Southwest Fisheries Science Center

NOAA FISHERIES - NATIONAL MARINE FISHERIES SERVICE - SOUTHWEST FISHERIES SCIENCE CENTER

SEPTEMBER 2021

PROCEEDINGS OF THE 2021 TRINATIONAL SARDINE & SMALL PELAGICS FORUM

La Jolla, California,
United States of America
January 11, 2021

edited by

Stephanie Flores

ADMINISTRATIVE REPORT LJ-21-03

Accessibility information

NOAA Fisheries Southwest Fisheries Science Center (SWFSC) is committed to making our publications and supporting electronic documents accessible to individuals of all abilities. The complexity of some of SWFSC's publications, information, data, and products may make access difficult for some. If you encounter material in this document that you cannot access or use, please contact us so that we may assist you.
Phone: 858-546-7000

SEPTEMBER 2021

PROCEEDINGS OF THE 2021 TRINATIONAL SARDINE & SMALL PELAGICS FORUM
La Jolla, California, United States of America
January 11, 2021

edited by

Stephanie Flores

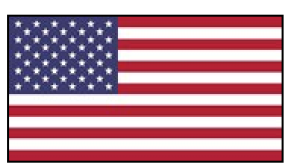
IBSS Corporation
Contracted by NOAA Fisheries
SWFSC Fisheries Resources Division
8901 La Jolla Shores Drive
La Jolla, CA 92037-1509

ADMINISTRATIVE REPORT LJ-21-03

(This page intentionally left blank)

PROCEEDINGS OF THE 21ST ANNUAL TRINATIONAL SARDINE & SMALL PELAGICS FORUM

JANUARY 11, 2021



Mission Statement
It is the mission of the Trinational Sardine and Small Pelagics Forum to collaborate on improving coast-wide science to support stock assessments: sampling for age, size composition, reproductive state, regional biomass estimates, stock structure, and development of a common data base, understanding industry trends and issues, and understanding of the role of small pelagics in the California Current Ecosystem.

Background
The COVID-19 pandemic in 2020 brought a previously-inconceivable level of change and caused long-term repercussions on a global scale. Among countless other bodies, this was also prevalent in fisheries science, management and industry. Travel restrictions deeply limited data gathering from 70+ year surveys and the loss of this year's data will have significant repercussions on the future of survey management. Scientists, management bodies, academics, and industry members were relegated to quarantine and labs and research were moved into the home. Despite these limitations, our members continued their work and research. Members joined the first virtual Trinational meeting to share their research from the past year and discuss the future of fisheries science and management moving forward.

The Trinational Sardine and Small Pelagics Forum encourages collaboration between federal and state agencies, academic institutions, industry, non-governmental organizations, and tribal organizations from Canada, Mexico, and the United States in improving coast-wide science to support stock assessments. Since its beginning in 2000, Mexico, Canada, and the United States have rotated hosting the annual forum.

Government entities
Canadian Department of Fisheries and Oceans (DFO), Instituto Nacional de Pesca (INAPESCA), NOAA Southwest Fisheries Science Center (SWFSC), NOAA West Coast Regional Office (WCRO), Pacific Fishery Management Council (PFMC), California Department of Fish and Wildlife (CDFW), Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife

Academic Institutions
Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Centro Interdisciplinario de Ciencias Marinas (CICIMAR), Scripps Institution of Oceanography (SIO), University of California, Santa Cruz (UCSC)

Industry Organizations and Non-Governmental Organizations
California Wetfish Producers Association (CWPA), Sportfishing Association of California (SAC), Pacific Seafood, Monterey Bay Aquarium, Cal Marine Fish Company, Ocean Gold Seafoods, Camara Nacional de la Industria Pesquera delegacion Sonora.

Tribal Organizations
Quinault Indian Nation

Table of Contents

Introduction

The Southwest Fisheries Science Center (SWFSC) hosted the 21st Annual Trinational Sardine and Small Pelagics Forum on Monday, January 11. The virtual platform this year broadened the Forum's reach and over 95 members from Canada, Mexico and the United States participated and represented government agencies, academia, and industry (Appendix I). Special thanks to Stephanie Flores and Laurie Barak (Fisheries Resources Division, FRD) for their aid in the logistical planning. We thank Dale Sweetnam for leading the Forum and Ravi Shiwmangal, Roszella Sanford, Juan Zwolinski, Owyn Snodgrass, Peter Kuriyama, Emily Gardner, and Kelsey James (FRD) for their help with the virtual logistics.

FRD Deputy Director, Dale Sweetnam, opened the meeting with greetings and well wishes. The past year has been particularly challenging and will have repercussions for years to come; however, a great deal of science still came about despite the limitations of government regulations and quarantine. Following the opening remarks, representatives from Canada, Mexico and the United States presented current quotas and landings, surveys, and industry information during the Regional Fisheries Reports. Pacific Fisheries Management Council (PFMC) member, Kerry Griffin, presented the Council Report and Peter Kuriyama (FRD) presented the Assessment of the Pacific Sardine Resource in 2020 for U.S.A. Management 2020-21. The second half of the day consisted of presentations on contributed papers.

Dale Sweetnam closed the forum with thanks to all who participated. The location and date of the fall 2021 Forum has yet to be determined

In Memory of Dr. John Hunter

Nancy Lo and Beverly Macewicz

We lost Dr. John Hunter on October 24, 2020, at age 86, after his sudden illness of dementia in his last three months. He was a great fisheries researcher and leader.

John Hunter, along with Tim Baumgartner, cofounded the Trinational Sardine Forum in 2000 to implement a coast-wide collection of data for sardine stock assessment and exchange information and keep abreast of trends in the fishery. He organized the first three Trinational Sardine Forums from 2000-2002 before his retirement in 2003.

John Hunter was the program leader of Coastal Eastern Pacific Population Biology of Fishes. He became the director of Fisheries Resources Division (FRD) after the passing of Rueben Lasker in 1988. With John Hunter's guidance, studies on egg and larvae development, health, and survival were successful as well as the spawning of some adult coastal pelagic species (CPS), such as northern anchovy (*Eugraulis mordax*) and Pacific sardine (*Sardinops sagax)*, and some bottom fish, such as Dover sole (*Solea solea*). He had great appreciation of statistical analyses applied to the spawning biomass estimates, like the daily egg production method, based on estimates of biological parameters of fish population, including growth, fecundity, mortality, and early life history.

Under his supervision, SWFSC conducted a coast-wide survey with Mexico in 1994. The coast-wide survey effort continued even after his retirement, with the 2006 survey with Canada and the 2008 survey along the west coast of the United States.

John Hunter will be greatly missed by all his colleagues and friends.

Regional Sardine Fisheries Reports

Information and Examples of Recent Fisheries and Oceans Canada Small Pelagic Fishes Science initiatives

Linnea Flostrand

Pacific Biological Station, DFO
3190 Hammond Bay Rd. Nanaimo, BC V9T 6N7

This presentation provides summary information on British Columbia (BC, Canada) Pacific sardine, Pacific herring (*Clupea pallasii*), northern anchovy and eulachon (*Thaleichthys pacificus*) observations from *Fisheries and Oceans Canada* (DFO) Pacific Science initiatives.

Summer research trawl surveys have been conducted off the west coast of Vancouver Island (WCVI) to collect information on pelagic fish and their ecology. Some surveys and years focused on studying Pacific sardine whereas others focused on Pacific herring, juvenile salmon, or other species. Trends in sardine distribution and relative abundance from 2006-2014 summer WCVI sardine night trawl surveys show a decline of sardine between years. The last year sardines were caught in that survey was 2012 which was also the last year sardines were caught and landed by purse seine in the Canadian Pacific Sardine Fishery before annual fishing closures since 2015. In 2013 and 2014 no sardines were observed in BC waters. Since 2014, however, some sardines have been observed in relatively small amounts by other surveys. Due to interest to integrate research objectives and resources to focus on a wider scope of species' ecology, starting in 2017, a new summer Integrated Pelagic Ecosystem Science (IPES) survey was initiated which conducts day and night trawl fishing in surface waters of the Vancouver Island continental shelf and rigorous ecological sampling.

Pacific herring is a major component of the BC pelagic ecosystem with a life history and wide distribution that includes nearshore spawning and young-of-the-year rearing, seasonal migrations, and offshore foraging by adults and sub adults. Herring are widely observed and studied nearshore and along the continental shelf, and have long supported several nearshore commercial and First Nation fisheries for roe, meat, spawn on kelp, and spawn on bough products. Pacific herring was a major species in catches from the WCVI sardine night trawl (2006-2014) and IPES surveys (2017-2019). Associated with nearshore spawning and fishing grounds, there is a long time series of herring catch sampling and spawn surveys that inform stock assessment efforts for five major and two minor fishery areas. In recent years management procedure framework evaluations have been developed for the two major southern stocks (WCVI and Strait of Georgia) and three major northern stocks (Haida Gwaii, Prince Rupert District and Central Coast). In the Strait of Georgia, DFO started a survey in 1992 to study young-of the-year herring ecology and recruitment forecasting. This survey also catches other species such as northern anchovy, which was especially prevalent in 2017-2019 surveys.

Eulachon are a smelt that spawn in rivers but have all active feeding stages in marine environments, extending from estuaries to offshore habitats of the continental shelf. Current conservation concerns only permit First Nations fisheries for Eulachon in B.C. waters. There are two main DFO Eulachon time series from the southern coast of B.C., a Fraser River egg and larval relative spawner index (since 1995) and catch-per-unit effort trends from a WCVI small mesh bottom trawl survey (since < 1995). The 2020 egg and larval survey had one of the highest index estimates in the time series but there has been considerable variability in abundance since 2015 following a series of low estimates over 2004-2014. It is unclear how spawner trends relate to eulachon in marine habitats, especially given uncertainty associated with mixed stock compositions and ageing fish. A recent study suggests that there can be considerable genetic overlap between spawners from different rivers on a regional scale as evidenced by trends in annual variation.

