Southwest Fisheries Science Center

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

JULY 2022

PROCEEDINGS OF THE 22ND ANNUAL TRINATIONAL SARDINE & SMALL PELAGICS FORUM Virtual Event May 2, 2022

edited by

Stephanie Flores

ADMINISTRATIVE REPORT LJ-22-01

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National Marine Fisheries Service
National Oceanic & Atmospheric Administration
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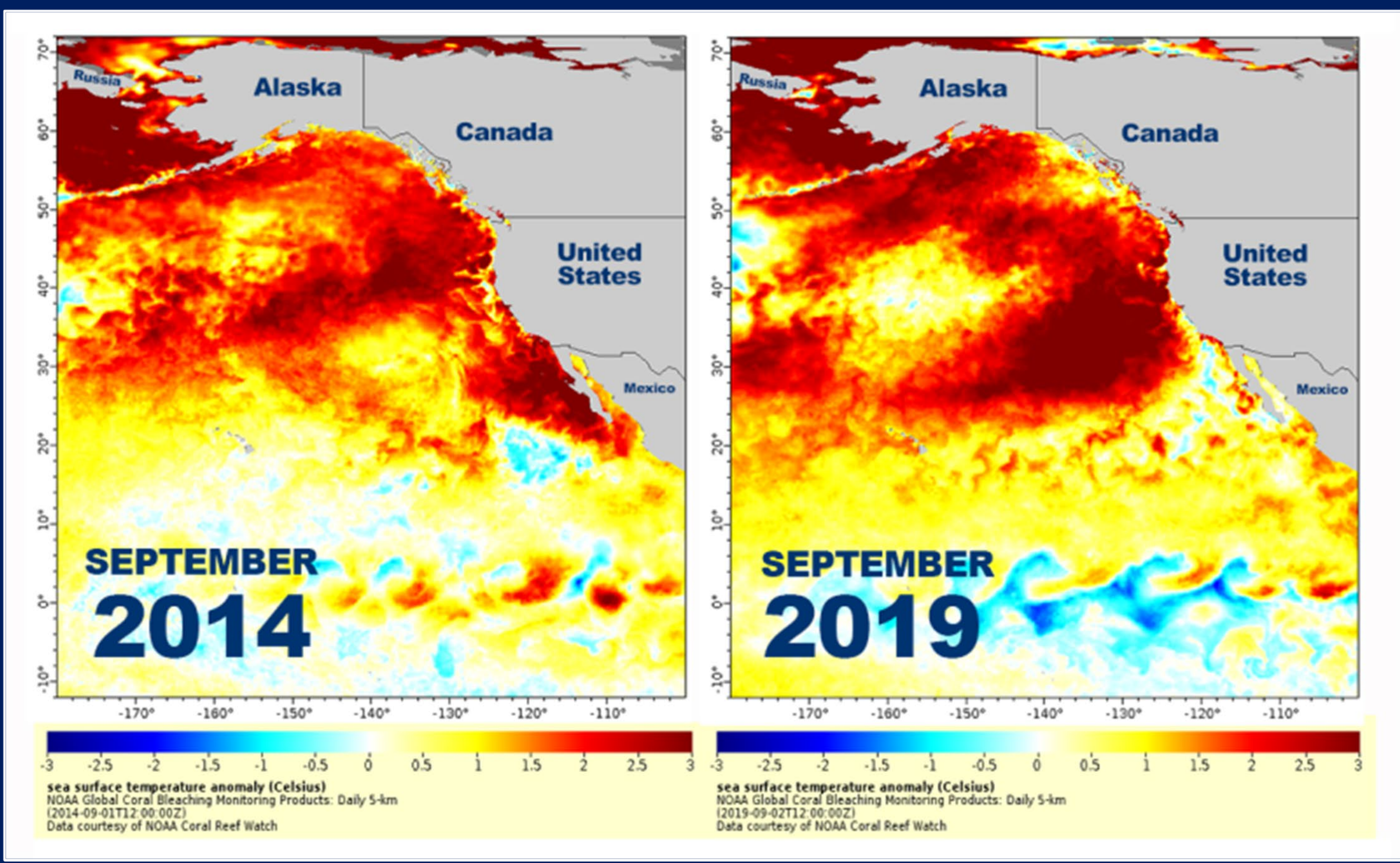
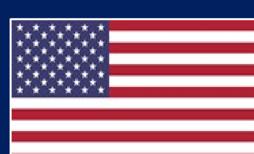
ADMINISTRATIVE REPORT LJ-22-01

22ND ANNUAL TRINATIONAL SARDINE & SMALL PELAGICS FORUM

MAY 2, 2022

VIRTUAL EVENT





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, 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. Affecting countless other entities, the pandemic had impacts on 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 repercussions on the future of surveys and management. Scientists, management bodies, academics, and industry members were relegated to staying at home, and labs and research were moved into the home. Despite these limitations, our members continued their work. 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 inaugural meeting in 2000, Mexico, Canada, and the United States have rotated hosting this 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 (WDFW), Oregon Department of Fish and Wildlife (ODFW)

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

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INTRODUCTION

The Southwest Fisheries Science Center Fisheries Resources Division (SWFSC FRD) hosted the 22nd Annual Trinational Sardine and Small Pelagics Forum on Monday, May 2. The virtual platform this year broadened the Forum's reach and over 93 participants from Canada, Mexico, and the United States participated and represented government agencies, academia, and industry (Appendix I). Special thanks to Stephanie Flores for her aid in the logistical planning. We thank Dale Sweetnam for leading the Forum and Kelsey James, Owyn Snodgrass, and Brittany Schwartzkopf for their roles as Q&A moderators. Thanks to Matt Craig for his review of the Proceedings.

FRD Deputy Director, Dale Sweetnam, opened the meeting with greetings and well wishes. He stated that while the past few years have been challenging, the promise of getting back to normal seems near as the pandemic appears to wane. He mentioned that he hopes everyone will be able to meet in person once again by the next Trinational.

Following the opening remarks, representatives from Mexico and the United States presented current quotas and landings, surveys, and industry information during the Regional Fisheries Reports. Jessi Doerpinghaus introduced herself as the new Pacific Fisheries Management Council (PFMC) member and gave a quick summary of the Council Report. Peter Kuriyama (FRD) then presented the Assessment of the Pacific Sardine Resource in 2022 for U.S.A. Management 2022-23. The second half of the day consisted of the presentation of contributed papers.

REGIONAL SARDINE FISHERIES REPORTS

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

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Directed CPS fisheries in the U.S. Pacific Northwest in 2020 and 2021 pursued *Doryteuthis opalenscens*, *Engraulis mordax*, and small-scale opportunity for *Sardinops sagax*. Purse seine fishing for CPS off Oregon focused on *D. opalenscens*. The Oregon Fish and Wildlife Commission (Commission) enacted new rules and set a control for potential use should it decide to change to a limited entry *D. opalenscens* fishery in the future. Washington CPS fisheries were limited to directed *E. mordax* fishing. For *S. sagax*, the biomass estimate for the northern subpopulation was again below the cutoff value of 150,000 mt for the 2020-2021 fishing year, thus restricting directed fisheries for this stock to small-scale fisheries landing less than 1 mt per day. Harvest of *S. sagax* in small-scale fisheries occurred only in Oregon. No directed CPS fisheries for *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 as well as information on Commission actions.

