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PROCEEDINGS OF THE 2017 TRINATIONAL SARDINE & SMALL PELAGICS FORUM

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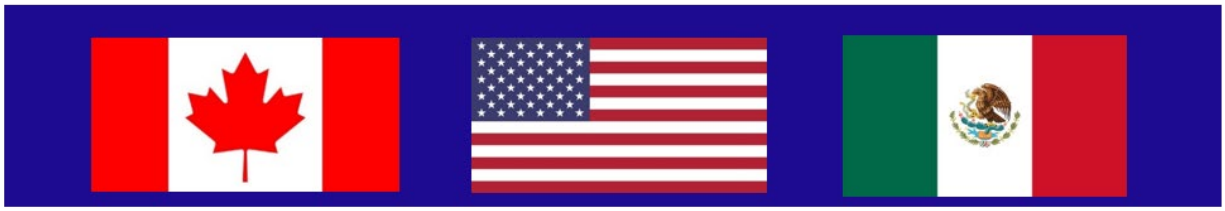

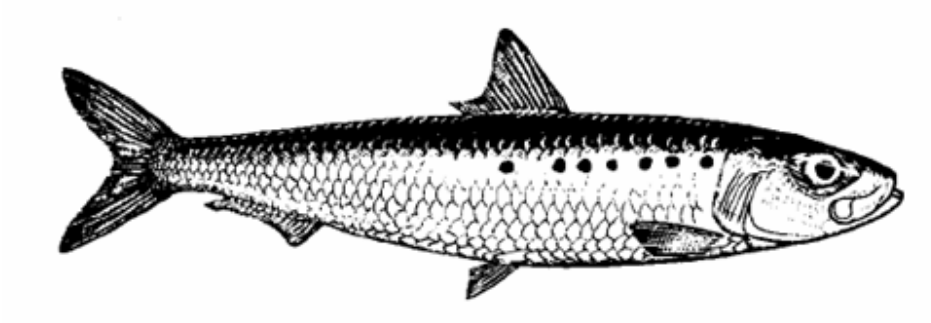

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CALIFORNIA WETFISH PRODUCERS ASSOCIATION

2017 Trinational Sardine and Small Pelagics Forum Participants

Trinational Sardine and Small Pelagics Forum Website

Mission Statement
It is the mission of the Trinational Sardine and Small Pelagics Forum to collaborate in improving coast-wide stock assessment: sampling for age, size composition, reproductive state, regional biomass estimates, stock structure, development of a common data base, following industry trends and issues and understanding of the role of sardine in the ecosystem.

Background
The past few years have been especially remarkable, with the obvious change in ocean conditions and the continued presence of the "warm blob." These changes have shown how the ocean is affected by prolonged warm conditions, and how the dynamics of species within it are changed as a result. Small pelagics are especially responsive to warm conditions, most notably within their placement (north, south, inshore, offshore). Information and research on sardine and other CPS stocks are sorely needed in order to provide an accurate coast-wide assessment for proper management in the upcoming years. It is the mission of the Trinational Sardine and Small Pelagics Forum to encourage collaboration between Canada, Mexico, and the United States in improving coast-wide stock assessments: sampling for age, size composition, reproductive state, regional biomass estimates, stock structure, development of a common data base, following industry trends and issues and understanding of the role of sardine and other small pelagics in the ecosystem.

Since its beginning in 2000, the annual Trinational Sardine and Small Pelagics Forum (TSF) has rotated among Mexico, Canada, and the United States, and comprised a wide range of participants from government, academia, and industry. Government partners include the Canadian Department of Fisheries and Oceans (DFO) and the Mexican government Instituto Nacional de Pesca (INAPESCA).

Agencies
Canadian Department of Fisheries and Oceans (DFO), Instituto Nacional de Pesca (INAPESCA), NOAA Southwest Fisheries Science Center (SWFSC), NOAA Northwest Fisheries Science Center (NWFSC), NOAA West Coast Region (WCRO), Pacific Fishery Management Council (PFMC), California Department of Fish and Wildlife (CDFW), Sportfishing Association of California, Camara Nacional de la Industria Pesquera delegacion Sonora.

Academic Institutions
Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Centro Interdisciplinario de Ciencias Marinas (CICIMAR), Coastal Pelagic Species Advisory Subpanel

Industry Organizations
California Wetfish Producers Association (CWPA), Pacific Seafood, Trimarine Group, Baja Mexico International, Oceano Industrial SAPI de CV, The Pew Charitable Trusts

Tribal Organizations
Quinault Indian Nation

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INTRODUCTION

The Southwest Fisheries Science Center (SWFSC) held the 18th Annual Trinational Sardine and Small Pelagics Forum (TSF) on December 7 and 8, 2017, in the Pacific Room at the Southwest Fisheries Science Center, in La Jolla, CA. Forty-eight participants from Canada, Mexico, and the United States attended and represented government agencies, academia, and industry (Appendix I). California Wetfish Producers Association aided greatly in logistical planning and sponsored the 2017 TSF reception.

Dr. Toby Garfield, interim Center Director for SWFSC, welcomed everyone and delivered the opening remarks. He thanked everyone for his or her attendance, especially those who traveled a great distance.

Following the opening remarks, representatives from Mexico and the United States presented current data, aging methods, and industry information during the Regional Fisheries Reports. Kerry Griffin (PFMC) presented the 2017 Pacific Fisheries Management Council Report, and Paul Crone presented the Assessment of the Pacific Sardine Resource in 2017 for U.S.A Management 2017-18.

