# PROCEEDINGS OF THE 23RD ANNUAL TRINATIONAL SARDINE & SMALL PELAGICS FORUM, VIRTUAL EVENT

**December 8, 2022**

Edited by Stephanie Flores

October 2023
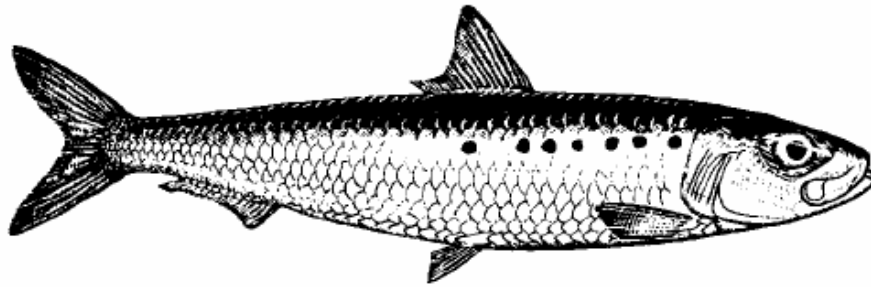
# 23RD ANNUAL TRINATIONAL SARDINE & SMALL PELAGICS FORUM

DECEMBER 8, 2022

VIRTUAL EVENT

# SOUTHWEST FISHERIES SCIENCE CENTER

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**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 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 (SWFSC) Fisheries Resources Division (FRD) hosted the 23rd Annual Trinational Sardine and Small Pelagics Forum on Thursday, December 8, 2022. The virtual event was well attended by 78 participants. This important meeting brings together scientists and representatives from government, academia, fishery management, fishing industry, non-governmental organizations, and other interested groups from Canada, the United States, and Mexico (Appendix I) to share research, knowledge, and information related to sardine and other small pelagic species.

The meeting consisted of three regional sardine reports and 11 contributed presentations on topics ranging from habitat models and fish recruitment, to age and growth and stock assessments. Presentations also covered a variety of focal species including anchovy, sardine, market squid, and even one California sea lion. The floor was then opened for a group discussion of coastal pelagic species (CPS) research and data needs/priorities for upcoming years.

Stephanie Flores coordinated the planning and execution of the Forum from start to finish, which involved managing communications with participants, organizing the agenda and program, scheduling presentations, and monitoring the virtual platform. Brad Erisman and Kelsey James from the Life History Program were passed the torch from the irreplaceable Dale Sweetnam and co-chaired the meeting with support from Peter Kuriyama, Owyn Snodgrass, and Roberto Silva who wrangled the Q&A session and kept things running smoothly throughout the day.

# REGIONAL SARDINE FISHERIES REPORTS

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

Gregory K. Krutzikowsky[1], Lisa Hillier[2], and Alan Sarich[3]

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Directed CPS fisheries in the U.S. Pacific Northwest in 2021 and 2022 pursued market squid (*Doryteuthis opalenscens*), northern anchovy (*Engraulis mordax*) and small-scale opportunity for Pacific sardine (*Sardinops sagax*). 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 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 sardine in small-scale fisheries occurred only in Oregon. No directed CPS fisheries for Pacific mackerel (*Scomber japonicus*) or jack mackerel (*Trachusrus symmetricus*) 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 regulatory considerations.

## Discussion

When asked about the low landings vs. higher incidental catches of Pacific mackerel in Oregon, Greg Krutzikowsky explained that mackerel isn't economically viable for fishermen to target unless the sardine fishery is open as well due to processing costs. A lot of the incidental landings in non-CPS years comes from the Pacific hake fishery. He also clarified that the Washington Department of Fish and Wildlife does not specifically track the sales of anchovy for fisheries management but that anchovy are primarily caught as bait for the albacore and groundfish fisheries in Washington.

