed fishery to be allocated seasonally per the Amendment 11 framework. To allow for incidental landings of Pacific sardines in other CPS fisheries and to ensure the fishery did not exceed the ABC, the Council recommended a set aside of 8,910 mt allocated across seasonal periods as follows:

	Jan 1- June 30	July 1- Sept 14	Sept 15 - Dec 31	Total
Seasonal Allocation (mt)	31,183	35,637	22,273	89,093
Set Aside %	5.2%	1.2%	3.6%	10%
Set Aside (mt)	4,632	1,070	3,208	8,910
Adjusted Allocation (mt)	26,550	34,568	19,065	80,083

Regarding Pacific mackerel, the Council recommended no changes to Pacific mackerel assessment methodology for the 2008 assessment update and recommended the next CPS stock assessment review panel be convened in 2009 rather than 2010 to fully review the status of Pacific sardine and Pacific mackerel.

- In June 2008, the Council adopted an updated Pacific mackerel assessment and the following management measures for the July 2008-June 2009 Pacific mackerel fishery: 1) Establish a harvest guideline for the directed fishery at 40,000 mt, providing an 11,772 mt set-aside for incidental landings in other fisheries. 2) Close the directed fishery and revert to an incidental-catch-only fishery with a 45 percent incidental landing allowance when Pacific mackerel are landed with other coastal pelagic species (CPS), except that up to 1 mt of Pacific mackerel could be landed without landing any other CPS. If needed, conduct an in-season review of the 2008-2009 Pacific mackerel fishery at the nearest feasible Council meeting, with the possibility of either releasing a portion of the incidental set-aside to the directed fishery or further constraining incidental landings to ensure total harvest remains below the ABC.

- In November 2008, the Council adopted a harvest guideline (HG) of 66,932 mt for the 2009 Pacific sardine fishery. This HG was based on a biomass estimate of 662,886 mt and the harvest control rule in the CPS FMP. The Council recommended that 1,200 mt of the HG be set-aside prior to allocation for dedicated Pacific sardine research activities in period 2. The Council recommended an adjusted allocation of 59,232 mt as the HG for the directed fishery to be allocated seasonally per the Amendment 11 framework. To allow for incidental landings of Pacific sardines in other CPS fisheries and to help to ensure the fishery does not exceed the total HG, the Council adopted a set aside of 6,500 mt allocated across seasonal periods as follows:

HG = 66,932 mt; Research set aside = 1,200 mt; Adjusted HG = 65,732 mt				
	Period 1	Period 2	Period 3	
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	23,006	26,293	16,433	65,732
Incidental Set Aside (mt)	1,000	1,000	4,500	6,500
Adjusted Allocation (mt)	22,006	25,293	11,933	59,232

If a seasonal allocation to the directed fishery is reached or exceeded in any period NMFS would close the directed sardine fishery and the fishery would revert to an incidental fishery with an incidental landing allowance of no more that 20 percent Pacific sardine by weight.

Under this proposal, the Council recommends NMFS take the following inseason automatic actions:

- Any unused seasonal allocation to the directed fishery from Period 1 or Period 2 rolls into the next period's directed fishery.

- Any overage of a seasonal allocation to the directed fishery from Period 1 or Period 2 is deducted from the next Period's directed fishery.

- Any unused Seasonal Incidental Set-Aside from Period 1 or Period 2 rolls into the next period's directed fishery.

- If both the seasonal allocation to the directed fishery and the Seasonal Incidental Set-Aside are reached or exceeded in any period, the retention of Pacific sardine will be prohibited and the overage will be deducted from the next period's directed fishery.

- Any of the research set-aside that is not used in Period 2 rolls into the third seasonal period's directed fishery HG.

- In November 2008, the Council also adopted a public review draft of the Terms of Reference document for the 2009 STAR Panel process. The Council also tasked Council staff with scheduling two STAR Panels for 2009; one in May 2009 focused on a full Pacific mackerel assessment and Pacific sardine assessment methodology, and a second in September 2009 that focuses on the review of a full Pacific sardine assessment.

- At the March 2009 meeting, the Council adopted a final Terms of Reference as a guide for the 2009 coastal pelagic species STAR process. The Council approved minor changes to the document as recommended by the Scientific and Statistical Committee (SSC). A final document will be posted to the Council website in the near future. The Council also scheduled two STAR Panels, both to be held at the Southwest Fisheries Science Center in La Jolla, California. The first occurred May 4-8, 2009 and will review a full assessment of Pacific mackerel as well as the survey design for a proposed Pacific sardine survey. The second occurred September 21-25, 2009 to review a full assessment of Pacific sardine.

  The Council also approved for public review two EFP proposals for an industry-sponsored Pacific sardine research survey in 2009. The Council requested that Pacific sardine industry representatives work to provide a detailed single proposal that addresses the recommendations of the SSC and the Coastal Pelagic Species Management Team (CPSMT). The Council asked the proposal be submitted for publication on the Council website as soon as feasible, but no later than April 15, 2009 to allow for adequate review in advance of the May 4-8, 2009 STAR Panel meeting where survey methodology is scheduled for thorough evaluation. The Council also recommended National Marine Fisheries Service (NMFS) adjust the research set-aside for this effort from 1200 metric ton (mt) to 2400 mt.

  The Council also reviewed the final NMFS guidelines for implementing National Standard 1 and held an initial scoping session on amending the coastal pelagic species FMP in accordance. In general, issues identified for further consideration include: updating the definition and implementation of the harvest control rules to comply with new management mechanisms such as ACLs, acceptable biological catch (ABC), and overfishing levels (OFLs), developing these mechanisms for monitored and prohibited harvest species, a listing of potential species to be categorized as ecosystem species, and revising measures for more efficient inseason monitoring and enhanced preseason and postseason accounting. Specifically, the Council was interested in advancing concepts brought forward by the SSC, CPSMT, CPS Advisory Subpanel, and public testimony. The Council reviewed initial analysis of potential alternatives at its November 2009 meeting in Costa Mesa, California, as the second stage of a four Council meeting process.

- In June 2009, the Council adopted the full Pacific mackerel assessment and the following harvest specifications and management measures for the July 2009-June 2010 Pacific mackerel fishery:
  1. Establish an acceptable biological catch of 55,408 metric ton (mt) and a harvest guideline for the directed fishery of 10,000 mt, which includes an incidental set-aside of 2,000 mt for incidental catch in non-divested fisheries.
  2. Should the directed fishery attain landings of 8,000 mt, the Council recommends that National Marine Fisheries Service (NMFS) close the directed fishery and revert to an incidental-catch-only fishery with a 45 percent incidental landing allowance when Pacific mackerel are landed with other coastal pelagic species (CPS), except that up to 1 mt of Pacific mackerel could be landed without landing any other CPS.

  Additionally, to provide time to address research and data needs associated with the Pacific mackerel assessment, the Council recommended no assessment in 2010 and a full assessment in 2011.

- At the November 2009 meeting, the Council expressed support for further development and analyses of the alternatives proposed pursuant to National Standard 1 (NS1) of the Magnuson Act. The Council supported analysis of sector specific annual catch limits, but not for the live bait fishery and requested an analysis of annual catch targets to address management uncertainty and to buffer against overfishing. Additionally, the Council supports the proposed meetings between the CPS Management Team and the Scientific and Statistical Committee CPS Subcommittee to further review the CPS harvest control rules and their adequacy for addressing uncertainty and preventing overfishing. The Council put a lower priority on including additional forage species in the CPS FMP and on development of mechanisms to streamline inseason management. The Council recommended work on these issues with a focus on meeting time-sensitive requirements of the MSA and guidelines for meeting National Standard 1.

  The Council also adopted a harvest guideline (HG) of 72,039 metric tons (mt) for the 2010 Pacific sardine fishery. This HG is based on a biomass estimate of 702,024 mt and the harvest control rule in the Coastal Pelagic Species (CPS) Fishery Management Plan. The Council recommends that 5,000 mt of the HG be set-aside prior to allocation for dedicated Pacific sardine research activities in 2010. The Council recommends an adjusted allocation of 67,039 mt as the HG for the directed fishery to be allocated seasonally per the Amendment 11 framework. To allow for incidental landings of Pacific sardines in other CPS fisheries and to help to ensure the fishery does not exceed the total HG, the Council adopted a set aside of 7,000 mt allocated across seasonal periods as follows:

HG = 72,039 mt Research set aside = 5,000 mt Adjusted HG = 67,039 mt				
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	23,463	26,816	16,760	67,039
Incidental Set Aside (mt)	1,000	1,000	1,000	3,000
Management Uncertainty			4,000	4,000
Adjusted Allocation (mt)	22,463	25,816	11,760	60,039

- At the March, 2010 meeting, the Council considered a proposed EFP for the industry-sponsored aerial sardine survey. This would be the third year of the aerial survey, which was reviewed by a STAR panel in May 2009. The proposed research survey would utilize the 5,000 mt EFP set-aside that the Council approved at the November 2009 meeting. 2,100 mt each would be allocated to the northwest and the southwest, respectively, with an additional 800 mt set aside for a fall pilot LIDAR survey in the Southern California Bight.

  Also at the March meeting, the Council considered and adopted Amendment 13 preliminary preferred alternatives for public review. These included:
  - All actively managed and monitored CPS species remain in the fishery, and krill are moved to a new Ecosystem Component species category.

- o Maintain existing Status Determination Criteria (SDC) for CPS FMP stocks, and develop MSY proxy for the northern subpopulation of northern Anchovy.
  - o No preferred alternative for overfishing levels (OFLs), acceptable biological catches (ABCs0 and annual catch limits (ACLs), pending additional analyses.
  - o Maintain the default harvest control rule for monitored stocks.
  - o Further analyze the use of accountability measures such as ACTs, set-asides, and management uncertainty buffers to address research, live bait, management uncertainty, and incidental fishery mortality.
  - o Maintain all current species in the current CPS FMP and transfer no species to state management.

- At the April 2010 meeting, the Council approved the EFP proposal, as modified in response to SSC and CPSMT suggestions. The Council voted to transmit a letter to NMFS Southwest Region, recommending approval of the EFP. The EFP was ultimately approved and issued by NMFS.

- At the June 2010 meeting, the Council adopted management measures for Pacific mackerel, for the fishing season beginning July 1, 2010 through June 30, 2011. Because there was no new assessment for 2010, the Council based management measures on the previous year's assessment. The following measures were adopted:
  - o Establish an acceptable biological catch of 55,408 metric ton (mt) and a harvest guideline for the directed fishery of 11,000 mt, which includes an incidental set-aside of 3,000 mt for incidental catch in non-directed CPS fisheries.
  - o Should the directed fishery attain landings of 8,000 mt, the Council recommends that National Marine Fisheries Service (NMFS) close the directed fishery and revert to an incidental-catch-only fishery with a 45 percent incidental landing allowance when Pacific mackerel are landed with other coastal pelagic species (CPS), except that up to 1 mt of Pacific mackerel could be landed without landing any other CPS.

  Also in June 2010, the Council took final action on Amendment 13 to the CPS FMP, Annual Catch Limits and Accountability Measures. In adopting the final FMP amendment, the Council selected the following alternatives:
  - o All actively managed, monitored species, and prohibited harvest species (krill) in the FMP are to be categorized as "in the fishery."
  - o Jacksmelt and Pacific herring are to be added to the FMP as ecosystem component (EC) species and monitor incidental catch in CPS fisheries.
  - o Modify the existing harvest control rules for actively managed species to include a buffer or reduction in acceptable biological catch (ABC) relative to overfishing limit (OFL) to account for scientific uncertainty. This buffer will be determined though the annual management cycle through a combination of scientific advice from the SSC and a policy determination of the Council.

  Control Rules for Actively Managed Species:

OFL	BIOMASS * FMSY * DISTRIBUTION
ABC	BIOMASS * BUFFER * FMSY * DISTRIBUTION
ACL	LESS THAN OR EQUAL TO ABC
HG	(BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION.
ACT	EQUAL TO HG OR ACL, WHICHEVER VALUE IS LESS

OFL = overfishing limit
ABC = acceptable biological catch
FMSY = fishing mortality rate that maximizes catch biomass in the long term.
ACL = annual catch limit
HG = harvest guideline
ACT = annual catch target

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

Control Rules for Monitored Species:

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

- o Add sector-specific ACLs, ACTs, and AMs, to the CPS FMP management framework for use in the annual harvest and management specification process.
- o Add language to specify that the Council will include ecological considerations when reviewing and/or adopting SDCs, OFLs, ABCs, and ACLs.

While not a change to the FMP, the Council confirmed that status determination criteria for CPS FMP are to remain as currently specified with the exception of the Northern subpopulation of Northern anchovy (for which no criteria existed at the time). The Council anticipated adopting a maximum sustained yield (MSY) proxy for this subpopulation through the annual management cycle at its November 2010 meeting.

- At the November 2010 meeting, the Council approved the sardine stock assessment and adopted management measures for the 2011 sardine fishery. Management measures were based on a biomass estimate of 537,173 metric tons (mt). The Council adopted an Overfishing Limit (OFL) of 92,767 mt, a P* value of 0.40, and a corresponding Acceptable Biological Catch (ABC) of 84,681 mt. The Council set an Annual Catch Limit (ACL) equal to the ABC of 84,681 mt. The Council adopted a harvest guideline (HG) of 50,526 mt, with a 4,200 mt set-aside for dedicated Pacific sardine research activities in 2011. (*Only 2,700 mt was subsequently proposed for EFP research, thereby adding 1,500 mt to the 2011 third period directed fishery*). The Council also adopted a set aside of 5,000 mt allocated across seasonal periods as in the following table. Incidental catch limits during closed periods and rollover provisions for quota overages and underages remain the same as prior years.

HG = 50,526 mt; EFP set aside = 4,200 mt; Adjusted HG = 46,326 mt				
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	16,214	18,530	11,582	46,326

Incidental Set Aside (mt)	1,000	1,000	1,000	3,000
Management Uncertainty (mt)			2,000	2,000
Adjusted Allocation	15,214	17,530	8,582	41,326

The Council also adopted catch limits for monitored CPS stocks, under the Amendment 13 provisions approved at the June 2010 meeting:

Stock	**OFL**	**ABC**	**ACL**	**ACT**
Jack mackerel	126,000 mt	31,000 mt	Equal to ABC	
Northern anchovy, Northern subpop	39,000 mt	9,750 mt	Equal to ABC	1,500 mt
Northern anchovy, central subpop	100,000 mt	25,000 mt	Equal to ABC	
Market squid	F_{msy} proxy resulting in Egg Esc ≥ 30%	F_{msy} proxy resulting in Egg Esc ≥ 30%	Exempt	

The Council approved new Terms of Reference (TOR) documents for the CPS STAR panel process and a Methodology Review process. The methodology review process TOR was developed as a way to provide independent review of new stock survey and assessment methods for use in CPS fisheries management. As of November 2010, the egg production and aerial survey methods were used in the sardine stock assessment. At the November meeting, the Council considered three other methods to be reviewed for potential use in the sardine stock assessment. These were the SWFSC's Acoustic-Trawl survey, LIDAR imagery, and satellite imagery. (*Note: subsequently, only the Acoustic-Trawl method was reviewed – and approved – for use in CPS stock assessments. The proponents of the other two methods withdrew from consideration prior to panel review*).

- At the March 2011 meeting, the Council considered a preliminary proposal to conduct stock survey research under a NMFS-issued Exempted Fishing Permit (EFP). Unlike the previous two years, the only proposal was aimed at conducting industry-sponsored aerial survey research off the Pacific Northwest. Northwest Sardine Survey (NWSS), LLC submitted the preliminary proposal. The California Wetfish Producers Association (CWPA) participated in the aerial survey during 2009 and 2010, but did not choose to pursue the research again in 2011. The NWSS proposal identified 2,100 mt to utilize for the aerial survey, representing half of the EFP set-aside from the November Council meeting. However, because the CWPA did not propose to use any of the EFP set-aside, the Northwest and California industry members agreed that it would be reasonable for the NWSS to increase its request, to 2,700 mt. The Council approved the proposal for public review, offering several suggestions, including adopting most of the CPSMT's requests in its supplemental report

- At the April 2011 meeting, the Council considered the revised EFP proposal, and voted to recommend that NMFS approve the EFP, subject to minor revisions. The Council Executive Director subsequently transmitted a letter of support to the NMFS Southwest Region, expressing support for the EFP proposal.

  Also at the April 2011 meeting, the Council considered a report of the CPS Methodology Review Panel, which provided guidance on potential for use of acoustic-trawl surveys in stock assessments for CPS fisheries. Acknowledging that there are concerns about whether the methodology should be used to develop absolute abundance estimates for Pacific sardine, the Council approved the methodology for potential contributory use in future stock assessments for Pacific Coast CPS fisheries.

- At the June 2011 meeting, the Council approved Pacific mackerel stock assessment and management measures for the 2011-2012 fishery, beginning July 1, 2011 and ending June 30, 2012. Because Amendment 13 was not yet in place, the Council adopted management benchmarks that would apply under both a pre- and post-Amendment 13 fishery. Therefore, management measures included OFL, ABC, HG, ACL, and ACT:

Biomass	211,126 mt
Overfishing Limit (OFL)	44,336 mt
P* (risk of overfishing)	0.45
Acceptable Biological Catch (ABC)	42, 375 mt
Annual Catch Limit (ACL)	40,514 mt
Harvest Guideline (HG)	40,514 mt
Annual Catch Target (ACT)	30,386 mt

  The ACT of 30,336 mt is 75% of the HG/ACL, and reflects a defacto incidental set-aside of 10,128 mt. After attaining the ACT, the fishery will revert to management similar to recent past years: Other CPS fisheries harvest may include up to 45% Pacific mackerel by weight, and directed harvest of Pacific mackerel up to 1 mt would be allowed). Upon attainment of the ACL (40,514 mt), no retention of Pacific mackerel would be allowed in CPS fisheries. The Council also adopted a provision to consider in April 2012 the possibility of re-allocating the incidental set-aside to the directed fishery. This provision was included in case mackerel become available and in demand. The set aside is relatively large compared with prior years. Therefore, the Council agreed that near the end of the fishing year (spring/summer 2012), if there is a large amount of set aside remaining, it has the option to allocate some of the set aside for directed harvest.

- At the November 2011 meeting, the Council approved the full stock assessment for Pacific sardine, which produced a biomass estimate of 988,385 mt. The Council considered the Quinault Tribal Nation’s intention to harvest up to 9,000 mt, and a 3,000 mt EFP set aside, and adopted an allocation plan as indicated in the table below. The Council also approved a recommendation to conduct a methodology review for the Canadian DFO trawl survey off Vancouver Island, which was subsequently scheduled for the spring of 2012.

Harvest Specifications for the 2012 Pacific sardine fishery. ACT = 109,409 mt; Tribal Set Aside = 9,000 mt; EFP set aside = 3,000 mt; Adjusted ACT = 97,409 mt				
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	34,093 (35%)	38,964 (40%)	24,352 (25%)	97,409
Incidental Set Aside (mt)	1,000	1,000	1,000	3,000
Adjusted Allocation (mt)	33,093	37,964	23,352	94,409

- At the March 2012 meeting, the Council recommended that the National Marine Fisheries Service approve and issue the EFP proposed by the Northwest Aerial Sardine Survey. Any of the 3000 mt set-aside that not utilized was to be re-allocated to the third period directed fishery. The Council also asked the CPSMT to explore ways to streamline the CPS EFP process, and report back at the June Council meeting.

- The Council adopted management measures and harvest specifications for the upcoming fishing year, including an Annual Catch Limit of 40,514 metric tons (mt), an Annual Catch Target of 30,386 mt, and incidental set-aside of 10,128 mt. The Council also adopted a provision to consider in April 2013 the possibility of re-allocating the incidental set-aside to the directed fishery. These measures were based on the 2011 Pacific mackerel stock assessment, which was approved at the June 2011 Council meeting.

- At the November 2012 meeting, the Council approved COP 23, which describes an EFP process for CPS fisheries. The Council also approved a workshop designed to review Pacific sardine harvest parameters, to be held in spring, 2013, and directed staff to develop a terms of reference and begin plans to implement the workshop.

  The Council also approved the stock assessment update, and established harvest specifications and management measures in the table below. In setting harvest for the 2013 fishing year, the Council recognized the Quinault Tribe's intent to harvest up to 9,000 mt, and an EFP set aside of 3,000 mt.

2013 Pacific sardine harvest specifications and allocation plan HG = 66,495 mt; Tribal set-aside = 9,000 mt; potential EFP set-aside = 3,000 mt Adjusted HG = 54,495 mt				
	Jan 1- Jun 30	Jul 1- Sep 14	Sep 15 – Dec 31	Total
Seasonal Allocation (mt)	19,073 (35%)	21,798 (40%)	13,624 (25%)	54,495
Incidental Set-Aside (mt)	1,000	1,000	1,000	3,000
Adjusted (Directed) Allocation (mt)	18,073	20,798	12,624	51,495

- At the March 2013 meeting, the Council recommended that NMFS approve the 3,000 mt EFP research set-aside, as requested by the Northwest Aerial Sardine Survey, LLC.

- At its April 2013 meeting, the Council considered a report on the sardine harvest parameters workshop, and scheduled potential action for the June 2013 meeting. (That was subsequently shifted to final action at the November 2013 meeting0. The Council also indicated support for changing the sardine fishery start date from January 1 to July 1, and scheduled final action for the June 2013 meeting.

- At the June 2013 meeting, the Council adopted Pacific mackerel management measures and harvest specifications for the 2013-2014 fishing year. These included an overfishing limit of 57,316 mt, a P* choice of 0.45, acceptable biological catch and annual catch limit (ACL) set equal to 52,358 mt, and an annual catch target (ACT) equal to 39,268 mt. The 13,089 mt difference between the ACL and ACT is an incidental catch buffer. The Council also approved a "check in" at the subsequent April meeting, to consider re-allocating some of the incidental catch to the directed fishery, in the case that landings are significantly up, and approaching the initial directed allocation.

  The Council also voted to amend the management and assessment schedule for Pacific mackerel. The new schedule calls for full stock assessments every four years starting in 2015, alternating with catch-only projection estimates every four years, in off-science years. Biennial harvest specifications will be made for two years at a time.

  Also at the June meeting, the Council voted to change the fishery start date for Pacific sardine to July 1, starting in 2014. A biomass projection estimate was to be used to set harvest specifications for the January 1-June 30 period during the 2014 transition year, and the Council anticipated a full stock assessment would be available to inform annual harvest specifications for the fishing year beginning July 1, 2014.

- At the November 2013 meeting, the Council adopted Pacific sardine management measures for the six-month period January 1-June 30, 2014. This includes approving a biomass estimate of 378,120 metric tons (mt) and an Overfishing Limit of 59,214 mt. Based on a P* choice of 0.4, the

Acceptable Biological Catch and Annual Catch Limit were set at 54,052 mt. The annual Harvest Guideline was set at 29,770 mt, with an Annual Catch Target set at 19,846 mt. Accounting for a 1,000 mt Tribal allocation and a 500 mt incidental set-aside, the January 1-June 30 allocation was set at 5,446 mt. Other management measures were to be consistent with the 2012 fishery, with the exception of (1) the incidental landing allowance that was set at 45 percent for mixed loads, after the directed fishery closes, and (2) there would be no rollover of uncaught fish from the first six-month period into the following fishing period.

The Council considered a letter of intent from the Northwest Aerial Sardine Survey, LLC to conduct survey research during summer 2014. The Council adopted the request for public review and scheduled a final determination, including the final tonnage amount, at the April 2014 Council meeting. (The request for an EFP set-aside was subsequently withdrawn).

The Council established a Maximum Sustainable Yield (MSY) reference point for the northern subpopulation of northern anchovy. Based on information that northern anchovy are subject to large population fluctuations and have relatively high productivity, the Council selected annual fishing rate: Fmsy = 0.3 as the appropriate MSY reference point.

The Council also endorsed methodology reviews of the California Department of Fish and Wildlife/California Wetfish Producers Association aerial survey methodology for the Southern California Bight, of the Northwest Aerial Sardine Survey, and the NMFS acoustic sardine survey. The methodology review was to be coordinated with the Southwest Fisheries Science Center to optimize logistical and financial contingencies. The Council also tasked the Coastal Pelagic Species (CPS) Management Team and CPS Advisory Subpanel with reviewing the draft Council Operating Procedure for a CPS methodology review process and with providing their recommendations at a future Council meeting.

- At the March 2014 meeting, the Council adopted the technical change of using the CalCOFI temperature index, rather than the Scripps Pier temperature recordings, in calculating the annual overfishing limit (OFL) for Pacific Sardine. The new temperature index and new temperature-productivity relationship was to be used for establishing the OFL starting with the April 2014 meeting, when the Council established annual harvest specifications and management measures for the fishing year beginning July 1, 2014. The Council directed the CPSMT and NMFS to further evaluate alternatives for applying the new temperature index and Fmsy relationship to annual harvest specifications, and to report back to the Council at the September 2014 meeting.

- At the April 2014 meeting, the Council adopted harvest specifications and management measures for Pacific sardine, for the fishing year running July 1, 2014 through June 30, 2015. This included an OFL of 39,210 mt and an ABC of 35,792 mt, based on a P* value of 0.40. The Council set the ACL and the ACT both to 23,293 mt, and adopted a 500 mt incidental set aside for each of the three fishing periods. Accounting for a Quinault Indian Nation allotment of 4,000 mt and a total of 1,500 met incidental set aside, the period allocations were set to 7,218 mt in Period 1 (July 1 – September 14), 4,323 mt for Period 2 (September 15 – December 31), and 6,252 mt for Period 3 (January 1 – June 30, 2015). The Council approved rollovers from Periods 1 and 2 into the subsequent Period, with no rollover from Period 3 into the next fishing year. The Council also adopted a mixed load allowance of up to 45 percent sardines caught in other CPS fisheries, after directed Pacific sardine fishing closes.

- At the June 2014 meeting, the Council adopted harvest specifications and management measures for Pacific mackerel. Based on a catch-only projection estimate of 157,106 mt, the Council adopted an OFL of 32,992 mt, an ABC and ACL both equal to 30,138 mt, an HG of 29,170 mt, and an ACT of 24,170 mt. The difference between the HG and the ACT is a 5,000 mt incidental set aside. Should the directed fishery realize the ACT (24,170 mt), the directed fishery will close, and shift to an incidental only fishery, with a 45 percent incidental landing allowance when Pacific mackerel are landed with other CPS, with the exception that up to 1 (one) mt of Pacific mackerel may be landed without landing any other CPS. The Council also adopted a check in provision, to consider reallocating a portion of the set aside to the directed fishery, should the directed fishery attain the ACT.

- At the November 2014 meeting, the Council adopted the technical change of using the CalCOFI temperature index, rather than the Scripps Pier temperature recordings, in calculating annual harvest specifications for Pacific Sardine; and adopted an accompanying harvest FRACTION term ranging between five and 20 percent. This replaces the current range of five and fifteen percent. This change also incorporated a new temperature-productivity relationship.

- At its March 2015 meeting, the Council took final action to protect a suite of currently unmanaged forage fish species and prohibit the development of new directed commercial fisheries. Although incidental retention of these shared ecosystem component species is allowed, directed commercial take is not allowed. A Council process to develop an exempted fishing permit must be completed prior to allowing directed take on any of the shared EC species, which are: round herring, thread herring, mesopelagic fishes, Pacific sand lance, Pacific saury, silversides, smelts in the family *Osmeridae*, and pelagic squids (except Humboldt squid).

- At its April 2015 meeting, the Council adopted Pacific sardine harvest specifications and management measures for the 2015 – 2016 fishery. Because the estimated biomass fell below the Cutoff of 150,000 metric tons, a directed fishery was precluded. Therefore the Council adopted an HG of zero, with a 7,000 mt ACL to allow for tribal harvest, incidental landings, live bait, research, and other minor sources of mortality. For incidental catches, the Council adopted an incremental approach, with 40% mixed loads allowed until 1,500 mt are landed. Then the mixed load amount drops to 30% until 4,000 mt are landed, and dropped to 5% until the ACL is met.

- At that same meeting, the Council took emergency action to close the current (2014 – 2015) fishery as soon as possible, to stay within the remaining quota, and urged NMFS to immediately assess landings and catch rate, to determine a closure date associated with the remaining available quota.

- At its June 2015 meeting, the Council adopted the Pacific mackerel stock assessment for management in both the 2015-16 and the 2016-17 fishing years. A projection estimate of biomass was used to estimate the second year biomass, assuming the full HG would be taken. The Council adopted the following harvest specifications and management measures:

	2015-16 (mt)	**2016-17 (mt)**

Biomass	120,425	118,968
OFL	25,291	24,983
$ABC_{0.45}$	23,104	22,822
ACL	23,104	22,822
HG	21,469	21,161
ACT	20,469	20,161

The Council also adopted a 45 percent incidental landing allowance once the directed fishery is closed, and up to three mt of Pacific mackerel per landing to be allowed in non-CPS fisheries.

- At its April 2016 meeting, the Council adopted Pacific sardine harvest specifications and management measures for the 2016 – 2017 fishery. Because the 106,137 mt estimated biomass again fell below the Cutoff of 150,000 metric tons, a directed fishery was precluded. Therefore the Council adopted an HG of zero, with a 8,000 mt ACL to allow for tribal harvest, incidental landings, live bait, research, and other minor sources of mortality. For incidental catches, the Council adopted an incremental approach, with 40% mixed loads allowed until 2,000 mt are landed. Then the mixed load amount drops to 20% until 5,000 mt are landed, and dropped to 10% until the ACL is met. The Council also adopted an OFL of 23,085 mt and an ABC of 19,236 mt.

TABLE 2-2. REGULATORY ACTIONS

January 25, 2000. NMFS published HGs for Pacific sardine and Pacific mackerel for the fishing year beginning January 1, 2000. A HG of 186,791 mt was established for Pacific sardine, based on a biomass estimate of 1,581,346 mt. The HG was allocated for Subarea A, which was north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and for Subarea B, which was south of 35° 40' N latitude to the Mexican border. The northern allocation was 62,264 mt; the southern allocation was 124,527 mt. The sardine HG was in effect until December 31, 2000, or until it was reached and the fishery closed. A HG of 42,819 mt was established for Pacific mackerel based on a biomass estimate of 239,286 mt. The HG for Pacific mackerel was in effect until June 30, 2000, or until it was reached and the fishery closed. (65*FR*3890)

September 11, 2000. NMFS announced the annual HG for Pacific mackerel in the EEZ off the Pacific coast. Based on the estimated biomass of 116,967 mt and the formula in the FMP, a HG of 20,740 mt was calculated for the fishery beginning on July 1, 2000. This HG is available for harvest for the fishing season July 1, 2000 through June 30, 2001. (65*FR*54817)

November 1, 2000. NMFS announced the closure of the directed fishery for Pacific mackerel in the EEZ off the Pacific coast on October 27, 2000. The FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on a formula in the FMP and to close the fishery when the HG is reached. The HG of 20,740 mt was reached before the end of the fishing season on June 30, 2001, which required closing the directed fishery and setting an incidental harvest limit for Pacific mackerel so that the harvest of other CPS would be further restricted. The intended effect of this action was to ensure conservation of the Pacific mackerel resource. For the reasons stated here and in accordance with the FMP and its implementing regulations at 50 CFR 660.509, the directed fishery for Pacific mackerel was closed October 27, 2000, after which time no more than 20 percent by weight of any landing of Pacific sardine could be Pacific mackerel. (65*FR*65272)

November 17, 2000. NMFS published a correction to the Pacific mackerel closure, which was published on November 1, 2000. In 65*FR*65272, the following correction was included: On page 65272, in the third column, under the heading SUPPLEMENTARY INFORMATION, the last sentence is corrected to read as follows: "For the reasons stated here and in accordance with the FMP and its implementing regulations at 50 CFR 660.509, the directed fishery for Pacific mackerel will be closed October 27, 2000, after which time no more than 20 percent by weight of a landing of Pacific sardine, northern anchovy, jack mackerel, or market squid may consist of Pacific mackerel." (65*FR*69483)

December 27, 2000. NMFS announced the annual HG for Pacific sardine in the EEZ off the Pacific coast for the January 1, 2001, through December 31, 2001, fishing season. This HG was calculated according to the regulations implementing the FMP. The intended effect of this action was to establish allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 1,182,465 mt and the formula in the FMP, a HG of 134,737 mt was calculated for the fishery beginning January 1, 2001. The HG was allocated one third for Subarea A, which was north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and two thirds for Subarea B, which was south of 35° 40' N latitude to the Mexican border. Any unused resource in either area would be reallocated between areas to help ensure that the OY would be achieved. The northern allocation is 44,912 mt; the southern allocation was 89,825 mt. (65*FR*81766)

February 22, 2001. NMFS announced changes to the restriction on landings of Pacific mackerel for individuals participating in the CPS fishery and for individuals involved in other fisheries who harvest small amounts of Pacific mackerel. The incidental limit on landings of 20 percent by weight of Pacific mackerel in landings of Pacific sardine, northern anchovy, jack mackerel, and market squid remained in effect; however, CPS fishermen could land up to one mt of Pacific mackerel even if they landed no other species from the trip. Non CPS fisherman could land no more than one mt of Pacific mackerel per trip. After the

HG of 20,740 mt was reached, all landings of Pacific mackerel would be restricted to one mt per trip. This action was authorized by the FMP and was intended to ensure that the fishery achieved, but did not exceed, the HG while minimizing the economic impact on small businesses. For the reasons stated here, no fishing vessel could land more than one mt of Pacific mackerel per fishing trip, except that fishing vessels with other CPS on board could land more than one mt of Pacific mackerel in a fishing trip if the total amount of Pacific mackerel on board the vessel did not exceed 20 percent by weight of the combined weight of all CPS on board the vessel. (66*FR*11119)

March 30, 2001. NMFS announced the closure of the fishery for Pacific mackerel in the EEZ off the Pacific coast at 12:00 a.m. on March 27, 2001. The FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on a formula in the FMP and to close the fishery when the HG is reached. The HG of 20,740 mt was reached. Following this date no more than one mt of Pacific mackerel could be landed from any fishing trip. The effect of this action was to ensure conservation of the Pacific mackerel resource. (66*FR*17373)

July 25, 2001. NMFS announced a HG of 13,837 mt for Pacific mackerel for the fishing season July 1, 2001 through June 30, 2002. A directed fishery of 6,000 mt was established, which, when attained, would be followed by an incidental allowance of 45 percent of Pacific mackerel in a landing of any CPS. If a significant amount of the HG remained unused before the end of the fishing season on June 30, 2002, the directed fishery would be reopened. This approach was taken because of concern about the low HG's potential negative effect on the harvest of Pacific sardine if the fishery for Pacific mackerel had to be closed. The two species occur together often and could present incidental catch problems. (66*FR*38571)

November 27, 2001. NMFS announced the closure of the directed fishery for Pacific mackerel in the EEZ off the Pacific coast at 12:00 noon on November 21, 2001. For the fishing season beginning July 1, 2001, 6,000 mt of the 13,837 mt HG was established for a directed fishery. More than 6,000 mt has been landed. Therefore, the directed fishery for Pacific mackerel was closed on November 21, 2001, after which time no more than 45 percent by weight of a landing of Pacific sardine, northern anchovy, jack mackerel, or market squid could consist of Pacific mackerel. The intended effect of this action was to ensure that the HG was achieved, but not exceeded, and to minimize bycatch of Pacific mackerel while other CPS were being harvested. (66*FR*59173)

December 27, 2001. NMFS published the HG for Pacific sardine for the fishing season beginning January 1, 2002. A HG of 118,442 mt was established for Pacific sardine based on a biomass estimate of 1,057,599 mt. The HG was allocated for Subarea A, which was north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and for Subarea B, which was south of 35° 40' N latitude to the Mexican border. The northern allocation is 39,481 mt; the southern allocation is 78,961mt. The sardine HG is in effect until December 31, 2002, or until it is reached and the fishery closed. (66*FR*66811)

April 5, 2002. NMFS announced the reopening of the directed fishery for Pacific mackerel in the U.S. EEZ off the Pacific coast on April 1, 2002. A significant portion of the Pacific mackerel HG remained unharvested (6,585 mt). Therefore, the incidental catch allowance that has been in effect since November 21, 2001 was removed, and any landing of Pacific mackerel could consist of 100 percent Pacific mackerel. This action was taken to help ensure that the HG was attained. If the HG was projected to be reached before June 30, 2002, the directed fishery would be closed and an appropriate incidental landing restriction imposed. (67*FR*16322)

July 11, 2002. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. This action proposes allowable harvest levels for Pacific mackerel off the Pacific coast. Based on the estimated biomass of 77,516 mt and the formula in the FMP, a HG of 12,456 was proposed for the fishery beginning on July 1, 2002, and continued through June 30, 2003, unless the HG was attained and the fishery closed before June 30. (67*FR*45952)

September 18, 2002. NMFS announced the closure of the fishery for Pacific sardine in the U.S. EEZ off the Pacific coast north of Point Piedras Blancas, California, (35° 40' N latitude) at 0001 hrs local time on September 14, 2002. The closure remained in effect until the reallocation of the remaining portion of the coastwide HG was required by the CPS FMP. That reallocation was expected to occur on or about October 1, 2002. The purpose of this action was to comply with the allocation procedures mandated by the FMP. (67*FR*58733)

September 26, 2002. Emergency rule. NMFS announced the reallocation of the remaining Pacific sardine HG in the U.S. EEZ off the Pacific coast. The CPS FMP required that NMFS conduct a review of the fishery 9 months after the beginning of the fishing season on January 1, and reallocate any unharvested portion of the HG, with 50 percent allocated north and south of Point Piedras Blancas, California. The allocation north of Point Piedras Blancas was reached on September 14, 2002, and the fishery was closed until the scheduled time for reallocation on October 1, 2002. This action reallocated the remainder of the HG earlier than the date specified in the FMP in order to minimize the negative economic effects on fishing and processing, primarily in the Pacific Northwest, which would result from delaying the reallocation. (67*FR*60601)

October 3, 2002. NMFS issued a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations required NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. This action was to conserve Pacific mackerel off the Pacific coast. Based on the estimated biomass of 77,516 mt and the formula in the FMP, a HG of 12,456 was proposed for the fishery beginning on July 1, 2002, and continued through June 30, 2003, unless the HG was attained and the fishery closed before June 30. There was a directed fishery of at least 9,500 mt, and 3,035 mt of the HG was utilized for incidental landings following the closure of the directed fishery. After closure of the directed fishery, no more than 40 percent by weight of a landing of Pacific sardine, northern anchovy, jack mackerel, or market squid could consist of Pacific mackerel, except that up to one mt of Pacific mackerel could be landed without landing any other CPS. The fishery was monitored, and if a sufficient amount of the HG remained before June 30, 2003, the directed fishery would be reopened. The goal was to achieve the HG and minimize the impact on other coastal pelagic fisheries. 67*FR*61994)

October 30, 2002. NMFS proposed a regulation to implement Amendment 10 to the CPS FMP, which was submitted by the Council for review and approval by the Secretary of Commerce. Amendment 10 addressed the two unrelated subjects of the transferability of limited entry permits and maximum sustainable yield for market squid. Only the provisions regarding limited entry permits require regulatory action. The purpose of this proposed rule was to establish the procedures by which limited entry permits could be transferred to other vessels and/or individuals so that the holders of the permits have maximum flexibility in their fishing operations while the goals of the FMP were achieved. (67*FR*66103)

November 25, 2002. NMFS proposed a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2003, through December 31, 2003. This HG has been calculated according to the CPS FMP and establishes allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 999,871 mt and the formula in the FMP, a HG of 110,908 mt was determined for the fishery beginning January 1, 2003. The HG is allocated one third for Subarea A, which is north of 35° 40' N latitude (Point Piedras Blancas) to the Canadian border, and two thirds for Subarea B, which is south of 35° 40' N latitude to the Mexican border. The northern allocation is 36,969 mt; the southern allocation is 73,939 mt. (67*FR*70573)

December 31, 2002. NMFS issued a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2003, through December 31, 2003. This HG was calculated according to the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 999,871 mt and the formula in the FMP, a HG of 110,908 mt was determined for the fishery beginning January 1, 2003. The HG was allocated one third for Subarea A, which was north of 35° 40' N latitude (Point Piedras Blancas, California) to the Canadian border, and two thirds for Subarea B, which was south of 35° 40' North latitude to Mexican border. The northern allocation was 36,969 mt; the southern allocation was 73,939 mt. If an allocation or the HG was reached, up to 45 percent by weight of Pacific sardine could be landed in any landing of Pacific mackerel, jack mackerel, northern anchovy, or market squid. (67*FR*79889).

January 27, 2003. NMFS issued a regulation to implement Amendment 10 to the CPS FMP, which was submitted by the Council for review and approval by the Secretary. Amendment 10 addresses the two unrelated subjects of the transferability of limited entry permits and maximum sustainable yield for market squid. Only the provisions regarding limited entry permits require regulatory action. The primary purpose of this final rule was to establish the procedures by which limited entry permits could be transferred to other vessels and/or individuals so that the holders of the permits have maximum flexibility in their fishing operations while the goals of the FMP were achieved. (68*FR*3819)

June 26, 2003. NMFS proposed a regulatory amendment to the CPS FMP. This amendment was submitted by the Council for review and approval by the Secretary. The proposed amendment would change the management subareas and the allocation process for Pacific sardine. The purpose of this proposed amendment was to establish a more effective and efficient allocation process for Pacific sardine and increase the possibility of achieving OY. (68*FR*37995)

July 29, 2003. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. (68*FR*44518)

September 4, 2003. NMFS issued a final rule to implement a regulatory amendment to the CPS FMP that changed the management subareas and the allocation process for Pacific sardine. The purpose of this final rule was to establish a more effective and efficient allocation process for Pacific sardine and increase the possibility of achieving OY. (68*FR*52523)

September 9, 2003. NMFS announced the reallocation of the remaining Pacific sardine HG in the EEZ off the Pacific coast. On September 1, 2003, 59,508 mt of the 110,908 mt HG was expected to remain unharvested. The CPS FMP required that a review of the fishery be conducted and any uncaught portion of the HG remaining unharvested in Subarea A (north of Pt. Arena, California) and Subarea B (south of Pt. Arena, California) be added together and reallocated, with 20 percent allocated to Subarea A and 80 percent to Subarea B; therefore, 11,902 mt was allocated to Subarea A and 47,600 mt was allocated to Subarea B. The intended effect of this action was to ensure that a sufficient amount of the resource was available to all harvesters on the Pacific coast and to achieve OY. (68*FR*53053)

October 3, 2003. NMFS issued a final rule to implement the annual HG for the July 1, 2003 - June 30, 2004 Pacific mackerel fishery in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations require NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. Based on this approach, the biomass for July 1, 2003, was 68,924 mt. Applying the formula in the FMP results in a HG of 10,652 mt, which was lower than last year but similar to low HGs of recent years. (68*FR*57379)

October 28, 2003. NMFS announced the closure of the fishery for Pacific sardine in the EEZ off the Pacific coast north of Pt. Arena, California (39° N latitude) at 12:01 a.m. local time on October 17, 2003. The purpose of this action was to comply with the allocation procedures mandated by the CPS FMP. (68*FR*61373)

December 3, 2003. NMFS proposed a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2004 through December 31, 2004. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. (68*FR*67638)

February 25, 2004. NMFS issued a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2004 through December 31, 2004. This action adopted a HG and initial subarea allocations for Pacific sardine off the Pacific coast that were calculated according to the regulations implementing the CPS FMP. Based on a biomass estimate of 1,090,587 mt (in U.S. and Mexican waters), using the FMP formula, the HG for Pacific sardine in U.S. waters for January 1, 2004 through December 31, 2004 was 122,747 mt. The biomass estimate was slightly higher than last year's estimate; however, the difference between this year's biomass was not statistically significant from the biomass estimates of recent years. Under the FMP, the HG was allocated one third for Subarea A, which was north of 39° N latitude (Pt. Arena, California) to the Canadian border, and two thirds for Subarea B, which was south of 39° N latitude to the Mexican border. Under this final rule, the northern allocation for 2004 would be 40,916 mt and the southern allocation would be 81,831 mt. (69*FR*8572). July 20, 2004. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast for the fishing season July 1, 2004 through June 30, 2005. The CPS FMP and its implementing regulations required NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. This action proposed allowable harvest levels for Pacific mackerel off the Pacific coast. (69 *FR* 43383)

September 14, 2004. Information memorandum. NMFS announced the reallocation of the remaining Pacific sardine HG in the U.S. EEZ off the Pacific coast. A regulatory amendment (69 *FR* 8572, February 25, 2003) required that NMFS conduct a review of the fishery 10 months after the beginning of the fishing season on January 1, and reallocate any unharvested portion of the HG, with 20 percent allocated north of Point Area, California, and 80 percent allocated south of Point Arena, California. (69 *FR* 55360)

October 21, 2004. NMFS issued a final rule to implement the annual HG for the July 1, 2004 - June 30, 2005 Pacific mackerel fishery in the EEZ off the Pacific coast. The CPS FMP and its implementing regulations required NMFS to set an annual HG for Pacific mackerel based on the formula in the FMP. Based on this approach, the biomass for July 1, 2003, was 81,383 mt. Applying the formula in the FMP resulted in a HG of 13,268 mt. (69 *FR* 61768)

December 8, 2004. NMFS proposed a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2005 through December 31, 2005. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. (69 *FR* 70973)

June 22, 2005. NMFS issued a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season January 1, 2005 through December 31, 2005. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. Based on a biomass estimate of 1,193,515 mt (in U.S. and Mexican waters) and using the FMP formula, NMFS calculated a HG of 136,179 mt for Pacific sardine in U.S. waters. Under the FMP, the HG was allocated one-third for Subarea A, which was north of 39°00' N. lat. (Pt. Arena, California) to the Canadian border, and two-thirds for Subarea B, which was south of 39° 00' N. lat. to the Mexican border. Under this final rule, the northern allocation for 2005 would be 45,393 mt, and the southern allocation would be 90,786 mt. (70 *FR* 36053)

August 29, 2005. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the U.S. EEZ off the Pacific coast. For specific regulations, see final rule language from October 21, 2005 below. (70 *FR* 51005)

October 21, 2005. NMFS issued a final rule to implement the annual HG for Pacific mackerel in the U.S. EEZ off the Pacific coast. The biomass estimate for July 1, 2005, was 101,147 mt. Applying the formula in the FMP resulted in a HG of 17,419 mt, which was 32 percent greater than last year but similar to low HGs of recent years. For the last three years, the fishing industry has recommended dividing the HG into a directed fishery and an incidental fishery, reserving a portion of the HG for incidental harvest in the Pacific sardine fishery so that the Pacific sardine fishery was not hindered by a prohibition on the harvest of Pacific mackerel. At its meeting on June 15, 2005, the CPSAS recommended for the 2005–2006 fishing season that a directed fishery of 13,419 mt and an incidental fishery of 4,000 mt be implemented. An incidental allowance of 40 percent of Pacific mackerel in landings of any CPS would become effective if the 13,419 mt of the directed fishery was harvested. The CPSAS also recommended allowing up to 1 mt of Pacific mackerel to be landed during the incidental fishery without the requirement to land any other CPS. (70 *FR 61235*)

October 28, 2005. NMFS announced that the Council submitted Amendment 11 to the CPS FMP for Secretarial review. Amendment 11 would change the framework for the annual apportionment of the Pacific sardine HG along the U.S. Pacific coast. The purpose of Amendment 11 was to achieve optimal utilization of the Pacific sardine resource and equitable allocation of the harvest opportunity for Pacific sardine. The public comment period on Amendment 11 was open through December 27, 2005. (70 *FR* 62087)

January 17, 2006. NMFS proposed a regulation to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season of January 1, 2006 through December 31, 2006. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. (71 *FR* 2510)

June 29, 2006. NMFS issued the final rule to implement Amendment 11 to the CPS FMP, which changed the framework for the annual apportionment of the Pacific sardine HG along the U.S. Pacific coast. The purpose of this final rule was to achieve optimal utilization of the Pacific sardine resource and equitable allocation of the harvest opportunity for Pacific sardine. (71 *FR* 36999)

July 5, 2006. NMFS issued a final rule to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast for the fishing season of January 1, 2006, through December 31, 2006. This HG was calculated according to the regulations implementing the CPS FMP and established allowable harvest levels for Pacific sardine off the Pacific coast. Based on the estimated biomass of 1,061,391 mt and the formula in the FMP, a HG of 118,937 mt was determined for the fishery beginning January 1, 2006. (71 *FR* 38111)

August 21, 2006. This notice retracted the Notice of Intent (NOI) to prepare an Environmental Impact Statementto analyze a range of alternatives for the annual allocation of the Pacific sardine HG proposed action published on July 19, 2004. Further scoping subsequent to the publication of the NOI revealed additional information indicating that it was unlikely the proposed action would result in significant environmental impacts. An EA was completed and a subsequent Finding of No Significant Impact was signed. (71 *FR* 48537)

October 20, 2006. NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the U.S. EEZ off the Pacific coast. (71 *FR* 61944).

December 7, 2006. NMFS proposed a regulation to implement new reporting and conservation measures under the CPS FMP. These reporting requirements and prohibitive measures would require CPS fishermen/vessel operators to employ avoidance measures when southern sea otters are present in the area they are fishing and to report any interactions that may occur between their vessel and/or fishing gear and sea otters. The purpose of this proposed rule was to comply with the terms and conditions of an incidental take statement from a biological opinion issued by the U.S. Fish and Wildlife Service regarding the implementation of Amendment 11 to the CPS FMP. (71 *FR* 70941).

January 31, 2007. NMFS issued a final rule to implement the annual HG and management measure for the 2006-2007 Pacific Mackerel fishery. Based on the estimated biomass of 112,700 mt and the formula in the FMP, a HG of 19,845 mt was in effect for the fishery which began on July 1, 2006. This HG applied to Pacific mackerel harvested in the U.S. EEZ off the Pacific coast from July 1, 2006 through June 30, 2007, unless the HG was attained and the fishery was closed before June 30, 2007. All landings made after July 1, 2006, will be counted toward the 2006–2007 HG of 19,845 mt. There was a directed fishery of 13,845 mt, followed by an incidental fishery of 6,000 mt. An incidental allowance of 40 percent of Pacific mackerel in landings of any CPS would become effective after the date when 13,845 mt of Pacific mackerel was estimated to have been harvested. A landing of one mt of Pacific mackerel per trip was permitted during the incidental fishery for trips in which no other CPS is landed. (72 *FR* 4464).

May 30, 2007. This action implemented new reporting and conservation measures under the CPS FMP. The purpose of this action was to prevent interactions between CPS fisherman and southern sea otters, as well as establish methods for fishermen to report these occurrences. These reporting requirements and conservation measures require CPS fishermen/vessel operators to employ avoidance measures when southern sea otters are present in the area they are fishing and to report any interactions that may occur between their vessel and/or fishing gear and sea otters. (72 *FR* 29891).

September 28, 2007 NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the U.S. EEZ Based on a total stock biomass estimate of 359,290 mt, the ABC for U.S. fisheries for the 2007-2008 management season was 71,629 mt. The estimated stock biomass for the 2006-2007 season was 112,700 mt, resulting in an ABC of 19,845 mt. off the Pacific coast for the fishing season of July 1, 2007 through June 30, 2008. (72 *FR* 55170).

October 25, 2007 NMFS issued the final rule to implement the annual HG for Pacific sardine in the U.S. EEZ off the Pacific coast (California, Oregon, and Washington) for the fishing season of January 1, 2007 through December 31,2007. The Pacific sardine HG was apportioned based on the following allocation scheme established by Amendment 11 to the CPS FMP: 35 percent (53,397 mt) was allocated coastwide on January 1; 40 percent (61,025 mt), plus any portion not harvested from the initial allocation was reallocated coastwide on July 1; and on September 15 the remaining 25 percent (38,141 mt), plus any portion not harvested from earlier allocations was released. (72 *FR* 60586).

January 31, 2008 NMFS issued the final rule to implement the annual HG for Pacific mackerel for the fishing season of July 1, 2007 through June 30, 2008. The HG for the 2007–2008 fishing season is 40,000 mt. If this total was reached, Pacific mackerel fishing would be closed to directed harvest and only incidental harvest would be allowed at a 45 percent by weight incidental catch rate when landed with other CPS, except that up to one mt of Pacific mackerel could be landed without landing any other CPS. (73 *FR* 5760).

August 20, 2008 NMFS proposed a regulation to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast for the fishing season of July 1, 2008 through June 30, 2009. (73 *FR* 49156).

August 20, 2008 NMFS issued a final rule that noticed effectiveness of reporting requirements of interactions that may occur between a CPS vessel and/or fishing gear and sea otters originally published on May 30, 2007 (see above). The May 30th final rule contained information collection requirements that at the time of publication had not yet been approved by OMB. The final rule stated that NMFS would publish a subsequent Federal Register notice announcing the effectiveness of those requirements. Therefore NMFS announces that OMB approved the collection of information requirements contained in the May 30, 2007, final rule under Control Number 0648-0566 with an expiration date of August 31, 2010. (73 *FR* 60191).

October 10, 2008 NMFS issued a final rule that notices effectiveness of reporting requirements of interactions that may occur between a CPS vessel and/or fishing gear and sea otters originally published on May 30, 2007 (see above). The May 30th final rule contained information collection requirements that at the time of publication had not yet been approved by OMB. The final rule stated that NMFS would publish a subsequent Federal Register notice announcing the effectiveness of those requirements. Therefore NMFS announces that OMB approved the collection of information requirements contained in the May 30, 2007, final rule under Control Number 0648-0566 with an expiration date of August 31, 2010. (73 *FR* 60191).

November 18, 2008 NMFS issued a final rule to implement the annual HG for Pacific mackerel in the EEZ off the Pacific coast for the fishing season of July 1, 2008, through June 30, 2009. The HG for the 2008–2009 fishing season is 40,000 mt. If this total is reached, Pacific mackerel fishing will be closed to directed harvest and only incidental harvest will be allowed at a 45 percent by weight incidental catch rate when landed with other CPS, except that up to one mt of Pacific mackerel can be landed without landing any other CPS. (73 *FR* 68362).

January 5, 2009. NMFS proposed a regulation to implement the annual harvest guideline (HG) for Pacific sardine in the U.S. exclusive economic zone (EEZ) off the Pacific coast for the fishing season of January 1, 2009, through December 31, 2009. This HG was proposed according to the regulations implementing the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP) and established allowable harvest levels for Pacific sardine off the Pacific coast. The proposed initial HG for the 2009 fishing year was 65,732 mt and was proposed to be divided across the seasonal allocation periods in the following way: January 1-June 30, 22,006 mt was allocated for directed harvest with an incidental set-aside of 1,000 mt; July 1-September 14, 25,293 mt was allocated for directed harvest with an incidental set-aside of 1,000 mt; September 15-December 31, 11,933 mt was to be allocated for directed harvest with an incidental set-aside of 4,500 mt. If during any of the seasonal allocation periods the applicable adjusted directed harvest allocation was projected to be taken, fishing would be closed to directed harvest and only incidental harvest would be allowed. (74 FR 252).

May 6, 2009. NMFS proposed a regulation to adjust the harvest specifications for Pacific sardine in the U.S. exclusive economic zone (EEZ) off the Pacific coast for the fishing season of January 1, 2009, through December 31, 2009. The proposed action increased the tonnage of Pacific sardine allocated for industry conducted research from 1200 metric tons (mt) to 2400 mt and decreases the second and third period directed harvest allocations by 750 mt and 450 mt, respectively. (74 FR 20897).

June 30, 2009. NMFS issued a final rule to adjust the harvest specifications for Pacific sardine in the U.S. exclusive economic zone (EEZ) off the Pacific coast for the fishing season of January 1, 2009, through December 31, 2009. This final rule increased the tonnage of Pacific sardine allocated for industry-conducted research from 1200 metric tons (mt) to 2400 mt and decreases the second and third period directed harvest allocations by 750 mt and 450 mt, respectively. (74 FR 31199).

July 13, 2009. NMFS issued a final rule to implement Amendment 12 to the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP) which would provide protection for all species of krill off the West Coast (i.e., California, Oregon and Washington). This rule would prohibit the harvest of all species of krill by any fishing vessel operating in the Exclusive Economic Zone (EEZ) off the West Coast, and would also deny the use of exempted fishing permits to allow krill fishing (74 FR 33372).

July 17, 2009. NMFS prohibited directed fishing for Pacific sardine off the coast of Washington, Oregon and California. This action was necessary because the directed harvest allocation total for the second seasonal period (July 1– September 14) was projected to be reached by the effective date of the rule. From the effective date of the rule until September 15, 2009, Pacific sardine could only be harvested as part of the live bait fishery or incidental to other fisheries; the incidental harvest of Pacific sardine is limited to 20–percent by weight of all fish per trip. Fishing vessels had to be at shore and in the process of offloading at 12:01 am Pacific Daylight Time on date of closure. (74 FR 34700).

September 23, 2009. NMFS issued a temporary rule prohibiting directed fishing for Pacific sardine off the coasts of Washington, Oregon and California. This action was necessary because the directed harvest allocation total for the third seasonal period (September 15–December 31) was projected to be reached by the effective date of the rule. From the effective date of this rule until December 31, 2009, Pacific sardine could only be harvested as part of the live bait fishery or incidental to other fisheries; the incidental harvest of Pacific sardine was limited to 20–percent by weight of all fish per trip. Fishing vessels had to be at shore and in the process of offloading at 12:01 am Pacific Daylight Time on date of closure. (74 FR 48421)

September 29, 2009. NMFS issued a proposed regulation to implement the annual harvest guideline (HG) for Pacific mackerel in the U.S. exclusive economic zone (EEZ) off the Pacific coast. This HG is proposed according to the regulations implementing the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP) and establishes allowable harvest levels for Pacific mackerel off the Pacific coast. The proposed total HG for the 2009–2010 fishing year was 10,000 metric tons (mt) and was proposed to be divided into a directed fishery HG of 8,000 mt and an incidental fishery of 2,000 mt. (74 FR 49845).

December 22, 2009. NMFS issued a temporary rule prohibiting the incidental harvest of Pacific sardine off the coasts of Washington, Oregon and California. This action was necessary because the incidental set aside for the third allocation period of the 2009 Pacific sardine season was reached. From the effective date of this rule until January 1, 2010, Pacific sardine can only be harvested as part of the live bait fishery. (FR 74 67986).

January 13, 2010. NMFS issued a proposed rule to implement annual harvest specifications for the 2010 sardine fishery off the U.S. West Coast. NMFS proposed a regulation to implement the annual harvest guideline (HG) and seasonal allocations for Pacific sardine in the U.S. exclusive economic zone (EEZ) off the Pacific coast for the fishing season of January 1, 2010, through December 31, 2010. This rule is proposed according to the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP). The proposed 2010 acceptable biological catch (ABC) or maximum HG is 72,039 mt. 5,000 mt of this 72,039 mt would initially be set aside for use under an Exempted Fishing Permit (EFP), if issued, leaving the remaining 65,732 mt as the initial commercial fishing HG. That HG would be divided across the seasonal allocation periods in the following way: January 1–June 30, 22,463 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; July 1–September 14, 25,861 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; September 15–December 31, 11,760 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt with an additional 4,000 mt set aside to buffer against reaching the ABC. (75 FR 1744).

March 10, 2010. NMFS issued the sardine Final Rule to implement the annual harvest specifications for the 2010 sardine fishery off the U.S. West Coast. The proposed allocation of the overall HG over three fishing periods, were identical to those proposed on January 13, 2010 (above). (75 FR 11068).

June 15, 2010. NMFS issued a temporary rule announcing the closure of the first period sardine fishery, effective at 12:01am Pacific Daylight Time June 12. From 12:01 am on the date of closure through June 30, 2010, Pacific sardine may be harvested only as part of the live bait fishery or incidental to other fisheries, with the incidental harvest of Pacific sardine limited to 30 percent by weight of all fish caught during a trip. (75 FR 33733).

July 22, 2010. NMFS issued a temporary rule announcing the closure of the second period sardine fishery, effective at 12:01am Pacific Daylight Time July 22. From 12:01 am on the date of closure through September 14, 2010, Pacific sardine may be harvested only as part of the live bait fishery or incidental to other fisheries, with the incidental harvest of Pacific sardine limited to 30 percent by weight of all fish caught during a trip. (75 FR 42610).

September 27, 2010. NMFS issued a temporary rule announcing the closure of the third period sardine fishery, effective at 12:01am Pacific Daylight Time September 24. From 12:01 am on the date of closure through December 31, 2010, Pacific sardine may be harvested only as part of the live bait fishery or incidental to other fisheries, with the incidental harvest of Pacific sardine limited to 30 percent by weight of all fish caught during a trip. (75 FR 59156).

January 27, 2011. NMFS issued a proposed rule on annual specifications and management measures for Pacific sardine, under the CPS FMP. The proposed 2011 maximum HG for Pacific sardine was 50,526 metric tons (mt), of which 4,200 mt was initially set aside for potential use under an Exempted Fishing Permit (EFP). The remaining 46,326 mt, constituting the initial commercial fishing HG, would be divided across the seasonal allocation periods in the following way: January 1–June 30: 16,214 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; July 1–September 14: 18,530 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; September 15– December 31: 11,582 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt, plus an additional 2,000 mt set aside to buffer against reaching the total HG. (76 FR 4854).

March 4, 2011. NMFS issued a temporary emergency rule to close first period directed sardine fishery, anticipating that the first period allocation of 15,214 metric tons would have been harvested by then. Under this rule, Pacific sardine could have been harvested only as part of the live bait fishery or incidental to other fisheries; and the incidental harvest of Pacific sardine was limited to 30-percent by weight of all fish caught per trip. The effective date was12:01 a.m. March 5, 2011. (76 FR 11969).

May 25, 2011. The Final Rule implementing the closure of the first period directed sardine fishery (see above) was issued. (76 FR 30276).

June 28, 2011. NMFS issued a Proposed Rule to implement parts of proposed Amendment 13 to the CPS FMP, which is intended to ensure the FMP is consistent with advisory guidelines published in Federal regulations. NMFS also issued a request for comments, which were due by July 28, 2011. Amendment 13 revises the framework process that was in place to set and adjust fishery specifications and management measures and modifies this framework to include the specification new reference points such as annual catch limit (ACL).

November 14, 2011. NMFS issued a final rule to implement parts of Amendment 13 to the CPS FMP, which is intended to ensure the FMP is consistent with advisory guidelines published in Federal regulations. Amendment 13 revised the framework process that was in place to set and adjust fishery specifications and management measures and modified this framework to include the specification new reference points such as annual catch limit (ACL). (76 FR 70362).

April 3, 2012. NMFS issued a proposed rule on annual specifications and management measures for Pacific sardine, under the CPS FMP. The proposed 2012 maximum HG for Pacific sardine was 109,409 metric tons (mt), of which 3,000 mt was initially set aside for potential use under an Exempted Fishing Permit (EFP) and 9,000 mt for potential harvest by the Quinault Indian Nation. The remaining 97,409 mt, constituting the initial commercial fishing HG, would be divided across the seasonal allocation periods in the following way: January 1–June 30: 34,093 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; July 1–September 14: 38,964 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; September 15– December 31: 24,352 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt. (77 FR 19991).

April 12, 2012. NMFS issued a proposed rule on annual specifications and management measures for Pacific mackerel, under the CPS FMP. The proposed 2011-2012 maximum HG for Pacific mackerel was 40,514 metric tons (mt), and the ACT was 30,386 mt. If the ACT was attained, the directed fishery would close, and the difference between the ACL and the ACT (10,128 mt) would be reserved as a set aside for incidental landings in other CPS fisheries and other sources of mortalities. (77 FR 21958).

August 8, 2012. NMFS issued a final rule on annual specifications and management measures for Pacific sardine, under the CPS FMP. The final 2012 maximum HG for Pacific sardine was 109,409 metric tons (mt), of which 3,000 mt was initially set aside for potential use under an Exempted Fishing Permit (EFP) and 9,000 mt for potential harvest by the Quinault Indian Nation. The remaining 97,409 mt, constituting the initial commercial fishing HG, would be divided across the seasonal allocation periods in the following way: January 1–June 30: 34,093 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; July 1–September 14: 38,964 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; September 15– December 31: 24,352 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt. (77 FR 47318).

June 18, 2012. NMFS issued a final rule on annual specifications and management measures for Pacific mackerel, under the CPS FMP. The final 2011-2012 maximum HG for Pacific mackerel was 40,514 metric tons (mt), and the ACT was 30,386 mt. If the ACT is attained, the directed fishery would close, and the difference between the ACL and the ACT (10,128 mt) would be reserved as a set aside for incidental landings in other CPS fisheries and other sources of mortalities. (77 FR 36192).

August 23, 2012. NMFS issued a temporary rule announcing the closure of the second period sardine fishery, effective at 12:01am Pacific Daylight Time August 23. From 12:01 am on the date of closure through September 14, 2012, Pacific sardine may be harvested only as part of the live bait fishery or incidental to other fisheries, with the incidental harvest of Pacific sardine limited to 30 percent by weight of all fish caught during a trip. (77 FR 50952).

December 7, 2012. NMFS issued a proposed rule on annual specifications and management measures for Pacific mackerel, under the CPS FMP. The proposed 2012-2013 maximum HG for Pacific mackerel was 40,514 metric tons (mt), and the ACT was 30,386 mt. If the ACT was attained, the directed fishery would close, and the difference between the ACL and the ACT (10,128 mt) would be reserved as a set aside for incidental landings in other CPS fisheries and other sources of mortalities. (77 FR 73005).

January 31, 2013. NMFS issued a proposed rule on annual specifications and management measures for Pacific sardine, under the CPS FMP. The proposed 2013 maximum HG for Pacific sardine was 66,495metric tons (mt), of which 3,000 mt was initially set aside for potential use under an Exempted Fishing Permit (EFP) and 6,000 mt for potential harvest by the Quinault Indian Nation. The remaining 57,495 mt, constituting the initial commercial fishing HG, would be divided across the seasonal allocation periods in the following way: January 1–June 30: 19,123 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; July 1–September 14: 22,998 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; September 15– December 31: 12,374 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt. (78 FR 6794).

March 26, 2013. NMFS issued a final rule on annual specifications and management measures for Pacific mackerel, under the CPS FMP. The final 2012-2013 maximum HG for Pacific mackerel was 40,514 metric tons (mt), and the ACT was 30,386 mt. If the ACT was attained, the directed fishery would close, and the difference between the ACL and the ACT (10,128 mt) would be reserved as a set aside for incidental landings in other CPS fisheries and other sources of mortalities. (78 FR 18249).