Due to the coronavirus pandemic in 2020, several surveys that would normally provide time series observations of small pelagic fishes were canceled, including IPES, Strait of Georgia juvenile herring, and the WCVI small mesh bottom trawl surveys.

Coastal Pelagic Species Fisheries in the U.S. Pacific Northwest

Lorna Wargo[1], Gregory K. Krutzikowsky[2] & Alan Sarich[3]

[1]Washington Department of Fish and Wildlife, 48 Devonshire Road, Montesano, WA 98563
[2]Oregon Department of Fish and Wildlife, 2040 SE Marine Drive, Newport, OR 97365
[3]Quinault Indian Nation, P.O. Box 189, Taholah, WA 98587

Directed CPS fisheries in the U.S. Pacific Northwest in 2019 and 2020 pursued market squid (*Doryteuthis opalenscens*), northern anchovy and small-scale opportunity for Pacific sardine. Purse seine fishing for CPS off Oregon focused on market squid. Washington CPS fisheries were limited to directed northern anchovy fishing. For Pacific sardine, the biomass estimate for the northern subpopulation was below the cutoff value of 150,000 mt for the 2019-2020 fishing year, thus restricting directed fisheries for this stock to small-scale fisheries landing less than 1 mt per day. Harvest of sardine in small-scale fisheries occurred only in Oregon. No directed CPS fisheries for Pacific mackerel (*Scomber japonicus*) occurred in the region. The Quinault Indian Nation did not participate in CPS fisheries during this period. A description of current CPS fisheries, landings, and biological data collections will be presented.

California Coastal Pelagic Species Report

Dane McDermott & Dana Myers

California Department of Fish and Wildlife
Dane.McDermott@wildlife.ca.gov Dana.Myers@wildlife.ca.gov

Coastal pelagic finfish species (CPS), including Pacific sardine, northern anchovy, Pacific mackerel, and jack mackerel (*Trachurus symmetricus*), are managed by the Pacific Fishery Management Council (PFMC) under the Coastal Pelagic Species Fishery Management Plan (CPS FMP). In 2019, the Pacific sardine stock assessment produced a biomass estimate well below the "cutoff" threshold value of 150,000 metric tons (mt) in the Harvest Guideline control rule. As a result, there was no directed commercial fishery for the 2019/2020 Pacific sardine fishing season, which runs July 1 through June 30, with a few exceptions. The National Marine Fisheries Service implemented an annual catch target of 4,000 mt for commercial incidental catch or as part of the tribal, live bait, minor directed (less than 1 mt), exempted fishing permit, or recreational fisheries. For the 2019/2020 fishing season, total California landings for Pacific sardine were approximately 2,054 mt, from 70 unique vessels, with 76 percent of the state total

(1,551 mt) landed in Southern California. For the 2019/2020 fishing season, 3,785 mt of Pacific mackerel were landed, and for the 2019 fishing year, 10,165 mt of northern anchovy and 9 mt of jack mackerel were also landed. Pacific sardine was declared overfished in June 2019 and a rebuilding plan was adopted by PFMC in September 2020.

The Fishery of Small Pelagic on the Western Coast of Baja California, Mexico, Fishing Season 2019.

Concepción Enciso-Enciso, Celia Eva Cotero-Altamirano, Eduardo Álvarez-Trasviña & Julio C. Peralta-Ramos

Centro Regional de Investigación Acuícola y Pesquera (CRIAP- Ensenada). INAPESCA.
Email: concepcion.enciso@inapesca.gob.mx

Aspects of the small pelagic fishery on the western coast of Baja California were analyzed during the 2019 fishing season. The total catch of the resource was 152,616 t, 49% above the historical average (2003-2018, 75,154 t per year). 71% of the total catch was of Pacific sardine (108,311 t), 27% (40,739 t) of northern anchovy, 1%, (2,372 t) of Pacific mackerel and 1% (1,195 t) of Pacific herring. Throughout the year the catches ranged from 4,526 t to 20,105 t. The highest catches were recorded in the months of April to December with an average of 14,419 t/month and the lowest records were in the months of January to May with an average of 7,615 t/month. The recorded fishing effort was 2,213 fishing trips made with a total of 24 vessels. The estimated average yield was 69 t/trip, 7% higher than that registered for the period 2003-2018. Regarding Pacific sardine catch in the region during the 2019 season, 80% corresponds to the temperate stock (129,016 t), 14% to the cold stock (21,524 t) and 6% to the warm stock (10,120 t). It was estimated that 70% of the Pacific sardine catch was below the legal minimum size (150 mm LP).

Se analizan aspectos de la pesquería de pelágicos menores en la costa occidental de Baja California, durante la temporada de pesca 2019. La captura total del recurso fue de 152,616 t, 49% por arriba del promedio histórico (2003-2018, 75,154 t anuales). El 71% de la captura total fue de sardina del Pacifico (108,311 t); el 27% (40,739 t) de anchoveta norteña, el 1%, (2,372 t) de macarela y el 1%, (1,195 t) de sardina crinuda. A lo largo del año las capturas oscilaron entre 4,526 t a 20,105 t. Las mayores capturas fueron registradas en los meses de abril a diciembre con 14,419 t/mes en promedio y los menores registros fueron en los meses de enero a mayo con un promedio 7,615 t/mes. El esfuerzo pesquero registrado fue de 2,213 viajes de pesca realizados con un total de 24 embarcaciones. El rendimiento promedio estimado fue de 69 t/viaje, 7% superior a lo registrado para el periodo 2003-2018. Respecto a la captura de sardina del Pacifico en la región durante temporada 2019, el 80% corresponde al stock Templado (129,016 t), el 14% al stock Frío (21,524 t) y el 6% al stock Cálido (10,120 t). Se estimó que el 70% de la captura de la sardina del Pacifico estuvo por debajo de la talla mínima legal (150 mm LP).

Discussion:

The presenter clarified that the procedure is to use an approximate temperature for the location of the catches.

Pacific Fishery Management Council Report/Update

Kerry Griffin

Pacific Fishery Management Council, Portland, Oregon, USA. Kerry.Griffin@noaa,gov

Pacific Fishery Management Council Activities

The Pacific Fishery Management Council (PFMC) is responsible for developing management measures for federally-managed fish species on the U.S. West Coast from Canada to Mexico, from 3 to 200 miles offshore. Four fishery management plans (FMP) describe the species, harvest control rules, gear, seasons, and other items related to management. The four FMPs are salmon, groundfish, highly migratory species, and coastal pelagic species (CPS). The PFMC also has an ecosystem FMP that provides guidance and information on ecosystem matters as it applies to fisheries management.

The CPS FMP includes Pacific sardine, Pacific mackerel, northern anchovy (northern and central subpopulations), jack mackerel, and market squid. Every year, the sardine biomass is assessed and harvest levels are established. Mackerel is assessed every two years, with annual management measures applied for two years at a time. The harvest levels for the other CPS stocks are set and are only updated as needed. Stock assessments for those stocks are also only done when there is a need and when there is sufficient data to support an assessment.

Recent and upcoming activities

Pacific sardine
The northern subpopulation of Pacific sardine was declared overfished in June 2019, thus requiring the development of a rebuilding plan. The Council's CPSMT, the SWFSC, and NMFS developed a rebuilding plan, and at its September 2020 meeting, the Council approved a status quo management approach for rebuilding the sardine population, noting that directed commercial harvest has been prohibited since 2015. The rebuilding plan and FMP amendment will be transmitted to NMFS in early 2021 for Secretarial approval.

Essential fish habitat
Councils are required to identify and describe essential fish habitat (EFH) for all federally managed stocks, and those EFH provisions must be reviewed periodically. The Council and the SWFSC launched a review of CPS EFH in October 2020, with a Phase 1 report to the Council expected at its April 2021 meeting. If the Council determines that new information warrants making changes to the CPS EFH provisions, may choose to move forward with Phase 2, to develop proposed changes to CPS EFH provisions.

Northern anchovy
The Council continues to look at ways to manage and assess the central subpopulation of northern anchovy (CSNA). The CPSMT has developed a process to periodically evaluate harvest reference points such as overfishing limit and acceptable biological catch and is scheduled to present the process to the Council at its June 2021 meeting. A stock assessment for the central subpopulation of northern anchovy is scheduled for late 2021.

Assessment of the Pacific Sardine Resource in 2020 for U.S. Management in 2020-2021

Peter T. Kuriyama[1], Juan P. Zwolinski[2], Kevin T. Hill[1]& Paul R. Crone[1]

[1]Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service. 8901 La Jolla Shores Drive, La Jolla, CA 92037
[2]Institute of Marine Sciences University of California Santa Cruz, Earth and Marine Sciences Building, Santa Cruz, CA 95064. USA (affiliated with SWFSC)

Full report: https://repository.library.noaa.gov/view/noaa/24744

Executive Summary

The Pacific sardine resource is assessed each year in support of the Pacific Fishery Management Council process of stipulating annual harvest specifications for the U.S. fishery for the management cycle that begins July 1, 2020, and ends June 30, 2021. The 2020 base model has many of the features found in the previous version of the assessment model (2017-2019) and focuses on the northern subpopulation of the species. The model retains the same fleet structure (Pacific Northwest, Mexico-Southern California spring and summer) and relies on the fishery-independent acoustic-trawl survey. Growth estimation was not internal to the model but treated as data input via weight-at-age values. One notable change to the assessment involves specification of catchability, a key scaling parameter in the assessment. The change accounts for the nearshore habitat, which the acoustic-trawl survey has not typically covered. The catchability of the acoustic-trawl survey was fixed at 1 for 2005-2014 and fixed at 0.73 for 2015-2019 to account for nearshore biomass. Stock biomass, used for calculating annual harvest specifications, is defined as the sum of the biomass for sardine ages one and older (mt) at the start of the management year. The trend of relatively low biomass levels has continued and the projected biomass in July 2020 is 28,276 mt.