**California Coastal Pelagic Species Report**

Angela Garelick and Melissa N. Liotta

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Coastal Pelagic Species (CPS) finfish, including Pacific Sardine (*Sardinops sagax*), Northern Anchovy (*Engraulis mordax*), Pacific Mackerel (*Scomber japonicus*), and Jack Mackerel (*Trachurus symmetricus*), are managed by the Pacific Fishery Management Council's CPS Fishery Management Plan. Pacific Sardine and Pacific Mackerel are managed on a July 1 to June 30 fishing season. Because Pacific Sardine is designated as overfished, there was no directed commercial fishery for the 2021-2022 season, but there was a federal annual catch target of 3,000 mt for commercial incidental catch or as part of the tribal, live bait, minor directed, exempted fishing permit, and recreational fisheries. Landings of Pacific Sardine in California for the 2021-2022 season were approximately 1,760 mt from 82 unique vessels, with 99.7% (1,756 mt) of landings in Southern California. The total landings of Pacific Mackerel are approximately 847 mt. Northern Anchovy and Jack Mackerel are managed

on a calendar year fishing season (January 1 to December 31), with 2022 landings (through November 4) of Northern Anchovy at 1,493 mt and Jack Mackerel at 29 mt. Compared to last season, 2021-2022 total landings for Pacific Sardine decreased by 29%, while Pacific Mackerel landings increased by 69%. So far during the 2022 fishing season, Northern Anchovy landings decreased by 48%, while Jack Mackerel landings increased by 26% compared to 2021.

**Pacific Fishery Management Council Report**

Jessi Doerpinghaus

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The Pacific Fishery Management Council (PFMC) is responsible for developing management measures for federally managed fish species on the U.S. West Coast, from three 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 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. Pacific 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 and the National Marine Fisheries Service (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. Based on recommendations from the stock assessment team, Science and Statistical Committee, and the CPS advisory bodies, the Council recommended delaying the proposed benchmark assessment in 2023 until completion of a series of workshops looking at stock structure and other assessment improvements in 2022-2023. The Council is expected to set harvest specification and allowances for the 2023-2024 fishing year in April 2023.

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 CPS Management Team and Southwest Fisheries Science Center (SWFSC) are planning to bring forward an analytical package for the Council to consider in April 2022 for selection of a range of alternatives and a preliminary preferred alternative with final action tentatively scheduled for June 2022.

## Northern Anchovy

In June 2022, the Council utilized the framework and flowchart described in Council Operating Procedure (COP) 9 for the first time in determining harvest specifications for the central subpopulation of northern anchovy (CSNA). The Council transmitted their recommendation of an overfishing limit of 243,779 mt and an annual catch limit of 25,000 mt to NMFS on October 7, 2022. Based on the COP 9 framework, the Council is next scheduled to review the status and harvest specifications for CSNA in 2024.

## FMP Amendments

The Council took final action on Amendment 20 to remove the "active" and "monitored" categories from the CPS FMP in April 2022 and transmitted this to NMFS on October 6, 2022. This action is intended to improve clarity regarding the management approaches for stocks or species in the CPS FMP and describe how each stock is managed in a stock-specific manner, rather than through use of a categorical assignments. Specifically, the intent was to remove references to the named management categories, but not to revise the manner in which the CPS stocks are managed. In addition, the Council began a housekeeping amendment in November 2022 to remove or update descriptions that have become out of date, reflect current fishery management practice as described in National Standard 1 Guidelines, and reorganize and revise the text to be more clear and concise. The proposed changes are out for public review and the Council is expected to take final action in April 2023.

# CONTRIBUTED PRESENTATIONS

**Revised Potential Habitat Model for the Northern Stock of Sardine**

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

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Acoustic-trawl-method (ATM) surveys have shown that between the summers of 2018 and 2021, the biomass of the southern stock of Pacific Sardine in U.S. waters has persisted year-round in the Southern California Bight, and has increased from 33,093 to 63,208 t. Meanwhile, the biomass for the northern stock of sardine has remained mostly off Washington and Oregon, and less than 40,000 t. These observations have brought into question which stock has contributed to the landings at Ensenada in recent years. To answer this question, the Zwolinski et al. (2011) model of potential habitat for the northern stock of Pacific Sardine was revised using egg data from spring 2011-2019. Using the method proposed by Demer and Zwolinski (2014), the revised model was then applied to delineate southern and northern stock landings at Ensenada. Setting the model probability to include habitat containing at least 95% of the sardine egg abundance, all of the landings at Ensenada were ascribed to the southern stock. The results of this approach are consistent with the observations that only southern stock Pacific Sardine have been present south of Point Conception in recent years.