June 17, 2013. NMFS issued a final rule on annual specifications and management measures for Pacific sardine, under the CPS FMP. The final 2013 maximum HG for Pacific sardine was 66,495metric tons (mt), of which 3,000 mt was initially set aside for potential use under an Exempted Fishing Permit (EFP) and 6,000 mt for potential harvest by the Quinault Indian Nation. The remaining 57,495 mt, constituting the initial commercial fishing HG, would be divided across the seasonal allocation periods in the following way: January 1–June 30: 19,123 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; July 1–September 14: 22,998 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt; September 15– December 31: 12,374 mt would be allocated for directed harvest with an incidental set-aside of 1,000 mt. (78 FR 36117).

August 20, 2012. NMFS issued a temporary rule announcing the closure of the second period sardine fishery, effective at 12:01am Pacific Daylight Time August 22. From 12:01 am on the date of closure through September 14, 2012, Pacific sardine may be harvested only as part of the live bait fishery or incidental to other fisheries, with the incidental harvest of Pacific sardine limited to 40 percent by weight of all fish caught during a trip. (78 FR 51097).

December 23, 2013. NMFS issued a proposed rule to change the starting date of the annual Pacific sardine fishery from January 1 to July 1. This would change the fishing season from one based on the calendar year to one based on a July 1 through the following June 30th schedule. No other changes to the annual allocation structure are proposed and the existing seasonal allocation percentages would remain as specified in the FMP; as would the current quota roll-over provisions. (78 FR 77413).

February 28, 2014. NMFS issued a final rule to change the starting date of the annual Pacific sardine fishery from January 1 to July 1. This changed the fishing season from one based on the calendar year to one based on a July 1 through the following June 30th schedule. No other changes to the annual allocation structure were made and the existing seasonal allocation percentages remain as specified in the FMP; as do the current quota roll-over provisions. (78 FR 11343).

February 6, 2015. NMFS issued a final rule on annual specifications and management measures for Pacific mackerel, under the CPS FMP. The final 2014-2015 HG for Pacific mackerel was 29,170 mt, with an ACT of 24,170 mt. The directed fishery would be closed if the ACT was attained, with the remaining 5,000 mt representing a set aside for incidental landings in other CPS fisheries and other sources of mortality. (80 FR 6662).

March 23, 2015. NMFS announced the approval of Amendment 14 to the CPS FMP, specifying an estimate of MSY for the NSNA. At its November 2013 meeting, the Council adopted an FMSY of 0.3 as the best MSY estimate for NSNA, and voted to include this reference point as part of Amendment 14 to the CPS FMP. This action was based on data compiled by the CPSMT and recommended by the Council's SSC.

June 29, 2015. NMFS issued a final rule to implement annual management measures and harvest specifications to establish the allowable catch levels of Pacific sardine in waters off the U.S. West Coast. The annual biomass estimate of 96,688 mt fell below the Cutoff value of 150,000, thereby precluding directed non-tribal harvest. NMFS set an ACL of 7,000 mt and an ACT of 4,000, to account for incidental harvest, tribal harvest, live bait, and other minor sources of mortality. NMFS implemented an OFL of 13,227 mt, and ABC of 12,074 mt, and the following conservation measures: incidental catch shall not exceed 40 percent by weight, until 1,500 mt of sardine are harvested, at which time the incidental allowance will become 30 percent. When 4000 mt has been harvested, the percent allowance will be reduced to five percent for the remainder of the fishing year. The Council also adopted a two mt incidental per landing allowance in non-CPS fisheries.

TABLE 2-3. Coastal pelagic species 2013 limited entry permit vessel listing[4] with calculated gross tonnage (GT) values for each vessel. (Page 1 of 2)

Vessel Name	Permit No.	Coast Guard Number/ Vessel ID	Calculated Vessel GT[1]	Permit GT Endorsement	Permit Transfer Allowance[2]
PROVIDER	1	572344	63.8	63.8	70.2
UNASSOCIATED	2	----	---	43.5	47.9
SEA VENTURE	3	WN4232NW	98.4	98.4	108.2
BARBARA H	4	643518	121.1	121.1	133.2
KAREN MARIE	5	593871	82.0	82.0	90.2
CACHALOT	6	654091	98.1	98.1	107.9
SAN PEDRO PRIDE	7	549506	160.7	160.7	176.8
FERRIGNO BOY	8	602455	139.3	139.3	153.2
KING PHILIP	9	1061827	156.9	156.9	172.6
SEA WAVE	10	951443	206.9	206.9	227.6
UNASSOCIATED	11	---	---	56.2	61.8
ANGELETTE	12	608579	114.8	114.8	126.3
PIONEER	13	246212	141.9	141.9	156.1
TRITON	14	CF7218UH	89.3	89.3	98.2
SAINT JOSEPH	15	633570	84.4	84.4	92.8
-----	16	---	---	137.5	151.3
RISING SPIRIT	17	WN0416RK	61.9	61.9	68.1
ATLANTIS	18	649333	63.8	63.8	70.2
SEA PEARL	19	CF7336UH	124.6	124.6	137.1
UNASSOCIATED	20	---	---	111.9	123.1
SPERANZA MARIE	21	643138	77.0	77.0	84.7
OCEAN ANGEL IV	22	OR868ADK	63.5	63.5	69.9
PACIFIC PREDATOR	23	OR018ADR	97.7	97.7	107.5
OCEAN ANGEL I	24	584336	63.8	63.8	70.2
SEA DIAMOND	25	509632	68.1	68.1	74.9
MANANA	26	253321	23.8	23.8	26.2
NEW QUEEN	27	OR588ADB	55.5	55.5	61.1
MINEO BROS.[3]	28	CF0163TF	73.4	73.4	80.7
UNASSOCIATED	29	---	---	42.0	46.2
MINEO BROS.[3]	30	CF0163TF	40.8	40.8	44.9
SHELLFISH	31	506989	340.2	340.2	374.2
ELDORADO	32	690849	54.9	54.9	60.4
KELSEY NICOLE	33	1210115	194.0	194.0	213.4
CAROL N ROSE	34	1211776	125.6	125.6	138.2
ENDURANCE	35	613302	42.0	42.0	46.2
NEW SUNBEAM	36	284470	27.0	27.0	29.7
CALOGERA A	37	984694	85.3	85.3	93.8
EILEEN	38	252749	119.9	119.9	131.9
PAMELA ROSE	39	693271	61.9	61.9	68.1
NEW STELLA	40	598813	71.8	71.8	79.0
TRAVELER	41	661936	44.0	44.0	48.4
LUCKY STAR	42	295673	41.5	41.5	45.7
OCEAN ANGEL II	43	622522	149.5	149.5	164.5
CRYSTAL SEA	44	1061917	137.0	137.0	151.8
TRIONFO	45	625449	79.2	79.2	87.1
RELENTLESS	46	CF2009TK	85.0	85.0	93.5
HEAVY DUTY	47	655523	84.4	84.4	92.8
ALIOTTI BROS	48	685870	107.2	107.2	117.9
LADY J	49	647528	40.7	40.7	44.8
INVINCIBLE	50	1225596	50.2	50.2	55.2
ENDEAVOR	51	971540	72.3	72.3	79.5

TABLE 2-3. Coastal pelagic species 2013 limited entry permit vessel listing[/4] with calculated gross tonnage (GT) values for each vessel. (Page 2 of 2)

Vessel Name	Permit No.	Coast Guard Number/ Vessel ID	Calculated Vessel GT[/1]	Permit GT Endorsement	Permit Transfer Allowance[2]
ANTOINETTE W	52	606156	37.0	37.0	40.7
CAPE BLANCO	53	648720	158.2	158.2	174.0
OCEAN ANGEL III	54	OR108ADL	82	126.5	139.2
UNASSOCIATED	55	---	---	40.4	44.4
KATHY JEANNE	56	507798	86.3	86.3	94.4
MERVA W	57	532023	54.4	54.4	59.8
SANTA MARIA	58	236806	91.1	91.1	100.2
STELLAR	59	1190501	73.3	74.5	82.0
PACIFIC KNIGHT	60	OR155ABZ	63.4	63.4	69.7
ALEUTIAN SPIRIT	61	621542	59.9	59.9	65.9
SEABOUND	62	AK9671AF	67.8	39.7	43.7
EMERALD SEA	63	626289	86.3	86.3	94.9
LUCKY MARIE	64	602150	35.1	54.5	60.0
BOUNTY	65	629721	26.4	26.4	29.0

/1 Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100. See 46 CFR 69.209.
/2 Maximum transfer allowance is based on permit GT + 10%.
/3 Vessel Mineo Bros is associated with permits 28 and 30
/4 Several CPS permit transfers occurred in 2013. The above list includes vessels with permits at the end of December 2013 that received renewal permit applications. Vessels that had permits earlier in the year but transferred their permit to other vessels were not included

TABLE 2-4. Vessel age and calculated gross tonnage (GT) for the initial and current Federal limited entry fleet.

	Initial Fleet	Current Fleet
Number of Vessels	65	56
Average Vessel Age	35 years	34 years
Range of Ages	12 to 66 years	4 to 70 years
Average GT	71.3	88
Range of GT	12.8 to 206.9	23.4 to 206.9
Sum of Fleet GT	4,635.9	4,753
Capacity Goal (GT)[1/]	---	5,650.9
Transferability Trigger	---	5,933.5

1/ Established in Amendment 10 to the CPS FMP.

TABLE 2-5. Oregon state limited entry sardine permitted vessels landing sardine during the 2014-15 fishery.

Vessel Name	Coast Guard Number[1/]	Year Built	Length	Breadth	Depth	Calculated Vessel GT[2/]
ANTHONY G	605599	1979	58	24	8	74.6
APRIL LANE	1249802	2014	50.5	22.5	10.2	77.7
ARCTIC FOX	1187928	2006	57.3	26	12.6	125.8
CORVA MAY	615795	1979	49.6	19	10.1	
EMERALD SEA	626289	1980	62.7	26	7.9	86.3
HARBOR GEM	974306	1982	58	19.5	10	75.8
LAUREN L KAPP	OR072ACX	----	72	---	---	---
LISA MARIE	1038717	1996	78	25.3	13	171.9
LOUI M	1246619	2013	58	22.5	10.6	92.7
MISS EMILY	1244893	2013	71	28	13	173.2
MISS ROXANNE	976542	1991	58	19.5	10	75.8
OCEAN DREAM	621541	1980	58	19	10.2	75.3
PACIFIC JOURNEY	OR661ZK	1996	71	22	10	104.7
PACIFIC PURSUIT	OR873ABY	1993	63	---	---	---
PACIFIC RAIDER	972638	1991	57.7	22.7	11	96.5
PACIFIC VENTURE	WN7995RP	---	59	19	---	45[3/]
SEQUEL	1240646	2012	57.8	22.7	11.5	101.1
WESTWIND	246530	1944	72.5	20.2	8.4	82.4

1/ Vessel dimension information was obtained from NOAA at www.st.nmfs.noaa.gov/st1/CoastGuard/VesselByName.html.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100
3/ Vessel Gross Tonnage provided by WDFW.

TABLE 2-5(b). Oregon state limited entry sardine permit vessels landing sardine in 2012.

Vessel Name	Coast Guard Number	Year Built	Length	Breadth	Depth	Calculated Vessel GT[2/]	Federal Limited Entry	WA Limited Entry
ANTHONY G	605599	1979	58	24	8	74.6		
CRYSTAL SEA	1061917	1997	66	26	12	138	X	
D C COLE	556145	1975	49.6	19	10.1	63.8		
DELTA DAWN	647246	1982	49.6	19	10.1	63.8		X
EMERALD SEA	626289	1980	62.7	26	7.9	86.3	X	X
EVERMORE	248555	1944	76.3	22.2	11.4	129.4		
HARBOR GEM	974306	1982	58	19.5	10	75.8		
LADY LAW	1131965	2002	74.7	25	13.3	166.4		
LAUREN L KAPP	OR072ACX	----	72	---	---	---		
OCEAN ANGEL II	622522	1980	74.5	28	10.7	149.5	X	
OCEAN DREAM	621541	1980	58	19	10.2	75.3		
PACIFIC JOURNEY	OR661ZK	1996	71	22	10	104.7	X	
PACIFIC PREDATOR	OR018ADR	---	57	20	---	---	X	
PACIFIC PURSUIT	OR873ABY	1993	63	---	---	---		
PACIFIC RAIDER	972638	1991	57.7	22.7	11	96.5		X
ROYAL PACIFIC	OR873ABY	---	73	---	---	---		
SEA VENTURE	WN4232NW	---	66	---	---	---	X	
SEQUEL	1240646	2012	57.8	22.7	11.5	101.1		
SHELTER COVE	1239174	2012	58	25	11	106.9		
SUNRISE	238918	1939	80.2	22.2	10.2	121.7		

WESTWIND	246530	1944	72.5	20.2	8.4	82.4		

1/ Vessel dimension information was obtained from NOAA at www.st.nmfs.noaa.gov/st1/CoastGuard/VesselByName.html.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100

TABLE 2-5 (c). Oregon state limited entry sardine permit vessels landing sardine in 2013.

Vessel Name	Coast Guard Number	Year Built	Length	Breadth	Depth	Calculated Vessel GT[2/]	Federal Limited Entry	WA Limited Entry
ANTHONY G	605599	1979	58	24	8	74.6		
ARCTIC FOX	1187928	2006	57.3	26	12.6	125.8		X
DELTA DAWN	647246	1982	49.6	19	10.1	63.8		X
JOHNNY A	625595	1980	49.6	22	9.7	70.9		
LAUREN L KAPP	OR072ACX	----	72	---	---	---		
MISS ROXANNE	976542	1991	58	19.5	10	75.8		
OCEAN DREAM	621541	1980	58	19	10.2	75.3		
PACIFIC JOURNEY	OR661ZK	1996	71	22	10	104.7		
PACIFIC PURSUIT	OR873ABY	1993	63	---	---	---		
PACIFIC RAIDER	972638	1991	57.7	22.7	11	96.5		X
PACIFIC VENTURE	WN7995RP	---	59	19	---	45[3]		
SEQUEL	1240646	2012	57.8	22.7	11.5	101.1		
ST. TERESA	623983	1980	49	18.5	8.5	51.6		
WESTWIND	246530	1944	72.5	20.2	8.4	82.4		

1/ Vessel dimension information was obtained from NOAA at www.st.nmfs.noaa.gov/st1/CoastGuard/VesselByName.html.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100
3/ Vessel Gross Tonnage provided by WDFW.
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TABLE 2-6. Washington limited entry sardine licenses in 2014.

Vessel Name	Coast Guard Number	Year Built	Length	Breadth	Depth	Calculated Vessel GT[2/]	Federal Limited Entry	Oregon Limited Entry
ARTIC FOX	1187928	2006	57.3	26.0	12.6	125.8		X
ATLANTIS[1/]	649333	1982	49.6	19.0	10.1	63.8	X	
CAPE CAUTION	606699	1979	49.6	19.0	10.1	63.8		
EMERALD SEA	626289	1980	62.7	26.0	7.9	86.3	X	X
HOT SPUR	942575	1988	52.6	21.0	9.2	68.1		
KELSEY NICOLE	1210115	1982	58	19.5	10	75.8	X	
LADY LAW	1131965	2002	74.7	25	13.3	166.4		X
LISA MARIE	1038717	1996	78.0	25.3	13	171.9		X
MARAUDER	975597	1991	58.0	22.8	10.5	93.0		X
OCEAN STORM	986786	1992	57.9	22.3	11.3	97.8		
PACIFIC GRACE	625595	1980	58	22	9.7	107		
RISING SUN	1244677	2013	58.0	22.7	11.5	101.4		

SHELTER COVE	1239174	2012	58	25	11	107		
ROBERT MAGNUS	1230071	2011	58	26	13	131.3		
VOYAGER	248217	1945	66.7	20.2	9.3	84.0		
WN7062SA		1977	68.4	22.0		100.0		
ZEALOT	986920	1992	57.9	22	10.5	89.6		

1/ Vessel dimension information was obtained from NOAA at www.st.nmfs.noaa.gov/st1/CoastGuard/VesselByName.html.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100

TABLE 2-6. Washington limited entry sardine licenses 2015.

Vessel Name	Coast Guard Number	Year Built	Length	Breadth	Depth	Calculated Vessel GT[2/]	Federal Limited Entry	Oregon Limited Entry
ARTIC FOX	1187928	2006	57.3	26.0	12.6	125.8		X
ATLANTIS[1/]	649333	1982	49.6	19.0	10.1	63.8	X	
CAPE CAUTION	606699	1979	49.6	19.0	10.1	63.8		
EMERALD SEA	626289	1980	62.7	26.0	7.9	86.3	X	X
HOT SPUR	942575	1988	52.6	21.0	9.2	68.1		
JUNO	260614	1950	138	30	12	199		

KELSEY NICOLE	1210115	1982	58	19.5	10	75.8	X	
LADY LAW	1131965	2002	74.7	25	13.3	166.4		X
LISA MARIE	1038717	1996	78.0	25.3	13	171.9		X
MARAUDER	975597	1991	58.0	22.8	10.5	93.0		X
OCEAN STORM	986786	1992	57.9	22.3	11.3	97.8		
PACIFIC GRACE	625595	1980	58	22	9.7	107		
PACIFIC RAIDER	972638	1991	57.7	22.7	11	96.5		X
RISING SUN	1244677	2013	58.0	22.7	11.5	101.4		
ROBERT MAGNUS	1230071	2011	58	26	13	131.3		
VOYAGER	248217	1945	66.7	20.2	9.3	84.0		
WN7062SA		1977	68.4	22.0		100.0		
ZEALOT	986920	1992	57.9	22	10.5	89.6		

1/Vessel dimension information was obtained from NOAA at www.st.nmfs.noaa.gov/st1/CoastGuard/VesselByName.html.
2/ Vessel Gross Tonnage GT=0.67(Length*Breadth*Depth)/100 (The CPSMT is working on discrepancies between Tables 2-3 through 2-6).

TABLE 4-1 (continued). Preliminary catch summary for vessels targeting Pacific sardine from NMFS-SWR coastal pelagic species pilot observer program, 2004-2008. (Page 2 of 2).

Target species - Pacific sardine					
Species	**Target Catch**	**Incidental Catch**	**Bycatch Returned**		
			Alive	**Dead**	**Unknown**
Unid. Smelt		2			
Unid. Surf Perch		1			
Unid. Turbot				60	
White Croaker		31 lbs	50 lbs		
Yellowfin Croaker		10 lbs			
CA Sea Lion			49		
Harbor Seal			1		
Unid. Gull			3	2	4

TABLE 4-2. Preliminary catch summary for vessels targeting market squid from NMFS-SWR coastal pelagic species pilot observer program, 2004-2008.

Target species - Squid					
Species	**Target Catch**	**Incidental Catch**	**Bycatch Returned**		
			Alive	**Dead**	**Unknown**
Squid	1274 mt		28 mt	350 lbs	2 mt
Anchovy		100 lbs	120 lbs		
Jack Mackerel		2 mt	18 lbs	2 lbs	
Pacific Mackerel		20 mt	20 mt	180 lbs	1 lb
Sardine		12 mt	13 mt	1077 lbs	3 lbs
Spanish Mackerel		20 lbs			
Bat Ray			53		1
Bat Star			1		
Blue Shark			2		
Common Mola			1		
Pelagic Stingray			60		
Pacific Butterfish		19			1
Sunstar		30	4		
Squid Eggs					505 lbs
Lobster			3		
Brittle Star				3000	
Unid. Batfish				2 lbs	
Unid. Crab		1	1		93
Unid. Croaker		3	2	16 lbs	
Unid. Flatfish		1	1	6	2
Unid. Jellyfish		4			
Unid. Mackerel		2 lbs	102 lbs		
Unid. Octopus		1			
Unid. Rockfish		1	1	4	
Unid. Ray			4		1
Unid. Sanddab		4	3		4
Unid. Seastar		1			
Unid. Seaslug					21
Unid. Scorpionfish		1			
Unid. Surfperch				3	
Unid. Skate		3		1	
Unid. Smelt		49			
Unid. Stingray		9	17		
Unid. Shark					1
Thresher Shark		1			
CA Sea Lion			98		
Harbor Seal			3		
Common Dolphin				1	
Unid. Gull			16	1	

TABLE 4-3. Preliminary catch summary for vessels targeting Pacific mackerel from NMFS-SWR coastal pelagic species pilot observer program, 2004-2008.

Target species - Pacific mackerel					
Species	**Target Catch**	**Incidental Catch**	**Bycatch Returned**		
			Alive	**Dead**	**Unknown**
Pacific Mackerel	40 mt				
Bat Ray			2		
CA Yellowtail			1		
Midshipman			1		
Sardine		16 mt			
Sea Cucumber		5			
Unid. Crab		1			
Unid. Flatfish			3		
Unid. Jellyfish			3		
Unid. Shark			1		

TABLE 4-4. Preliminary catch summary for vessels targeting northern anchovy and northern anchovy/Pacific sardine from NMFS-SWR coastal pelagic species pilot observer program, 2004-2008.

Target species - Anchovy and Anchovy/Sardine					
Species	**Target Catch**	**Incidental Catch**	**Bycatch Returned**		
			Alive	**Dead**	**Unknown**
Anchovy	373 mt		2 mt	1 mt	
Sardine		21 mt	2 mt		
Bat Ray			4		
CA Lizardfish			4		
Kelp Bass		1			
Midshipman					5
Pacific Bonito			20 lbs		
Pacific Mackerel		2			
Queenfish		50 lbs	11 lbs		
Round Stingray			1		
Sculpin		2			
Spiny Dogfish			1		
Unid. Croaker		20	45		
Unid. Flatfish		10			
Unid. Hake		4			
Unid. Seastar			1		
Unid. Smelt		2			
Unid. Turbot			1	1	20
White Croaker		50 lbs	35 lbs		
Yellowfin Croaker		50 lbs	10 lbs		
CA Sea Lion			5		
Sea Otter			1		

Table 4-5. Percent frequency by occurrence of incidental catch in sampled Pacific sardine, Pacific mackerel, and Northern anchovy* landings, by port, 2011-2015. Table values represent proportion of each incidental species out of total incidental observed each year. *Collection of Northern anchovy samples began in 2014.

	All Ports Combined					**Monterey/Moss Landing**					**Ventura/Port Hueneme/Terminal Island/San Pedro**				
Common Name	**2011**	**2012**	**2013**	**2014**	**2015**	**2011**	**2012**	**2013**	**2014**	**2015**	**2011**	**2012**	**2013**	**2014**	**2015**
Finfish															
Anchovy, northern	7.4	1.9	0.9	7.9	0.2	8.9	4	3.6	12.1	0.3	3.0	0.5	0.4	1.1	
Barracuda, California	0.5	0.4		0.6	0.7	0.3	0.4		0.2	0.9	1.0	0.5		1.1	
Bass, barred sand	0.2	0.7	0.3	0.1	0.2						1.0	1.2	0.4	0.4	0.9
Bass, kelp		1.3	4.4	1.9	0.2							2.2	5.3	4.9	0.9
Bass, striped		0.3					0.4					0.2			
Blacksmith			0.3	0.1									0.4	0.4	
Bonito, Pacific		0.1	3.8	0.4	1.3				0.5	0.3		0.2	4.6	0.4	4.3
Butterfish	4.4	1.8	1.5	3.2	6.7	4.3	3.6	3.6	4.8	8.2	5.0	0.5	1.1	0.8	2.6
Cabezon		0.1					0.4								
Combfish, longspine	0.2	0.1				0.3						0.2			
Corbina, California		0.1										0.2			
Croaker, unspecified			0.3										0.4		
Croaker, white	5.7	3.1	0.9	1.2	0.4	6.2	6.9	5.4	1.4	0.3	4.0	0.5		0.8	0.9
Croaker, yellowfin		0.3		0.4	0.2		0.7		0.5					0.4	0.9
Cusk eel, basketweave	0.5	0.1		0.3	0.4					0.3	2.0	0.2		0.8	0.9
Cusk-eel, spotted															
Eel, unspecified					0.2					0.3					
Eel, wolf (wolf-eel)	0.2	0.3				0.3						0.5			
Eel, yellow snake															
Fish, unspecified															
Flatfish, unspecified	1.0	1.9	0.6	0.6	0.4	0.3	0.7		1.0	0.6	3.0	2.7	0.7		
Flounder, starry	1.2	0.9		0.1		1.6	2.2		0.2						
Flounder, unspecified															
Flyingfish	0.2	0.3	0.3	0.1							1.0	0.5	0.4	0.4	
Greenling, kelp	0.2			0.1		0.3								0.4	
Grunion, California															
Hagfish															
Halfmoon					0.4					0.3					0.9
Halibut, California	2.5	1	1.8	0.4	0.9	2.3	1.4	1.8		0.3	3.0	0.7	1.8	1.1	2.6
Herring, Pacific	0.7	1.2				1.0	2.9								
Jacksmelt	2.0	2.8	0.9	0.1	0.7	2.0	6.1	5.4	0.2	0.9	2.0	0.5			
Kelpfish, giant		0.3	0.6	0.1								0.5	0.7	0.4	
Lingcod	2.2	0.1				3.0						0.2			
Lizardfish, California	0.5	1.2	1.2	2.3	2.2		0.7	5.4	3.3	2.4	2.0	1.5	0.4	0.8	1.7
Mackerel, jack	1.0	5.7	13.5	4.5	9.4	0.3			0.2	12.7	3.0	9.7	16.1	11.3	
Midshipman, plainfin	3.2	0.1	0.6	0.6	2.5	3.9			1.0	2.1	1.0	0.2	0.7		3.5
Midshipman, specklefin		0.7	1.8	0.7	0.7							1.2	2.1	1.9	2.6
Midshipman, unspec															
Opaleye															
Perch-like, unspecified		0.3			0.2		0.7			0.3					

Pipefish, bay																	
Pipefish, kelp		0.1		0.1										0.2		0.4	
Poacher, unspecified																	
Queenfish	0.2	0.1			0.7						0.6		1.0	0.2			0.9
Rockfish, chilipepper				0.4	0.2					0.7	0.3						
Rockfish, unspecified		0.6		0.1						0.2				1.0			
Salema																	
Salmon, Chinook		0.6						1.1						0.2			
Sanddab, longfin				0.1												0.4	
Sanddab, Pacific	5.2	2.2	5	6.1	8.1		6.6	4.3	7.1	6.4	9.7		1.0	0.7	4.6	5.7	3.5
Sanddab, speckled		0.7	0.3	0.9					1.8	1.4				1.2			
Sanddab, unspecified	0.2	1.9			0.4			1.4			0.6		1.0	2.2			
Scorpionfish, California	2.0	1.3	2.6	3.2	1.8								7.9	2.2	3.2	8.3	7.0
Sculpin, pithead																	
Sculpin, roughback		0.3												0.5			
Sculpin, staghorn	1.7	1.0	0.6		0.9		2.3	2.5	3.6		1.2						
Sculpin, undentiified		0.3		0.1						0.2				0.5			
Sculpin, yellowchin																	
Seabass, giant (black)																	
Shad, American		1.5			0.2			3.6			0.3						
Sheephead, California				0.1												0.4	
Silversides	0.2												1.0				
Smelt, surf				0.3												0.8	
Smelt, true																	
Snapper, Mexican																	
Sole, C-O			0.9	0.7	0.2										1.1	1.9	0.9
Sole, English	1.2	0.4		0.1	0.2		1.6	1.1		0.2	0.3						
Sole, fantail		1.0	1.8	0.4	0.2			0.4						1.5	2.1	1.1	0.9
Sole, petrale			0.3		0.2						0.3				0.4		
Sole, rock																	
Sole, sand	3.7	1.5	1.5	0.4			4.9	2.9	8.9	0.7				0.5			
Sole, slender																	
Sole, unspecified																	
Sunfish, ocean				0.1						0.2							
Surfperch, barred																	
Surfperch, black		0.1	0.6					0.4							0.7		
Surfperch, kelp																	
Surfperch, pink		0.3												0.5			
Surfperch, rainbow	0.2						0.3										
Surfperch, rubberlip	0.2		0.3	0.1			0.3								0.4	0.4	
Surfperch, shiner		0.6	0.9	0.4	0.4			1.1		0.2	0.3			0.2	1.1	0.8	0.9
Surfperch, unspecified		0.1	0.6	0.1	0.2					0.2				0.2	0.7		0.9
Surfperch, walleye																	
Tonguefish	0.2			0.3	0.2					0.5	0.3		1.0				
Topsmelt	0.5	0.1											2.0	0.2			
Turbot, curlfin	0.7	1.5	0.3	0.9	0.2		1.0	0.4	1.8	1.4	0.3			2.2			
Turbot, diamond	0.5	0.6											2.0	1			
Turbot, hornyhead	0.7	2.2	4.4	2.2	1.3		0.3	0.4	1.8	0.2	0.3		2.0	3.5	4.9	5.3	4.3

Turbot, spotted		0.1	0.6											0.2	0.7		
Turbot, unspecified	0.5		0.6	0.3	0.2					0.5	0.3		2.0		0.7		
Whiting, Pacific				0.7						1.2							
Total % Freq. Incidents	52.2	47.0	54.5	44.8	54.9		52.5	50.5	50.0	40.0	57.5		51.5	44.5	55.4	52.5	46.4
Elasmobranchs																	
Guitarfish, shovelnose	0.2						0.3										
Ratfish, spotted																	
Ray, bat	2.7	3.1	1.2	0.1	1.8		2.0	3.2	1.8	0.2	1.2		5.0	3.0	1.1		3.5
Ray, California butterfly		0.1	0.3		0.4			0.4							0.4		1.7
Ray, Pacific electric	3.9	0.6	1.5	4.2	4.9		4.6	0.7	3.6	6.7	6.4		2.0	0.5	1.1	0.4	0.9
Ray, unspecified		1.0		0.1	0.2			0.4		0.2	0.3			1.5			
Shark, brown smoothhound																	
Shark, gray smoothhound																	
Shark, horn		0.7	0.3	0.7	0.2									1.2	0.4	1.9	0.9
Shark, leopard		0.3		0.3						0.2				0.5		0.4	
Shark, Pacific angel		1.6	1.5	0.6	0.7									2.7	1.8	1.5	2.6
Shark, pelagic thresher																	
Shark, smooth hammerhead																	
Shark, spiny dogfish																	
Shark, unspecified		0.1												0.2			
Skate, big	1.2	1.0	0.3				1.6	2.5	1.8								
Skate, California	0.2	0.3	0.9	0.1	0.4			0.4			0.3		1.0	0.2	1.1	0.4	0.9
Skate, long-nosed		0.1						0.4									
Skate, thornback	1.2	1.5	2.1	0.9	1.1		0.3	1.8	5.4		0.6		4.0	1.2	1.4	2.3	2.6
Skate, unspecified		0.1		0.1	0.2					0.2				0.2			0.9
Stingray, round		0.6		0.3	0.4									1		0.8	1.7
Total % Freq. Incidents	9.6	11.3	7.9	7.6	8.5		8.9	9.7	7	7.6	6.8		11.9	12.4	7.0	7.5	14.4
Invertebrates & Plants																	
Algae, marine		0.6			1.6					0.5	2.1			1.0			
Bryozoan	0.2												1.0				
Crab shells		0.3	0.6		0.7			0.7	1.8		0.9				0.4		
Crab, box																	
Crab, decorator		0.4		3.5				0.4						0.5			
Crab, Dungeness	3.4	1.8	1.2		1.3		4.6	4.3	7.1	5.5	1.8					0.4	
Crab, globe	0.2	1.0	0.6										1.0	1.7	0.7		
Crab, rock unspecified		0.9	0.3	0.3					1.8					1.5			
Crab, sheep		0.4	2.3					0.4						0.5	2.8	0.8	
Crab, slender																	
Crab, spider		0.7		1.9										1.2			
Crab, swimming	0.5	0.6	1.2	0.6	1.1					0.2			2.0	1.0	1.4	4.5	4.3
Crab, unspecified	0.7	1.3	0.9	1.0	2.2			0.4			1.2		3.0	2.0	1.1	1.5	5.2
Eelgrass	0.5	1.5			1.6			1.1		1.0	0.3		2.0	1.7		1.1	5.2
Gorgonians (sea fans)					0.4												1.7
Invertebrate, unspecified		0.1		6.4										0.2			

Jellyfish	4.9	1.2	0.6	11.8	1.6		6.6	2.9	3.6	10.5	2.1						
Kelp	8.9	11.0	11.4	0.6	16.0		8.2	10.1	5.4	9.3	15.2		10.9	11.7	12.6	15.8	18.3
Kelp, feather boa	0.2	3.8		0.4	0.9			1.4		1.0	1.2		1.0	5.5			
Lobster, California spiny		1.5	1.2											2.5	1.4	1.1	
Nudibranch				1.0													
Octopus, unspecified	1.2	2.4	3.8		0.4		1.3	2.9	8.9	0.7	0.3		1.0	2.0	2.8	1.5	0.9
Pleurobranch				0.3													
Prawn, ridgeback				0.4						0.5							
Prawn, spot		0.1		1.6						0.5				0.2		0.4	
Salps	0.5	0.1		1.5	0.7						0.9		2.0	0.2		4.2	
Sea cucumber	0.2	0.9	0.6		0.4			0.4		1.7			1.0	1.2	0.7	1.1	1.7
Sea pansy																	
Sea stars	3	1.6	1.2		0.2		3.6	3.6	3.6		0.3		1.0	0.2	0.7		
Shrimp,black-spotted bay	2.7	0.9		0.1	0.2		3.3	2.2			0.3		1.0				
Shrimp, unspecified	0.5	0.3	0.3		3.1						2.7		2.0	0.5	0.4	0.4	4.3
Snail, top																	
Snail, unspecified				0.3													
Sponge, unspecified	0.2						0.3			0.5							
Squid, jumbo				15.0													
Squid, market	10.1	7.8	11.4		11.2		10.8	8.3	5.4	20.0	14.8		7.9	7.5	12.6	7.2	0.9
Squid, market (Egg Cases)																	
Surfgrass				0.4													
Tunicates					1.3					0.7	1.8						
Turkish Towel		0.3						0.7									
Total % Freq. Incidents	38.2	41.7	37.5	47.6	36.4		38.7	39.7	37.5	53.4	35.7		36.6	43.0	37.5	40.0	39.2
Total All Incidents	406	679	56	685	551		305	277	285	420	426		101	402	341	265	125
Total Observed Landings	89	186	7	100	162		33	34	110	24	108		56	146	118	76	54

Table 4-6. Incidental catch reported on landing receipts with greater than fifty percent market squid (by tonnage per landing) from 2010 – 2014 for round haul gear.

	2011		2012		2013		2014		2015	
Common Name	Number of Landings	Metric Tons	Number of Landings	Metric Tons	Number of Landings	Metric Tons	Number of Landings	Metric Tons	Number of Landings	Metric Tons
Anchovy, northern	2	2	2	1	4	5	1	0	2	18
Bonito, Pacific	0	0	0	0	0	0	0	0	1	5
Mackerel, jack	11	16	51	70	23	19	30	19	45	61
Mackerel, Pacific	29	79	114	128	52	92	144	248	119	184
Sardine, Pacific	41	94	150	190	55	113	40	31	27	23

TABLE 4-7. Percent frequency by occurrence of bycatch in observed loads of California market squid by port, 2011-2015. Table values represent proportion of each incidental species out of total incidental observed each year.

	Total All Ports					**San Pedro/Terminal Island**					**Ventura/Port Hueneme**					**Monterey/Moss Landing**				
Common Name	**2011**	**2012**	**2013**	**2014**	**2015**	**2011**	**2012**	**2013**	**2014**	**2015**	**2011**	**2012**	**2013**	**2014**	**2015**	**2011**	**2012**	**2013**	**2014**	**2015**
Finfish																				
Anchovy, northern	2.8	3.6	3.5	3.2	4.0	1.7	17.6	2.9	3.6		1.3	3	4.3	4.0	1.8	3.6	2.8	2.7	2.8	5.4
Barracuda, California	0.6	1.1	0.4	0.4	0.6	0.9			1.0		2.7	2	0.8							0.9
Bass, kelp			0.3	0.5				1.0	1.5				0.3							
Blacksmith			0.1	0.2					0.5				0.3							
Bonito, Pacific			0.1	0.2	0.9			1.0		4.2				2.0	1.8					
Butterfish (Pacific pompano)	3.8	10.1	10	4.6	5.2	1.7	8.8	10.7	1.5	4.2	4	11.4	11.6	2.0	1.8	4.6	8.5	7.7	6.7	6.3
Combfish, longspine	0.4		0.1	0.2							1.3		0.3			0.3			0.3	
Croaker, white (kingfish)	1.6	1.5	1.0	0.4	0.6				0.5		1.3	0.3	0.5			2.3	3.2	2.0	0.3	0.9
Eel, wolf (wolf-eel)	0.2	0.5	0.5	0.2								0.3				0.3	0.9	1.3	0.3	
Fish, unspecified		0.1															0.3			
Flatfish, unspecified	0.6		0.3	0.9	1.5	2.6		1.0		2.1				2.0				0.3	1.2	1.8
Flounder, starry		1.3	0.1	0.4													3.2	0.3	0.6	

Flyingfish		0.5	0.6	0.2					1.0	0.5				1.0	1.1								
Halibut, California	0.2		0.1	0.2			0.9		1.0													0.3	
Herring, Pacific	0.2	1.1	1.3	0.5															0.3	2.5	3.4	0.9	
Jacksmelt	1.4	2.2	2.5	3.0	4.3				1.0	0.5	2.1			1.5	0.3				2.3	3.2	5.7	4.9	5.8
Lizardfish, California	0.4	0.8	2.8	2.3	0.6		0.9	5.9	3.9		2.1		1.3	1.0	3.0						2.3	4.0	0.4
Mackerel, jack	2.8	2.8	2.6	4.9	12.5		11.1	8.8	2.9	10.3	10.4		1.3	3.8	3.0	6.0	10.5			0.9	2.0	1.5	13.5
Mackerel, Pacific	14.5	2.8	4.3	8.4	14.9		17.9	2.9	3.9	12.9	14.6		13.3	4.6	5.4	16.0	33.3		13.4	0.6	3.0	4.6	10.3
Mackerel, unspecified		0.3																		0.6			
Midshipman, plainfin	0.6	1.2	1.7	1.8	1.2		0.9		1				1.3	2.3	1.9				0.3		1.7	3.1	1.8
Midshipman, specklefin	0.2	0.1	0.8	0.2	0.6				2.9	0.5	2.1		1.3	0.3	0.8								0.4
Midshipman, unspecified	0.4			0.2			1.7			0.5													
Poacher, unspecified																							
Rockfish, Blue			0.6	0.4	0.3																1.7	0.6	0.4
Rockfish, chilipepper			0.9	0.9																	2.3	1.5	
Rockfish, unspecified		0.1	0.5	0.2	0.3				1.0											0.3	1.0	0.3	0.4
Salmon, Chinook	0.4	0.9	0.5																0.7	2.2	1.3		
Sanddab, longfin	0.4	0.3	0.1	0.2			0.9		1.0	0.5			1.3							0.6			
Sanddab, Pacific	8.2	3	2.7	5.3	6.4				5.8	4.1	4.2		16.0			2.0			9.5	7	5.0	6.4	8.5
Sanddab, speckled	0.6	0.1	0.9	2.5	0.6		1.7									8.0	3.5		0.3	0.3	2.3	3.1	
Sanddab, unspecified		6.3	5.6	0.4				2.9		1.0				10.2	11.3					1.9	0.3		
Sardine, Pacific	10.6	6.7	5.3	4.4	9.8		20.5	14.7	1.9	2.6	8.3		8.0	6.1	4	2.0	7.0		7.5	6.6	8.1	5.8	10.8
Scorpionfish, California	1.4	0.1	0.6	0.2	0.3		4.3	2.9	2.9	0.5	2.1		2.7		0.5								
Sculpin, pithead																							
Sculpin, staghorn	2	1.2	0.5	0.2									1.3	0.3	0.5				2.9	2.5	0.7	0.3	
Sculpin, undentiified		0.4	0.3	0.4										0.3	0.3					0.6	0.3	0.6	
Silversides																							
Sunfish, ocean	0.4	0.3	0.1	0.2										0.3	0.3				0.7	0.3		0.3	
Surfperch, shiner	0.2	0.9	1.2	0.4	0.3				1.9		2.1			1.8	1.9	2.0			0.3			0.3	
Topsmelt		0.1	0.4												0.8					0.3			
Turbot, hornyhead	3.2	1.7	3.4	1.4	0.6				4.9	1.5	2.1		2.7	2.5	3.5				4.6	0.9	2.7	1.5	0.4

Turbot, spotted																							
Turbot, unspecified		0.4	0.4	0.4											0.8					0.9		0.6	
Whiting, Pacific			0.4	0.2																	1.0	0.3	
Total % Freq. Incidents	58.2	52.8	57.6	49.6	65.5		67.5	64.7	53.4	44.3	60.4		61.3	52.8	57.3	46.0	59.6		53.9	51.6	59.4	53.2	68.2
Elasmobranchs																							
Ray, bat	1.4	4.6	3.8	1.4	3.4		3.4	11.8	10.7	2.6	2.1		4.0	6.6	4.0	6.0	10.5			1.3	1.0		1.8
Ray, Pacific electric	2	1.3	1.9	1.8	0.6								1.3	1.0	0.8				2.9	1.9	4.0	3.1	0.9
Shark, horn		0.1	0.1											0.3	0.3								
Shark, unspecified																							
Skate, long-nosed		0.1																		0.3			
Skate, unspecified		0.3		0.2																0.6		0.3	
Stingray, round																							
Total % Freq. Incidents	3.4	6.5	5.8	3.3	3.9		3.4	11.8	10.7	2.6	2.1		5.3	7.9	5.1	6.0	10.5		2.9	4.1	5.0	3.4	2.7
Invertebrates & Plants																							
Algae, marine	0.2		0.3	0.4	1.2		0.9														0.7	0.6	1.8
Cnidaria (Sea Anemones)	0.4	0.1					1.7	2.9															
Crab, box		0.3												0.5									
Crab, Dungeness	4	3.4	0.9	3.5	1.8						2.1								6.5	7.9	2.3	6.1	2.2
Crab, rock unspecified	0.4	0.4	0.3	0.5	0.6		0.9	5.9		1.0	2.1		1.3	0.3	0.3	2.0	1.8				0.3		
Crab, sheep		0.3	0.1		0.3				1.0											0.6			0.4
Crab, Shore																							
Crab, swimming	0.4			0.2	0.9		0.9				4.2		1.3				1.8					0.3	
Crab, unspecified	0.2		0.1	0.7	0.9		0.9		1.0	1.5	2.1					2.0							0.9
Eelgrass		1.5	3.2	1.9	0.9			2.9	1.0	3.6	6.3			1.8	0.8					0.9	7.0	1.2	
Gorgonians (sea fans)																							
Grass, Turtle																							
Jellyfish	7.4	4.8	1.9	5.4	3.0					0.5				0.5	0.3				12.1	10.8	4.7	9.2	4.5
Kelp	15.5	12	12.8	15.9	10.1		13.7	11.8	13.6	24.2	8.3		17.3	13.7	14.0	22.0	14.0		15.7	9.8	11.1	10.1	9.4
Kelp, feather boa	0.4	0.9	1.2	1.1	1.2		1.7													2.2	3.0	1.8	1.8

Lobster, California spiny			0.1						1.0														
Salps		4.4	4.4	3.2						5.2				8.4	9.1	16.0							
Sea cucumber	1.2		0.4				0.9						2.7		0.8				1.0				
Sea Cucumber, warty																							
Sea Hare		2.3	0.5		0.9						2.1			4.3	1.1		3.5						
Sea Slug																							
Sea stars	2.6	3.1	2.5	1.2	1.2		0.9			0.5	2.1		1.3	1.5	3.5		3.5		3.6	5.4	2.0	1.8	0.4
Squid, jumbo	0.2	0.4					0.9													0.9			
Squid, market (Egg Cases)	5.2	3.5	6.7	8.4	3.7		5.1		18.4	16.5	8.3		9.3	4.8	6.7	6.0	5.3		4.2	2.2	2.7	4.0	2.2
Surfgrass		3.2	1.0	4.7	3.7									3.3	1.1					3.5	1.3	8.3	5.4
Tunicates	0.2		0.1				0.9														0.3		
Urchin, Purple		0.1												0.3									
Total % Freq. Incidents	38.4	40.7	36.6	47.1	30.5		29.1	23.5	35.9	53.1	37.5		33.3	39.3	37.6	48.0	29.8		43.1	44.3	35.6	43.4	29.1
Total All Incidents	498	744	773	571	328		117	316	103	194	48		75	394	372	50	57		306	316	298	327	223
Total Observed Landings	143	196	196	135	103		77	39	92	72	8		14	74	64	22	58		52	39	40	41	37

TABLE 4-8. Expanded salmonid bycatch in Pacific sardine fisheries in Oregon and Washington, 2000-2015/16.

	Oregon [1/]							Washington[2/]						
	Chinook		Coho		Total		Grand Total	Chinook		Coho		Total		Grand Total
	(live)	(dead)	(live)	(dead)	(live)	(dead)		(live)	(dead)	(live)	(dead)	(live)	(dead)	
2015/16[4/]					0	0	0	0	0	0	0	0	0	0
2014/15					17	7	24	44	146	27	166	71	312	383
2014[3/]					0	0	0	6	21	4	24	10	45	55
2013					117	81	198	207	683	125	779	332	1,462	1,794
2012					61	64	125	244	806	148	919	392	1,725	2,117
2011					35	37	72	56	186	34	212	90	398	488
2010					110	76	186	87	288	53	328	140	616	756
2009					126	115	241	56	186	34	212	90	398	488
2008					123	75	198	45	149	27	170	72	319	391
2007					349	170	519	33	108	20	124	53	232	285
2006					164	93	257	31	101	19	116	50	217	267

2005					411	176	587	47	156	29	178	76	334	410
2005					518	305	823	35	225	19	105	54	330	384
2003					315	185	500	92	262	81	231	173	493	666
2002					199	81	280	150	356	61	765	211	1,121	1,332
2001	45	45	201	134	246	179	425	449	170	571	504	1,020	674	1,694
2000	43	72	159	43	202	115	317	38	3	276	116	314	119	433

1/ Oregon salmon bycatch data for 2000-2001 are expanded from a bycatch rate of salmon/trip based on vessel observation program.
Oregon salmon bycatch data for 2002-2015 are from logbooks. No sardine fishery landings were made in Oregon during January 1-June 30, 2014.
2/ Washington totals calculated from observed 2000-2004 observed bycatch rates.
3/ January 1, 2014 – June 30, 2014.
4/ The 2015/16 directed sardine fishery was closed.

TABLE 4-9. Reported logbook catches of non-target species caught in Oregon sardine fishery since 2007. There were no sardine fishery landings in Oregon during the 2014 Interim Fishery, January 1-June 30, 2014. The directed fishery for sardines was closed during the 2015-2016 fishery year.

Species	2007	2008	2009	2010	2011	2012	2013	2014 Interim Fishery	2014-2015	2015-2016
Blue Shark	0	1	0	0	0	0	0	0	0	0
Thresher Shark	3 (2 released alive)	0	0	0	0	0	0	0	0	0
Unknown Shark	5	0	0	0	0	0	0	0	0	0
Salmonids	519 67% alive; 33% dead	198 62% alive; 38% dead	248 53% alive; 47% dead	186 59% alive; 41% dead	72 49% alive; 51% dead	125 49% alive; 51% dead	198 59% alive; 41% dead	0	24 71% alive; 29% dead	0
Mackerel	473,441 lbs	59,205 lbs	30,872 lbs	15,280 lbs	20 lbs	947,200 lbs	569,650 lbs	0	1,146,300 lbs	0
Anchovy	500 lbs	8,300 lbs	12,045 lbs	20,450 lbs	0	0	15,000 lbs	0	0	0
Herring	0	52,200 lbs	2,000 lbs	0	0	6,000 lbs	3,000 lbs	0	0	0
Hake	0	525 lbs	0	0	0	0	0	0	0	0
Squid	0	225 lbs	0	30 lbs	0	0	0	0	200 lbs	0
Jellyfish	0	0	0	0	0	0	0	0	0	0
Dogfish	-	-	200 lbs	0	0	0	0	0	0	0
Shad	0	0	0	0	0	0	2 lbs	0	0	0

TABLE 4-10. Recorded incidental catch (mt) in Oregon sardine fishery since 2010 (from fish ticket data). Excludes species landed under an Exempted Fishery Permit. There were no sardine fishery landings in Oregon during the 2014 Interim Fishery, January 1-June 30, 2014. The directed fishery for sardines was closed during the 2015-2016 fishery year.

Species	2010	2011	2012	2013	2014 Interim Fishery	2014-2015	2015-2016
Pacific mackerel	39.2	5.2	1,585.8	435.6	0	1,008.1	0
Jack mackerel	<0.01	0	70.9	60.1	0	245.0	0
Pacific herring	0	0	0.35	0	0	0	0
Northern anchovy	1.2	21.2	0	12.5	0	0	0
American shad	0	0	0.005	0.02	0	0.001	0
Sablefish	0	0	0	0.01	0	0	0

Table 4-11. Species noted as encountered on CDFW Live Bait Logs, 1996-2015.

Year	Days Fished	Jack Mackerel	Pacific Mackerel	Barracuda	Herring	Grunion	Smelts (Atherinids)	Shiner Surfperch	White Croaker	Queenfish	Market Squid	Pacific Bonito
2015	833	20	99				4				3	6
2014	794	15	98			1	4				1	1
2013	752	2	43				1				47	
2012	762	1	27	7							41	
2011	896	4	34	2			1				31	
2010	673	1	69								9	1
2009	965	2	77	6						1		
2008	957		92	9							2	6
2007	954	2	88	27			2				6	12
2006	1,002	4	160	5								2
2005	1,045	51	182	24							1	13
2004	950	79	82	2							4	8

2003	1,147	24	145	23							2	1
2002	1,150	9	155	55							1	
2001	1,179	11	190	57		1					28	
2000	495	25	96	46		1					2	
1999	449	16	77	7	1		1					
1998	809	8	189	69	1			1				
1997	773	46	190	104				3				
1996	522	10	45	27	3		5					

TABLE 4-12. Estimates of Pacific sardine and Northern anchovy live bait harvest in California. Data for 1939-1992 from Thomson et al. (1994), and 1993-2014 from CDFW live bait logs. Values are in metric tons with the assumption that 1 scoop =12.5 lbs.

Year	Anchovy	Sardine	Year	Anchovy	Sardine
1939	1,364	0	1977	6,410	0
1940	1,820	0	1978	6,013	107
1941	1,435	0	1979	5,364	0
1942	234	0	1980	4,921	12
1943	WII	WII	1981	4,698	6
1944	WII	WII	1982	6,978	38
1945	WII	WII	1983	4,187	193
1946	2,493	0	1984	4,397	53
1947	2,589	0	1985	3,775	11
1948	3,379	0	1986	3,956	17
1949	2,542	0	1987	3,572	216
1950	3,469	0	1988	4,189	50
1951	4,665	0	1989	4,594	100
1952	6,178	0	1990	4,842	543
1953	5,798	0	1991	5,039	272
1954	6,066	0	1992	2,572	1,807
1955	5,557	0	1993	669	176
1956	5,744	0	1994	2,076	1,506
1957	3,729	0	1995	1,278	2,055
1958	3,843	0	1996	703	1,801
1959	4,297	0	1997	1,077	2,344
1960	4,225	0	1998	304	2,037
1961	5,364	0	1999	453	2,411
1962	5,595	0	2000	834	1,270
1963	4,030	0	2001	1,347	1,226
1964	4,709	0	2002	1,010	1,759
1965	5,645	0	2003	978	3,124
1966	6,144	0	2004	192	3,900
1967	4,898	0	2005	1,464	2,817
1968	6,644	0	2006	476	3,601
1969	4,891	0	2007	699	3,352
1970	5,543	0	2008	719	2,968
1971	5,794	0	2009	774	2,702
1972	5,307	0	2010	504	1,860
1973	5,639	0	2011	1,053	2,073

1974	5,126	0	2012	356	2,594
1975	5,577	0	2013	739	1,847
1976	6,202	0	2014	1,157	1,567
			2015	723	1,996

TABLE 4-13. Ratio of anchovy to sardine in reported live bait catch in California, 1994-2015. Values are in metric tons with the assumption that 1 scoop =12.5 lbs.

Year	Anchovy	Sardine	Total	Proportion Anchovy	Proportion Sardine
2015	723	1,996	2,719	0.27	0.73
2014	1,157	1,567	2,742	0.42	0.58
2013	739	1,847	2,586	0.29	0.71
2012	356	2,594	2,950	0.12	0.88
2011	1,053	2,073	3,126	0.34	0.66
2010	504	1,860	2,364	0.21	0.79
2009	774	2,702	3,476	0.22	0.78
2008	719	2,968	3,687	0.20	0.80
2007	699	3,352	4,051	0.17	0.83
2006	476	3,601	4,077	0.12	0.88
2005	1,464	2,817	4,281	0.34	0.66
2004	192	3,900	4,092	0.05	0.95
2003	978	3,124	4,102	0.24	0.76
2002	1,010	1,759	2,769	0.36	0.64
2001	1,347	1,226	2,573	0.52	0.48
2000	834	1,270	2,104	0.40	0.60
1999	453	2,411	2,864	0.16	0.84
1998	304	2,037	2,341	0.13	0.87
1997	1,077	2,344	3,421	0.31	0.69
1996	703	1,801	2,504	0.28	0.72
1995	1,278	2,055	3,333	0.38	0.62
1994	2,076	1,506	3,582	0.58	0.42

TABLE 4-14. Directed Sardine Fishery By-Catch from Fish Tickets (metric tons) in Washington.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2014-2015	2015-2016
Arrowtooth Flounder														0.02			Fishery closed
American Shad			0.18						<0.01				0.01	0.02			
Chinook		<0.01		<0.01									0.03	0.12		<0.01	
Chum													<0.01				
Coho	<0.01												0.29	0.08		0.01	
Mackerel	4.32	272.44	259.32	52.40	22.34	19.04	40.61	35.73	6.32	4.45	2.09	0.43	636.17	195.95			
Misc				0.34			1.37			2.34				0.01			
Northern Anchovy						1.81					5.44						
Pacific Herring			0.02						4.69				<0.01	<0.01			
Pink Salmon													<0.01	<0.01			
General Shark	0.10	0.01								0.01							
Sole Rex														<0.01			
Spiny Dogfish									<0.01				<0.01	<0.01			
Starry Flounder	<0.01																

Table 6-1. West coast landings (mt) and exvessel revenues for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid, 1981-2014.

Year	Pacific Sardine mt	Pacific Sardine Rev	Pacific Mackerel mt	Pacific Mackerel Rev	Jack Mackerel mt	Jack Mackerel Rev	Anchovy mt	Anchovy Rev	Squid mt	Squid Rev
1981	15	$3,018	35388	$7,282,561	17778	$3,653,556	52309	$3,273,441	23510	$5,077,890
1982	2	$538	36065	$7,263,745	19617	$3,983,940	42155	$2,164,877	16360	$3,584,584
1983	1	$175	41479	$8,035,125	9829	$1,792,251	4430	$417,294	1959	$837,924
1984	1	$868	44086	$8,279,871	9154	$1,369,090	2899	$415,093	993	$502,704
1985	6	$1,414	37773	$6,563,566	6876	$1,292,060	1638	$238,589	11071	$4,282,943
1986	388	$82,680	48089	$7,783,354	4777	$828,421	1557	$234,514	21290	$4,518,595
1987	439	$63,116	46725	$6,675,830	8020	$1,194,126	1467	$309,472	19984	$3,954,945
1988	1188	$171,522	50864	$8,213,502	5068	$795,811	1518	$417,081	37316	$7,559,112
1989	837	$195,162	47713	$7,054,274	10745	$1,657,311	2511	$697,609	41017	$7,521,615
1990	1664	$190,583	40092	$5,357,653	3254	$442,694	3259	$625,228	28447	$4,729,885
1991	7587	$892,955	32067	$5,341,049	1712	$248,654	4068	$651,310	37389	$6,072,324
1992	18056	$1,875,359	19045	$4,006,788	1526	$238,846	1166	$223,737	13119	$2,446,138
1993	15236	$1,535,750	12086	$1,499,633	1950	$275,383	2003	$477,937	42889	$10,300,695
1994	11644	$1,515,282	10293	$1,436,788	2906	$381,324	1859	$550,517	55483	$14,376,035
1995	40256	$3,556,901	8823	$1,150,282	1877	$291,812	2016	$368,659	70363	$22,361,538
1996	32553	$3,151,710	9730	$1,317,223	2437	$304,875	4505	$700,430	80665	$21,899,940
1997	43290	$4,440,711	20168	$2,781,258	1533	$247,164	5779	$811,580	70388	$20,679,030
1998	43321	$3,627,534	21561	$2,538,792	1777	$380,867	1584	$245,132	2903	$1,627,365
1999	60333	$5,176,502	9094	$1,093,828	1557	$201,827	5286	$954,259	92040	$33,353,591
2000	67982	$7,100,136	22058	$2,930,364	1451	$260,581	11832	$1,445,814	118821	$27,219,397
2001	75801	$8,927,393	7618	$1,137,499	3852	$569,951	19345	$1,433,556	86386	$16,964,384
2002	96897	$10,377,738	3744	$520,410	1026	$204,064	4882	$623,286	72880	$18,259,492
2003	71923	$7,033,562	4213	$649,827	231	$58,205	1929	$341,913	45068	$25,390,723
2004	89350	$9,788,527	3708	$565,459	1160	$253,322	7019	$819,181	40116	$19,801,015
2005	86464	$9,831,482	3586	$569,365	294	$61,369	11414	$1,127,029	55755	$31,470,536
2006	86610	$9,282,556	6610	$880,926	1174	$199,293	12960	$1,335,011	49186	$26,963,876
2007	127789	$13,258,430	5759	$849,327	646	$145,080	10548	$1,138,875	49475	$29,096,360
2008	87190	$14,578,912	3597	$696,984	323	$53,624	14654	$1,657,118	38101	$26,457,043
2009	67084	$12,499,092	5138	$1,103,601	121	$19,234	3519	$514,994	93107	$56,873,568
2010	66892	$12,301,806	2107	$414,896	314	$62,667	1284	$562,604	130864	$71,160,383
2011	46746	$9,734,040	1365	$327,096	104	$18,727	2814	$692,334	121557	$66,567,538
2012	101555	$21,176,646	6070	$1,244,558	272	$39,007	2705	$455,277	97734	$64,024,600
2013	63892	$14,826,994	8704	$1,644,175	1095	$209,409	6061	$1,100,566	104405	$73,733,910
2014	23244	$8,827,458	7043	$1,691,195	1824	$354,461	10588	$1,653,133	86201	$61,107,231

Source: PacFIN - 2012-2014 data extracted March 29, 2015.
[2]Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

Table 6-2. West coast landings (mt) and exvessel revenues for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by fishery sector, 1981-2014.