Stock

This assessment focuses on the northern subpopulation of Pacific sardine (NSP) that ranges from northern Baja California, Mexico 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, Zwolinski et al. 2011, Garcia-Morales et al. 2012, 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 et al. 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 are below in Table 1.

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. Y-S stands for year-semester for calendar and model values.

Calendar Y-S	Model Y-S	ENS Total	ENS NSP	SCA Total	SCA NSP	CCA	OR	WA	BC
2005-2	2005-1	38,000	4,397	16,615	1,581	7,825	44,316	6,605	3,231
2006-1	2005-2	17,601	11,215	18,291	17,117	2,033	102	0	0
2006-2	2006-1	39,636	0	18,556	5,016	15,710	35,547	4,099	1,575
2007-1	2006-2	13,981	13,320	27,546	20,567	6,013	0	0	0
2007-2	2007-1	22,866	11,928	22,047	5,531	28,769	42,052	4,662	1,522
2008-1	2007-2	23,488	15,618	25,099	24,777	2,515	0	0	0
2008-2	2008-1	43,378	5,930	8,980	124	24,196	22,940	6,435	10,425
2009-1	2008-2	25,783	20,244	10,167	9,874	11,080	0	0	0
2009-2	2009-1	30,128	0	5,214	109	13,936	21,482	8,025	15,334
2010-1	2009-2	12,989	7,904	20,334	20,334	2,909	437	511	422
2010-2	2010-1	43,832	9,171	11,261	699	1,404	20,415	11,870	21,801
2011-1	2010-2	18,514	11,588	13,192	12,959	2,720	0	0	0
2011-2	2011-1	51,823	17,330	6,499	182	7,359	11,023	8,008	20,719
2012-1	2011-2	10,534	9,026	12,649	10,491	3,673	2,874	2,932	0
2012-2	2012-1	48,535	0	8,621	930	598	39,744	32,510	19,172
2013-1	2012-2	13,609	12,828	3,102	973	84	149	1,421	0
2013-2	2013-1	37,804	0	4,997	110	811	27,599	29,619	0
2014-1	2013-2	12,930	412	1,495	809	4,403	0	908	0
2014-2	2014-1	77,466	0	1,601	0	1,831	7,788	7,428	0
2015-1	2014-2	16,497	0	1,543	0	728	2,131	63	0
2015-2	2015-1	20,972	0	1,421	0	6	0	66	0
2016-1	2015-2	23,537	0	423	185	1	1	0	0
2016-2	2016-1	42,532	0	964	49	234	3	170	0
2017-1	2016-2	28,212	6,936	513	145	0	0	0	0
2017-2	2017-1	99,967	0	1,205	0	170	1	0	0
2018-1	2017-2	24,534	6,032	395	198	0	2	0	0
2018-2	2018-1	43,370	0	1,424	0	35	6	2	0
2019-1	2018-2	32,169	11,210	754	551	58	2	0	0
2019-2	2019-1	46,943	0	855	0	131	8	0	0

Data and Assessment

The integrated assessment model was developed using Stock Synthesis (SS version 3.30.14), and includes fishery and survey data collected from mid-2005 through 2019. 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, 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 Pacific Northwest (PNW) fleet. A single AT survey index of abundance from ongoing SWFSC surveys (2006-2019) was included in the model.

The 2020 base model incorporates the following specifications:

- Sexes were combined; ages 0-8+;
- Two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
- MexCal fleets: age-based selectivity (time-varying and non-parametric [option 17 in Stock Synthesis]);
- PNW fleet: asymptotic age-based selectivity (time-varying for the inflection point);
- AT survey age compositions with effective sample sizes set to 1 per cluster (externally);
- Age compositions for the spring AT survey omitted;
- Fishery 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 set to 0.3;
- Initial equilibrium ("SR regime" parameter) estimated with the 'lambda' for this parameter set to zero (no penalty contributing to total likelihood estimate);
- Natural mortality (M) estimated with a prior;
- Recruitment deviations estimated from 2005-2018;
- Virgin recruitment estimated, and total recruitment variability (σ_R) fixed at 1.2;
- Initial fishing mortality (F) estimated for the MexCal S1 fleet and assumed to be 0 for the other fleets;
- F for the 2020-1 to 2020-2 model years set to those for the 2018 (S2) and 2019 (S1) model years.
- AT survey biomass 2006-2019, partitioned into two (spring and summer) surveys, with catchability (*Q*) set to 1 for 2005-2014 and 0.733 for 2015-2019;
- AT survey selectivity is assumed to be uniform (fully-selected) above age 1 and estimated annually for age-0.

Spawning Stock Biomass and Recruitment

Time series of estimated spawning stock biomass (SSB, mmt) and associated 95% confidence intervals are displayed in Figure 1 and Table 2. The initial level of SSB was estimated to be 717,077 mt. The SSB has continually declined since 2005-2006, reaching historically low levels in recent years (2014-present). The SSB was projected to be 20,623 mt (CV=19%) in January 2020.

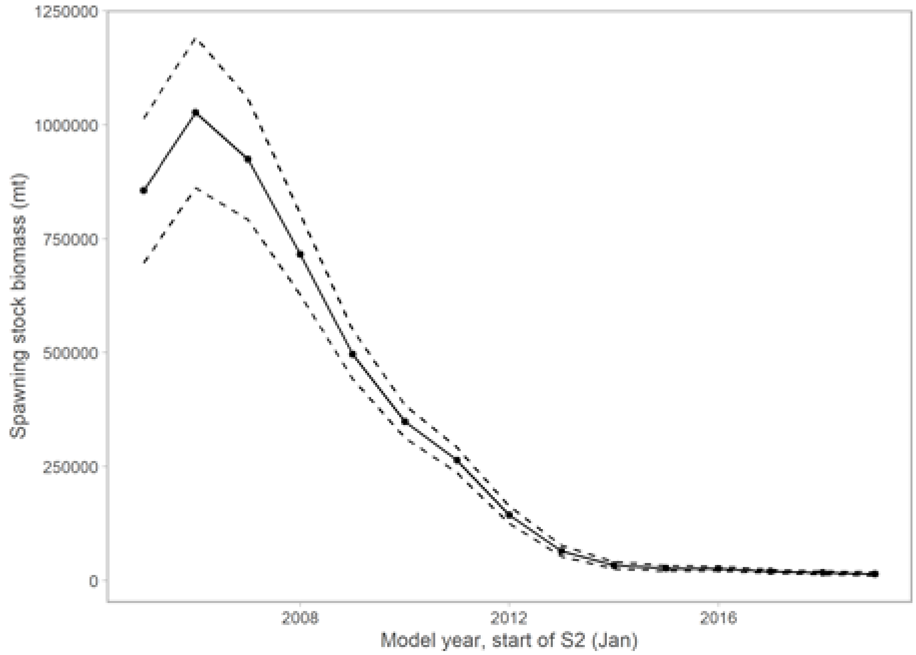


Figure 1. Spawning stock biomass time series (95% CI dashed lines) for 2020 base model.

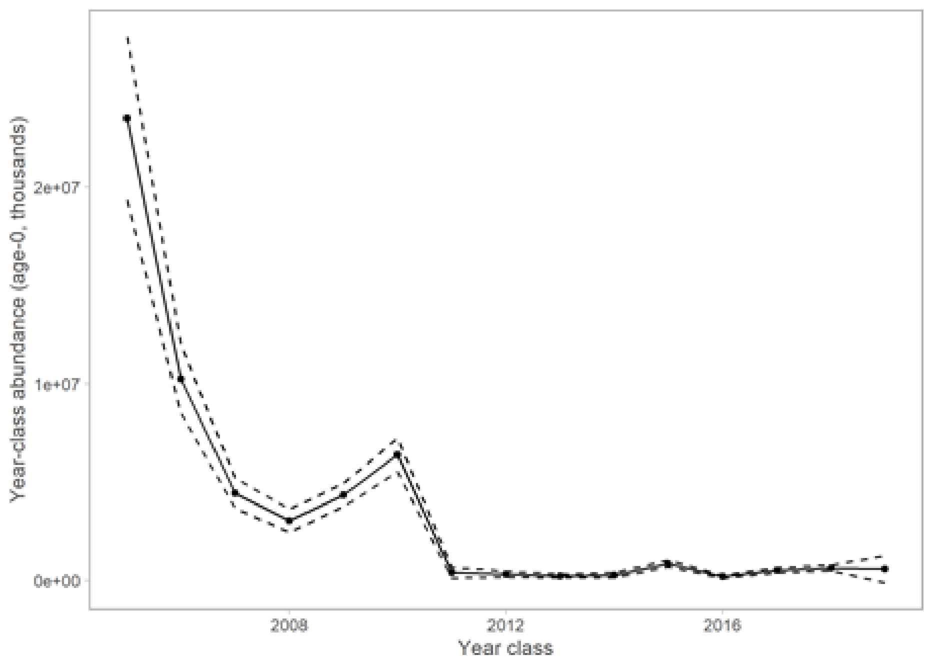


Figure 2. Estimated recruitment (age-0, thousands of fish) time series for 2020 base model.