Day two of the forum included a long discussion on research plans and reports for Mexico and the United States. Noteable new research included efforts to induce sardine (*sardinops sagax*) spawning in captivity. Other topics of discussion included the 2017 coast-wide surveys, experimental fishing permits, current fisheries closures and their effect on the industry, and future research of stock structure (e.g. genetics, microchemistry, traditional approaches, etc.).

The Trinational Sardine and Small Pelagics Forum concluded with plans for the 2018 forum to be held in La Paz, Mexico, from December 12-16.

PLENARY SESSION HIGHLIGHTS

2017 Northwest Coastal Pelagic Species Fisheries Report

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Pacific Sardine

Directed landings were approved for the Quinault Indian Nation. However, directed fishery are still closed for non-tribal fisheries since first mandated in July 2015. Non-tribal Washington fisheries have limited entry and require logbooks, non-tribal Oregon requires similarly but bycatch reduction measures are also required. Incidental lands for both state fisheries are only through other CPS gears.

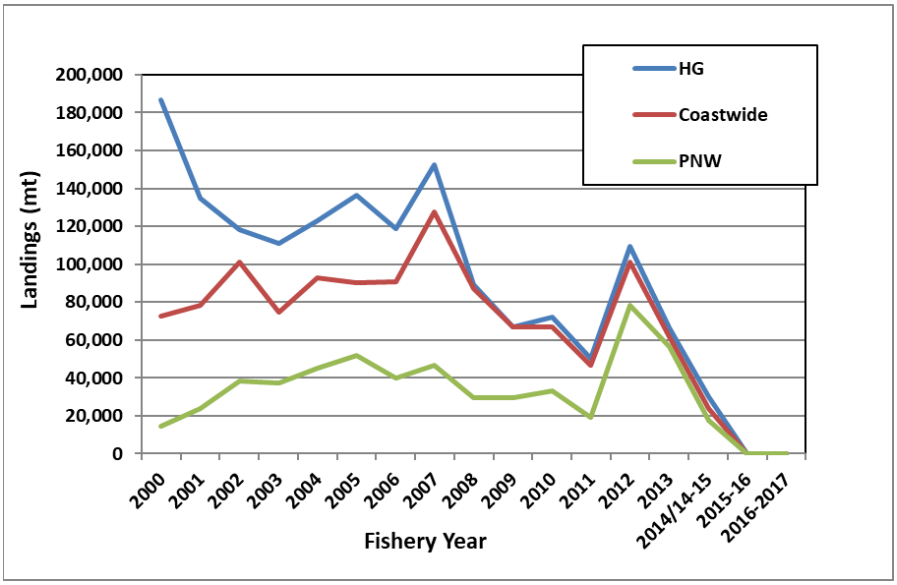

Figure 1. Sardine Landings (mt)

Pacific Mackerel

The Quinault Indian National does not have directed fishing activity for Pacific mackerel at this time. In Washington, a new open access directed opportunity for Pacific mackerel was established in 2016, however there have been no participants in the fishery nor landings to date. Targeting Pacific mackerel is likely not economically advantageous unless it is in conjunction with the sardine fishery, which is not present at the moment. Similarly, Oregon has had an open access Pacific mackerel fishery but has not had any directed landings in 2017.

Northern Anchovy

The Quinault Indian Nation began fishing for anchovy through directed fishing. Currently fishing is being done by only one vessel. Washington directed CPS activity has been limited to anchovy fishing. Open access includes both purse seine and Lampara. Anchovy are used as bait for the albacore tuna fisheries and sport bottomfishing. This is currently the only CPS fishery authorized in state waters, though incidental landings of other CPS are allowed. Oregon saw no directed CPS fishing activity in 2017. Adopted anchovy possession and landing limits for in river .fishing on the Columbia River to match Washington: 5 mt tons daily – 10 mt weekly.