	Landings (mt)					**Exvessel Revenues (2012 $)**				
Year	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**	**Sardine**	**P. Mackerel**	**J. Mackerel**	**Anchovy**	**Squid**
	Southern California									
1981	14.7	33,971.0	17,558.3	47,269.7	10,684.7	$3,017	$7,045,481	$3,605,298	$2,898,402	$1,178,861
1982	1.8	33,955.4	19,326.2	38,955.4	5,696.4	$495	$6,878,540	$3,924,928	$1,872,452	$726,230
1983	0.6	37,826.4	7,345.3	3,629.0	858.2	$162	$7,489,688	$1,470,615	$259,374	$328,737
1984	0.8	36,868.2	3,618.6	345.8	73.5	$602	$7,471,293	$714,529	$126,734	$44,720
1985	3.7	35,001.6	6,647.4	200.4	6,055.9	$878	$6,219,560	$1,233,017	$63,874	$1,779,202
1986	286.6	46,086.2	4,586.0	313.0	14,533.7	$63,447	$7,536,697	$769,368	$67,486	$2,907,552
1987	317.3	45,751.5	7,810.0	251.4	13,831.2	$57,812	$6,556,223	$1,160,882	$57,973	$2,627,917
1988	1,172.2	50,793.8	4,945.6	252.7	31,526.8	$170,737	$8,188,279	$765,602	$67,327	$6,209,966
1989	505.1	47,633.9	10,703.7	733.6	33,317.4	$69,151	$7,031,225	$1,624,697	$340,308	$5,853,791
1990	1,300.7	37,554.1	3,060.3	352.5	20,399.7	$160,539	$5,032,362	$402,401	$115,651	$3,295,115
1991	6,415.1	31,753.3	1,648.9	1,004.1	29,210.1	$784,564	$5,281,608	$229,843	$211,946	$4,088,135
1992	13,950.9	18,181.7	1,096.8	347.3	4,526.3	$1,447,823	$3,913,199	$218,582	$76,518	$710,517
1993	13,867.4	11,723.2	1,272.1	421.6	32,293.0	$1,447,977	$1,475,010	$179,350	$102,554	$7,162,902
1994	9,033.8	9,902.7	2,512.2	506.1	33,903.2	$965,567	$1,385,404	$277,581	$166,275	$8,103,665
1995	34,142.3	8,144.3	1,597.1	682.3	59,780.7	$3,041,558	$1,070,914	$194,737	$191,386	$19,170,370
1996	23,923.8	8,857.7	2,065.1	758.2	61,647.8	$2,218,154	$1,180,169	$276,653	$241,577	$16,628,530
1997	26,536.4	15,178.6	830.0	1,666.8	52,328.7	$2,777,380	$2,322,631	$182,838	$201,186	$15,119,013
1998	31,917.6	19,507.9	1,012.4	579.5	2,405.3	$2,973,924	$2,377,495	$319,551	$117,142	$1,374,414
1999	39,533.4	8,781.4	927.5	3,646.7	80,417.6	$3,802,050	$1,077,339	$185,372	$537,661	$29,248,694
2000	39,123.3	21,877.8	1,218.8	4,832.7	93,534.5	$4,491,202	$2,918,713	$226,996	$540,505	$21,341,824
2001	40,763.8	6,751.8	3,623.9	7,572.0	71,318.8	$4,846,918	$1,075,310	$561,721	$775,109	$13,836,345
2002	39,500.4	3,368.3	1,003.6	1,943.1	40,307.2	$4,519,526	$488,590	$202,342	$286,405	$9,627,564
2003	22,910.8	3,981.5	135.9	847.7	21,608.8	$2,074,295	$626,811	$54,549	$180,585	$12,275,449
2004	23,733.4	3,085.9	1,027.1	2,869.4	26,821.2	$2,715,448	$507,548	$248,623	$445,648	$13,066,177
2005	24,140.5	3,242.8	210.9	4,959.1	45,525.5	$2,534,615	$539,203	$51,723	$693,559	$26,081,668
2006	26,799.9	5,840.7	1,025.8	5,071.5	43,112.0	$3,446,619	$821,962	$168,442	$720,670	$23,699,611

2007	42,989.7	4,891.1	459.9	2,668.5	31,132.3	$5,026,215	$770,314	$106,682	$297,993	$18,535,146
2008	30,913.2	3,249.0	214.7	2,027.3	27,969.3	$3,468,465	$636,434	$42,368	$247,357	$19,317,666
2009	12,422.3	5,028.7	97.7	1,663.0	60,640.2	$1,784,395	$1,093,425	$18,233	$245,216	$37,944,924
2010	27,829.1	2,053.1	295.5	305.6	80,454.6	$3,659,385	$411,365	$62,002	$135,056	$44,142,917
2011	17,601.6	1,341.2	79.7	779.1	77,678.1	$2,401,169	$325,146	$10,284	$328,353	$43,084,374
2012	17,840.3	3,475.0	138.2	214.0	67,834.2	$3,272,433	$882,035	$27,149	$71,176	$44,759,836
2013	6,028.9	8,072.1	891.9	383.6	54,409.9	$1,313,553	$1,520,649	$178,605	$229,584	$38,552,275
2014	1,418.4	5,009.2	690.6	99.7	24,620.0	$303,563	$1,126,360	$132,626	$78,077	$17,233,682
	Northern California									
1981		1,361.1	213.4	4,820.9	12,824.8		$223,981	$46,048	$317,696	$3,898,935
1982	<0.1	2,060.6	281.6	3,003.7	10,611.3	$43	$372,678	$56,408	$246,887	$2,848,714
1983	<0.1	3,465.2	2,458.5	653.1	961.5	$13	$506,740	$307,431	$118,201	$426,762
1984	0.3	7,164.7	5,486.3	2,432.9	488.0	$265	$794,045	$645,844	$251,586	$256,523
1985	2.2	2,719.0	228.1	1,397.0	3,890.1	$537	$329,330	$58,925	$156,162	$2,004,560
1986	84.5	1,999.9	191.1	1,200.9	6,319.8	$19,234	$245,295	$58,990	$142,295	$1,543,137
1987	47.9	963.0	210.2	1,100.7	5,953.9	$5,292	$117,005	$33,244	$182,953	$1,296,130
1988	3.0	65.2	121.9	1,188.6	5,196.9	$766	$22,364	$30,168	$307,615	$1,221,875
1989	238.0	69.1	41.5	1,684.0	7,149.5	$125,826	$17,626	$32,572	$293,407	$1,575,986
1990	127.1	2,509.9	194.0	2,845.5	8,047.1	$29,945	$312,147	$40,285	$464,354	$1,434,563
1991	985.9	300.8	43.8	2,986.0	8,175.9	$108,392	$53,592	$16,297	$395,771	$1,983,073
1992	3,127.7	386.8	112.2	773.3	8,559.7	$427,523	$86,104	$19,277	$112,846	$1,729,335
1993	676.1	39.5	400.8	1,529.0	7,057.4	$87,130	$14,115	$93,340	$345,821	$2,370,285
1994	2,295.1	40.4	191.7	1,273.8	15,921.3	$549,715	$19,343	$95,994	$333,375	$5,146,045
1995	5,681.2	461.4	109.4	1,203.7	3,197.7	$506,307	$63,541	$77,767	$100,126	$1,037,016
1996	7,988.2	710.5	91.8	3,659.0	5,004.9	$887,870	$95,926	$13,746	$394,713	$1,483,964
1997	13,359.8	3,217.6	329.6	4,050.8	8,490.8	$1,593,521	$436,330	$63,496	$567,970	$2,994,012
1998	10,493.4	1,469.7	39.9	901.7	14.1	$646,581	$148,747	$15,868	$67,473	$15,541
1999	17,475.1	6.5	24.2	1,541.9	306.6	$1,286,623	$11,345	$1,790	$350,294	$81,445
2000	11,367.5	41.1	50.5	6,920.8	7,125.9	$969,290	$6,765	$27,704	$857,189	$1,918,321
2001	7,102.6	172.8		11,704.9	8,026.6	$1,434,262	$20,579		$588,915	$1,847,746
2002	13,779.2	0.3	1.9	2,706.7	25,935.8	$1,329,680	$551	$413	$264,582	$7,008,990
2003	7,920.9	1.0	19.8	705.7	16,729.1	$673,572	$4,361	$2,503	$81,964	$9,468,037
2004	15,837.5	490.0	<0.1	3,890.8	5,735.0	$1,241,378	$52,883	$15	$290,736	$2,958,639
2005	8,509.3	0.4	0.5	6,192.2	1,916.9	$601,000	$746	$325	$383,094	$985,816
2006	17,841.9	31.8	140.9	7,705.0	516.8	$1,651,935	$9,946	$30,460	$568,926	$257,455
2007	34,781.9	123.4	166.8	7,704.4	25.3	$3,192,827	$18,980	$36,252	$803,519	$16,258
2008	26,711.7	206.6	59.5	12,216.0	65.6	$4,100,307	$33,782	$10,842	$1,306,141	$44,942
2009	25,011.9	14.3		978.4	1,183.0	$3,755,614	$2,117		$107,850	$910,780
2010	4,305.5	<0.1	<0.1	717.5	20,137.5	$572,570	$4	$12	$327,609	$11,054,402

2011	10,071.9	14.6		1,822.2	14,487.3	$1,994,875	$1,452		$289,294	$7,947,935
2012	4,241.4	100.3		2,273.5	16,851.3	$945,302	$27,749		$301,596	$11,148,182
2013	895.5	0.1		5,549.2	20,964.2	$177,341	$8		$819,419	$15,015,443
2014	6,165.3	240.3	89.4	10,376.4	53,659.1	$1,654,048	$72,681	$15,952	$1,518,011	$38,461,649
	Pacific Northwest									
1981		<0.1		1.3	0.1		$1		$295	$45
1982		<0.1		5.2	51.3		$41		$9,579	$9,124
1983		8.4		2.9	134.9		$7,842		$5,375	$79,908
1984		3.1		10.1	429.4		$894		$10,007	$199,971
1985		0.4	<0.1	11.7	794.6		$212	$1	$11,869	$318,706
1986		<0.1		22.1	12.0		$1		$19,824	$2,683
1987		1.5		77.6			$521		$58,735	
1988		0.6		40.4	<0.1		$343		$32,618	$1
1989		4.9		61.8	43.6		$1,170		$54,109	$7,684
1990		10.4		50.3			$3,673		$41,797	
1991		0.7	19.3	54.5	<0.1		$210	$2,425	$37,282	$29
1992	3.9	468.2	316.5	41.7	6.1		$2,924	$798	$32,968	$1,606
1993	0.2	310.1	276.6	44.2	59.3		$3,532	$2,660	$27,071	$31,240
1994		285.5	202.3	70.4	105.7		$12,547	$7,744	$48,319	$35,670
1995		197.0	148.6	129.8	111.8		$4,379	$7,190	$77,084	$41,478
1996		126.7	260.5	85.6	104.0		$23,719	$7,978	$63,391	$36,896
1997		1,766.9	373.7	59.1	123.0		$19,630	$830	$41,614	$49,456
1998	9.5	583.7	724.5	102.5	8.8	$6,960	$12,390	$45,447	$60,517	$3,627
1999	776.9	305.8	604.4	97.8	1.1	$87,539	$5,122	$14,198	$66,298	$1
2000	14,369.8	138.2	181.1	78.8	5.7	$1,632,378	$4,696	$5,880	$48,048	$58
2001	23,907.6	692.7	227.9	68.0	1.9	$2,639,249	$41,248	$8,135	$69,531	$261
2002	38,543.5	374.8	20.4	231.8	2.0	$4,527,451	$31,191	$1,303	$72,299	$587
2003	37,178.1	213.8	75.7	252.9	12.2	$4,157,685	$16,806	$1,153	$69,052	$5,105
2004	45,045.3	129.1	132.9	226.5	19.7	$5,827,937	$4,081	$4,670	$68,521	$5,539
2005	51,831.2	341.4	80.4	232.1	14.5	$6,681,387	$29,222	$8,601	$37,300	$5,214
2006	40,032.5	706.2	7.1	169.7	27.2	$4,182,466	$48,287	$391	$37,610	$15,636
2007	46,808.8	740.5	14.8	158.0	0.6	$5,038,135	$58,904	$1,169	$35,467	$295
2008	29,384.3	66.6	48.3	368.6		$7,003,309	$10,142	$415	$91,954	
2009	29,507.0	57.6	2.4	851.3	0.2	$6,955,534	$6,219		$144,578	
2010	33,233.0	51.0	4.0	258.1	7.6	$7,935,687	$3,502	$12	$99,939	
2011	19,032.0	7.4	24.3	212.2	<0.1	$5,335,651	$482	$8,443	$74,687	$1
2012	78,510.6	2,470.9	126.1	217.5	0.1	$16,927,917	$330,665	$10,797	$82,505	
2013	56,746.0	632.0	202.8	128.4	0.1	$13,309,790	$123,446	$30,795	$51,547	
2014	15,572.5	1,717.1	1,043.1	112.4	0.5	$6,849,624	$480,003	$205,787	$57,045	$409

Other										
1981		55.9	6.3	217.1	0.2		$13,099	$2,211	$57,048	$49
1982		48.5	9.5	190.9	0.4		$12,487	$2,602	$35,959	$517
1983		179.4	25.5	144.7	3.9		$30,855	$14,206	$34,345	$2,518
1984		50.0	49.3	110.1	2.7		$13,640	$8,716	$26,765	$1,490
1985		51.8	0.2	28.5	330.3		$14,466	$117	$6,685	$180,476
1986		3.1	0.1	21.4	424.1		$1,362	$62	$4,910	$65,222
1987	<0.1	9.0		37.6	199.2	$13	$2,081		$9,811	$30,899
1988	0.1	4.0	<0.1	36.6	592.1	$20	$2,514	$41	$9,520	$127,270
1989	0.2	4.9	0.1	31.7	506.8	$186	$4,252	$41	$9,786	$84,154
1990	0.3	17.3	<0.1	10.5	0.3	$100	$9,471	$7	$3,425	$208
1991		11.8	0.1	23.8	2.6		$5,640	$89	$6,311	$1,088
1992	<0.1	8.1	0.3	3.3	26.5	$13	$4,563	$189	$1,405	$4,680
1993	0.7	13.4	<0.1	7.9	3,479.5	$642	$6,976	$34	$2,492	$736,270
1994		64.6	<0.1	9.1	5,553.0		$19,493	$6	$2,549	$1,090,655
1995	77.5	20.2	21.9	0.1	7,273.2	$9,037	$11,448	$12,118	$63	$2,112,674
1996	180.3	35.2	19.6	2.2	13,908.6	$45,687	$17,409	$6,497	$750	$3,750,551
1997	36.1	4.8		2.4	9,445.5	$69,809	$2,668		$810	$2,516,549
1998	0.9	0.1			475.0	$69	$160			$233,784
1999	3.0	0.2	0.8	0.1	11,314.8	$290	$21	$467	$6	$4,023,453
2000	49.0	0.6	<0.1	<0.1	18,154.9	$7,266	$190	$2	$73	$3,959,194
2001	70.4	0.4	0.1		7,038.8	$6,964	$362	$96		$1,280,032
2002	9.2	<0.1	<0.1		6,634.6	$1,081	$78	$7		$1,622,351
2003	1,547.2	16.8		122.9	6,717.8	$128,010	$1,848		$10,312	$3,642,133
2004	23.1	2.9	<0.1	32.4	7,540.0	$3,764	$947	$15	$14,276	$3,770,659
2005	97.4	1.1	1.9	30.7	8,297.7	$14,481	$195	$721	$13,075	$4,397,838
2006	6.3	30.9		14.2	5,530.1	$1,536	$731		$7,807	$2,991,174
2007	51.6	4.0	4.6	16.9	18,317.3	$1,253	$1,129	$978	$1,896	$10,544,661
2008	80.6	75.3		41.7	10,065.8	$6,831	$16,626		$11,666	$7,094,436
2009	80.2	37.1	20.9	26.7	31,283.7	$3,550	$1,839	$1,002	$17,350	$18,017,865
2010	1,084.2	3.0	14.2	2.4	30,264.8	$134,165	$26	$641		$15,963,063
2011	13.8	1.5	0.3		29,392.0	$2,344	$16			$15,535,227
2012	165.2	23.9	7.3		13,048.0	$30,994	$4,108	$1,061		$8,116,582
2013	115.7	0.4	<0.1	<0.1	29,031.0	$26,311	$73	$8	$15	$20,166,193
2014	79.7	76.6	0.7		7,921.4	$20,224	$12,149	$96		$5,411,490

Source: PacFIN - 2012-2011 data extracted March 29,2015.

[2]Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

Table 6-3. Average annual real[1] exvessel prices (2013 $) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid, 1981-2014.

	Pacific Sardine	Pacific Mackerel	Jack Mackerel	Anchovy	Squid
Year	**$/lb**	**$/lb**	**$/lb**	**$/lb**	**$/lb**
1981	$0.09	$0.09	$0.09	$0.03	$0.10
1982	$0.12	$0.09	$0.09	$0.02	$0.10
1983	$0.08	$0.09	$0.08	$0.04	$0.19
1984	$0.39	$0.09	$0.07	$0.06	$0.23
1985	$0.11	$0.08	$0.09	$0.07	$0.18
1986	$0.10	$0.07	$0.08	$0.07	$0.10
1987	$0.07	$0.06	$0.07	$0.10	$0.09
1988	$0.07	$0.07	$0.07	$0.12	$0.09
1989	$0.11	$0.07	$0.07	$0.13	$0.08
1990	$0.05	$0.06	$0.06	$0.09	$0.08
1991	$0.05	$0.08	$0.07	$0.07	$0.07
1992	$0.05	$0.10	$0.07	$0.09	$0.08
1993	$0.05	$0.06	$0.06	$0.11	$0.11
1994	$0.06	$0.06	$0.06	$0.13	$0.12
1995	$0.04	$0.06	$0.07	$0.08	$0.14
1996	$0.04	$0.06	$0.06	$0.07	$0.12
1997	$0.05	$0.06	$0.07	$0.06	$0.13
1998	$0.04	$0.05	$0.10	$0.07	$0.25
1999	$0.04	$0.05	$0.06	$0.08	$0.16
2000	$0.05	$0.06	$0.08	$0.06	$0.10
2001	$0.05	$0.07	$0.07	$0.03	$0.09
2002	$0.05	$0.06	$0.09	$0.06	$0.11
2003	$0.04	$0.07	$0.11	$0.08	$0.26
2004	$0.05	$0.07	$0.10	$0.05	$0.22
2005	$0.05	$0.07	$0.09	$0.04	$0.26
2006	$0.05	$0.06	$0.08	$0.05	$0.25
2007	$0.05	$0.07	$0.10	$0.05	$0.27
2008	$0.08	$0.09	$0.08	$0.05	$0.31
2009	$0.08	$0.10	$0.07	$0.07	$0.28
2010	$0.08	$0.09	$0.09	$0.20	$0.25
2011	$0.09	$0.11	$0.08	$0.11	$0.25
2012	$0.09	$0.09	$0.06	$0.08	$0.30
2013	$0.11	$0.09	$0.09	$0.08	$0.32
2014	$0.17	$0.11	$0.09	$0.07	$0.32

Source: PacFIN - 2012-2014 data extracted March 29, 2015.
2Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

Table 6-4. West coast landings (mt) and real[1] exvessel revenues (2013 $) for Pacific sardine, Pacific mackerel[2], jack mackerel, anchovy and market squid by state, 1981-14.

Year	Pacific Sardine mt	Pacific Sardine Rev	Pacific Mackerel mt	Pacific Mackerel Rev	Jack Mackerel mt	Jack Mackerel Rev	Anchovy mt	Anchovy Rev	Squid mt	Squid Rev
	California									
1981	15	$3,018	35388	$7,282,560	17778	$3,653,556	52308	$3,273,146	23510	$5,077,845
1982	2	$538	36,065	$7,263,704	19,617	$3,983,940	42,150	$2,155,298	16,308	$3,575,460
1983	1	$175	41,471	$8,027,282	9,829	$1,792,251	4,427	$411,919	1,824	$758,016
1984	1	$868	44,083	$8,278,978	9,154	$1,369,090	2,889	$405,086	564	$302,733
1985	6	$1,414	37,772	$6,563,354	6,876	$1,292,059	1,626	$226,720	10,276	$3,964,238
1986	388	$82,680	48,089	$7,783,353	4,777	$828,421	1,535	$214,691	21,278	$4,515,912
1987	439	$63,116	46,724	$6,675,310	8,020	$1,194,126	1,390	$250,737	19,984	$3,954,945
1988	1,188	$171,522	50,863	$8,213,158	5,068	$795,811	1,478	$384,462	37,316	$7,559,111
1989	837	$195,162	47,708	$7,053,104	10,745	$1,657,311	2,449	$643,501	40,974	$7,513,931
1990	1,664	$190,583	40,081	$5,353,971	3,254	$442,694	3,208	$583,431	28,447	$4,729,885
1991	7,587	$892,955	32,066	$5,340,839	1,693	$246,229	4,014	$614,028	37,389	$6,072,296
1992	18,052	$1,875,359	18,577	$4,003,864	1,209	$238,047	1,124	$190,769	13,112	$2,444,532
1993	15,236	$1,535,750	11,776	$1,496,101	1,673	$272,723	1,959	$450,866	42,830	$10,269,455
1994	11,644	$1,515,282	10,008	$1,424,242	2,704	$373,580	1,789	$502,198	55,377	$14,340,365
1995	40,256	$3,556,901	8,626	$1,145,903	1,728	$284,623	1,886	$291,575	70,252	$22,320,060
1996	32,553	$3,151,710	9,603	$1,293,504	2,177	$296,896	4,419	$637,039	80,561	$21,863,045
1997	43,290	$4,440,711	18,401	$2,761,628	1,160	$246,333	5,720	$769,966	70,265	$20,629,574
1998	43,311	$3,620,574	20,978	$2,526,402	1,052	$335,419	1,481	$184,615	2,895	$1,623,739
1999	59,557	$5,088,963	8,788	$1,088,706	952	$187,629	5,189	$887,961	92,039	$33,353,590
2000	53,612	$5,467,758	21,920	$2,925,668	1,269	$254,701	11,753	$1,397,766	118,815	$27,219,338
2001	51,893	$6,288,144	6,925	$1,096,250	3,624	$561,817	19,277	$1,364,025	86,384	$16,964,123
2002	58,353	$5,850,287	3,369	$489,218	1,005	$202,761	4,650	$550,987	72,878	$18,258,905
2003	34,745	$2,875,877	3,999	$633,021	156	$57,052	1,676	$272,861	45,056	$25,385,618
2004	44,305	$3,960,590	3,579	$561,378	1,027	$248,653	6,793	$750,660	40,096	$19,795,475
2005	34,633	$3,150,095	3,244	$540,144	213	$52,768	11,182	$1,089,729	55,740	$31,465,322
2006	46,577	$5,100,090	5,904	$832,639	1,167	$198,902	12,791	$1,297,402	49,159	$26,948,240
2007	80,980	$8,220,294	5,018	$790,424	631	$143,912	10,390	$1,103,408	49,475	$29,096,065
2008	57,806	$7,575,603	3,531	$686,842	274	$53,210	14,285	$1,565,164	38,101	$26,457,043
2009	37,577	$5,543,558	5,080	$1,097,381	119	$19,234	2,668	$370,416	93,107	$56,873,568
2010	33,659	$4,366,119	2,056	$411,394	310	$62,655	1,026	$462,664	130,857	$71,160,383

2011	27,714	$4,398,389	1,357	$326,614	80	$10,285	2,601	$617,647	121,557	$66,567,537
2012	23,044	$4,248,728	3,599	$913,892	145	$28,210	2,488	$372,772	97,733	$64,024,600
2013	7,146	$1,517,204	8,073	$1,520,729	892	$178,614	5,933	$1,049,018	104,405	$73,733,910
2014	7,672	$1,977,834	5,326	$1,211,191	781	$148,674	10,476	$1,596,088	86,201	$61,106,822
	Oregon									
1981			<1	1					<1	45
1982			<1	$41			<1	$100	51	$9,124
1983			8	$7,804					135	$79,908
1984			3	$808					429	$199,971
1985			<1	$2	<1	$1	<1	$39	795	$318,706
1986			<1	$1					12	$2,683
1987			1	$521						
1988			1	$343			<1	$1	<1	$1
1989			5	$1,120			<1	$15	44	$7,684
1990			10	$3,607						
1991			<1	$170	19	$2,425			<1	$29
1992	4		462	$155	317	$799			6	$1,606
1993			280	$858	277	$2,660			59	$31,240
1994			252	$9,609	202	$7,744	1	$200	106	$35,670
1995			189	$3,562	149	$7,190	<1	$485	112	$41,478
1996			61	$3,824	258	$7,667			104	$36,896
1997			1,611	$2,288	373	$750			123	$49,456
1998	1	$775	538	$8,636	686	$43,749			9	$3,627
1999	776	$85,889	259	$1,008	496	$4,644			1	$1
2000	9,528	$1,112,940	119	$2,600	161	$3,645	<1	$300	6	$58
2001	12,780	$1,548,230	322	$1,364	196	$2,814			2	$261
2002	22,711	$2,624,471	127	$2,426	9	$23	3	$1,697	2	$587
2003	25,258	$2,716,680	160	$9,304	74	$1,020	39	$3,111	12	$5,105
2004	36,111	$4,600,302	107	$1,761	126	$3,450	13	$4,611	20	$5,539
2005	45,110	$5,858,819	318	$26,699	70	$6,742	68	$1,560	14	$5,214
2006	35,668	$3,743,074	665	$34,874	5	$90	9	$17	27	$15,636
2007	42,144	$4,551,001	702	$49,668	14	$990	5	$2,220	1	$295
2008	22,949	$5,665,290	58	$7,811	46	$415	260	$56,674		
2009	21,481	$5,290,596	53	$4,766	2		39	$8,678		
2010	20,852	$5,252,316	49	$2,872	3		138	$28,869	8	
2011	11,023	$3,191,592	7	$372	14	$2,838	21	$6,558	<1	$1

2012	42,619	$8,976,817	1,779	$171,178	95	$5,383				
2013	26,289	$6,299,323	439	$79,831	123	$12,358	13	$4,108		
2014	7,789	$3,521,759	1,172	$324,624	800	$146,577			<1	$409
	Washington									
1981							1	295		
1982							5	$9,479		
1983			<1	$38			3	$5,375		
1984			<1	$86			10	$10,007		
1985			<1	$210			12	$11,830		
1986							22	$19,824		
1987							78	$58,735		
1988							40	$32,617		
1989			<1	$50			62	$54,094		
1990			<1	$75			50	$41,797		
1991			<1	$40			54	$37,282		
1992			6	$2,769			42	$32,968		
1993			30	$2,674			44	$27,071		
1994			33	$2,938			70	$48,119		
1995			7	$817			130	$76,599		
1996			65	$19,895	3	$311	86	$63,391		
1997			156	$17,342	1	$80	59	$41,614		
1998	8	$6,185	46	$3,754	39	$1,698	103	$60,517		
1999	1	$1,650	47	$4,114	108	$9,554	98	$66,298		
2000	4,842	$519,438	19	$2,096	20	$2,235	79	$47,748		
2001	11,127	$1,091,019	371	$39,884	32	$5,321	68	$69,531		
2002	15,833	$1,902,980	248	$28,765	12	$1,280	229	$70,602		
2003	11,920	$1,441,005	54	$7,502	2	$133	214	$65,941		
2004	8,934	$1,227,635	22	$2,320	7	$1,220	213	$63,910		
2005	6,721	$822,568	24	$2,523	11	$1,859	164	$35,740		
2006	4,364	$439,392	41	$13,413	2	$301	161	$37,593		
2007	4,665	$487,134	38	$9,236	1	$179	153	$33,247		
2008	6,435	$1,338,019	9	$2,331	3		109	$35,280		
2009	8,026	$1,664,938	4	$1,453			812	$135,900		
2010	12,381	$2,683,371	2	$630	1	$12	120	$71,070		
2011	8,009	$2,144,059	<1	$110	10	$5,605	191	$68,129		
2012	35,892	$7,951,100	692	$159,487	31	$5,414	217	$82,505		

2013	30,457	$7,010,467	193	$43,615	80	$18,437	116	$47,439		
2014	7,784	$3,327,865	545	$155,379	243	$59,210	112	$57,045		

Source: PacFIN - 2012-2014 data extracted March 29, 2015.
[2]Pacific mackerel landings and revenues also include landings and revenues of unspecified mackerel.

Table 6-5. West coast CPS landings (mt) and real[1] exvessel revenues (2014 $) by gear group, 1981-2014.

Year	**Roundhaul or Lampara**	**Dip Net**	**Pot or Trap**	**Trawl**	**Hook and Line**	**Gillnet**	**Other or Unknown**
	Landings (metric tons)						
1981	120,578	8,231	<1	11	9	79	
1982	110,254	3,693	52	13	27	81	
1983	57,078	490	<1	9	2	44	40
1984	56,712	64	<1	6	1	189	
1985	56,288	495	1	20	9	430	<1
1986	75,795	88	4	3	<1	133	
1987	75,048	213	1	6	7	1,314	<1
1988	94,190	140	1	39	1	1,395	<1
1989	102,070	248	<1	132	3	100	
1990	76,010	489	1	15	34	72	
1991	81,817	724	37	128	4	63	
1992	47,666	4,322	3	808	15	31	
1993	68,249	5,171	2	595	3	44	
1994	78,449	2,997	59	511	49	11	13
1995	121,050	1,410	1	387	121	9	42
1996	128,457	855	1	402	64	31	
1997	138,571	236	<1	2,190	90	18	
1998	69,672	37	<1	1,339	44	6	
1999	166,703	528	72	962	12	10	
2000	219,825	1,563	45	281	215	4	141
2001	190,411	1,791	1	636	120	3	
2002	178,638	761	<1	12	10	2	
2003	123,129	133	<1	85	12	<1	<1
2004	140,330	790	<1	115	8	<1	63
2005	154,875	2,504	11	106	9	<1	
2006	154,752	1,582	83	33	84	<1	
2007	193,348	826	<1	15	25	<1	<1
2008	143,364	444		51	3	<1	
2009	167,133	1,831	<1	2	3	<1	
2010	198,085	3,304	31	12	2	2	
2011	168,258	4,301		25	<1	<1	<1
2012	202,889	5,319	<1	47	7	1	<1
2013	180,741	3,223	43	126	22	1	<1
2014	128,186	293	13	316	51	<1	6

Table 6-5, continued

Year	Roundhaul or Lampara	Dip Net	Pot or Trap	Trawl	Hook and Line	Gillnet	Other or Unknown
	Revenues						
1981	$18,385,887	$837,365	$149	$3,923	$4,786	$28,701	
1982	$16,472,812	$453,188	$11,159	$4,263	$8,793	$23,992	
1983	$10,849,406	$191,941	$927	$3,330	$1,317	$13,276	$7,040
1984	$10,428,830	$34,720	$1,765	$2,756	$935	$48,658	
1985	$11,886,900	$311,346	$699	$9,200	$3,892	$131,792	$830
1986	$13,347,151	$26,573	$1,025	$1,887	$131	$40,859	
1987	$11,873,522	$40,619	$1,946	$2,379	$1,768	$244,597	$9
1988	$16,790,882	$32,533	$705	$29,090	$495	$252,703	$1
1989	$16,831,629	$42,856	$43	$29,879	$870	$25,068	
1990	$11,194,170	$45,967	$731	$6,605	$28,860	$29,595	
1991	$13,058,904	$53,766	$6,867	$23,773	$4,656	$18,588	
1992	$8,234,277	$477,450	$1,908	$8,706	$19,573	$11,219	
1993	$13,199,342	$784,529	$1,743	$8,535	$3,575	$18,957	
1994	$17,645,932	$469,382	$17,589	$28,174	$41,213	$5,551	$2,403
1995	$27,194,028	$361,157	$526	$17,816	$53,475	$4,586	$8,975
1996	$27,023,423	$190,155	$495	$39,977	$62,480	$15,497	
1997	$28,699,975	$80,974	$100	$45,886	$91,153	$8,373	
1998	$8,242,660	$24,660	$135	$77,097	$57,897	$3,010	
1999	$40,499,923	$188,043	$15,884	$36,073	$25,416	$5,924	
2000	$38,456,636	$392,481	$10,088	$10,442	$38,407	$1,892	$14,643
2001	$28,552,344	$383,367	$398	$28,813	$34,291	$1,627	
2002	$29,766,977	$186,258	$293	$2,341	$24,111	$1,311	
2003	$33,361,814	$74,381	$66	$6,056	$27,405	$121	$19
2004	$30,791,296	$372,100	$2	$3,449	$19,796	$102	$34,501
2005	$41,529,484	$1,486,631	$6,268	$14,307	$16,506	$156	
2006	$37,754,406	$861,199	$7,180	$15,467	$20,233	$172	
2007	$43,951,737	$502,026	$30	$3,448	$27,119	$67	$39
2008	$43,132,322	$296,145	$0	$1,689	$10,698	$39	
2009	$69,942,757	$1,045,944	$23	$472	$18,293	$183	
2010	$82,660,943	$1,796,001	$16,819	$970	$11,819	$1,047	
2011	$74,636,218	$2,691,494		$9,062	$31	$55	$90
2012	$83,210,572	$3,651,172	$241	$5,926	$19,291	$3,438	$38
2013	$89,153,183	$2,290,778	$30,463	$19,159	$17,485	$385	$8
2014	$73,301,802	$214,640	$2,253	$42,201	$37,038	$78	$4,333
Source: PacFIN - 2012-2014 data extracted March 29, 2015.							

TABLE 8-1. Commercial landings (metric tons) of CPS in Ensenada, Baja California, Mexico, for calendar years 2000-2015[1/,2/,3/,4/5]. Sardine landings include both southern and northern subpopulations.

Year	Pacific sardine	Northern anchovy	Pacific mackerel	Jack mackerel	Market squid
2000	67,845	1,562	7,182	0	na
2001	46,071	76	4,078	0	na
2002	46,845	0	7,962	0	na
2003	41,342	1,287	2,678	0	na
2004	41,897	1,797	1,530	0	na
2005	55,323	4,873	2,343	0	72
2006	57,237	1,567	2,318	0	554
2007	36,847	4,058	3,057	0	415
2008	66,866	991	180	0	5,378
2009	55,911	2,444	8	0	3,685
2010	56,821	3,139	85	0	10,991
2011	70,336	1,760	2,601	0	15,091
2012	59,069	1,809	186	0	4,802
2013	51,413	2,428	327	0	16,707
2014	90,396	539	975	0	2,978
2015	37,468	46,850	1,219	0	63

1/ Data for 2000 to 2002 from García and Sánchez (2003).
2/ Data for 2003 provided by Dr. Celia Eva-Cotero, INAPESCA-Ensenada (pers. comm.).
3/ Data for 2004 provided by Dr. Manuel O. Nevarrez, INAPESCA-Guaymas (pers. comm.).
4/ Data for 2005-2015 from CONAPESCA (http://www.conapesca.sagarpa.gob.mx/wb/cona/cona_anuario_estadistico_de_pesca).
5/ Anchovy landings for 2015 range from 26,143 mt (CONAPESCA statistics) to 46,850 mt (Concepcion Enciso-Enciso, pers. comm., 2015 Trinational Sardine Forum presentation).

TABLE 8-2. Pacific sardine northern subpopulation biomass-at-age and summary biomass (Hill et al. 2016).

Model year	POPULATION BIOMASS-AT-AGE (metric tons)									SUMMARY BIOMASS	
(July-1)	0	1	2	3	4	5	6	7	8+	Ages 0+	Ages 1+
1993	54,514	169,893	82,329	53,218	34,192	26,940	21,019	22,918	49,615	514,637	460,123
1994	50,502	168,567	222,510	78,938	44,108	26,123	19,591	14,821	49,409	674,570	624,068
1995	16,874	153,856	206,290	200,564	63,056	33,008	18,744	13,671	43,303	749,366	732,492
1996	27,046	51,769	194,404	191,440	163,020	47,648	23,833	13,144	38,536	750,840	723,794
1997	86,420	82,963	64,887	177,661	153,731	122,403	34,297	16,683	34,922	773,967	687,548
1998	60,986	264,146	101,897	57,959	140,509	114,474	87,683	23,928	34,841	886,423	825,437
1999	10,100	184,128	308,032	87,200	44,731	103,112	81,148	60,636	39,469	918,555	908,455
2000	11,090	28,657	208,011	274,405	70,103	33,499	73,605	56,169	67,387	822,928	811,837
2001	23,063	30,843	30,323	173,530	210,634	50,418	22,977	48,951	79,800	670,539	647,477
2002	2,862	60,597	29,692	24,157	129,098	147,098	33,591	14,846	80,648	522,589	519,727
2003	113,533	7,279	53,349	21,805	16,920	85,287	92,707	20,526	56,271	467,677	354,144
2004	54,925	337,485	8,368	43,507	15,482	10,999	52,448	55,138	43,981	622,333	567,408
2005	94,741	166,137	417,266	7,145	29,903	9,403	6,259	28,796	52,715	812,364	717,624
2006	29,083	285,559	207,485	368,097	5,126	19,063	5,630	3,619	45,568	969,228	940,145
2007	45,458	86,549	347,469	185,133	280,688	3,557	12,516	3,576	30,037	994,984	949,526
2008	15,555	131,706	96,376	287,468	137,197	192,774	2,320	7,907	20,356	891,658	876,103
2009	44,229	44,305	143,523	79,863	215,319	95,556	127,695	1,489	17,440	769,418	725,189
2010	12,396	127,540	50,393	122,884	59,983	148,535	62,505	80,862	11,481	676,580	664,184
2011	1,810	35,980	147,709	43,341	90,579	40,171	94,027	38,272	55,215	547,105	545,295
2012	548	5,010	36,413	113,804	30,406	59,079	24,893	56,420	54,506	381,079	380,531
2013	827	1,419	4,842	27,458	69,621	16,260	29,494	11,981	51,790	213,692	212,865
2014	3,039	2,162	1,384	3,625	16,563	36,603	7,971	13,934	29,043	114,324	111,285
2015	14,851	9,217	2,576	1,131	2,504	10,350	21,563	4,537	23,598	90,326	75,476
2016	---	46,274	12,468	2,534	951	1,927	7,562	15,260	19,159	---	106,137

TABLE 8-3. U.S. Pacific sardine landings (PacFIN) and harvest guidelines (HG) in metric tons since onset of management under the federal CPS-FMP. Landings include both the southern and northern subpopulations.

					HARVEST LIMITS		
Management year	CA	OR	WA	U.S. Total	OFL	ABC	HG/ACL
2000	53,611	9,528	4,842	67,981	n/a	n/a	186,791
2001	51,893	12,780	11,127	75,801	n/a	n/a	134,737
2002	58,353	22,711	15,833	96,896	n/a	n/a	118,442
2003	34,746	25,258	11,920	71,923	n/a	n/a	110,908
2004	44,305	36,111	8,936	89,351	n/a	n/a	122,747
2005	34,633	45,110	6,722	86,465	n/a	n/a	136,179
2006	46,577	35,668	4,364	86,609	n/a	n/a	118,937
2007	80,980	42,144	4,665	127,789	n/a	n/a	152,564
2008	57,805	22,949	6,435	87,189	n/a	n/a	89,093
2009	37,577	21,482	8,026	67,085	n/a	n/a	66,932
2010	33,658	20,853	12,392	66,903	n/a	n/a	72,039
2011	27,715	11,023	8,009	46,747	92,767	84,681	50,526
2012	23,044	42,666	35,739	101,448	154,781	141,289	109,409
2013	7,146	26,288	30,461	63,895	103,284	94,281	66,495
2014 (Jan-Jun)	5,647	0	908	6,555	59,214	54,052	(6,966)
2014-15	3,754	9,920	6,907	20,581	39,210	35,792	23,293
2015-16	158	1	0	159	13,227	12,074	7,000
2016-17	---	---	---	---	23,085	19,236	8,000

TABLE 8-4. West Coast Pacific sardine landings (metric tons) by country, 2000-2015. Landings include both the southern and northern subpopulations.

Year	Ensenada México	United States	B.C. Canada	Total
2000	67,845	67,980	1,721	137,547
2001	46,071	75,800	1,266	123,137
2002	46,845	96,887	739	144,472
2003	41,342	71,921	978	114,240
2004	41,897	89,348	4,438	135,683
2005	55,323	86,464	3,232	145,018
2006	57,237	86,609	1,575	145,421
2007	36,847	127,780	1,522	166,149
2008	66,866	87,186	10,425	164,477
2009	55,911	67,083	15,334	138,328
2010	56,821	66,892	22,223	145,936
2011	70,336	46,746	20,719	137,802
2012	59,069	101,148	19,172	179,389
2013	51,413	63,892	0	115,304
2014	90,396	22,744	0	113,140
2015	37,468	3,833	0	41,301

TABLE 8-5. RecFIN estimated recreational harvest of Pacific (chub) mackerel by state (type 'A+B1' estimate in metric tons), 2000-2015. Estimates from 2000-2003 are based on MRFSS sampling. Estimates from 2004-2015 are based on CRFS and ORBS sampling programs, and are not directly comparable to MRFSS estimates.

Calendar year	CA	OR	WA	Total
2000	250.00	0.07	0.00	250.07
2001	561.39	0.05	0.00	561.44
2002	279.11	0.11	0.00	279.22
2003	341.35	0.27	0.00	341.61
2004	546.44	0.10	0.00	546.53
2005	313.05	0.07	0.00	313.12
2006	464.24	0.11	0.00	464.35
2007	240.73	0.92	0.00	241.65
2008	321.81	0.02	0.00	321.83
2009	237.41	0.06	0.00	237.47
2010	235.59	0.00	0.00	235.59
2011	165.54	0.01	0.00	165.55
2012	143.69	0.19	0.00	143.88
2013	109.67	0.27	0.00	109.94
2014	178.78	0.16	0.00	178.93
2015	306.44	0.54	0.00	306.98

TABLE 8-6. RecFIN estimated recreational harvest of Pacific (chub) mackerel by fishing mode (type 'A+B1' estimate in metric tons), 2000-2015. Estimates from 2000-2003 are based on MRFSS sampling. Estimates from 2004-2015 are based on CRFS and ORBS sampling programs, and are not directly comparable to MRFSS estimates.

Calendar year	Shore Modes	Party/ Charter	Private/ Rental	Total
2000	51.30	76.85	121.92	250.07
2001	347.05	52.23	162.17	561.44
2002	92.88	25.74	160.59	279.22
2003	208.40	25.39	107.82	341.61
2004	406.35	20.28	119.91	546.53
2005	224.99	46.47	41.67	313.12
2006	406.16	15.63	42.57	464.35
2007	187.02	20.20	34.43	241.65
2008	276.35	20.06	25.42	321.83
2009	183.92	13.35	40.21	237.47
2010	201.25	9.47	24.87	235.59
2011	139.17	6.75	19.63	165.55
2012	122.44	7.80	13.64	143.88
2013	79.49	16.56	13.88	109.94
2014	103.91	36.21	38.82	178.93

2015	210.51	32.65	63.82	306.98

TABLE 8-7. Pacific mackerel harvest specifications and commercial and recreational landings in the U.S. (metric tons) by July-June management years since the onset of the federal CPS-FMP.

	HARVEST LIMITS				
Mgmt Year	OFL	ABC	HG/ACL	Directed/ACT	U.S. Landings
2000-01	n/a	n/a	20,740	n/a	19,838
2001-02	n/a	n/a	13,837	6,000	8,391
2002-03	n/a	n/a	12,535	9,500	2,936
2003-04	n/a	n/a	10,652	7,500	4,769
2004-05	n/a	n/a	13,268	9,100	4,484
2005-06	n/a	n/a	17,419	13,419	4,217
2006-07	n/a	n/a	19,845	13,845	7,255
2007-08	n/a	n/a	71,629	40,000	6,636
2008-09	n/a	n/a	51,772	40,000	4,567
2009-10	n/a	n/a	55,408	8,000	3,281
2010-11	n/a	n/a	55,408	11,000	2,304
2011-12	44,336	42,375	40,514	30,386	2,003
2012-13	44,336	42,375	40,514	30,386	5,514
2013-14	57,316	52,358	52,538	39,269	12,007
2014-15	32,992	30,138	29,170	24,170	5,579
2015-16	25,291	23,104	21,469	20,469	4,664
2016-17	24,983	22,822	21,161	20,161	---

Table 9-1. Total landings (mt) of sardines and other species, and number of vessels and processors that participated under Exempted Fishery Permits during 2009-2013. (Source: ODFW and WDFW fish ticket records).

Species	**2009**	**2010**	**2011**	**2012**	**2013**	**5-Year Total**
Sardines	1,178.0	2,013.9	2,699.7	2,914.4	1,526.9	10,333.0
Pacific Mackerel	3.8	9.3	1.2	200.6	13.6	228.4
Jack Mackerel	0.0	0.0	0.0	1.5	0.0	1.5
Jellyfish	2.0	0.0	0.0	0.0	0.0	2.0
Number Vessels	2	3	4	5	2	7
Number Processors	1	1	1	3	1	3

Table 9-2. EFP landings in California. Total landings (mt) of sardines and other species, and number of vessels and processors that participated under Exempted Fishing Permits during 2009-2012. (Sources: Northwest Aerial Sardine Survey, LLC; * NMFS WCR; **CWPA).

Species	**2009**	**2010**
Sardines	1685mt*	1,218.2mt
Pacific Mackerel	756.0mt	9.8mt
Jacksmelt	40.00mt	
Kingfish	412.0mt	
Other spp		0.0
Number Vessels **	2	3
Number Processors **	2	2

PACIFIC MACKEREL BIOMASS PROJECTION ESTIMATE FOR USA MANAGEMENT IN 2017-18 AND 2018-19

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Introduction

Beginning in 2015, the Pacific Fishery Management Council (Council) began an assessment/management schedule for Pacific mackerel (*Scomber japonicus*) based on: 1) conducting a *full* (benchmark) assessment every four years starting in 2015; 2) conducting a catch-only projection assessment every four years starting in 2017; and 3) setting harvest and management guidelines as biennial specifications that serve for two consecutive (fishing) years. In 2015, a full assessment was conducted for purposes of providing management advice that served for two (fishing) years, 2015-16 and 2016-17. A catch-only projection assessment is presented here, which provides harvest guidelines (HG) for managing the Pacific mackerel resource for fishing years 2017-18 and 2018-19. The next benchmark assessment and review will take place during the spring 2019. The most recent management guidelines regarding allowable catches for Pacific mackerel through the 2016-17 fishing year are presented in Table 1.

Methods and Results

Details regarding the assessment model *H3*, which has served as the baseline model for advising management since 2015, are presented in the stock assessment report (see Crone and Hill 2015). The projection model this year was parameterized similarly as the previous catch-only projections conducted in 2013 and 2014 (e.g., see Crone and Hill 2014), whereby only catch time series were updated in model *H3*, with no other changes to data or parameterizations in the model. Also, as for previous projections: 1) sensitivity analysis was conducted to address uncertainty regarding forecasted catch and most importantly, recent recruitment strength that is typically variable and poorly informed in the model; and 2) harvest control rule estimates were based on a tier-2 σ value = 0.72 and probability level (P*) = 0.45 for calculating an acceptable biological catch (ABC), i.e., both σ and P* are presented as placeholders, given final values are based on SSC/PFMC decisions (See Appendices for additional tables that present yields for a range of P* values based on tier-1 and tier 2 categories. Important assessment model information follows, including data, parameterizations, and sensitivity analyses.

- Recent Pacific mackerel landings (catch) are presented in Table 2. See footnotes for particular catch estimates.

- No other data or parameterizations were changed in the baseline model, including no changes to the underlying stock-recruitment relationship (e.g., estimates of virgin recruitment, steepness, and recruitment deviations), growth estimates, natural mortality assumptions, selectivity parameterizations, etc.
- Sensitivity analyses.
  - As performed in past projection analyses, estimated biomass and derived management quantities were robust to alternative catch time series assumed in the model. This sensitivity analysis was conducted to evaluate how uncertainty in predicting future catches affects estimated management quantities (metrics such as OFL, ABC, and HG) from the projection model. Model scenarios assuming both reduced and increased levels for forecasted catch had relatively little influence on estimates of abundance and associated stock status, primarily given that landings have remained at low levels over an extended timeframe.
    - For example, using average catches (2014-16) instead of the HG associated with USA commercial fisheries had a minor impact on management metrics and only for the 2nd year of the projection period, e.g., roughly, 15% increase in yields for fishing year 2018-19.
    - Increasing forecasted landings also had little impact on management quantities and only for the 2nd year of the projection period, e.g., doubling expected landings in the future (which would reflect an extreme case) resulted in roughly 20% reduction in yields for fishing year 2018-19.
    - Finally, note that uncertainty surrounding future catches of Pacific mackerel is largely related to Mexico's contribution to the overall landings in very recent years, with more certainty associated with predicting landings for USA fisheries (at least in the short-term).
  - Derived management quantities were sensitive to alternative assumptions regarding recent recruitment success, which resulted in differences in estimated stock biomass (age 1+ fish, mt) time series used for advising management (Table 3 and Figure 1).
    - In addition to the default projection for the baseline model, two alternative recruitment scenarios were evaluated, including assuming forecasted recruitment was equal to: 1) recent 3-yr average recruitment (2012-14); and historical 3-yr (continuous low) average recruitment (1997-99). See Figure 2 for magnitude of recent vs. historical (low) 3-yr running average for estimated recruitment.
    - Alternative recruitment (age-0 fish) scenarios were implemented internally in the model via adjusting forecast recruitment deviations in an iterative manner over a series of model runs for the projection period. This method of evaluating future recruitment success in an integrated population dynamics model produces results that better reflect the assumptions and parameterizations of the baseline model (i.e., more internally consistent) than fixing recruitment external to the model via adjustments to the estimated number-at-age matrix generated from the model and subsequently, manually implementing fixed levels of both natural (M) and fishing mortality (F) over time. Both the internal and external methods for evaluating different assumptions regarding future recruitment success resulted in generally similar estimates of important management quantities. Finally, only the external method was conducted in past projections.
    - Estimated stock biomass (age-1+ fish, mt) and recruitment (age-0 fish, 1,000s) time series associated with the three recruitment scenarios are presented in Figures 1 and 2, respectively.

References

Crone, P. R., and K. T. Hill. 2014. Pacific mackerel biomass projection estimate for USA management (2014-15). Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220. Agenda Item G.2.b, Projection Estimate Report, June 2014. 3 p. http://www.pcouncil.org/wp-content/uploads/G2b_Pmack_ProjectnEst_JUNE2014BB.pdf

Crone, P.R., and K.T. Hill. 2015. Pacific mackerel (*Scomber japonicus*) stock assessment for USA management in the 2015-16 fishing year. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon, 97220. 131 p. http://www.pcouncil.org/wp-content/uploads/2015/05/G2a_PMackerel_Assmt_Full_E-Only_JUN2015BB.pdf

Table 1. Pacific mackerel harvest specifications for fishing years 2015-16 and 2016-17, which are based on the most recent SSC/PFMC deliberations conducted in June 2015. Acronyms follow: OFL is overfishing limit; $ABC_{0.45}$ is acceptable biological catch for tier-2 σ = 0.72 and P* = 0.45; ACL is acceptable catch limit; HG is harvest guideline; Incidental is incidental catch allowed; and ACT is acceptable catch target.

Harvest statistic	Fishing year	
	2015-16 (mt)	2016-17 (mt)
Biomass	120,435	118,968
OFL	25,291	24,983
$ABC_{0.45}$	23,104	22,822
ACL	23,104	22,822
HG	21,469	21,161
Incidental	1,000	1,000
ACT	20,469	20,161

Table 2. Pacific mackerel landings (mt) for fishing years 2014 to 2018.

Fishing year	Commercial				Recreational	Total
	MX	CA	OR	WA	CA	
2014-15[a]	1,241 (2,825)	3,765 (5,446)	1,215 (1,172)	502 (545)	100 (136)	**6,823** (10,124)
2015-16	4,938	4,367	7	2	99	**9,413**
2016-17[b]	6,551	2,700	6	2	66	**9,325**
2017-18[c]	4,247	NA	NA	NA	88	**30,624**
2018-19[d]	4,247	NA	NA	NA	88	**28,171**

[a]2014-15 catch estimates were updated, given landings included in last assessment (2015) reflected forecasted catches (presented in parentheses).
[b]2016-17 catch estimates reflect forecasted landings, given catch estimates for fishing year 2016-17 were only available through fall 2016 or early winter 2017, depending on the fishery.
[c]2017-18 catch estimates are as follows: MX=avg. catch 2014-16; CA/OR/WA=HG 2017-18; Recreational=avg. catch 2014-16.
[d]2018-19 catch estimates are as follows: MX=avg. catch 2014-16; CA/OR/WA=HG 2018-19; Recreational=avg. catch 2014-16.

Table 3. Pacific mackerel harvest control rules (HCR) for fishing year: A) 2017-18; and B) 2018-19. Acronyms follow: OFL is overfishing limit; ABC is acceptable biological catch; HG is harvest guideline; E_{MSY} is proxy for exploitation rate at maximum sustainable yield; σ is sigma uncertainty level; and P* is the overfishing probability value for ABC calculation. See report for other terms presented in the table. Note that the following HCR table is a placeholder presently, based on previous decisions used in past projections for this stock. See Appendices for HCR tables that present yields associated with tier-1 and tier-2 σ levels across a range of P* values for each recruitment scenario, which are intended to aid the decision process for adopting appropriate levels of uncertainty when setting final management guidelines in June 2017.

A) Fishing year (2017-18)

Harvest control rule formulas

OFL = BIOMASS x E_{MSY} x DISTRIBUTION

ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION

HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION

HCR value	Baseline model	Avg. R (2012-14)	Avg. R (1997-99)
Tier-2 σ	0.72	0.72	0.72
P*	0.45	0.45	0.45
ABC buffer for tier-2 P*=0.45	0.9135	0.9135	0.9135
CUTOFF (mt)	18,200	18,200	18,200
$E_{MSY} \equiv$ FRACTION	0.3	0.3	0.3
DISTRIBUTION (U.S.)	0.7	0.7	0.7
BIOMASS (age-1+ fish, mt)	143,403	152,790	96,436

HCR statistic	Baseline model	Avg. R (2012-14)	Avg. R (1997-99)
OFL (mt)	30,115	32,086	20,252
ABC (mt)	27,510	29,311	18,500
HG (mt)	26,293	28,264	16,430

B) Fishing year (2018-19)

Harvest control rule formulas

OFL = BIOMASS x E_{MSY} x DISTRIBUTION

ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION

HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION

HCR value	Baseline model	Avg. R (2012-14)	Avg. R (1997-99)
Tier-2 σ	0.72	0.72	0.72
P*	0.45	0.45	0.45
ABC buffer for tier-2 P*=0.45	0.9135	0.9135	0.9135
CUTOFF (mt)	18,200	18,200	18,200
$E_{MSY} \equiv$ FRACTION	0.3	0.3	0.3
DISTRIBUTION (U.S.)	0.7	0.7	0.7
BIOMASS (age-1+ fish, mt)	131,724	139,820	58,323

HCR statistic	Baseline model	Avg. R (2012-14)	Avg. R (1997-99)
OFL (mt)	27,662	29,362	12,248
ABC (mt)	25,269	26,822	11,188
HG (mt)	23,840	25,540	8,426

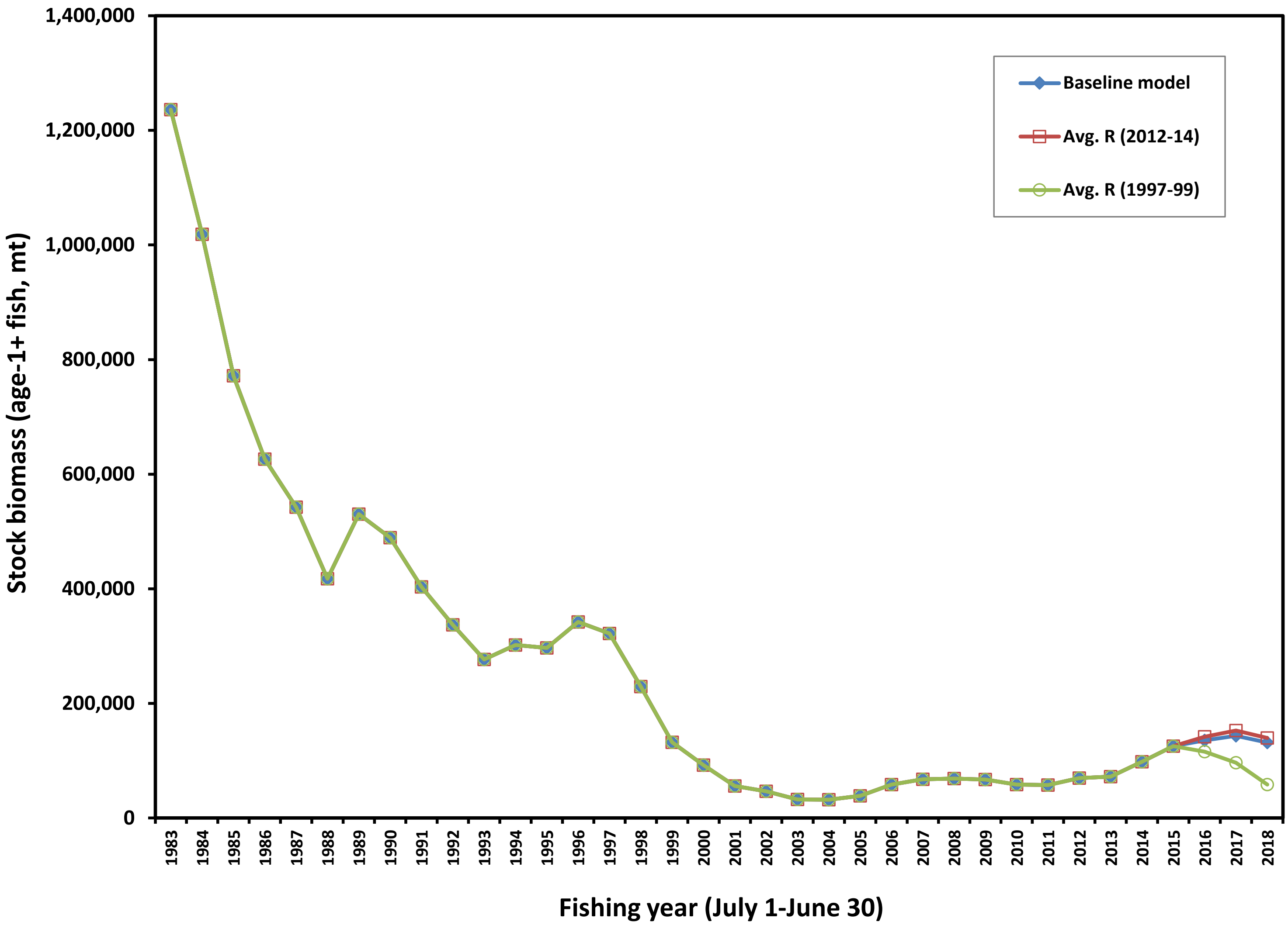

Figure 1. Estimates of Pacific mackerel stock biomass (age 1+ fish, mt) associated with alternative assumptions (model scenarios) regarding recent recruitment success.

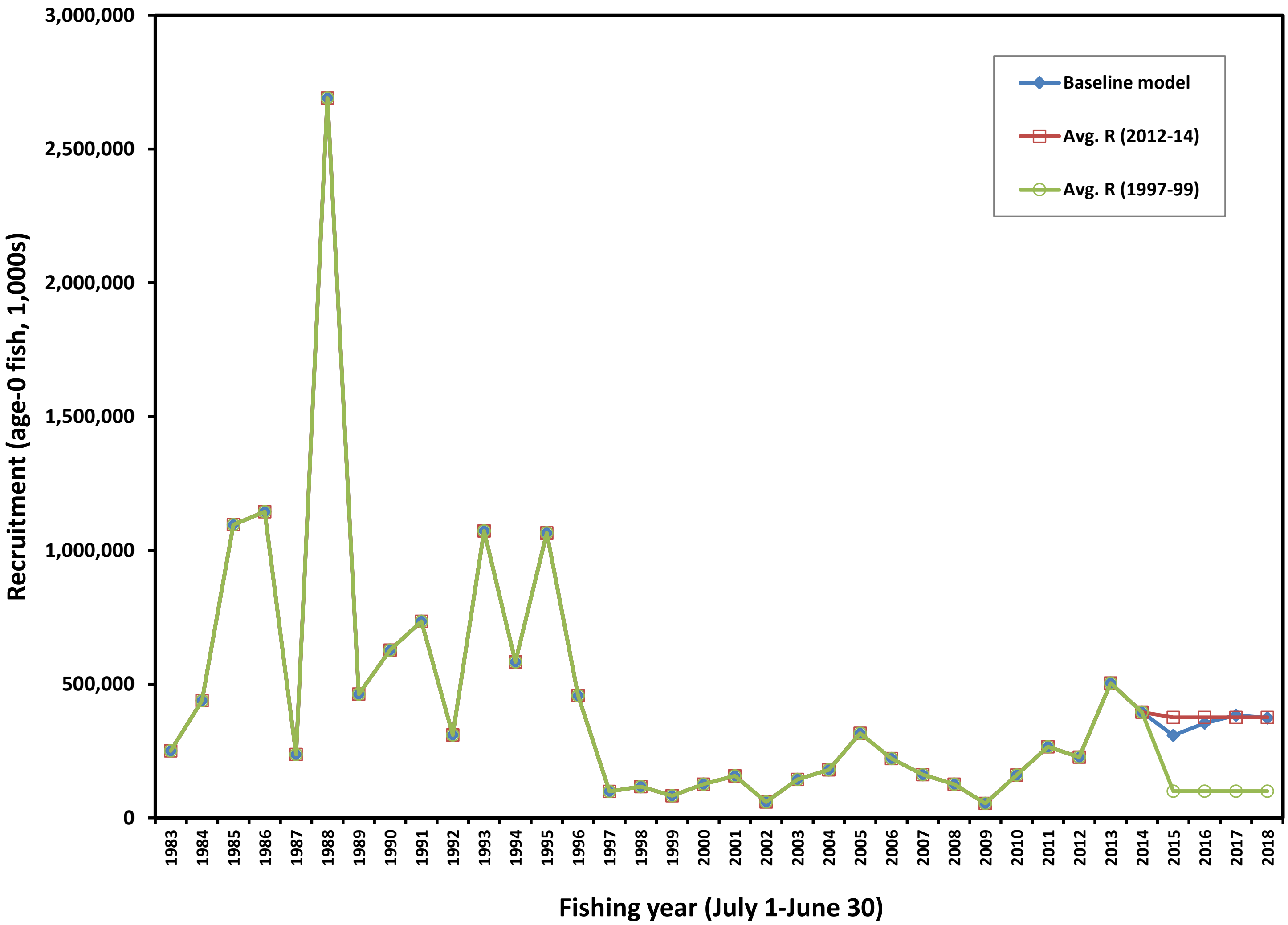

Figure 2. Estimates of Pacific mackerel recruitment (age-0 fish, 1,000s) associated with alternative assumptions (model scenarios) regarding recent recruitment success.

APPENDIX A

Table A1-A3. Pacific mackerel harvest control rule (HCR) tables for baseline model and two alternative recruitment scenarios using the **tier-1 σ category**: A1 is baseline model; A2 is average recruitment (2012-14); and A3 is average recruitment (1997-99). For each recruitment scenario (A1-A3), tables are presented for two consecutive fishing years: A) 2017-18; and B) 2018-19. See Table 3 for acronym definitions.

A1) Baseline model

A) Fishing year (2017-18)

Harvest Control Rule Formulas									
OFL = BIOMASS * E_{MSY} * DISTRIBUTION									
ABC_{P*} = BIOMASS * $BUFFER_{P*}$ * E_{MSY} * DISTRIBUTION									
HG = (BIOMASS - CUTOFF) * E_{MSY} * DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	143,403								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\text{-}1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**30,115**								
$ABC_{Tier\text{-}1}$ =	28,783	27,490	26,214	24,934	23,622	22,243	20,736	18,985	16,658
HG =	**26,293**								

B) Fishing year (2018-19)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	131,724								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\text{-}1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**27,662**								
$ABC_{Tier\text{-}1}$ =	26,439	25,251	24,079	22,903	21,699	20,431	19,048	17,439	15,301
HG =	**23,840**								

A2) Average recruitment (2012-14)

A) Fishing year (2017-18)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	152,790								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**32,086**								
ABC_{Tier-1} =	30,667	29,289	27,930	26,566	25,169	23,699	22,094	20,228	17,748
HG =	**28,264**								

B) Fishing year (2018-19)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	139,820								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**29,362**								
ABC_{Tier-1} =	28,064	26,803	25,559	24,311	23,032	21,687	20,218	18,511	16,241
HG =	**25,540**								

A3) Average recruitment (1997-99)

A) Fishing year (2017-18)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	96,436								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**20,252**								
ABC_{Tier-1} =	19,356	18,486	17,628	16,768	15,886	14,958	13,945	12,767	11,202
HG =	**16,430**								

B) Fishing year (2018-19)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	58,323								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**12,248**								
ABC_{Tier-1} =	11,706	11,180	10,661	10,141	9,607	9,046	8,434	7,721	6,775
HG =	**8,426**								

APPENDIX B

Table B1-B3. Pacific mackerel harvest control rule (HCR) tables for baseline model and two alternative recruitment scenarios using the **tier-2 σ category**: B1 is baseline model; B2 is average recruitment (2012-14); and B3 is average recruitment (1997-99). For each recruitment scenario (B1-B3), tables are presented for two consecutive fishing years: A) 2017-18; and B) 2018-19. See Table 3 for acronym definitions.

B1) Baseline model

A) Fishing year (2017-18)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	143,403								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**30,115**								
ABC_{Tier-2} =	27,510	25,093	22,819	20,644	18,530	16,429	14,279	11,969	9,214
HG =	**26,293**								

B) Fishing year (2018-19)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) * E_{MSY} * DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	131,724								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**27,662**								
ABC_{Tier-2} =	25,269	23,050	20,960	18,963	17,021	15,091	13,116	10,994	8,464
HG =	**23,840**								

B2) Average recruitment (2012-14)

A) Fishing year (2017-18)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	152,790								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**32,086**								
ABC_{Tier-2} =	29,310	26,736	24,312	21,996	19,743	17,504	15,214	12,752	9,817
HG =	**28,264**								

B) Fishing year (2018-19)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	139,820								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier-2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**29,362**								
ABC_{Tier-2} =	26,822	24,466	22,249	20,129	18,067	16,018	13,922	11,670	8,984
HG =	**25,540**								

B3) Average recruitment (1997-99)

A) Fishing year (2017-18)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	96,436								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\text{-}2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**20,252**								
$ABC_{Tier\text{-}2}$ =	18,500	16,875	15,345	13,883	12,461	11,048	9,602	8,049	6,196
HG =	**16,430**								

B) Fishing year (2018-19)

Harvest Control Rule Formulas									
OFL = BIOMASS x E_{MSY} x DISTRIBUTION									
ABC_{P*} = BIOMASS x $BUFFER_{P*}$ x E_{MSY} x DISTRIBUTION									
HG = (BIOMASS - CUTOFF) x E_{MSY} x DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	58,323								
P*	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\text{-}2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060
E_{MSY} ≡ FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.7								
Harvest Control Rule Values (MT)									
OFL =	**12,248**								
$ABC_{Tier\text{-}2}$ =	11,188	10,206	9,280	8,396	7,536	6,682	5,807	4,868	3,747
HG =	**8,426**								

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
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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:

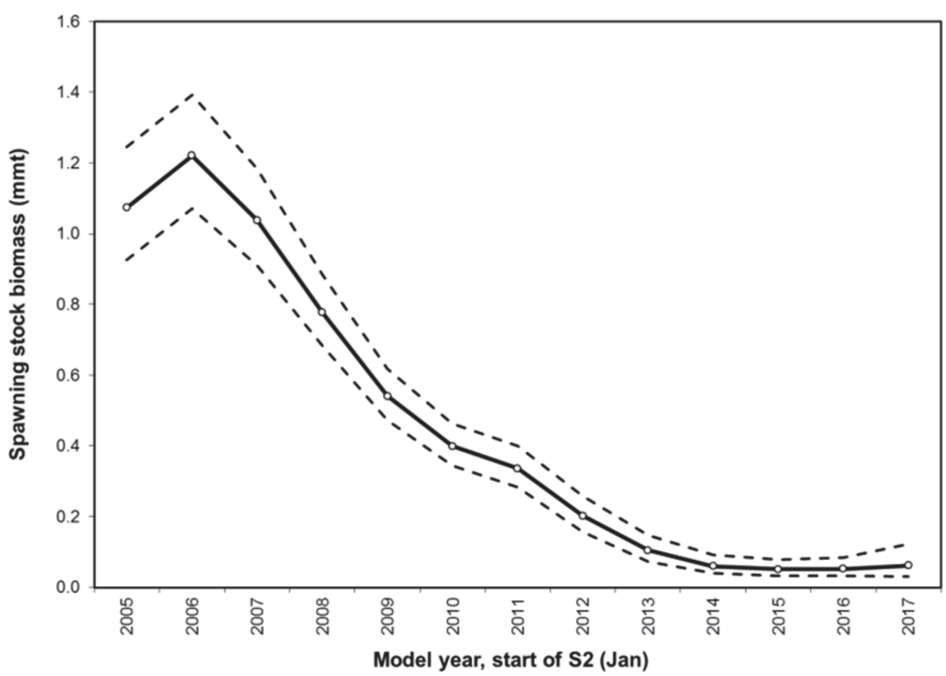
- NSP catches for the MEXCAL fleet computed using an environmental-based optimal habitat index;
- two seasons (semesters, Jul-Dec=S1 and Jan-Jun=S2) for each model year (2005-16);
- sexes were combined;
- maximum age=10, with nine age bins (ages 0-8+);
- two fleets (MEXCAL and PNW), with an annual selectivity 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);

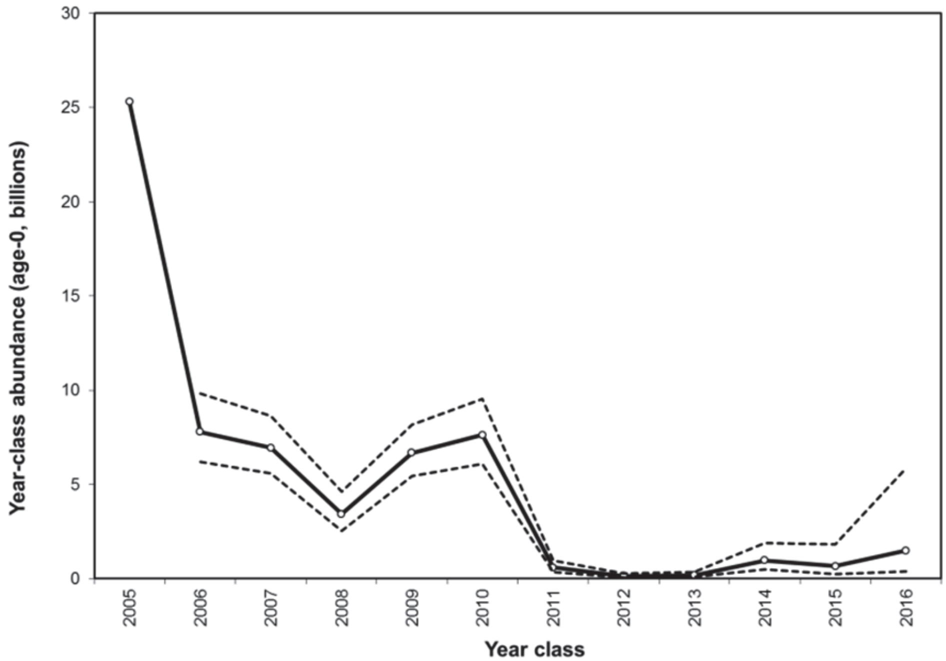
- Beverton-Holt stock-recruitment relationship, with virgin recruitment (R_0), steepness (*h*), and initial equilibrium recruitment offset (R_1) estimated, and average recruitment variability fixed (σ_R=0.75);
- *M* was fixed (0.6 yr^{-1});
- recruitment deviations estimated from 2005-15;
- initial fishing 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.