Time series of estimated recruitment (age-0, thousands of fish) abundance is presented in Figure 2 and Table 2 the figure and table below. The initial level of recruitment (R_0) was estimated to be 23,481,700 age-0 thousands of fish. As indicated for SSB above, recruitment has largely declined since 2005-2006, with the exception of a brief period of modest recruitment success from 2009-1010. In particular, the 2011-2019 year classes have been among the weakest in recent history.

Table 2. Spawning stock biomass (SSB) and recruitment (1000s) estimates and asymptotic standard errors for 2020 base model. SSB estimates were calculated at the beginning of Season 2

(S2) of each model year (January). Recruits were age-0 fish (1000s) calculated at the beginning of each model year (July).

Calendar Y-S	Model Y-S	SSB	SSB sd	Recruits	Recruits sd
–	VIRG-1	0	0	0	0
–	VIRG-2	186,412	46,615	2,497,660	631,756
–	INIT-1	0	0	0	0
–	INIT-2	717,077	210,708	0	0
2005-2	2005-1	0	0	23,481,700	4,138,620
2006-1	2005-2	944,410	114,999	0	0
2006-2	2006-1	0	0	10,243,900	1,746,000
2007-1	2006-2	1,136,270	109,953	0	0
2007-2	2007-1	0	0	4,440,300	770,711
2008-1	2007-2	1,010,600	81,786	0	0
2008-2	2008-1	0	0	3,036,910	596,284
2009-1	2008-2	760,343	51,472	0	0
2009-2	2009-1	0	0	4,349,860	586,281
2010-1	2009-2	508,691	31,034	0	0
2010-2	2010-1	0	0	6,382,960	858,061
2011-1	2010-2	346,715	20,725	0	0
2011-2	2011-1	0	0	400,378	275,621
2012-1	2011-2	265,112	16,697	0	0
2012-2	2012-1	0	0	320,608	160,608
2013-1	2012-2	148,558	13,115	0	0
2013-2	2013-1	0	0	230,611	98,577
2014-1	2013-2	69,620	9,106	0	0
2014-2	2014-1	0	0	267,296	131,230
2015-1	2014-2	37,557	6,214	0	0
2015-2	2015-1	0	0	874,285	171,644
2016-1	2015-2	30,991	4,662	0	0
2016-2	2016-1	0	0	198,698	82,566
2017-1	2016-2	33,300	4,377	0	0
2017-2	2017-1	0	0	533,748	135,803
2018-1	2017-2	27,435	4,083	0	0
2018-2	2018-1	0	0	644,242	147,018
2019-1	2018-2	24,561	3,595	0	0
2019-2	2019-1	0	0	580,925	683,231
2020-1	2019-2	20,623	3,924	0	0
2020-2	2020-1	0	0	0	0
2021-1	2020-2	16,768	11,190	0	0

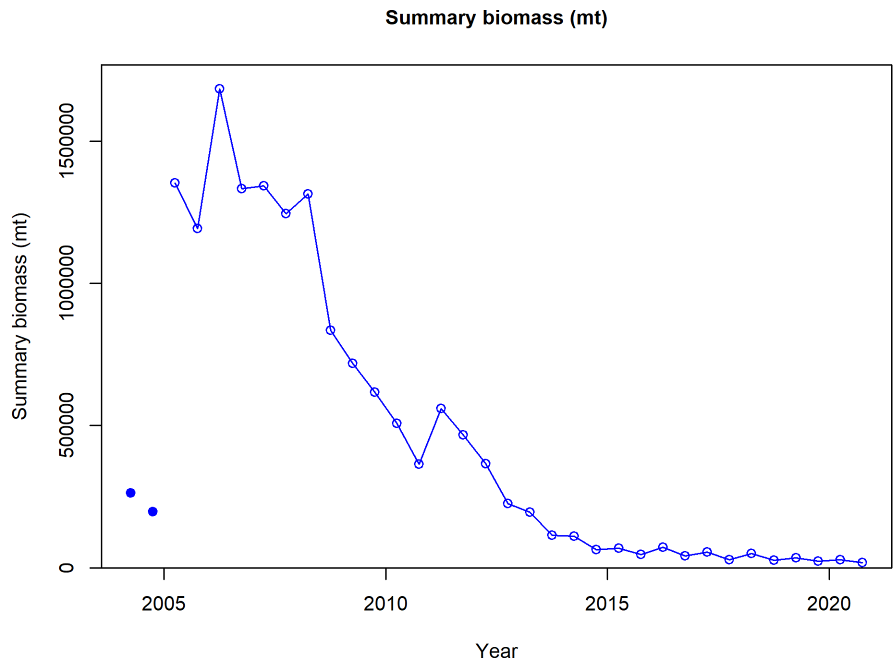


Figure 3. Estimated stock biomass (age 1+ fish; mt) time series for 2020 base model.

Stock Biomass for PFMC Management in 2020-21

Stock biomass, used for calculating annual harvest specifications, is defined as the sum of the biomass for sardine ages one and older (age 1+, mt) at the start of the management year. Time series of estimated stock biomass from the 2020 base model are presented in Figure 3. As discussed above for both SSB and recruitment, a similar trend of declining stock biomass has been observed since 2005-06. The 2020 base model stock biomass is projected to be 28,276 mt in July 2020.

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 2020 base model estimates, the U.S. exploitation rate has averaged about 9% since 2005, peaking at 31% in 2013. The total exploitation rates were 23% in 2019, largely driven by catches from Mexico. Exploitation rates for the NSP, calculated from the 2020 base model, are presented in Figure 4 and Table 3.

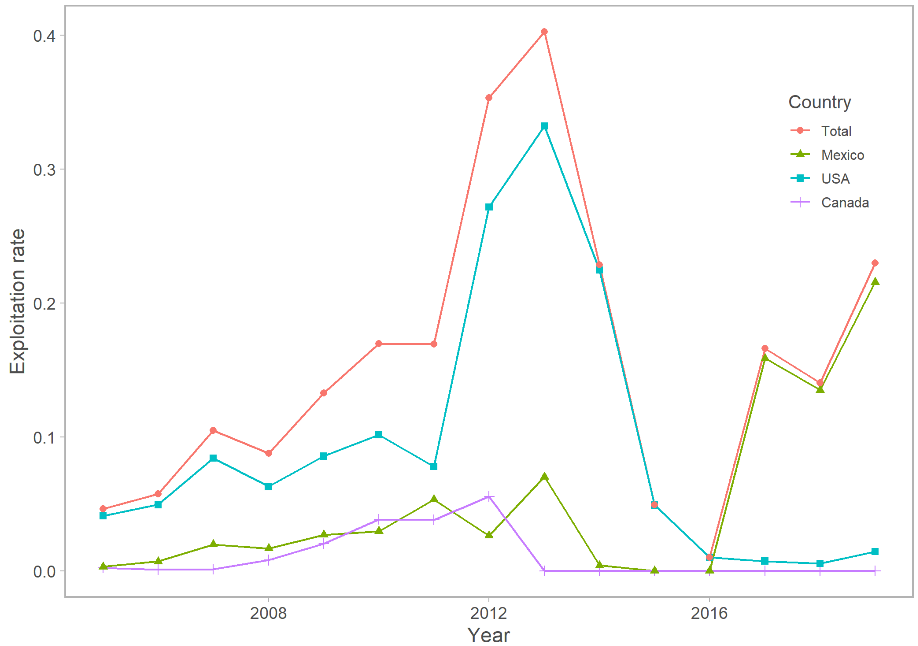


Figure 4. Annual exploitation rates (calendar year landings / July total biomass) for 2020 base model.

Table 3. Annual exploitation rate (calendar year landings / July total biomass) by country.

Calendar Year	Mexico	USA	Canada	Total
2005	0	0.04	0	0.05
2006	0.01	0.05	0	0.06
2007	0.02	0.08	0	0.1
2008	0.02	0.06	0.01	0.09
2009	0.03	0.09	0.02	0.13
2010	0.03	0.1	0.04	0.17
2011	0.05	0.08	0.04	0.17
2012	0.03	0.27	0.06	0.35
2013	0.07	0.33	0	0.4
2014	0	0.22	0	0.23
2015	0	0.05	0	0.05
2016	0	0.01	0	0.01
2017	0.16	0.01	0	0.17
2018	0.13	0.01	0	0.14
2019	0.22	0.01	0	0.23

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 (2017), and NMFS (2019, *Supplementary materials to the California Current integrated ecosystem assessment (CCIEA) California Current ecosystem status report 2019*) for comprehensive information regarding environmental processes generally hypothesized to influence small pelagic species that inhabit the CCE.

Harvest Control Rules

Evaluation of Scientific Uncertainty

Scientific uncertainty in the base model is based on asymptotic standard errors associated with SSB estimates from the 2020 base model. Base model SSB was projected to be 16,769 mt (SD=11,190 mt; CV=0.607) in January 2021, so the corresponding σ for calculating P-star buffers is 0.607, rather than the newly adopted default value (0.50) for Tier 1 assessments.

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 1, 2020, to June 30, 2021, BIOMASS is the stock biomass (ages 1+, mt) projected as of July 1, 2020, CUTOFF (150,000 mt) is the lowest level of biomass for which directed harvest is allowed, FRACTION (EMSY 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. The base model estimated stock biomass is projected to be below the 150,000 mt threshold, so the HG for 2020-21 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 (Table 23), and E_{msy} for OFL and ABC is bounded between 0 to 0.25. Based on recent conditions in the CCE, the average temperature for 2017-19 was 15.9965 °C, resulting in E_{msy}=0.22458.

Estimated stock biomass in July 2020 from the 2020 base model was 28,276 mt. The overfishing limit (OFL, 2019-2020) associated with that biomass was 5,525 mt. Acceptable biological catches (ABC, 2020-2021) for a range of P-star values (Tier 1 σ =0.607; Tier 2 σ =1.0) associated with the base model are presented below.