California Coastal Pelagic Species Report

Dana Myers

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Coastal pelagic species (CPS), including *S. sagax*, *E. mordax*, *S. japonicus*, and *Trachurus symmetricus*, are managed by the National Marine Fisheries Service (NMFS) under the Pacific Fishery Management Council's (PFMC) CPS Fishery Management Plan. *S. sagax* was declared overfished in June 2019 and a rebuilding plan was adopted by PFMC in September 2020. In 2020, the *S. sagax* stock assessment estimated age 1+ biomass at below the "cutoff" threshold value of 150,000 metric tons (mt) in the harvest control rule. As a result, the primary directed commercial *S. sagax* fishery was closed for the 2020/2021 fishing season (July 1, 2020, through June 30, 2021). NMFS implemented an annual catch limit of 4,288 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 2020/2021 fishing season, total landings of *S. sagax* in California were approximately 2,479 mt from 66 unique vessels, with 72 percent of the state total (1,792 mt) landed in Southern California. Also for the 2020/2021 fishing season, 500 mt of *S. japonicus* was landed. For CPS managed on a calendar year fishing season (January 1 through December 31), 2021 landings totaled 2,894 mt of *E. mordax* and 23 mt of *T. symmetricus*.

The Coastal Pelagic Species Fishery off the Western Coast of the Baja California Peninsula, Mexico, Fishing Season 2021.

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

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In Mexico, the coastal pelagic species fishery (CPSF) are the most important fishing resource at the national level due to their capture volumes, with a total production of 1.09 million tons (t) registered in the 2021 fishing season representing 50% of the total fishing and aquaculture production in the country. The Ensenada (ENS) and Bahía Magdalena (BM) fleets operate off the western coast of the Baja California peninsula (Zone A), whose catches of 271,955 t recorded by both fleets represented 25% of the total catches of CPSF and 70% above the historical average in Zone A (2003-2020, 160,126 t/year). Of the total, *S. sagax* contributed a catch of 199,126 t (73%), *E. mordax* with 44,100 t (16%), *Opisthonema libertate* with 13,732 t (5%), *S. japonicus* with 8,437 t (3%), *Etrumeus acuminatus* with 4,000 t (2%), and *Cetengraulis mysticetus* with 2,927 t (1%). The monthly catch yield ranged between 16,356 and 26,281 t/month and an average of 22,663 t/month. The recorded fishing effort for Zone A was 2,912 fishing trips made with 34 vessels (23 in ENS and 11 in BM). The average yield (CPUE) was 93.4 t/trip (83.7 ENS and 126.1 BM), which was 13.5% higher than the average CPUE recorded for the period 2003-2020. Of the total *S. sagax* catch recorded in Zone A, it was estimated that 70% corresponds to the temperate stock, 25% to the cold stock, and 5% to the warm stock.

Fishery Management Council Report/Update

Jessi Doerpinghaus

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Pacific Fishery Management Council Activities

The Pacific Fishery Management Council (PFMC/Council) is responsible for developing management measures for federally managed fish species on the U.S. West Coast, 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). There is also an ecosystem FMP that provides guidance and information on ecosystem matters as it applies to fisheries management.

The CPS FMP includes *S. sagax*, *S. japonicus*, *E. mordax* (northern and central subpopulations), *T. symmetricus*, and *D. opalescens*. Every year, the *S. sagax* 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

S. sagax

The northern subpopulation of *S. sagax* was declared overfished in June 2019 and NMFS approved the rebuilding plan in June 2021. Under the rebuilding plan, the primary directed commercial fishery is closed, with limited harvest allowed for live bait, minor directed fishing, exempted fishing permits, and incidental landings. Total harvest has averaged about 2,300 per season since 2015. In April 2022, the Council reviewed the stock assessment update and approved specifications for the 2022-23 fishing season. Based on discussions at that meeting, there will be forthcoming workshops targeted at resolving uncertainties within the stock assessment including issues on stock structure and catch by the Mexican fleet.

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 and completed Phase 1 at its April 2021 meeting. The CPS Management Team and SWFSC continue to work on potential revisions to CPS EFH for Council consideration at a future meeting.

Engraulis mordax

The Council adopted a process in June 2021 to periodically evaluate harvest reference points such as overfishing limit and acceptable biological catch of the central subpopulation of *E. mordax* (CSNA). A framework and flowchart describes that process and schedule. A stock assessment for CSNA was completed in December 2021. The Council and its advisory bodies will be reviewing the assessment and making recommendations on harvest specifications at the June 2022 meeting.

Update Assessment of the Pacific Sardine Resource in 2022 for U.S. Management in 2022-2023

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Update Assessment of the Pacific Sardine Resource in 2022 for U.S. Management in 2022-2023 (full copy)

Introduction

The *S. sagax* northern subpopulation (NSP) resource is assessed annually in support of the PFMC's process of specifying annual catch levels for the U.S. fishery. The following update assessment was conducted to provide a biomass estimate for harvest specifications during the 2022-2023 fishing year. This model contains updated data through model year-semester 2021-1 (July-December of calendar year 2021). Similar to the 2021 catch-only projection, catches from Ensenada, Mexico remained high. Additionally, observations from the acoustic-trawl survey indicated continued low biomass levels.

Methods

The following update assessment for 2022 management is based on data and methods described by Kuriyama et al. (2020), as reviewed by a Stock Assessment Review Panel in February 2020 and the Scientific and Statistical Committee in April 2020. The assessment update was conducted using Stock Synthesis (SS v.3.30.14).

The projection model included *S. sagax* NSP landings (metric tons) from six major fishing regions: Ensenada, Mexico (ENS), southern California (SCA), central California (CCA), Oregon (OR), Washington (WA), and British Columbia, Canada (BC). Catch data for the fisheries off ENS, SCA, and CCA were pooled into a single "MexCal" fleet, and catch data from OR, WA, and BC were combined and treated as a single "PacNW" fleet in the model. The *S. sagax* model is based on a July-June model year, with two semester-based seasons per year (S1-July to December and S2-January to June).

The 2020 benchmark assessment used F values (yr-1; as opposed to catch) to forecast for 2021. This update assessment used this approach and used similar assumptions to forecast for 2022. The updated data values are shown in the following section.

Data

Catch values were updated through model year-semester 2021-1 (Tables 1a and 1b). The model year-semester 2020-2 catch value of 48,312 mt was assumed to be constant for 2021-2, consistent with the assumptions made in the 2020 base model.

Table 1a: *S. sagax* landings (mt) for major fishing regions off northern Ensenada, Mexico, the United States, and British Columbia, Canada. Ensenada (ENS) and Southern California (SCA) landings are presented as totals and northern subpopulation values. Time periods shown are calendar year-semester and model year-semester.