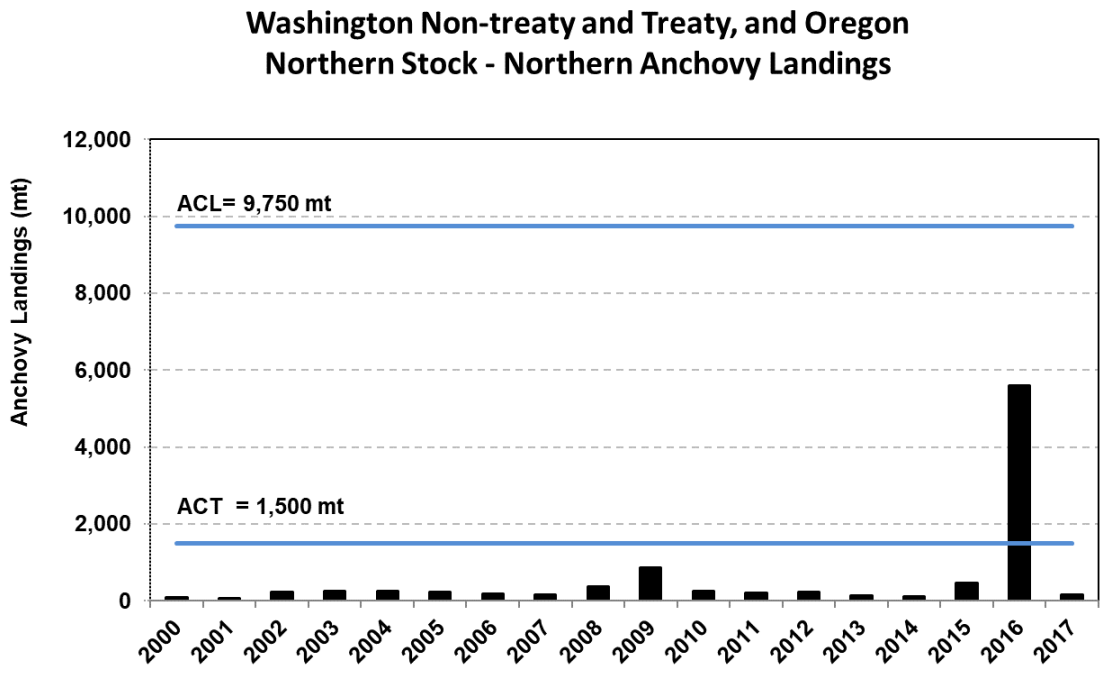

Figure 2. Northern Anchovy Landings (mt)

Market Squid

There is currently no fishing activity for market squid for the Quinault Indian Nation. Washington requires a special director-issued permit for fishing market squid, however, no permits were requested. Oregon has open access and logbooks are required. Market squid is fished at Cape Perpetua on the central coast and is for both bait and human consumption. Fishing activity often presents as an occasional burst, especially following a strong El Niño.

2017 California Sardine Fishery Report

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Coastal pelagic finfish species, including Pacific Sardine (*Sardinops sagax*), Northern Anchovy *(Engraulis mordax*), Pacific Mackerel (*Scomber japonicus*), and Jack Mackerel (*Trachurus symmetricus*) are managed by the Pacific Fishery Management Council. In 2016, the Pacific Sardine stock assessment produced a biomass estimate below the "cutoff" threshold value of 150,000 metric tons (mt) in the Harvest Guideline control rule. As a result, there was no directed non-tribal commercial fishery for the 2016/17 sardine fishing year, which runs July 1 through June 30. The National Marine Fisheries Service implemented an annual catch limit of 8,000 mt, with Pacific Sardine take allowed only as incidental catch in other fisheries, or as part of the tribal, live bait or recreational fisheries. For the 2016/2017 fishing season, incidental California landings for Pacific Sardine totaled approximately 514 mt. There were slightly higher landings within the southern fishery, making up 52 percent of the state total. Forty vessels in the federal limited entry permit fishery made Pacific Sardine landings into California ports. Also during the 2016/2017 fishing season, 2,342 mt of Pacific Mackerel were landed. During 2016, 8,369 mt of Northern Anchovy and 207 mt of Jack Mackerel were landed in California.

Market Squid

Fisheries saw an increase in market squid beginning in 2010, but in 2015 the standing dropped back down to the initial average.

Northern Anchovy

Northern Anchovy landings level is currently placed at 25,000 metric tons. This year over 70% was landed in the north, where it is likely the fat content was more valuable than those caught in the southern fisheries.

Pacific Sardine

Pacific Sardine can live up to 13 years, but the commercial fishery most often catches them around age 5. The average length of commercially caught sardine increased from 2011 through 2014, but decreased again in 2015. Sample sizes have also seen a decrease in the past two years.

Pacific sardine is traditionally one of California's largest fisheries, with landings heavily influenced by markets. However, due to dramatically reduced biomass estimates in recent years, there hasn't been a directed fishery for over three seasons.

California Wetfish Producers association will be joining with an aerial team to survey waters in northern California for a study on the effectiveness of aerial surveys in the determination of stock biomass. A spotter plane will estimate the biomass of a spotted school and direct a vessel to it. The vessel will in turn wrap as much of the school as possible to compare observer estimates with the wrapped fish. This effort will hopefully position aerial surveys as a strong option in providing stock biomass data that is often uncounted in traditional survey methods.

2017 Canadian Sardine Fisheries

Discussion
No official report was presented as the sardine stock has been missing in Canadian waters for a number of years. While a fishery quote was given in 2012, not enough sardine were caught to fill it. There have been scattered reports of sardine in Canadian waters in the past few years, but none in 2017. Some bycatch from the trawl fishery were found with sardine in their stomach, but overall the sardine population is not present in Canada at this time. If history is any indication, it will be another 27-30 years before the population reestablishes.

The Small Pelagic Fishery In The Western Coast Off The Peninsula Of Baja California, Mexico, Fishing Season 2016.

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We analyzed important aspects of the small pelagic fishery in both Baja California (BC) and Baja California Sur (BCS) off western coast of the Baja California Peninsula during fishing season 2016. The total catch of small pelagic fish was recorded in 123,943 t (72,016 t for BC and 51,926 t for BCS), 11.2% lower than the historical average of 2000-2015 (139,650 t annually). Of the total catch: 78,990 t was recorded as Pacific sardine (64%), 25,660 t of thread herring (21%), 12,877 t of mackerel (10%), 4,250 t of anchovy (3%) and 2,055 t of Japanese sardine (2%). The highest catches were registered mainly between the months of April to November with an average of 14,656 t / month. The fishing effort was 2,291 fishing trips for the all season with 37 vessels (27 for BC and 10 for BCS). The average yield was 54.1 t / trip, which was 19% lower than reported for the period 2003-2015. The average size recorded was 152.6 mm LP, where 43.5% of the total catches for Pacific sardines were below the legal minimum size (150 mm LP). The fleet operated mainly in the vicinity of Bahía Vizcaino, the central part of the western coast of the peninsula of Baja California.