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

Table 4. Harvest Formula Parameters

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10
BIOMASS (ages 1+, mt)	28,276	-	-	-	-	-	-	-	-
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{(Sigma\ 0.607)}$	0.92657	0.85748	0.79148	0.72742	0.66408	0.60003	0.53312	0.45943	0.36852
ABC $Buffer_{Tier\ 2}$	0.88191	0.77620	0.68023	0.59191	0.50942	0.43101	0.35472	0.27761	0.19304
CalCOFI SST (2016-2018)	15.9965	-	-	-	-	-	-	-	-
E_{MSY}	0.224584	-	-	-	-	-	-	-	-
FRACTION	0.200000	-	-	-	-	-	-	-	-
CUTOFF (mt)	150,000	-	-	-	-	-	-	-	-
DISTRIBUTION (U.S.)	0.87	-	-	-	-	-	-	-	-

Table 5. Harvest Control Rule Values (MT)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10
OFL	**5,525**	-	-	-	-	-	-	-	-
$ABC_{(Sigma\ 0.607)}$	5,119	4,737	4,373	4,019	3,669	3,315	2,945	2,538	2,036
$ABC_{Tier\ 2}$	4,872	4,288	3,758	3,270	2,814	2,381	1,960	1,534	1,067
HG	**0**	-	-	-	-	-	-	-	-

Management Performance

The U.S. HG/ACL values and catches since the onset of federal management are presented in Figure 5.

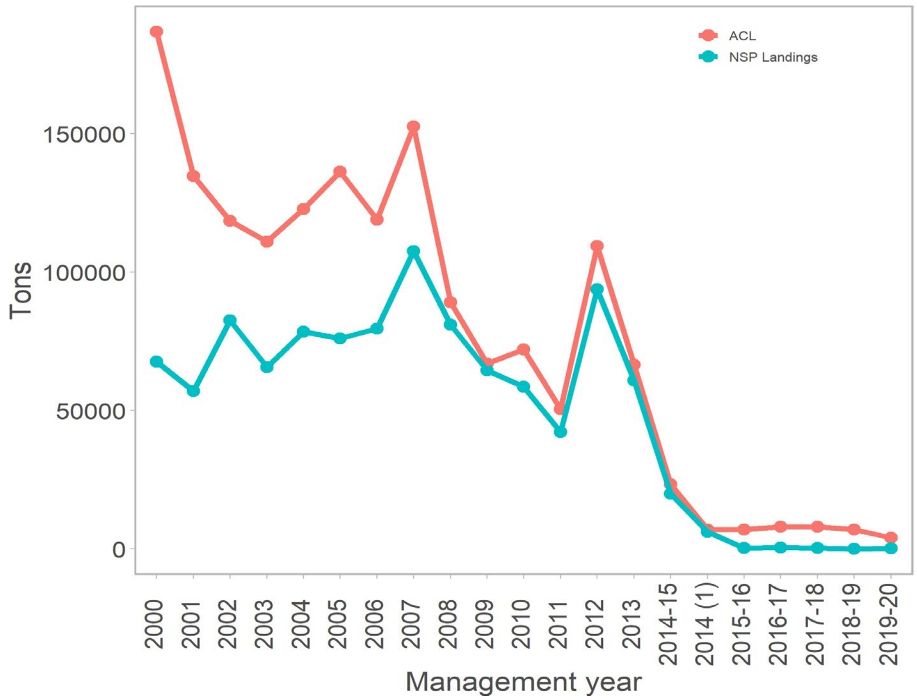


Figure 5. U.S. HG and ACL values and catches.

Discussion:

When asked whether the assessment takes into consideration sardine movement relative to the spatial extent of the acoustic trawl survey, the presenter explained that they were trying to capture this with the time-varying age-based selectivity curve. They don't have the data beyond the acoustic trawl survey footprint but try to account for it with the selectivity dimension.

The catchability *Q*, based on the 2019 aerial surveys, was modified for the 2015-2019 years in this presentation. When asked whether they expected that nearshore aerial surveys in the future might provide a *Q* that is consistent with the data from that single year, the general consensus was that this is unlikely. It would be logistically challenging to coordinate exact locations with the survey on the cove, make matching up the data consistently unlikely. The aerial survey and acoustic trawl data also provide entirely different information. Instead, the use of nearshore boats and saildrones in the future may provide a broader reach while providing equivalent data. The use of *Q* in this instance was to acknowledge that some of the fish may not have been captured by the survey but that the source of this data will likely change over time.

In respect to the use of predator diet data towards estimating natural mortality (*M*) in the future, the challenge is how close they can get the predator diet data (in terms of spatial scale) to that of the acoustic trawl survey. Adding samples to an estimate of natural mortality would be difficult since it's such a small area relative to the full population range. However, the group is looking into alternative data sources for an upcoming anchovy assessment.

Contributed Papers

Climate Variability and Sardine Recruitment Success in the California Current

Tim Baumgartner & Jose Augusto Valencia

Deptartamento de Oceanografía Biológica, División de Oceanología, CICESE,
Ensenada, B.C. MEXICO

We investigate the relationship between recruitment success of the springtime spawning stock of the Pacific sardine and conditions in the central region of the California Current system by means of a statistical model set up to reflect sensitivity of specific life stages to seasonal climate forcing. The series of sardine recruitment success is taken from annual stock assessments over the period of 36 years, 1982-2018. The data are taken from the annual stock assessment carried out by the Southwest Fisheries Science Center of NOAA-NMFS in La Jolla California. Ocean climate variability is represented by the Pacific Decadal Oscillation, coastal upwelling and Ekman pumping off central California.

Four seasonal indices of each climate variable (a total of 12 climate indices) was prescreened using successive, overlapping 3-month means with lagged correlations to the series of annual sardine recruitment success. The prescreening process identifies seasonal periods of the three forcing variables that exert the strongest influence on each of the life stages in the recruitment process specified as 1) environmental conditioning of pre- spawning adults, 2) spawning and larval growth/mortality, 3) juvenile growth/mortality, and 4) the stage of recruitment to the adult population that together extend over a span of 27 months. The statistical model presented here is the first step in the procedure known as *stepwise regression* beginning with the full suite of the independent variables but can be refined to a smaller number of variables to improve the fit to the to the recruitment series.

Stock Assessment and Management of the Tempered Stock of Pacific Sardine Sardinops sagax on the West Coast off the Baja California Peninsula, Mexico (1989-2019).

Concepción Enciso-Enciso[1,2], Manuel O. Nevárez-Martínez[1], Rebeca Sánchez-Cárdenas[3], Emigdio Marín Enriquez[3], Luis A. Salcido-Guevara[3], Carolina Minte-Vera[4] & Martin E. Hernández-Rivas[5].

[1]Instituto Nacional de Pesca (INAPESCA).
[2] Posgrado en Ciencias en Recursos Acuáticos, FACIMAR-UAS.
[3] Facultad de Ciencias del Mar (FACIMAR-UAS).
[4] Comisión Interamericana del Atún Tropical (CIAT).
[5] Centro Interdisciplinario de Ciencias Marinas (CICIMAR-IPN).
Email: concepcion.enciso@inapesca.gob.mx

Due to the volumes caught, the Pacific sardine is the most important fishing resource in Mexico. It is a highly migratory organism that presents large fluctuations in its abundance and distribution. Three stocks have been identified: a cold stock, a temperate one and a warm one, which dynamically overlap, and are influenced by the surface temperature of the sea. Current regulations suggest active management, which requires permanent evaluation of the different stocks to define management based on abundance (Control Rule). The objective of this study is to evaluate the abundance of the temperate stock of sardine on the western coast of the Baja California peninsula for the period 1989-2019. From data on catch by age, fishing effort and independent indicators of the fishery (eggs and biomass estimation by acoustics), a statistical analysis of catch by age (ACE) was applied, which allowed estimating the population size and obtaining some reference points for management. The results indicated a great interannual variability in abundance, ranging between 701,687 and 1,554,329 t for the total biomass and from 381,384 to 876,546 t for the spawning biomass. Considering the spawning biomass for 2019 B_{REP}=644,415 t, the exploitation rate E_{MRS}=0.238 $year^{-1}$ (FRACTION) and the minimum biomass B_{MIN}=38,909 t, the Biologically Acceptable Catch was estimated as a Control Rule for the 2020 fishing season CBA_{2020}=143.822 t. The projection of the exploitation level throughout the analyzed period (1989-2019) infers that the temperate stock of sardine has remained at sustainable levels take into consideration the control rule.

Por los volúmenes de captura la sardina del Pacifico es el recurso pesquero más importante en México. Es un organismo altamente migratorio que presenta grandes fluctuaciones en su abundancia y en de su distribución se han identificado tres stocks: un stock frio, uno templado y uno cálido, que se superponen dinámicamente influenciados por la temperatura superficial del mar. La normatividad vigente sugiere un manejo activo, lo que demanda la evaluación permanente de los diferentes stocks para definir el manejo en función de la abundancia (Regla de Control). El objetivo del presente estudio es evaluar la abundancia del stock templado de *S. sagax* en la costa occidental de la península de Baja California para el periodo 1989-2019. A partir de datos de captura por edades, esfuerzo pesquero e indicadores independientes de la pesquería (huevos y estimación de biomasa por acústica), se aplicó un análisis estadístico de captura por edades (ACE), lo que permitió estimar el tamaño poblacional y obtener algunos puntos de referencia para su manejo. Los resultados indicaron una gran variabilidad interanual en la abundancia, oscilando entre 701,687 y 1,554,329 t para la biomasa total y de 381,384 a 876,546 t en la biomasa reproductora. Considerando la biomasa reproductora para 2019 B_{REP}= 644,415 t, la tasa de explotación E_{MRS}=0.238 $año^{-1}$ (FRACCION) y la biomasa mínima B_{MIN}=38,909 t, se estimó la Captura Biológicamente Aceptable como Regla de Control para la temporada de pesca 2020 CBA_{2020}=143,822 t. La proyección del nivel de explotación a lo largo del periodo analizado (1989-2019) infiere que el stock templado de *S. sagax* ha permanecido en niveles sostenibles considerando la regla de control.