Calendar Y-S	Model Y-S	ENS Total	ENS NSP	SCA Total	SCA NSP	CCA	OR	WA	BC
2015-1	2014-2	16,496.60	-	1,543.20	-	727.70	2,131.30	62.60	-
2015-2	2015-1	20,971.90	-	1,420.90	-	6.10	0.10	66.10	-
2016-1	2015-2	23,536.70	-	423.40	184.80	1.10	1.30	-	-
2016-2	2016-1	42,532.10	-	964.50	49.40	234.10	2.70	170.40	-
2017-1	2016-2	28,211.90	6,935.80	513.10	144.70	0.10	0.10	-	-
2017-2	2017-1	99,966.60	-	1,205.40	-	170.40	1.20	-	-
2018-1	2017-2	25,720.60	9,736.30	395.30	197.80	-	2.20	-	-
2018-2	2018-1	38,049.30	-	1,424.20	-	35.30	5.80	2.00	-
2019-1	2018-2	30,118.90	11,634.30	749.70	546.80	58.10	2.50	-	-
2019-2	2019-1	64,295.20	-	869.50	49.30	174.30	7.70	0.50	-
2020-1	2019-2	74,817.30	29,555.30	681.40	144.20	328.50	0.10	-	-
2020-2	2020-1	74,686.80	-	1,203.70	113.50	428.80	0.40	-	-
2021-1	2020-2	56,274.10	48,005.40	601.70	269.60	37.30	2.90	-	-
2021-2	2021-1	86,643.20	-	1,093.00	89.90	2.90	8.60	2.70	-

Table 1b: Finalized catch values for fleet by model year-semester (bolded columns). Preliminary values used in the 2021 catch-only projection are adjacent to the bolded columns. The values in bolded columns show up-to-date values used in the 2022 update assessment. Catch is assumed to be the same for model year-semester 2021-2 for the MexCal S2 fleet.

Calendar Y-S	Model Y-S	MexCal_S1	**MexCal_S1**	MexCal_S2	**MexCal_S2**	PNW	**PNW**
2019-2	2019-1	223.61	**223.61**	0	**0**	8.20	**8.198**
2020-1	2019-2	0	**0**	33,070.23	**33,070.23**	0.06	**0.06**
2020-2	2020-1	764.00	**542.27**	0	**0**	0.42	**0.42**
2021-1	2020-2	--	**0**	--	**48,312.25**	--	**2.93**
2021-2	2021-1	--	**92.84**	--	**0**	--	**11.22**
2022-1	2021-2	--	**0**	--	**48,312.25**	--	**2.93**

Results

Summary biomass (age 1+) for the 2022 fishing year is forecast to be 27,311 mt (Fig. 5), and recruitment is forecast to be 241 million age-0 fish (Fig. 6). The update assessment estimated higher recruitment events in 2018, 2019, and 2020 (Fig. 6), likely the result of higher catch values than previously used for both the 2021 catch-only projection (Kuriyama et al. 2021) and 2020 benchmark (Kuriyama et al. 2020).

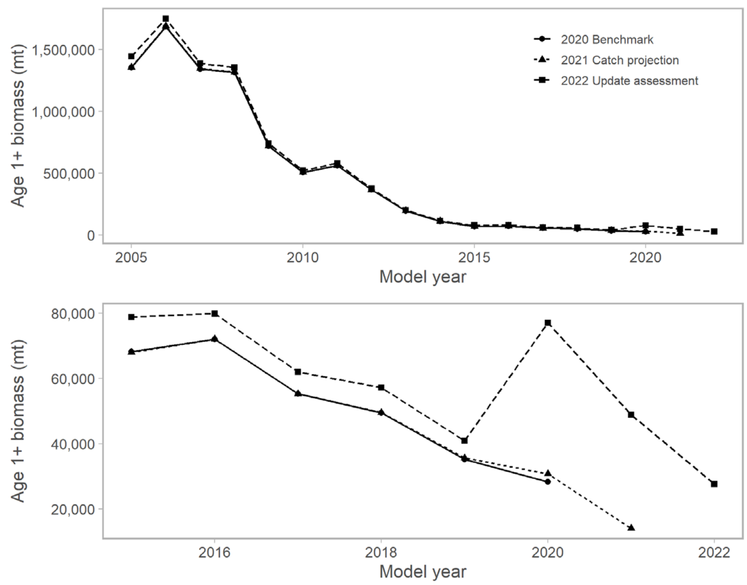

Figure 5: Time series of summary biomass (age 1+; mt) for the 2020 benchmark assessment (circles), 2021 catch-only projection (triangles), and 2022 update assessment (squares). The last point of each line is the forecast summary biomass.

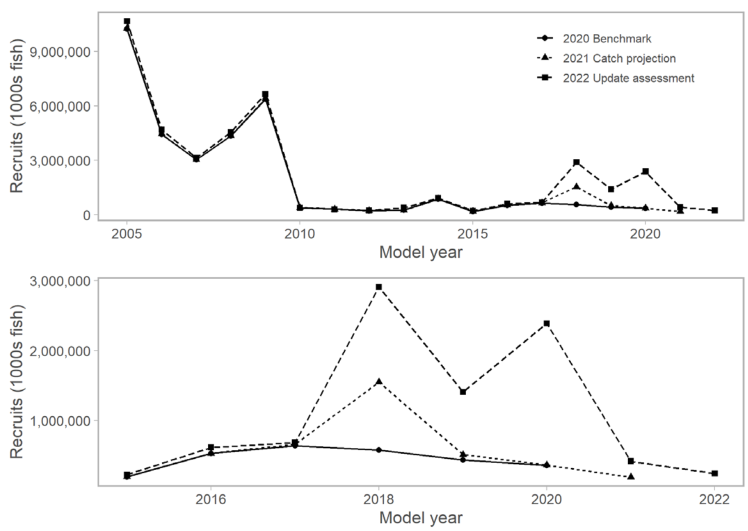

Figure 6: Time series of recruits entering the population (thousands of age-0 fish) for the 2020 benchmark assessment (circles), 2021 catch-only projection (triangles), and the 2022 update assessment (squares). The top panel shows values from 2005-2022, the bottom shows 2015-2022.

Exploitation Status

Exploitation rate is defined as the calendar year catch divided by the total mid-year biomass (July-1, ages 0+). Based on the latest model and historic catches, the U.S. exploitation rate was less than 1% in 2021 (Fig. 7). Mexico had an annual exploitation rate of 27%, and the total exploitation rate for Mexico, USA, and Canada was 28% of the total biomass. These exploitation rates are lower than those reported in the 2021 catch-only projection due to the higher recruitments estimated for recent years.

Harvest Control Rules

The harvest guidelines are shown in Table 4 and are based on the forecast age 1+ biomass of 27,369 mt. The stock is below the 150,000 mt management threshold and the harvest guideline is 0 mt for 2022.

Acceptable biological catches for a range of P-star values are also shown in the Table 4 (Tier 1 σ=0.5; Tier 2 σ=1.0; Tier 3 σ=2.0).

Table 4: Harvest control rules for the 2022-2023 management year.

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)	**27,369**								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{(Tier\ 1;\ Sigma\ 0.5)}$	0.93910	0.88102	0.82476	0.76936	0.71373	0.65651	0.59558	0.52688	0.43936
ABC $Buffer_{(Tier\ 2;\ Sigma\ 1.0)}$	0.88191	0.77620	0.68023	0.59191	0.50942	0.43101	0.35472	0.27761	0.19304
ABC $Buffer_{(Tier\ 3;\ Sigma\ 2.0)}$	0.77777	0.60248	0.46272	0.35036	0.25950	0.18577	0.12582	0.07707	0.03726
CalCOFI $SST_{(2019\text{-}2021)}$	16.0393								
E_{MSY}	0.231257								
FRACTION	0.200000								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values (MT)									
OFL =	**5,506**								
ABC(Sigma 0.607) =	5,171	4,851	4,542	4,236	3,930	3,615	3,280	2,901	2,419
ABCTier 2 =	4,856	4,274	3,746	3,259	2,805	2,373	1,953	1,529	1,063
ABCTier 3 =	4,283	3,318	2,548	1,929	1,429	1,023	693	424	205
HG =	**0**								

Recent Management Performance

U.S. landings in the past years have remained below the annual catch limits (or annual catch targets, when applicable; Table 5). The 2021-2022 annual catch target was 3000 mt for *S. sagax* (Table 5). Landings-to-date of the northern subpopulation in the U.S. were 105 mt for 2021-22, 3.5% of the annual catch target (Table 6).