**Biomasses, Distributions and Demographics of Coastal Pelagic Species Nearshore**

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The Southwest Fisheries Science Center (SWFSC) conducts annual or bi-annual acoustic-trawl-method (ATM) surveys to estimate the biomasses, distributions and demographics of coastal pelagic fish species (CPS) in the California Current Ecosystem. NOAA Fisheries Survey Vessels sample acoustically to depths as shallow as ~20 m, and trawl in depths as shallow as ~30 m. Because CPS may reside in shallower areas, the ATM surveys have been augmented since 2017 with cooperative nearshore sampling from fishing vessels equipped with scientific instrumentation and purse-seine gear. We present a time series of nearshore CPS biomasses and percent additions to offshore estimates, and consider the challenges, costs and benefits of this nearshore sampling. For example, results indicate that when CPS stocks are large, the nearshore biomass is inconsequential; and when CPS stocks are small, the relatively small nearshore area does not contain an appreciable biomass. However, without the nearshore sampling, the southern stock of sardine may not have been observed in the Southern California Bight and around the Channel Islands in recent years.

## Discussion

David Demer clarified that the stock of southern sardine found compressed close to the shore likely was the result of the distribution of potential habitat- temperature and chlorophyll-a concentration.

**Preliminary Results of the Summer 2022 California Current Ecosystem Survey**

Josiah S. Renfree[1], Alice Beittel[1], Noelle M. Bowlin[1], Brad E. Erisman[1], Kelsey James[1], Scott A. Mau[1], David W. Murfin[1], Thomas S. Sessions[1], Kevin L. Stierhoff[1], Lanora Vasquez[1], William Watson[1], Juan P. Zwolinski[1,2], and David A. Demer[1]

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The Summer 2022 California Current Ecosystem Survey (CCES) was conducted from 27 June to 30 September. The CCES uses the Acoustic-Trawl Method (ATM) to assess populations of coastal pelagic fishes (CPS) and krill using multi-frequency echosounders, surface trawls, obliquely integrating net tows, and a Continuous Underway Fish-Egg Sampler (CUFES). The 2022 survey spanned a region from the U.S.-Canada border to Central Baja California, Mexico. Sampling was conducted from multiple platforms, including NOAA ship Reuben Lasker, fishing vessels Lisa Marie and Long Beach Carnage, and two wind-powered uncrewed surface vehicles (USVs; Saildrone, Inc.). Due to logistical challenges with Lasker staffing, Lisa Marie sampled the region north of Bodega Bay, CA; Lasker sampled south of Bodega Bay, CA; USVs sampled interstitial transects from central Washington to northern California; and Long Beach Carnage sampled nearshore transects between northern California to the U.S.-Mexico border, including around Santa Cruz and Santa Catalina Islands in the Southern California Bight. Preliminary maps are presented for CPS backscatter, eggs, and species proportions, and plots are shown of their length distributions. The species proportions in daytime purse-seine catches off WA, OR, and N. CA were significantly different from those obtained historically from nighttime surface trawls in this area, and from those in Lasker's trawls in an overlapping area near Bodega Bay in summer 2022. Because the daytime purse-seine did not effectively sample Jack Mackerel, deep schools offshore, and schools in clear water, the summer 2022 acoustic samples in this area were interpreted using the length distributions from summer 2022 catches coupled with the species proportions from summer 2021 nighttime trawl catch clusters. A preliminary analysis of uncertainty is presented.

## Discussion

Josiah Renfree addressed why sampling wasn't done further offshore. While the Lisa Marie and Reuben Lasker did sample offshore, sampling is typically constrained by time and anticipated habitat of the northern stock of Pacific sardine. In previous years, they have conducted occasional long offshore transects, but survey protocol is to sample westward until they no longer acoustically observe CPS within the final three 3-nmi. Transects are indeed extended offshore as long as CPS echoes are observed.