*Presentation totals were updated to 67,034 for BC and 71,494 for BCS, for a total of 138,528. This was a 12% average increase from 2016 to 2017.

Resumen
Se analizan aspectos importantes de la pesquería de pelágicos menores en los estados de Baja California (BC) y Baja California Sur (BCS), de la costa occidental de la península de Baja California durante la temporada de pesca de 2016. La captura total de pelágicos menores fue de 123,943 t (72,016 t para BC y 51,926 t para BCS), fue 11.2% menor al promedio histórico de 2000-2015 (139,650 t anuales). El 64%, (78,990 t), fue de sardina monterrey; el 21%, (25,660 t), sardina crinuda; el 10%, (12,877 t), de macarela; El 3%, 4,250 t de anchoveta; y el 2%, 2,055 t de sardina japonesa. Las mayores capturas se registraron principalmente entre los meses de abril a noviembre con un promedio de 14,656 t/mes. El esfuerzo pesquero registrado para el total de la temporada fue de 2,291 viajes de pesca realizados con 37 embarcaciones (27 para BC y 10 para BCS). El rendimiento promedio estimado fue de 54.1 t/viaje, lo cual fue 19% inferior a lo registrado para el período 2003-2015. La talla promedio registrada fue de 152.6 mm LP, donde el 43.5% de la captura total de sardina monterrey estuvo por debajo de la talla mínima legal (150 mm LP). La flota operó principalmente en las inmediaciones de Bahía Vizcaíno, en la parte central del litoral occidental de la península de Baja California. Palabras clave: Baja California, Pelágicos menores, Captura, esfuerzo, rendimiento, tallas.

Discussion
The vast majority of what was caught from Ensenada to the border this year was anchovy, there hasn't been any sardine caught north of Ensenada at this time. While the fisheries catch throughout the year, there tends to be less catch from February through April. This is when sardine adults migrate offshore during this time, and there is less northern stock to be caught. The larger landings are typically when the southern stock comes northward from July through November. However, even during this period, the southern stocks seemed to stay south of Ensenada this past year. The majority of the sardine that were caught measured about 16 cm. It was mentioned that this seems uncommonly small, but it was clarified that over the past few years there hasn't been much over 18 cm.

There was a 12% average increase in catch from 2016 to 2017. This was likely due to a change in fishing styles. Since the vessels had to go further south, they extended the length of their trips, sometimes staying for two nights instead of just one. The longer trips meant more hours fishing and ultimately provided a more productive trip overall.

2017 PACIFIC FISHERY MANAGEMENT COUNCIL REPORT

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The Pacific Fishery Management Council (Council) has considered several CPS-related activities this year, including a CPS small scale Fishery Management Plan amendment, consideration of new stock survey methodologies, and consideration of process changes for adopting harvest limits for stocks in the Monitored category.

Sardine Fishery Management Measures
The 2017 April meeting set specifications and management measures for the period of July 2017 through June 2018. The biomass estimate fell well below the 150k metric ton requirement at an estimate of 86,586 metric tons, so the sardine fishery was closed again. Incidental landings were limited to 40% sardine up to 5k metric tons, whereupon it was decreased by 20% and then 10%. An incidental allowance of 2k metric tons was approved for non-CPS fisheries, as was a small incidental also allowed for the Quinalt tribe.

CPS FMS Amendment 16
The Council was also set to make an amendment for small scale sardine fisheries who target sardine in small quantities for niche markets. These fisheries were initially shut down at the time of the main closure of the sardine fishery. CPS FMS Amendment 16 would allow fishing with seine nets with the stipulation that the total caught would be less than one ton a day, and only one vessel trip a day. At the time of this meeting the final approval had not yet been secured, but it was believed that it would be approved by early 2018.

CDFW Aerial Survey Methodology Review
Council approved the CDFW aerial survey methodology for potential use in stock assessments, with conditions (recruitment index, estimate of variance).

Pacific Mackerel Harvest Specifications
Pacific mackerel harvest specifications are set every two years. Earlier this year the council determined specific specifications for July 2017-June 2018 and July 2018-June 2019 of ACTs (Annual Catch Targets) of 25,293 mt and 22,840 mt, respectively.

Northern Anchovy
The Council will meet in April 2018 to review Northern anchovy status, assessment, and process for reviewing reference points. They will also discuss the annual catch limit and assessment review. In the past few years anchovy numbers have increased significantly and it is becoming a much more prominent point of discussion. Current annual catch limits are based on old assessments, and new assessments are needed but due to a lack in research in recent years the stock is data poor. Work is needed to grow this database and produce a new assessment.

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2017 FOR U.S.A. MANAGEMENT IN 2017-18

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Full report

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). Finally, the applicability of the assessment approach adopted here for ongoing management of the Pacific sardine stock is generally discussed in the context of other species that comprise the coastal pelagic species assemblage, such as Pacific mackerel and northern anchovy.

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:

Table 1. 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	BV
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.