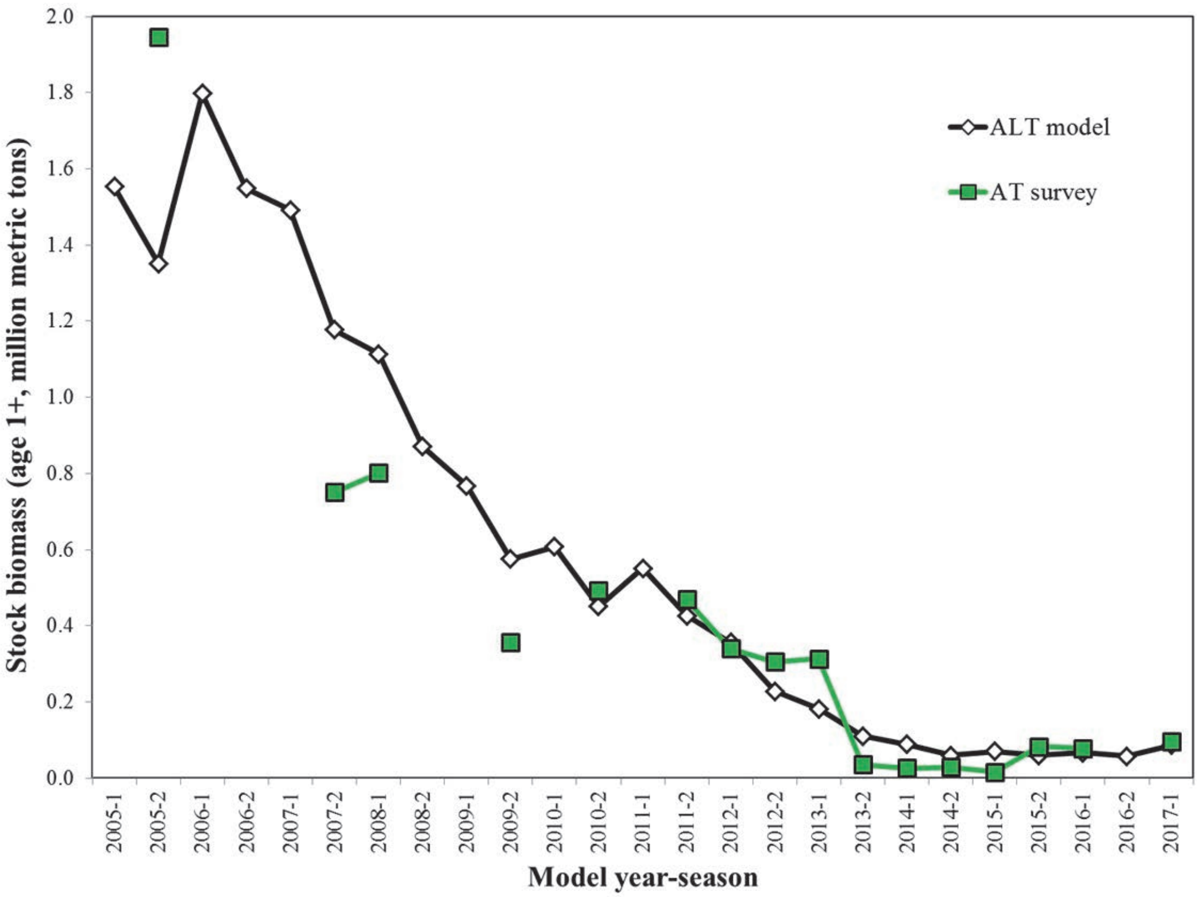




Calendar Yr-Sem	Model Yr-Seas	SSB (mt)	SSB Std Dev	Year class abundance (1000s)	Recruits Std Dev
2005-2	2005-1	---	---	25,280,200	---
2006-1	2005-2	1,073,370	81,231	---	---
2006-2	2006-1	---	---	7,795,940	921,117
2007-1	2006-2	1,220,870	82,137	---	---
2007-2	2007-1	---	---	6,941,430	776,514
2008-1	2007-2	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	---	---

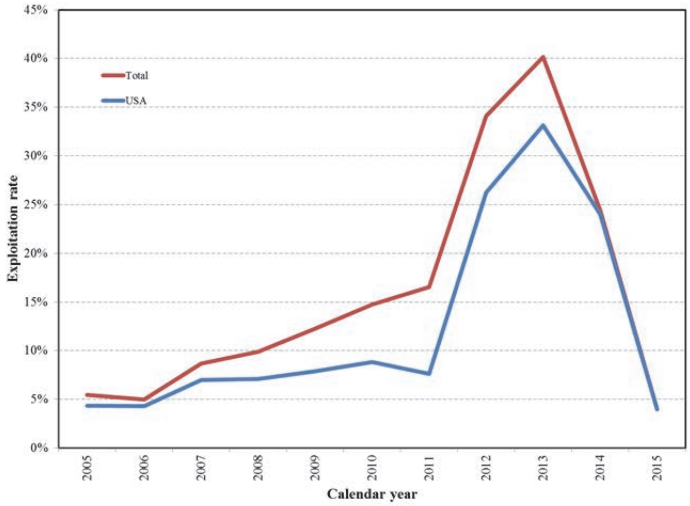
Stock Biomass for PFMC Management in 2017-18

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**.

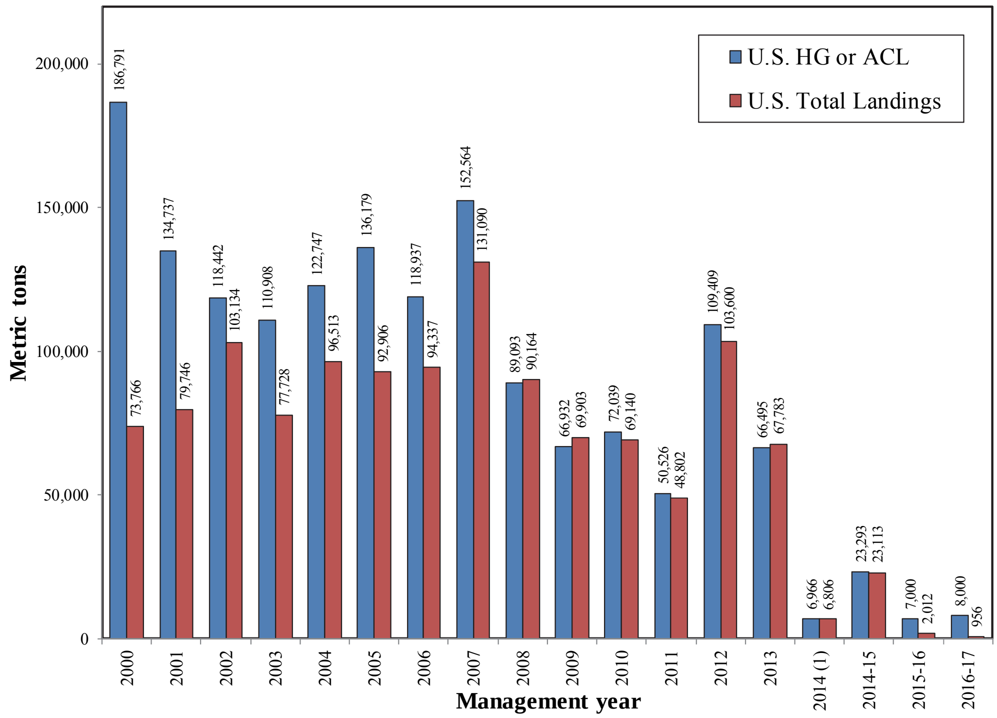
Acceptable biological catches (ABC, 2017-18) for a range of *P-star* values (Tier 1 σ=0.36; Tier 2 σ=0.72) associated with model ALT are presented in the following table.

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.

Response: 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.

Response: 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.

Response: 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.

Response: 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.

Response: 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.

Response: 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.

Response: 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.

Response: 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.

Response: 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.

Response: 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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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 Yr-Sem	Model Yr-Seas	NSP Catch (model ALT) 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.

			ASSESSMENT	
			T_2016 / T_2017[a]	ALT
PARAMETERIZATIONS		Time period	1993-16 / 1993-17	2005-17
		Surveys	AT, DEPM, TEP	AT
		Fisheries	MEX-CAL, PNW	MEX-CAL, PNW
		Longevity	15 years	10 years
		Natural mortality	Fix (*M*=0.4)	Fix (*M*=0.6)
		Growth	Estimated	Emp. weight-at-age
		Stock-recruitment	Beverton-Holt (*h* fix=0.80)	Beverton-Holt (*h* est=0.36)
		Selectivity	Length data/Length-based	Age data/Age-based
		Catchability	AT (*Q* fix=1.0)	AT (*Q* est=1.1)
DATA COMPONENTS	Fisheries	Catch	■	■
		Length comps	■	
		Age comps (cond. age-at-length)	■	
		Age comps (aggregated)		■
		Emp. weight-at-age		■
	Surveys	AT abundance series (spring)	■	
		AT abundance series (summer)	■	
		AT abundance series (annual)		■
		DEPM abundance series	■	
		TEP abundance series	■	
		AT length comps	■	
		AT age comps (cond. age-at-length)	■	
		AT age comps (aggregated)		■
		AT emp. weigth-at-age		■

[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	0.141048
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

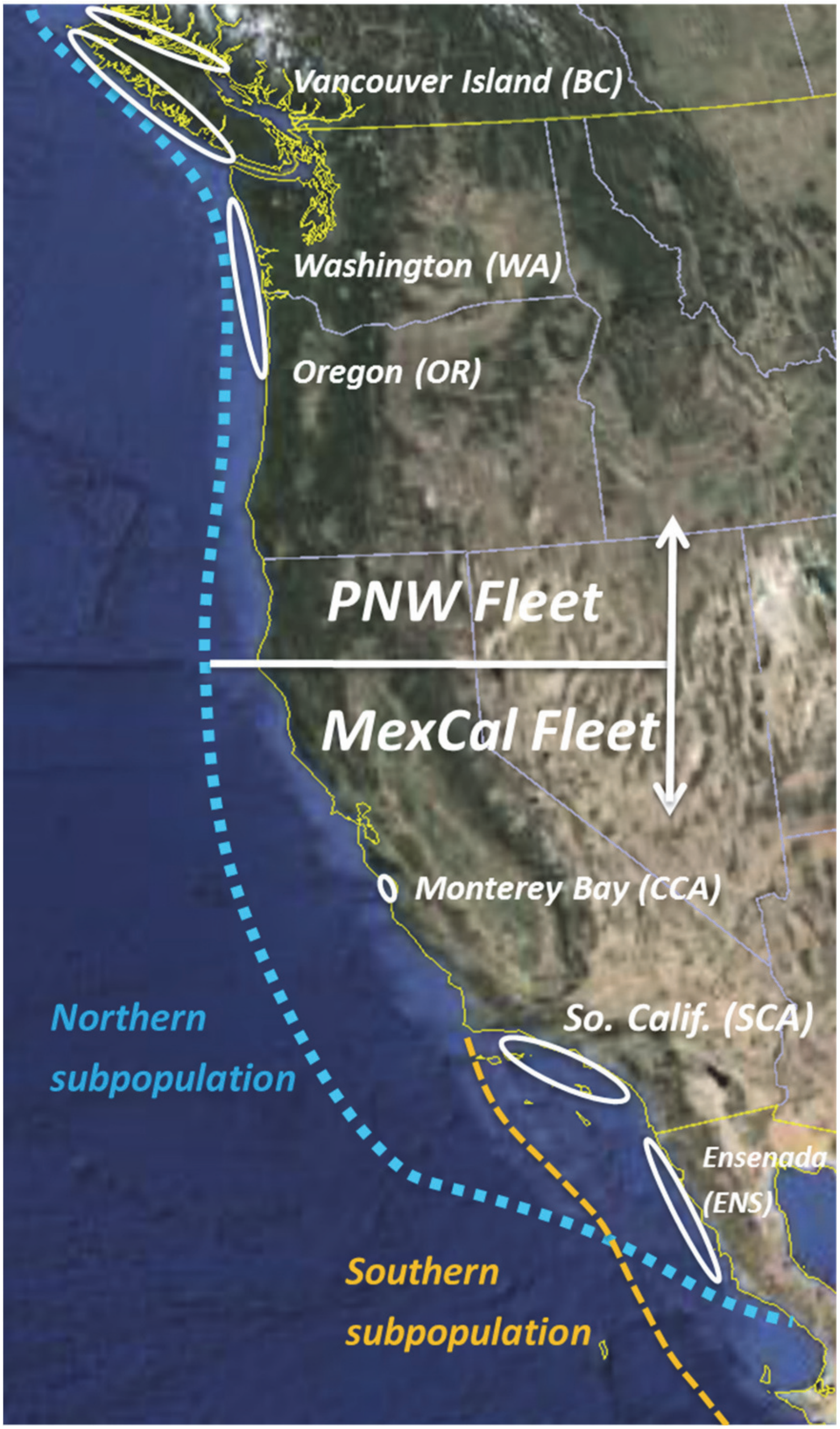


Figure 1. Distribution of the northern subpopulation of Pacific sardine, primary commercial fishing areas, and modeled fleets.

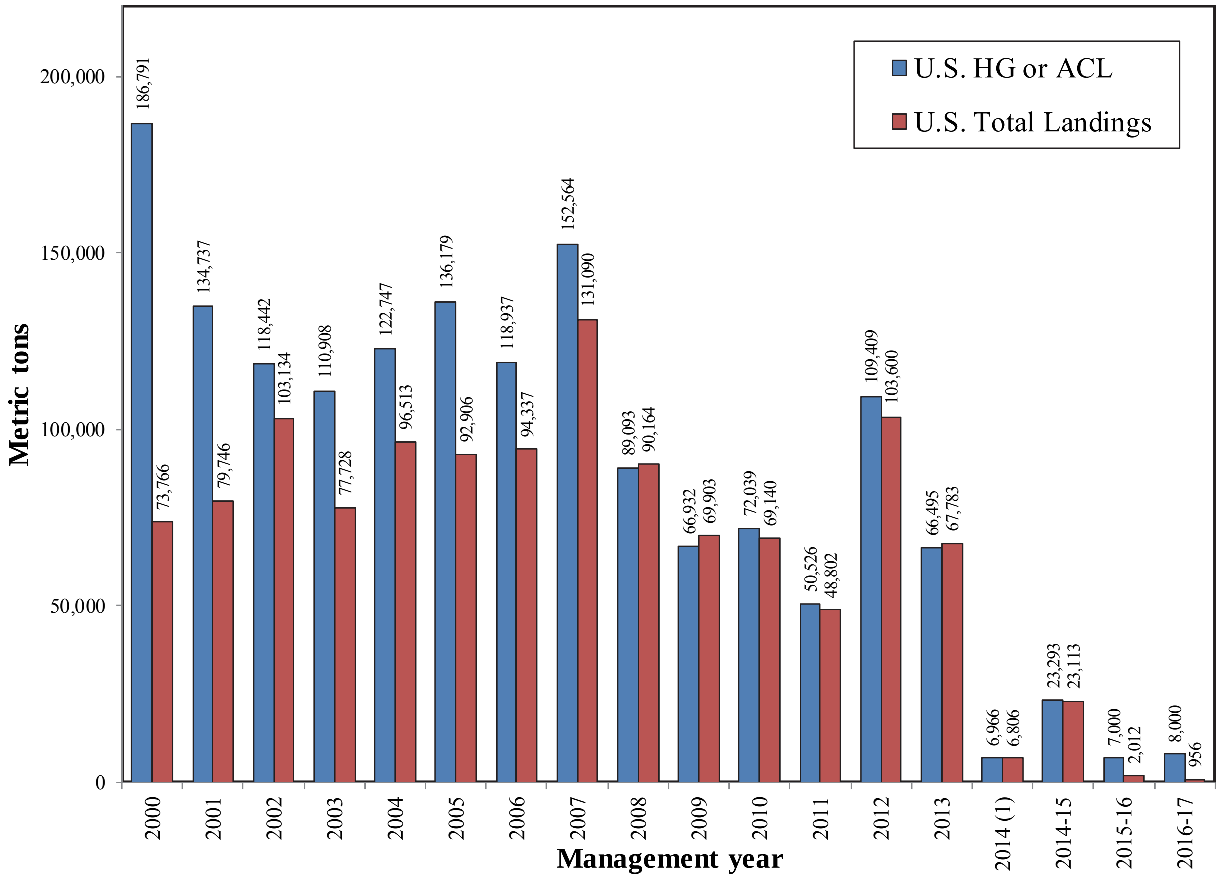


Figure 2. U.S. Pacific sardine harvest guidelines or acceptable catch limits and landings since the onset of federal management.

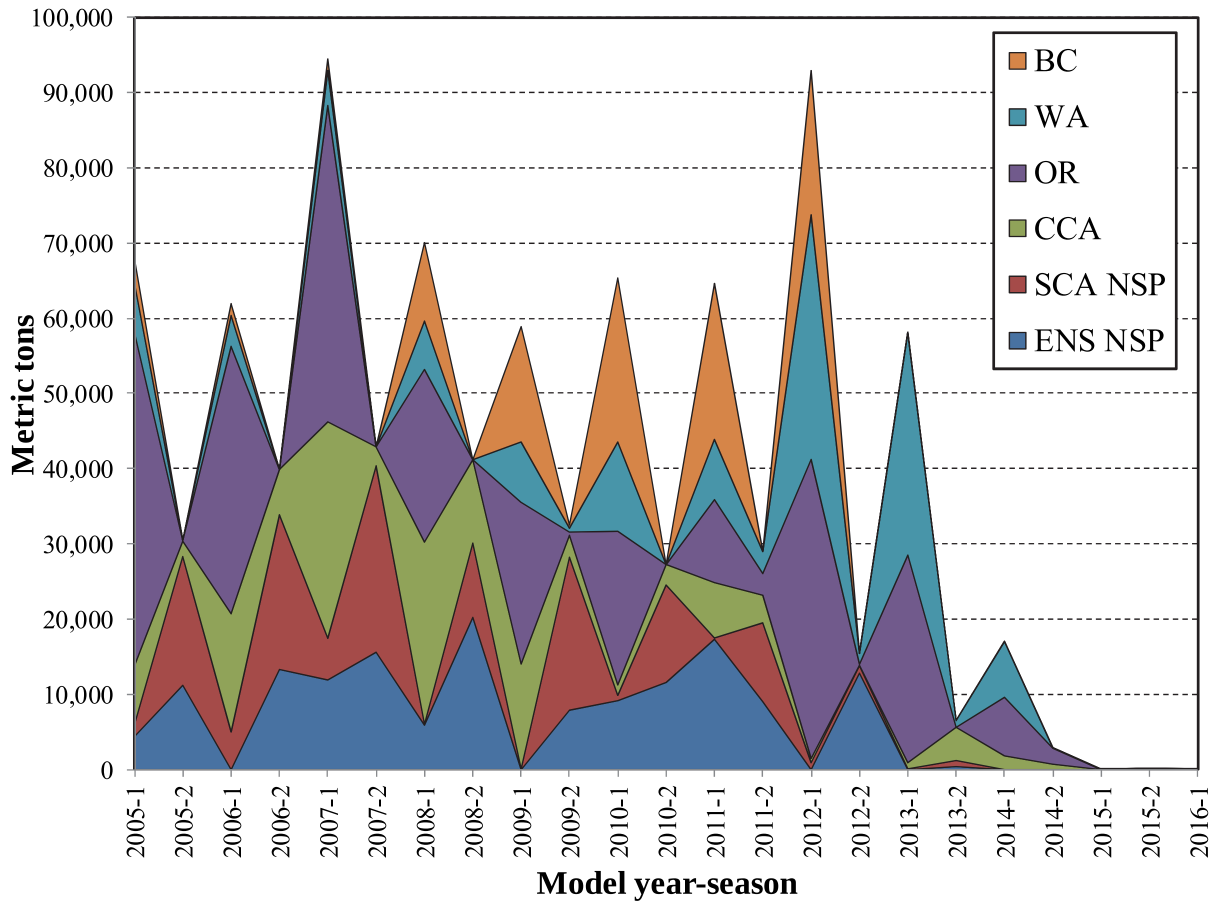


Figure 3. Pacific sardine NSP landings (mt) by major fishing region.

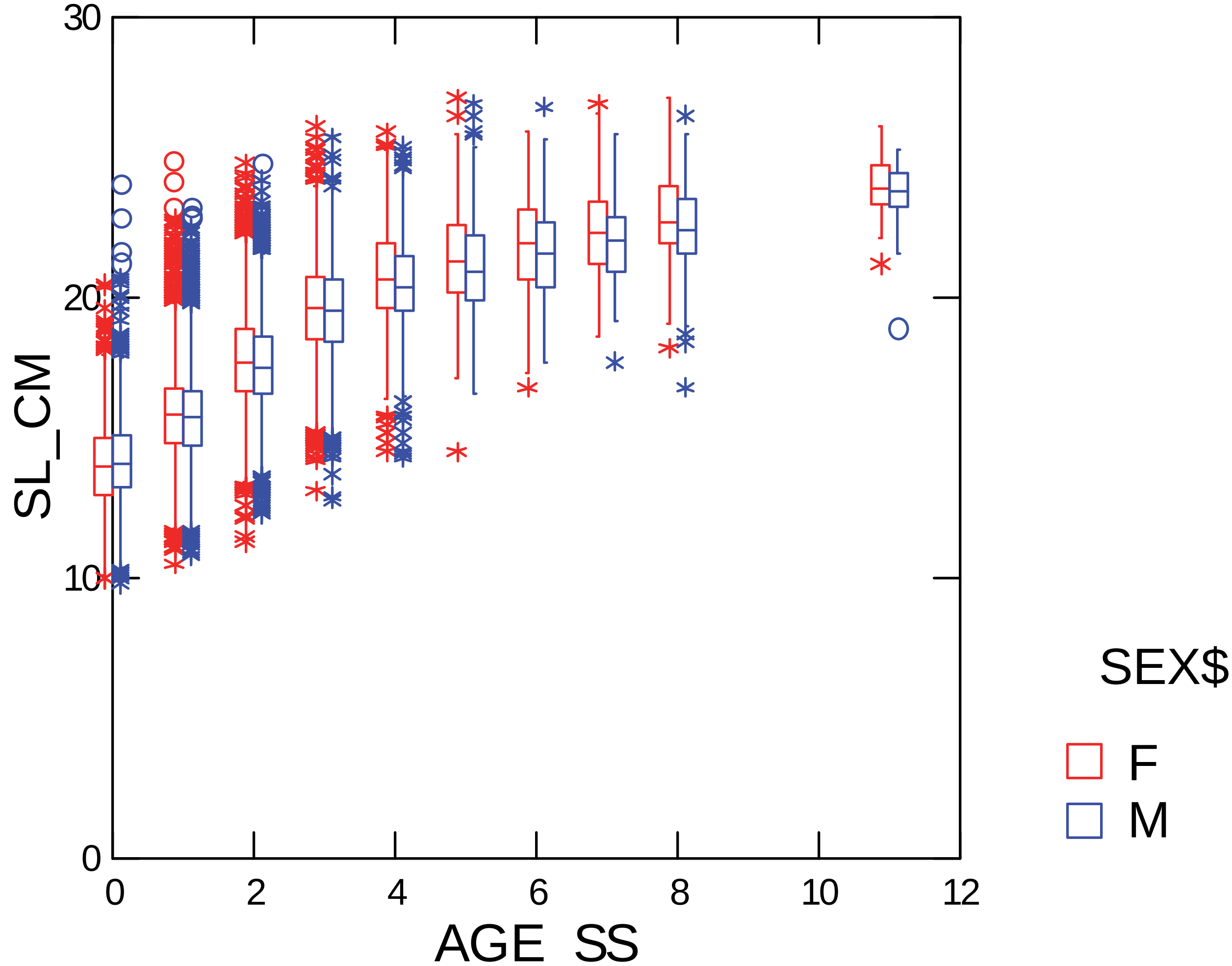


Figure 4. Length-at-age by sex from NSP fishery samples (1993-2013; Hill et al. 2014), indicating lack of sexually dimorphic growth. Box symbols indicate median and quartile ranges for the raw data.

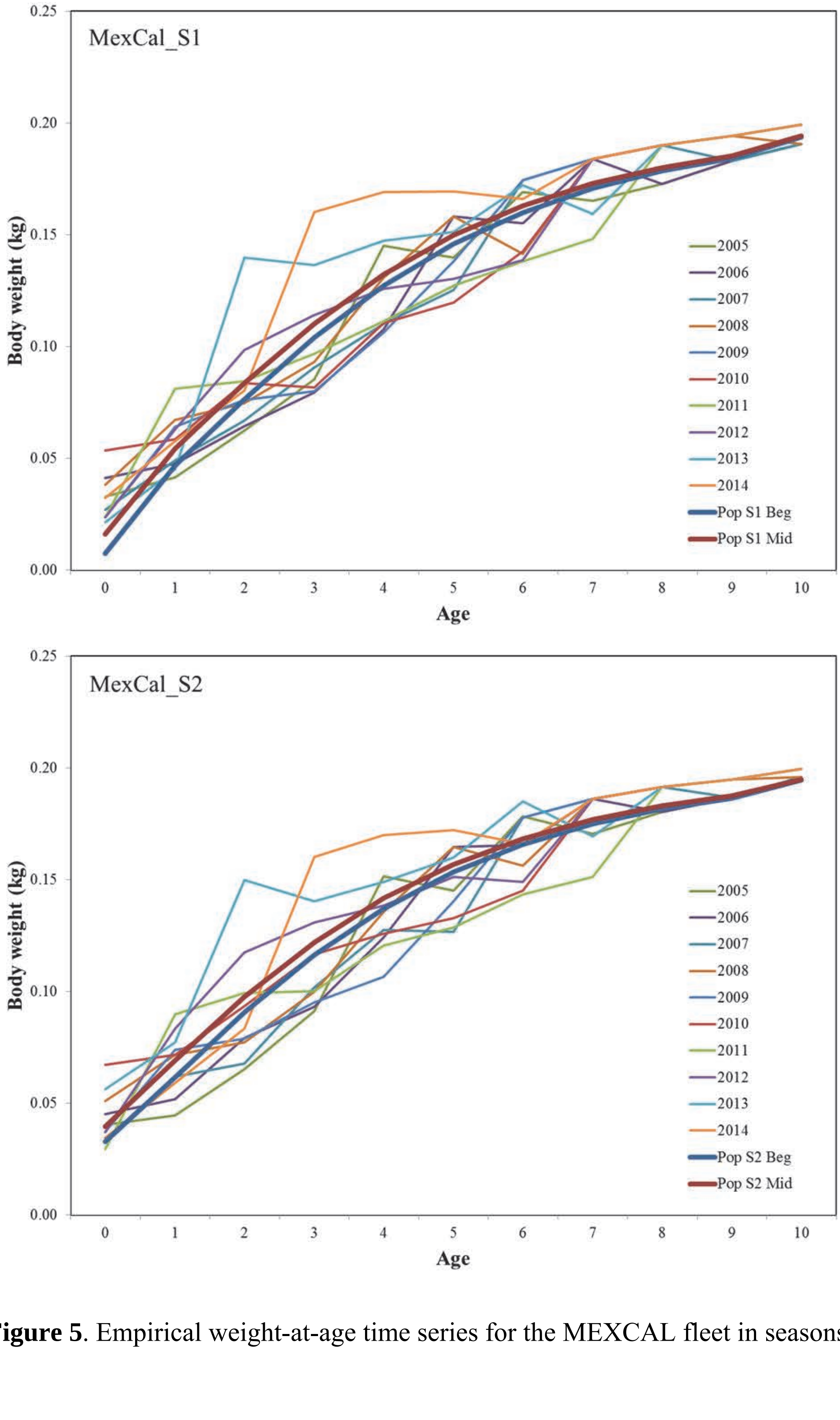
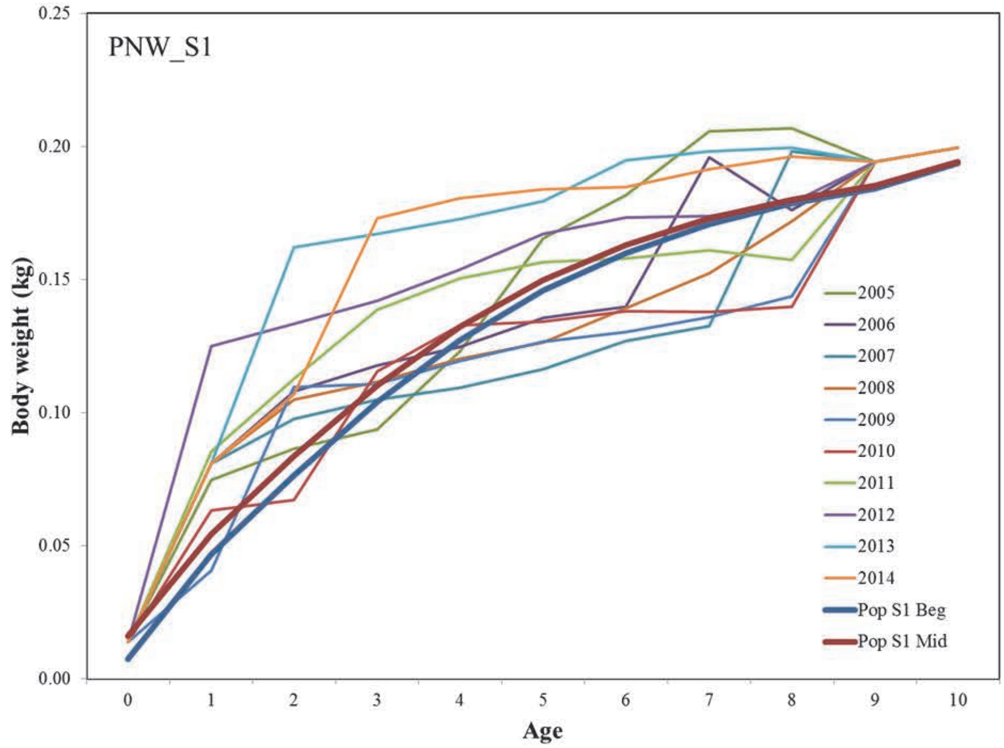


Figure 5. Empirical weight-at-age time series for the MEXCAL fleet in seasons 1 and 2.



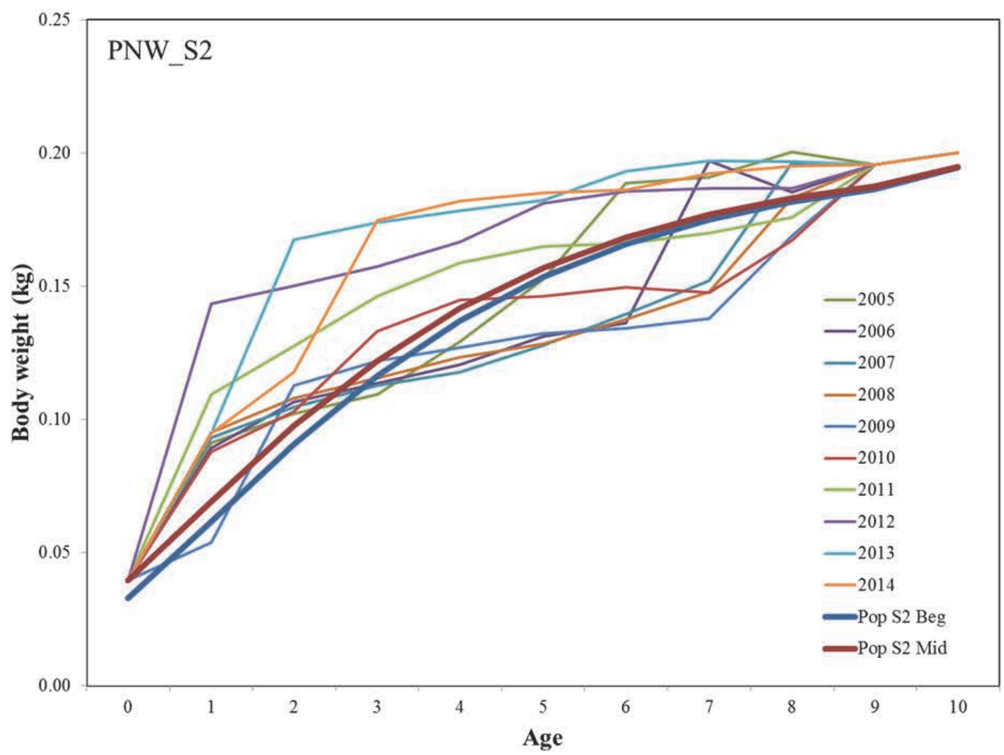


Figure 6. Empirical weight-at-age time series for the PNW fleet in seasons 1 and 2.

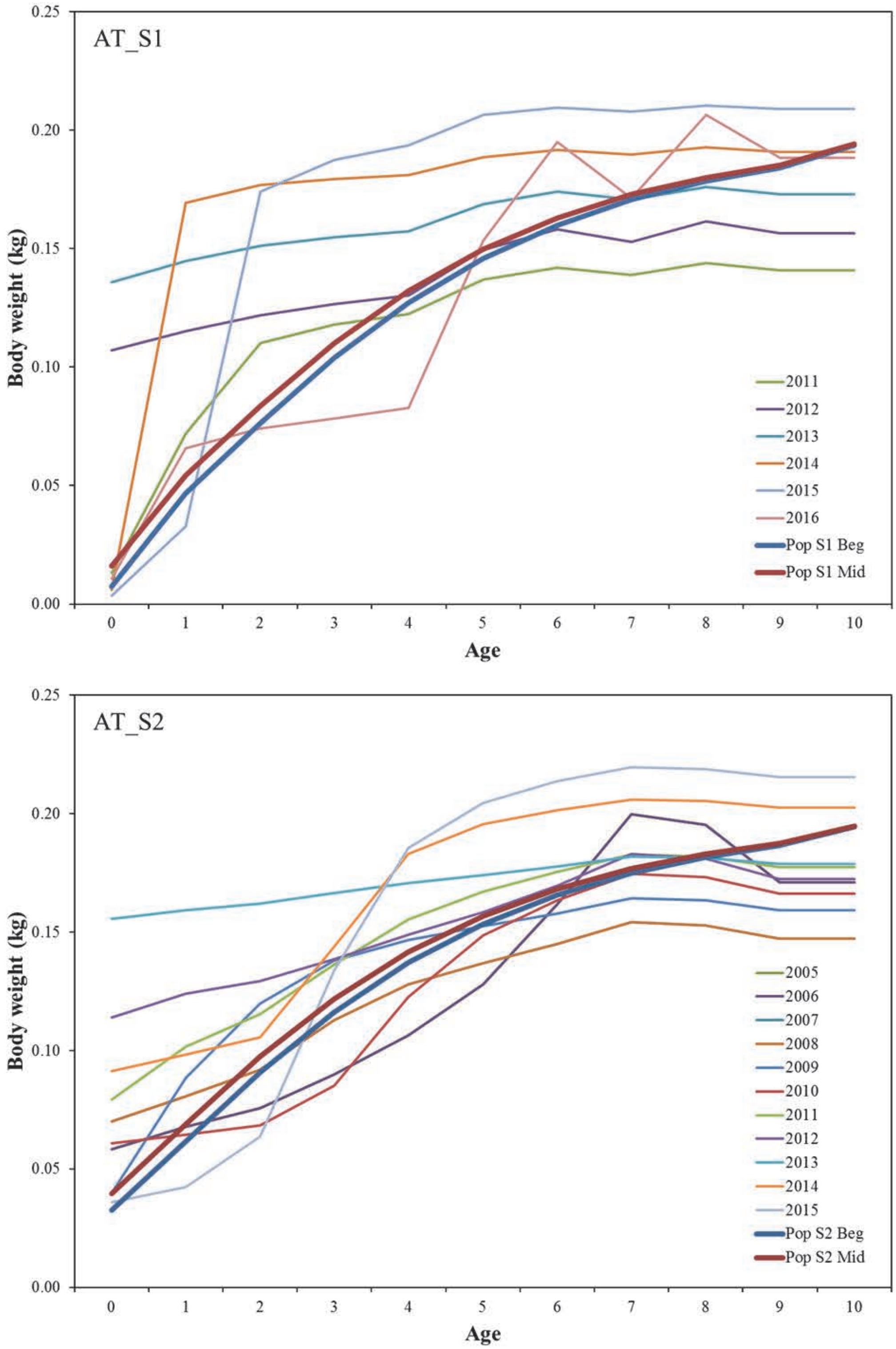


Figure 7. Empirical weight-at-age time series for the AT survey in seasons 1 and 2.

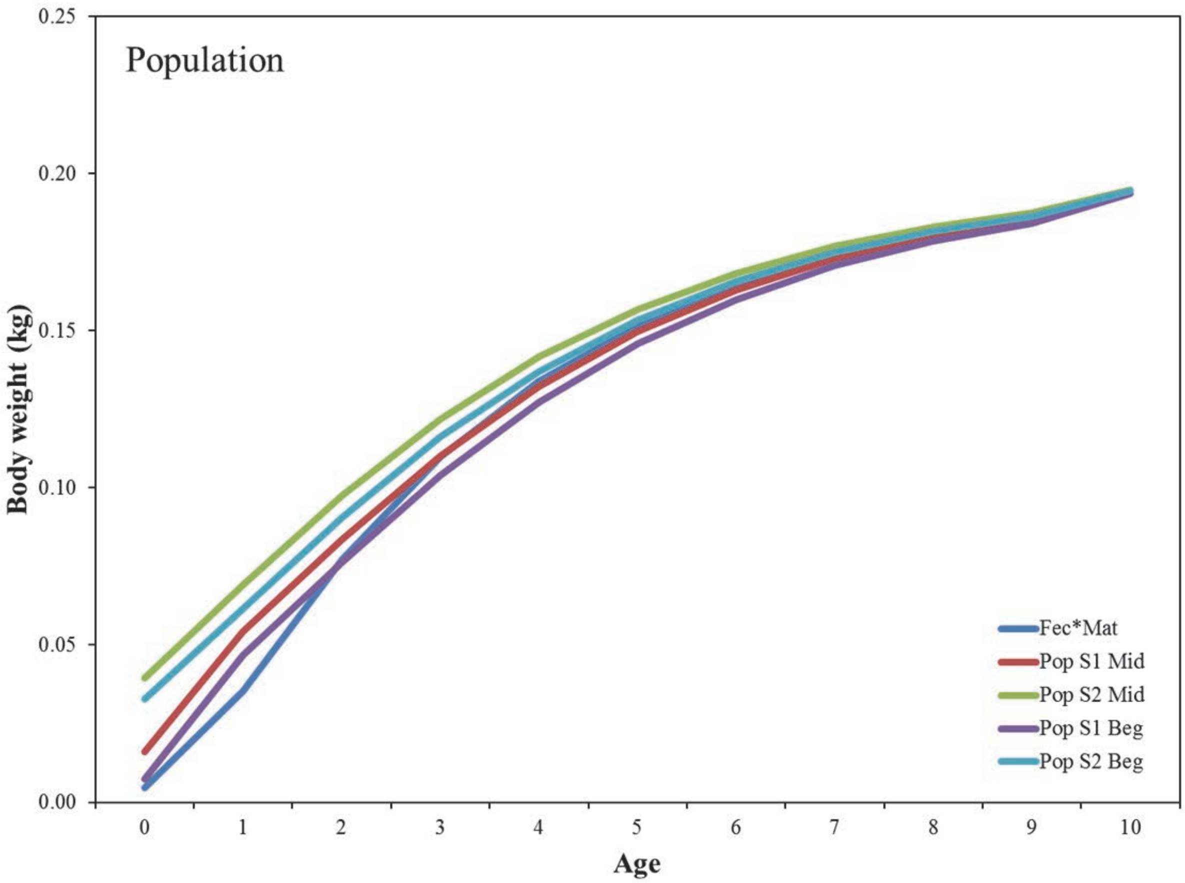


Figure 8. Population body weights-at-age and SSB-at-age applied in model ALT. Population body weights-at-age are provided at the beginning and middle of seasons 1 and 2, and fecundity*maturity-at-age is used to calculate SSB at the beginning of season 2.

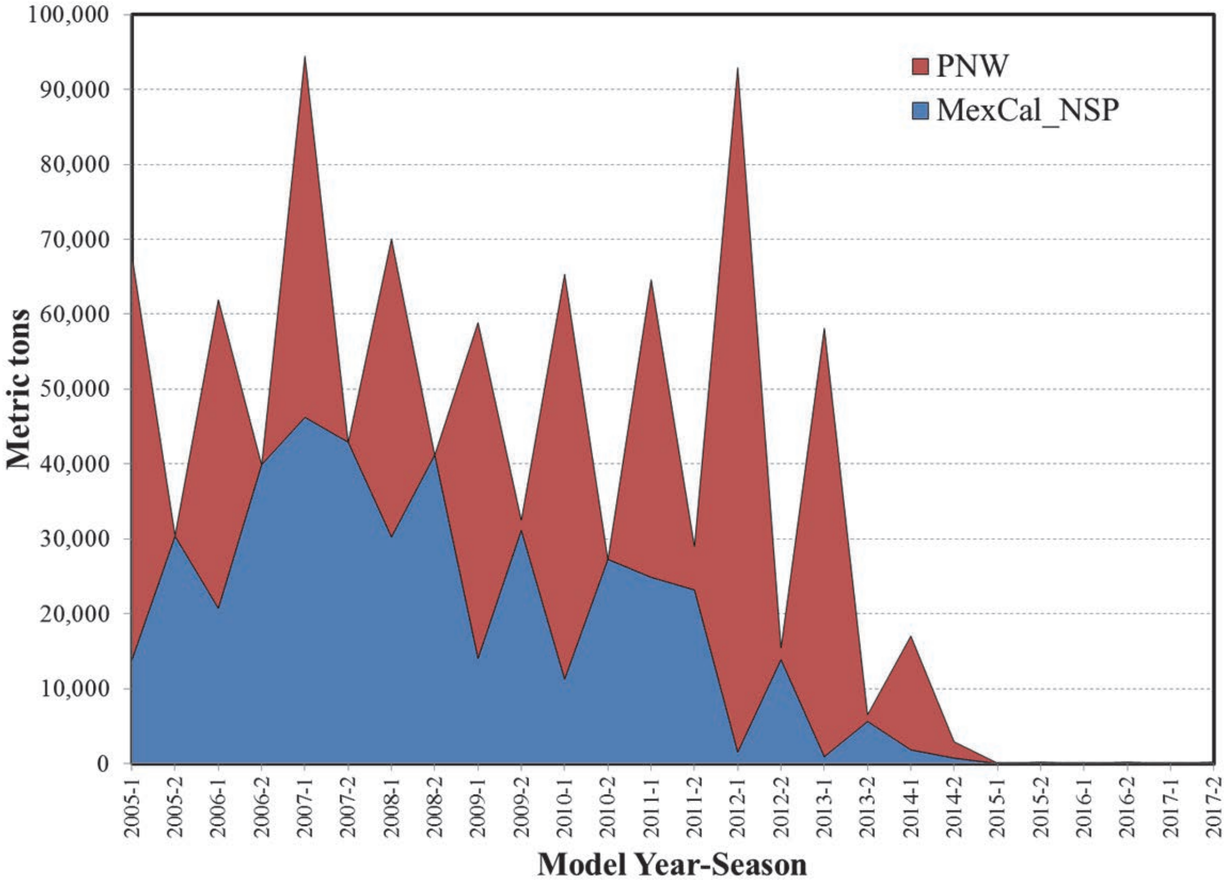
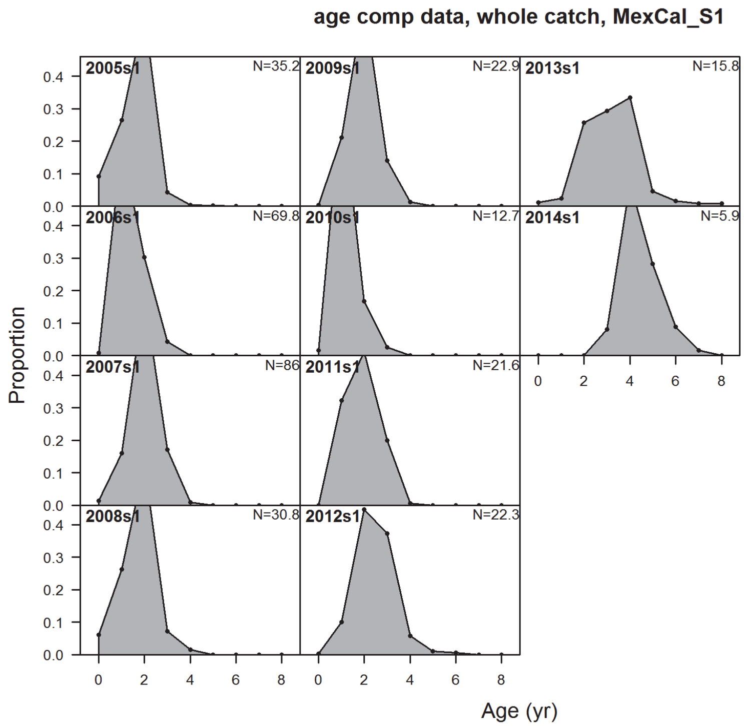


Figure 9. Pacific sardine NSP landings (mt) by fleet, model year and semester as used in model ALT.



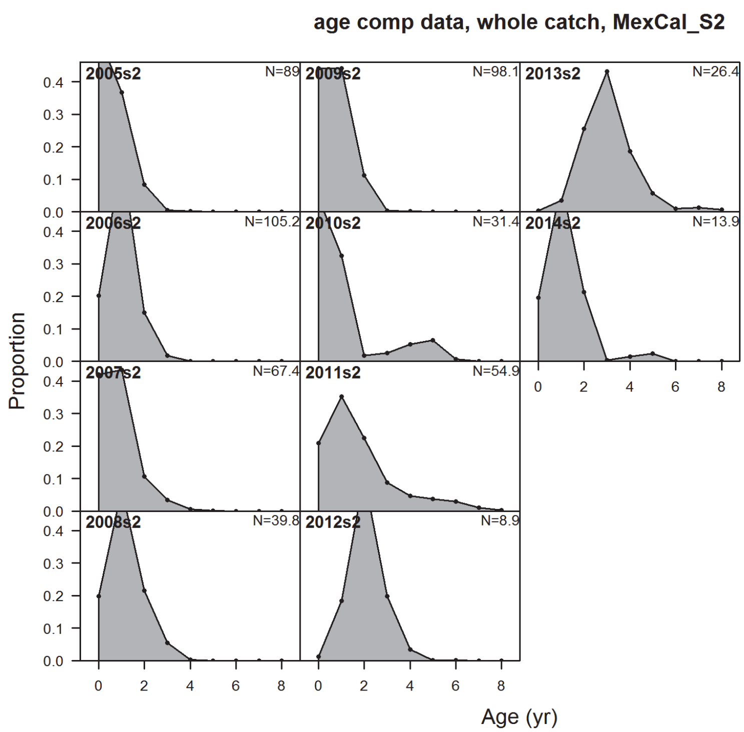


Figure 10. Age composition time series for the MEXCAL fleet in seasons 1 (upper) and 2 (lower). N represents input sample sizes.

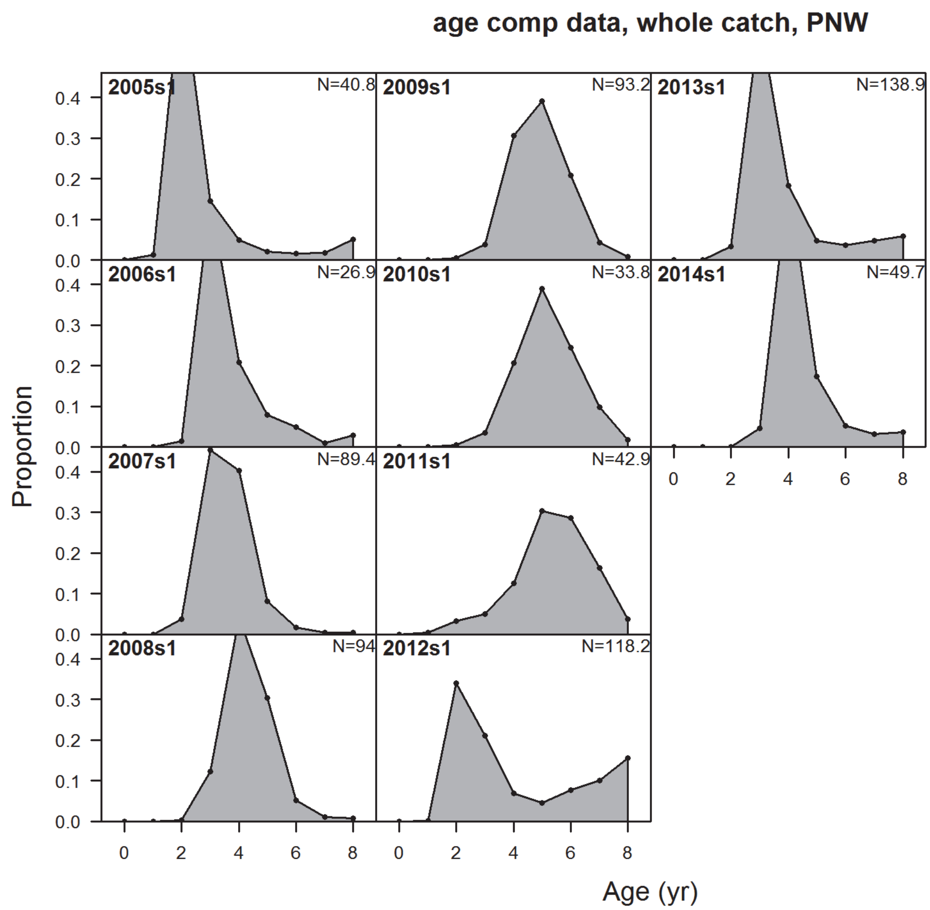


Figure 11. Age composition time series for the PNW fleet in season 1. N represents input sample sizes.

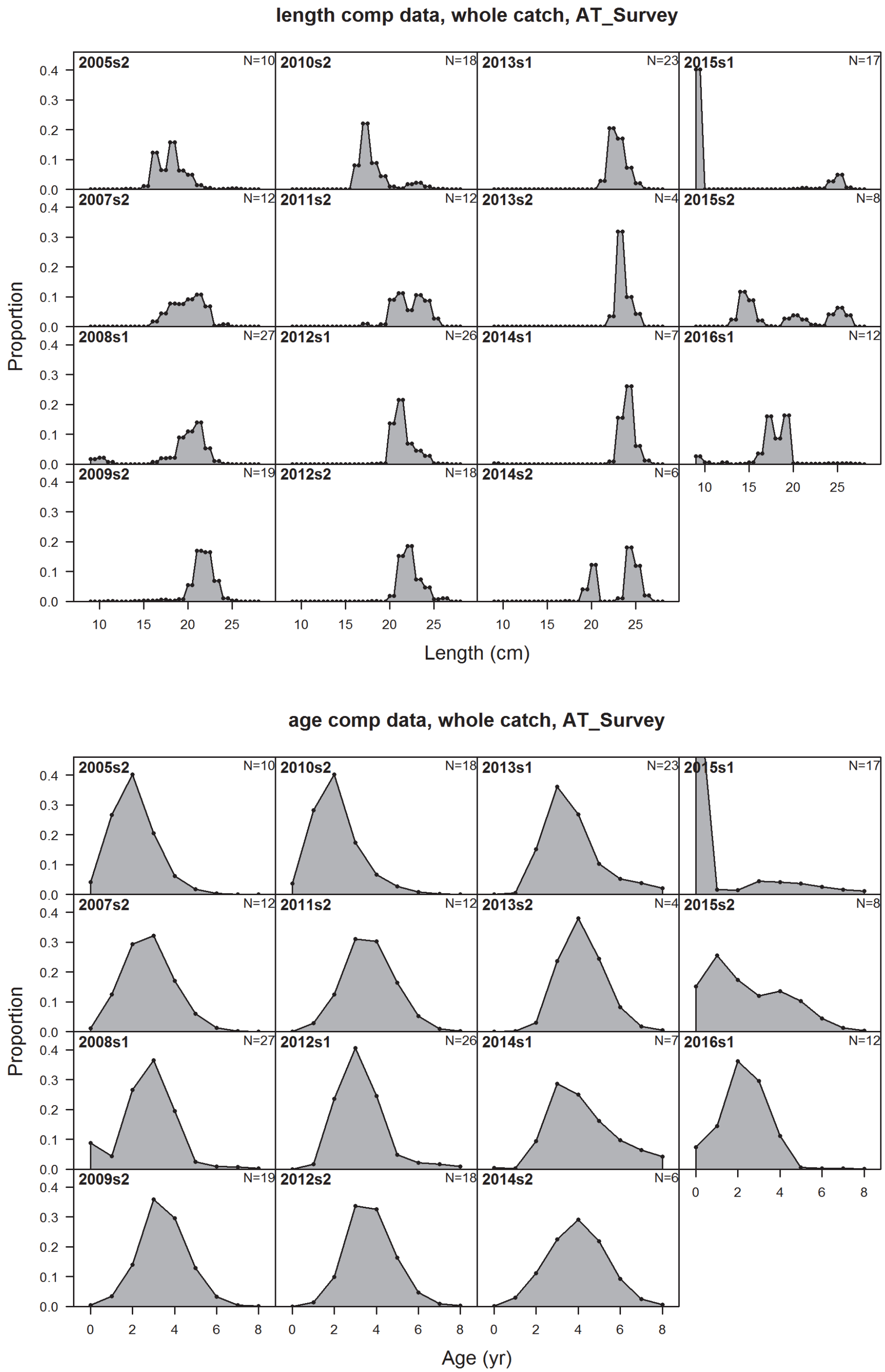


Figure 12. Length- (upper panel) and age-composition (lower panel) time series for the AT survey. N represents input sample sizes.

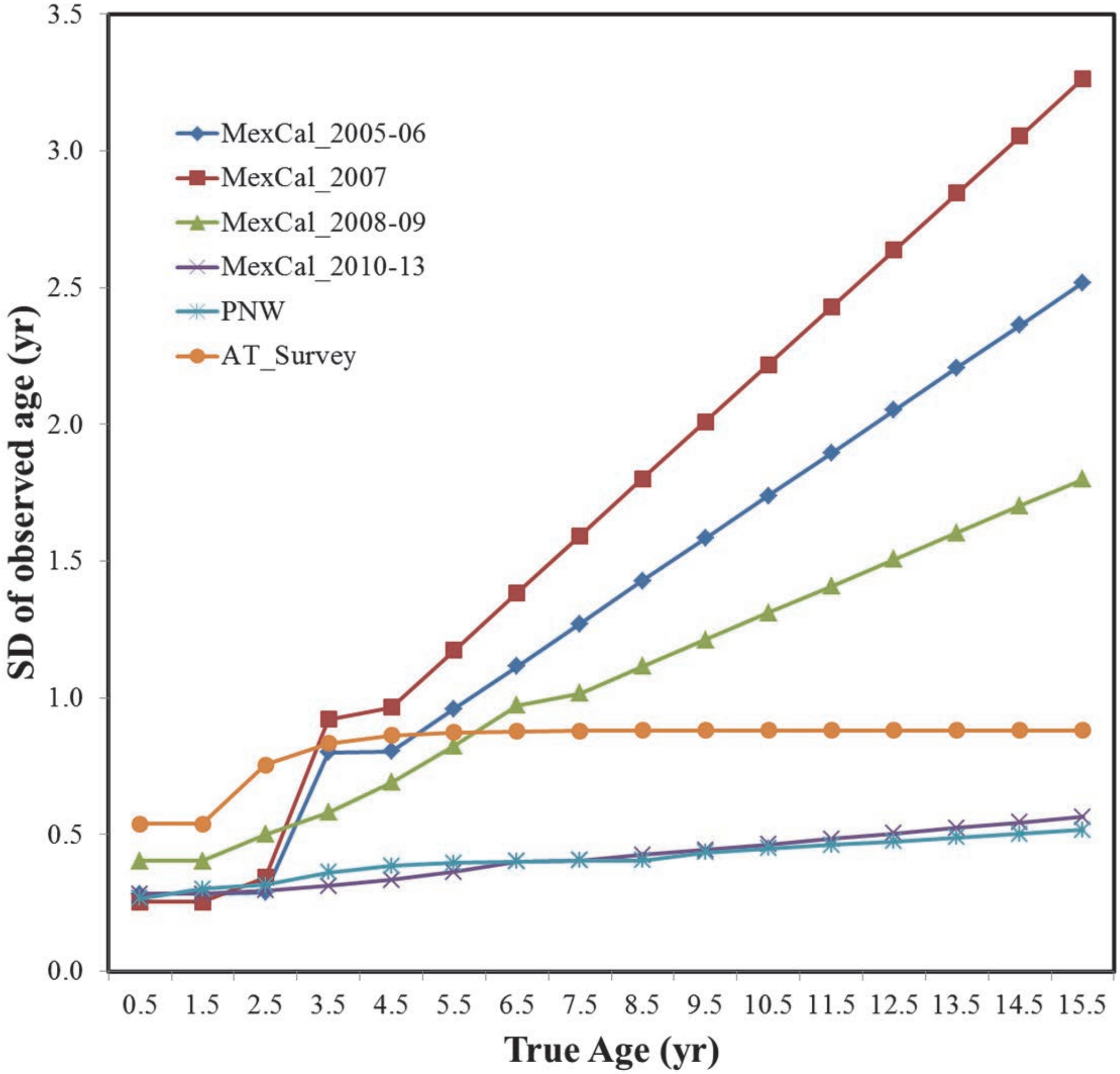


Figure 13. Laboratory- and year-specific ageing errors applied in model ALT.

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).

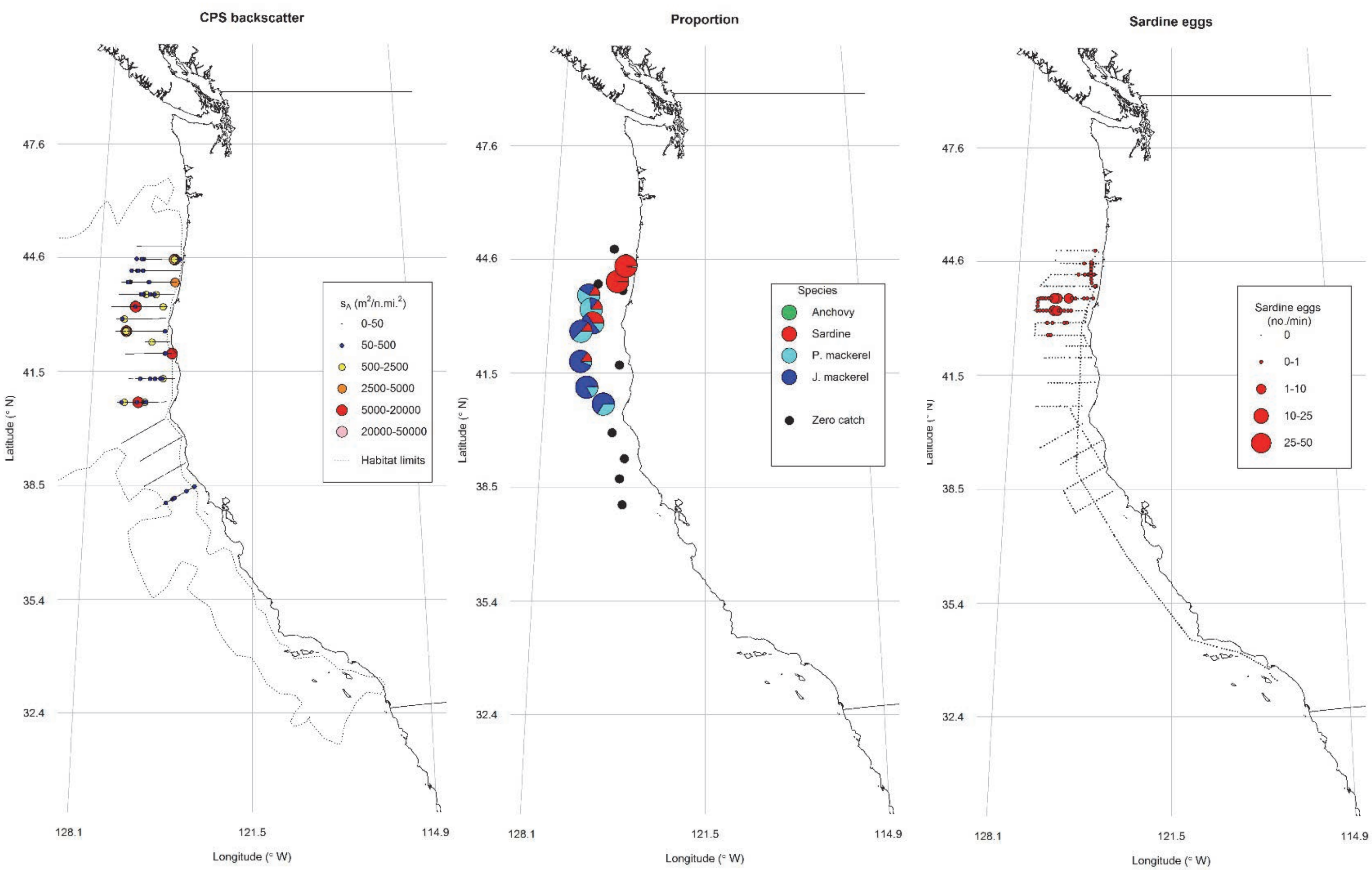
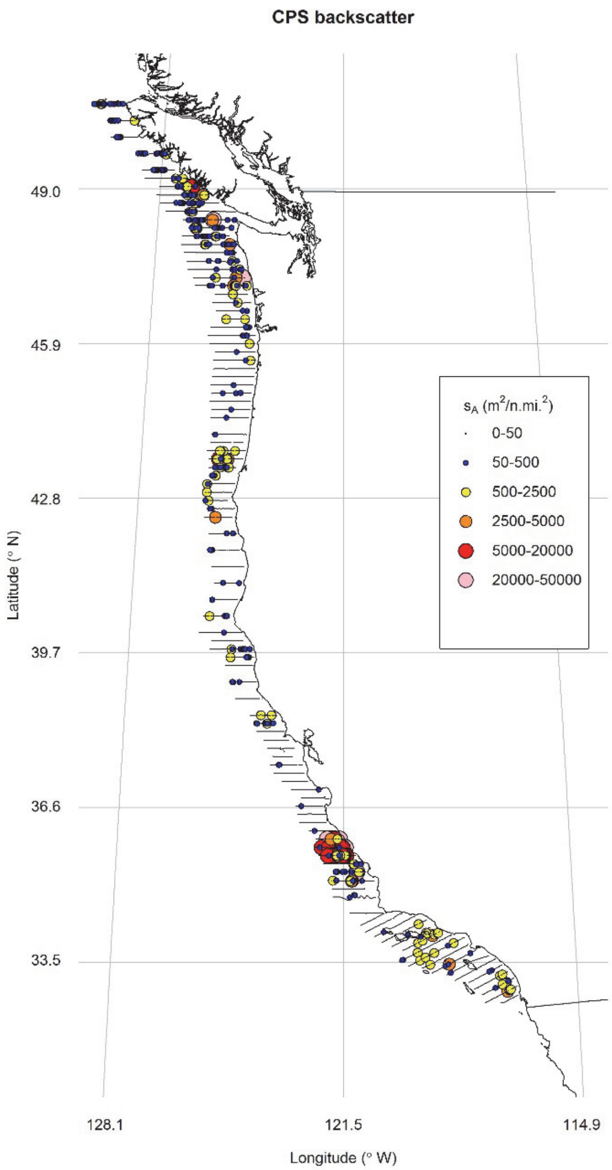


Figure 15. Results from the AT survey for summer 2016. Acoustic backscatter (s_A, m^2 n.mi.^{2}) from coastal pelagic fish species (CPS; left); acoustic proportions of CPS in trawl clusters (right), including northern anchovy (*Engraulis mordax*), Pacific mackerel (*Scomber japonicus*), jack mackerel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



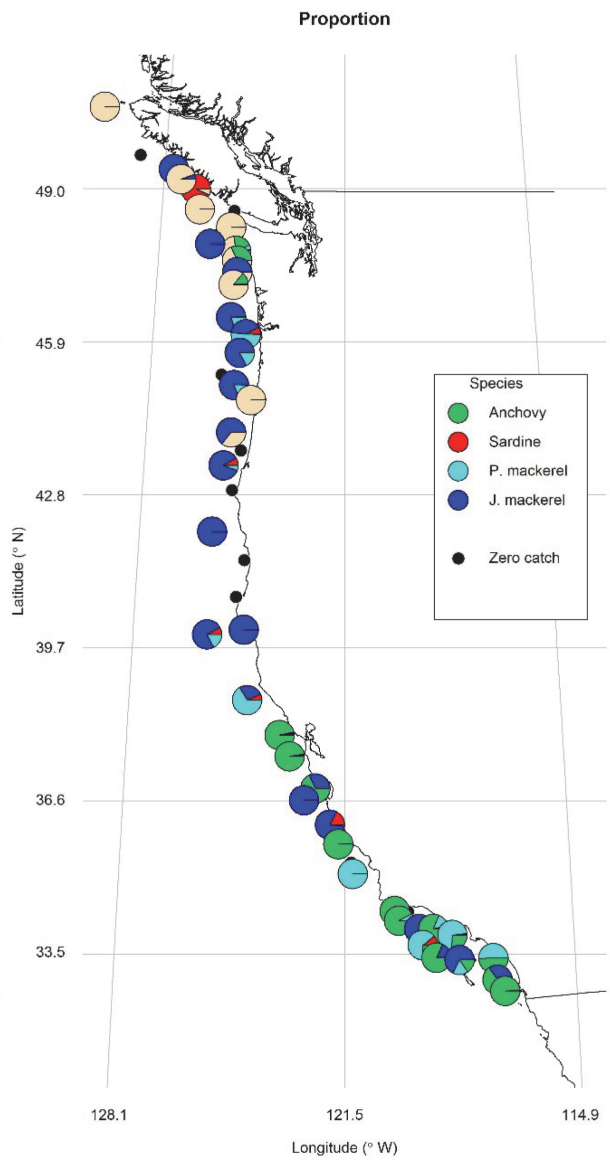


Figure 16. Sardine biomass densities versus stratum (Table 6) estimated in the AT survey for spring 2016. The red numbers represent the locations of trawl clusters with at least one sardine.