Table 5: USA northern subpopulation (NSP) landings, overfishing limit (OFL), allowable biological catch (ABC), annual catch limit (ACL), and annual catch target (ACT) values for recent fishing years. All units are in mt.

Fishing-year	USA NSP Landings	OFL	ABC	ACL	ACT
2017-2018	372	16,957	15,497	8,000	
2018-2019	651	11,324	9,436	7,000	
2019-2020	705	5,816	4,514	4,514	4,000
2020-2021	852	5,525	4,288	4,288	4,000
2021-2022	105	5,525	3,329	3,000	3,000

Table 6: Annual catch limit (ACL), annual catch target (ACT) values, and NSP catches from USA, Mexico, and Canada for recent fishing years. All units are in mt. Note, Mexican landings for the 2021-2022 fishing year (*) have not been reported yet.

Fishing-year	USA ACL	USA ACT	USA Landings	Mexico Landings	Canada Landings
2017-2018	8,000		372	9,736	0
2018-2019	7,000		651	11,634	0
2019-2020	4,514	4,000	705	29,555	0
2020-2021	4,288	4,000	852	48,005	0
2021-2022	3,000	3,000	105	*	0

Uncertainties

The uncertainties discussed in the 2020 benchmark and 2021 catch-only projection reports remain in this assessment. The amount of nearshore biomass and proportion of northern subpopulation in Mexican waters remains an uncertainty. Specifically, the MexCal_S2 F value of 4, used in projecting the population forward for management, is a major uncertainty.

This assessment estimated an increase in recruits compared to the previous assessments, likely in order to match the population dynamics to the input catch values removed by the fisheries. This increase is shown in Table 8, comparing the total (age 0+) biomass values across recent assessments. The increases in summary (age 1+) biomass values are shown in Table 9.

Research and Data Needs

While uncertainty regarding nearshore biomass remains, the 2021 spring and summer AT surveys increased nearshore coverage using acoustics in collaboration with the fishing industry. The spring 2021 survey found a majority of the observed biomass nearshore and outside of the core survey grid (Table 2). There were updates to the CCPSS aerial survey, and these data were incorporated through adjustments to Q. The recommendations for the aerial survey included the need to coordinate visual estimates with randomly sampled purse-seine point sets, temporal rather than spatial replication, and sufficient biological sampling on mixed anchovy and sardine schools. The 2021 spring and summer acoustic-trawl surveys will make strides toward increasing nearshore coverage using acoustics in collaboration with the fishing industry.

CONTRIBUTED PRESENTATIONS

Against the odds: A Historical Trinational Survey of CPS during a Pandemic

David Demer[1], Isaac Rojas[2], Kevin Stierhoff[1], Roberto Vallarta[2], Josiah Renfree[1], Greg Shaughnessy[3], Lorna Wargo[4], and Juan Zwolinski[1]

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[3]Ocean Gold Seafoods, COO. West Coast Pelagic Conservation Group, VP Commercial Fisherman. P.O. Box 1104 Westport WA 98595
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Since 2006, the FRD at SWFSC has used the acoustic-trawl method (ATM) to assess status and trends of populations of coastal pelagic species (CPS) in the California Current. The COVID-19 pandemic precluded an ATM survey during 2020. Although the pandemic continued in 2021, the FRD endeavored to conduct not just one, but two CPS surveys from NOAA ship *Reuben Lasker*. Additionally, the spring survey was augmented with nearshore sampling from FV *Long Beach Carnage*; and the summer survey included nearshore sampling from FVs *Long Beach Carnage* and *Lisa Marie* as well as interstitial and offshore-extended transects by four Saildrones. Moreover, *Lasker*'s sampling was permitted to extend into Mexican waters for the first time in over five decades and, through a historic collaboration with INAPESCA and coordination with their sampling from RV *Dr. Jorge Carranza Fraser*, the survey assessed CPS populations from Cape Flattery, WA, to Punta Abreojos, Baja California Sur. The presentation will include details of these collaborative data collections and analyses and a summary of the results from 2021 focused on the trajectories of the Central Stock of *E. mordax* and the Northern Stock of *S. sagax*. Also included is a vignette of industry's collaboration to sample CPS nearshore.

Aerial Survey of Small Pelagic Species in Nearshore California Waters

Kirk Lynn[1], Emmanis Dorval[2], Dianna Porzio[3], Trung Nguyen[3], and Dana Myers[1]

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S. sagax and *E. mordax* are important West Coast fisheries managed within the Coastal Pelagic Species (CPS) complex by the Pacific Fishery Management Council (PFMC) and the National Marine Fisheries Service. The California Department of Fish and Wildlife and the California Wetfish Producers Association have collaborated in conducting an aerial survey of nearshore Pacific *S. sagax* biomass within the Southern California Bight since the summer of 2012, and *E. mordax* since 2013. In 2017, the survey was extended to include nearshore abundance in Northern California. The PFMC conditionally approved the aerial survey methodology for use in CPS stock assessments in June 2017. A nearshore cooperative survey project began in late 2018 to develop a variance estimator and a bias correction factor for aerial biomass. Survey data indicate observer estimates are negatively biased, underestimating fish biomass by approximately 10%. Replicated strata have been implemented for this survey beginning in 2020 to improve variance estimation. Nearshore aerial biomass has recently been used in stock assessments of *S. sagax* and *E. mordax* to adjust catchability of the offshore Southwest Fisheries Science Center acoustic-trawl survey, providing a more complete picture of stock status for these species.

Reproductive Biology of Sardine (Sardinops caeruleus) from the Western Coast of Baja California During 2020

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

Small pelagic fishes, specifically *S. caeruleus*, are the most important resource in Mexico. The National Fishery and Aquaculture Institute, as scientific advisor to Fishery Authority, maintains a monitoring program to manage fisheries with the goal of sustainability.

Biological samples were collected from the commercial fleet to determine reproductive biology during the 2020 season. Researchers recorded the standard lengths, individual weights, sex and maturity of the *S. caeruleus*. In the lab, samples from female and males gonads were processed with histological techniques.

The results indicated that the size structure was between 75 - 194 mm with an average of 136 mm and a mode of 140 mm standard length. Reproductive activity was observed throughout the year, though the spawning peak was detected in April and three other peaks in July, August, and November. Researchers observed a strong relationship between temperature and upwelling with maturity. The length at maturity was at 146 mm.

A Preliminary Review of Biological Data Used to Evaluate Subpopulation Structure in Pacific Sardine.