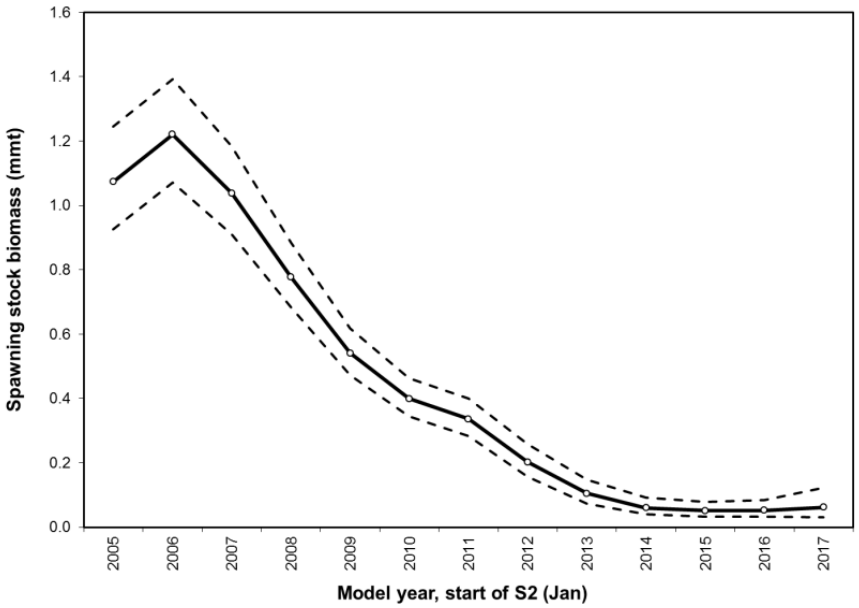


Figure 1. Spawning stock biomass time series (±95% CI) for model ALT

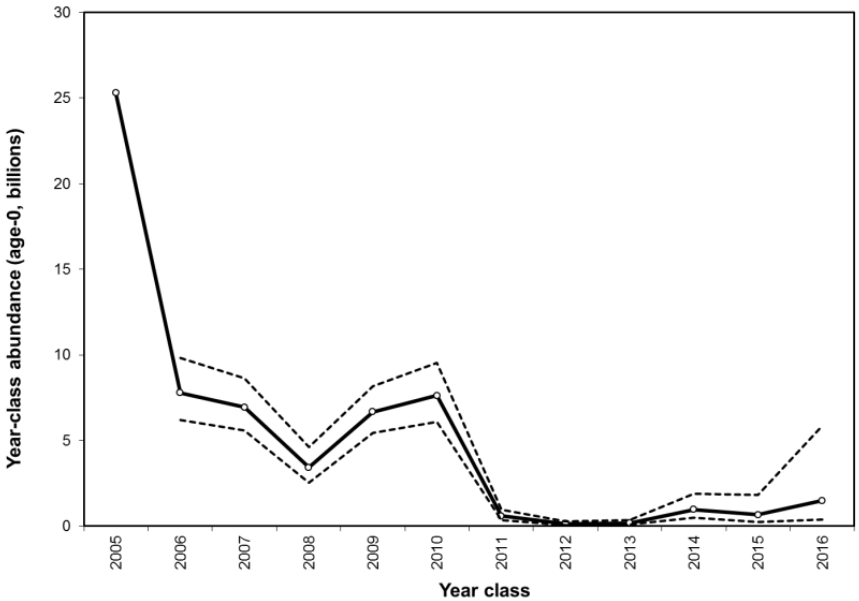


Figure 2. Recruit (age-0 fish, billions) abundance time series (±95% CI) for model ALT.

Table 2. 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).

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**.