**Provisional Plans for the Summer 2023 Acoustic-Trawl Method Survey of Coastal Pelagic Fishes in the California Current Ecosystem (2307RL)**

Kevin L. Stierhoff[1], Alice Beittel[1,3], Noelle M. Bowlin[1], Brad E. Erisman[1], Josiah S. Renfree[1], William Watson[1], Juan P. Zwolinski[1,2], David A. Demer[1]

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In summer 2023, the Southwest Fisheries Science Center (SWFSC) will conduct its annual acoustic-trawl-method (ATM) survey of coastal pelagic fish species (CPS) in the California Current Ecosystem. This international survey will be conducted between Cape Scott, British Columbia and Punta Eugenia, Baja California, Mexico, primarily by NOAA ship Reuben Lasker during 81 days at sea (3 July - 30 Sept), but will also involve coordination with Mexican colleagues from Instituto Nacional de Pesca y Acuacultura (INAPESCA) aboard research vessel Dr. Jorge Carranza Fraser, three or more wind-powered uncrewed surface vehicles (USVs; Saildrone, Inc.), and fishing vessels Lisa Marie and Long Beach Carnage. A provisional set of objectives and logistics will be presented and feedback will be encouraged. For example, one aim is to begin the survey in the south to reduce transit days and coordinate NMFS-INAPESCA sampling off Baja California during the peak spawning period for the southern (temperate) stock of Pacific Sardine. Also, we plan to compare catches, e.g., from nighttime trawl and purse seines.

## Discussion

Kevin Stierhoff addressed concerns about trawling taking place hours after the fish are acoustically located and whether sardine behavior may cause fewer fish to be sampled due to the delay. Trawling takes place relatively soon after staff acoustically identify high abundances of backscatter, often by the end of the day and within 12 hours. This sampling cannot ensure the fish located acoustically will be the same ones caught in the trawl but rather will consist of a general sampling of the fish in a high abundance area in general.

He then addressed a concern that the length of the transect lines offshore are shorter than previous surveys before 2021. Kevin explained that the trawls extend to the continental shelf and are adaptively extended if the crew encounters backscatter at the end of the lines.

When asked at what stage (or after the eggs hatch) do the larvae or juveniles make their way into nearshore waters, Kevin responded that the belief is that adult sardines are spawning in the nearshore waters even in winter. The larvae are present nearshore and offshore through both downwelling which would bring the larvae nearshore and the inverse, the larvae are offshore when upwelling would bring them inshore. However, the team typically sees sardine larvae from July-September. However, since 2015, they are showing up earlier in the year and further inshore. It is unusual, especially the juvenile stage being caught in coastal WA waters.

# Update on Summer 2022 Larval, Juvenile, and Adult Coastal Pelagic Species in the Northern California Current

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Several long-term ocean monitoring projects quantify the number, biomass, and distribution of many larval, juvenile, and adult coastal pelagic species in the northern California Current. Data through 2021 were presented at the 22nd Trinational Coastal Pelagics Species (CPS) meeting in spring of 2022. Here, we extend the dataset to include summer 2022 results.

Surveys by NOAA's Northwest Fisheries Science Center (NWFSC) and Oregon State University (OSU) include a biweekly oceanographic/plankton survey 1-25 nm from shore, with an extended effort several times a year out to 200 nm along the Newport Hydrographic (NH) line, ongoing since 1998. These efforts capture the larval stages of coastal pelagic species such as Pacific sardine (*Sardinops sagax*) and northern anchovy (*Engraulis mordax*). In addition to sampling for larval fish, 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.

Spatial/temporal presence of northern anchovy and Pacific sardine 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/early spring. During the first 17 yrs of sampling (1998-2014) along the NH line, we observed no larval Pacific sardine or northern anchovy from plankton nets in winter (Jan-Mar). However, larval Pacific sardine (*Sardinops sagax*) and northern anchovy (*Engraulis mordax*) were both present in high numbers in winter during the warm ocean years of 2015-16, and present but in lower numbers in 2017-18. Pacific sardine were absent in 2019-20 and present in low numbers in 2021 (winter-spring and summer) and early-spring 2022. Northern anchovy, normally a dominant larval taxa during the summer in the NCC, were present only in very low numbers in the summers of 2020-21, but returned to normal abundances in late-spring and through summer of 2022. In 2021, larval Pacific sardine were caught in nearshore waters in winter and spring, and in nearshore and offshore waters (NH-65 & NH-85) in summer. In 2022, larval Pacific sardine were caught at the most nearshore station (NH-01) in April. Their presence inshore throughout both the downwelling and upwelling seasons in 2021, and during the downwelling season in 2022, suggests continual spawning of adults close to shore. 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, and decapod larvae) in the NCC, and typically taking place in May to