Discussion:

The presenter clarified that most of the sardine have been too small to harvest in Ensenada, especially in the 2019 and 2020 fishing seasons, which lowers the average size but also indicates a great recruitment. This was reflected in the catch reports where they had exceptional catches in the last four seasons but of small sizes.

Preparing a Rebuilding Plan for the Northern Subpopulation of Pacific Sardine

Gregory K. Krutzikowsky

Oregon Department of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365, e-mail greg.krutzikowsky@state.or.us

In June 2019, the northern subpopulation of Pacific sardine was declared overfished by the National Marine Fisheries Service (NMFS). The Pacific Fishery Management Council (Council) was tasked with recommending and transmitting a rebuilding plan for this stock to NMFS by October 2020. Staff at the Southwest Fisheries Science Center conducted extensive modeling work on rebuilding based on the 2020 stock assessment. The Coastal Pelagic Species Management Team (CPSMT) evaluated options and developed recommendations for a rebuilding plan that would meet the requirements set forth by the Magnusson-Stevens Fishery Conservation and Management Act. The presenter outlined some of the work and analyses done by the CPSMT that resulted in the rebuilding plan and parameters adopted by the Council in September 2020 that was subsequently submitted to NMFS for review and implementation.

Discussion:

Some discussion revolved around MSA language when discussing rebuilding a stock, such as sardine, when it is unclear whether overfishing or natural population variability is the root cause. The term “overfishing” is currently used but there has been some work towards changing the term to “depleted,” though this terminology would have to be incorporated into the MSA update if it is to be used in the future.

Provisional Plans for Spring 2021 CPS and Summer 2021 CCE Surveys from FSV Reuben Lasker

David A. Demer[1], Kevin Stierhoff[1] & Juan P. Zwolinski[2]

[1]Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service. 8901 La Jolla Shores Drive, La Jolla, CA 92037
[2]Institute of Marine Sciences University of California Santa Cruz, Earth and Marine Sciences Building, Santa Cruz, CA 95064. USA (affiliated with SWFSC)

Since 2006, the Fisheries Resources Division (FRD) at NOAA’s Southwest Fisheries Science Center (SWFSC) has used the acoustic-trawl method (ATM) to assess populations of coastal pelagic species (CPS) in the California Current. Although an ATM survey was not conducted during 2020 due to the COVID-19 pandemic, the FRD aims to conduct two CPS surveys from NOAA ship *Reuben Lasker* during 2021.

The Spring 2021 Survey will be conducted from the U.S.-Mexico border to San Francisco during 25 days at sea (DAS), 20 March to 13 April 2021. Transects will be spaced 15 nmi. in the Southern California Bight (SCB) and 20 nmi north of Point Conception. The primary aims are to assess the Central Stock of Northern Anchovy (CSNA) and the Northern Stock of Pacific Sardine (NSPS).

The Summer 2021 Survey will be conducted from the northern extent of Vancouver Island, Canada, potentially to Punta Eugenia, Baja California Norte (BJN) during 86 DAS, 2 July to 15 October 2021. The primary objectives are to assess the CSNA, the Northern Stock of Northern Anchovy, the NSPS, the Southern Stock of Pacific Sardine, and portions of the stocks of jack mackerel, Pacific mackerel, and Pacific herring within the survey area. Additional information will be collected on their prey and oceanographic habitats. In areas where CPS are historically abundant, transects will be spaced 10-nmi. Elsewhere, the 20-nmi transect spacing will be changed to 10-nmi spacing if CPS are encountered.

In both surveys, transects will extend as far offshore as necessary to map the western extent of CPS, and as close to shore as navigable, usually 20 to 40-m depth. During the summer survey, sampling closer to shore will be conducted from FV *Lisa Marie* and *Long Beach Carnage*. Also, efforts will be made to coordinate with CPS sampling from RV *Dr. Jorge Carranza Fraser* off Baja California; hake sampling from FSV *Bell M. Shimada*; aerial CPS surveys by California Department of Fish and Wildlife, and potentially with acoustic sampling by saildrones.

Discussion:

It was noted that NOAA headquarters had requested names of survey staff with the future possibility of getting priority vaccinations, though at this time no further information was available.

Towards Elucidating Mechanisms Controlling the Recruitment of Coastal Pelagic Fishes

Andrew R. Thompson

Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service. 8901 La Jolla Shores Drive, La Jolla, CA 92037
Andrew.Thompson@noaa.gov

Recruitment variability largely drives the abundance of stocks of coastal pelagic fishes (CPS), but the mechanisms governing year class strength are elusive for many species. Elucidating causes of northern anchovy recruitment success and failure was a major research focus at the Southwest Fisheries Science Center (SWFSC) in the 1970s-1980s, and SWFSC scientists Ruben Lasker and John Hunter and their teams provided important insight on drivers of anchovy recruitment dynamics. Following the extraordinarily high anchovy recruitment over the past five years, we now have an opportunity to build on their work using fishes collected by NOAA fisheries surveys at multiple life stages (larval, juvenile and adult) and recently developed analytical tools. To augment understanding of recruitment drivers, we are 1) assessing whether the condition of fish at early and juvenile life stages impacts recruitment and 2) elucidating the environmental conditions fish experience early in life in years with variable recruitment. Research with individual fish involves extracting otoliths from pre-recruits to test if individuals grow faster (based on size-adjusted otolith width increments) as larvae or juveniles in years with high recruitment. To determine if specific oceanographic conditions early in life associate with high recruitment, we are also planning to implement otolith microchemistry analyses to compare chemical signatures between larvae and surviving juveniles. In addition, we are running compound-specific stable isotope analyses to evaluate whether efficient transfer of energy from larval prey to fish correlates with recruitment. Finally, we are quantifying ionocyte expression to gauge if exposure to acidic water affects recruitment. To discern the impact of environmental conditions on larval/juvenile survival, we are building spatial distribution and individual based models fueled by Regional Ocean Modeling System data to evaluate oceanographic conditions and dispersal trajectories in years with contrasting recruitment. We are also planning to use environmental DNA results of low trophic level assemblages to quantify the larval fish prey field in years with low versus high recruitment. Understanding the mechanistic causes of recruitment variability is challenging, but by discerning how fishes interact with their physical and biological environment at various early life history stages we have an opportunity to better understand and predict conditions under which coastal pelagic fishes such as anchovy boom and bust. Providing accurate forecasts of recruitment, and thus the population trajectories of CPS, would be extraordinarily valuable for fisheries management.

A Multiscale and Multimodel Framework to Explain Pelagic Fish Larvae Spatial Distribution Linked to Ocean Thermal Fronts across the Large Domain of the Southern California Current System

Amelia de la O Navarrete[1], Ruben Rodriguez-Sanchez[1], Hector Villalobos[1], Sofia Ortega-Garcia[1] & Raul Martinez-Rincon[2]

[1]CICIMAR-Instituto Politécnico Nacional
[2]CIBNOR. La Paz, B.C.S., México
rodrig@ipn.mx

In the process of characterizing the suitable nursery habitat of a fish species across a large marine ecosystem, ocean thermal fronts are not included with a spatiotemporal representation similar to other environmental factors that are considered. In this regard, here we show methods and approaches for advancing the indexing of surface thermal fronts. There is plenty of scientific literature that discusses the relevance of ocean fronts in marine ecosystems and their association with biological and ecological traits of fish species. Experimental research to support those hypotheses have been successfully developed focusing on mesoscale eddies and large fronts that are persistent over time, or with sufficient temporal persistence to collect physical-biological data across a selected front structure. However, fronts are ubiquitous on the surface of the ocean since they are a common feature of mesoscale and submesoscale ocean processes, and their time-persistence ranges from daily to interannual scales, resulting in a heterogeneous spatial dynamics of fronts across the large domain of any ocean current system. Besides the aforementioned multiscale natural complexity, there is an inherent spatiotemporal dependence of the selected scale in the process for compiling an index. Surface thermal fronts were detected for the IMECOCAL area, off the Pacific coast of the Baja California peninsula, concurrent in time with 8 surveys carried out for fish larvae collections, 5 in spring from years 2006-2010 and 3 in summer from years 2006-2008. In this work, fronts were detected using the Cayula-Cornillon algorithm from 5-day composite SST images with a spatial resolution of 1 km. Fronts with a persistence greater than 2 days were considered relevant for fish larvae, therefore, to estimate different frontal indices based on 5-day composite images, persistence with increments of 1 day were considered. Another index was built based on 5- day average images. All indexes were calculated for areas 20x40 NM, centered on each sampling station, which are arranged in a grid-like pattern of the IMECOCAL plan. Standardized abundance data for Pacific mackerel collected at each station were selected for this analysis. A large number of zero abundance values for this species was the common feature in stations positive for ichthyoplankton. To cope with overdispersion caused by the large number of zeros we used zero-inflated generalized additive models. Spatio-temporal modeling of *T. symmetricus* was performed individually for each front index. The Akaike criterion and the explained deviance were used for ranking the models; also resulting maps and diagnostic plots provided elements for model selection criteria. Because differences of each model and resulting maps were based on only the front index used, we may suggest which is the best temporal scale for indexing fronts that might be included in future process for characterizing the suitable nursery habitat of *T. symmetricus*.