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The rise and fall of the *S. sagax* fishery off the west coast of the U.S. and Canada is a well-documented series of events that has influenced the economics, management, and research of exploited fish species for decades. Numerous studies have attempted to understand and explain the rapid declines in *S. sagax* landings during the early 1940s. One prevailing hypothesis is the supposition that there are multiple subpopulations of *S. sagax*, the existence of which influences the dynamic nature of the abundance of these fish across the west coast of North America. Recently, a renewed interest in the underlying biological information that led early researchers towards hypothesized subpopulation divisions in *S. sagax* has developed. With this renewed interest, we are taking the opportunity to explore and evaluate the earliest biological studies pertaining to this topic. We are beginning by revisiting commonly cited papers that included studies on vertebral counts, tagging, and serological antigen responses, all of which took place from the 1920s to the 1960s. We plan to continue this review to include other biological information in the coming months.

Discussion:

Some discussion revolved around the temporal aspects of *S. sagax* as they migrate seasonally. One suggestion was to re-aggregate the data, if available, into groups by their associations with corresponding potential oceanographic habitats. However, the presenter noted that while the vertebral count studies used all the same data, so there certainly could be a temporal "problem" in that things could have changed, the data don't show a change and the other studies were all within a pretty tight time range. Overall, regardless of spatio-temporal sampling issues, neither vertebral count nor antigens are considered valid criteria for assessing population structure as the field has since advanced considerably. Rather, the presenter is reviewing all studies of reproductive biology of *S. sagax* both in relation to current views on stock structure and through the lens of reproductive ecology of marine fishes.

Stock Assessment of the Temperate Stock of Pacific Sardine* Sardinops sagax *on the West Coast of the Baja California Peninsula, Mexico (1989-2021).

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S. sagax is the most important fishery resource in Mexico due to the volumes recorded. It is an organism that has historically shown great fluctuations both in its abundance and in its distribution. Three stocks have been identified for *S. sagax*: cold stock (*CS*), temperate stock (*TS*), and warm stock (*WS*); which dynamically overlap, influenced by the sea surface temperature. Current Mexican regulations suggest active management, which requires permanent evaluation of the different stocks. The objective of the present study is to evaluate the abundance of *TS* off the western coast of the Baja California peninsula for the period 1989-2021. From catch-by-age data, fishing effort and indicators dependent and independent of the fishery (CPUE, estimation of biomass by acoustics), a statistical analysis of catch-by-age (ACE) was applied, which allowed estimating the population size and get some reference points for management. The results indicated a great interannual variability in abundance (*TTB*), ranging between 853,476 t and 1,592,519 t and spawning biomass (*SSB*) between 404,189 t to 770,484 t. Considering *SSB* estimated for 2021 SSB_{2021}= 496,894 t, the exploitation rate E_{MSY}=0.268 yr^{-1} and the minimum biomass B_{MIN}=39,605 t, the Control Rule for the 2022 fishing season was estimated at CBA_{2022}=122,312 t. With the projection of the Kobe diagram throughout the analyzed period (1989-2021), it is inferred that the level of exploitation for *TS* has remained at sustainable levels at both objective reference points (*F/FMRS* and SSB/SSB_{MSY}).

Validation of Pacific Sardine Annuli in a Captive Growth Experiment

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S. sagax are an economically important forage fish in the eastern North Pacific Ocean. Their boom and bust cycles of abundance make them particularly challenging to assess and manage. The stock assessment incorporates fishery-dependent and fishery-independent age data generated by SWFSC, CDFW, and WDFW to facilitate the annual estimation of abundance. These federal and state agencies have worked closely with laboratories in Canada (DFO) and Mexico (CICIMAR-IPN) on ageing methodology to ensure consistency, however the annuli of *S. sagax* have not been validated. Live *S. sagax* (mostly age 0) were collected, marked with oxytetracycline (OTC), and raised in captivity at different temperatures (13°C, 15°C, 17°C, & 21°C) for up to one year. Individuals did not grow differently across most temperatures. Similarly, otolith growth was not different across most temperatures. Of 21 individuals that were in captivity for one year, 17 had deposited 2-3 increments distal to the OTC mark. This is evidence to validate the assumption that annuli are deposited annually in young *S. sagax* (1-2 years old). This also supports the ageing methodology used for this species by all ageing laboratories in the U.S., Mexico, and Canada.

Discussion:

When asked what they believe was the source of change in seasonal otolith increment deposition (given that the fish were reared in captivity, held at constant temperature, and fed consistently throughout the year), the presenter explained that the presence of the deposits despite a lack of external cues suggests internal regulation, though this has not been verified. She also affirmed that they changed the duration of day length during each season. Thus, in terms of photoperiod, the lab fish experienced nearly the same variation as they would in the wild.

Why do Sardine Populations Undergo Multidecadal Booms and Crashes?

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Evidence from historical fish scale deposition in coastal sediments indicates *S. sagax* populations have undergone frequent periods of booms and crashes as a result of unidentified driving factors. An evaluation of life history characteristics of *S. sagax* that differ from those of anchovy and other small, coastal pelagic fish may provide clues to the reasons why their stocks undergo dramatic fluctuations when other species appear to be unaffected. While both *S. sagax* and anchovy feed on small zooplankton, *S. sagax* are unique in their ability to also filter-feed on microplankton in the 10-100 µm size range, which includes diatoms and dinoflagellates. Some diatoms produce oxidized fatty acids (oxylipins) that inhibit copepod reproduction, but the conditions that promote their blooms and induce oxylipin production in the ocean are not well known. Some dinoflagellate toxins may also play a role in inhibiting *S. sagax* reproduction and viability, but they have not been tested. A key to predicting the success of *S. sagax* may lie in better knowledge of what drives the succession of plankton species and toxin production at the bottom of the food chain. Other possible factors that might periodically inhibit successful *S. sagax* reproduction are pathogens such as viruses that caused significant mortality events in *S. sagax* in British Columbia and Australia in recent years. Annual migrations of the cold stock of *S. sagax* between California and the Pacific Northwest may promote the spread of periodic viral or other pathogen infections; multi-year infections may diminish the brood stock to levels that prevent sufficient recruitment and maintenance of healthy populations.

Long-term population projections of Pacific sardine driven by ocean warming and changing food availability

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S. sagax in the California Current upwelling system has supported important fisheries in the past, but contrary to expectations, remains at low biomass despite recent warm ocean conditions. After decades of research and advances in biological understanding, *S. sagax* vulnerability to combined climatic changes, fisheries exploitation and ecosystem shifts remains incompletely understood, posing challenges for management and long-term adaptation.

We developed a process-based population model which reproduces the last boom-and-bust of the U.S. *S. sagax* population based on ocean temperature, early life stage and adult food, and upwelling strength. An ensemble model configuration set fit to observations considers a wide range of possible parameter combinations, identifying response mechanisms and bracketing ecological uncertainty. Population abundance, catch and distribution for the 21st century are projected from high-resolution, downscaled ocean-biogeochemical simulations under three earth system models (ESM).

The population model demonstrates that the lack of recovery in 2010 can be explained by reduced food availability, despite suitable warm ocean conditions and no fisheries harvest. Ensemble projections show a likely recovery of the *S. sagax* stock to early 2000's abundance and catch levels by mid-century, with generally increasing trends driven by increased recruitment success, as a function of warming temperatures and modulated by food availability. Ecological process uncertainty is of the same magnitude as uncertainty associated with different ESM projections. After 2065, uncertainty related to the thermal optimum of early life stage survival dominates in faster-warming ESM projections. A marked northward shift of spawning habitat leads to increased availability to the Pacific Northwest fishing fleet in the second half of the 21st century.