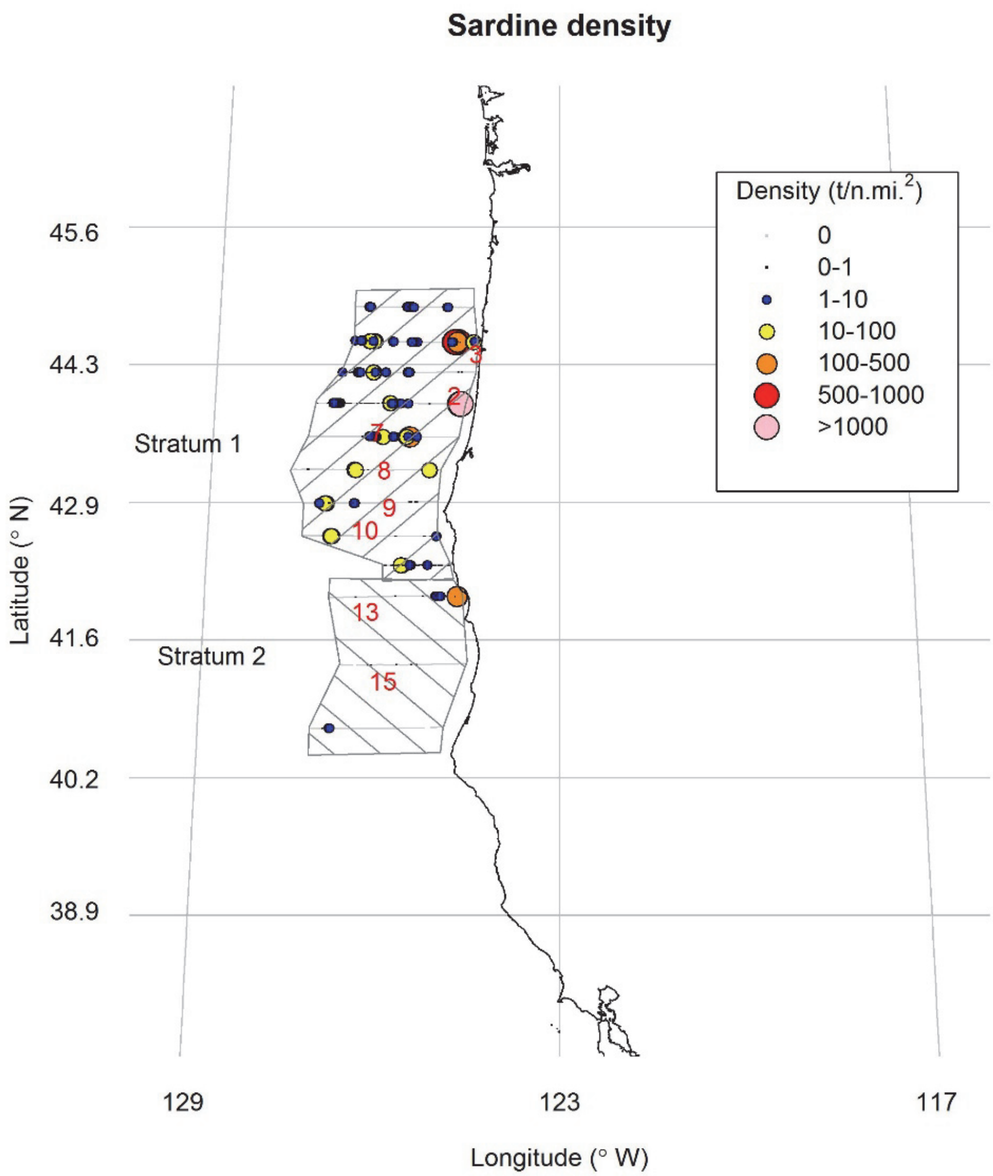


Figure 17. Estimated sardine abundance by length-class for the entire survey area and for the two strata (Figure 16) for the AT survey in spring 2016. The corresponding number of sardine sampled in each stratum is provided in Table 6.

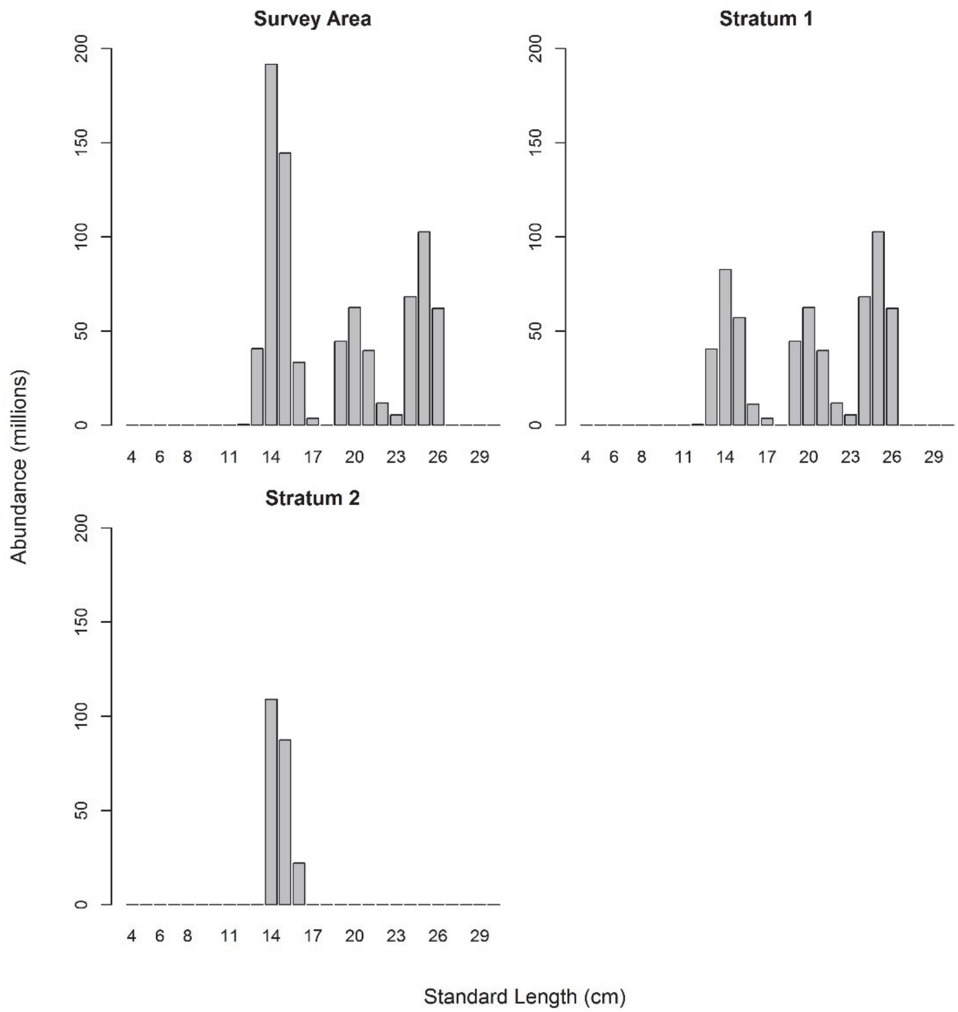


Figure 18. Sardine biomass densities versus stratum (Table 7) estimated in the AT survey for summer 2016. Numbers in red represent the locations of trawl clusters with at least one sardine.

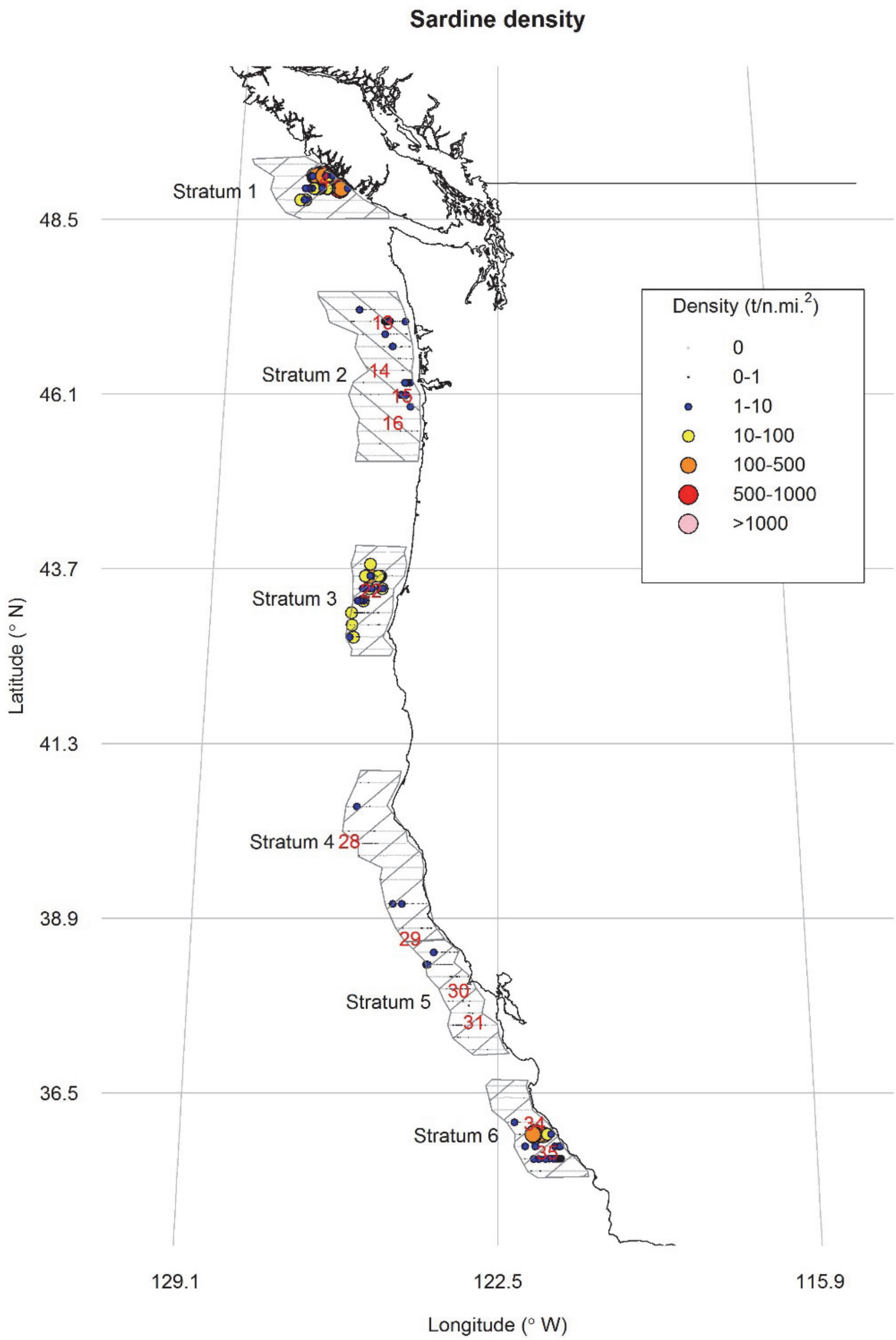
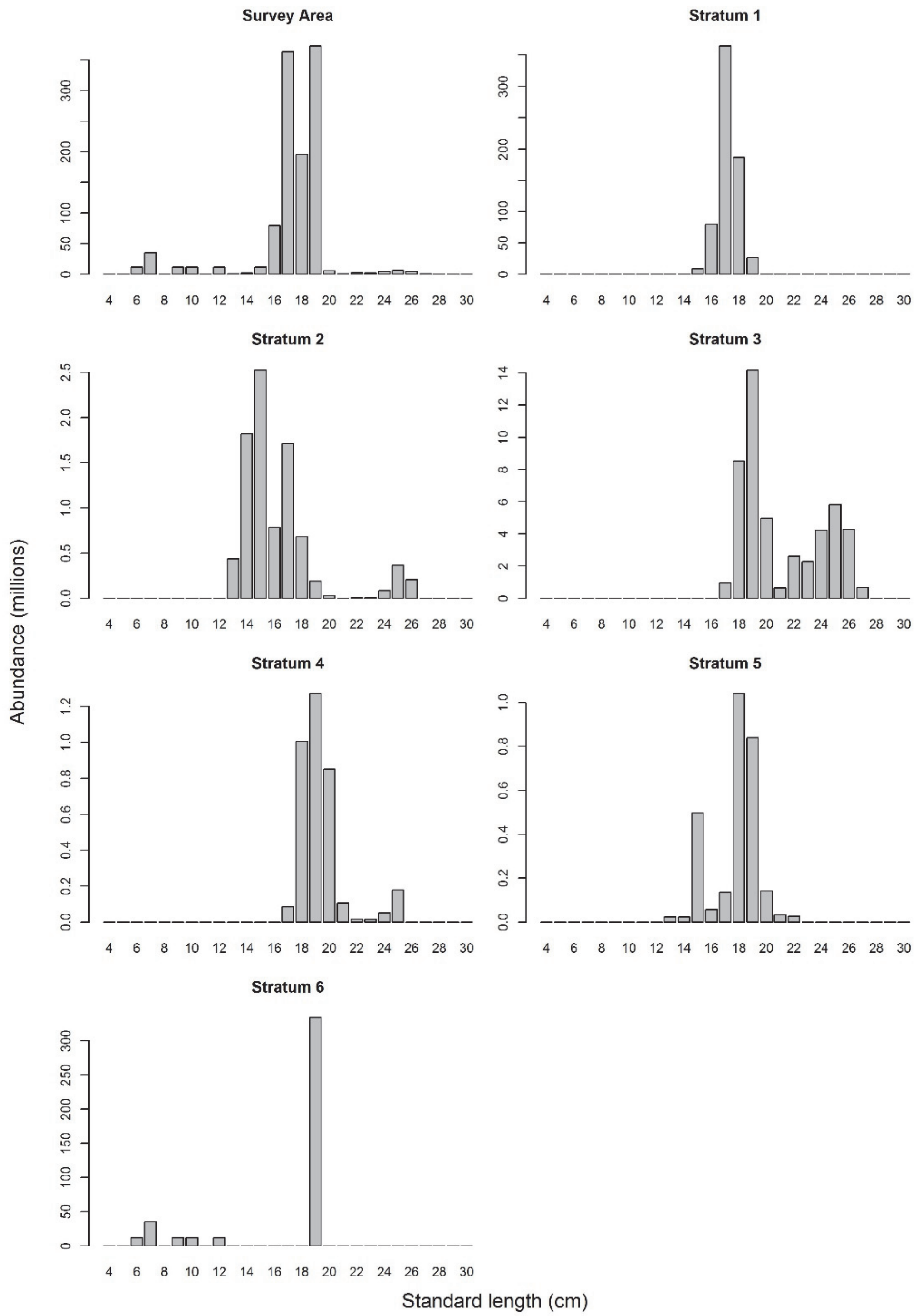


Figure 19. Estimated sardine abundance by length-class for the entire survey area and for the six strata (Figure 18) in the AT survey in summer 2016. The corresponding number of sardine sampled in each stratum is provided in Table 7.



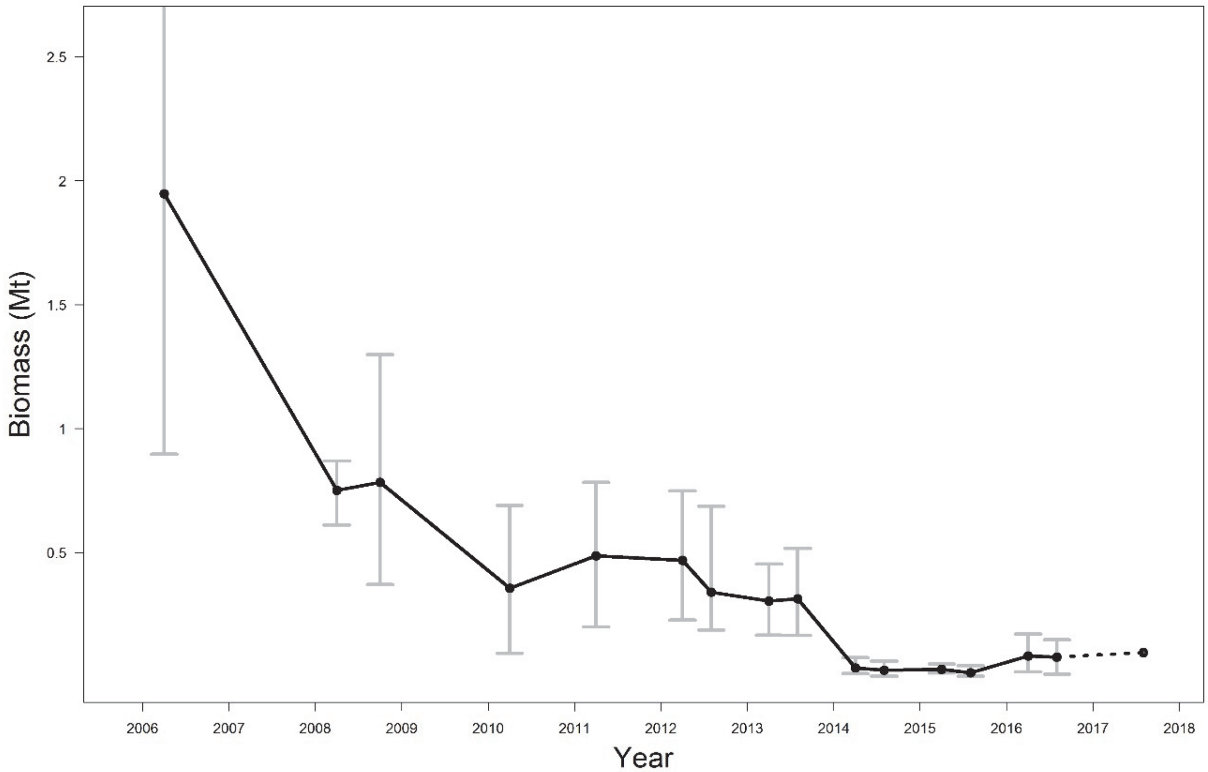


Figure 20. Time-series of Pacific sardine biomass with respective 95% confidence intervals as estimated by acoustic-trawl (AT) surveys. The biomass in July 2017 was projected based on the summer 2016 AT biomass and the expected recruitment using the ALT model's S-R relationship.

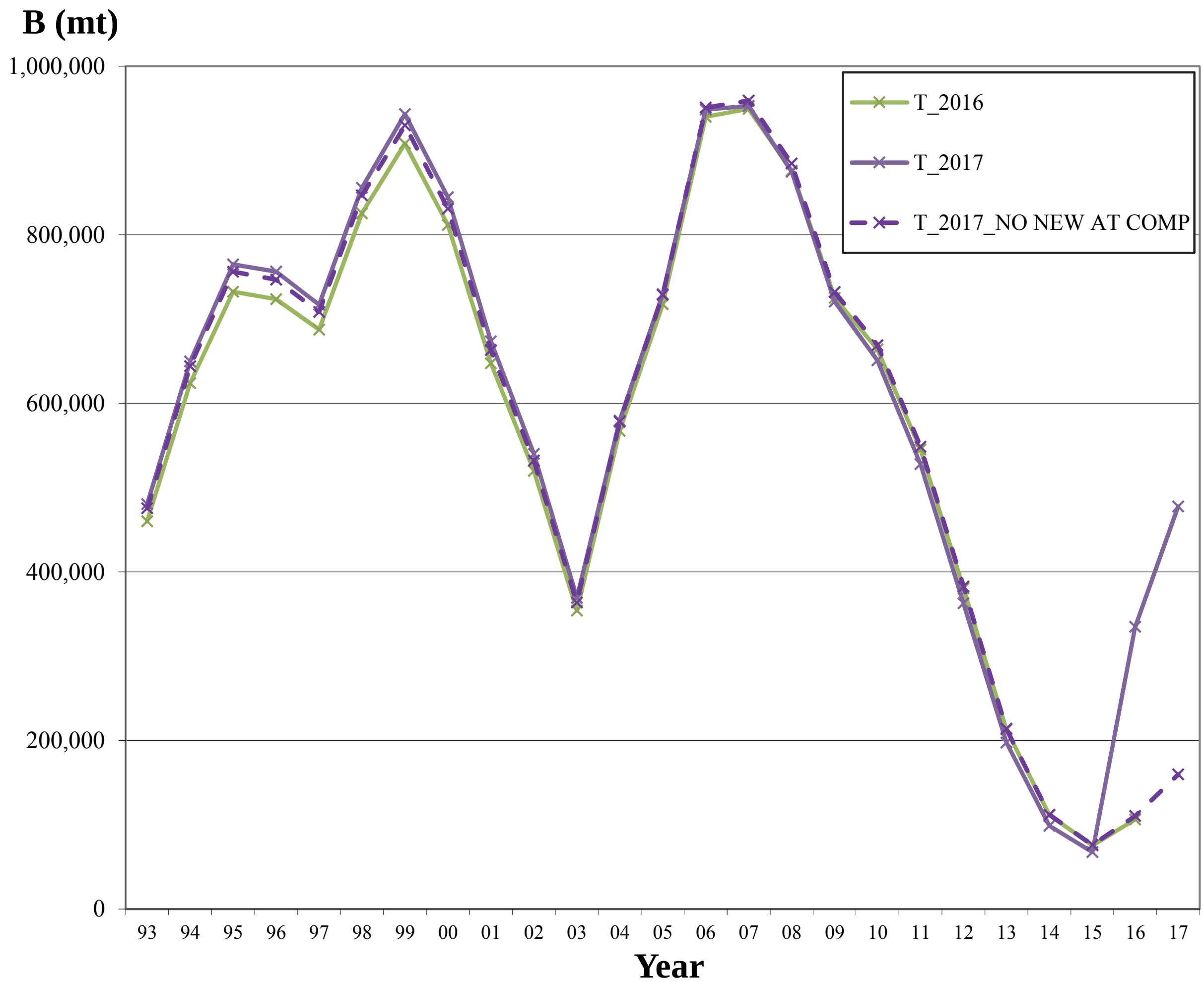


Figure 21. Estimated stock biomass (age 1+ fish, mt) time series for the 2016 update model (T_2016), the update model with 2016 AT biomass and length compositions (T_2017), and the update model with no new AT length compositions.

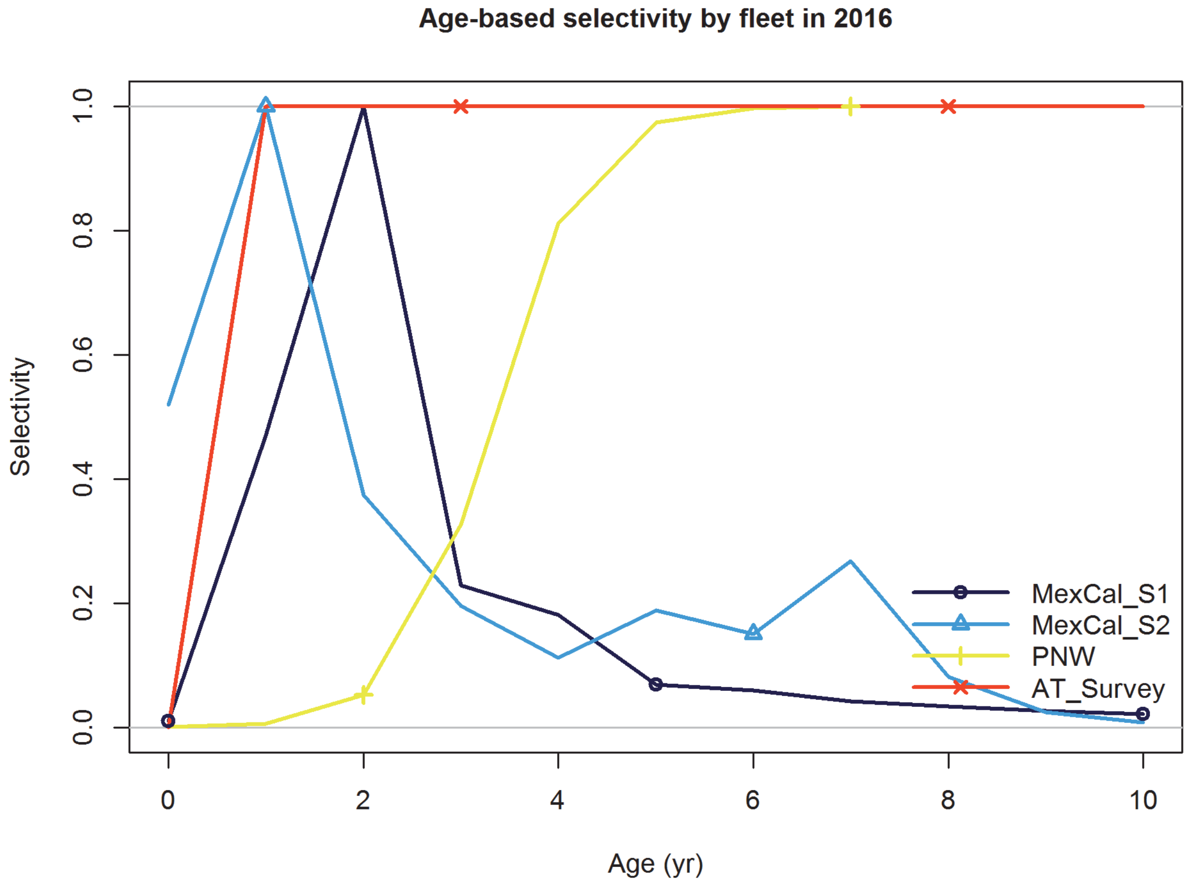


Figure 22. Age-selectivity patterns for model ALT.

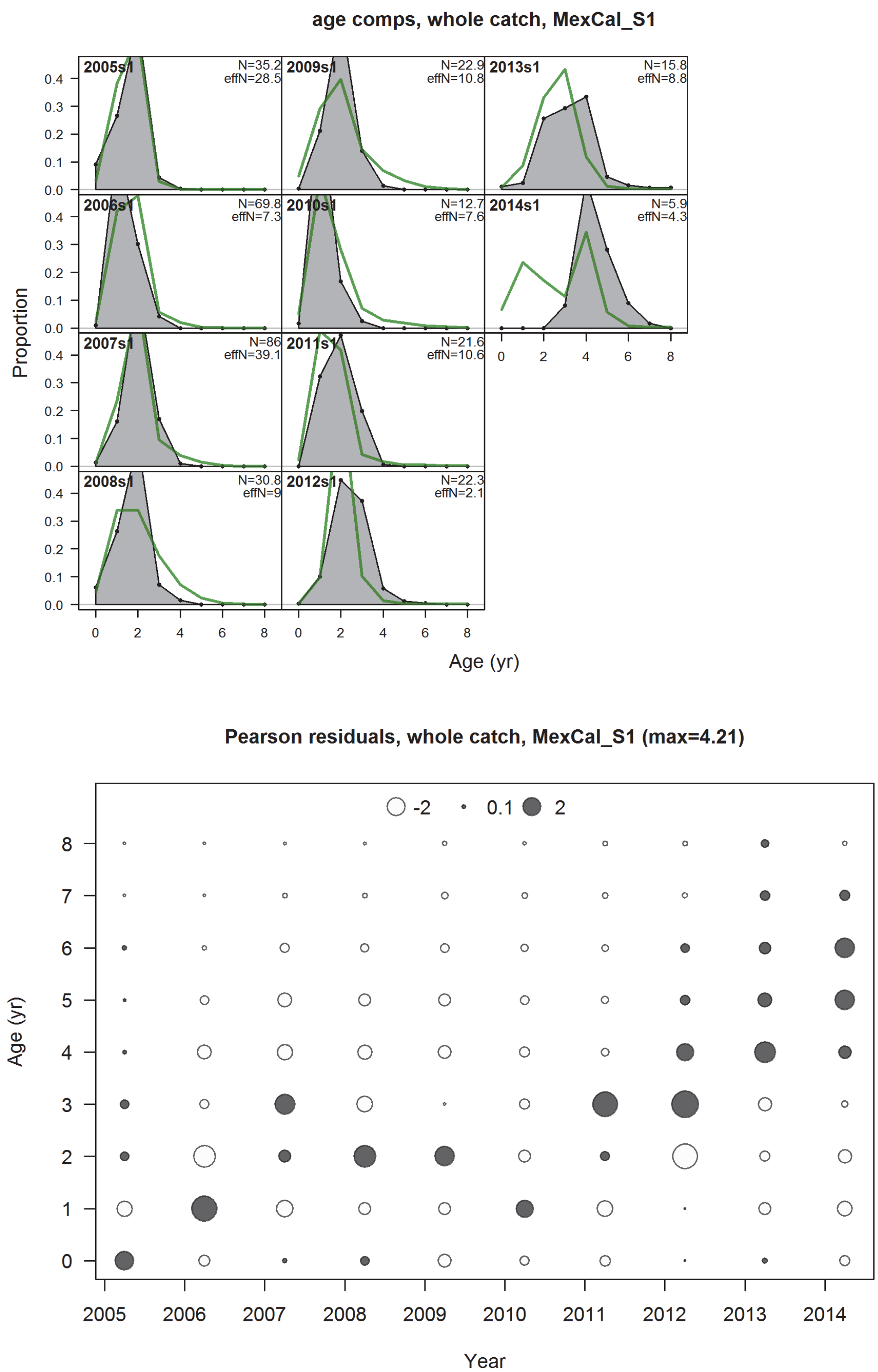
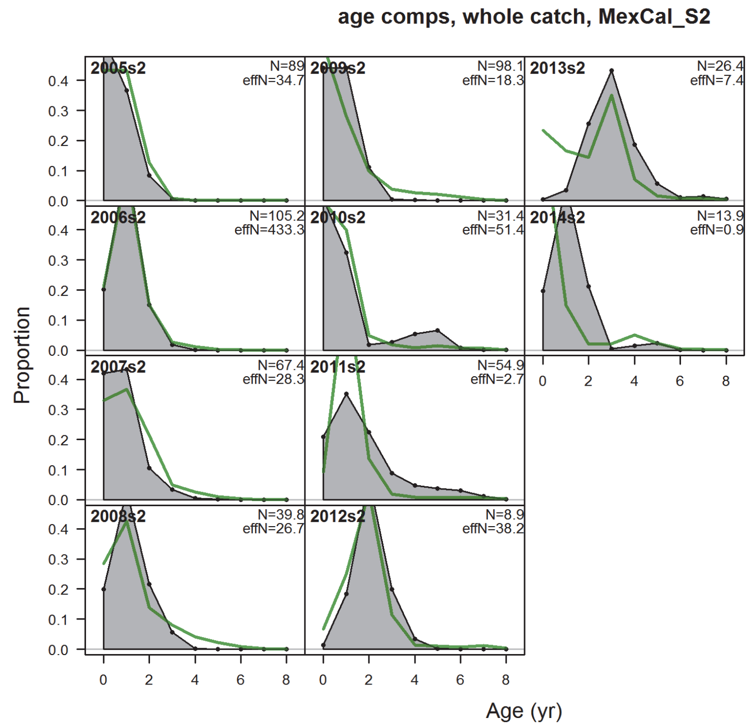


Figure 23. . Fit to age-composition time series and residual plot for the MEXCAL_S1 fleet in model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.



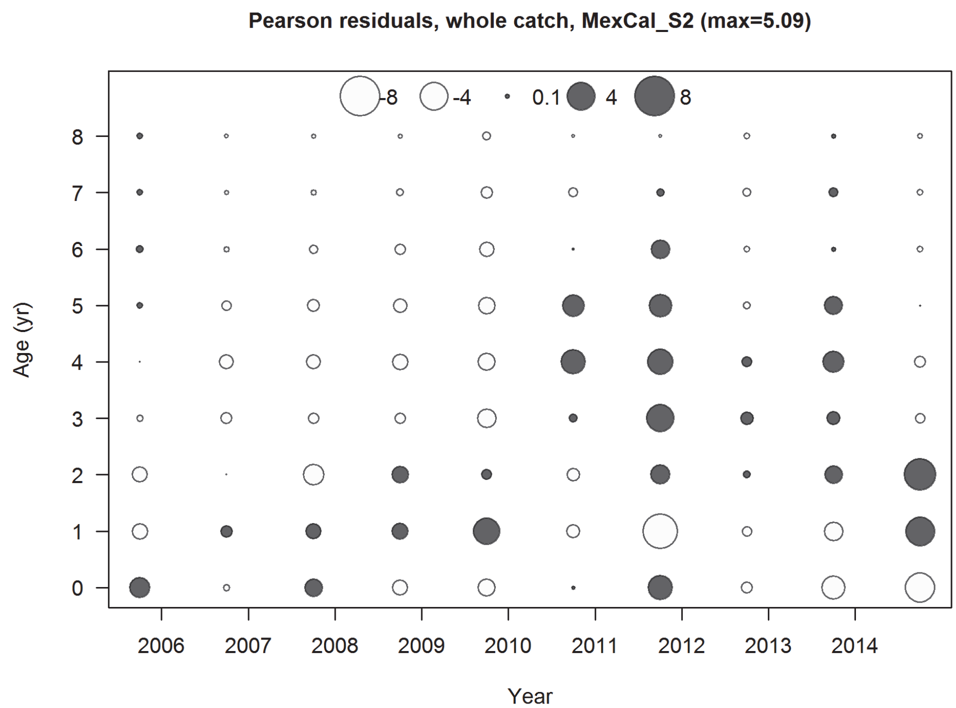
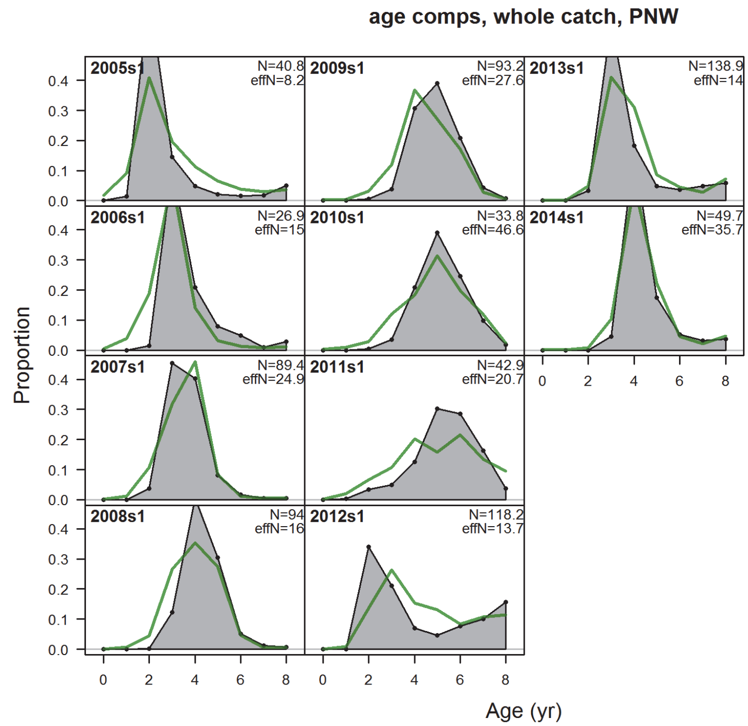


Figure 24. Fit to age-composition time series and residual plot for the MEXCAL_S2 fleet in model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.



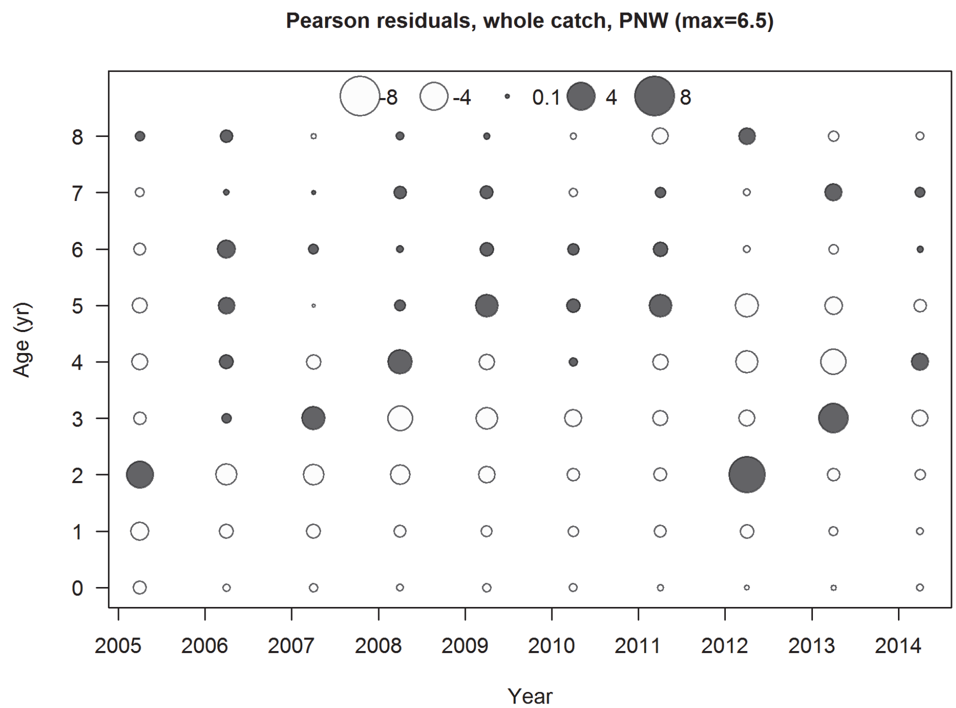


Figure 25. Fit to age-composition time series and residual plot for the PNW fleet in model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.

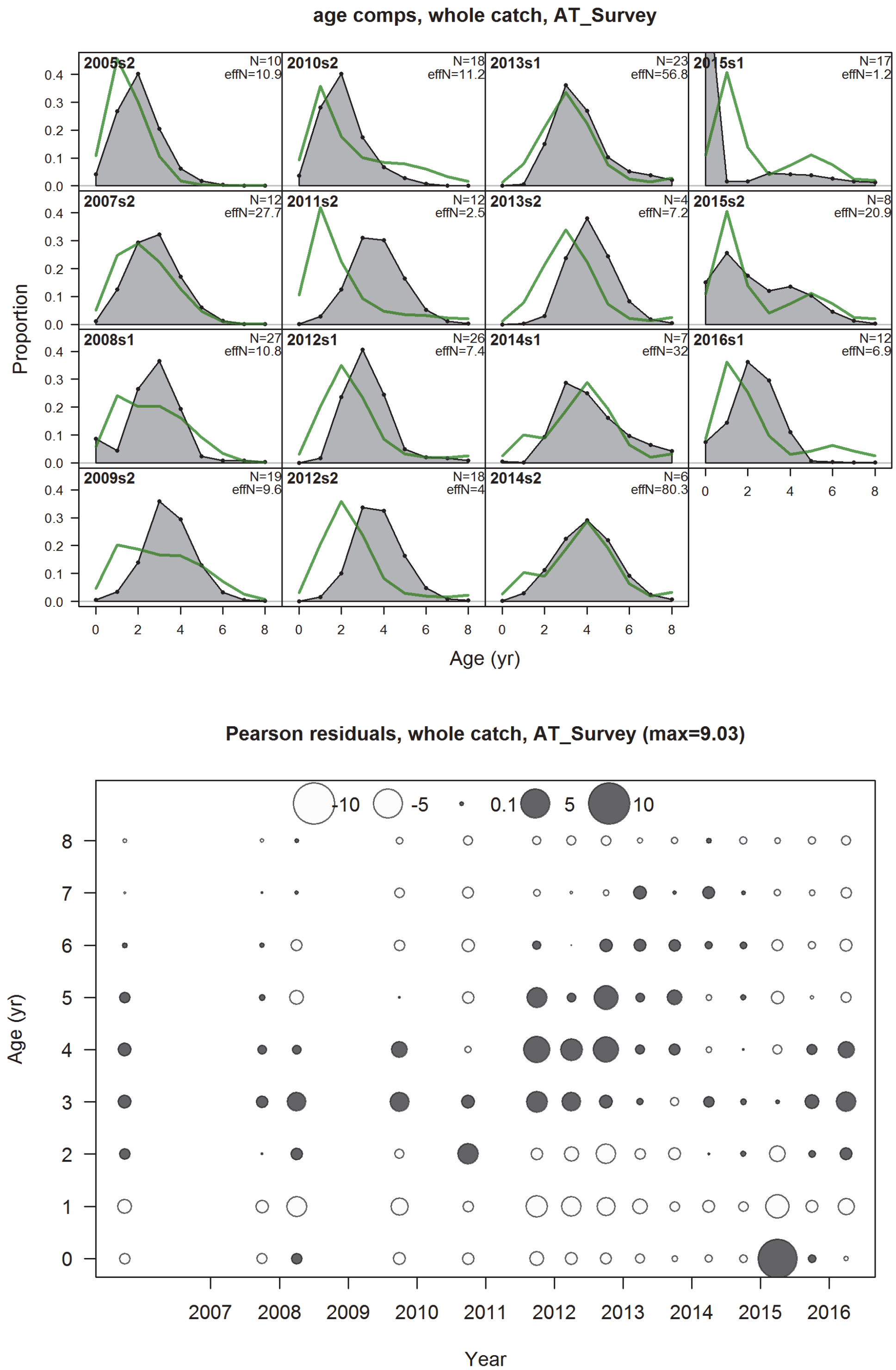


Figure 26. Fit to age-composition time series and residual plot for the AT survey for model ALT. N represents input sample sizes and effN is the effective sample size given overall statistical fit in the model.

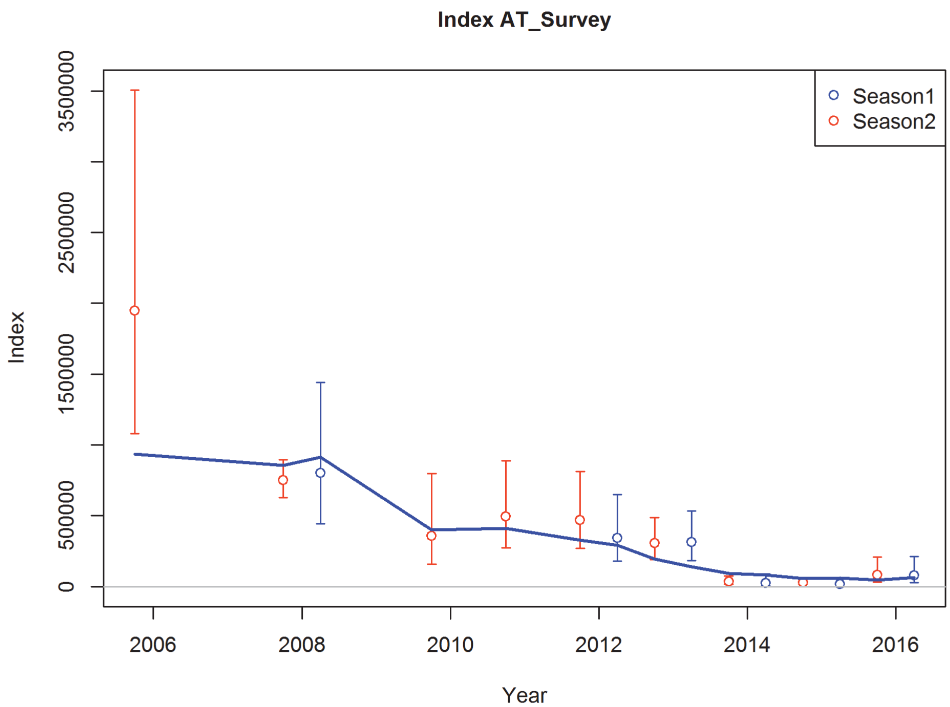


Figure 27. Fit to the AT survey abundance index in arithmetic (upper panel) and log (lower panel) scales for model ALT. Q=1.1 (estimated).

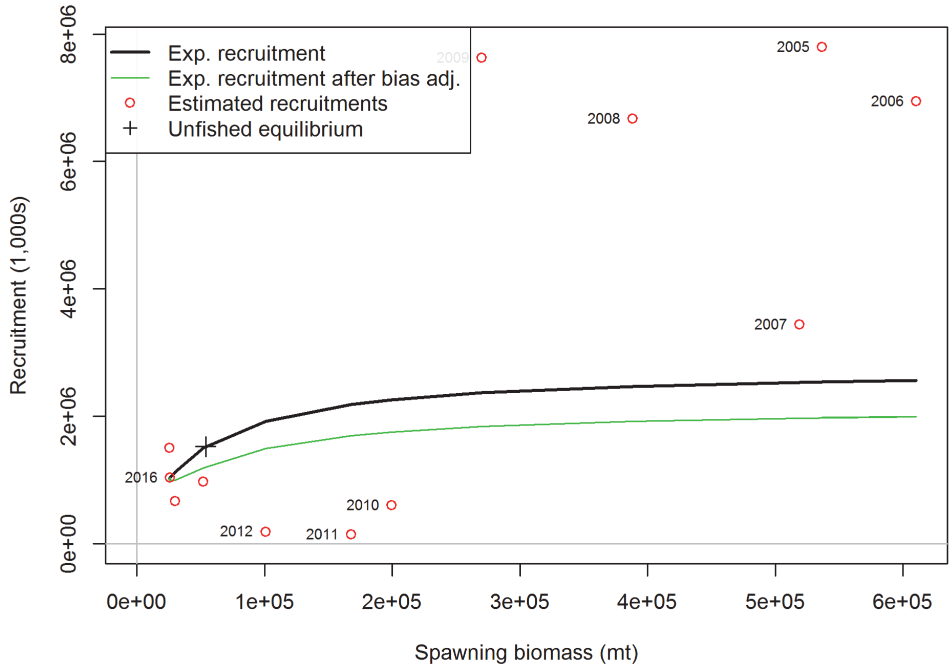


Figure 28. Estimated stock-recruitment (Beverton-Holt) relationship for model ALT. Steepness is estimated (*h*=0.36). Year labels represent year of SSB producing the subsequent year class.

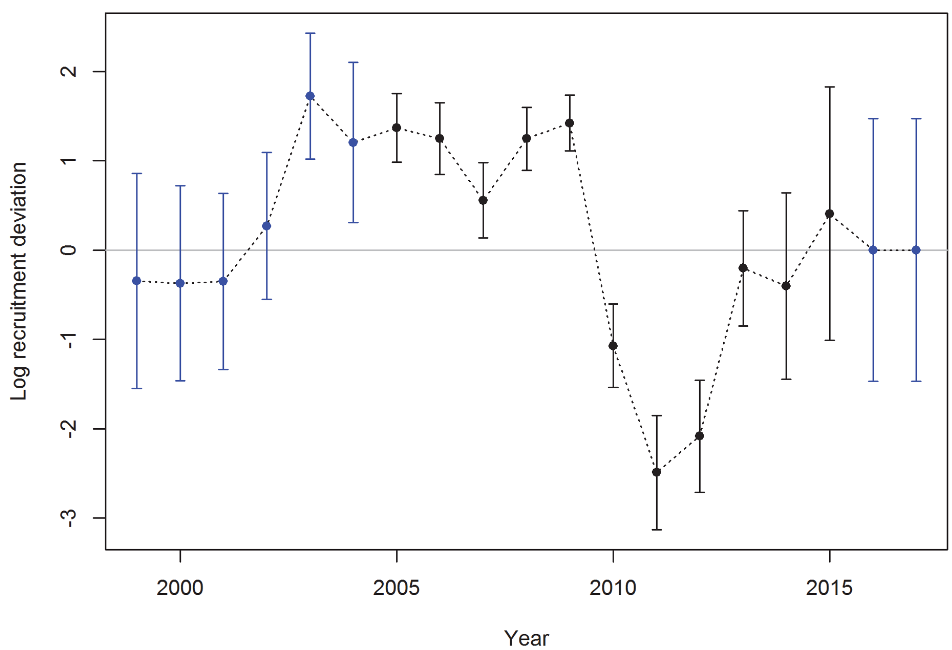


Figure 29. Recruitment deviations and standard errors (σ_R = 0.75) for model ALT. Year labels represent year of SSB producing the subsequent year class.

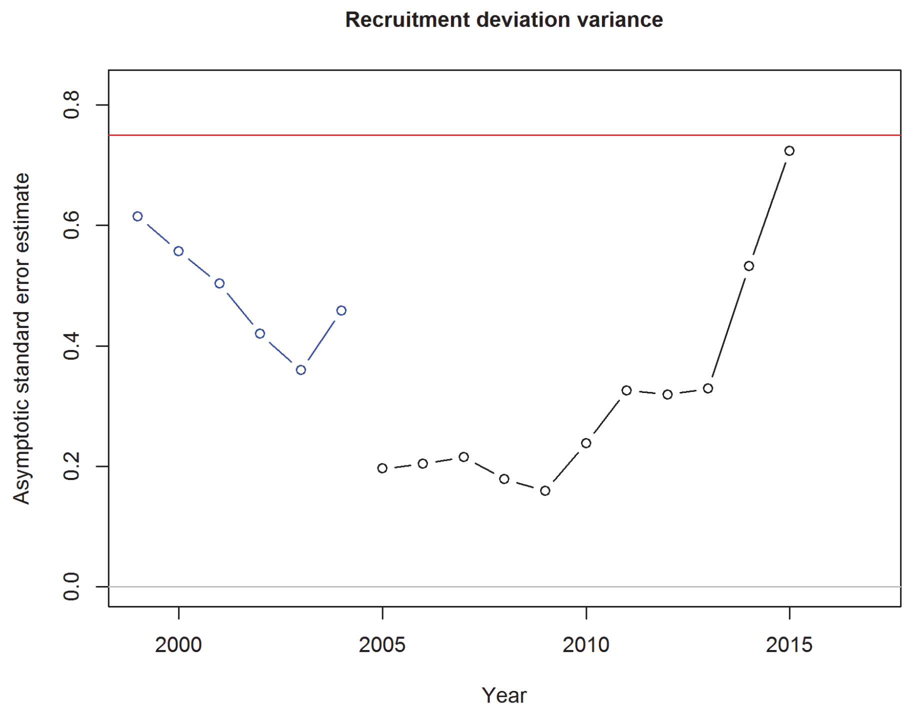


Figure 30. Asymptotic standard errors for estimated recruitment deviations for model ALT.

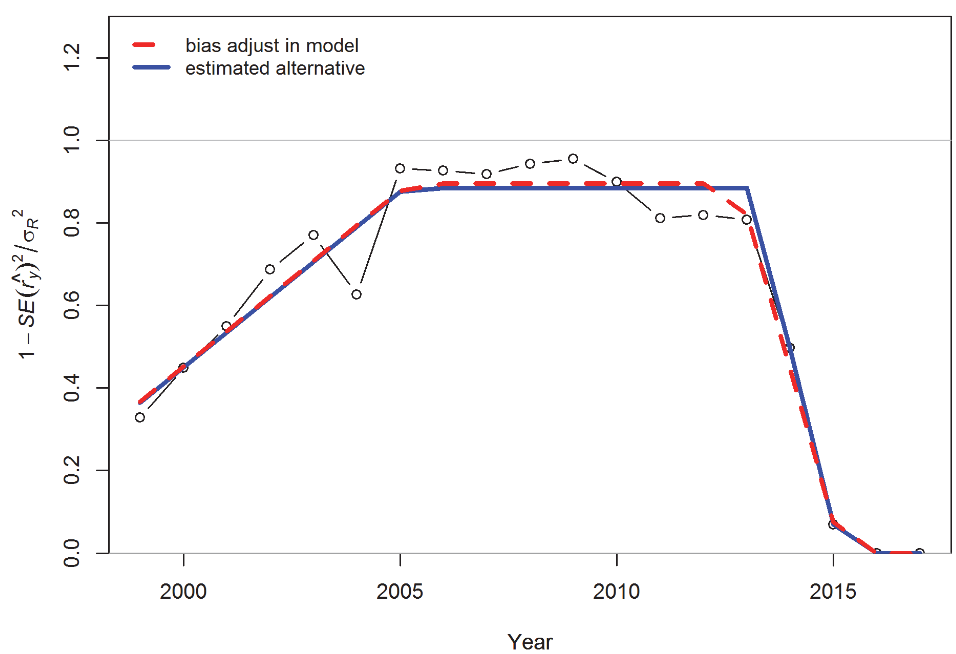


Figure 31. Recruitment bias adjustment plot for early, main, and forecast periods in model ALT.

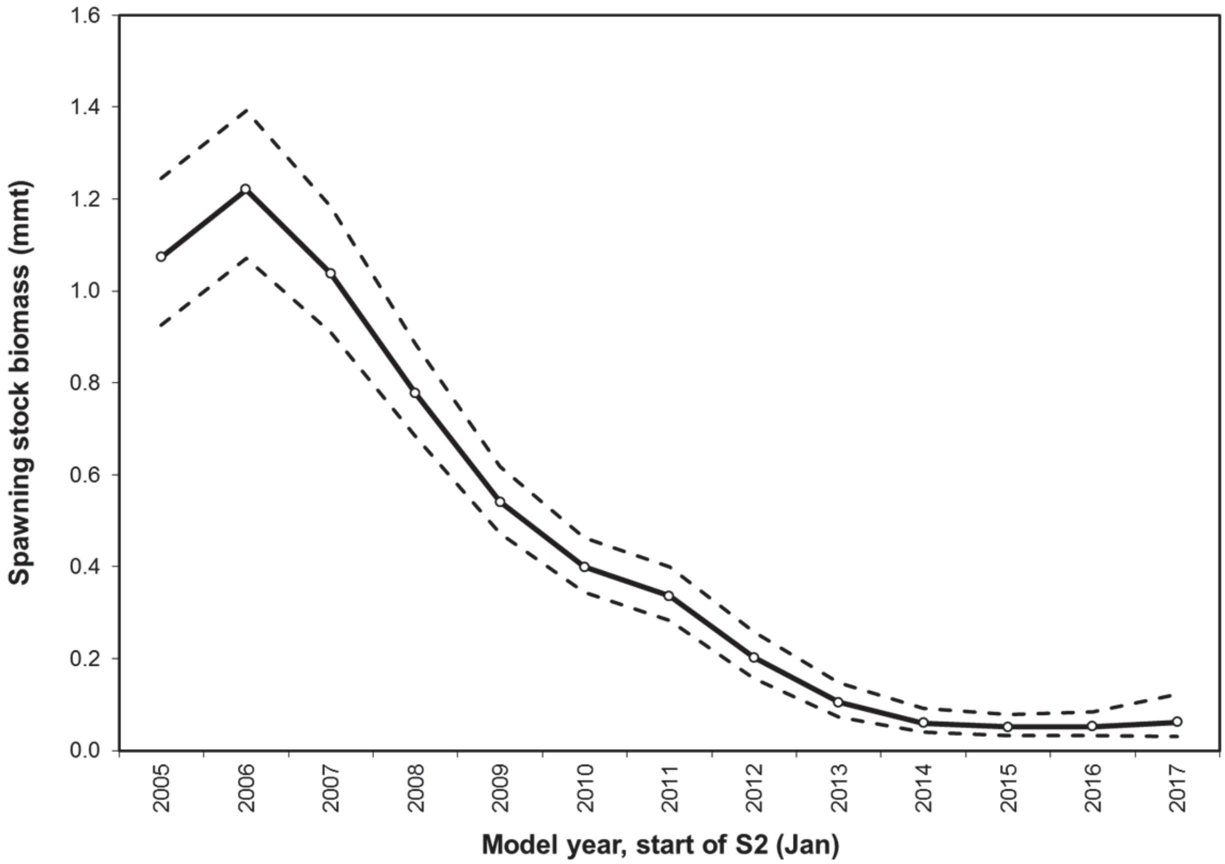


Figure 32. Spawning stock biomass time series (±95% CI) for model ALT.

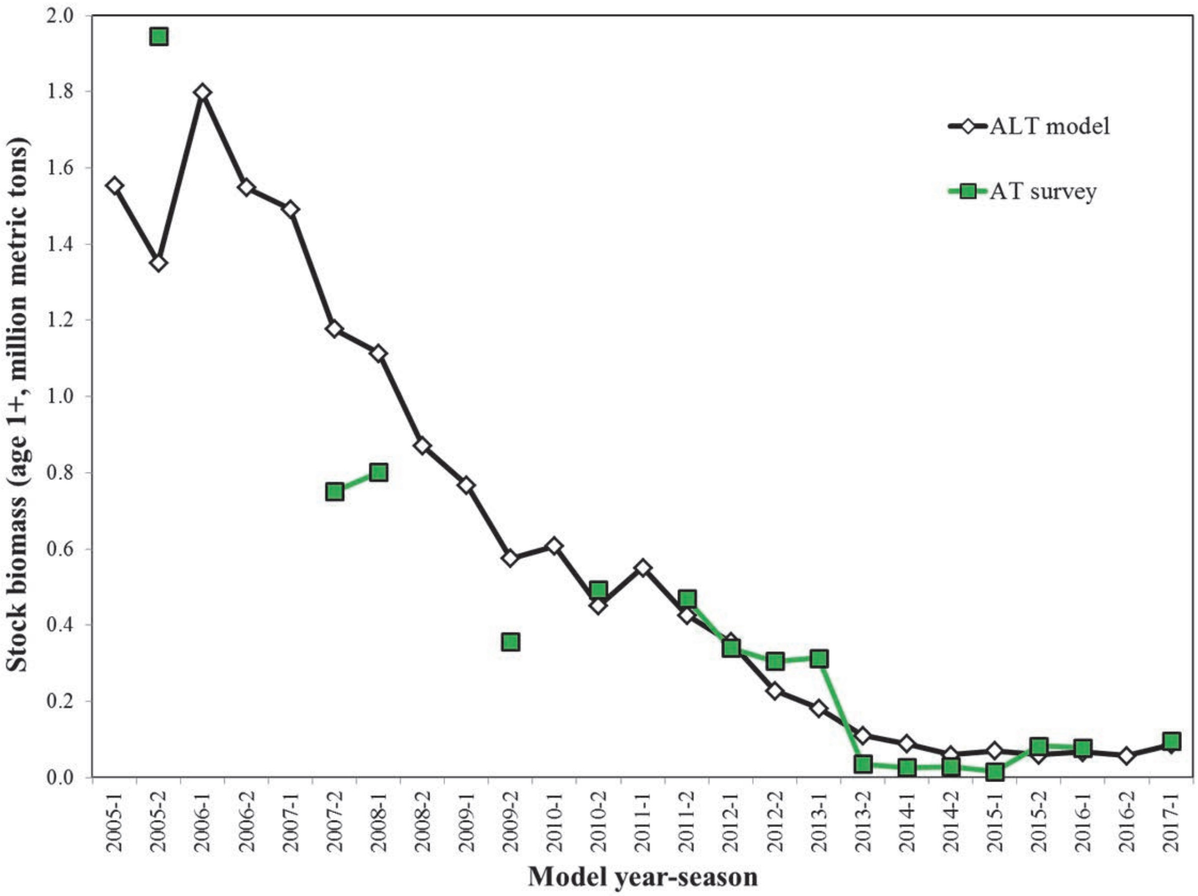


Figure 33. Estimated stock biomass (age 1+ fish, mt) time series for the AT survey and model ALT.

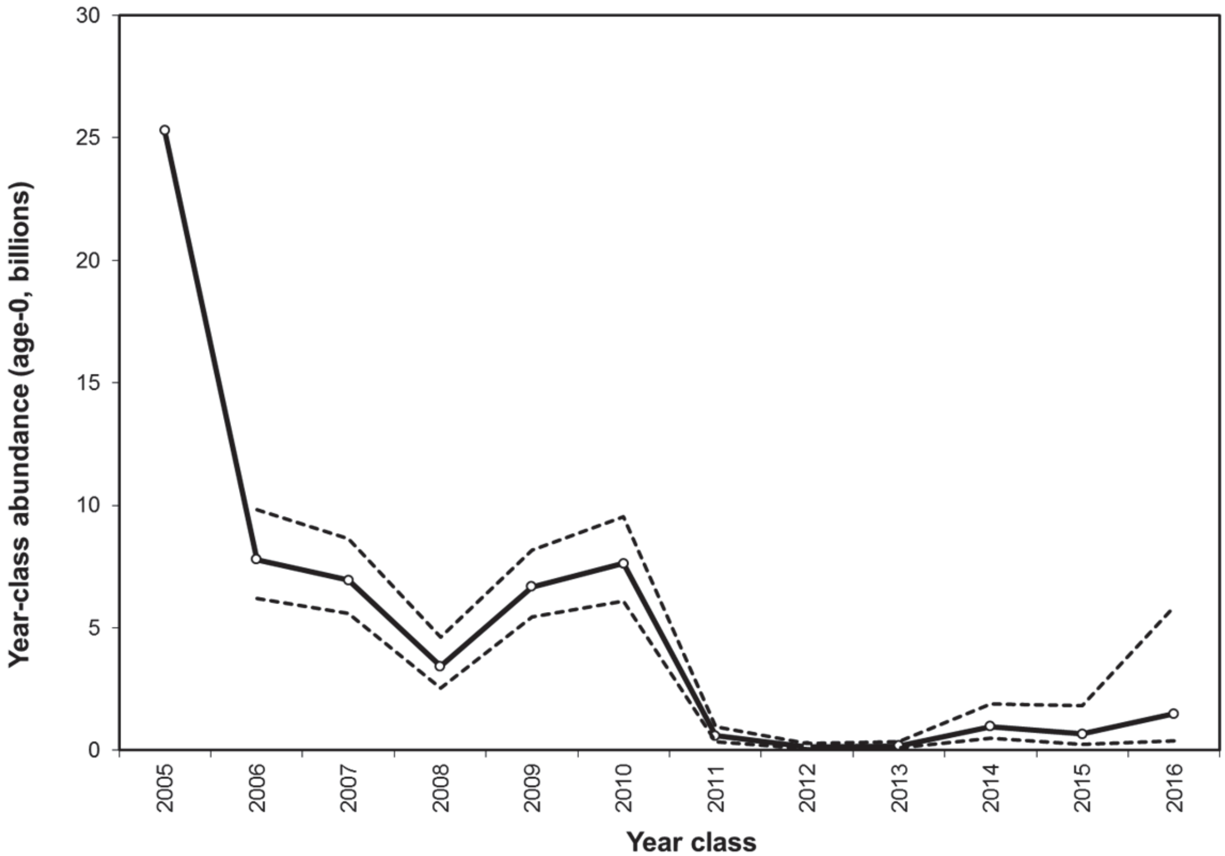


Figure 34. Recruit (age-0 fish, billions) abundance time series (±95% CI) for model ALT.

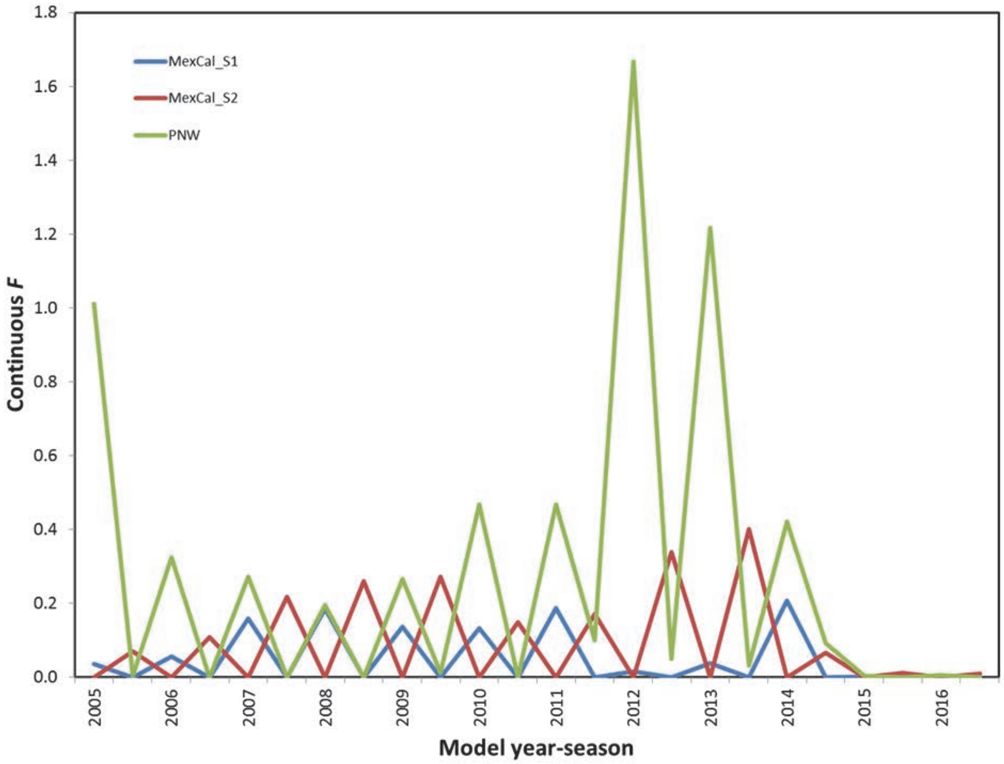


Figure 35. Instantaneous fishing mortality (apical *F*) time series for model ALT. Note that high *F* values for the PNW fleet reflect rates for fishes ages 6 and older.

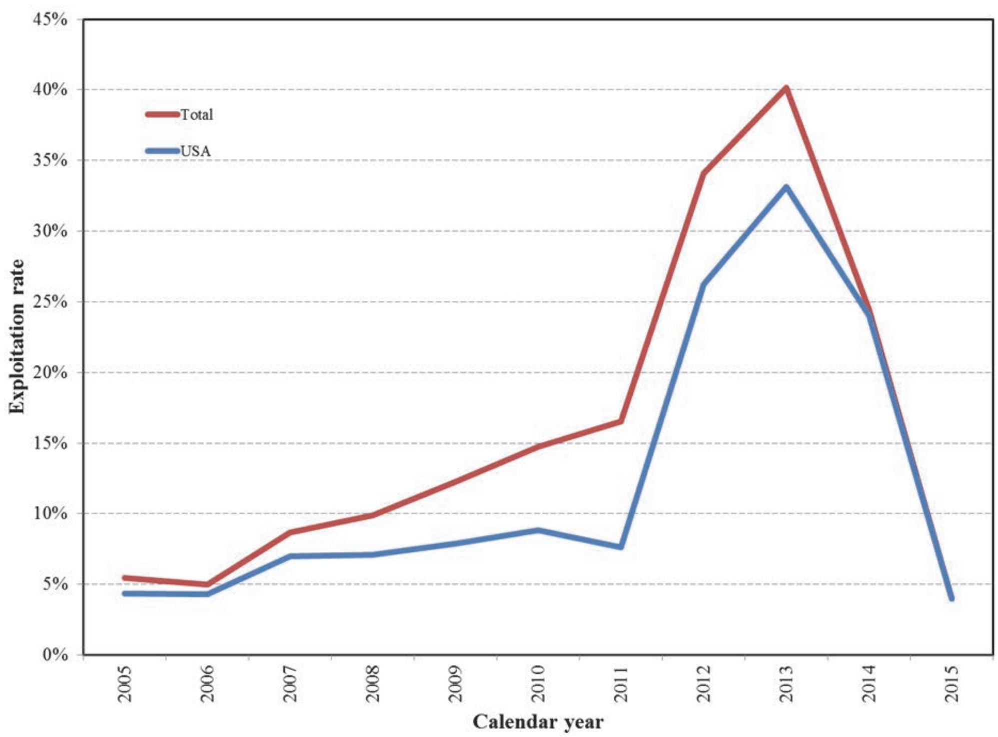


Figure 36. Annual exploitation rate (CY landings / July total biomass) for model ALT.