Ecosystem-Based Management Adds Incentives for Cooperative Management of Pacific Sardine

Andrés M. Cisneros-Montemayor

University of British Columbia
a.cisneros@oceans.ubc.ca

Transboundary fish stocks complicate sustainable fishing strategies, particularly when stakeholders have diverse objectives and regulatory and governance frameworks. Pacific sardine in the California Current is shared by up to three fishing nations— Canada, the United States, and Mexico—and climate-driven abundance and distribution dynamics can complicate cooperative fisheries, leading to overfishing. This study builds on previous analyses by integrating ecosystem linkages into a game theory model of transboundary sardine fisheries under various climate scenarios. Cooperative fishing strategies that account for the ecosystem-wide value of sardine as forage for other species result in increased economic benefits compared to strategies that only account for the single-species value of sardine fisheries to a given fishing country. Total ecosystem landed value is maximized at a sardine fishing rate only somewhat lower than sardine F_{MSY}, which is more precautionary but still allows the fishery to operate. Incorporating ecosystem dynamics into management-applicable models can highlight ways in which ecosystem-based fisheries management can improve both sustainability and profitability and help managers prioritize wider ecological research. Ecosystem-based management will be increasingly required to understand and adapt to the observed rapid shifts in species distributions due to climate change, and to design strategies to achieve sustainable and profitable fisheries amidst changing ecosystems.

Discussion:

The presenter clarified that politics also plays a role in ecosystem-based management and is required for cooperative arrangements. Climate change will also likely influence further species distribution resulting in more transboundary stocks. Transboundary agreements will have to be put into place if industries and public want to continue fishing the same stocks.

Reproductive Biology of Sardine Sardinops Caeruleus from the Western Coast of Baja California During 2019

Celia Eva Cotero Altamirano, Concepción Enciso Enciso, Marianne Moreno Willerer, Julio Peralta & Héctor Valles Ríos.

Instituto Nacional de Pesca. Centro Regional de Investigación Pesquera Ensenada
Km 97.5 Carretera Tijuana-Ensenada Apartado Postal No. 187. Ensenada, B. C. C.P.22760
cecotero@yahoo.com

The reproductive behavior of the species and its relation with the environment has a relevant importance in the dynamics of populations, in particular those that are commercially exploited, in this way this researcher contributes with fundamental elements that support the normativity and management instruments.

The small pelagic fishes are the most important of massive resource in the Mexico were the Pacific Sardine (*Sardinops caeruleus)* is the objective specie. A monitoring program is maintained by the National Fishery Institute as scientific advisor to Fishery Authority, according to the General Law of fisheries and aquaculture as goal is the management fisheries to do they sustainable.

Biological samples were collected from sardine commercial fleet. Biological samples were collected from sardine commercial fleet for determine reproductive biology during 2019 season. Standard lengths individual weights, sex and maturity was registered of the sardines. In the lab samples both female and males gonads were processed with histological techniques.

The results indicated that the size structure was between 85 - 205 mm and average was 134 mm and a mode 120 mm of standard length. Reproductive activity was observed throughout the year, the spawning peak was detected in March, and another important one in JULIO. Strong relationship both of temperature and upwelling with maturity was observed during the study. The length at maturity was at 165 mm.

Impacts of Temperature Acclimation on the Physiology of Pacific Sardine (Sardinops Sagax)

Lonthair, J.[1,3], Wegner, N.C.[1], Fangue, N.A.[2] & Komoroske, L.M.[3]
[1] Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service (NMFS). La Jolla, CA 92037, USA.
[2] Department of Wildlife, Fish & Conservation Biology, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA
[3] Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, MA 01003, USA

The impacts of temperature acclimation on marine teleosts have been well-documented, with alterations to respiratory constraints and enzymatic activity potentially affecting population and ecological dynamics. Recent studies have shown alterations in fish body size across species and ecosystems associated with ocean warming. However, studies on the impacts of ocean warming on Pacific sardine, a key forage fish in California food webs and fisheries, have been less well-documented. Although, we know that the Pacific sardine is physiologically sensitive to temperature, the impacts of ocean warming on metabolic rate, and other physiological parameters have not been examined. Here we sought to explore this knowledge gap and observe the physiological alterations during the changes associated with both acute and long-term temperature acclimation. Key metrics analyzed were metabolic rate, which includes maximum metabolic rate and routine metabolic rate, critical thermal maximum (CT_{max}), and critical oxygen threshold (P_{crit}). Overall, this data allows us to begin to elucidate the physiological responses associated with different temperature exposure in a critical California coastal pelagic species, which has significant implications for future fisheries yield projections, stock assessments, and ecosystem stability.

Toxic Phytoplankton Potentially Limit Sardine Productivity

Barbara Javor

Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service (NMFS). La Jolla, CA 92037, USA.
barbara.javor.noaa@gmail.com

Unlike other fish, Pacific sardine are both primary consumers that filter phytoplankton and secondary consumers that prey on zooplankton. Natural episodes of phytoplankton toxicity might influence both zooplankton and sardine productivity. The periodicity and composition of potential phytoplankton toxins often cannot be predicted, but they can be detected in bioassays with suitable test organisms such as larval brine shrimp. The results are recorded as larval mortality after 24 h exposure to phytoplankton samples. A significant episode of high mortality in the bioassays was detected in the Southern California Bight in summer, 2018, and two episodes of high mortality were observed in summer, 2019. Although chemical analyses of the toxins are not yet available, we expect the active agents are likely to include diatom oxylipins (oxidized fatty acids) that are not routinely tracked in harmful algal blooms in the California Current Ecosystem. Evidence from other labs indicates oxylipin production is mediated enzymatically in diatoms particularly during the decline of the blooms and after cell breakage during passage in the predator's gut; hence, oxylipin concentrations may be lower in seawater and healthy algal cells than in senescent cells and the consumer's gut. To estimate the frequency and intensity of potential phytoplankton toxicity on filter feeders, the brine shrimp bioassay should be employed routinely in seawater of sardine habitats in La Jolla, during CalCOFI cruises, and in other West Coast marine laboratories. Additionally, I suggest that krill-based ecosystems in polar oceans may also be limited by phytoplankton toxicity in some years because krill, like sardine, occupy a mixed trophic status as primary and secondary consumers in those food chains.

Conclusion

The Forum was well attended and provided many opportunities to share information across international lines. The Forum concluded with closing remarks from Dale Sweetnam (FRD) thanking everyone for making the time to attend. The location and date of the fall 2021 Forum has yet to be determined.

Appendix I: List Of Participants

Canada

Andres Cisneros
University of British Columbia
a.cisneros@oceans.ubc.ca

Nicholas Ens
Fisheries and Oceans Canada
ensnicholas@gmail.com

Linnea Flostrand
Department of Fisheries and Oceans Canada
Linnea.Flostrand@dfo-mpo.gc.ca

Jake Schweigert
Fisheries and Oceans Canada
jake.schweigert@dfo-mpo.gc.ca

Mexico

Tim Baumgartner
CICESE
tbaumgar@cicese.mx

Amelia De La O Navarrete
IPN-CICIMAR
adelaon1400@alumno.ipn.mx

Concepción Enciso-Enciso
Instituto Nacional de Pesca y Acuacultura
concepcion.enciso@inapesca.gob.mx

Celia Eva Cotero Altamirano
Instituto Nacional de Pesca y Acuacultura
eva.cotero@inapesca.gob.mx

Martin Hernandez-Rivas
CICIMAR-IPN
mrivas@ipn.mx

Mercedes Jacob Cervantes
Centro Regional de Acuacultura y Pesca
Mazatlán, INAPESCA
laura.jacob@inapesca.gob.mx

Julian Rene Torres Villegas
jvillega@ipn.mx

Ruben Rodriguez-Sanchez
CICIMAR-IPN
rrodrig@ipn.mx

Alfonso Rosiñol De Vecchi
Canainpesca Baja California
arosinol@oceanoindustrial.com

Leon Tissot-Plant
Camara de la Industria Pesquera del Sonora
leontp47@hotmail.com

United States

Ella Adams
NOAA
ella.adams@noaa.gov

Andy Blair
F/V Lisa Marie & West Coast Pelagic
Conservation Group
neworegon14@aol.com

Ricky Blair
F/V Lisa Marie & West Coast Pelagic
Conservation Group
rickyrblair@gmail.com

Noelle Bowlin
SWFSC FRD
noelle.bowlin@noaa.gov

Briana Brady
CA Department of Fish and Wildlife
briana.brady@wildlife.ca.gov

Sherri Charter
SWFSC FRD
sherri.charter@noaa.gov

Matt Craig
SWFSC FRD
matthew.craig@noaa.gov

Paul Crone
SWFSC FRD
paul.crone@noaa.gov

Steve Crooke
Sportfishing Association of California
SJCrooke97@aol.com

Taylor Debevec
National Marine Fisheries Service
taylor.debevec@noaa.gov

Dave Demer
SWFSC FRD
david.demer@noaa.gov

Phillip Dionne
Washington Dept. of Fish and Wildlife
phillip.dionne@dfw.wa.gov

Emmanis Dorval
SWFSC FRD- Lynker Technologies
emmanis.dorval@noaa.gov

Brad Erisman
SWFSC FRD
brad.erisman@noaa.gov

Stephanie Flores
SWFSC FRD
stephanie.flores@noaa.gov

Anne Freire
Contractor with OAI at NOAA SWFSC
anne.freire@noaa.gov

Emily Gardner
SWFSC FRD
emily.gardner@noaa.gov

Kerry Griffin
Pacific Fishery Management Council
Kerry.Griffin@noaa.gov

Pierre-Yves Hernvann
University of California, Santa Cruz /
NWSFC NOAA Seattle
pierre.yves.hernvann@gmail.com