This work assesses the combined impacts of multiple environmental drivers, and quantifies sources of uncertainty to future abundance and distribution of *S. sagax* under novel environmental conditions. Even for a fish species presumably favored by warmer conditions, there are risks of stock declines in food-limited years and when passing unknown thermal optima. Improved quantitative understanding of population responses will open pathways for environment-responsive fisheries management strategies to mitigate climate change impacts.

Oxygen consumption, hypoxia tolerance, and temperature sensitivity of Pacific sardine,* Sardinops sagax*, under different temperature regimes.

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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. However, studies on the impacts of ocean warming on *S. sagax*, a key forage fish, have been understudied. *S. sagax* is known to be physiologically sensitive to temperature, however, the impacts of temperature on metabolic performance and other physiological parameters have not been examined. Here we sought to observe potential changes to key physiological metrics at three ecologically relevant temperature acclimations across a size range of sardines. We observed an increase in both routine and maximum metabolic rate with temperature. However, we found no impact of temperature acclimation on hypoxia tolerance but did observe that increasing body size significantly decreased hypoxia tolerance. Finally, we found a significant increase in thermal tolerance with elevated temperature acclimation, with warmer acclimated fish having a higher critical thermal maximum (CTmax). Overall, these data allow us to begin to elucidate size-specific physiological responses to temperature exposure in a critical California coastal pelagic species, which has significant implications for future fisheries yield projections, stock assessments, and ecosystem stability.

Discussion:

When asked whether temperature treatment impacts fish growth over the course of the study, the presenter noted that they did see reduced growth in the warmer temperature environments after increasing temperature over the ~1 year acclimation. He went on to explain that, using the scaling coefficient, they were able to mass-correct their metabolic performance measurements, which allows for comparison across the different size groups without fear that the differences are due to the impact of size on growth. He also clarified that they took the extra metabolic cost of warming temperature into account when determining the feed structure. Fish fed in warmer climates were fed a proportionally appropriate feed amount.

Also, due to the experimental design and the ability to measure their metrics across a wide range of sizes, they decided to limit the study to 19.5C. Previous observations by Emmanis Dorval found that 21C resulted in higher amounts of mortality.

A future question may explore whether the animals could/would acclimate to a warmer temperature. Metabolic performance metrics can be used to determine when aerobic scope is depleted, which could provide context to what that thermal limit is, but this would require collecting more metabolic performance metrics at different temperatures.

Spatial Dynamics of the Sardine in the California Current: Connecting Seasonal, Interannual and Long-Term Movements.

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In the attempt to understand the population dynamics of the *S. sagax* in the California Current System (CCS), two perspectives have been fundamental, the comparative approach with other ecosystems and the interdisciplinary research integrating observations, data , techniques, methods, perspectives, concepts and theories from several disciplines. Examples of integration have been studying the separate and combined effect of fishing and environmental variability; understanding the individual and superimposed effect of environmental variables of different time scales of *S. sagax*; the integration of observations and results produced by methods and techniques from different disciplines (*e.g.*, VPA, acoustics and aerial surveys, egg and larvae surveys, egg production method); as well as data analysis with different statistical techniques and the comparison of results resulting from multiple models to achieve robust inferences. Continuing in this progressive learning to appreciate and integrate the differences that derive from different scales and theories, we present here results integrated on the basis of published knowledge related to understanding the dynamics of the *S. sagax* population, both in a holistic perspective in the CCS, as well as structured in several units. The focus is on *S. sagax* movements at different spatial scales consistent with the time scales being analyzed. The ultimate goal is to understand how movements on minor spatial-temporal scales interrelate with large-scale, long-term changes in *S. sagax* abundance. To address this objective, we reconstructed the seasonal migrations and interannual spatial changes of *S. sagax* during the different stages of ENSO events over the course of the last warming period, when the bulk of the *S. sagax* biomass and the center of distribution of the population moved northward of the CCS. The analysis is based on spatially explicit monthly CPUE records of *S. sagax* caught as bait by tuna bait-boats along the southern part of the CCS over an 18-year period (1980-1997). The patterns observed in the distribution of the relative abundances of *S. sagax* in the different time scales analyzed are coherent and consistent, which allows inferring the movements of the *S. sagax* and could be used as a proxy to identify changes over time in the latitudinal distribution of environmental conditions factors that prevailed and gave rise to those patterns. For now, potential climatic drivers of spatial-temporal *S. sagax* shifts are not discussed in this presentation. The absence or inconsistency of long-term data is problematic when it comes to identifying climate drivers in the large domain of CCS. Thus, a fundamental assumption underlying the spatial-temporal changes described here is the implicit association with seasonal-scale ocean temperatures, the interannual changes in temperature associated with the different stages of ENSO events, and the regime shift toward warm ocean conditions that began in the mid-1970s.

Discussion:

When asked whether their data suggests a single, large mixed population along the entire Pacific coast, the presenter stated that this data does not deny the existence of 2-3 *S. sagax* stocks in the Pacific but rather shows that they are dynamic in time and space and that they are defined when the population is expanded. When the population expands, 2-3 important habitats are recognized (which allows the identification of 2-3 stocks) but they are not perennial habitats. When the favorable-unfavorable habitats change latitudinally, the population adapts to available favorable habitats and that is when there is a greater mixture. They expanded that this concept works with or without regional stocks. It is biomass that is moving around with the environment and the time scale is long enough that modest mixing of fish from different source areas can create the same pattern as rigid, never mixing, fishery stocks.

Evaluating Robustness of Harvest Control Rules to Variability in Pacific Sardine Recruitment

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Pelagic forage fishes exhibit large, cyclic fluctuations in biomass driven by periods of highly successful recruitment followed by stock collapse. Fluctuations in ocean temperatures, currents, and productivity resulting from climate change may disrupt or alter these recruitment cycles, and fisheries management must adapt to this added uncertainty if sustainable harvest of forage species is to continue. Using *S. sagax* as a case study, we conducted a management strategy evaluation to assess the robustness of current and alternative environmental harvest control rules under a variety of recruitment variability scenarios. The current control rule for *S. sagax* determines catch limits for the northern subpopulation as a function of biomass estimates from the stock assessment and an environmental correction using average sea surface temperature measured by CalCOFI. Alternative harvest control rules tested here included a constant harvest rate and rules developed to account for reliance of predators on forage fish prey. We tested each of these rules against scenarios in which randomly generated recruitment deviations were produced from distributions reflecting historical estimates, with and without autocorrelation, or in which the mean recruitment followed a trend as may be expected as climate changes. Successful harvest control rules had higher mean stock biomass and catch, with low catch variability, few fishery closures, shorter stock rebuilding periods, and higher mean lengths and ages on average. Our study explores the possibilities and potential impediments to sustainably harvesting highly variable forage fish stocks in an increasingly dynamic ocean.

Larval, Juvenile, and Adult Coastal Pelagic Species in the Northern California Current and Recent Observations on Phenological and Distributional Shifts of Pacific Sardine and Northern Anchovy.