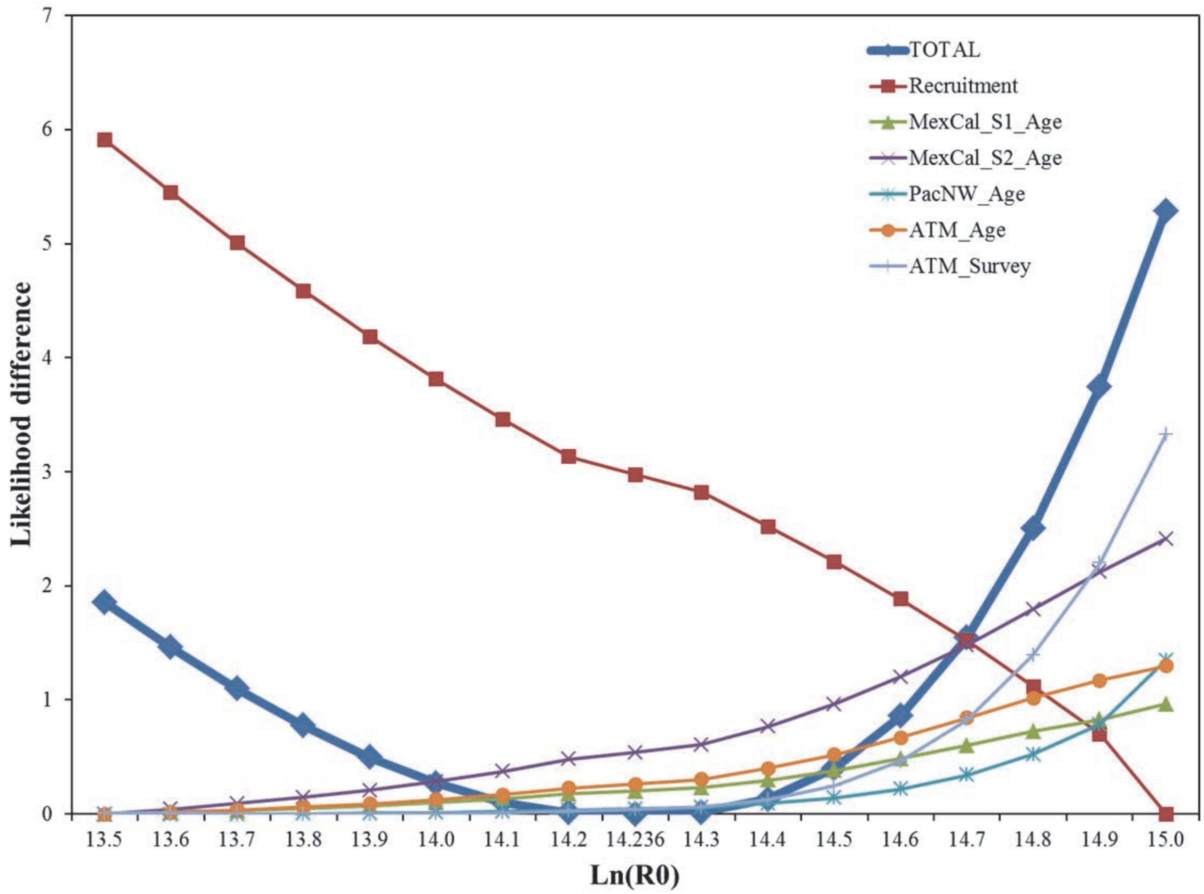
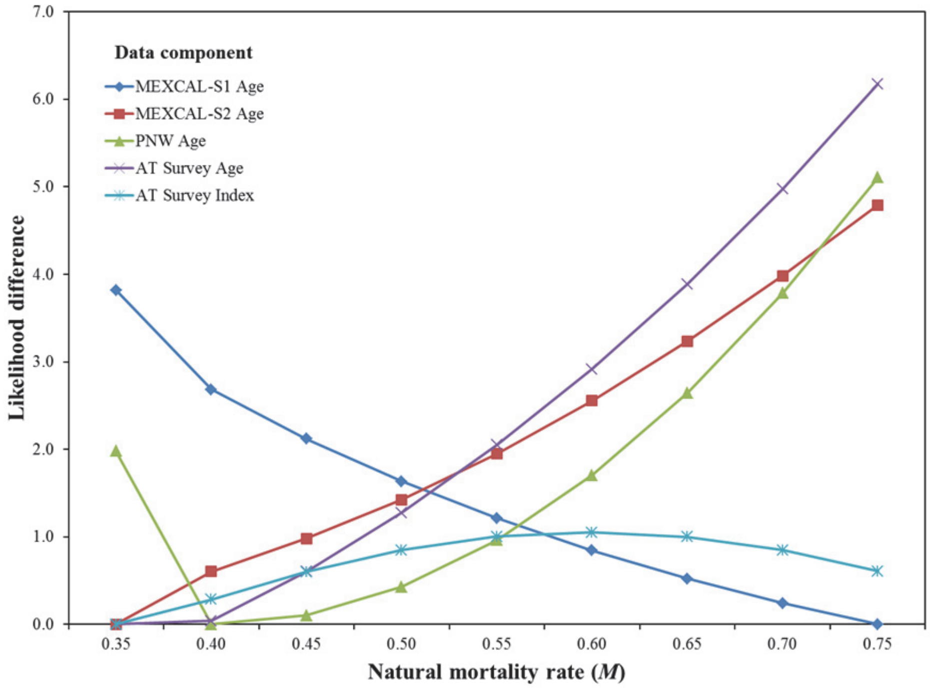


Figure 37. Virgin recruitment (logR_0) profile and associated difference in likelihood estimates for data components, recruitment, and total in model ALT.



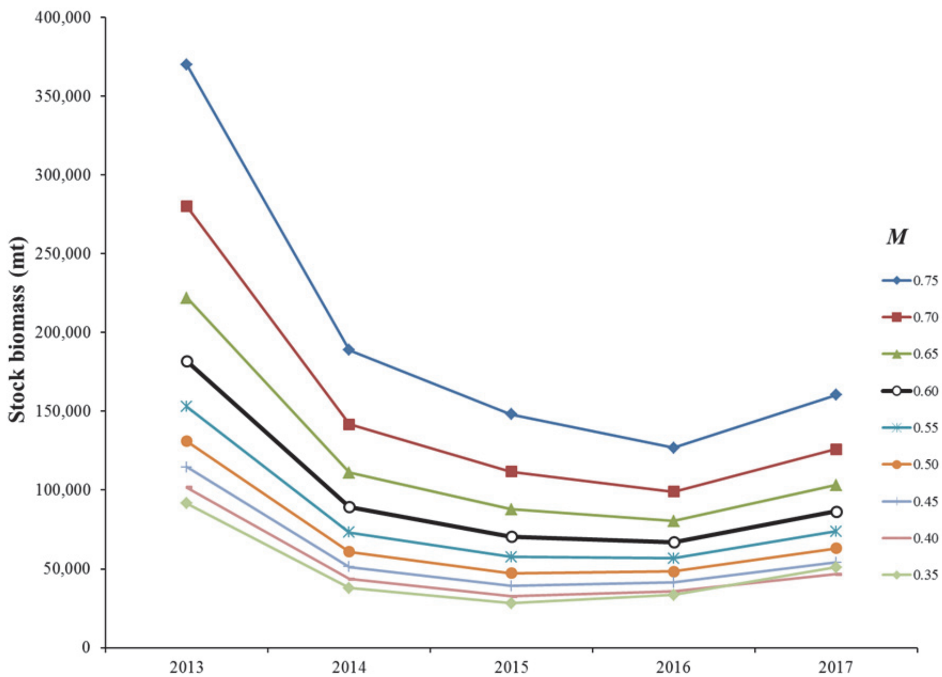


Figure 38. Likelihood differences (upper) and estimated stock biomass (age 1+, mt) for recent years (2014-17) (lower) associated with a range of fixed natural mortality values (M=0.35-0.75 yr^{-1}).

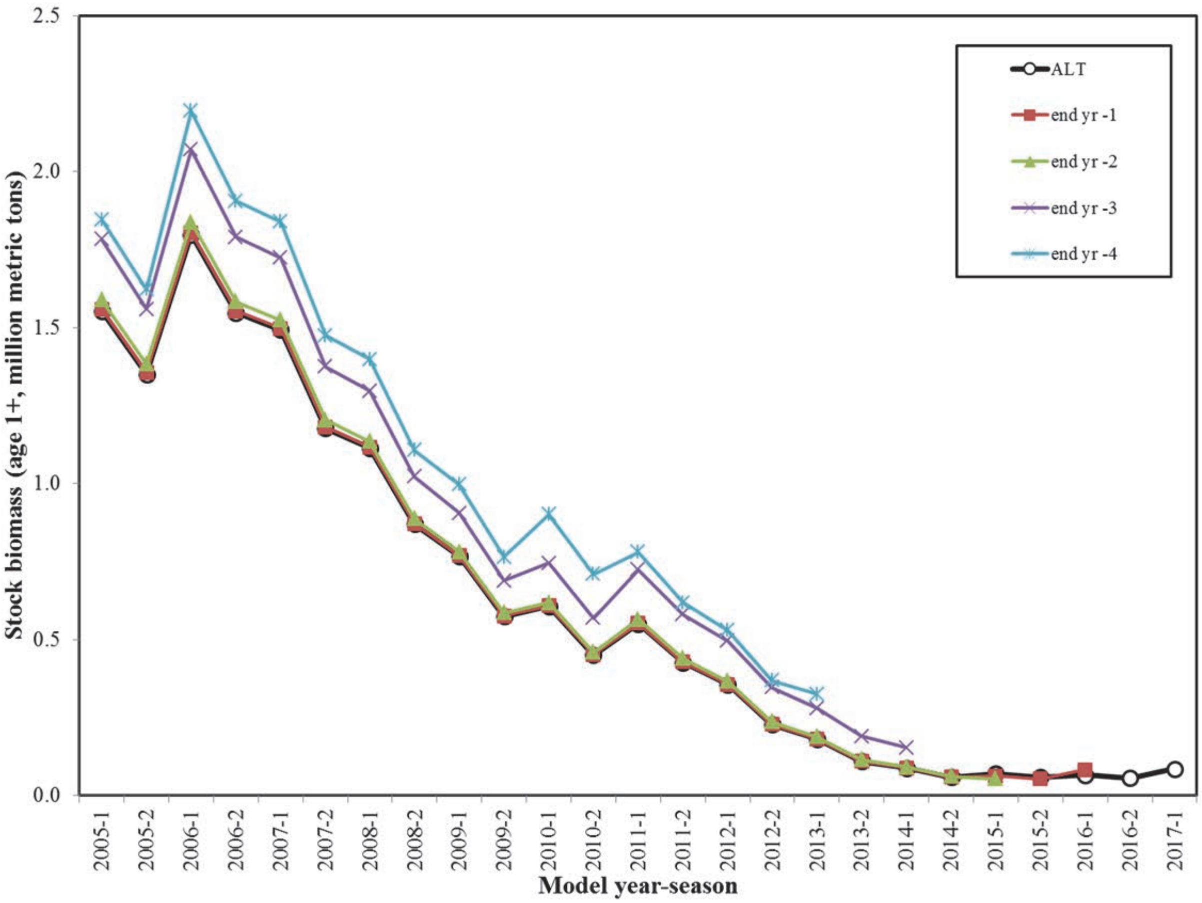


Figure 39. Retrospective analyses of stock biomass (age 1+) for model ALT.

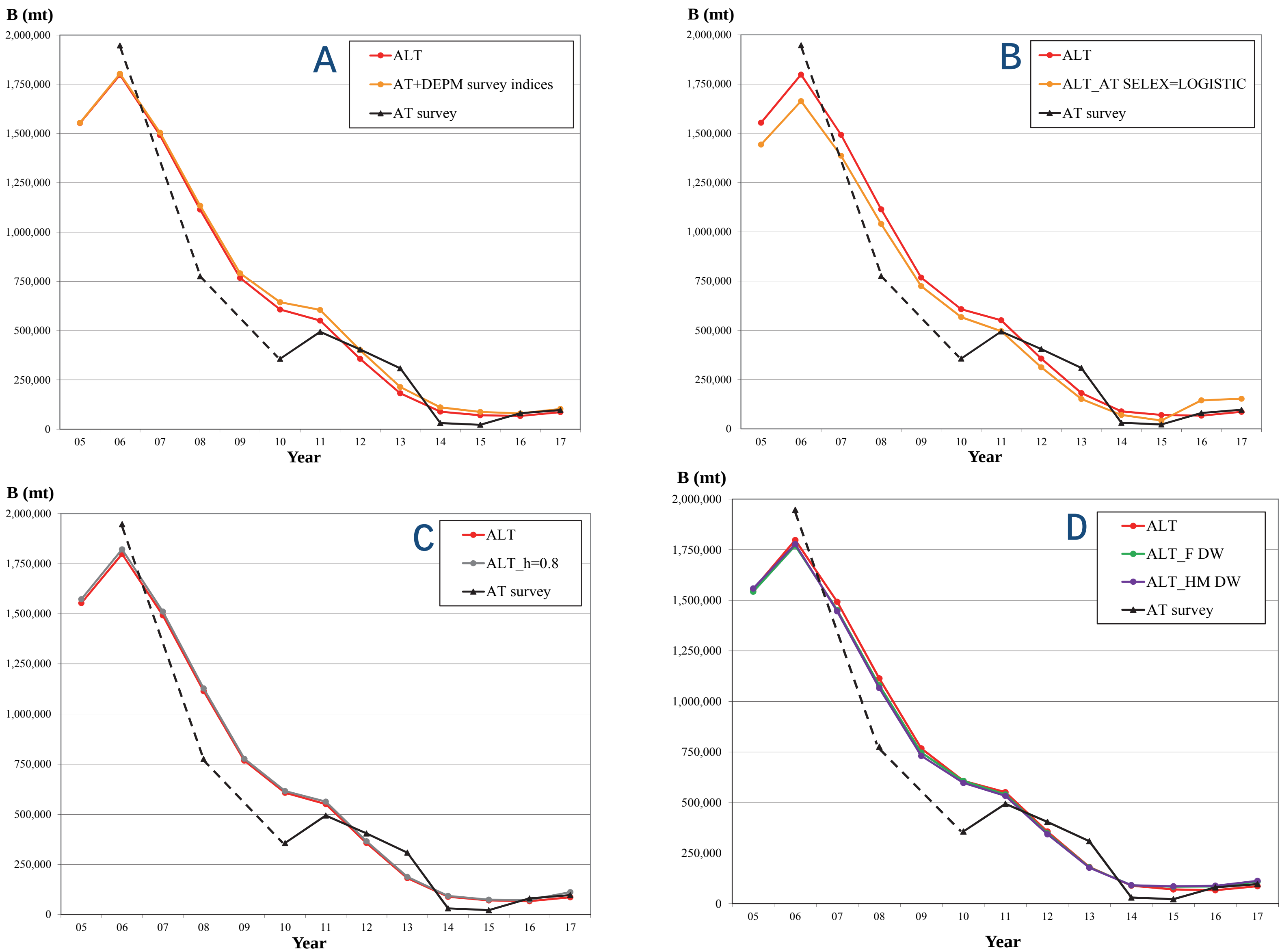


Figure 40. Estimated stock biomass (age-1+ fish, mt) time series associated with sensitivity analysis for model ALT: A) model ALT vs. model ALT (including DEPM abundance index); B) model ALT vs. model ALT (including 2-parameter logistic selectivity for the AT survey); C) model ALT vs. model ALT (including 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.

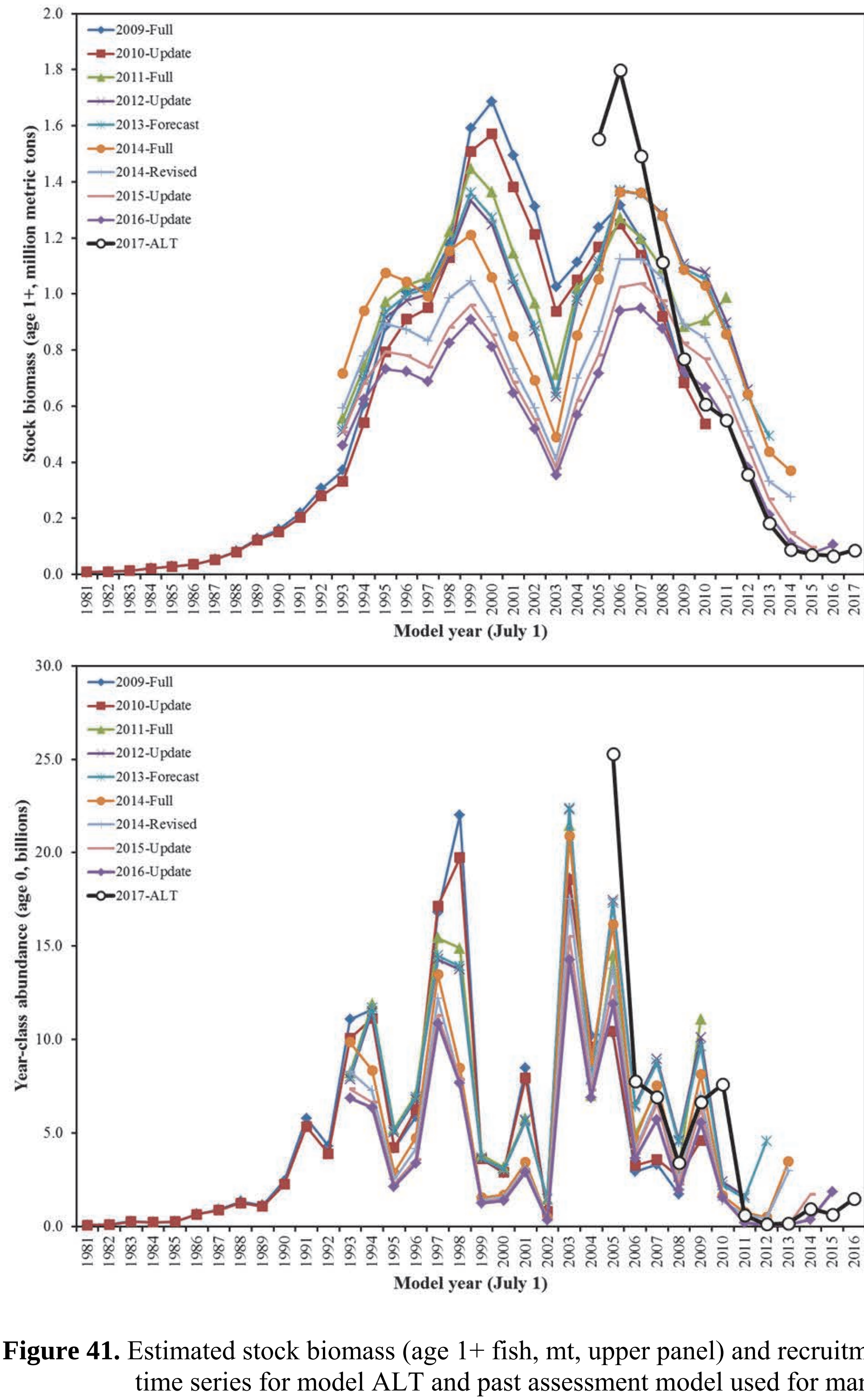


Figure 41. Estimated stock biomass (age 1+ fish, mt, upper panel) and recruitment (lower panel) time series for model ALT and past assessment model used for management.

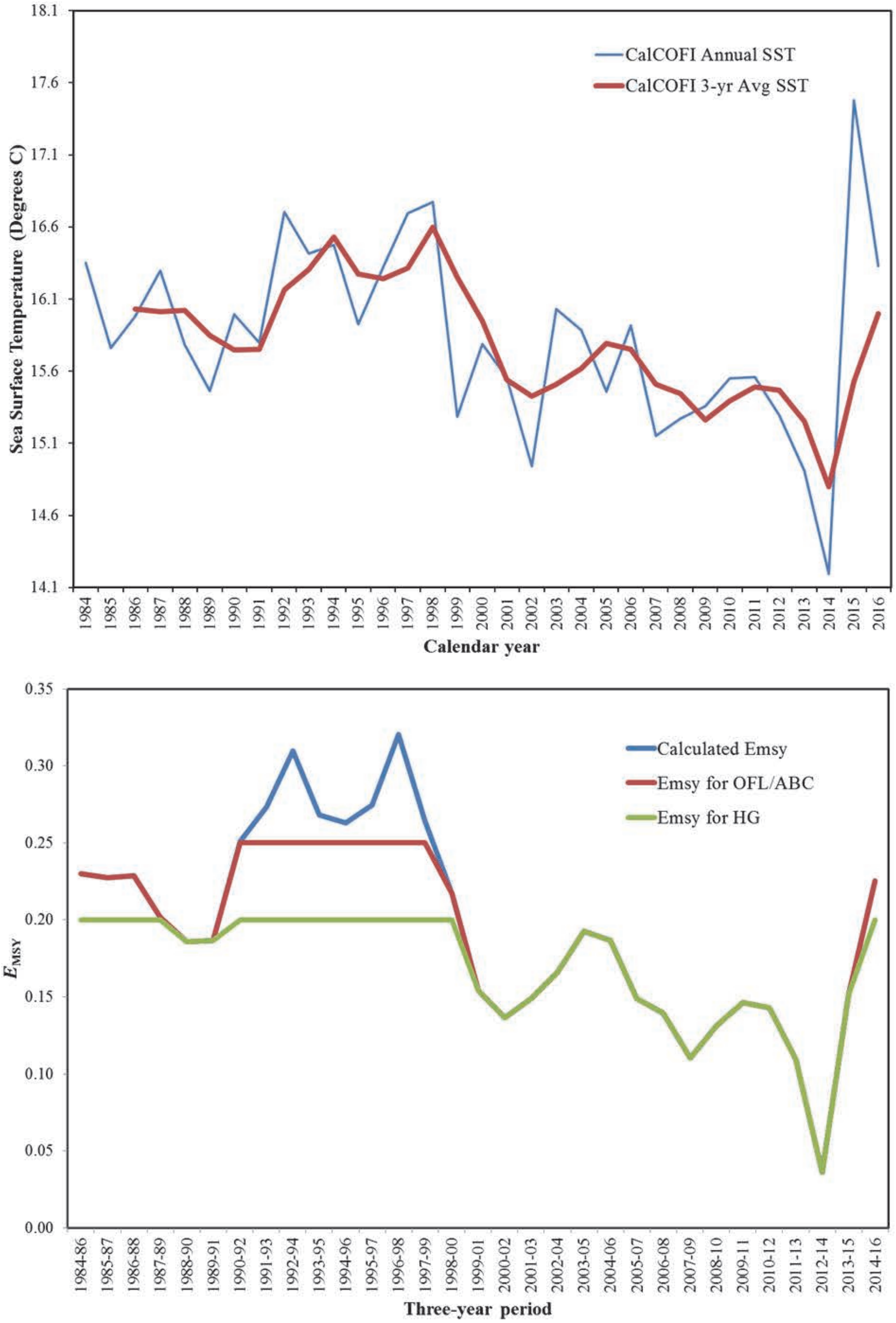


Figure 42. CalCOFI sea surface temperatures (SST, °C, upper panel) and calculated E_{MSY} values (lower panel).

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/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
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.

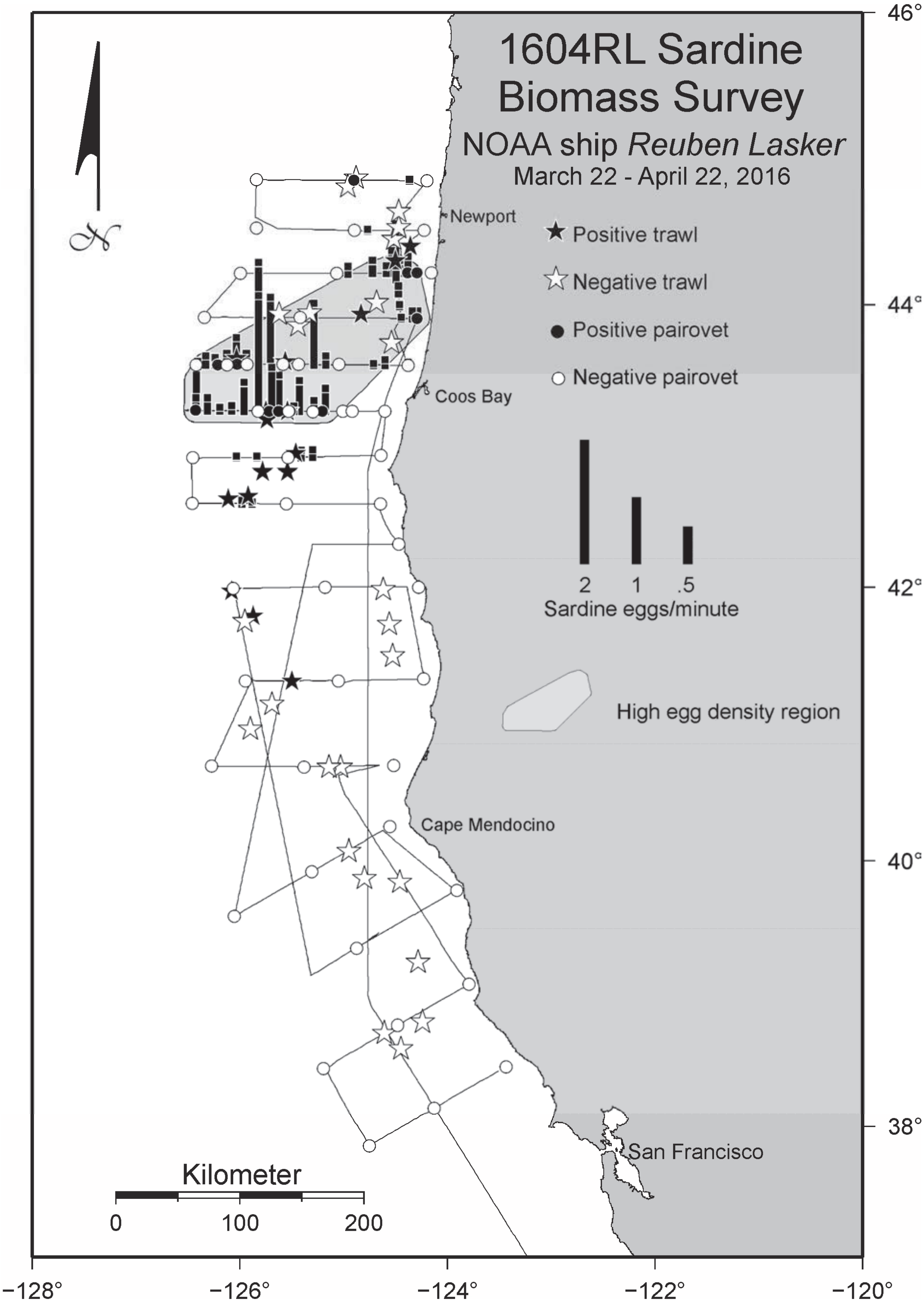

Figure 1. DEPM survey area and location of CalVET (Pairovet) and bongo tows, CUFES, and trawl locations during the 2016 survey aboard the NOAA ship *Reuben H. Lasker*.

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
```

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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
```

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                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
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                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
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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     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
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                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
```

			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
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			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

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                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
```

Appendix C

PFMC Scientific Peer Reviews and Advisory Body Reports.

Pacific Sardine
STAR Panel Meeting Report

NOAA / Southwest Fisheries Science Center
La Jolla, California
February 21-23, 2017

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Will Satterthwaite, SSC, Southwest Fisheries Science Center
Evelyn Brown, SSC, Lummi Natural Resources, LIBC
Jon Vølstad, Center for Independent Experts (CIE)
Gary Melvin, Center for Independent Experts (CIE)

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

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC

1) Overview

The Pacific Sardine Stock Assessment and Review (STAR) Panel (Panel) met at the Southwest Fisheries Science Center (SWFSC), La Jolla, CA from February 21-23, 2017 to review a draft assessment by the Stock Assessment Team (STAT) for the northern subpopulation of Pacific Sardine. Introductions were made (see list of attendees, Appendix 1), and the agenda was adopted. A draft assessment document and background materials were provided to the Panel in advance of the meeting on a Council FTP site.

Drs. Paul Crone, Kevin Hill, and Juan Zwolinski presented the assessment methodology. Paul Crone first outlined the assessment philosophy, which focused on selecting an approach that made most use of the data source considered by the STAT to be most objective, i.e. the Acoustic Trawl Method (ATM) survey. The STAT provided results for two assessment approaches: (a) use of the summer 2016 ATM survey estimate and associated age-composition projected to 1 July 2017, and (b) a model-based assessment that provides an estimate of age 1+ biomass on 1 July 2017.

Juan Zwolinski described the survey-based method for estimating age 1+ biomass on 1 July 2017, which involved estimating numbers-at-age on 1 July 2016 from the summer 2016 ATM survey from numbers-at-length using an age-length key that pooled data over multiple summer surveys, and projecting these numbers forward accounting for natural mortality and growth, and adding the estimated recruitment for 2016. The recruitment for 2016 was based on the stock-recruitment relationship estimated by model ALT, and the spawning stock biomass for 2016 was estimated by back-projecting the summer 2016 numbers-at-age to 1 January 2016.

Kevin Hill and Paul Crone described the data on which the model-based assessment was based, as well the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.24aa. Model ALT differed from the model on which the 2016 update assessment was based by starting the assessment in 2005 rather than 1993, excluding the Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices, estimating rather than pre-specifying stock-recruitment steepness, pre-specifying weight-at-age rather than estimating it within the assessment, assuming that selectivity for the ATM survey is zero for age 0 and uniform for age 1 and older, estimating survey catchability (Q), assuming that selectivity is age- rather than length-based, modelling ages 0-10+yr rather than ages 0-15+yr, assuming natural mortality (*M*) is $0.6yr^{-1}$ rather than $0.4yr^{-1}$ for all age classes and fitting the catch and ATM survey age-composition data (rather than the associated length-composition data). Unlike the 2016 and earlier assessments, model ALT included additional live bait landings, which generally reflected a minor contribution to the total landings in California. However, model ALT did not include biological composition data from the live bait catches, given this fishery sector had not been regularly sampled in the past, with samples being available for only the most recent year of the time period modelled in the assessment.

The review and subsequent explorations of the assessment through sensitivity analyses were motivated primarily by the need for the survey-based method to provide an estimate of age 1+ biomass and its CV, to better understand the rationale for the changes made to the model on which the last full assessment was based that led to model ALT, and to identify the best approach for providing an estimate of age 1+ biomass on 1 July 2017. The Panel had several comments and concerns regarding the ATM survey methodology and ways in which estimates of close-to-absolute abundance can be obtained. However, this was not a review of the ATM survey, since a second Council-sponsored ATM methodology review is planned for early 2018. Therefore, comments regarding the ATM survey and how estimates of abundance from that survey are constructed are reflected primarily in the Research Recommendations section of the report.

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

2) Day 1 requests made to the STAT during the meeting – Tuesday, February 21

Request 1: Provide documentation on the procedures used to calculate the survey age-composition data, including how age-length and age-biomass keys are constructed.
Rationale: These calculations are critical to projecting biomass after accounting for natural mortality, somatic growth, and recruitment; but the draft assessment document did not describe these calculations in sufficient detail for them to be reproduced. In addition, the age-compositions for the ATM survey in model ALT were computed using the method.
Response: Dr. Zwolinski presented written documentation and figures. The function "multinom" from the R package "nnet" fits a multinomial log-linear model using neural networks. The response is a discrete probability distribution (see Fig. 1). It is simpler to use than the alternative (sequential logistic models), and it provides a smoother transition between classes than an empirical age-at-length key. The age and lengths used for constructing the age-length key were from surveys from 2004 to the present. Due to the assumption of a July first date and its effect on ageing, the STAT built a season-specific age-length key using data pooled across time, separately for spring/summer.

The Panel agreed that aggregation across years is not appropriate if some length classes represent multiple ages, which is the case for Pacific sardine. Moreover, substantial spatial and temporal variation occurs in size-at-age, and merging the data from several years creates bias in annual estimates of age compositions of varying magnitude and direction.

Request 2: Provide full specification, including equations, of the calculations used to 1) project from the ATM survey biomass estimate to the estimated age-1+ biomass on July 1 of the following fishing year, and 2) calculate the uncertainty associated with that biomass estimate.
Rationale: The projection calculations need to be reproducible. Management advice (Overfishing Level OFL, Acceptable Biological Catch ABC, and Harvest Guideline HG) for Pacific sardine requires an estimate of age 1+ biomass (OFL, ABC, HG) and its uncertainty (ABC) on July 1, 2017.
Response: For 1), Dr. Zwolinksi walked the Panel through a spreadsheet that made these calculations and the Panel agreed that the calculations were sensible, conditional on the age-weight key. For 2), assuming independence of age 1 and age 2+ biomass, the total variance was calculated by summing the respective variances. This calculation is negatively biased because it ignores uncertainty in age-composition and weight-at-age. It was noted that the resultant coefficient of variation (CV) for age 1+biomass is lower than the CV for either component (age 1 versus age 2+) due to their assumed independence.

Request 3: Plot cohort-specific rather than year-specific growth curves (weight-at-age) for the ATM survey and overlay raw data/information on sample sizes. Make it clear which values are estimated versus inferred. Do this for the fisheries data as well.
Rationale: Cohort-specific curves are easier to interpret as growth trajectories than year-specific curves. It is important to understand how much data drives these estimates, and to understand the

consequences of applying the same age-length key for all years with survey data to calculate the weight-at-age and age-composition for the ATM survey.
Response: Dr. Hill presented tables including sample sizes and estimated means for each cohort-season-age combination. The tables were formatted to highlight entries that were inferred versus estimated. Dr. Hill calculated means whenever 3 or more samples were available. However, these means were sometimes overwritten based on the assumption that animals did not shrink. The ATM data showed substantial variation in weight-at-age across years (Fig. 2), and possibly increasing size-at-age in recent years. The MexCal catch data appeared less variable overall, and it was noted that fishery sample sizes were generally larger than the ATM sample sizes. The smoothing was not applied to the PNW catch.

The Panel noted that the adopted method ended up discarding data for cohorts with unusually large mean sizes for (for example) age-0 fish by not allowing "shrinkage", whereas it may have been the age-0 means that were anomalous rather than the means calculated for older ages. The Panel also noted that in many cases, the sample sizes were very small. The weight-at-age key used within the survey-based projection did not exclude "shrinkage". Using the weight-at-age key in model ALT produced an imperceptible difference in model-estimated age 1+ biomass.

Request 4: Verify that model ALT was run with ATM survey selectivity set equal to 0 for age-0 fish. Contact Dr. Rick Methot to better understand how selectivity is being modeled under the chosen selectivity option in SS.
Rationale: The model outputs appear to indicate that the model predicts non-zero catches of age-0 fish despite the intent to specify selectivity to be zero on age-0 fish. This may have significant unintended consequences for the likelihood calculations.
Response: This question was not fully resolved. It appears that Stock Synthesis predicts some catch of nominal "age 0" even given selectivity of zero on true age-0 fish because aging error leads to the expectation that some age-1 fish will be caught and mis-categorized as age 0. Further, model runs revealed that the model was unable to converge if aging error was set to zero or made very small, but reductions in the specified aging error led to the expected reduction in the predicted age-0 catch. It was noted that surveys likely include a mix of age-1 fish mis-categorized as age-0, as well as fish that are truly age 0.

Dr. Methot also noted that Stock Synthesis had not been as thoroughly debugged for semester-based models as for strictly annual models.

See also Requests 5, 8, and 9.

Request 5: Re-run model ALT with age 0 fish removed from the input file for the ATM survey.
Rationale: Similar to Request 4, the model likelihood should not be influenced by data on age-0 fish if it is assumed selectivity on age-0 fish is zero, but the model appears to be generating non-zero predictions and comparing these against the input data.
Response: The model still predicted catch of age-0 fish in this scenario. This is consistent with the explanation suggested for this pattern under Request 4.

Request 6: Report the CV of the estimate of terminal biomass based on changes in how the compositional data are weighted.
Rationale: The weighting of composition data appeared to have little effect on the point estimate of biomass, but it is important to understand implications of alternative weighting schemes for uncertainty as well.

Response: Data weighting increased the CV by 2-3%. The base model had a CV of approximately 36%, Francis-weighting led to a CV of approximately 38%, and harmonic mean weighting led to a CV of about 39%.

Request 7: Show more outputs from T_2017 and T_2017_No_New_AT_Comp.
Rationale: These outputs would help the Panel evaluate the reasons for proposing a move away from a strict update of the previously accepted model structure, i.e. identify problems with a strict update that the new model structure addresses.
Response: Selectivity curves for the spring and summer ATM surveys were noticeably different depending on whether the two most recent survey length-compositions were included in the assessment or not (Fig. 3). These models appeared to yield acceptable fits to abundance indices, but the fits to observed length-compositions were poor. It appears that the model estimates very low selectivity on small fish for the summer survey (since selectivity does not vary across years, and very few small fish are encountered most years) such that when small fish are encountered, they are expanded to a very large number. During Panel discussion, it was noted that this unexpected behavior should not happen if selectivity were forced to be the same for the spring and summer surveys.

Day 2 requests made to the STAT during the meeting – Wednesday, February 22
Request 8: Develop a model in which selectivity for age-0 animals in the survey is time-varying.
Rationale: The availability of age-0 animals to the survey seems to be highly variable among years, but influential on the results. A selectivity function in which age-0 selectivity varies among years should "discount" the influence of occasional catches of age-0 animals.
Response: A model was presented that assumed essentially full selection on age-1+ animals, and time-varying age-0 selectivity. The model estimated nearly zero selectivity on age-0 fish in all years except 2015, when estimated selectivity on age-0 fish was nearly 1.0 (atypically large pulse of small/young fish observed in summer 2015). Fits to composition data were similar to those for model ALT, except that the spike of age-0 fish in 2015 was captured better. The estimate of age 1+biomass on 1 July, 2017 for this model was 77,845 t.

Request 9: Run a variant of model ALT in which the age-composition data are assigned to a new fleet (6) that has logistic selectivity (estimated separately for the spring and summer periods).
Rationale: Selectivity for the ATM survey is assumed to be uniform on animals aged 1 and older so age-composition data are not required for this survey. The selectivity pattern for the trawl component of the survey is not uniform on age-1+ animals (some age-0 animals are caught) and it may be possible to represent this using a logistic selectivity function.
Response: This model performed generally similar to a logistic formulation applied to the ATM survey for both age-composition and as an abundance index, but it misses the summer 2016 ATM survey estimate of biomass from above whereas the logistic fits that estimate closely. However, the logistic model had a negative log-likelihood of approximately 311, compared to 305 for this variant, and 333 for model ALT. Thus, both a model with logistic ATM selectivity and a model that assumed 1+ selectivity for ATM survey estimates and logistic selectivity for the associated age-composition data fit the data somewhat better than model ALT.

Request 10: Conduct a retrospective evaluation of how well alternative assessment methods can predict the biomass from the summer ATM surveys. For each year Y for which there is a summer ATM survey estimate for year Y and year Y+1, report predictions of year Y+1 biomass based on

(a) the estimate of biomass from the results of the ATM survey during summer of year Y, (b) the estimate of biomass based on applying the projection method to the results from the ATM survey in summer of year Y, and (c) model ALT based on data through year Y.
Rationale: The Panel wished to understand which method was able to predict the ATM survey estimate of biomass most accurately.
Response: The STAT provided results for the three selected approaches as well estimates of age 1+ biomass obtained by projecting the actual assessments used for 2012, 2013, 2014 and 2015 forward ("Past assessment" in Fig. 4) and estimates of age 1+ biomass obtained by projecting the model used for 2014, 2015 and 2016 management advice ("2014 formulation"). Model ALT generally came closest to predicting the survey biomass estimate the following year, doing so by a substantial margin for 2014. "Past assessment" was usually the worst. Model ALT had the lowest residual variance. Relative errors were a CV of 1.07 for Model ALT, 1.26 for the 2014 model formulation, 1.50 for the last survey without projection, 1.62 for the values adopted in management specifications, and 1.70 for projections from the previous ATM survey (see Appendix 2 for the specifications for the method).

Day 3 requests made to the STAT during the meeting – Thursday, February 23
Request 11: Develop a method for estimating recruitment solely from ATM data, explain how these recruitment estimates could be used to project forward from an ATM biomass estimate, and then add results for that method to the retrospective comparison described in Request 10.
Rationale: During discussion of Request 10, it was clear that much of the concern regarding the currently proposed method of projecting from the survey was its dependence on model ALT for stock-recruitment estimates for conducting the projection, resulting in its dependence on the same assumptions the STAT was hoping to avoid by moving away from an integrated assessment. It was pointed out that it could be possible to develop estimates of age 1 biomass on 1 July, 2017 strictly from the ATM data.
Response: The STAT modified the survey projection method so that projected biomass of 1-year-olds was the average over the most recent five years (see Appendix 2 for details). As desired, this approach was not tied to the model ALT. However, the residual standard deviation for this approach ("Survey projection 2"), while better than "Survey projection", was still worse than Model ALT and the 2014 model formulation (1.45) (Fig. 4).

3) Technical Merits and/or Deficiencies of the Assessment

Alternative assessment approaches

The Panel considered four ways to estimate age 1+ biomass on 1 July 2017: (a) use the estimate of biomass from the summer 2016 ATM survey, (b) project the estimate of biomass from the summer 2016 ATM survey to 1 July 2017 using the 'survey projection' model (or an alternative approach), (c) model ALT, and (d) the model on which the 2014-16 assessments were based. The Panel had concerns with, and comments on, all of these methods:

- Assuming that the 1 July 2017 biomass equals the estimate of biomass from the summer 2016 ATM survey ignores mortality (from natural causes and from fishing), growth and recruitment from July 2016 to July 2017. However, this method is simple to implement because it does not rely on a model, nor does it rely on estimates of age composition for which sample sizes are low.
- Projecting the biomass from the 2016 ATM survey to 1 July 2017 accounts for mortality, growth and recruitment from July 2016 to July 2017. However, the approach used to

convert from length composition to age composition is incorrect, and the method used to derive the CV of age 2+ biomass does not allow for uncertainty in population age composition, projected weight-at-age and maturity-at-age. In addition, the method relies heavily on model ALT because approximately half of the age 1+ biomass on 1 July 2017 consists of age-1 animals, i.e. the estimate of this biomass is based to a substantial extent on the stock-recruitment function from model ALT. Finally, the value for M of 0.6yr^{-1} has no clear justification. The version of the projection model provided initially to the Panel did not account for catches so it could not be applied were the targeted sardine fishery to be re-opened, and does not account for the limited catches during 2016.

- Model ALT has several of the problems associated with the 'survey projection' model, i.e. the age-composition data are based on a year-invariant age-length key, and the basis for M=0.6yr^{-1} lacks strong empirical justification (and indeed likelihood profiles indicate some support for lower M than the value adopted for model ALT). In addition, the model presented to the Panel predicted age-0 catch in the ATM survey even though it is assumed that age-0 animals are not selected during the ATM survey. It appears that the model predictions of age-0 animals in the ATM survey are actually model-predicted numbers of age-1 animals that are predicted to be mis-read as age-0 animals. However, examination of the ATM survey length-frequencies suggests that that some age-0 animals (or animals that were spawning earlier in the year) are encountered during the surveys (Fig. 5). Model ALT estimates Q to be 1.1, which is unlikely given some sardine are not available to the survey owing to being inshore of the survey area.
- The model on which the 2014-16 assessments were based was approved for management by the 2014 STAR Panel. However, that assessment had some undesirable features, including extreme sensitivity to the occurrence of small (<~15cm fish) in the ATM surveys, poor fits to the length-composition and survey data, and sensitivity to the initial values for the parameters (i.e. local minima). These sensitivities and the resultant high uncertainty about population scale were noted in previous reviews.

The Panel explored alternatives to the current selectivity formulation to better understand why model ALT was predicting age-0 catch when selectivity for age-0 fish was set to zero. It was noted that the results are generally robust to assuming that selectivity is a logistic function of length (but that implies that some age-1+ animals are not available to the ATM survey), allowing for time-varying age-0 selectivity, and estimating a separate selectivity pattern for ATM survey age-composition data.

The Panel noted that the 'survey projection' model and model ALT both rely on the samples from the ATM surveys to compute weight-at-age and survey age-composition data. The samples sizes for age from each survey are very small (16 – 1,051), which means that estimates of, for example, weight-at-age are highly uncertain. The procedure of ensuring that weight-at-age for a cohort does not decline over time seems intuitively correct. However, if the estimated mean weight of young fish in a cohort is anomalously high or low due to sampling errors (owing to small samples), it can impact the weight-at-age of that cohort for all subsequent ages.

Model ALT estimated steepness rather than fixing it equal to 0.8. The results were not sensitive to fixing versus estimating steepness, but the estimate of 0.36 was low.

Selection of an assessment approach

The Panel considered the merits of the various approaches. It concluded that:

- The approach on which 2014-16 management was based exhibited undesirable assessment diagnostics, and produced extremely high estimates of recruitment when large numbers of small fish were observed in the ATM survey length-frequencies. The approach also performed poorly in retrospective analysis (Fig. 4)[1]. The Panel and STAT agreed that this approach should not be used for 2017 management.
- The survey projection method (and the modified version, "Survey projection 2") seems a viable and defensible way to estimate age 1+ biomass using the ATM survey results, especially if the method could be modified to not use the results from model ALT. However, as currently formulated, this method performs no better than assuming that the age 1+ biomass in July 2017 equals the survey estimate of biomass for summer 2016 (Fig. 4). Thus, while viable, this approach requires further development and review prior to adoption.
- Estimating the biomass on 1 July of year Y+1 based on the ATM survey estimate for year Y is simple, but the Panel was concerned that this method ignored catches during year Y and may lead to additional risk. Thus, the basic approach is viable, but needs additional testing prior to adoption.

Given the current management approach that requires an estimate of age-1 biomass at the start of July, the Panel and STAT agreed that model ALT was the best approach at present for conducting an assessment for the northern subpopulation of Pacific sardine, notwithstanding the concerns listed above. The results from the assessment are robust to changes to how selectivity is modelled, the value for steepness and data weighting, but there were several concerns with this model that could not be resolved during the Panel meeting. Assuming uniform selectivity leads to lower estimates of current 1+ biomass, but this assumption reflects the expectation that all fish in the survey area are vulnerable to detection during an acoustic survey.

The final model (model ALT) incorporates the following specifications:

- catches for the MexCal fleet computed using the environmentally-based method;
- two seasons (semesters, Jul-Dec=S1 and Jan-Jun=S2) for each assessment year from 2005 to 2016;
- sexes were combined; ages 0-10+.
- two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PacNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
  - MexCal fleet: age-based selectivity (one parameter per age)
  - PacNW fleet: asymptotic age-based selectivity;
  - age-compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
- Beverton-Holt stock-recruitment relationship with "steepness" estimated;
- *M* was fixed (0.6 yr^{-1});
- recruitment deviations estimated from 2005-2015;
- virgin recruitment estimated, and σ_R fixed at 0.75;
- initial *F*s estimated for the MexCal S1 fleet and assumed to be 0 for the other fleets;

[1] Care needs to be taken interpreting Fig. 4 given the low number of years involved and the fact the observed 1+ biomass is subject to considerable sampling error.

- ATM survey biomass 2006-2013, partitioned into two (spring and summer) surveys, with Q estimated;
  - age-compositions with effective sample sizes set to 1 per cluster (externally);
  - selectivity is assumed to be uniform (fully-selected) above age 1 and zero for age 0.

The estimate of age 1+ biomass on 1 July 2017 from model ALT is 86,586t (CV 0.363). Model ALT indicates that age 1+ biomass has rebuilt close to that in 2014, owing to a substantial increase in biomass based on the indices from the survey (Fig. 6). The estimate of age 1+ biomass is less than the estimate of age 1+ biomass on 1 July 2016 from the 2016 stock assessment (106,137t). This is a consequence of the change in assessment methodology, in particular that selectivity for the ATM survey is assumed to be uniform for fish aged 1 and older (assuming that selectivity is logistic in model ALT increases the estimate of 1+ biomass from 86,586t to 153,020t).

Future directions

The STAT strongly supports that management advice for Pacific sardine be based on the estimates of biomass from the ATM survey rather than a projection model or an integrated assessment. The Panel notes the following ways in which management could be based on the ATM survey results.

- Change the start-date of the fishery so that the time between conducting the survey and implementation of harvest regulations is minimized.
- Use Management Strategy Evaluation to evaluate the risk to the stock of basing management actions on an estimate of biomass that could be a year old at the start of the fishing season (if the fishery start date is unchanged). Review of an updated MSE would likely not require a Methodology Panel, but could instead be conducted by the SSC.

The Panel notes that there may be benefits to attempting to use both the spring and summer ATM surveys as the basis for an ATM survey-only approach and that moving to an assessment approach that relies on the most recent ATM survey (or two) may be compromised by reductions in ship time and/or problems conducting the survey. It agrees with the STAT that there is value in continuing to collect biological data and to update model ALT even if management moves to an ATM survey-only approach.

4) Areas of Disagreement

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

5) Unresolved Problems and Major Uncertainties

The core issues for stock assessments continue to be related to the temporal and spatial scale of the surveys and insufficient sample sizes of age-length for sardine in the ATM survey. The ability of a single boat following fixed transects along the entire sardine NSP region over a single period to sufficiently observe and sample a highly mobile schooling fish that exhibits high variability in recruitment, migratory patterns and timing, school structure, and depth distribution remains a core challenge. The relatively small sample size of sardine for biological analysis remains a concern related to acoustic expansions, population model estimates, and projection forecasts that depend on age composition and size-at-age information. A solution may require more resources than SWFSC has at its disposal so that will require Council action; resolution of this issue is outside of the ability of the Panel to address.

The Panel identified concerns with all of the proposed assessment approaches as highlighted in Section 3 of this report. In relation to model ALT, the Panel was unable to fully resolve the issue of observations of age-0 animals in the ATM survey age compositions, and how to compute age-composition and weight-at-age for the ATM survey.

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

a) CPSMT issues

The CPSMT (MT) representative appreciates the substantial efforts by the STAT and the constructive Panel discussion, and offers the following comments.

The STAT proposed the ATM survey as the preferred approach over an integrated model for estimating sardine biomass. However, because the ATM survey at this time does not better estimate biomass projected to the start of the 2017-18 fishing year, the integrated model (Model ALT) was ultimately recommended. The MT representative agrees this was a reasonable approach to meet management requirements for a July 1, 2017 biomass estimate, but nevertheless also supports further consideration for shifting to the ATM survey to estimate biomass. The MT representative notes that issues of spatial and temporal coverage, and sample size remain for the survey. This has implications for the model ALT as well.

The review noted problems associated with some very small sample sizes produced by the trawl component of the ATM survey. Given that fish captured in trawls informs the species composition of the acoustic signals, as well as providing biological data, additional effort is required to refine and improve trawling operations. Additionally, more of the fish (particularly during the summer survey) that are collected need to be processed for ageing. The MT representative notes small sample size was flagged as a concern in the last full update conducted in 2014 and strongly supports the Panel recommendation that the SWFSC conduct analyses to estimate optimal sample size and to refine the survey methodology.

The lack of nearshore coverage by the ATM survey persists. Research needs to be conducted to explore possible approaches for surveying this area. Collaborative projects with industry should be encouraged to leverage their expertise. Further, emphasis should be placed on ensuring that the survey has sufficient sea-days to effectively cover the entire west coast irrespective of whether the ATM survey is used within a model or if the ATM survey is to be considered the preferred approach to inform the biomass estimate for management. The current plan to reduce the number of sea-days from 80 in 2016 to 50 in 2017 is concerning. The 50-day summer survey planned for 2017 does not include the area south of Monterey. If distance between transects were increased, the survey could possibly be extended to Point Conception, which would still not include the Southern California Bight. Fewer days at sea and the corresponding likely decrease in number of trawls also reduces the data upon which to base species composition and to produce biological data.

An MSE to evaluate the effects of using the ATM biomass estimate to inform the following year's harvest control rules is proposed as a high research priority (G). If the MSE were to find the one-year lag does create unacceptable outcomes one approach would be to develop an improved projection model. Another proposed fix would be to move the fishing year start date. While possible, the MT representative would like to highlight that the start date was adjusted beginning in 2014 to afford the STAT more time between the conclusion of field seasons and the deadline for STAR review of stock assessments. More significantly, shifting the start date can raise management issues because embedded in it is the period-based catch allocation scheme. Selecting an existing allocation period start date (January 1, July 1 and September 1) is perhaps more straightforward and would not necessarily require substantial analysis. Selecting any other starting point would likely necessitate an analysis of impacts and therefore more time to implement (i.e. two to three Council meetings). How to best accomplish aligning a shift to using only an ATM survey-derived biomass estimate with a change to the fishing year will require additional deliberation.

b) CPSAS issues

The CPSAS representative commends the Panel and STAT for their extensive and thoughtful body of work throughout the 2017 sardine STAR panel. Unfortunately, the 2017 sardine assessment again encountered the same difficulties observed in previous STAR panels. Most of the unresolved problems and major uncertainties listed in the 2011 and 2014 STAR panel reports still exist.

Earlier panels pointed out significant scaling issues. The 2017 assessment also encountered issues with ageing, notably an age-length key that was deemed incorrect. One persistent problem is the very small sample size for biological composition data obtained during ATM surveys and other sampling; another is the high variability in length-at-age observed in sardine year-to-year. As pointed out during the meeting, an age/length key averaged over seasons is not valid; it ignores differential cohort strengths. This presents a major problem in model projections, and adds another layer of uncertainty considering the current time lag between field surveys and the development of either ATM survey-based or model-based management advice for the fishery.

Assigning July 1 as the standardized birth date for sardine also presents problems, particularly in light of recent year ocean conditions that have precipitated sardine spawning earlier in the year, too early to be observed in April DEPM surveys, and producing age-0 fish assumed too small to be captured in ATM surveys. Yet an abundance of small fish exists! In fact, the 2015 summer ATM survey did encounter a spike of very small fish. A record number of pelagic juvenile sardines (and anchovies) also was found in the 2015 juvenile rockfish cruise. However, the length-composition data for the small fish were omitted from the assessment model in 2015 because the biomass estimate produced was "unrealistic."

Ironically, none of the approaches considered at this STAR panel meeting found adequate evidence of recruitment in 2016 to boost the stock assessment "number" in 2017. In fact, the projected biomass estimate for 2017 is lower than 2016 at a time that sardines are increasing in abundance, apparently coast-wide, but certainly in California. The current report attributed this to a change in assessment methodology.

Fishermen from the Pacific Northwest and California who attended the STAR panel meeting reported that they have observed an abundance of 3-6 inch fish for the past couple of years, particularly in live bait catches. California fishermen delivered samples of these fish to the SWFSC and California Department of Fish and Wildlife (CDFW). But while the 2016 draft stock assessment did include a small number of live bait catches (now the only active non-treaty fishery for sardine on the West Coast), the corresponding biological-composition data were not aged and hence included in the assessment.

In the opinion of the fishermen, an opinion shared by this CPSAS representative, none of the four approaches considered during the panel meeting accurately reflect the biomass of sardine now in the ocean. The Panel also voiced concerns with all the methods presented; those concerns are reflected in the body of this report under **Technical Merits and/or Deficiencies of the assessment.**

The CPSAS representative highlights major concerns, including:

- The STAT now recommends the ATM survey as the most objective survey method. However, ATM surveys at present do not capture fish in the upper water column, nor a large biomass of young fish (sizes 3 inches and up) that fishermen have observed in nearshore waters since late 2014; this biomass is largely inside ATM survey tracks. But the ATM survey is assigned a catchability quotient (Q) of 1 nonetheless, meaning it "sees" all the fish. The Q for Model ALT, which is based largely on ATM survey data, is estimated at 1.1, which the STAR Panel report calls into question, given for example the unquantified volume of fish in nearshore waters.
- The summer 2016 ATM survey reported a fourfold increase in age 1+ biomass, but the biomass estimate produced is substantially lower than the estimate used for management in 2016. The STAR panel found fault with the methodology used to project the 2016 biomass to 2017. So do we – but using the 2016 ATM biomass estimate without adjusting for recruitment ignores reality.
- In addition, the proposal to simply use the biomass estimate from the summer ATM survey directly, to avoid uncertainty in model assumptions, could bypass surveying a substantial portion of the biomass if/when cruises are shortened, or disrupted. For example, the 2017 summer survey schedule is only 50 days, down from 80 days in 2016. This means the survey may not extend much below San Francisco, which will miss a substantial portion of California's historical fishing grounds.
- Also, a proposal to change the fishing season start date to more closely follow the survey, thus avoiding the need to project recruitment, is not as simple as it sounds. The current seasonal structure is tied to an allocation framework that would require serious discussion and analysis before any change could be implemented.
- At the end of the day, the STAR panel cautiously recommended proceeding with Model ALT, as the "least-worst" way to produce the age 1+ biomass estimate and CV required for management in 2017. The CPSAS hopes the SSC and Council will acknowledge all the caveats, and recognize that this is a "stop-gap" approach until the ATM methodology review can be accomplished in 2018, along with further review and improvement of Model ALT input and assumptions and potential review of other assessment indices.
- The CPSAS representative again voices concern that stock assessments appear to be gravitating toward one independent index measuring one point in time, based on ATM surveys. We strongly encourage a continuation of multiple surveys as each survey type has strengths and weaknesses. Other fishery-independent research, i.e. the juvenile rockfish survey, was informative in 2016 and should be approved to provide information for future sardine stock assessments, as this could serve as another indicator of recruitment.
- Clearly the small sample size and inadequate biological composition data are causing serious problems in assessing the sardine (and anchovy) resource. Industry has offered to help collect data, and we hope this offer will be acted upon in a way that such information can be incorporated into future stock assessments.

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

Other recommendations:

- Please work collaboratively with industry to resolve persistent data deficiencies, including assessing the nearshore, upper water column, and the need for substantial increase in sample size and biological composition data for sardine (and other CPS), particularly ageing.
- Recognize that the 2017 assessment is "déjà vu all over again" and most of the unresolved problems and major uncertainties listed in the 2011 and 2014 STAR panel reports still exist.
- Prior panel, SSC, CPSMT and CPSAS reports have recommended a methods review of the ATM survey ASAP as a high priority research and data need. We continue to emphasize this need, and further recommend that such review also encompass review of Model ALT and other potential data collection options, including the juvenile rockfish survey, CDFW/CWPA aerial survey and any other promising data collection prospects available by the time of the scheduled ATM review in January 2018.
- We also support the STAT high-priority recommendation to address: "*technical issues related to echosounder deployment and associated signal interpretation (e.g., uncertainty surrounding species-specific target strength [TS], sonar bias related to backscatter uncertainty, and areas of the upper water column that potentially are not capable of being surveyed*)."

Dr. Zwolinski noted that target strength is currently based on "similar" fish, not Coastal Pelagic Species (CPS) found in the California Current. The STAT and Panel recognized that incorrect target strength could result in both over or under-estimation of biomass

Finally, the CPSAS representative points out that improving survey and assessment methodology to accurately reflect abundance of sardine (and other CPS) is absolutely essential: the future of the industry hangs in the balance.

7) Research Recommendations

High priority

A. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata
B. The clusters (the Primary Sampling Units, PSUs) with age-length data should be grouped into spatial strata (post-strata, or collapsed post-strata used in ATM biomass estimators). The variance in estimates of age-length compositions can then be estimated by bootstrapping of PSUs, where age-length keys are constructed for each bootstrap replicate. The sub-sample size of fish within clusters that are measured for lengths should be increased, and length-stratified age-sampling should be implemented. This approach would likely increase coverage of age samples per length class and reduce data gaps.

C. The survey projection method should be developed further. Specifically, the survey age-composition should be based on annual age-length keys, and the uncertainty associated with population age-composition, weight-at-age and maturity-at-age needs to be quantified and included in the calculation of CVs. A bootstrapping procedure could be used to quantify the uncertainty associated with population age-composition and projected weight-at-age. Uncertainty in weight-at-age could also be evaluated using a retrospective analysis in which the difference between observed and predicted weight-at-age for past years was calculated. Ultimately, improved estimates of weight-at-age and measures of precision of such estimates could be obtained by fitting a model to the empirical data on weight-at-age.
D. The methods for estimating 1 July age 1+ biomass based on the results of the ATM survey during the previous year currently use only the results of the summer survey. Improved precision is likely if the results from the spring and summer surveys were combined. This may become more important if the number of days for surveying is reduced in future. Consideration should be given to fish born after 1 July.
E. 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.
F. Modify Stock Synthesis so that the standard errors of the logarithms of age-1+ biomass can be reported. These biomasses are used when computing OFLs, ABCs and HGs, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not age-1+ biomass.
G. The approach of basing OFLs, ABCs and HGs for a year on the biomass estimate from the ATM survey for the previous year should be examined using MSE so the anticipated effects of larger CVs and a possible time-lag between when the survey was conducted and when catch limits are implemented on risk, catch and catch variation statistics can be quantified.
H. 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.
I. The assessment would benefit from the availability of estimates of 1+ biomass that include quantification of the biomass inshore of the survey area and in the upper water column.
J. It is unclear how the habitat model is applied to determine survey design. Is this an *ad hoc* decision or is there a formal procedure? The next Panel should be provided with comprehensive documentation on how the habitat model is applied.
K. 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.
L. Explore the potential of collaborative efforts to increase sample sizes and/or gather data relevant to quantifying effects of ship avoidance, problems sampling near-surface schools, and currently unsampled nearshore areas.
M. Reduce aging error and bias by coordinating and standardizing aging techniques and performing an aging exchange (double blind reading) to validate aging and estimate error. Standardization might include establishing a standard "birth month" and criteria for establishing the presence of an outer annuli. If this has already been established, identify labs, years, or sample lots where there is deviation from the criteria. The outcome of comparative studies should be provided with every assessment.

Medium priority

N. Continue to explore possible additional fishery-independent data sources such as the SWFSC juvenile rockfish survey and the CDFW/CWPA cooperative efforts (additional sampling and aerial surveys). 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.
O. 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; this should include an analysis of age-structure on the mean distribution of sardine in terms of inshore-offshore (especially if industry partner-derived data were available).
P. Consider a model that has separate fleets for Mexico, California, Oregon-Washington and Canada.
Q. Compare annual length-composition data for the Ensenada fishery that are included in the MexCal data sets for the northern sub-population 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.

Low priority

R. Consider a model that explicitly models the sex-structure of the population and the catch.
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.
T. 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.

Recommendations that should be addressed during the 2018 review of the ATM survey

A. In relation to the habitat model
    a. Investigate sensitivity of the assessment to the threshold used in the environmental-based method (currently 50% favourable habitat) to further delineate the southern and northern subpopulations of Pacific sardine.
    b. Further validate the environmentally-based stock splitting method. The habitat model used to develop the survey plan and assign catches to subpopulation seems to adequately predict the spawning/egg distribution in the CalCOFI core DEPM region, but eggs were observed where they were not expected in northern California, Oregon and Washington during one of the two years when the survey extended north. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. Once statistically significant discriminant metrics (e.g. morphometric, otolith morphology, otolith micro-structure, and possibly using more recent developments in genetic methods) have been chosen, these should be

applied to samples from areas where mixing may be occurring or where habitat is close to the environmentally-based boundary. This can be used to help set either a threshold or to allocate proportions if mixing is occurring.

c. Consider including environmental covariates in model-based approaches that would account quantitatively for environmental effects on distribution and biomass. The expertise from a survey of fishermen could be extremely useful in identifying covariates that impact the distribution of clusters.

B. The SWFSC plans to examine ship avoidance using aerial drone sampling; there is an ongoing significant effort by Institute of Marine Research in Norway to understand the same issue using sonar, and the SWFSC acoustics team should communicate and coordinate with those researchers.

C. The effect of population size affecting the number and spacing of school clusters likely affects the probability of acoustic detection in a non-linear way; this could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed. A simulation exercise should be conducted using the current, decreased and increased survey effort over a range of simulated population distribution scenarios to explore this.

D. The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the night time scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters.

E. The ATM survey design and estimation methods need to be more precisely specified. A document must be provided to the ATM review (and future assessment STAR Panels) that:
   - delineates the survey area (sampling frame);
   - specifies the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
   - specifies the rule for stopping a transect (offshore boundary);
   - specifies the rules for conducting trawls to determine species composition;
   - specifies the rule for adaptive sampling (including the stopping rule); and
   - specifies rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account density should be considered.

References

Venables,W.N. and D.B. Ripley, B.D., 2002. Modern Applied Statistics with S, 4th ed. Springer-Verlag, New York.

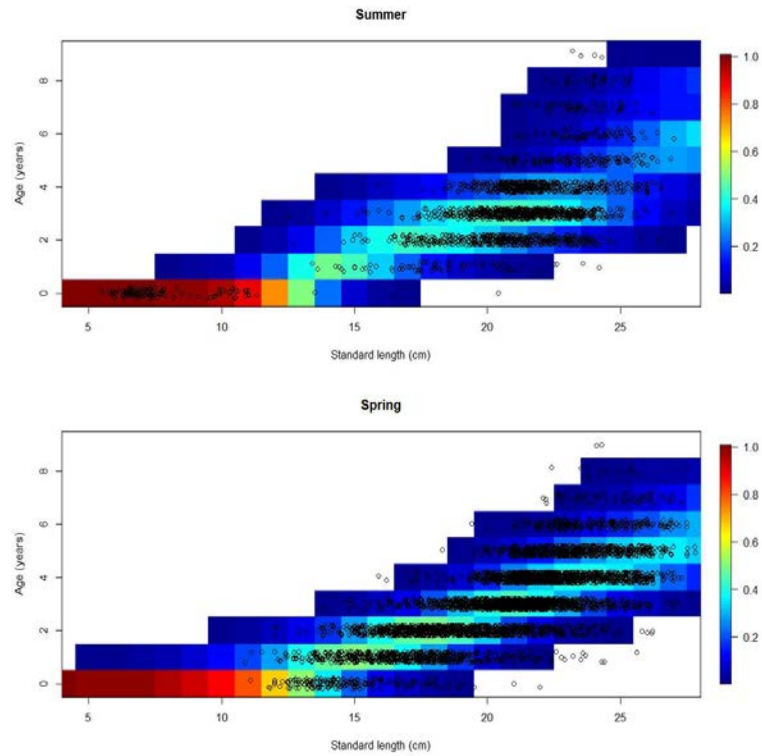

Fig. 1. Age-length key constructed using age and length information from sardine collected during Spring (upper panel) and Summer (lower panel) ATM surveys from 2004 to the present. The colored surface in the background is the multinomial surface $P(x = i|length)$ for $i \in \{0,1,\ldots,8,9+\}$ fit using the *multinom* function available in the *nnet* package for R (Venables and Ripley, 2002). The points in the foreground represent the pairs of data used to fit the model.