early-June. The distribution of juvenile Pacific sardine in May 2022 ranged from 46° N to 44°N across the continental shelf and were present at 41% of the stations sampled which was a more narrow distribution than in 2021. With the presence of juvenile Pacific sardine in the coastal waters of the NCC in May 2022, this again suggests the successful recruitment to the later life-stage as was observed in recent years. Juvenile salmon started utilizing juvenile sardines as a prey in 2016, the first occurrence in the 24-yr time series, and have eaten them as a prey item each year since then (no data yet for 2022).

In 2022, the overall abundance and biomass of all forage was lower than in most recent years. The bio-volume from the mid-water trawl at night was low (except for ctenophores at several stations) and there were relatively low larval and YOY fish concentrations (except for moderate-high rockfish). Nekton sampled during 2022, which was the 25th year of June surface trawling (daytime sampling; 1998-2022) was low in abundance, with the exception of above-average catches of California market squid (*Doryteuthis opalescens*). Also from the June surface trawling efforts, the frequency of occurrence of adult Pacific sardine and northern anchovy was among the lowest in the time series, and the prevalence of whitebait smelt (*Allosmerus elongatus*), surf smelt (*Hypomesus pretiosus*), and Pacific herring (*Clupea pallasii*) was average. Adult krill (primarily *Thysanoessa spinifera* and *Euphausia pacifica*) have been quantified during May/June in 2011, 2013-19, and 2021-22 using a mid-water trawl net towed at night from approximately 42-46°N (north to 48°N in 2011 and 2022). Highest catch years were 2013-14 and 2021. Recently, in 2022, catches were anomalous in that krill was below average nearshore and above average off the shelf. Based on our spatiotemporal analysis of the June trawl survey catches (no fine-liner), the 2022 indices of total adult California market squid abundance for Oregon and Washington waters were 125% and 175%, respectively, of the long-term average since 1998. However, these relative indices declined to 69% and 91%, respectively, when compared to the average estimates since 2012, when squid abundances increased dramatically in survey catches off Oregon and Washington.

# New Lenses May Provide Novel Insights on Fish Recruitment

Andrew Thompson

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"The answer to the question, 'what limits clupeoids?' seems to be 'almost everything'. More realistically, the question should be phrased 'what limits clupeoids mostly?' Other questions follow this one: When, in the life cycle, does this occur? What are the interrelationships between limiting factors and between species? What can be learned from species life histories and fishery oceanography that will allow us to predict recruitment" – Lasker 1985 CJFAS 42:31-38.

Fisheries scientists have been attempting to resolve the mechanisms governing massive fluctuations in year class strength (recruitment) of marine fishes for more than a century. Elucidating processes affecting recruitment have proven difficult, however, as the ocean is large and processes affecting larval fish survival can occur at microscopic scales. Fortunately, modern technologies are providing us with the potential to observe conditions at relevant scales and, if not solve, at least allow us to make significant progress towards understanding mechanisms driving recruitment dynamics.

In the California Current Ecosystem (CCE), we are currently applying multiple novel approaches to try to elucidate recruitment dynamics of northern anchovy (*Engraulis mordax*). Anchovy abundance was high from the 1960s to the late 1980s, declined rapidly in the late 1980s/early 1990s was low from 1991-2012 with a brief resurgence in 2015, and was then extremely low from 2012-2014. However, a strong recruitment event in 2015 and subsequent years rendered adult anchovy abundance at near-record high levels by 2021, and abundances remained very high in 2022. We are applying several lines of inquiry to discern the causes for these large fluctuations over the past 70 years. Compound Specific Stable Isotope Analysis showed that the trophic position of larval anchovy (*Engraulis mordax*) prey predicted anchovy spawning stock biomass two years later, and that a sudden, lasting transition to higher trophic level prey in 1989 predicted the 1990s population collapse. Analysis of larval anchovy condition and otoliths also indicated that maternal effects and ocean conditions impact the quality of ~ 3-5 week old larvae, and that recruitment positively correlated with larval condition between 2009 and 2019. To provide insight on the identity of anchovy larval prey during low and high recruitment years, we are conducting Environmental DNA (eDNA) analysis of water samples that is identifying phytoplankton and zooplankton assemblage composition from 2014-present. To better resolve the role of oceanography on anchovy recruitment, we are building Individual Based Models that will trace the transport and survival of larvae from 2000-2020. In addition, we are using larval age and size frequency data to estimate rates of Growth and Mortality to evaluate recruitment potential from 1951-present. This holistic approach will hopefully shed light on the title of Lasker's 1985 review paper: "What Limits Clupeoid Production?".