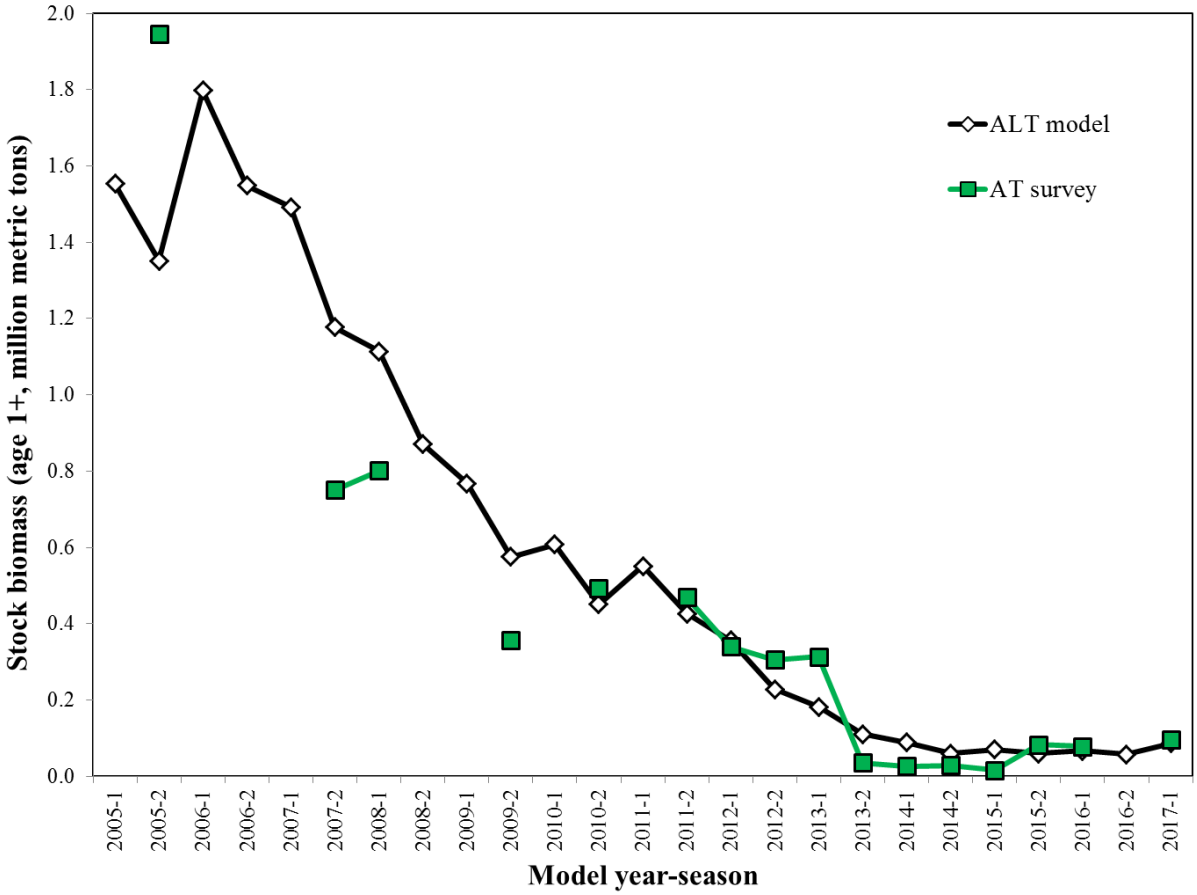
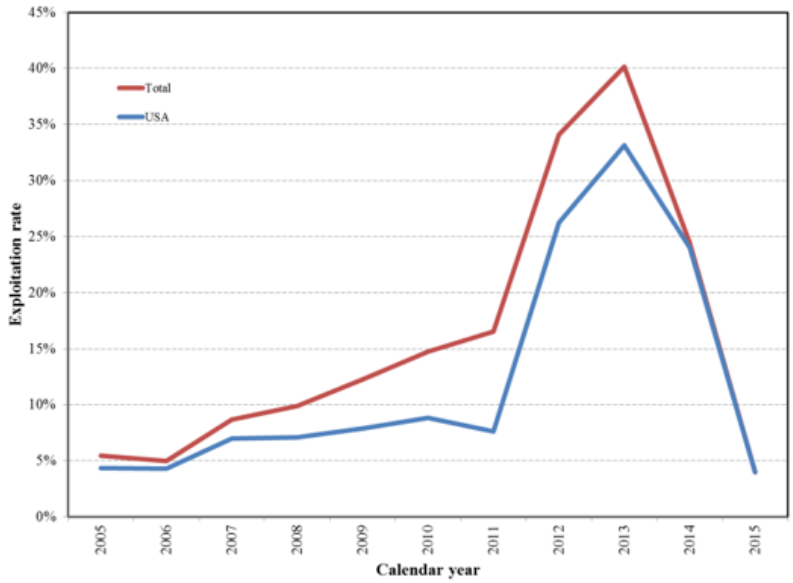


Figure 3. Estimated stock biomass (age 1+ fish, mt) time series for the AT survey and model ALT.

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%

Figure 4. Annual exploitation rate (CY landings / July total biomass) for model ALT.

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:

$$\text{HG} = (\text{BIOMASS} - \text{CUTOFF}) \bullet \text{FRACTION} \bullet \text{DISTRIBUTION};$$

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,

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

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 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**								

Figure 5. Harvest control rules for the model-based assessment (model ALT).

Management Performance

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

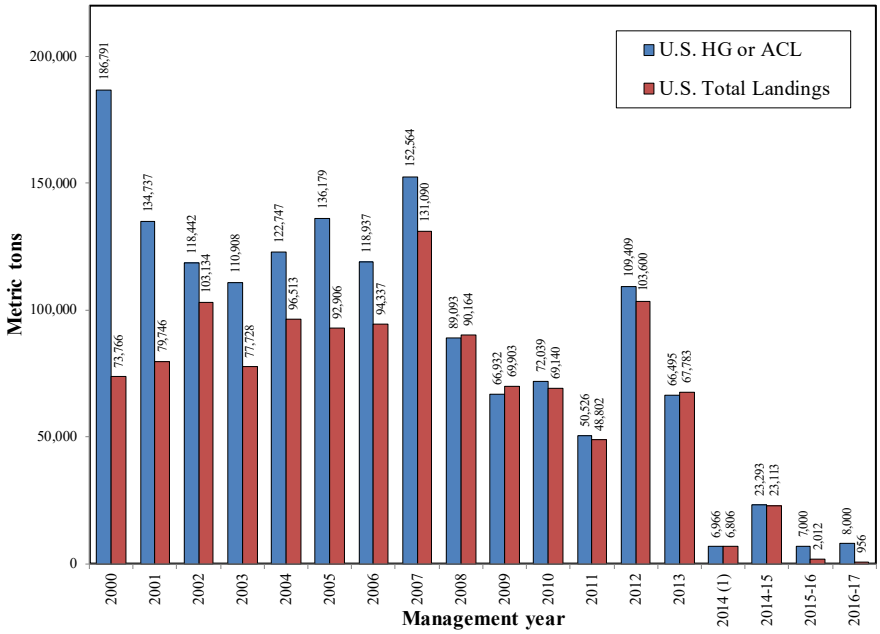


Figure 6. U.S. Pacific sardine harvest guidelines or acceptable catch limits and landings since the onset of federal management.

Unresolved Problems and Major Uncertainties

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.

RESEARCH DISCUSSION

Coast-wide Surveys

United States

Two sectors of the industry will be sponsoring surveys through the EFP. These surveys were reviewed in November and approved, and will be seeking final approval from the PFMC in April. The surveys will be conducted for two very different objectives.