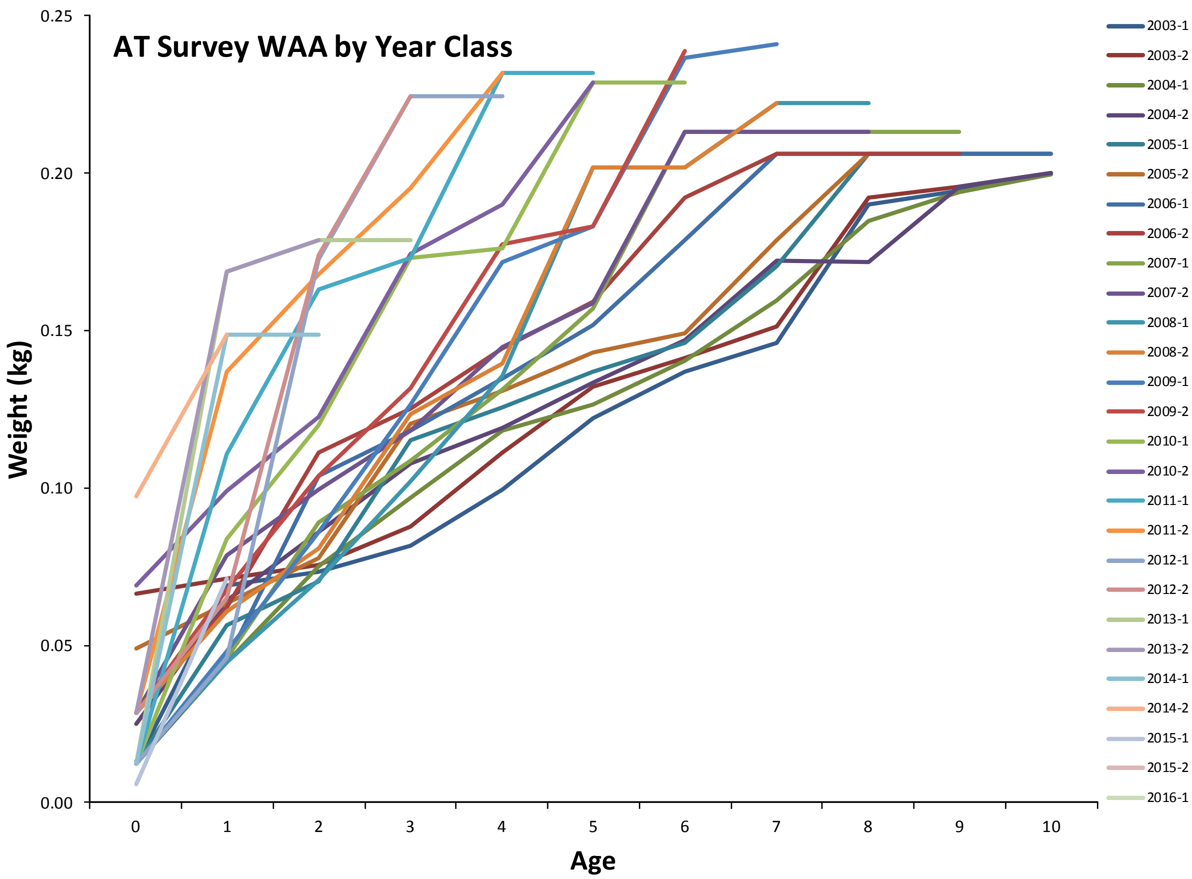

Fig. 2. Weight-at-age by cohort for the ATM survey.

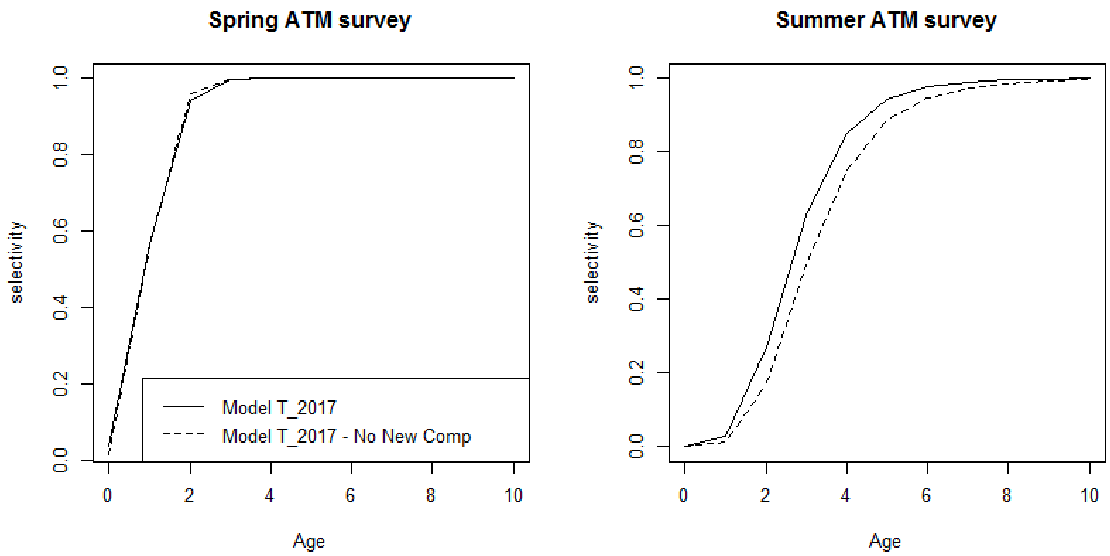

Fig. 3. ATM survey selectivity for the spring and summer surveys from Model T2017 and a variant of that model in which the last two ATM length-compostions are dropped from the model.

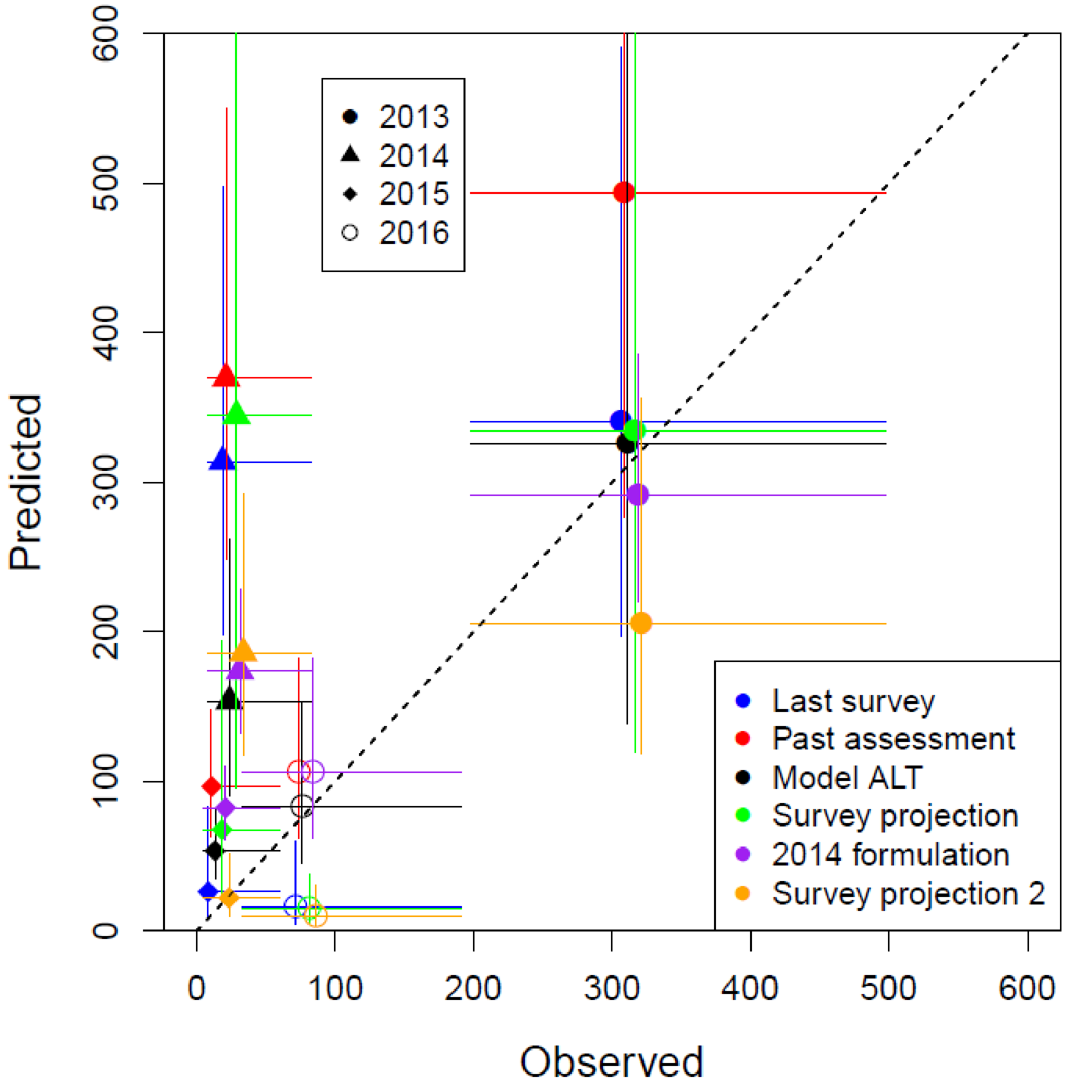

Fig. 4. Observed (x-axis values, ATM survey biomass estimates) and model-predicted (y-axis values) biomass on 1 July of each of 2013, 2014, 2015 and 2016. The observed values are the summer ATM survey estimates. The lines indicate 90% confidence intervals under the assumption of log-normal error. The x-axis values are jittered for ease of presentation.

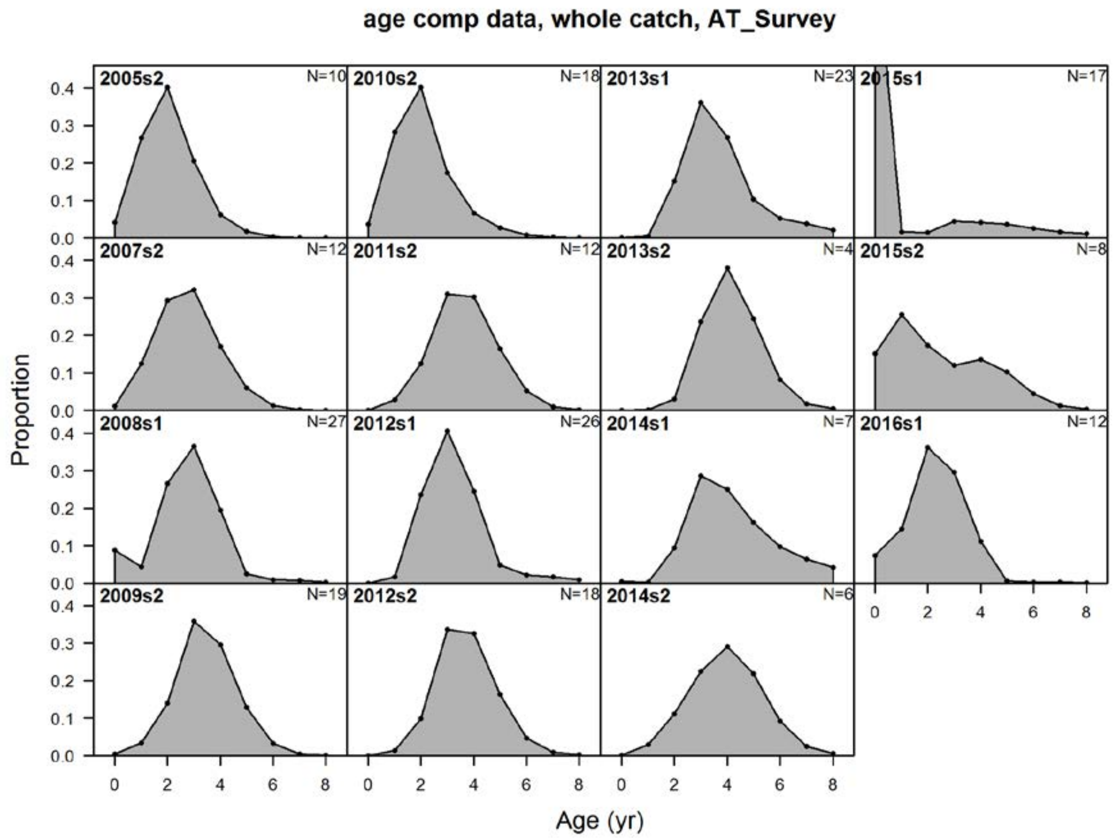

Fig. 5. The ATM survey age-compostion data.

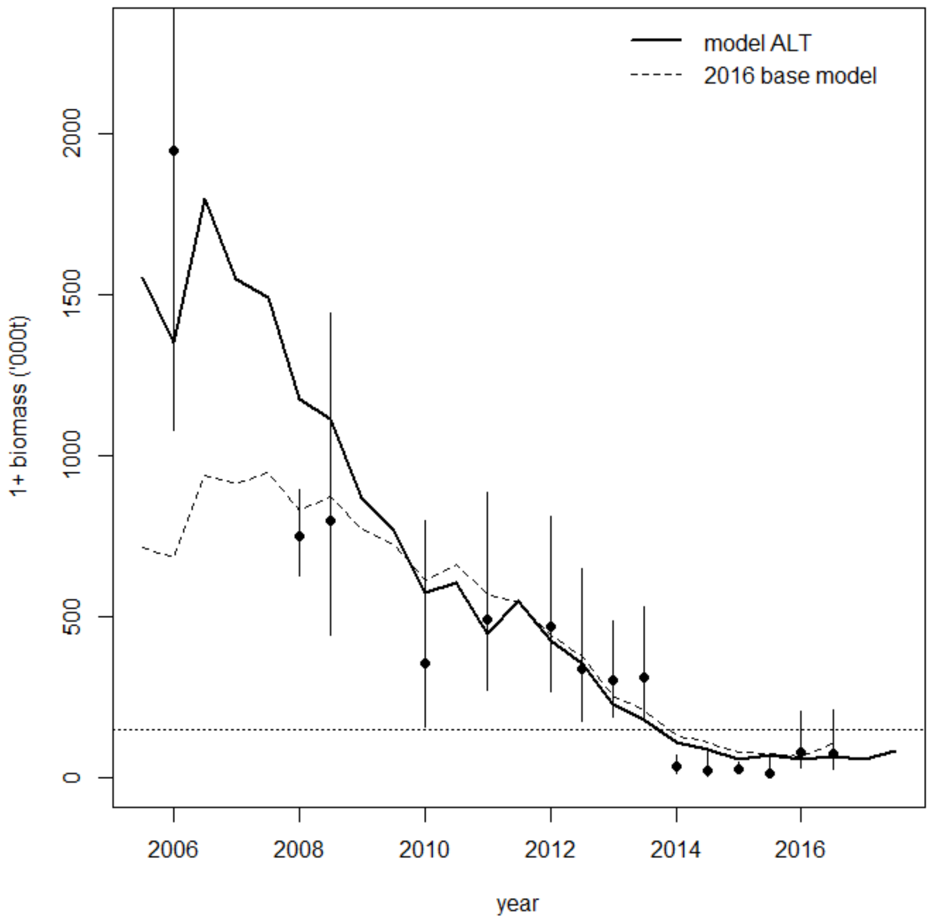

Fig. 6. Time-trajectories of 1+ biomass from model ALT and the 2016 base model. The ATM survey estimates of biomass and their 95% confidence intervals are indicates by the dots and the vertical bars, respectively.

Appendix 1
2017 Pacific Sardine STAR Panel Meeting Attendees

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Will Satterthwaite, SSC, Southwest Fisheries Science Center
Evelyn Brown, SSC, Lummi Natural Resources, LIBC
Jon Vølstad, Center for Independent Experts (CIE)
Gary Melvin, Center for Independent Experts (CIE)

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

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC

Other Attendees
Dale Sweetnam, SWFSC
Alan Sarich, CPSMT/Quinault Indian Nation
Emmanis Dorval, SWFSC
Chelsea Protasio, CPSMT/CDFW
Kirk Lynn, CPSMT/CDFW
Ed Weber, SWFSC
Josh Lindsay, NMFS WCR
Erin Kincaid, Oceana
Al Carter, Ocean Gold
Jason Dunn, Everingham Bros Bait
Nick Jurlin, F/V Eileen
Neil Guglielmo, F/V Trionfo
Andrew Richards, Commercial
Hui-Hua Lee, SWFSC
Bev Macewicz, SWFSC
Chenying Gao, Student
Steven Teo, SWFSC
Kevin T.R. Piner, SWFSC
Andy Blair, Commercial
Jamie Ashley, F/V Provider
John Budrick, CDFW
Steve Crooke, CPSAS
Gilly Lyons, Pew Trusts

<u>Acronyms</u>
CDFW – California Department of Fish and Wildlife
CPSAS - Coastal Pelagic Species Advisory Subpanel
CIE – Council on Independent Experts
CPSMT - Coastal Pelagic Species Management Team
CWPA – California Wetfish Producers Association
SSC - Scientific and Statistical Committee
SWFSC - Southwest Fisheries Science Center (National Oceanic and Atmospheric Administration)
WCR – West Coast Region

Appendix 2
Projection of summer AT biomass 1 year into the future (Juan Zwolinski)

Given a vector of abundance-at-age from a summer survey during year t $\hat{\mathbf{a}}_{\mathrm{t}} = [\hat{a}_{0t}, a_{1t}, \dots, a_{9+t}]$, with ages 0 through 9 and above, and where $\hat{a}_{0t}$ is the expected abundance of age-0 sardine estimated in one of the two possible ways described below, the abundance of sardine age 1 and older (zge-1+) at year *t+1* can be estimated by $\hat{\mathbf{a}}_{t+1} = \hat{\mathbf{a}}_{\mathrm{t}} \times e^{-(M+F)}$, where M and F are natural and fishing instantaneous mortality coefficients relative to one year, respectively. The corresponding biomass is obtained by the pointwise product $\hat{\mathbf{a}}_{\mathrm{t+1}} \times \mathbf{w}_{\mathrm{t}}$, where the empirical mean weight-at-age $\mathbf{w}_t = [w_{1t}, \dots, w_{9+t}]$ is estimated from the survey during year *t*. If fishing mortality is expressed in catch, then $\hat{\boldsymbol{a}}_{t+1}$ can be approximated by $\hat{\boldsymbol{a}}_{t+1} = (\hat{\mathbf{a}}_t \times e^{-(M/2)} - \mathbf{c}_t) \times e^{-(M/2)}$, where $\hat{\boldsymbol{c}}_t = [c_{0t}, c_{1t}, \dots, c_{9+t}]$ is the expected catch in numbers per age class.

Estimating a_{0t}

Summer AT surveys are not reliable estimators of the abundance of age-0 sardine at time *t* ($a_{0\mathrm{t}}$). Therefore, any projection of biomass from a survey at year *t* to year *t+1* requires a_{0t} to be estimated. Assuming that no fishing occurs for age-0 sardine, the expected age-0 abundance $\hat{a}_0$ can be estimated as the mean of the implied age-0 abundances calculated from *n* surveys such that:

$$E[a_0] = \hat{a}_0 = \frac{1}{\mathrm{n}} \sum_n a_1 \times e^M .$$

Alternatively, a_{0t} can be estimated using the stock-recruitment relationship from the most recent assessment. In order to do so, the abundance $\boldsymbol{a}_t = [a_{1t}, \dots, a_{9+t}]$ from the summer survey has to be regressed 6 months and converted into spawning stock biomass (SSB) at *t-0.5*. Using empirical mean weight-at-age in winter $\mathbf{w}_{\mathrm{t-0.5}} = [w_{0t-0.5}, \dots, w_{8+t}]$, and the vector of proportions of mature fish per age class $\mathbf{s}_{\mathrm{t-0.5}} = [s_{0t-0.5}, \dots, s_{8+t}]$, $\mathrm{SSB}_{t\text{-}0.5}$ is obtained by the sum of the pointwise-product $\mathbf{a}_{\mathrm{t-0.5}} \times \mathbf{w}_{\mathrm{t-0.5}} \times \mathbf{s}_{\mathrm{t-0.5}}$, where $\mathbf{a}_{\mathrm{t-0.5}}$ can be calculated by $\hat{\mathbf{a}}_{\mathrm{t-0.5}} = \hat{\mathbf{a}}_{\mathrm{t}} \times e^{(M+F)/2}$ in case F is reasonably known. If fishing is expressed in catch, then $\hat{\mathbf{a}}_{\mathrm{t-0.5}} = (\hat{\mathbf{a}}_{\mathrm{t}} \times e^{(M/4)} + \mathbf{c}_{\mathbf{t-0.5}}) \times e^{(M/4)}$. There, $\mathbf{c}_{\mathbf{t-0.5}}$ is the vector of catch-at-age that occurred in the 6 months prior to the survey.

Center for Independent Experts (CIE) Independent Peer Review Report of the Pacific Sardine Stock Assessment

Southwest Fisheries Science Center (SWFSC)

La Jolla, CA, February 21-23, 2017

Jon Helge Valstad

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Table of Contents

Executive Summary

In the US, the Pacific sardine is currently a limited entry fishery managed by the Pacific Fishery Management Council using a Harvest Control Rule where the total allowable catch for a given year is based on a forward projection estimate of age 1+ biomass (mt) from the prior year assessment. The main objective of this STAR review was to evaluate two proposed alternative assessment methods for giving quota advice for 2017: (1) the Acoustic-Trawl Method (ATM) survey, which is preferred by the SWFSC stock assessment team, and (2) Model ALT which is implemented using the Stock Synthesis Model. An alternative ATM survey projection method was also considered during the review. The relatively parsimonious Model ALT reduced the parameter space compared to a standard implementation of Stock Synthesis by estimating several parameters external to the model using empirical data, and by fixing parameters. The performance of several assessment methods under the current HCR was compared based on their ability to predict a current ATM survey estimate of age 1+ biomass in the prior year´s assessment. The ATM survey method is considered to provide the most reliable estimate of the current year 1+ biomass, but the survey methods are not sufficiently documented to assess the accuracy of the estimate, and have several issues that could lead to bias in the absolute biomass estimates and associated variance. Although the ATM survey itself will be reviewed in 2018, and was not a focus of this review, all assessment methods rely heavily on survey estimate of absolute biomass of age 1+ fish. Therefore, I discuss some possible sources of bias in this review, and provide some recommendations for reducing such biases. It is well known from the literature that post-stratification based on density values observed during the survey, as was done in the ATM survey, can result in negative bias in variance estimates. The variance estimation by bootstrapping for the ATM survey also treats the transects within post-strata as simple random. This is common practice in analysis of systematically spaced transects, and is conservative since it will likely overestimate the variance for evenly spaced transects. However, in the ATM survey the handling of the adaptive component results in variable transect spacing (unequal inclusion probability) in some post-strata, which can bias the variance estimates in unknown directions when this is ignored in the analysis. The use of seasonal fixed age-length keys based on multi-year trawl survey data from 2006 can also yield biases with varying magnitude and directions in estimates of age-compositions, and will cause negative bias in variance estimates for age-compositions, and therefore estimates of age 1+ biomass. The assumption that the ATM method provides unbiased absolute biomass estimates assumes that target strength is known, and ignores vessel avoidance, incomplete survey coverage and other factors that can cause bias. Also, as revealed during this review the current forward projection method for the ATM survey method does not perform well. As currently formulated, this method performs no better than assuming no change and applying the survey estimate of age 1+ biomass in 2016 as an estimate also for age 1+ biomass in July 2017. Thus, while viable, this approach requires further development and review prior to adoption. The review panel considered Model ALT method to perform best for the current management advice that relies on a projection estimate of 1+ biomass for 2017, even though several errors in the model were discovered during the review. Major sources of uncertainty for stock assessments under the current HCR, regardless of method, is related to highly variable recruitment, growth, and uncertainty in natural mortality, *M*. Accuracy of assessments is also highly influenced by the temporal and spatial coverage of the ATM survey, the post-stratification used for estimation, insufficient sample sizes of age-length, and the use of fixed age-length keys. The assumption of multinomial distribution of numbers at age in the ATM survey method and the ALT model is likely to be unrealistic given the highly-clustered trawl sampling, causing additional errors.

Background

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. Background material and reports (Appendix A) for the review was provided by the NMFS project contact two weeks prior to the review. A Statement of Work (Annex B) is established by the NMFS Project Contact and Contracting Officer's Technical Representative, and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest.

CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance with the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee. Further information on the CIE process can be obtained from www.ciereviews.org.

This independent reviewer was requested by the Center of Independent Exerts to participate in a stock assessment review (STAR) panel to conduct independent peer review of the 2016 draft assessment by the Stock Assessment Team (STAT) for the northern subpopulation of Pacific Sardine. The STAR Panel (Appendix C), including the two CIE Reviewers, are responsible for determining if a stock assessment or technical analysis is sufficiently complete. It is their responsibility to identify assessments that cannot be reviewed or completed for any reason.

1. Description of the Reviewer's Role in the Review Activities

A peer review meeting was held at the Southwest Fisheries Science Center (SWFSC) in La Jolla, California, from February 21-24 to review a draft assessment by the Stock Assessment Team (STAT) for the northern subpopulation of Pacific Sardine. The Stock Assessment Review (STAR) panel consisted of three members of the Scientific and Statistical Committee (SSC): Dr. André Punt (University of Washington, Chair), Dr. Will Satterthwaite (SWFSC), and Dr. Evelyn Brown (Lummi Natural Resources), and two reviewers from the Center for Independent Experts (CIE): Dr. Jon Vølstad (Norway), and Dr. Gary Melvin (Canada). The STAR panel was expertly chaired by Andre Punt.

My input in the review was particularly related to statistical survey sampling methods and propagation of errors in input data through the assessment modeling that provides biomass estimates for quota advice. I have long experience and expertise in the design, analysis, and execution of fishery-independent surveys for use in stock assessments, and have experience with demersal and mid-water trawl surveys, acoustic-trawl surveys of pelagic fishes, and in the use of aerial surveys. I also have expertise in the application of fish stock assessment methods, particularly length/age-structured modeling approaches. For comments related to technical aspects of acoustic survey methods I defer to fellow CIE reviewer Gary Melvin who specializes in acoustic methods.

By way of background, I am chief scientist and leader of the Fishery Dynamics research group at Institute of Marine Research, Bergen, Norway. My education includes a bachelor with double majors in mathematics and biology, a master degree in Fishery Biology incl. management, and a Ph.D. in quantitative fisheries biology (biometrics) from University of Bergen, Norway. My PhD studies included research as a visiting scholar at Northeast Fisheries Science Center, Woods Hole, and graduate courses in mathematical statistics at University of Bergen and at the Department of Biomathematics (now department of Statistics), Oxford University (UK), as a British Council Scholar. My dissertation was on survey design and analysis of abundance surveys. I have more than 25 years of international research experience in statistical survey methods, quantitative fisheries biology, and statistical ecology from academia, national institutes, and private industry. My research primarily focuses on the development and optimization of statistical survey techniques for assessment of fisheries resources and the environment, and the quantification of uncertainty in stock assessments.

My preparations in advance of the peer review meeting included a review of background material and reports (Appendix A) provided by the SWFSC Project Contact Dr. Dale Sweetnam (SWFSC) via email on February 7 via link to ftp-site. This was a very effective way of distributing the extensive material. All the presentations (see below) were added to the ftp site during the review meeting.

A series of very informative power point presentations were given during the review meeting by the SWFSC Stock Assessment Team. My fellow peer reviewers and I asked questions during the presentations and participated in the panel discussions on validity, results, recommendations, and conclusions. Will Satterthwaite (SSC, SWFSC) acted as rapporteur.

Drs. Paul Crone, Kevin Hill, and Juan Zwolinski presented the assessment methodology. Two alternative assessment approaches were presented:

1. Direct use of the summer 2016 Acoustic Trawl Method (ATM) survey estimate and associated age-composition projected to 1 July 2017, which is the method preferred by SWFSC, and

2. Model ALT which is a model-based assessment that provides an estimate of age 1+ biomass on 1 July 2017 based on a modified more parsimonious Stock Synthesis model where many parameters are estimated externally from empirical data.

Juan Zwolinski described the survey-based method for estimating age 1+ biomass on 1 July 2017 that involved:

- estimating numbers-at-age on 1 July 2016 from the summer 2016 ATM survey from numbers-at-length using an age-length key that pooled data over multiple summer surveys, and
- projecting these numbers forward accounting for natural mortality and growth, and adding the estimated recruitment for 2016. The recruitment for 2016 was based on the stock-recruitment relationship estimated by model ALT, and the spawning stock biomass for 2016 was estimated by back-projecting the summer 2016 numbers-at-age to 1 January 2016.

Kevin Hill and Paul Crone described the data on which the model-based assessment was based, as well the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.24aa. Model ALT differed from the model on which the 2016 update assessment was based by:

- starting the assessment in 2005 rather than 1993,
- excluding the Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices,
- estimating rather than pre-specifying stock-recruitment steepness,
- pre-specifying weight-at-age rather than estimating it within the assessment,
- assuming selectivity for the ATM survey to be zero for age 0 and uniform for age 1 and older,
- estimating survey catchability (Q), assuming selectivity to be age- rather than length-based,
- modelling ages 0-10+yr rather than ages 0-15+yr, assuming natural mortality (M) is 0.6yr-1 rather than 0.4yr-1 for all age classes and fitting the catch and ATM survey age-composition data (rather than the associated length-composition data).

Unlike the 2016 and earlier assessments, model ALT included additional live bait landings, which generally reflected a minor contribution to the total landings in California in the past. However, model ALT did not include biological composition data from the live bait catches, given this fishery sector had not been regularly sampled in the past, with samples being available for only the most recent year of the time series modelled in the assessment.

The review and request by the STAR panel for additional analysis during the meeting were motivated primarily by the need to better understand the rationale for model ALT, and to identify the best approach for providing a projection of age 1+ biomass on 1 July 2017 that is currently required by management. The Panel had several comments and concerns regarding the ATM survey methodology and ways in which estimates of close-to-absolute abundance can be obtained. However, this was not a review of the ATM survey, since a second Council-sponsored ATM methodology review is planned for early 2018. Therefore, comments in the Panel Report regarding the ATM survey and how estimates of abundance from that survey are constructed are reflected primarily in the Research Recommendations section of the report. However, since both assessment methods considered in the review strongly depends on the ATM survey, I have made several comments in the next section, and in section (3).

2. Findings by ToR

The bibliography list (Appendix A) and the Statement of Work (Appendix B) describe the documents reviewed and review activities, respectively, as part of an independent peer review completed for the Center for Independent Experts (CIE).

2.1. Acoustic Trawl Method (ATM) Survey Assessment

In the assessment approach based on the ATM survey two methods are used to project the current (2016) estimate of age 1+ biomass to an estimate of age1 biomass for 2017. The preferred approach in the Draft Stock Assessment Document projecting the biomass from the 2016 ATM survey to 1 July 2017 accounting for mortality, growth and recruitment from July 2016 to July 2017. However, the approach used to convert from length composition to age composition is incorrect, and the method used to derive the CV of age 2+ biomass does not allow for uncertainty in population age composition, projected weight-at-age and maturity-at-age. In addition, the method relies heavily on model ALT because approximately half of the age 1+ biomass on 1 July 2017 consists of age-1 animals, i.e. the estimate of this biomass is based to a substantial extent on the stock-recruitment function from model ALT. Finally, the value for M of 0.6yr-1 has no clear justification. The version of the projection model provided initially to the Panel did not account for catches so it could not be applied were the targeted sardine fishery to be re-opened, and does not account for the limited catches during 2016. An alternative assessment based on the ATM survey proposed during the review meeting assume that the 1 July 2017 biomass equals the estimate of biomass from the summer 2016 ATM survey. This “projection” ignores mortality (from natural causes and from fishing), growth and recruitment from July 2016 to July 2017. However, this method is simple to implement because it does not rely on a model, nor does it rely on highly uncertain recruitment estimates and estimates of age composition for which sample sizes are low.

The Panel had several comments and concerns regarding the ATM survey methodology and ways in which estimates of close-to-absolute abundance can be obtained. In a prior CIE review in 2011, it was concluded that there are no major problems with acoustic technique and methodology and it was the best that could be used at that time. Although this is not a review of the ATM survey, since a second Council-sponsored

ATM methodology review is planned for early 2018, I have several comments in section (3) since the ATM survey results are critical input to all assessment models being evaluated.

2.2. Model ALT Assessment

The final model (model ALT) incorporates the following specifications:

- catches for the MexCal fleet computed using the environmentally-based method;
- two seasons (semesters, Jul-Dec=S1 and Jan-Jun=S2) for each assessment year from 2005 to 2016;
- sexes were combined; ages 0-10+.
- two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PacNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
  - MexCal fleet: age-based selectivity (one parameter per age)
  - PacNW fleet: asymptotic age-based selectivity;
  - age-compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
- Beverton-Holt stock-recruitment relationship with "steepness" estimated;
- *M* was fixed (0.6 yr^{-1});
- recruitment deviations estimated from 2005-2015;
- virgin recruitment estimated, and σ_R fixed at 0.75;
- initial *F*s estimated for the MexCal S1 fleet and assumed to be 0 for the other fleets;
- ATM survey biomass 2006-2013, partitioned into two (spring and summer) surveys, with Q estimated;
  - age-compositions with effective sample sizes set to 1 per cluster (externally);
  - selectivity is assumed to be uniform (fully-selected) above age 1 and zero for age 0.

The estimate of age 1+ biomass on 1 July 2017 from model ALT is 86,586t (CV 0.363). Model ALT indicates that age 1+ biomass has rebuilt close to that in 2014, owing to a substantial increase in biomass based on the indices from the survey.

Model ALT has several of the problems associated with the 'survey projection' model, i.e. the age-composition data are based on a year-invariant age-length key, and the basis for M=0.6yr-1 lacks strong empirical justification (and indeed likelihood profiles indicate some support for lower M than the value adopted for model ALT). In addition, the model presented to the Panel predicted age-0 catch in the ATM survey even though it is assumed that age-0 animals are not selected during the ATM survey. It appears that Stock Synthesis with the ALT parametrization predicts some catch of nominal "age 0" even when the selectivity is set to zero for age-0 fish. The STAR review panel requested several additional model runs to gain insights, because aging error could result in some age-1 fish in catches being misclassified as age 0. Furthermore, model runs revealed that the model was unable to converge if aging error was set to zero or made very small, but reductions in the specified aging error led to the expected reduction in the predicted age-0 catch. It was noted that surveys likely include a mix of age-1 fish misclassified as age-0, as well as fish that are truly age 0. Dr. Methot has also noted that Stock Synthesis had not been as thoroughly debugged for semester-based models as for strictly annual models

2.3. Evaluating the Performance of Assessment Approaches

The performance of several assessment methods under the current HCR was compared based on their ability to predict a current ATM survey estimate of age 1+ biomass in the prior year´s assessment. The

STAR review considered four methods:

a) ATM survey method using the 1+ biomass estimate from the prior year as is,
   i. This assumption ignores mortality (from natural causes and from fishing), growth and recruitment from July 2016 to July 2017.
b) ATM survey method projecting the biomass from the prior summer ATM survey estimate using the 'survey projection' model (or an alternative approach),
c) Model ALT assessment and projection, and for comparison,
d) the assessment model and projection on which the 2014-16 estimates of biomass were based.

Results are provided in Fig. 4 from the STAR Panel.

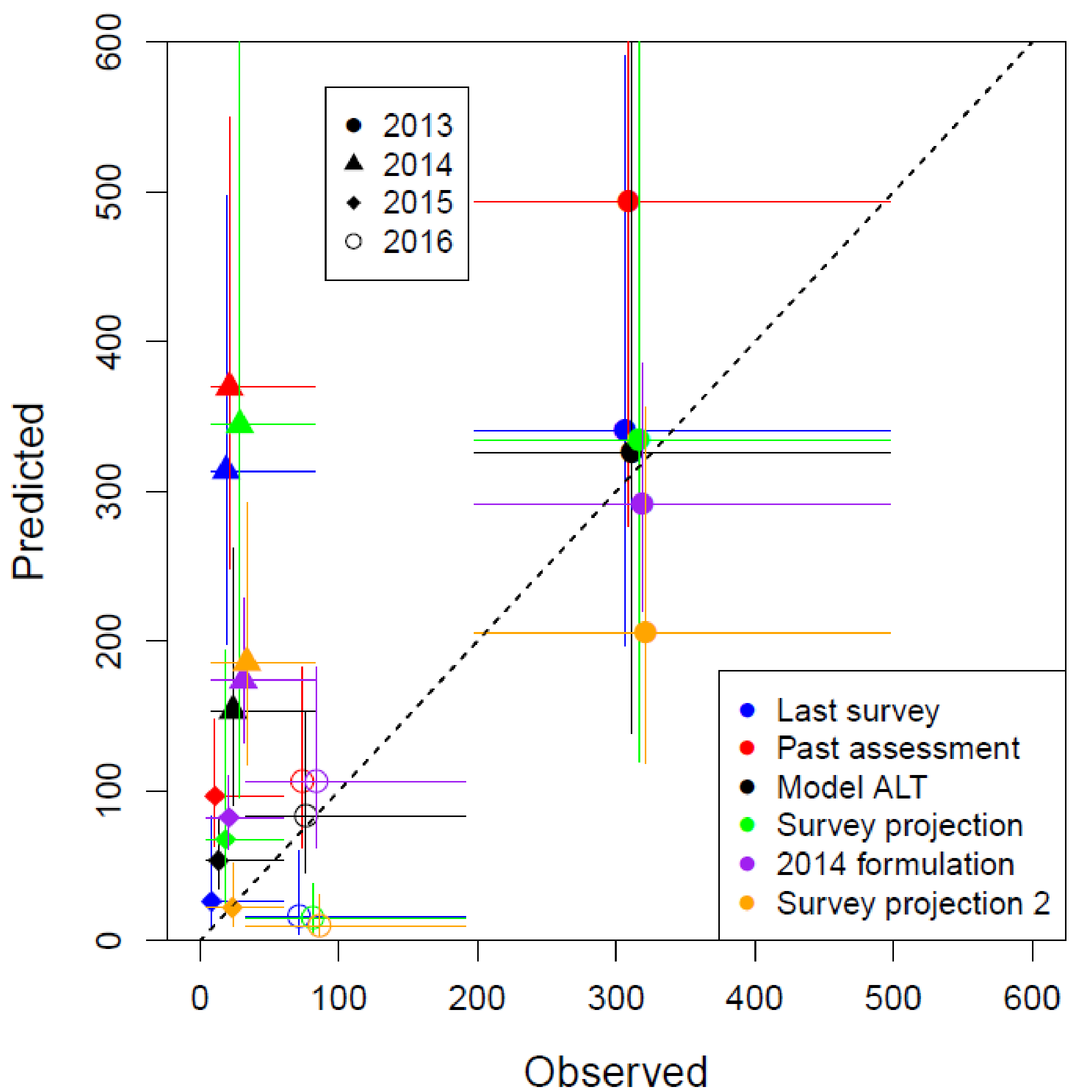

Fig. 4. (From Final Report of Sardine STAR Panel). Observed (x-axis values, ATM survey biomass estimates) and model-predicted (y-axis values) biomass on 1 July of each of 2013, 2014, 2015 and 2016. The observed values are the summer ATM survey estimates. The lines indicate 90% confidence intervals under the assumption of log-normal error. The x-axis values are jittered for ease of presentation.

The Panel had concerns with these methods. The ATM survey is considered to provide the most reliable estimate of the current year 1+ biomass, but the survey design and analysis methods are not sufficiently documented to assess the accuracy of the estimate, and have several issues that could lead to bias in the absolute biomass estimates and associated variance. Projecting the biomass from the 2016 ATM survey to 1 July 2017 (Method b) accounts for mortality, growth and recruitment from July 2016 to July 2017. However, the approach used to convert from length composition to age composition using fixed seasonal age-length keys based on data since 2006 is incorrect, and the method used to derive the CV of age 2+ biomass does not allow for uncertainty in population age composition, projected weight-at-age and maturity-at-age. In addition, the estimate of this biomass is based to a substantial extent on the stock-recruitment function from model ALT. Finally, the value for M of 0.6yr-1 has no clear justification.

Model ALT (Method c) has several of the problems associated with the 'survey projection' model, i.e. the age-composition data are based on a fixed age-length key, and the basis for M=0.6yr-1 lacks strong empirical justification. In addition, the model presented to the Panel predicted age-0 catch in the ATM survey even though it is assumed that age-0 animals are not selected during the ATM survey. Also, Model ALT estimates Q to be 1.1, which is unlikely given some sardine are not available to the survey owing to being inshore of the survey area.

The model (d) on which the 2014-16 assessments were based was approved for management by the 2014 STAR Panel. However, that assessment had some undesirable features, including extreme sensitivity to the occurrence of small (<~15cm fish) in the ATM surveys, poor fits to the length-composition and survey data, and sensitivity to the initial values for the parameters (i.e. local minima). These sensitivities and the resultant high uncertainty about population scale were noted in previous reviews.

The Panel explored alternatives to the current selectivity formulation to better understand why model ALT was predicting age-0 catch when selectivity for age-0 fish was set to zero. It was noted that the results are generally robust to the assumption that selectivity is a logistic function of length, allowing for time-varying age-0 selectivity, and estimating a separate selectivity pattern for ATM survey age-composition data.

The Panel noted that the 'survey projection' model and model ALT both rely on the samples from the ATM surveys to compute weight-at-age and survey age-composition data. These estimates are highly uncertain since the samples sizes for age from each survey are very small (16 – 1,051 fish; and VERY few trawl clusters which are the primary sampling units for the age-comps).

3. Conclusions and Recommendations

The SWFSC assessment scientists (STAT) did an outstanding job presenting the assessment results, and were very helpful throughout the review meeting by providing additional analysis upon request and answering questions related to the panel's interpretation of the available data and results. The panel members had broad and complimentary expertise that covered all the review subjects. The effectiveness of the review process was substantially enhanced by the expert leadership of the chair, Andre Punt, and the panel greatly benefited from the input from the Pacific Fishery Management Council, and representatives from the fishing industry. One criticism I have is that the stock assessment report and material provided that formed the basis for the review provided insufficient details to fully assess the quality of the input-data and model specification. I recognize that the stock assessment scientists responsible for the report may have had insufficient time to fully document the methods.

The STAR panel cautiously recommended proceeding with Model ALT, as the "least-worst" way to produce the age 1+ biomass estimate and CV required for management in 2017. Given the current

HCR, the Panel and STAT agreed that model ALT was the best approach at present for conducting an assessment for the northern subpopulation of Pacific sardine, notwithstanding the concerns listed above. The alternative assessment approaches provided more uncertain predictions of age 1+ biomass July 1, 2017:

- The approach on which 2014-16 management was based exhibited undesirable assessment diagnostics, and produced extremely high estimates of recruitment when large numbers of small fish were observed in the ATM survey length-frequencies. The approach also performed poorly in retrospective analysis (Fig. 4). The Panel and STAT agreed that this approach should not be used for 2017 management.
- The survey projection method (and the modified version, "Survey projection 2") seems a viable and defensible way to estimate age 1+ biomass using the ATM survey results, especially if the method could be modified to not use the results from model ALT. However, as currently formulated, this method performs no better than assuming the age 1+ biomass in July 2017 equals the survey estimate of biomass for summer 2016 (Fig. 4). Thus, while viable, this approach requires further development and review prior to adoption.
- Estimating the biomass on 1 July of year Y+1 based on the ATM survey estimate for year Y is simple, but the Panel was concerned that this method ignored catches during year Y and may lead to additional risk. Thus, the basic approach is viable, but needs additional testing prior to adoption.

I agree fully with these recommendations in the STAR review report on how management could be based on the ATM survey results:

- Change the start-date of the fishery so that the time between conducting the survey and implementation of harvest regulations is minimized.
- Use Management Strategy Evaluation to evaluate the risk to the stock of basing management actions on an estimate of biomass that could be a year old at the start of the fishing season (if the fishery start date is unchanged). Review of an updated MSE would likely not require a Methodology Panel, but could instead be conducted by the SSC.

As the review Panel noted, there may be benefits in using both the spring and summer ATM surveys as the basis for the assessment. Relying an ATM survey based assessment approach that relies on an estimate for the current year may be compromised by proposed reductions in ship time and/or problems conducting the survey. Also, as pointed out by the STAT there is value in continuing to collect biological data and to update model ALT even if management moves to an ATM survey-only approach.

In the following section, I have some more comments on the STM survey, and recommendations for future documentation and analysis.

Acoustic Trawl Method Survey

The systematic design for acoustic-trawl survey is robust for covering Pacific sardine with varying patchiness and areas of occupancy, provided that the spatial coverage E-W and N-S is adequate. The acoustic survey transect design is systematic with a close to regular spacing of transects allocated in advance, and adaptive component with reduced transect spacing in some areas of expected high abundance. Abundance and biomass is estimated by treating transects as simple random samples within post-strata, and the variance is estimated by bootstrap with equal selection probability of transects. However, based on provided material, documents, and discussions during this review it is apparent that the ATM survey is not based on probabilistic sampling design where every transect (primary sampling unit, PSU) has a known probability of being selected. The adaptive sampling component where additional acoustic transects are added in areas with observed high density of Pacific sardines is not well documented, and appears to be ad-hoc. The post-stratification of transects used in the estimating abundance and biomass by age class takes are based on sampling intensity (spacing of transects) and measured density. The grouping of transects with low density into separate strata is inappropriate and likely to cause bias in the variance estimates. Also, even though SWFSC staff argued that transects within all post-strata have equal spacing (and selection probability), this is not documented and is contradicted by figures presented during the review showing post-strata and acoustic transects.

Before the upcoming 2018 review of the ATM survey, it is strongly recommended that SWFSC specify the survey design and estimation methods in sufficient details. A document should be provided to the ATM review (and future assessment STAR Panels) that:

- delineates the annual survey area (sampling frame);
- specifies the spatial stratification (if any) and transect spacing within strata planned (true stratification);
- specifies the rule for stopping a transect (offshore boundary);
- specifies the rules for conducting trawls to determine species composition;
- specifies the rule for adaptive sampling (including the start and stopping rule); and
- specifies rules for post-stratification, and how density observations are considered in post-stratification.
- alternative post-stratification without considering density should be considered.

It is particularly important that the sampling frame covers the area of occupancy, that allocation of transects be based on probabilistic methods and that biases be minimized. The systematic allocation of transects with random start, and known selection probabilities, provides unbiased estimates of means and totals provided that the estimators apply weights that consider the probabilities of selection. However, systematic sampling precludes unbiased analytical variance estimates, and if the systematic survey is treated as simple random the estimated variance is likely to be biased upwards (Cochran, 1977). The systematic transect survey can also be considered a stratified sampling design with 1 PSU (transect) in each spatial stratum. A common approach to approximate the variances in estimates of means and totals in systematic designs is to group neighboring strata to yield a pseudo design with more than one PSU per stratum that is treated as it were the actual design (Wolter, 1985; Dunn and Harrison, 1993, Korn and Graubard, 1999). The variance and the relative standard error (RSE) (Jessen, 1978) is then estimated under the assumption of simple random sampling within the collapsed strata (Fuller, 2009). See Nøttestad et al. (2017) for an application for trawl sampling of mackerel.

The sardine habitat model based on remotely sensed SST, chlorophyll, and sea-surface gradient (Zwolinski et al. 2011) is currently used to (1) develop the sampling frame, and (2) assign catches to subpopulation but not to allocate sampling effort within the survey area, which is based on an ad-hoc adaptive sampling with denser spacing of transects in areas with high density of sardine. One reason for this adaptive component, with use of post-stratification in the analysis, instead of stratifying in advance (true stratification) on habitat is that the habitat is very dynamic even within the time period of the surveys. It is strongly recommended that the best available models be used for sample allocation, and that any real-time adaptive component be conducted using methods that minimizes bias (see for example, Harbitz et al. 2009; Thomposon and Seber 2009).

Assuming we have defined the sampling frame using a model, allocation based on the model will only affect precision, and even a relatively crude model that can identify areas with higher than average density will likely give better precision than equal spacing throughout the survey area. The habitat model predicts probabilities of capture for broad categories of habitat (e.g., "optimal", "good", "unsuitable" habitat). This is fine for defining the sampling frame but for sample allocation/stratification, the distribution of model predictions should be used to create strata that are most similar within. Alternative model approaches should also be considered for stratification. Ed Weber (SWFSC) is currently working with a sardine habitat model based on a ROMS model (Wang and Chao 2004) coupled with a biological model known as CoSiNE (Carbon, Silicate, Nitrogen Ecosystem model Chai et al., 2002; Liu and Chai, 2009). He demonstrated the model to me after the review meeting. Based on simulations of historic surveys he is testing if stratification based on modeled habitat could improve the precision of acoustic surveys. Using modeled data for stratification, and to allocate more transects (with known probability) to strata that are expected to have high density and variance, instead of satellite data, appears to have a several advantages. It is mechanistic, at least to the level of secondary production. It does not suffer from data gaps due to cloud cover. It could potentially be projected into the future for short periods.

Clearly, the changes in spatial distributions over time, both horizontally and vertically, may introduce biases in acoustic indices of abundance of changing magnitudes and directions. Such biases can be caused by vessel avoidance, acoustic shadowing and depth dependent acoustic target strength (Skaret et al., 2005; Løland et al., 2007; Hjellvik et al., 2008). Random sampling errors in acoustic survey indices of abundance due to spatial sampling has been shown to be the main source of uncertainty in acoustic measurements of abundance (Rose et al. 2000). Løland et al. (2007) investigated several additional sources of error in acoustic survey estimates of the Norwegian Spring Spawning herring stock in the wintering area. They did, however, conclude that acoustic sampling error (variation among transects) was the largest contributor to the total uncertainty of the estimate. The ATM surveys at present do not capture fish in the upper water column, and appears to miss a large biomass of young fish (sizes 3 inches and up) that fishermen have observed in nearshore waters since late 2014; this biomass is largely inside ATM survey tracks. The SWFSC plans to examine ship avoidance using aerial drone sampling. There is an ongoing significant effort by Institute of Marine Research in Norway to understand the same issue using sonar, and the SWFSC acoustics team should communicate and coordinate with those researchers. The possible bias due to not detecting fish that are near the surface by acoustics could be investigated using sonar. This is currently being done in acoustic-trawl surveys for herring by Institute of Marine Research, Norway, and is addressed in a large effort to reduce uncertainty in stock assessments (REDUS project: www.redus.no).

Trawl sampling and the estimation of age-compositions

The current practice of treating data on numbers-at-age from the trawl survey as multinomial is problematic because the trawl samples are clustered, and age-samples are subsamples from trawl hauls. This is likely to result in cluster effects, resulting in correlation among age-groups (see ICES 2016a,b, 2017, and Aanes and Vølstad 2016). It is recommended that the age-data be evaluated. Ideally, it would be possible to run bootstrap resampling on the PSUs to create replicated Model ALT runs that reflect the complexity in input data. See the Norwegian Spring-spawning Herring case study under the REDUS project in ICES WKCOSTBEN (ICES 2017) for an example where the more complex error structure in input data is accounted for. The statistical assessment model XSAM (developed by Sondre Aanes, Norwegian Computing Centre) has been chosen for the assessment of Norwegian Spring Spawning Herring by ICES Benchmark assessments (2016a,b) because it can take into account the complex error structure in input-data in age-based assessment.

It is further recommended that the level of biological sub-sampling and data collections at each trawl station (or clusters of trawl stations) be evaluated through simulations to see how subsample size at the trawl stations affects the precision in estimates of numbers at age through age-length keys for the combined acoustic-trawl survey. The effective sample size for estimating age is likely to be driven by the number of transects and trawl stations sampled, and may be little affected by the sub-sample sizes of fish that are aged at each trawl station. Stewart and Hamel (2014) and Aanes and Vølstad (2015) have shown that it is sufficient to collect ~10-20 ages from each station to estimate the age distribution and that higher numbers of age-samples will only marginally improve the precision in estimates of age-composition, since the variance is driven by the number of PSUs sampled (number of trawl stations). Results in Nøttestad et al. (2017) show that for Atlantic mackerel the collections of extra length samples within trawl stations, and trawl stations with length-only samples can increased the precision in the estimates of abundance indices at age for age groups that occur in low proportions.

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Appendix 2: Copy of Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program External Independent Peer Review

STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment

February 21-24, 2017

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards.
(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).
Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

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

Requirements

Two CIE reviewers shall participate during a panel review meeting in La Jolla, California during 21-24 February, and shall conduct impartial and independent peer review accordance with the SoW and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes

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

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

Tasks for reviewers

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

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

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

- Attend and participate in the panel review meeting
    - The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
- Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance

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

Place of Performance

The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California.

Period of Performance

The period of performance shall be from the time of award through April 30, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables:

The contractor shall complete the tasks and deliverables in accordance with the following schedule.

No later than January 24, 2017	CIE sends reviewers contact information to the COTR, who then sends this to the NMFS Project Contact
No later than February 7, 2017	NMFS Project Contact sends the CIE Reviewers the pre-review documents
February 21-24, 2017	The reviewers participate and conduct an independent peer review during the panel review meeting
March 10, 2017	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
March 31, 2017	CIE submits CIE independent peer review reports to the COTR
April 7, 2017	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each TOR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $10,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

   a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

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

   c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

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

   e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

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

Appendix 1: Terms of Reference for the Peer Review of the Pacific sardine stock assessment

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

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

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

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

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

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

Appendix 2: DRAFT AGENDA: CPS STAR PANEL

Tuesday, 21 February

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

Wednesday, 22 February

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

Thursday, 23 February

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

Friday, 24 February

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

Appendix 3: STAR Panel Summary Report (Template)

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

Appendix 3: Panel membership or other pertinent information from the panel review meeting

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Will Satterthwaite, SSC, Southwest Fisheries Science Center
Evelyn Brown, SSC, Lummi Natural Resources, LIBC
Jon Vølstad, Center for Independent Experts (CIE)
Gary Melvin, Center for Independent Experts (CIE)

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

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC

Other Attendees
Dale Sweetnam, SWFSC
Alan Sarich, CPSMT/Quinault Indian Nation
Emmanis Dorval, SWFSC
Chelsea Protasio, CPSMT/CDFW
Kirk Lynn, CPSMT/CDFW
Ed Weber, SWFSC
Josh Lindsay, NMFS WCR
Erin Kincaid, Oceana
Al Carter, Ocean Gold
Jason Dunn, Everingham Bros Bait
Nick Jurlin, F/V Eileen
Neil Guglielmo, F/V Trionfo
Andrew Richards, Commercial
Hui-Hua Lee, SWFSC
Bev Macewicz, SWFSC
Chenying Gao, Student
Steven Teo, SWFSC
Kevin Piner, SWFSC
Andy Blair, Commercial
Jamie Ashley, F/V Provider
John Budrick, CDFW
Steve Crooke, CPSAS
Gilly Lyons, Pew Trusts

CDFW – California Department of Fish and Wildlife
CPSAS - Coastal Pelagic Species Advisory Subpanel
CIE – Council on Independent Experts
CPSMT - Coastal Pelagic Species Management Team
CWPA – California Wetfish Producers Association

SSC - Scientific and Statistical Committee (of the Pacific Fishery Management Council)
SWFSC - Southwest Fisheries Science Center (National Oceanic and Atmospheric Administration)
WCR – West Coast Region

CIE Reviewer's Report on the STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment

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Executive Summary

The review of the 2017-2018 Pacific Sardine Stock Assessment developed by the Southwest Fisheries Science Center (SWFSC) STAT team was conducted by a STAR Panel, at the SWFSC Torrey Pines Court Laboratory, La Jolla, CA, from 21-24 February 2017. The main objectives of the Panel were to review two new approaches to the assessment of the Northern subpopulation of Pacific sardine (NSP): the first is the acoustic trawl method which was approved by a 2011 STAR Panel to provide an estimate of absolute abundance of the NSP, and the second a revised/modified model based assessment using Stock Synthesis model Version 3.24aa with a single index of abundance. Previous assessment approaches (e.g., T_2016 update) were also examined but not really considered to provide advice on the 2017 1+ biomass.

The assessment document and all background material necessary to conduct the Panel Review was made available almost two weeks in advance, allowing plenty of time to prepare for the meeting. In general, the Panel review adhered to the agenda provided to Panel members prior to the meeting, although the Chair was flexible and allowed diversion into other subject areas when they were relevant to the discussion. Several Panel requests for additional information or clarification of procedures were made to the technical team over the first 3 days. These requests were fulfilled promptly and to the satisfaction of the Panel. Much of the success of the Panel Review can be attributed to the technical team who did an excellent job of summarizing the information and providing the available data to address the issues at hand. The Chair kept the group focused on the topic being addressed, while at the same time allowing everyone, including observers, to express their views or contribute their expert opinion. A number of the attendees also provided valuable input during the course of the meeting.

The Panel concluded that neither of the two assessment approaches presented at the 2017 Pacific Sardine stock assessment was fully acceptable. The Acoustic-Trawl survey, while all agreed was likely the better approach, did not provide a reasonable mechanism to project the 1+ biomass forward approximately 1 year to July 1, required by management. On the other hand, the model-based approach had its own issues with the treatment age 0 in the model that were not fully resolved during the review. However, the Panel concluded that based on the available information the model-based was the better approach to provide the required estimate of biomass for management of the NSP Pacific sardine resource.

Many of the issues associated with the spatial-temporal distribution of fish and sample size, identified by the last review, continue to plague the 2017 sardine assessment. The Panel again raised concerns about the survey coverage, especially in light of the fishing industry's reports of large quantities of sardines in the nearshore water not surveyed by the research vessel. The limited amount of sampling conducted by the survey vessel and the samples available for ageing in some years was a major surprise and concern for the Panel. Development of an age length key and estimating age distribution from such few samples is problematic. Furthermore, the use of a multi-year age length key due to the lack of sufficient samples is generally frowned upon by those involved in age structured assessments. Both the distribution of sardines and sample size need to be addressed in the near future.

There is an excellent opportunity to resolve some of the issues associated with coverage and sampling. During the meeting, there were several offers from the fishing industry to assist the STAT with improving the survey coverage to areas not covered by the large vessel and to work with the survey vessel to collect additional samples. These opportunities should be explored by the STAT, and if feasible, a coordinated program developed to ensure the efficient use of vessel time and effort, as well as the integration of industry-collected data into the assessment process.

The Panel was informed that the survey vessel time for the summer survey will be reduced from the current 80 days to 50 days in 2018. This represents a significant reduction in survey time and will at a minimum increase the variance of the biomass estimates and likely impact (reduce) the survey coverage and sampling time. This is another reason to explore collaboration with the fishing industry. The effects of this change/reduction in vessel time need to be evaluated if they are to continue into the future.

The Panel's report, to some extent summarized in this report, represents the consensus view of the STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment and I fully concur with its content, recommendations, and conclusions. Overall, there were no major areas of disagreement between the STAT and Panel, nor among members of the Panel.

1.0 BACKGROUND

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). Under this mandate the NMFS (Office of Science and Technology) coordinates and manages a contract for providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer-reviews of NMFS scientific projects. The CIE reviewers are selected by the CIE Steering Committee and the CIE Coordination Team to conduct the independent peer review of the NMFS science in compliance with the predetermined Terms of Reference (TORs) for the peer review. In this case the "Terms of Reference for the groundfish and coastal pelagic species stock assessment review process for 2017-2018", provided as background material for the meeting, describes objectives and the roles and responsibilities of the participants. Two CIE reviewers served on a five-person Stock Assessment and Review (STAR) Panel, Chaired by Andre Punt, to review the 2017-2018 Pacific Sardine Stock Assessment. The Statement of Work (SoW) described in Appendix I identified the roles, responsibilities and reporting structure for the CIE reviewer. The reviewers are chosen on their expertise to provide an impartial, independent peer review without conflicts of interest, report on methods, outcomes and recommendations of the stock assessment review.

The Pacific sardine stock is assessed regularly (currently, every 1-2 years) by SWFSC scientists and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). The stock assessment data and models are formally reviewed by a Stock Assessment Review (STAR) Panel once every three years, with a coastal pelagic species subcommittee of the SSC reviewing updates in interim years. Independent peer review is required by the PFMC review process. The STAR Panel reviews draft stock assessment documents and any other pertinent information for Pacific sardine, works with the stock assessment (STAT) team to make necessary revisions, and produces a STAR Panel report for use by the PFMC and other interested persons for developing management recommendations for the fishery.

Each CIE reviewer is contracted to participate in the STAR Panel review meeting and to deliver an independent peer-review report to be approved by the CIE Steering Committee. This report, although generally consistent with, and similar to the STAR Panel report, is independent of the Panel report.

The specific tasks of the CIE Reviewers are to (See details in the SOW – Appendix 1):

- Review the background materials and reports prior to the review meeting

- Attend and participate in the panel review meeting

- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs

- Assist the Chair of the meeting with contributions to the summary report, if required by the TORs

- Deliver their reports to the Government according to the specified milestone dates

1.1 Overview

A Pacific Sardine Stock Assessment and Review (STAR) Panel (Panel) was convened to review a draft assessment by the Stock Assessment Team (STAT) for the Northern Subpopulation of Pacific Sardine at the Southwest Fisheries Science Center, La Jolla, CA from February 21-24, 2017. The structure, responsibilities, goals, objectives and reporting requirements were defined under the terms of reference for the groundfish and coastal pelagic species stock assessment review process for 2017-18. In essence, the Panel reviewed three approaches for providing advice to management; two new assessment approaches and the default of updating the previous assessment. A list of attendees and the agenda are provided in the Appendices. It should be noted that because the CIE reviewer report is a standalone document, several sections of this report contain text that has been extracted almost verbatim from the STAR Panel report as the reviewer contributed to the document and feels it provides a good overview of the process and discussions.

Stock assessment team members, Drs. Paul Crone, Kevin Hill, and Juan Zwolinski presented a general overview of the assessment methodology for each of the different assessment approaches. Paul Crone first outlined the assessment history and philosophy, then moved on to focus on selecting an approach that was considered by the STAT to be most objective, i.e. the Acoustic Trawl Method (ATM) survey. In addition, because of the management schedule and fishing year, there is a requirement to provide the age 1+ biomass on July 1, 2017. The STAT provided results for two assessment approaches: (a) use of the summer 2016 Acoustic-Trawl method (ATM) survey biomass estimate and associated age-composition projected to 1 July 2017, and (b) a model-based assessment (ALT) that provides an estimate of age 1+ biomass on 1 July 2017. Both were considered as viable options for estimating biomass.

Dr. Juan Zwolinski provided a general overview of the spring (March/April) and the summer (July/September) acoustic-trawl surveys; the former concentrated in the southern USA, and the latter had broad coverage from California to Canada. Methodologies were discussed, however, because an ATM methodology review is scheduled for January 2018, only in general terms. Much of this survey approach had been reviewed and approved by a STAR Panel Review in 2011. He also described the survey-based method for estimating/projecting the age 1+ biomass on 1 July 2017. The method involved estimating numbers-at-age on 1 July 2016 from the summer 2016 ATM survey from numbers-at-length using an age-length key (pooled data over multiple summer surveys), and projecting these numbers forward under natural mortality, growth, and adding the estimated recruitment for 2016. Recruitment for 2016 was based on the stock-recruitment relationship estimated from ALT model outputs. The spawning stock biomass for 2016 was estimated by back-projecting the summer 2016 numbers-at-age to 1 January 2016.

Kevin Hill and Paul Crone presented the data on the model-based assessment, as well the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.24aa. The major differences in Model ALT from the model on which the 2016 update assessment (T_2016) were starting the assessment in 2005 rather than 1993, excluding the Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices, estimating rather than pre-specifying stock-recruitment steepness, pre-specifying weight-at-age rather than estimating it within the assessment, assuming that selectivity for the ATM survey is zero for age 0 and uniform for age 1 and older, estimating survey catchability (Q), assuming that selectivity is age- rather than length-based, modelling ages 0-10yr rather than ages 0-15yr, assuming natural mortality (*M*) is $0.6yr^{-1}$ rather than $0.4yr^{-1}$ for all age classes and fitting the catch and ATM survey age-composition data (rather than the associated length-composition data). Unlike the 2016 and earlier assessments, the model ALT included additional live bait landings, which generally reflected a minor contribution to the total landings in California and was the only active sector in the US sardine fishery. However, model ALT did not include biological composition data from the live bait catches, given this fishery sector had not been regularly sampled in the past. Samples were available for only the most recent year of the time series modelled in the assessment.

The review and subsequent explorations of the assessment through sensitivity analyses were motivated primarily by the need for the survey-based method to provide an estimate of age 1+ biomass and its CV, to better understand the rationale for the changes made to the model on which the last full assessment was based that led to model ALT. The Panel had several comments and concerns regarding the ATM survey methodology and ways in which estimates of close-to-absolute abundance can be obtained. However, it was stressed throughout the meeting that this was not a review of the ATM survey, since an ATM methodology review is planned in early 2018. Therefore, comments regarding the ATM survey and how estimates of abundance from that survey are constructed are reflected primarily in the Research Recommendations section of the report.

In the end, the Panel was not fully satisfied with either of the approaches used to estimate the age 1+ biomass on July 1, 2017. The ATM had problems with the approach used to project almost a year forward and the ALT model with the treatment age 0 in the model. These issues are discussed in more detail below; however, the Panel concluded that the ALT model was the better available approach to provide the required estimate of biomass for management of the NSP Pacific sardine resource.

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

1.2 Goals and Objectives:

The specific goals and objectives for the 2017 Pacific Sardine Stock Assessment Review are those defined in the of groundfish and CPS STAR process document as follows:

1) ensure that stock assessments represent the best scientific information available and facilitate the use of this information by the Council to adopt OFLs, ABCs, ACLs, harvest guidelines (HGs), and annual catch targets (ACTs);
2) meet the mandates of the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) and other legal requirements
3) follow a detailed calendar and fulfill explicit responsibilities for all participants to produce required reports and outcomes;
4) provide an independent external review of stock assessments;
5) increase understanding and acceptance of stock assessments and peer reviews by all members of the Council family;
6) identify research needed to improve assessments, reviews, and fishery management in the future; and
7) use assessment and review resources effectively and efficiently.

It is important to note that the following report to the CIE reflects my independent opinions and views on the issues and questions identified in the terms of reference, statement of work, and the above goals and objectives. The report is, however, generally consistent with the recommendations and conclusions of the other panel members and CIE reviewers. Overall, there was general consensus among the panel members with no identifiable areas of disagreement.

2.0 Description of the individual reviewers' Role

The CIE reviewers essentially served two roles on the STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment. First, to participate as a full panel member in the review of the practices and procedures involved in the proposed assessment methods/approaches, and second to provide an independent review of the methodology and process.

To meet these requirements for the assessment of the Pacific sardine resource in 2017 a reviewer must have achieved recognition in several fisheries related fields. In this context, I am considered an expert in the assessment of small pelagic fish stocks, fisheries acoustics as applied to assessment of small and large pelagics, and their application to the management of the stocks. Currently, I am a senior Research Scientist with the Canadian Department of Fisheries and Oceans responsible for the research and assessment of large and small pelagic fish species. In addition, I am the scientist responsible for the acoustic program in my region of Canada and I have spent more than 25 years as the lead for small pelagic stock assessment program. I have a B.Sc., M.Sc., and PhD in fisheries related fields and have served on several international stock assessment review groups. Between 2010 and 2014, I was the Chair of the ICES North Sea Technical Review working group which provided quality control for all North Sea fish stocks assessed by ICES. Recently I was appointed Chair of the ICCAT western Bluefin tuna assessment working group.