## The School Trap Hypothesis Predicts the Distribution Patterns and Environmental Preferences of Pacific Sardine in the California Current Following the 2010s Collapse

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The oceanographic environment has been proposed as the main driver of boom and boost events in small pelagic species. However, for the Pacific sardine off the West Coast of the US, neither the mechanisms driving their dynamics nor the environmental proxies for their productivity are fully understood. For example, sardine's resurgence in the 1990s lagged the environmental regime-shift by approximately ten years, suggesting other mechanisms may be modulating the stock's productivity. One hypothesis proposes that the schooling nature of small pelagic fishes forces individuals of a depleted stock to join schools of other more abundant fishes. This "school trap" effect results in the depleted species compromising its own habits in exchange for the protection that the mixed-species schools offer. In this presentation, we show that the school trap hypothesis predicts virtually every distributional pattern observed from the currently depleted stock of Pacific Sardine, including interrupted migrations and shifts in their environmental preferences. The changes in behavior promoted by sardine schooling predominantly with the far more abundant Jack Mackerel may explain why the stock failed to respond positively to favorable oceanographic conditions that have occurred off the West Coast in the last five years.

## Preliminary Estimate of Length at Maturity for Pacific Mackerel (*Scomber japonicus*) for Consideration in the 2023 Stock Assessment

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Here we provide preliminary results on an updated estimate of length at sexual maturity for Pacific Mackerel (*Scomber japonicus*) for consideration in the 2023 benchmark stock assessment. Samples of ovarian tissues (n = 912) were collected from female Pacific Mackerel during fishery-independent surveys conducted from 2010 through 2021 by NOAA Southwest Fisheries Science Center. Samples were processed histologically, standardized terminology was used to classify each sample as either immature (never spawned) or mature (previously spawned or first spawning), and the length at sexual maturity was then estimated using an analytical method based on logistic, non-linear regression. The estimated length at maturity (L50) for all sampled females was $274 \pm 1.29$ mm FL, and all females (L95) larger than $310 \pm 2.60$ mm FL were predicted to be mature. Our preliminary estimate of length at maturity based on recent data is similar to previous estimates used in stock assessments for Pacific Mackerel, indicating that maturity schedules in Pacific Mackerel off California have remained relatively constant over time.

**Modeling Growth of the Central Subpopulation of Northern Anchovy (*Engraulis mordax*)**

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Somatic growth rate is an important determinant of population growth and recruitment in marine fishes and is a primary biological parameter in fisheries assessment, management and research. Despite its importance, no recent work has modeled somatic growth of Northern Anchovy (*Engraulis mordax*), which is currently the most abundant forage fish in the northeastern Pacific Ocean and an important part of the food web. Here we present preliminary results on the first comprehensive investigation to model growth of the central subpopulation of Northern Anchovy, which was assessed in 2021, 26 years after the previous stock assessment. We fit the Gompertz, logistic, and von Bertalanffy growth functions to length-at-age data to determine the best model fit. All models produced similar results, but the von Bertalanffy growth function (VBGF) was the best fit according to AIC values. As age data came from samples collected year-round, we calculated fractional ages and fit two modifications of the traditional VBGF to model seasonal oscillations in growth [i.e., Somers Model (1988) and Pauly Model (1992)]. The Somers Model was deemed the best fit when compared to the traditional VBGF and Pauly Model for fractional ages. We found the traditional VBGF using integer ages may overestimate L∞ (130.6) and underestimate the rate at which L∞ is reached (K = 0.52) compared to the Somers Model using fractional ages (L∞ = 126.2; K = 0.68). The preliminary results of this work demonstrate the importance of incorporating seasonality when modeling somatic growth in marine fishes when samples are collected year-round.