The first survey is an extension of a previous survey taken place on the seine vessel Lisa Marie. The vessel was outfitted with an EK60 and went inshore for 5-6 days from Westport to Newport, OR. They have applied for an EFP and funding to carry out an additional 25 days. The proposal will include some seine sets to attempt to catch samples for species composition. This survey, based on an industry ship as opposed to a larger NOAA vessel, would allow the vessel to investigate near inshore where the NOAA vessel cannot go and make comparable track lines for data use later on. There is a possibility that this survey will follow in conjunction with the NOAA Summer 2018 CCES Cruise, though the additional of MMTD in the survey will likely requires that the vessel go further offshore and not allow for a nearshore collaboration.

The second survey is a 7-day collaborative research project with the California Department of Fish and Wildlife an the California Wetfish Producers Association in August to address issues with the aerial survey. The primary objective of this pilot project will be to validate aerial observer tonnage estimates and species identification for future use in biomass estimates. Validation will be completed using purse seines to catch and land schools spotted by the pilot. The survey plan will also include flying replicate transects into the survey design, using the transect pattern developed by the CDFW aerial survey plan. Validation of aerial observer sampling methods may lead to the development of estimating CPS biomass in near-shore waters inaccessible to NOAA ships.

Mexico

IMECOCAL has sufficient funding to do one cruise in 2018 for eight days. The survey will take place between July and September, depending on oceanographic conditions. Overall, the survey will study the effects of fronts on activity, but will also include some biological studies with bongo nets, temperature assessments, and salinity assessments as well. They have been working with D. Griffith to design an outboard CUFES system on the vessel.

INAPESCA plans to perform a sardine survey in August 2018. They have located a small boat outfitted with acoustic equipment off Baja California. The vessel will travel the Pacific coast of Baja California, coming in as close as 15 miles offshore, and will travel from Ensenada to Cabo San Lucas.

Stock Structure

The SWFSC FRD Genetic Program updated the group. While there is no ongoing genetic work on coastal pelagics at the moment, the group has been considering mining the genetic samples taken from the surveys over the years. Specifically, they would be looking at genome markers associated with local selection to identify stocks better than previous attempts, however, this is still the early planning stages.

Industry Trends and Issues

United States

The Pacific Fishery Management Council voted to keep the sardine fishery closed for the third year in a row in early April. Industry representatives discussed the effects of this closure, in particular that there is not much of a fleet remaining after the past few years. The Industry not only depends on what is present to catch, but also has to balance this with market demand. Squid catch has been decent in the years past it is never a given, and moreover the financial gain from this stock is not enough to offset the loss from restricted catch. Industry representatives estimated this would be yet another hard year for the fisheries.

Mexico

The 2016/2017 fishing season has been good, the best in several years for sardine. A lot of anchovy also showed up, though they have not yet been fished as a primary target. However, if sardine decline in the upcoming months, as they are apt to do, the Mexican fisheries will turn their sights towards anchovy. This is also the third year squid hasn't shown up, there are very few catches and they are significantly smaller.

Despite the increase in sardine catch, sardine pricing has been a bit off this year as China and Africa began supplying large quantities of the catch. This, combined with an increase in catch, has caused the price of Mexico's exported sardine to drop from previous years.

CONCLUSION

The two full-day Forum was well attended and provided many opportunities to share information across national lines. The Forum concluded with closing remarks from Dale Sweetnam (SWFSC) thanking everyone for making the time to attend.

The Trinational Sardine and Small Pelagics Forum concluded with plans for the 2018 forum to be held in La Paz, Mexico, from December 12-16.

Please visit https://swfsc.noaa.gov/tsf/ for more information.

ACRONYMS

CDFW	California Department of Fish and Wildlife
CIAD	Centro de Investigación en Alimentación y Desarrollo
CICESE	Centro de Investigación Científica y de Educación Superior de Ensenada
CICIMAR	Centro Interdisciplinario de Ciencias Marinas
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CRIP	Centro Regional de Investigación Pesquera
DFO	Department of Fisheries and Oceans, Canada
FACIMAR	Facultad de Ciencias del Mar
IMECOCAL	Investigaciones Mexicanas de la Corriente de California
INAPESCA	Instituto Nacional de la Pesca
IPN	Instituto Politécnico Nacional
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
OAI	Ocean Associates Inc. (Contractor to SWFSC)
ODFW	Oregon Department of Fish and Wildlife
PSC	Pacific Seafood Co
SAFS	School of Aquatic and Fishery Sciences, University of Washington
SIO	Scripps Institution of Oceanography, University of California San Diego
SWFSC	Southwest Fisheries Science Center, National Marine Fisheries Service
UABC	Universidad Autónoma de Baja California Instituto de Investigaciones Oceanológicas
WDFW	Washington Department of Fish and Wildlife