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Since 1998, NOAA's Northwest Fisheries Science Center with Oregon State University (OSU) have maintained several long-term ocean monitoring surveys. The Newport Hydrographic (NH) line is a biweekly oceanographic/plankton survey within the first 25 nm from shore, with an extended effort several times a year out to 200 nm. NOAA/OSU have also been using large trawl nets to sample micro-nekton and nekton in the northern California Current (NCC; Oregon and Washington), typically in May/June. For the first 17-yrs of sampling (1998-2014) along the NH line, we had no observations of larval *S. sagax* and *E. mordax* from plankton nets in winter (Jan-Mar). However, larval *S. sagax* and *E. mordax* were present in high numbers in winter during the warm ocean years of 2015-16, present only in lower numbers in 2017-18, and absent in 2019-20. Larval *S. sagax* were once again present in modest abundance in winter 2021. Spatial/temporal presence of *E. mordax* and *S. sagax* larvae in the NCC would typically occur in summer and offshore, yet newly hatched larvae of both taxa have been sampled repeatedly at the most inshore station: NH-01 (1 nm from shore) in winter. In 2021, *S. sagax* larvae were caught in nearshore waters in winter and spring, and in nearshore and offshore waters (NH-65 & NH-85) in summer. Their ongoing presence inshore throughout both the downwelling and upwelling seasons in 2021 suggests continual spawning of adults close to shore from winter until fall. These unusual occurrences of larvae represent both a latitudinal and cross-shelf phenological shift in reproduction of the adults.

Several fine-mesh trawl surveys have been conducted in recent years to quantify micro-nekton (such as juvenile fish, krill, decapod larvae) in the NCC and typically take place in May to early June. Juvenile *S. sagax* were sampled in coastal waters in May 2021 (30.0 ±3.2 mm SL) and larger juveniles were collected during a trawling survey in June that is conducted without a fine-mesh liner (49.2 ±11.0 mm SL). The distribution of juvenile *S. sagax* in May 2021 ranged from 48° N to 43° N across the continental shelf and were present at 75% of the stations sampled. Length-weight relationships were calculated (Wt. (gms) = 0.0019*L(cm)4.016) and energy density (3.5 Kj per ww (gms) was measured on the juvenile *S. sagax*. Juvenile *S. sagax* were also sampled in May of 2017 and 2018, north of 46° N, but at lower abundance and frequency of occurrences than 2021.

In 2021, the abundance and biomass of forage was higher than in most recent years. Adult krill (primarily *Thysanoessa spinifera* and *Euphausia pacifica)* have been quantified during May/June in 2011, 2013-2020, and 2021 using a mid-water trawl net towed at night from approximately 42-46° N. Highest catch years were 2011, 2013-14, and 2021. Adult krill (primarily *T. spinifera*) has also been quantified in May 2017-18 and 2021 with a fine-mesh liner net at the surface during daytime, and the biomass of krill sampled in May 2021 was 10 times higher than in the previously quantified year of 2018, and catches were close to zero in 2017. Catches of juvenile *D. opalescens* (<60 mm ML) were the highest in May 2021 of the three study years using a fine-mesh liner net and the biomass of juvenile smelt (Osmerids) in 2021 was double that observed in 2017 and 2018. The biomass of juvenile *Ammodytes personatus* was highest in 2021, and overall all juvenile fishes had a higher biomass in 2021 than during the previous two study years, with the exception of juvenile rockfish (*Sebastes* spp.) and *Ronquilus jordani*. The total biomass of micro-nekton (fish and invertebrates) caught in 2021 was 32 times higher than in 2017 and 8.5 times higher than in 2018. Lastly, based on our spatiotemporal analysis of the June trawl survey catches (no fine-liner), the 2021 indices of total adult California *D. opalescens* abundance for Oregon and Washington waters were 147% and 37%, respectively, of the long-term average since 1998. However, these relative indices declined to 77% and 20%, respectively, when compared to the average estimates since 2012 when *D. opalescens* abundances increased dramatically in survey catches off Oregon and Washington.

Portfolio Substitution between Coastal Pelagic Species under Shifting Target Species Distributions and Policy Constraints.

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Fishermen often target a diverse set of species. More diverse portfolios may reduce income risk, increasing fisher resilience to climate-driven changes in target species' spatial distributions and availability. Therefore, evaluations of climate risk to a particular fishery need to consider climate impacts on the availability of multiple target species and how such changes may impact substitution behavior. Regulations and other constraints (e.g., port infrastructure constraints on where landings of a particular species may occur) may also reduce the degree of substitution we observe. However, what factors influence diversification and how climate-driven changes in target species distribution may interact with other constraints to affect changes in substitution behavior remains unclear for many fisheries. In this study, we analyze how historical changes in forage species distribution and the closure of the *S. sagax* fishery affected landing substitution between three coastal pelagic species: *S. sagax, D. opalescens*, and *E. mordax* that are targeted by the U.S. West Coast Coastal Pelagic Fleet. Using a discrete choice modeling approach embedded in our landing model, we also study how spatial distribution and closure affected the coastal pelagic species fisheries' participation decisions over the 2000-2019 period. Our preliminary results show strong substitution between *D. opalescens* and *S. sagax* when both were available, while the *S. sagax* closure in 2015 was associated with reduced *D. opalescens* landings suggesting lower fishers' participation in this fishery.

Evaluation of Fourier-Transform near Infrared Spectroscopy to Improve Ageing of Coastal Pelagic Species.

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Surface ageing (i.e. whole otolith ageing) has been the traditional method used to determine age of coastal pelagic species (CPS) in Canada, U.S. and Mexico. Previous research has shown considerable variability among produced ages by both individual readers and ageing laboratories. Since 2011, ageing errors have been computed and included in all CPS assessments, but these errors tend to increase with the number of age readers within a given laboratory. As CPS assessments are based on a relatively large number of otolith samples collected from annual trawl surveys and port sampling, developing methods to improve both the accuracy and precision of age data, while increasing the efficiency of the ageing process has been a high priority for the SWFSC Life History Program (LHP). To increase repeatability while decreasing ageing errors of CPS, the LHP is part of a NOAA multi-year strategic initiative, which conducts research & development of Fourier-transform near infrared spectroscopy (FT-NIRS) technology across all NOAA Fisheries ageing laboratories. FT-NIRS quantitatively measures the absorption of near infrared energy in

organic molecules for use in rapid collection of biological data, and this technology has been adapted as a means of estimating fish age from the spectral analysis of otoliths**.** The primary objective of the LHP is to evaluate the feasibility of using FT-NIRS as the principle method of ageing *S. Sagax, E. mordax,* and *S. japonicus*. Preliminary results for *S. Sagax* indicate that FT-NIRS can estimate the age of fish with a similar degree of precision to traditional ageing. Next steps will be to improve the *S. Sagax* prediction model developed from FT-NIRS methodology, and to continue comparing traditional ages to FT-NIRS age estimates. Future work will be to use FT-NIRS to estimate ages for *E. mordax* and *S. japonicus*, and the final step will be determining how to integrate FT-NIRS age estimates into stock assessments if the method is successful.

Spatial Analysis of the Small Pelagics Fishery in the Gulf of California (2013-2014)

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Spatial analysis, regarding in particular the geographical distribution of exploited fish species, is key to identifying fishing areas, predicting catches, and understanding the relationship of fish populations with their environment. However, detailed information on the location and composition of catches in the small pelagic fishery in the Gulf of California is scarce. In this work, data collected during January 2013 to July 2014 through the observers' program on board the Sonora *S. sagax* fleet were used. For the species best represented in the captures, geostatistical spatial indicators were obtained based on simple statistics that summarize the geographic location (center of gravity), dispersion (inertia and isotropy) and space occupation (number of spatial patches, positive and spreading area), allowing to detect differences in their distribution patterns. The *S. sagax* and *E. mordax* were found mainly in the region of Angel de la Guarda and Tiburon islands, while *O. libertate* and *C. mysticetus* remained essentially on the east coast of the gulf. During 2013, elongation and spatial variability were low for all species, while in 2014, tropical affinity species (*O. libertate* and *C. mysticetus*) had higher elongation, variability, and spatial occupancy.