## Discussion:

Brittany Schwartzkopf further discussed some of the variability shown in her seasonal models. December is the slowest month likely because of reduced temperatures; however, they are seeing evidence of fast growth in some individuals during this period. This is showing up as "split bands" in the otoliths, characterized by translucent bands that seems to "split" the band and are caused by a period of fast growth due to the fish finding a good amount of food during the winter, likely due to a bloom.

## California Sea Lions as Samplers of Market Squid Dynamics in the Southern California Bight

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Market squid (*Doryteuthis opalescens*) is a key coastal pelagic species of the California Current Ecosystem and supports one of California's most valuable fisheries. Yet, critical aspects of its dynamics and status remain unknown due to lack of adequate sampling coverage in space and time. Market squid are short-lived, with large population fluctuations and migrations that have been linked to seasonal and interannual temperature variation. California sea lions (*Zalophus californianus*) are important predators of market squid, which are more common in sea lion diet in the Southern California Bight (SCB) than any other prey species. California sea lions primarily consume large juvenile to adult size classes of market squid, with consumption shown to correlate to landings and to vary with El Niño Southern Oscillation (ENSO) index. We correlated quarterly indices of market squid consumption from the southern Channel Islands from 1999 to 2015 with spawning stock biomass (SSB) estimates of market squid for two management areas that overlap with known foraging ranges for these islands. We found strong correlation between market squid SSB and sea lion diet indices for the SCB as a whole, as well as evidence of resolution of subregional differences in SSB in diet indices from different islands, with promising results for refining parameters upon which egg escapement (an MSY proxy) is derived for this species. We also found strong temporal autocorrelation in quarterly squid consumption indices, with potential for better characterizing the spawner-recruit relationship, predicting market squid SSB three to six months in advance, and harnessing the power of a 40+-year quarterly time series of sea lion diet in the SCB to illuminate market squid population dynamics and environmental drivers. Sea lions prove to be effective samplers of market squid, with potential applications to monitoring this key species, better understanding its population dynamics, and improving stock assessment.

### Discussion:

When asked whether ontogenetic shifts are present in sea lion diet, Alex Curtis clarified that the SWFSC team focuses on collecting similarly-sized scat to consistently sample a comparable life stage for the animals. This varies throughout the year, as more males are present in the summer for breeding season, but primarily they sample adult females.

**Evidence of Density-Dependent, Time-Varying Processes in Pacific Sardine Stock Assessments**

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The factors that drive Pacific sardine (*Sardinops sagax*) dynamics are not well understood. Sardine, have large population fluctuations and likely have a number of time-varying biological processes, such as movement and growth. These factors pose challenges to both stock assessments and studies that infer environmental relationships from stock assessment output. Here we develop a stock assessment approach, that synthesizes all data previously used in assessments, to first estimate growth and its temporal variation and second relate the output to environmental time series. The first goal is to evaluate the degree of biological complexity supported by the data. The most complex assessment configuration estimates time-varying age-based selectivity (as a proxy for sardine movement) and a form of time-varying growth (either cohort-specific or annually-varying). The simplest assessment configuration has constant selectivity and time-invariant growth. The second goal is to relate the output from the best fitting model to environmental time series (such as sea surface temperature and Pacific Decadal Oscillation) that have been hypothesized to drive sardine dynamics. The model with time-varying age-based selectivity and cohort-specific growth best fit the data. Cohort growth deviations seemed to be density-dependent as they were significantly negatively correlated with age 1+ biomass. Recruitment success, from the best fit model, was significantly positively correlated with combined summer and spring PDO (r=0.76) and annual sea surface temperature (r=0.45), among other covariates. While this is a statistical rather than mechanistic relationship, the results can inform the configurations and inclusion of environmental effects in future stock assessments.

# GROUP DISCUSSION

The group discussion focused on future research and data needs and priorities. Attendees were asked to complete a survey ahead of time to indicate their priorities for any or all CPS in their region. These answers were compiled and discussed during an open discussion session at the end of the forum. Topics were divided into four groups: general (not species-specific), Pacific sardine, northern anchovy, and other CPS.