My primary role was to participate in the 2017 Review as an informed expert and to contribute to the discussions and recommendations put forward by the STAT and the STAR Panel. Prior to the meeting, the stock assessment document was provided by the STAT team along with numerous background reports/documents on the fishery, methods, outputs and recommendations. The majority were read before the meeting so that well informed questions and discussions could be undertaken. Once the meeting began, my main focus was to be on the acoustic aspect of the assessment methodology; however, we were informed that because there will be a methodology review of the Acoustic –Trawl survey approach in January of 2018, much of the discussion will be deferred until. The meeting was still open to discussion on this subject, but most issues would be identified for investigation at the 2018 review.

Thereafter my focus shifted to the other areas of the review, participating in the discussions on the model-based assessment, major issues such as ageing, changes in mortality, the projection of biomass to July 1, 2017, the conclusions/

recommendations of the STAR Panel, contributions to the Panel Report and the preparation of an independent reviewer's report.

3.0 Summary of Findings for each term of Reference:

The summary presented below is an overview of the review and is generally consistent with the observations and results found in the STAR Panel Review Report. However, in several sections the text has been enhanced or is more inclusive to elaborate on specific issues. Prior to discussing the outcomes of the review associated with each TOR, I would like to make a few general comments regarding the documentation and the presentations. The stock assessment team (STAT) provided a good overview of the methodology and approaches described in the assessment document (Hill et al., 2017). The presentations by individual members of the team were informative and coherent. However, there were a number of cases where insufficient details were provided in the methods section of the assessment document for the Panel members to have a clear understanding about what or how something was done. This resulted in several extended discussions on the issue that could have been resolved with a few additional sentences in the assessment document. The STAT was very helpful in providing the details or the source of the details to the Panel where clarification was requested. Of particular concern were biological sampling protocols and the post stratification and analytical approaches used in the acoustic biomass estimation. Both involved extended discussions to clarify several areas of uncertainty.

The STAT team prepared and presented two new assessment approaches to the STAR Panel for review; One based on the outputs from an Acoustic-Trawl survey (ATM) as an absolute estimate of abundance, and the other an integrated model based method (SS3) to estimate biomass (ALT). Both methods were found to have merit but the former was obviously preferred by the STAT. The option to simply update the previous assessment (T_2016 to T2017) was not really being proposed or considered, although it was approved for management of resource by the 2014 STAR Panel. This was due to some undesirable features, such as extreme sensitivity to the occurrence of small fish in the ATM surveys, poor fits to the length-composition and survey data, as well as sensitivity to initial values for the parameters.

Although acoustic technology plays an extremely important role in the assessment, discussion on much of the acoustic methodology and assumptions was deferred. The Panel was informed that an acoustic methods meeting was scheduled for January of 2018 and that issues could, and should, be identified, but that detailed discussion of the issue would be postponed until the methods meeting. The assumption that the ATM was an acceptable approach was based on the 2011 Acoustic-Trawl Survey Method for Coastal Pelagic Species- Report of Methodology Review Panel Meeting, conclusions that: "Overall, the Panel is satisfied that the design of the acoustic-trawl surveys, as well as the methods of data collection and analysis are adequate for the provision of advice on the abundance of Pacific sardine, jack mackerel, and Pacific mackerel, subject to caveats, in particular related to the survey areas and distributions of the stocks at the times of surveying. The Panel concluded that estimates from the acoustic-trawl surveys can be included in the 2011 Pacific sardine stock assessment as "absolute estimates".

Finally, there was a preconceived, or biased, preference of which model approach was preferred by the STAT team. While most of the Panel agreed that the simplest approach was likely the better, the text of the document only identified the merits of a survey-based assessment and the drawbacks of a model-based assessment. This somewhat unbalanced overview was discussed early during the meeting and the team agreed to provide a more balanced overview in the assessment document. Ironically, in the end, it was the model-based approach (ALT) that was selected to provide the advice to management for 2017.

One constraint in the process was the necessity for the approach to provide a mechanism for projecting a biomass estimate for the start of the fishing year, in this case 1 July 2017. As happened in this review, the STAT and the STAR Panel agreed that the ATM was the better and simpler approach for providing estimates of biomass, but because of the issues associated with the projection method proposed for the ATM the panel was left with no alternative but to recommend the use of the ALT model to provide advice to management. Both approaches provided similar biomass estimates. Several methods to provide a suitable projection approach for the ATM were investigated during the meeting but none were deemed acceptable. Alternative approaches to resolve this problem are proposed in the STAR Panel report recommendations.

The role of the STAR Panel is to conduct a detailed technical evaluation of a full stock assessment to advance the best available scientific information to the Council. The specific responsibilities of the STAR panel are to:

1) Review draft stock assessment documents, data inputs, and analytical models, along with other pertinent information (e.g., previous assessments and STAR panel reports, when available);

2) Discuss the technical merits and deficiencies of the input data and analytical methods during the open review panel meeting, work with the STATs to correct deficiencies, and, when possible, suggest new tools or analyses to improve future assessments; and

3) Develop STAR panel reports for all reviewed species to document meeting discussion and recommendations.

3.1 Review draft stock assessment documents, data inputs, and analytical models

Approximately two weeks before the STAR Panel meeting access to a web-site containing the draft Pacific Sardine Assessment Document and background material was granted. This was an excellent source on material from which to prepare for the actual review meeting. At the meeting, the SWFSC assessment team provided a good overview of the assessment approaches and the logic for their preference. Details were provided on each approach, survey design, analytical methods, and results during the meeting. This information greatly assisted the Review Panel in their review of assessment approach. When the Panel requested for a more detailed explanation or additional analysis the team generally provided the information the next day. The Panel and the CIE reviewers appreciated their efforts and acknowledge the extensive research effort to evaluate factors that may affect or bias outputs. The documented and presented information was sufficient to conduct the STAR Panel Review of the assessment and generally represents the best scientific information available at the moment. The ATM methodology Review to be held in 2018 will hopefully resolve the issues and recommendations associated with this assessment approach.

In general, the Panel review adhered to the agenda provided to attendees prior to the meeting. However, some flexibility was permitted by the chair when the discussion led into an area to be discussed later that was helpful to address the issue on-hand. Each CIE Reviewer participated in the discussion and review of the specific topics identified in the agenda and made a significant contribution to the Panel's draft summary report. The review chair collated the draft text and completed the Panel report with input from all Panel members. The review can be divided into 4 broad topics; the overview, acoustic-trawl surveys, the integrated assessment model (ALT), and conclusions/recommendations, each of which are discussed below.

3.2 Discuss the technical merits and deficiencies of the input data and analytical methods during the open review panel meeting.

The STAR Panel report provides a detailed summary of the Panel's views on the merits and deficiencies of both assessment approaches as well as suggestions to evaluated and potentially correct these deficiencies. Over the 3-day meeting, most areas of uncertainty or concern were addressed and where possible additional information or data reruns were requested to improve the Panel's understanding of procedures and processes (Section 3.3.1).

In addition, specific issues were raised and are identified below.

3.2.1 Acoustic Trawl Method (ATM) survey.

There were a number of merits and deficiencies identified during the 2017 Star Panel Review for the Acoustic Trawl Method survey. Both the STAT and the STAR Panel agreed that the ATM likely provided the better approach to assess the NSP Pacific sardine stock in term of biomass. Unfortunately, the proposed approach to project the stock forward by about 1 year was deemed circular and performed poorly to other projection methods tested during the meeting. While the detailed discussion of the acoustic methods were deferred until the 2018 methods review, several areas of weakness in the survey approach were discussed (survey coverage, biological sampling, stratification, and ageing). Factors such as TS were not investigated but could have had a significant impact on the estimated biomass (assumed to be absolute). Herein lies another example of where some additional detail in the documentation could have helped. Target strength is a function of fish length and usually expressed in terms of total length for pelagic species. Yet, the length measured during the survey was standard length. Although not requested during the meeting, a simple statement indicating the TS equation was correct for length measurement would have clarified what was actually done.

Survey Coverage:

Survey coverage has been, and continues to be, a major issue for both the spring and summer acoustic surveys in that they do not provide complete coverage of the seasonal distribution of the species. Each year the fishing industry (Captains and representatives) reports a varying amount of Pacific sardine in the inshore waters not covered by the AT surveys. According to the industry representatives present at this year's Panel, large amounts of sardines were observed inshore over the last two years during the time of the survey that would not be accounted for by the survey. If these observations can be confirmed and quantified, it would complete the survey coverage, and likely increase the 1+ biomass of the Northern Pacific stock. Even the 2011 Panel Review, which acknowledged that the survey was adequate to provide an absolute biomass estimate for the area covered, suggested that methods be explored to obtain information, particularly on the inshore and to a lesser extent on the offshore areas.

From a personal point of view, this is an excellent opportunity for the STAT team and the SWFSC to explore collaboration opportunities for surveying with the fishing industry. A major challenge for the larger research vessels is the minimum depth restrictions, imposed for safety reasons, limiting how close to shore the vessel can survey. Fishermen are general very familiar with local conditions and could, assuming a coordinated effort, provide coverage of those areas not covered by the survey vessel, thus eliminating the continuous uncertainty associated with what is and isn't in the inshore waters during the survey. Furthermore, there appears to be a sincere interest by the fishing industry to collaborate with the STAT team on surveying.

Another deficiency not directly related to spatial coverage, but the scope of the technology used to survey, is the amount of sardines distributed in the acoustic surface dead zone (10-15m below the surface). Currently, the surveys are conducted with hull mounted acoustic echo-sounders that can only detect fish directly under the vessel. Pacific sardines are commonly found very near the surface, thus any fish occurring in the dead zone would go undetected and would likely avoid the vessel, especially during the day. Recommendations have been made in previous reviews to investigate this section of the water column using sonar technology; however, no new information was presented at the review. The recommendation to use drone technology to address these and other areas of uncertainty are to be encouraged but they should not occur at the expense of more conventional technologies (e.g., sonar and aerial surveys).

Biological Sampling:

Biological Sampling appears to be another deficiency of the ATM. The current practice of surveying during the day and fishing during the night was again questioned. The assumption that fish present during the day are the same fish caught and occur with the same species composition (representative) is a major source of uncertainty. It should also be noted that a large number of the sets (Trawls) contain 0 catches (up to 50% in some years). Combine that with the pooling of sets into clusters and the actual sample size decreases substantially.

For this survey, the Primary Sampling Unit (PSU) is a cluster of sets undertaken in a general area. How the locations of the sets are determined is another area of uncertainty. It was curious to note that some clusters (multiple sets) occurred in areas where no fish were observed and no fish were caught. It was explained that because fishing occurred at night that fishing stations may or may not be in areas with fish. Given that the purpose of sampling is to determine species and size composition of the acoustic targets, fishing in areas without fish for multiple sets is somewhat futile. This practice of fishing for the sake of fishing also appears to be an inefficient use of precious vessel time. Better use of fishing time needs to be addressed and may help to improve biological sampling.

The species composition data from the sets are used to apportion the acoustic backscatter into species backscatter and subsequently into species specific biomass. Efforts should be made to improve (increase) biological sampling and reduce the uncertainty. This is another area where collaboration with the fishing industry could benefit both science and the industry. Working with the fishing industry could remove some of the uncertainty associated with day surveying and night sampling if fishing vessels were used to confirm acoustic targets. Purse seines are generally non-size selective and in many cases the entire school can be caught, permitting additional sampling with an actual biomass estimate. Additional samples would also be available for ageing.

Ageing:

The Panel discussed a number of issues associated with the number of samples aged and the development of age-length keys related to both assessment approaches being reviewed. Probably most surprising to the Panel was the limited number of otoliths collected for a given AT survey. The number of fish sampled for age ranged from 16 to 1,051 per year, but were generally less than 500, especially in the most recent years. The explanation provided by the STAT was that samples were difficult to collect during the survey as the biomass was low. The Panel expressed concern about the application of so few ages to age length keys and the implication of this on the age and weight at length used for the models. Of particular concern was the practice of pooling samples from several years to create a generic ALK that was applied to the length distributions. Most fishery scientists frown (a must not do) upon this practice as it removes the effects of all inter-annual or density dependent growth variability. The generic ALK will also have an impact on all age-related factors associated with the assessment. Several unusual patterns were noted in the weight at age figures for a number of years. The only real solution is to increase the number of samples collected and to increase the number of otoliths retained for ageing so that sufficient otoliths are collected to generate an annual ALK. This is another area that should be explored where collaboration/coordination with the fishing industry could benefit both the resource and the analysis. Fishing vessels could be utilized to sample fish during the survey or to supplement low samples in specific areas where research samples are limited.

Post survey stratification:

The method used to post stratify the AT survey into stratum was unclear in the assessment report and caused several members of the Panel to express their concern about using the presence and density of fish to post stratify the survey area. A fair amount of discussion ensued on the approach, sampling design and the potential bias of using the latter two criteria to stratify the survey observations. Eventually, the actual procedure for increasing the intensity (spacing) of transects was explained and the Panel felt more comfortable with the approach. However, there were still uncertainties associated with how things were done and what triggered a change in transect spacing. This issue will be dealt with further by the second CIE Reviewer and under the recommendations that should be addressed at the upcoming review of ATM scheduled for early 2018. Recommendation E states that the ATM survey design and estimation methods need to be more precisely specified.

3.2.2 Model-based assessment

The second assessment approach reviewed by the Panel was the model-based assessment (ALT) utilizing Version 3.24aa of the Stock Synthesis Assessment Toolbox to evaluate the status of the NSP of Pacific sardine stock. This model differs significantly in configuration and input parameters from the model used to update the assessment in 2016. Consequently, the requirement for a STAR Panel review. Changes include starting the model in 2005 (previously 1993) and excluding the Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices. Stock recruitment steepness and weight-at-age was pre-defined with the assumption that selectivity of the AT survey being 0 for age 0 and uniform for all other ages. Catchability was estimated under an age-based rather than a length-based model, ages modeled were reduced from 15 to 10 years and natural mortality increased from 0.4 to 0.6. Given that there is no directed fishery on the NSP resource so landings from the small live bait catches were included for 2015 and 2016 for the first time.

It was evident from the assessment document and presentations that the STAT team preferred the survey based method over the model-based approach to the assessment. The challenge for the preferred approach was to project forward almost a year from the last survey to the beginning of the management year. Thus, one of the key drivers in the review was to explore the method proposed by the STAT to estimate age 1+ biomass and its associated CV on July 1, 2017 from the ATM. If the proposed method was unacceptable then the Panel must identify the best approach to achieve and estimate biomass for management purposes.

Several inconsistencies, especially for age 0 were noted by the Panel in the outputs of the ALT model. A significant amount of time was spent on resolving issues associated with the ALT model. It appears that the seasonal option in the modelling (SS3) toolbox had not been fully tested and that it was producing unusual outputs related to the Age 0 fish. Several requests were made to the STAT team to try to resolve/understand these problems. Although not fully resolved to the satisfaction of the Panel, a work around process was established and projections for the 1+ biomass was available for the ALT model. Several approaches to estimate age 1+ biomass were explored by the Panel and are described below.

The first was to assume that the 1 July 2017 biomass equals the estimate of biomass from the summer 2016 ATM survey; simply ignoring mortality (natural causes and fishing), growth and recruitment from July 2016 to July 2017. This method was considered as the simplest approach and the easiest to implement because it does not rely on a model or estimates of age composition for which sample sizes are low.

The second approach was to project the biomass from the 2016 ATM survey to 1 July 2017 taking into account mortality, growth and recruitment between July 2016 and July 2017. Unfortunately, the approach used to convert from length-composition to age-composition was incorrect, and the method used to derive the CV of age 2+biomass did not allow for uncertainty in the population age-composition, projected weight-at-age and maturity-at-age. In addition, the method relied heavily on model ALT because approximately half of the age 1+ biomass on 1 July 2017 consisted of age-1 animals. As such, the estimate of biomass is based to a substantial extent on the stock-recruitment function from model ALT. Finally, the value for M of 0.6yr-1 has no clear justification. The version of the projection model provided initially to the Panel did not account for catches, meaning that the procedure could not be applied in the future when the targeted sardine fishery re-opened. Furthermore, it did not account for the limited catches during 2016.

The third approach was to use the ALT model projections. The ALT Model has similar problems associated with the 'survey projection' model, i.e. the age-composition data are based on a year-invariant age-length key, and the basis for M=0.6yr-1 lacks strong empirical justification (and indeed likelihood profiles indicate some support for lower M than the value adopted for model ALT). In addition, the model presented to the Panel predicted age 0 catch in the ATM survey even though it is assumed that age-0 animals are not selected during the ATM survey. It appears that the model predictions of age-0 animals in the ATM survey are actually model-predicted numbers of age-1 animals that are predicted to be mis-read as age-0 animals. However, examination of the ATM survey length-frequencies suggests that that some age-0 animals (or animals that were spawning earlier in the year) are encountered during the surveys. The Model ALT also estimates Q to be 1.1, which is unlikely given some sardine are not available to the survey owing to being inshore of the survey area.

Finally, projections from the previous assessment model were examined. The model on which the 2014-16 assessments were based was approved for management by the 2014 STAR Panel. However, that assessment had some undesirable features, including extreme sensitivity to the occurrence of small (<~15cm fish) in the ATM surveys, poor fits to the length-composition and survey data, and sensitivity to initial values for the parameters (i.e. local minima) as noted in previous reviews. The Panel explored alternatives to the current selectivity formulation to better understand why model ALT was predicting age 0 catch when selectivity for age-0 fish was set to zero. It was noted that the results were generally robust assuming that selectivity is a logistic function of length (but that implies that some age-1+ animals are not available to the ATM survey), allowing for time-varying age 0 selectivity, and estimating a separate selectivity pattern for ATM survey age-composition data.

The Panel noted that the 'survey projection' model and model ALT both rely on the samples from the ATM surveys to compute weight-at-age and survey age-composition data. The sample sizes for age from each survey were very small which means that estimates of, for example, weight-at-age are highly uncertain. The procedure of ensuring that weight-at-age for a cohort does not decline over time seems intuitively correct. However, if the estimated mean weight of young fish in a cohort is anomalously high owing to small samples, it can impact the weight-at-age of that cohort for all subsequent ages. When Model ALT steepness was estimated rather than fixing it equal to 0.8, the results were not sensitive to fixing versus estimating steepness, but the estimate of 0.36 was low.

In the end the Panel considered four ways to meet the management requirement to estimate age 1+ biomass on 1 July 2017: (1) the simple approach of using the of biomass estimate from the summer 2016 ATM survey without projecting forward, (2) projecting biomass from the 2016 ATM survey (summer) to 1 July 2017 using the proposed 'survey projection' model (and/or an alternative approach), (3) model ALT, and (4) the model on which the 2014-16 assessments were based. The Panel concluded that although neither method was fully acceptable that option 3, the ALT model, was likely the best available approach to meet the management needs.

3.3 Develop STAR panel reports for all reviewed species to document meeting discussion and recommendations.

This section summarizes the discussion and recommendations that form an integral part of the STAR Panel report. As a full member of the panel, I made a significant contribution to the preparation and editing of the final report. Consequently, I see no merit in rewording the sections related to requests for additional information, the recommendations and conclusions of the STAR panel report so I have extracted the appropriate sections and included them in my report. Although I fully agree with the content, there are a few areas where I have enhanced the text to complement that contained in the Panel report.

3.3.1 Requests made to the STAT (Taken Directly from the STAR Panel Report)

Day 1– Tuesday, February 21:

***Request 1*:** Provide documentation on the procedures used to calculate the survey age-composition data, including how age-length and age-biomass keys are constructed.

Rationale: These calculations are critical to projecting biomass after accounting for natural mortality, somatic growth, and recruitment; but the draft assessment document did not describe these calculations in sufficient detail for them to be reproduced. In addition, the age-compositions for the ATM survey in model ALT were computed using the method.

Response: Dr. Zwolinski presented written documentation and figures. The function "multinom" from the R package "nnet" fits a multinomial log-linear model using neural networks. The response is a discrete probability distribution (see Fig. 1). It is simpler to use than the alternative (sequential logistic models), and it provides a smoother transition between classes than an empirical age-at-length key. The age and lengths used for constructing the age-length key were from surveys from 2004 to the present. Due to the assumption of a July first date and its effect on ageing, the STAT built a season-specific age-length key using data pooled across time separately for spring/summer.
The Panel agreed that aggregation across years is not appropriate if some length-classes represent multiple ages, which is the case for Pacific sardine. Moreover, substantial spatial and temporal variation occurs in size-at-age, and smoothing this out by merging the data from several years creates bias in annual estimates of age compositions of varying magnitude and direction.

Request 2: Provide full specification, including equations, of the calculations used to 1) project from the ATM survey biomass estimate to the estimated age 1+ biomass on July 1 of the following fishing year, and 2) calculate the uncertainty associated with that biomass estimate.

Rationale: The projection calculations need to be reproducible. Management advice (Overfishing Level OFL, Acceptable Biological Catch ABC, and Harvest Guideline HG) for Pacific sardine requires an estimate of age 1+ biomass (OFL, ABC, HG) and its uncertainty (ABC) on July 1, 2017.

Response: For 1), Dr. Zwolinksi walked the Panel through a spreadsheet that made these calculations and the Panel agreed that the calculations were sensible, conditional on the age-weight key. For 2), assuming independence of age- 1 and age- 2+ biomass, the total variance was calculated by summing the respective variances. This calculation is negatively biased because it ignores uncertainty in age-composition and weight-at-age. It was noted that the resultant coefficient of variation (CV) for age 1+biomass is lower than the CV for either component (age- 1 versus age- 2+) due to their assumed independence.

Request 3: Plot cohort-specific rather than year-specific growth curves (weight-at-age) for the ATM survey and overlay raw data/information on sample sizes. Make it clear which values are estimated versus inferred. Do this for the fisheries data as well.

Rationale: Cohort-specific curves are easier to interpret as growth trajectories than year-specific curves. It is important to understand how much data drives these estimates, and to understand the consequences of applying the same age-length key for all years with survey data to calculate the weight-at-age and age-composition for the ATM survey.

Response: Dr. Hill presented tables including sample sizes and estimated means for each cohort-season-age combination. The tables were formatted to highlight entries that were inferred versus estimated. Dr. Hill calculated means whenever three or more samples were available. However, these means were sometimes overwritten based on the assumption that animals did not shrink. The ATM data showed substantial variation in weight-at-age across years (Fig. 2), and possibly increasing size-at-age in recent years. The MexCal catch data appeared less variable overall, and it was noted that fishery sample sizes were generally larger than the ATM sample sizes. An error was discovered in the weight-at-age data for the PNW catch, which could not be resolved during the Panel meeting.

The Panel noted that the adopted method ended up discarding data for cohorts with unusually large mean sizes for age-0 fish by not allowing "shrinkage", whereas it may have been the age-0 means that were anomalous rather than the means calculated for older ages. The Panel also noted that in many cases, the sample sizes were very small. The weight-at-age key used within the survey-based projection did not exclude "shrinkage". Using the weight-at-age key in model ALT produced an imperceptible difference in model-estimated age 1+ biomass.

Request 4: Verify that model ALT was run with ATM survey selectivity set equal to 0 for age-0 fish. Contact Dr. Rick Methot to better understand how selectivity is being modeled under the chosen selectivity option in SS.

Rationale: The model outputs appear to indicate that the model predicts non-zero catches of age-0 fish despite the intent to specify selectivity to be 0 zero on age-0 fish. This may have significant unintended consequences for the likelihood calculations.

Response: This question was not fully resolved. It appears that Stock Synthesis predicts some catch of nominal "age- 0" even given selectivity of zero on true age-0 fish because aging error leads to the expectation that some age-1 fish will be caught and miscategorized as age- 0. Further model runs revealed that the model "blew up" if aging error was set to zero or made

very small, but reductions in the specified aging error led to the expected reduction in the predicted age-0 catch. It was noted that surveys likely include a mix of age-1 fish miscategorized as age-0, as well as fish that are truly age-0.
Dr. Methot also noted that Stock Synthesis had not been as thoroughly debugged for semester-based models as for strictly annual models.
See also Requests 5, 8, and 9.

Request 5: Re-run model ALT with age- 0 fish removed from the input file for the ATM survey.

Rationale: Similar to Request 4, the model likelihood should not be influenced by data on age-0 fish if it is assumed selectivity on age-0 fish is zero, but the model appears to be generating non-zero predictions and comparing these against the input data.

Response: The model still predicted catch of age-0 fish in this scenario. This is consistent with the explanation suggested for this pattern under Request 4.

Request 6: Report the CV of the estimate of terminal biomass based on changes in how the compositional data are weighted.

Rationale: The weighting of compositional data appeared to have little effect on the point estimate of biomass, but it is important to understand implications of alternative weighting schemes for uncertainty as well.

Response: Data weighting increased the CV by 2-3%. The base model had a CV of approximately 36%, Francis-weighting led to a CV of approximately 38%, and harmonic mean weighting led to a CV of about 39%.

Request 7: Show more outputs from T_2017 and T_2017_No_New_AT _Comp

Rationale: These outputs would help the Panel evaluate the reasons for proposing a move away from a strict update of the previously accepted model structure, i.e. identify problems with a strict update that the new model structure addresses.

Response: Selectivity curves for the spring and summer ATM surveys were noticeably different depending on whether the two most recent survey length-compositions were included in the assessment or not (Fig. 3). These models appeared to yield acceptable fits to abundance indices, but the fits to observed length-compositions were poor. It appears that the model estimates very low selectivity on small fish for the summer survey (since selectivity does not vary across years, and very few small fish are encountered most years) such that when small fish are encountered, they are expanded to a very large number. During Panel discussion, it was noted that this unexpected behavior should not happen if selectivity were forced to be the same for the spring and summer surveys.

Day 2 – Wednesday, February 22

Request 8: Develop a model in which selectivity for age-0 animals in the survey is time-varying.

Rationale: The availability of age-0 animals to the survey seems to be highly variable among years, but influential on the results. A selectivity function in which age-0 selectivity varies among years should "discount" the influence of occasional catches of age-0 animals.

Response: A model was presented that assumed essentially full selection on age-1+ animals, and time-varying age-0 selectivity. The model estimated nearly zero selectivity on age-0 fish in all years except 2015, when estimated selectivity on age-0 fish was nearly 1.0. Fits to compositional data were similar to those for model ALT, except that the spike of age-0 fish in 2015 was captured better. The estimate of age 1+biomass on 1 July, 2017 for this model was 77,845 t.

Request 9: Run a variant of model ALT in which the age-compositions are assigned to a new fleet (6) that has logistic selectivity (estimated separately for the spring and summer periods).

Rationale: Selectivity for the ATM survey is assumed to be uniform on animals aged 1 and older so age-composition data are not required for this survey. The selectivity pattern for the trawl component of the survey is not uniform on age-1+ animals (some age-0 animals are caught) and it may be possible to represent this using a logistic selectivity function.

Response: This model performed generally similarly to a double-logistic formulation applied to the ATM survey for both age-composition and as an abundance index, but it misses the summer 2016 ATM survey estimate of biomass from above, whereas the double-logistic fits that estimate closely. The double-logistic model had a negative log-likelihood of approximately 311, compared to 305 for this variant and 333 for model ALT. Thus, both a model with logistic ATM selectivity and a model that assumed 1+ selectivity for ATM survey estimates and logistic selectivity for the associated age-composition data fit the data somewhat better than model ALT.

Request 10: Conduct a retrospective evaluation of how well alternative assessment methods can predict the biomass from the summer ATM surveys. For each year Y for which there is a summer ATM survey estimate for year Y and year Y+1, report predictions of year Y+1 biomass based on (a) the estimate of biomass from the results of the ATM survey during summer of year Y, (b) the estimate of biomass based on applying the projection method to the results from the ATM survey in summer of year Y, and (c) model ALT based on data through year Y.

Rationale: The Panel wished to understand which method was able to predict the ATM survey estimate of biomass most accurately.

Response: The STAT provided results for the three selected approaches as well as the estimates of age 1+ biomass obtained by projecting the actual assessments used for 2012, 2013, 2014 and 2015 forward ("Past assessments" in Fig. 4) and estimates of age 1+ biomass obtained by projecting the model used for 2014, 2015 and 2016 management advice ("2014 formulation"). Model ALT generally came closest to predicting the survey biomass estimate the following year, doing so by a substantial margin for 2014. "Past assessment" was usually the worst. Model ALT had the lowest residual variance. Relative errors were a CV of 1.07 for Model ALT, 1.26 for the 2014 model on which 2014, 2015 and 2016 management advice was based on formulation, 1.50 for the last survey without projection, 1.62 for the values adopted in management specifications, and 1.70 for projections from the past previous ATM survey (see Appendix 2 for the specifications for the method).

Day 3 – Thursday, February 23

Request 11: Develop a method for estimating recruitment solely from ATM data, explain how these recruitment estimates could be used to project forward from an ATM biomass estimate, and then add results for that method to the retrospective comparison described in Request 10.

Rationale: During discussion of Request 10, it was clear that much of the concern regarding the currently proposed method of projecting from the survey was its dependence on model ALT for inputs, resulting in its dependence on the same assumptions the STAT was hoping to avoid by moving away from an integrated assessment. It was pointed out that it could be possible to develop estimates of age 1 biomass on 1 July, 2017 strictly from the ATM data.

Response: The STAT modified the survey projection method so that projected biomass of 1-year-olds was the average over the most recent five years. As desired, this approach was not tied to the model ALT. However, the residual standard deviation for this approach ("Survey projection 2"), while better than "Survey projection", was still worse than Model ALT and the 2014 model formulation (1.45) (Fig. 4).

4.0 Recommendation and Conclusions

One of the primary objectives of the stock assessment process and the STAR Panel Review was to provide advice to management on 2017-2018 NSP Pacific sardine resource using the best available information/data. The Panel reviewed multiple options, described above and concluded for 2017 that, given the current management approach requires an estimate of age-1 biomass at the start of July, model ALT was the best approach at present for conducting this assessment notwithstanding the concerns listed above. The results from the assessment are robust to changes in how selectivity is modelled, the value for steepness and data weighting, but there were several concerns with this model that could not be resolved during the Panel meeting. Assuming uniform selectivity leads to lower estimates of current 1+ biomass, but this assumption reflects the expectation that all fish in the survey area are vulnerable to detection during an acoustic survey.

The STAT strongly recommends that management advice for Pacific sardine be based on the estimates of biomass from the ATM survey rather than a projection model or an integrated assessment. The STAR Panel is in general agreement with this approach and notes the following ways in which management could be based on the ATM survey results given the July 1 biomass estimate requirement. The first would be to change the start-date of the fishery so that the time between conducting the survey and the implementation of harvest regulations is minimized. And, secondly to use Management Strategy Evaluation to evaluate the risk to the stock of basing management actions on an estimate of biomass that could be a year old at the start of the fishing season (if the fishery start date is unchanged). Review of an updated MSE would likely not require a Methodology Panel, but could instead be conducted by the SSC.

The Panel further notes that there may be benefits to attempting to use both the spring and summer ATM surveys as the basis for an ATM survey-only approach and that moving to an assessment approach that relies on the most recent ATM survey (or two) may be compromised by reductions in ship time and/or problems conducting the survey. From the CIE Reviewer perspective, the reduction of vessel time will have implications for the AT survey and at a minimum will increase the variance estimates of biomass and the uncertainty about survey coverage.

The Panel agrees with the STAT that there is value in continuing to collect biological data and to update model ALT even if management moves to an ATM survey-only approach.

4.1 Research Recommendations:

The Panel identified a number of research recommendations that have been prioritized in three categories: High, medium and low.

High priority

A. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata.

B. The clusters (the Primary Sampling Units, PSUs) with age-length data should be grouped into spatial strata (post-strata, or collapsed post-strata used in ATM biomass estimators). The variance in estimates of age-length compositions can then be estimated by bootstrapping of PSUs, where age-length keys are constructed for each bootstrap replicate. The sub-sample size of fish within clusters that are measured for lengths should be increased, and length-stratified age-sampling should be implemented. This approach would likely increase coverage of age samples per length class and reduce data gaps.

C. The survey projection method should be developed further. Specifically, the survey age-composition should be based on annual age-length keys, and the uncertainty associated with population age-composition, weight-at-age and maturity-at-age needs to be quantified and included in the calculation of CVs. A bootstrapping procedure could be used to quantify the uncertainty associated with population age-composition and projected weight-at-age. Uncertainty in weight-at-age could also be evaluated using a retrospective analysis in which the difference between observed and predicted weight-at-age for past years was calculated. Ultimately, improved estimates of weight-at-age and measures of precision of such estimates could be obtained by fitting a model to the empirical data on weight-at-age.

D. The methods for estimating 1 July age 1+ biomass based on the results of the ATM survey during the previous year currently use only the results of the summer survey. Improved precision is likely if the results from the spring and summer surveys were combined. This may become more important if the number of days for surveying is reduced in the future. Consideration should be given to fish born after 1 July.

E. 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.

F. Modify Stock Synthesis so that the standard errors of the logarithms of age-1+ biomass can be reported. These biomasses are used when computing OFLs, ABCs and HGs, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not age-1+ biomass.

G. The approach of basing OFLs, ABCs and HGs for a year on the biomass estimate from the ATM survey for the previous year should be examined using MSE so the anticipated effects of larger CVs and a possible time-lag between when the survey was conducted and when catch limits are implemented on risk, catch and catch variation statistics can be quantified.

H. 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.
I. The assessment would benefit from the availability of estimates of 1+ biomass that include quantification of the biomass inshore of the survey area and in the upper water column.
J. It is unclear how the habitat model is applied to determine survey design. Is this an *ad hoc* decision or is there a formal procedure? The next Panel should be provided with comprehensive documentation on how the habitat model is applied.
K. 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.
L. Explore the potential of collaborative efforts to increase sample sizes and/or gather data relevant to quantifying effects of ship avoidance, problems sampling near-surface schools, and currently un-sampled nearshore areas.
M. Reduce aging error and bias by coordinating and standardizing aging techniques and performing an aging exchange (double blind reading) to validate aging and estimate error. Standardization might include establishing a standard “birth month” and criteria for establishing the presence of an outer annuli. If this has already been established, identify labs, years, or sample lots where there is deviation from the criteria. The outcome of comparative studies should be provided with every assessment.

Medium priority

N. Continue to explore possible additional fishery-independent data sources such as the SWFSC juvenile rockfish survey and the CDFW/CWPA cooperative efforts (additional sampling and aerial surveys). 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.
O. 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; this should include an analysis of age-structure on the mean distribution of sardine in terms of inshore-offshore (especially if industry partner-derived data were available).
P. Consider a model that has separate fleets for Mexico, California, Oregon-Washington and Canada.

Q. Compare annual length-composition data for the Ensenada fishery that are included in the MexCal data sets for the northern sub-population 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.

Low priority

R. Consider a model that explicitly models the sex-structure of the population and the catch.
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.
T. 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.

4.2 Recommendations that should be addressed during the 2018 review of the ATM survey

The Panel was informed that a methodology review of the ATM approach was scheduled for January 2018. Because of this, a number of issues and detailed discussions regarding this approach were deferred until the review. However, the Panel did make several recommendations, listed below, that should be considered for the 2018 review.

A. In relation to the habitat model:

a. Investigate sensitivity of the assessment to the threshold used in the environmental-based method (currently 50% favourable habitat) to further delineate the southern and northern subpopulations of Pacific sardine.
b. Further validate the environmentally-based stock splitting method. The habitat model used to develop the survey plan and assign catches to subpopulation seems to adequately predict the spawning/egg distribution in the CalCOFI core DEPM region, but eggs were observed where they were not expected in northern California, Oregon and Washington during one of the two years when the survey extended north. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. Once statistically significant discriminant metrics (e.g. morphometric, otolith morphology, otolith micro-structure, and possibly using more recent developments in genetic methods) have been chosen,

these should be applied to samples from areas where mixing may be occurring or where habitat is close to the environmentally-based boundary. This can be used to help set either a threshold or to allocate proportions if mixing is occurring.

c. Consider including environmental covariates in model-based approaches that would account quantitatively for environmental effects on distribution and biomass. The expertise from a survey of fishermen could be extremely useful in identifying covariates that impact the distribution of clusters.

B. The SWFSC plans to examine ship avoidance using aerial drone sampling; there is an ongoing significant effort by Institute of Marine Research in Norway to understand the same issue using sonar, and the SWFSC acoustics team should communicate and coordinate with those researchers.

C. The effect of population size affecting the number and spacing of school clusters likely affects the probability of acoustic detection in a non-linear way; this could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed. A simulation exercise should be conducted using the current, decreased and increased survey effort over a range of simulated population distribution scenarios to explore this.

D. The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the night time scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters.

E. The ATM survey design and estimation methods need to be more precisely specified. A document must be provided to the ATM review (and future assessment STAR Panels) that:

- delineates the survey area (sampling frame);
- specifies the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
- specifies the rule for stopping a transect (offshore boundary);
- specifies the rules for conducting trawls to determine species composition;
- specifies the rule for adaptive sampling (including the stopping rule); and
- specifies rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account density should be considered.

DISCLAIMER

The information in this report has been provided for review purposes only. The author makes no representation, express or implied, as to the accuracy of the information and accepts no liability whatsoever for either its use or any reliance placed on it.

Appendix I: Background material

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Appendix II: Statement of Work for Dr. Gary Melvin

Statement of Work
National Oceanic and
Atmospheric Administration
(NOAA) National Marine Fisheries
Service (NMFS)
Center for Independent
Experts (CIE) Program
External Independent
Peer Review
STAR Panel Review of the 2017-2018 Pacific Sardine
Stock Assessment
February 21-24, 2017

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation’s marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.
Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards.
(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).
Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

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

Requirements

Two CIE reviewers shall participate during a panel review meeting in La Jolla, California during 21-24 February, and shall conduct impartial and independent peer review accordance with the SoW and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

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

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

Tasks for reviewers

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

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

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

- Attend and participate in the panel review meeting • The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
  - After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
- Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign

National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration- system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California.

Period of Performance

The period of performance shall be from the time of award through April 30, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables

The contractor shall complete the tasks and deliverables in accordance with the following schedule.

No later than January 24, 2017	CIE sends reviewers contact information to the COTR, who then sends this to the NMFS Project Contact
No later than February 7, 2017	NMFS Project Contact sends the CIE Reviewers the pre-review documents
February 21-24, 2017	The reviewers participate and conduct an independent peer review during the panel review meeting
March 10, 2017	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
March 31, 2017	CIE submits CIE independent peer review reports to the COTR
April 7, 2017	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:
(1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each TOR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $10,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

Annex I: Review Panel Agenda

Revised AGENDA

2017 Pacific Sardine Stock Assessment Review

Southwest Fisheries Science Center
8901 La Jolla Shores Dr., La Jolla, CA 92037
La Jolla, CA 92037
858-334-2800

This is a public meeting, and time for public comment may be provided at the discretion of the meeting Chair. This is a work session for the primary purpose of reviewing the current Pacific sardine stock assessment, under the Pacific Fishery Management Council's (Council) terms of reference for the CPS stock assessment reviews. The Stock Assessment Review Panel will review the assessment and produce a report to the full SSC, in advance of the April 2017 Council meeting in Sacramento, California. The assessment will be used for setting sardine harvest specifications and management measures for the July 1, 2017 – June 30, 2018 fishery.

TUESDAY, FEBRUARY 21, 2017 – 10 A.M.

A. Call to Order, Introductions, Approval of Agenda — André Punt, Chair
(10 a.m., 15 minutes)

B. Terms of Reference for CPS Stock Assessment Review Process — Kerry Griffin
(10:15 a.m., 15 minutes)

C. Pacific Sardine Stock Assessment Team Presentation Overview — Paul Crone, Kevin Hill
(10:30 a.m., 15 minutes)

D. Acoustic-Trawl Survey — Juan Zwolinski
(10:45 a.m., 45 minutes)

E. Pacific Sardine Stock Assessment Team Presentation — Kevin Hill, Paul Crone
(11:30 p.m., 1 hour 30 minutes)

LUNCH
(1 p.m. – 3p.m., 2 hours)

NOTE: The Pacific Room is needed for another purpose from 1 p.m. until 3 p.m. The STAR Panel and attendees can move to Stenella Meeting room during this time.

E. Pacific Sardine Stock Assessment Team Presentation (continued if needed) Kevin Hill
(3:00 p.m., 30 minutes) Paul Crone

F. Discussion and Requests Panel
(3:30 p.m., 1 hour 30 minutes)

WEDNESDAY FEBRUARY 22, 2017

G. Work Session – STAT and STAR Panel All
(8 a.m., 2 hours)

H. Public Comment
(10 a.m., 0.5 hours)

I. Response to Requests Kevin Hill
(10:30 a.m., 1.5 hours)

LUNCH

J. Initial Report Writing and STAT Work Session Panel
(1 p.m., 2.5 hours)

K. Discussion and Requests Panel
(3:30 p.m., 1 hour)

L. Public Comment André Punt
(4:30 p.m., 0.5 hours)

THURSDAY FEBRUARY 23, 2017

M. Response to Requests Kevin Hill
(8 a.m., 2 hours)

BREAK

N. Discussion and Requests Panel
(10:30 a.m., 1.5 hours)

LUNCH

O. Response to Requests Kevin Hill
(1 p.m., 1 hour)

P. Public Comment
(2 p.m., 0.5 hours)

BREAK

Q. Report Writing and STAT Work Session
(3 p.m., 2 hours)

FRIDAY FEBRUARY 24, 2017

R. Response to Comments (If Necessary) Kevin Hill
(8 a.m., 1 hour)

S. Discussion – Next Steps and Deadlines André Punt
(9 a.m., 1 hour) Kerry Griffin

BREAK

T. Finalize Report Assignments André Punt
(10:30 a.m., 1.5 hours)

U. Work Session as Necessary and Meeting Wrap Up André Punt
(12:00 p.m.)

ADJOURN

Appendix III: List of Participants

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Will Satterthwaite, SSC, Southwest Fisheries Science Center
Evelyn Brown, SSC, Lummi Natural Resources, LIBC
Jon Vølstad, Center for Independent Experts (CIE)
Gary Melvin, Center for Independent Experts (CIE)

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

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC

Other Attendees
Dale Sweetnam, SWFSC
Alan Sarich, CPSMT/Quinault Indian Nation
Emmanis Dorval, SWFSC
Chelsea Protasio, CPSMT/CDFW
Kirk Lynn, CPSMT/CDFW
Ed Weber, SWFSC
Josh Lindsay, NMFS WCR
Erin Kincaid, Oceana
Al Carter, Ocean Gold
Jason Dunn, Everingham Bros Bait
Nick Jurlin, F/V Eileen
Neil Guglielmo, F/V Trionfo
Andrew Richards, Commercial
Hui-Hua Lee, SWFSC
Bev Macewicz, SWFSC
Chenying Gao, Student
Steven Teo, SWFSC
Kevin Piner, SWFSC
Andy Blair, Commercial
Jamie Ashley, F/V Provider
John Budrick, CDFW
Steve Crooke, CPSAS
Gilly Lyons, Pew Trusts

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

The Scientific and Statistical Committee (SSC) reviewed the 2017 stock assessment of the northern subpopulation of Pacific sardine. Drs. Kevin Hill and Paul Crone (Southwest Fisheries Science Center) presented the results of the stock assessment and Dr. André Punt (SSC) provided an overview of the Stock Assessment Review (STAR) Panel report. The SSC appreciates the effort put forth by the stock assessment team to improve the assessment model in response to previous full and update assessment concerns.

The SSC endorses the 2017 Pacific sardine base case assessment model (termed model ALT in the assessment document) as the best available science for use in managing the northern subpopulation of Pacific sardine. The base case model uses an integrated assessment approach to estimate age-1+ biomass at the start of the 2017/2018 fishing year (July 1, 2017). This model is more stable, shows improved fit to recent surveys, and has improved retrospective patterns and thus is an improvement over the 2014 full assessment model and subsequent update assessments. Major differences include starting the assessment in 2005 rather than 1993, excluding the Daily Egg Production Method and Total Egg Production indices, and changing model specifications for natural mortality, weight-at-age, survey selectivity, catchability, and steepness of the stock-recruitment relationship.

There is no direct information on the size of the 2016 year-class, so it is estimated from the stock-recruitment relationship. As a result, there is considerable uncertainty associated with the estimate of age-1+ biomass in 2017. A substantial proportion of total biomass will be from that incoming cohort of uncertain size, especially when the stock size is estimated to be low, as it is presently. There are additional key uncertainties associated with natural mortality, weight-at-age, survey selectivity, and catchability.

The estimate for total age-1+ biomass on July 1, 2017, is 86,586 mt. The SSC recommends an overfishing limit (OFL) of 16,957 mt and that the base model be considered a category 1 assessment with a default sigma (σ) of 0.36 to be used in determining the acceptable biological catch.

The SSC reiterates that the assessment and OFL are only for the northern subpopulation of Pacific sardine, although some portion of the U.S. catch in each year is likely from the southern subpopulation.

There may be benefits to the survey-based approach advocated by the stock assessment team, and the planned early 2018 review of this survey could provide further information on the suitability of this approach. There would be less uncertainty in the calculation of the OFL when using a survey-based approach if the time-lag between conducting the survey and the start of the fishing year was minimized. Further evaluation of a survey-based assessment approach through a management strategy evaluation would be beneficial.

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

The Coastal Pelagic Species Management Team (CPSMT), Coastal Pelagic Species Advisory Subpanel (CPSAS) and Scientific and Statistical Committee (SSC) jointly received a presentation from Drs. Kevin Hill and Paul Crone concerning the Pacific sardine full stock assessment conducted in 2017. The CPSMT recommends that the Pacific Fishery Management Council (Council) adopt the Alternative Stock Assessment (ALT) model within the full assessment for management of the 2017-2018 sardine fishery (Agenda Item G.5.a, Stock Assessment Report). The age 1^+ biomass estimated from this assessment for July 1, 2017 is 86,586 metric tons (mt).

Similar to the 2016-2017 biomass estimate of 106,137 mt, the 2017-2018 biomass estimate of 86,586 mt is below the CUTOFF value of 150,000 mt. Accordingly, the Fishery Management Plan dictates a closure of the primary directed fishery for Pacific sardine for the upcoming fishing year (July 1, 2017 - June 30, 2018). This closure, however, does not preclude the allowance for incidental catch in other CPS and non-CPS fisheries as well as directed live bait, recreational and tribal harvest fisheries.

Harvest Specifications for 2017-2018

Table 1 (below) contains the overfishing limit (OFL) and a range of acceptable biological catch (ABC) values based on various P* (probability of overfishing) values. The CPSMT recommends use of a P* value of 0.40, consistent with previous sardine management specifications. The SSC designated the 2017 assessment as a Tier 1. The P* value of 0.40 applied to the 2016-2017 OFL of 16,957 mt, using a Tier 1 sigma of 0.36, produces an acceptable biological catch (ABC) of 15,479 mt.

During the 2015-2016 fishing season, the CPSMT evaluated the potential needs for incidental allowances for other CPS fisheries when the primary directed sardine season is closed (April 2015 Agenda item G.1.b, Supplemental CPSMT Report). That evaluation considered the historical levels of incidental sardine catch under a range of species and fishery dynamics. Consistent with that evaluation, the CPSMT again recommends an annual catch limit (ACL) of 8,000 mt (Table 2) to allow other fisheries to proceed. The CPSMT also recommends the same accountability measures as 2016-2017, presented following Table 2.

The Quinault Indian Nation request of 800 mt, the live bait fishery, and other minimal sources of mortality, such as recreational take, will be accounted for against the ACL. Coastwide incidental non-tribal landings for the 2016-2017 season through March 30, 2017 total 358 mt, while the Quinault Indian Nation reports 85 mt.

Table 1. Pacific sardine harvest formula parameters for 2017-2018.

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 2. 2017-2018 Calculated OFL, ABC and CPSMT-Recommended ACL.

Biomass	86,586 mt
OFL	16,957 mt
P* buffer	0.4
$ABC_{0.4}$	15,479 mt
ACL	8,000 mt

List of CPSMT-Recommended Accountability Measures

The following would be automatic in season actions for CPS fisheries:

- An incidental per landing allowance of 40 percent Pacific sardine in non-treaty CPS fisheries until a total of 2,000 mt of Pacific sardine are landed.
- When the 2,000 mt is achieved the incidental per landing allowance would be reduced to 20 percent until a total of 5,000 mt of Pacific sardine have been landed.
- When 5,000 mt have been landed, the incidental per landing allowance would be reduced to 10 percent for the remainder of the 2017-2018 fishing year.

A 2 mt incidental per landing allowance in non-CPS fisheries.

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COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON FINAL ACTION ON SARDINE ASSESSMENT, SPECIFICATIONS, AND MANAGEMENT MEASURES

The Coastal Pelagic Species Advisory Subpanel (CPSAS) heard a presentation by Dr. Kevin Hill on the Assessment of the Pacific Sardine Resource in 2017 for U.S. Management in 2017-18 (Agenda Item G.5.a, Stock Assessment Report), given at the Science and Statistical Committee (SSC) meeting. CPSAS members also heard a summary review of the Pacific Sardine Stock Assessment Review (STAR) Panel Meeting Report (Agenda Item G.5.a, STAR Panel Report) by Dr. Andre Punt. CPSAS members reviewed both documents prior to the SSC meeting.

A majority of the CPSAS remains extremely frustrated that this STAR panel review found the same unresolved problems as in prior assessments. As noted in the STAR Panel Report under Unresolved Problems and Major Uncertainties (page 9), "***The core issues for stock assessments continue to be related to the temporal and spatial scale of the surveys and insufficient sample sizes of age-length for sardine in the ATM survey."***

The STAR Panel Report expressed concerns with all the assessment approaches offered, but reviewers were asked to recommend the "least worst" option for the Council to set management measures for the 2017 sardine fishery. Model ALT turned out to be marginally better than the biomass estimated in the summer Acoustic Trawl Method (ATM) survey proposed by the Stock Assessment Team (STAT). Following discussion, the SSC ultimately approved this approach for 2017, recognizing this as the basis for two years of update assessments before the next full assessment review.

A majority of the CPSAS ask the Council to heed fishermen who are reporting a large biomass of sardines (as well as anchovy) in waters inshore of the current ATM survey area. We agree with the concerns expressed in the CPSAS representative's statement in the STAR Panel Report. Quoting from that statement: *"ATM surveys at present do not capture fish in the upper water column, nor a large biomass of young fish (sizes 3 inches and up) that fishermen have observed in nearshore waters since late 2014; this biomass is largely inside ATM survey tracks. But the ATM survey is assigned a catchability quotient (Q) of 1 nonetheless, meaning it "sees" all the fish. The Q for Model ALT, which is based largely on ATM survey data, is estimated at 1.1, which the STAR Panel report calls into question, given for example the unquantified volume of fish in nearshore waters.*

The summer 2016 ATM survey reported a fourfold increase in age 1+ biomass, but the biomass estimate produced is substantially lower than the estimate used for management in 2016. The STAR panel found fault with the methodology used to project the 2016 biomass to 2017. So do we – but using the 2016 ATM biomass estimate without adjusting for recruitment ignores reality."

A majority of the CPSAS also express concern that stock assessments seem to be gravitating to only one independent index, ATM surveys, which measure only one point in time. In our view this is a big problem, based on the following:

- The current trawl speed (4 knots or less) likely results in under sampling larger sardines.
- The nearshore area (where young sardines are often concentrated) is not sampled.

- ATM surveys have not been able to estimate recruitment.
- Q is assumed to be 1 – and in Model ALT, Q freely estimated is 1.1, which the STAR panel questioned. Clearly, current ATM surveys do not "see" all the fish, and thus biomass estimates must be considered to be negatively biased.
- In fact, the projected biomass estimate for 2017 is lower than 2016 at a time that sardines are increasing in abundance, apparently coast-wide, but certainly in California. The STAR Panel Report attributed the reduction in biomass to a change in assessment methodology.

Nevertheless, this assessment is a recipe for disaster, and the impact is being felt coastwide. Fishermen are having a hard time finding schools of CPS with a mix of less than 40 percent sardines.

The majority of the CPSAS ask the Council to consider the following recommendations:

- Assessments should be based on more than one survey index. The 2015 and 2016 juvenile rockfish surveys were informative as evidence of recruitment and should be considered in future stock assessments.
- Please support cooperative research with industry to survey nearshore waters now missed in National Oceanic and Atmospheric Administration acoustic surveys.
- The Terms of Reference (TOR) for stock assessments should be revised to provide more flexibility, particularly in update years, to incorporate new findings and data into assessments that more accurately reflect ocean conditions. The TOR should also provide for a process to reopen a fishery based on new lines of evidence as soon as possible, rather than the current requirement to wait for the next full assessment. Without flexibility to adaptively manage dynamic CPS stocks, industry is forced to sit idle for the better part of one or two years, or even more –which may be beyond its economic tipping point.

Management Measures

The majority of the CPSAS recommends continuing the management measures approved by the Council in 2016, including:
Annual Catch Limit (ACL) 8,000 mt
Automatic in-season actions:

- An incidental per landing allowance of 40 percent Pacific sardine in non-Treaty CPS fisheries until a total of 2,000 mt of Pacific sardine are landed.
- When the 2,000 mt is achieved, the incidental per landing allowance would be reduced to 20 percent, until a total of 5,000 mt of Pacific sardine have been landed.
- When 5,000 mt have been landed, the incidental per landing allowance would be reduced to 10 percent for the remainder of the 2017-2018 fishing year.

In addition, the Council should adopt a 2 mt incidental per landing allowance in non-CPS fisheries.

Conservation representative statement:

The conservation representative of the CPSAS recommends setting incidental catch for Pacific sardine at a precautionary level that both protects the spawning stock while not unduly constraining other fisheries, including other CPS fisheries. Of an 8,000 mt ACL for the current season, approximately 1,000 mt in sardine landings have been recorded so far, suggesting that the current ACL on its own is not having a constraining effect on other fisheries. Given that the July 2017 projected biomass for Pacific sardine is lower than the estimated biomass from the past two years, and the overfishing limit and acceptable biological catch for the coming season will necessarily be reduced from the 2016-2017 specifications, the Council could consider and adopt an ACL for 2017-2018 that is commensurately reduced from last year's ACL. The conservation representative suggests that a high level of precaution is appropriate in setting incidental catch, given Pacific sardine's continued low abundance and its essential role as forage in the California Current Ecosystem. Finally, the conservation representative echoes the majority of the CPSAS's support for cooperative research to improve the capacity of acoustic surveys to survey inshore waters.

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Decision Summary Document
Pacific Fishery Management Council

April 7-11, 2017

Council Meeting Decision Summary Documents are highlights of significant decisions made at Council meetings. Results of agenda items that do not reach a level of highlight significance are typically not described in the Decision Summary Document. For a more detailed account of Council meeting discussions, see the Council meeting record and voting logs or the Council newsletter.

Habitat

Current Habitat Issues

The Council directed staff to communicate with the Federal Energy Regulatory Commission and California Department of Water Resources to express Council concerns about thermal regulation at Oroville Dam, to ask for clarity on specific issues related to those concerns, and to invite representatives of the two agencies to present to the Council and/or Habitat Committee (HC) in June. The Council directed staff to work with California Department of Fish and Wildlife staff to identify those specific concerns. The Council may send a follow-up letter in the future.

In addition, the Council directed staff to send the HC's letter to the U.S. Army Corps of Engineers on the Permit Renewal and Expansion on the Coast Seafoods project with edits outlined in the Supplemental California Dept. of Fish and Wildlife Report and further edited by the Council.

The Council also requested both an update from the HC and a draft letter commenting on the Environmental Protection Agency's National Pollution Discharge Elimination System general permit for the June Briefing Book.

Salmon Management

Sacramento River Winter Chinook Harvest Control Rule

The Council reviewed the progress of the ad hoc Sacramento River Winter Chinook Workgroup since their last report in September 2016. The Council provided feedback on the initial analysis and is tentatively scheduled to provide preliminary recommendations for control rules at the September 2017 Council meeting and final recommendations at the November 2017 Council meeting.

Methodology Review Preliminary Topic Review

The Council supported the list of items for review submitted by the Scientific and Statistical Committee (SSC) and the Model Evaluation Workgroup (MEW) that included: 1) Complete the documentation of the development of the new Chinook Fishery Regulation Assessment Model (FRAM) base period including algorithms, and 2) review and update the FRAM documentation and User Manual that is currently on the Council website.

The Council is scheduled to adopt the final list of topics at the September Council meeting and any final methodology changes/updates at the November Council meeting.

Final Action on 2017 Salmon Management Measures

The Council adopted management measures for 2017 ocean salmon fisheries. Detailed management measures and a press release are posted on the Council's webpage.

Groundfish Management

Final Action on Electronic Monitoring of Non-whiting Midwater and Bottom Trawl Fisheries Regulations and Update on Exempted Fishing Permit (EFP)

The Council received an update on ongoing EFPs and modified several of the preferred alternatives they had adopted in September 2014 for the non-whiting midwater trawl and bottom trawl fisheries. A complete list of final alternatives is available on the Council website. The Council also directed:

- NMFS, in consultation to the Council, to develop a process that does not require rulemaking to adjust the discard species list;
- NMFS to maintain the current practice of having Pacific States Marine Fisheries Commission (PSMFC) perform video review responsibilities, but develop protocols for transferring financial responsibility for the video review from NMFS to the industry. The Council would like NMFS to examine the feasibility of using a sole provider (PSMFC) model indefinitely;
- NMFS and Council staff work with the Groundfish Electronic Monitoring Policy Advisory Committee/Technical Advisory Committee, Groundfish Management Team (GMT), and other appropriate Council advisory bodies to develop a process for reducing the level of video review to the minimum level necessary to audit logbooks, and to develop new discard mortality rates for halibut when vessels use electronic monitoring (EM); and
- Revisions to the draft regulations to include:

    1. Changes in the final preferred alternatives adopted by the Council;

    2. A requirement for self-enforcing agreement groups to submit an annual report to the Council;

    3. Deep-sea sole, sanddabs, and starry flounder in the list of species that can be discarded. Deep-sea sole and sanddabs would be counted as individual fishing quota (IFQ) species, if mixed with IFQ species; and

4. A provision to allow state-managed species to be landed when using EM, but prohibit sale or use of those fish, and include a landing limit of 150 pounds for California halibut.

Salmon Endangered Species Act (ESA) Consultation Recommendations

The Council provided guidance to NMFS on the proposed action that will be the basis for ESA section 7 consultation on the take of listed salmonids in the Pacific Coast groundfish fishery. The recommendations include:

- A description of groundfish fisheries including the likely future distribution of fishing, range of directed catch volumes, and range of Chinook salmon bycatch rates, which can be used to estimate amount and stock composition of Chinook take.
- Chinook salmon bycatch thresholds of 11,000 for the whiting fishery, 5,500 for all other groundfish fisheries, and a 3,500 reserve to be used for additional bycatch in either of the two fisheries. The sum of these three thresholds, 20,000 Chinook, equals the sum of the bycatch thresholds specified in the current biological opinion.
- Considering additional bycatch mitigation measures as part of the 2019-2020 biennial harvest specifications and management measures process.

NMFS intends to request Council recommendations on a draft incidental take statement at the September 2017 meeting, prior to completing the biological opinion.

Trawl Catch Shares and Intersector Allocation Progress Reports and Cost Recovery Report

Catch Share Program Review: Review document will be made available as early as possible to facilitate public review.

Intersector Allocation Review: The Council identified issues requiring additional information and proposed a process involving a public review draft adopted at the June Council meeting and final action taken in the fall. The Council directed that the next draft of the intersector allocation review document:

- address the recommendations in the GMT report and the GAP report;
- include approaches for addressing the sablefish management line and related allocation issues;
- focus on set-asides in the non-trawl sectors for a select number of the species identified as trawl-dominant (i.e., darkblotched rockfish, Pacific ocean perch, petrale sole, and longspine thornyhead north of 40° 10' N. latitude);
- evaluate species that may be constraining the non-trawl fishery while not being fully attained in the trawl fishery (e.g., lingcod south of 40° 10' N. latitude); and,
- discontinue development of the yellowtail rockfish cap issue.

Cost Recovery: Council and NMFS staff will meet to discuss ways to address transparency concerns such as those raised by the GAP report.

Groundfish Non-Salmon Endangered Species Workgroup Report

The Groundfish Endangered Species Workgroup (Workgroup) reports to the Council biennially on estimated bycatch of Endangered Species Act- (ESA) listed marine mammals, sea turtles, eulachon, green sturgeon, and seabirds subject to a 2013 biological opinion on the continued operation of the Pacific Coast groundfish fishery. The Workgroup found that recent take of subject species did not warrant consideration of additional mitigation measures by the Council. The Workgroup noted that new biological opinions will be completed in 2017 for eulachon and short-tailed albatross. Based on the Workgroup Report, the Council made the following recommendations:

- Conduct a risk analysis of humpback whale takes in the groundfish fixed gear fishery and work with the fleet to reduce the risk of such takes;
- GMT work with NMFS to better estimate eulachon take in the groundfish fishery;
- Complete the new seabird biological opinion and report to the Council at the June or September 2017 meeting to allow development of additional mitigation measures, as appropriate, through the 2019-2020 groundfish biennial harvest specifications and management measures process; and,
- Facilitate greater engagement by industry representatives in future Workgroup meetings.

Final Action on Inseason Adjustments

The Council recommended increasing the open access fixed gear trip limits for sablefish north of 36° N. latitude limits to 300 pounds per day, or one landing per week of up to 1,000 pounds, not to exceed 2,000 pounds per two months because effort and landings are tracking behind recent years.

Klamath Chinook salmon, a bycatch species in the groundfish trawl fisheries, will not meet escapement goals for 2017 by a historically large margin. The Council recommended the whiting fleet voluntarily move north to avoid Chinook salmon, recognizing there could be increased interactions with Pacific ocean perch (POP), especially given the historically high whiting quotas. Therefore, the Council also recommended that NMFS reallocate 3.5 mt of POP from the incidental open access off-the-top deduction to the mothership sector and 3.5 mt to the catcher-processor sector as soon as possible.

The Council also directed the GMT to develop alternatives for potentially distributing the POP, darkblotched, and canary rockfish buffers later in the year and report back at the June Council meeting in Spokane, Washington.

Updated Coordinates for the 125 Fathom (fm) Rockfish Conservation Area Line in California

The Council adopted revised coordinates for the 125 fm line at Usal and Noyo canyons in California for public review, as shown in Table 1 of the CDFW Report. These modifications are intended to provide access to canyons that were previously open when the 150 fm line was in effect (2003-2016). The Council is scheduled to take final action on the updated coordinates at the June 2017 Council meeting. The modifications for Delgada, Point Ano Nuevo, Cordell Banks contained in the CDFW Report and any other proposed modifications will be forwarded for consideration in the 2019-2020 harvest specifications and management measures process at the September 2017 Council meeting.

Sablefish Electronic Ticket Reporting Requirements

The Council directed its Enforcement Consultants and Groundfish Advisory Subpanel to meet together at the June Council meeting, discuss non-regulatory possibilities for resolving concerns about the 24-hour reporting requirement associated with electronic fish tickets, and report to the Council.

Coastal Pelagic Species Management

Central Subpopulation of Northern Anchovy (CSNA) Overfishing Limit (OFL) Process

The SSC will further review methods for developing an OFL for the central subpopulation of northern anchovy, evaluate the results of the January 2018 acoustic-trawl survey methodology review as it could apply to anchovy biomass and F_{msy} estimates, and report to the Council in April 2018.

Methodology Review Planning

The Council approved a proposed methodology review of the SWFSC's acoustic-trawl survey, tentatively scheduled for January 2018, and directed that the review address recommendations included in the SSC report. The Council will consider a proposed Terms of Reference for the review at its September 2017 meeting.

Small-Scale Fishery Management Final Action

The Council adopted Coastal Pelagic Species (CPS) Fishery Management Plan Amendment 26 allowing for small-scale directed fishing on CPS finfish stocks that are otherwise closed to directed fishing. The amendment will allow for landings up to one metric ton per day, with a limit of one trip per day. The Coastal Pelagic Species Management Team will provide an update on the small-scale fishery at its April 2018 meeting.

Final Action on Sardine Assessment, Specifications, and Management Measures

The Council adopted the 2017 sardine stock assessment report and the following harvest specifications and management measures, as described in the Supplemental CPSMT Report:

Biomass	**86,586 mt**
OFL	**16,957 mt**
P* buffer	**0.4**
$ABC_{0.4}$	**15,479 mt**
ACL	**8,000 mt**

They adopted the following automatic inseason actions for CPS fisheries:

- An incidental per-landing allowance of 40 percent Pacific sardine in non-treaty CPS fisheries until a total of 2,000 mt of Pacific sardine are landed.
- When the 2,000 mt is achieved, the incidental per-landing allowance would be reduced to 20 percent until a total of 5,000 mt of Pacific sardine have been landed.
- When 5,000 mt have been landed, the incidental per-landing allowance would be reduced to 10 percent for the remainder of the 2017-2018 fishing year.

The Council also adopted a 2 mt incidental per-landing allowance in non-CPS fisheries, and acknowledged a letter from the Quinault Indian Nation stating their intent to harvest up to 800 mt of sardine. Tribal landings would be accounted for within the ACL.

Pacific Halibut Management

Final Incidental Landing Restrictions for the 2017-2018 Salmon Troll Fishery

The Council adopted final incidental landing restrictions May 1, 2017 through December 31, 2017 and April 1-30, 2018 as follows: license holders may land no more than one Pacific halibut per two Chinook, except one Pacific halibut may be landed without meeting the ratio requirement, and no more than 35 halibut landed per trip. Limits may be modified by inseason action.

Administrative Matters

Legislative Matters

The Council approved the requested letter to Rep. Jaime Herrera-Beutler commenting on H.R. 200, the Strengthening Fishing Communities and Increasing Flexibility in Fisheries Management Act (a Magnuson-Stevens Act reauthorization bill) with minor edits.

Membership Appointments and Council Operating Procedures

The Council adopted revisions to Council Operating Procedure (COP) 1 regarding the submission of supplemental written public comments at Council meetings and COP 20 regarding the deadline for submission of exempted fishing permits for Highly Migratory Species.

Additionally, the Council is currently soliciting nominations for a vacant California seat on the Ecosystem Advisory Subpanel. The deadline for submitting nominations is May 11, 2017. See the Council web page for further information.

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