APPENDIX I: LIST OF PARTICIPANTS

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APPENDIX II: AGENDA

Thursday, December 7th

8:00	Registration/Check-in
9:00	Welcome and opening remarks. Dr. Toby Garfield, Interim Director, Southwest Fisheries Science Center
9:15	Meeting logistics. Dale Sweetnam, Southwest Fisheries Science Center
9:25	Regional Sardine Fisheries Reports
9:40	Northwest Coastal Pelagic Species Fisheries. Cyreis Schmitt (ODFW), Lorna Wargo WDFW), Alan Sarich (Quinault Nation), presented by Dale Sweetnam*(SWFSC)
9:55	California sardine and small pelagics fishery report. Kirk Lynn* and Dianna Porzio (CDFW)
10:15	***Break***
10:45	The small pelagic fishery in Baja California, fishing season 2016. Concepción Enciso-Enciso*, Lourdes Z. Brasil-Buitimea y Celia Eva Cotero-Altamirano (INAPESCA CRIP-Ensenada)
11:00	2017 Pacific Fishery Management Council Report/Update. Kerry Griffin* (PFMC)
11:15	Assessment of the Pacific Sardine Resource in 2015 for U.S.A. Management in 2017-18. Kevin T. Hill, Paul R. Crone*, and Juan P. Zwolinski (SWFSC)
12:00	***Lunch***
13:00	Contributed papers
	Recent observations on Pacific sardine and northern anchovy from Northwest Fisheries Science Center surveys. Kym Jacobson* (NWFSC), Ric Brodeur (NWFSC), Toby Auth (PSMFC), Elizabeth Daly (CIMEC) and Cheryl Morgan (CIMEC)
13:30	Spawning biomass estimates for the subarctic stock of the Pacific sardine (*Sardinops sagax*) off Baja California, Mexico, April, 2002, and April, 2003. Tim Baumgartner (CICESE) Augusto Valencia (UABC)
14:00	Environmental dependence of Pacific sardine recruitment – reexamining Zwolinski and Demer (2014). Juan P. Zwolinski (CIMEC) and David A. Demer (SWFSC)
14:30	***Adjourn***
15:00-17:00	***Offsite Reception: International Meet and Greet at Rock Bottom Brewery in the "Flat." Appetizers provided.***

Friday, December 8th

8:30	Evaluation of the reproductive state of Pacific sardine (*Sardinops sagax*) during experiments to induce spawning in captivity. Beverly J. Macewicz, E. Dorval, P. Appel, M. Human, W. Watson
9:00	Reproductive biology of Sardinops caeruleus from the Pacific coast of Baja California during 2016. Celia Eva Cotero-Altamirano*, Concepción Enciso-Enciso, Héctor Valles Ríos, Lourdes Brasil Buitumea (INAPESCA CRIP-Ensenada)
9:30	Why do Pacific sardine populations undergo booms and busts? We've got an answer! Barbara Javor (SWFSC)
10:00	Small scale spatial variability in the quality of market squid spawning habitats during the two fishing years preceding the 2016 El Niño. Emmanis Dorval (OAI), Joel van Noord (CWPA), Christian S. Reiss (SWFSC), and A.D. Christian (School of Environment, UMASS Boston).
10:30	***Break***
11:00	Research Plans, Experimental Fishing Permits, and Coast-wide Surveys
	Stock structure (genetics, microchemistry, traditional approaches, others)
	Fishery Closures
	Continued environmental effects of the Warm Blob and El Nino
	Industry needs
11:30	Working group (WG) Discussion Sessions
12:00	Closing Remarks (Decide on a 2018 meeting location)
12:30	***Adjourn*** and ***Lunch***

APPENDIX III: ORAL PRESENTATIONS

Recent observations on Pacific sardine and northern anchovy from Northwest Fisheries Science Center surveys.

Kym Jacobson[1], Ric Brodeur[1], Toby Auth[2], Elizabeth Daly[3] and Cheryl Morgan[3]

[1]Northwest Fisheries Science Center, NMFS/NOAA, Hatfield Marine Science Center, Newport, Oregon, USA
[2]Pacific States Marine Fisheries Commission, Hatfield Marine Science Center, Newport, Oregon, USA
[3]Cooperative Institute for Marine Resources Studies, Oregon State University, Hatfield Marine Science Center, Newport, Oregon, USA

Spawning biomass estimates for the subarctic stock of the Pacific sardine (Sardinops sagax) off Baja California, Mexico, April 2002 and April 2003

Tim Baumgartner[1] and Augusto Valencia[2]

[1]Departamento de Oceanografía , CICESE, Ensenada

[2]Instituto de Investigaciones Oceanológicas, UABC, Ensenada

Environmental dependence of Pacific sardine recruitment – reexamining Zwolinski and Demer (2014)

Juan P. Zwolinski[1] and David A. Demer[2]

[1]Institute of Marine Sciences, University of California Santa Cruz, Earth and Marine Sciences Building, Rm A317, Santa Cruz, CA 95064
[2]Fisheries Resource Division, Southwest Fisheries Science Center, NMFS-NOAA, 8901 La Jolla Shores Dr., La Jolla, CA 92037
Correspondence to J.P. Zwolinski: tel: 858-546-5654; fax: 858-546-5656; e-mail: jzwolins@ucsc.edu

Evaluation of the reproductive state of Pacific sardine (Sardinops sagax) during experiments to induce spawning in captivity

B.J. Macewicz[1], E. Dorval[2], P. Appel[2], M. Human[2], W. Watson[1],

[1]NOAA-NMFS-SWFSC Fisheries Resources Division
[2]Ocean Associates Inc. under contract with SWFSC

Reproductive biology of Sardinops caeruleus from the Pacific coast of Baja California during 2016.

Celia Eva Cotero-Altamirano*, Concepción Enciso-Enciso, Héctor Valles Ríos, Lourdes Brasil Buitumea. Instituto Nacional de Pesca (CRIP-Ensenada)

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Why do Pacific sardine populations undergo booms and busts? We've got an answer!

Barbara Javor,
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Small scale spatial variability in the quality of market squid spawning habitats during the two fishing years preceding the 2016 El Niño

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