Roger Hewitt
SWFSC FRD
roger.hewitt@noaa.gov

James Hilger
SWFSC FRD
james.hilger@noaa.gov

Kevin Hill
SWFSC FRD
kevin.hill@noaa.gov

Kristen Hinton
Washington Department of Fish and Wildlife
Kristen.hinton@dfw.wa.gov

Michelle Horeczko
California Department of Fish and Wildlife
Michelle.Horeczko@wildlife.ca.gov

Megan Human
Contractor with OAI at NOAA SWFSC
megan.human@noaa.gov

John Hyde
SWFSC FRD
John.Hyde@noaa.gov

Kym Jacobson
NOAA Fisheries/Northwest Fisheries Science Center
kym.jacobson@noaa.gov

Kelsey James
SWFSC FRD
kelsey.james@noaa.gov

Barbara Javor
Retired NMFS/SWFSC
barbara.javor.noaa@gmail.com

Jeff Kaelin
Lund's Fisheries, Inc.
jkaelin@lundsfish.com

Stefan Koenigstein
UCSC, NOAA SWFSC
stkoenig@ucsc.edu

Lisa Komoroske
University of Massachusetts & NOAA-SWFSC
lkomoroske@umass.edu

Gregory Krutzikowsky
Oregon Dept. of Fish and Wildlife
greg.krutzikowsky@state.or.us

Peter Kuriyama
SWFSC FRD
peter.kuriyama@noaa.gov

Josh Lindsay
NMFS West Coast Region
joshua.lindsay@noaa.gov

Nancy Lo
Retired NMFS/SWFSC
nancylo@san.rr.com

Frank Lockhart
West Coast Region NMFS
frank.lockhart@noaa.gov

Joshua Lonthair
NOAA - Southwest Fisheries Science Center & UMass - Amherst
joshua.lonthair@noaa.gov

Kirk Lynn
California Department of Fish and Wildlife
kirk.lynn@wildlife.ca.gov

Beverly Macewicz
Retired NMFS/SWFSC
bevjm@san.rr.com

Erica Mason
Scripps Institution of Oceanography, University of San Diego & NOAA Fisheries SWFSC
erica.mason@noaa.gov

Lynn Massey
NMFS West Coast Region
lynn.massey@noaa.gov

Dane McDermott
California Department of Fish and Wildlife
dane.mcdermott@wildlife.ca.gov

Barbara Muhling
UC Santa Cruz and NOAA SWFSC
barbara.muhling@noaa.gov

Dana Myers
California Department of Fish and Wildlife
dana.myers@wildlife.ca.gov

Trung Nguyen
California Department of Fish and Wildlife
trung.nguyen@wildlife.ca.gov

Mike Okoniewski
Consultant to Pacific Seafood-Board West Coast Pelagic Conservation Group
MOkoniewski.consultant@pacificseafood.com

John O'Sullivan
Monterey Bay Aquarium
josullivan@mbayaq.org

Richard Parrish
Retired NMFS/SWFSC
rhparrish@sbcglobal.net

Diane Pleschner-Steele
California Wetfish Producers Association
dplesch@gmail.com

Dianna Porzio
California Department of Fish and Wildlife
dianna.porzio@wildlife.ca.gov

Antonella Preti
SWFSC FRD
antonella.preti@noaa.gov

Chelsea Protasio
California Department of Fish and Wildlife
chelsea.protasio@wildlife.ca.gov

Todd Sandell
Washington Dept. of Fish and Wildlife,
Marine Fish Unit
Todd.Sandell@dfw.wa.gov

Will Satterthwaite
SWFSC FED
will.satterthwaite@noaa.gov

Brittany Schwarzkopf
SWFSC FRD
brittany.schwartzkopf@noaa.gov

Greg Shaughnessy
Ocean Gold Seafoods/West Coast Pelagic group
gshaughnessy@oceancos.com

Christina Show
SWFSC FRD
christina.show@noaa.gov

Jill Smith
Oregon Dept of Fish and Wildlife
Jill.M.Smith@state.or.us

Owyn Snodgrass
SWFSC FRD
owyn.snodgrass@noaa.gov

Kevin Stierhoff
SWFSC FRD
kevin.stierhoff@noaa.gov

Steve Stohs
SWFSC FRD
stephen.stohs@noaa.gov

Dale Sweetnam
SWFSC FRD
dale.sweetnam@noaa.gov

Andrew Thompson
SWFSC FRD
andrew.thompson@noaa.gov

Desiree Tommasi
SWFSC and UCSC
desiree.tommasi@noaa.gov

Lanora Vasquez Del Mercado
SWFSC FRD
lanora.vasquezdelmercado@noaa.gov

Russ Vetter
Retired NMFS/SWFSC
russdvetter@gmail.com

Anthony Vuoso
Cal Marine Fish Company
avuoso@calmarinefishco.com

Lorna Wargo
Washington Department of Fish and Wildlife
Lorna.Wargo@dfw.wa.gov

Bill Watson
SWFSC FRD
william.watson@noaa.gov

Nick Wegner
SWFSC FRD
nick.wegner@noaa.gov

Ed Weber
SWFSC FRD
ed.weber@noaa.gov

Annie Yau
SWFSC FRD
annie.yau@noaa.gov

Appendix II: Agenda

Monday, January 11

9:00 **Opening remarks and meeting logistics.** Dale Sweetnam* (SWFSC).

9:10 **In memory of Dr. John Hunter.** Nancy Lo* and Beverly Macewicz.

9:30 Regional Sardine Fisheries Reports

Information and Examples on Recent Fisheries and Oceans Canada Initiatives on Small Pelagic Fishes. Linnea Flostrand* (DFO).

10:00 **Coastal Pelagic Species Fisheries in the U.S. Pacific Northwest.** Lorna Wargo* (WDFW), Gregory K. Krutzikowsky (ODFW), Alan Sarich (Quinault Nation).

10:15 **California Coastal Pelagic Species Report.** Dana Myers* and Dane McDermott (CDFW).

10:30 **The Fishery of Small Pelagic on the Western Coast of Baja California, Mexico, Fishing Season 2019.** Concepción Enciso-Enciso*, Celia Eva Cotero-Altamirano, Eduardo Álvarez-Trasviña y Julio C. Peralta-Ramos. (CRIAP- Ensenada; INAPESCA).

10:45 **Pacific Fishery Management Council Report/Update.** Kerry Griffin* (PFMC)

11:00 **Assessment of the Pacific Sardine Resource in 2020 for U.S. Management in 2020-21.** Peter T. Kuriyama*, Juan P. Zwolinski, Kevin T. Hill, and Paul R. Crone (SWFSC).

11:15 Contributed Papers

Climate Variability and Sardine Recruitment Success in the California Current. Tim Baumgartner* and Jose Augusto Valencia (CICESE).

11:30 **Stock Assessment and Management of the Tempered Stock of Pacific sardine *Sardinops sagax* on the West Coast off the Baja California Peninsula, Mexico (1989-2019).** Concepción Enciso-Enciso* (INAPESCA; FACIMAR-UAS), Manuel O. Nevárez-Martínez (INAPESCA), Rebeca Sánchez-Cárdenas (FACIMAR-UAS), Emigdio Marín Enriquez (FACIMAR-UAS), Luis A. Salcido-Guevara (FACIMAR-UAS), Carolina Minte-Vera (CIAT), and Martin E. Hernández-Rivas (CICIMAR-IPN).

11:45 **Preparing a Rebuilding Plan for the Northern Subpopulation of Pacific Sardine.** Gregory Krutzikowsky* (ODFW).

12:00-12:30: Lunch break

12:30 **Provisional Plans for Spring 2021 CPS and Summer 2021 CCE Surveys from FSV *Reuben Lasker*.** David A. Demer*, Kevin Stierhoff, and Juan P. Zwolinski (SWFSC).

12:45 **Towards Elucidating Mechanisms Controlling the Recruitment of Coastal Pelagic Fishes.** Andrew Thompson* (SWFSC).

13:00 **A Multiscale and Multimodel Framework to Explain Pelagic Fish Larvae Spatial Distribution Linked to Ocean Thermal Fronts Across the Large Domain of the Southern California Current System.** Amelia de la O Navarrete (CICIMAR), Ruben Rodriguez-Sanchez*(CICIMAR), Hector Villalobos (CICIMAR), Sofia Ortega-Garcia (CICIMAR) and Raul Martinez-Rincon (CIBNOR).

13:15 **Ecosystem-Based Management Adds Incentives for Cooperative Management of Pacific Sardine.** Andres Cisneros* (UBC).

13:30 **Reproductive Biology of Sardine *Sardinops caeruleus* From the Western Coast of Baja California During 2019.** Celia Eva Cotero Altamirano*, Concepción Enciso Enciso, Marianne Moreno Willerer, Julio Peralta, Héctor Valles Ríos (INAPESCA).

13:45 **Impacts of Temperature Acclimation on the Physiology of Pacific Sardine (*Sardinops Sagax*).** Lonthair, J. (SWFSC; ECO UMass Amherst), Wegner, N.C. (SWFSC), Fangue, N.A. (WFCB UC Davis), and Komoroske, L.M. (ECO UMass Amherst).

14:00 **Toxic Phytoplankton Potentially Limit Sardine Productivity.** Barbara Javor* (Retired SWFSC)

14:15 Group Discussion: Making up for Time Lost in 2020 and Planning for 2021.

15:00 Closing Remarks & Host of the December 2021 Forum.