Reproductive Biology of Anchovy* Engraulis mordax *from the Western Coast of Baja California During 2021

Celia Eva Cotero Altamirano, Concepción Enciso-Enciso, Griselda Ocampo Fierro, Estefanía Murillo Núñez, Eduardo Álvarez Trasviña, and Julio Peralta Ramos

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The reproductive behavior of the species and its relation within the environment is important in the dynamics of populations, and particularly with populations that are commercially exploited. This research contributes fundamental elements that support the normativity and management measures.

Small pelagic fishes are the most important resource in the Mexico, where *S. caeruleus* is the target species and *E. mordax* is used as an alternate when the target species is unavailable. The National Fishery and Aquaculture Institute, as scientific advisor to Fishery Authority, maintains a monitoring program to manage fisheries with the goal of sustainability.

Biological samples of *E. mordax* were collected from the commercial fleet to determine reproductive biology during 2021 season. Anchovy catches were observed in the months of April to July. Researchers recorded the standard lengths, individual weights, sex and maturity of the *E. mordax*. In the lab, samples from female and males gonads were processed with histological techniques.

The results indicated that the size structure was between 65 – 139 mm with an average of 106 mm standard length. The length of females and males were observed to be significantly different, with females larger than males at108 and 105 mm respectively.

Reproductive activity was also observed during this time and the spawning peak was detected in May. During the study, researchers observed a strong relationship in both temperature and upwelling with maturity. The length at maturity was at 111 mm for females and 108 for males.

CONCLUSION

The Forum was well attended and provided many opportunities to share information across international and agency lines. Dale Sweetnam closed the forum with thanks to all who participated.

The location and date of the 23rd Trinational Sardine and Small Pelagics Forum has yet to be determined.

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APPENDIX II: AGENDA

Monday, May 2

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

Regional Sardine Fisheries Reports

9:15 **Coastal Pelagic Species Fisheries in the U.S. Pacific Northwest.** Gregory K. Krutzikowsky*, Lisa Hillier, and Alan Sarich

9:30 **California Coastal Pelagic Species Report.** Dana Myers

9:45 **The Coastal Pelagic Species Fishery off the Western Coast of the Baja California Peninsula, Mexico, Fishing Season 2021.** Concepción Enciso-Enciso*, Celia Eva Cotero-Altamirano, Eduardo Álvarez-Trasviña and Julio C. Peralta-Ramos

10:00 **Pacific Fishery Management Council Report/Update.** Jessi Doerpinghaus

10:15 **Update Assessment of the Pacific Sardine Resource in 2022 for U.S. Management in 2022-2023.** Peter T. Kuriyama*, Kevin T. Hill, and Juan P. Zwolinski

10:45 Break

Contributed Presentations

11:00 **Against the Odds: A Historical Trinational Survey of CPS during a Pandemic.** David Demer*, Isaac Rojas, Kevin Stierhoff, Roberto Vallarta, Josiah Renfree, Greg Shaughnessy, Lorna Wargo, and Juan Zwolinski

11:30 **Aerial Survey of Small Pelagic Species in Nearshore California Waters.** Kirk Lynn*, Emmanis Dorval, Dianna Porzio, Trung Nguyen, and Dana Myers

11:45 **Reproductive Biology of Sardine, *Sardinops caeruleu*s, From the Western Coast of Baja California During 2020.** Celia Eva Cotero Altamirano*, Concepción Enciso-Enciso, Griselda Ocampo Fierro, Estefanía Murillo Núñez., Eduardo Álvarez Trasviña, and Julio Peralta Ramos.

12:00-12:30: Lunch Break

12:30 **A Preliminary Review of Biological Data Used to Evaluate Subpopulation Structure in Pacific Sardine**. Matthew Craig*, Brad Erisman, Barbara Muhling, and Andrew Thompson.

12:45 **Stock Assessment of the Tempered Stock of Pacific Sardine Sardinops sagax on the West Coast off the Baja California Peninsula, Mexico (1989-2021).** Concepción Enciso-Enciso* and Manuel O. Nevárez-Martínez

13:00 **Validation of Pacific Sardine Annuli in a Captive Growth Experiment.** Kelsey C. James* and Emmanis Dorval

13:15 **Why do Sardine Populations Undergo Multidecadal Booms and Crashes?** Barbara Javor

13:30 **Long-Term Population Projections of Pacific Sardine Driven by Ocean Warming and Changing Food Availability.** Stefan Koenigstein*, Michael G. Jacox, Mercedes Pozo Buil, Jerome Fiechter, Barbara A. Muhling, Peter Kuriyama, Stephanie Brodie, Toby D. Auth, Elliott L. Hazen, Steven J. Bograd, and Desiree Tommasi

13:45 **Oxygen Consumption, Hypoxia Tolerance, and Temperature Sensitivity of Pacific Sardine, *Sardinops Sagax*, Under Different Temperature Regimes.** Joshua Lonthair*, Nicholas C. Wegner, Nann A. Fangue, and Lisa M. Komoroske

14:00 **Spatial Dynamics of the Sardine in the California Current: Connecting Seasonal, Interannual and Long-Term Movements.** Ruben Rodriguez-Sanchez*, Hector Villalobos and Sofia Ortega-Garcia

14:15 **Evaluating Robustness of Harvest Control Rules to Variability in Pacific Sardine Recruitment.** Robert P. Wildermuth*, Desiree Tommasi, Peter Kuriyama, James Smith, and Isaac Kaplan

14:30 Break

14:45 **Larval, Juvenile, and Adult Coastal Pelagic Species in the Northern California Current and Recent Observations on Phenological and Distributional Shifts of Pacific Sardine and Northern Anchovy.** Elizabeth A. Daly*, Toby D. Auth, Kym C. Jacobson, Cheryl A. Morgan, Brandon E. Chasco, Brian J. Burke , and Brian K. Wells

15:00 **Portfolio Substitution between Coastal Pelagic Species under Shifting Target Species Distributions and Policy Constraints.** Felipe Quezada*, Desiree Tommasi, Stephen Stohs, Timothy Frawley, Jonathan Sweeney, Isaac Kaplan, and Barbara Muhling

15:15 **Evaluation of Fourier-Transform Near Infrared Spectroscopy to Improve Ageing of Coastal Pelagic Species.** Brittany D. Schwartzkopf*, Emma Saas, Dianna Porzio, and Emmanis Dorval

15:30 **Spatial Analysis of the Small Pelagics Fishery in the Gulf of California (2013-2014).** A. Buenfil-Ávila, Hector Villalobos*, M.O. Nevárez-Martínez, and Enrique Morales-Bojorquez

15:45 **Reproductive Biology of Anchovy Engraulis Mordax from the Western Coast of Baja California During 2021.** Celia Eva Cotero Altamirano*, Concepción Enciso-Enciso, Griselda Ocampo Fierro, Estefanía Murillo Núñez, Eduardo Álvarez Trasviña, and Julio Peralta Ramos.

16:00 **Discussion and Outstanding Issues**

16:45 **Closing Remarks & Host of the 2023 Forum.**