**General**

General topics included measuring recruitment and understanding the drivers behind surges and ebbs.

Attendees also discussed quantitatively sampling coastal pelagics in nearshore waters. Discussion highlighted a broader interest in the forage base rather than solely commercially important taxa. General consensus was that this information may already exist in some capacity already; however, it has not been systematically captured and catalogued as the focus has been on other dominant species (anchovy and sardine). Any information derived from these data would have to take into account the natural limitations and bias that may exist in these opportunistic records.

Another research topic included the impact of offshore wind farms on CPS environment (e.g., upwelling or wind wakes on CPS food sources or ocean transport of larvae or juveniles to nearshore areas, or of adults to offshore waters to feed or spawn). NOAA has been making many efforts to coordinate some form of monitoring with BOEM during this ongoing permitting process.

**Pacific Sardine**

Research topics provided by attendees included $E_{msy}$ for sardine in FMP harvest control rules needing to be reexamined and likely revised to better reflect a mechanistic understanding of drivers of stock productivity, length-at-age for southern and northern stocks of Pacific sardine, total stock biomass of the southern stock of Pacific sardine, migratory and spawning behaviors of southern stock Pacific sardine, and potential oceanographic habitat for southern stock Pacific sardine.

Discussion revolved around a review to validate the concept of two subpopulations for sardine, and how this concept of stock/population might impact management efforts. General consensus recognized that there is ongoing research addressing this and that it's likely mixing occurs amongst what is currently termed northern and southern stocks. Attendees discussed a collaboration to investigate a recruitment index for sardine.

**Northern Anchovy**

Attendees provided two northern anchovy research topics. The first was research into the potential oceanographic habitat for central stock northern anchovy. The second was an assessment of the northern stock of northern anchovy's long-term average biomass and biomass variability over time for use in the reevaluation of harvest parameter specifications.

**Other CPS**

The final three research topics consisted of determining spawning locations and sample adult abundance of Pacific sandlance in the North California Current, determining the stock structure and drivers of productivity and abundance of market squid in the PNW, and testing the efficiency of nighttime trawls for catching hake representative of their population

## CONCLUSION

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

The location and date of the 24th Trinational Sardine and Small Pelagics Forum has yet to be determined.

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# APPENDIX II: AGENDA

**Thursday, December 8**

10:00   **Opening remarks and meeting logistics.** Brad Erisman

**Regional Sardine Fisheries Reports**

10:15   **Coastal Pelagic Species Fisheries in the U.S. Pacific Northwest.** Gregory K. Krutzikowsky, Lisa Hillier, and Alan Sarich.

10:30   **California Coastal Pelagic Species Report.** Angela Garelick and Melissa N. Liotta.

10:45   **Pacific Fishery Management Council Report.** Jessi Doerpinghaus.

**Contributed Presentations**

11:00   **Revised Potential Habitat Model for the Northern Stock of Sardine.** Juan P. Zwolinski* and David A. Demer.

11:15   **Biomasses, Distributions and Demographics of Coastal Pelagic Species Nearshore.** David A. Demer*, Kevin L. Stierhoff, Josiah S. Renfree, and Juan P. Zwolinski

11: 30  **Preliminary Results of the Summer 2022 California Current Ecosystem Survey**. Josiah S. Renfree*, Alice Beittel, Noelle M. Bowlin, Brad E. Erisman, Kelsey James, Scott A. Mau, David W. Murfin, Thomas S. Sessions, Kevin L. Stierhoff, Lanora Vasquez, William Watson, Juan P. Zwolinski, and David A. Demer.

11: 45  **Lunch Break**

12:30   **Provisional Plans for the Summer 2023 Acoustic-Trawl Method Survey of Coastal Pelagic Fishes in the California Current Ecosystem (2307RL).** Kevin L. Stierhoff*, Alice Beittel, Noelle M. Bowlin, Brad E. Erisman, Josiah S. Renfree, William Watson, Juan P. Zwolinski, David A. Demer.

12:45   **Update on Summer 2022 Larval, Juvenile, and Adult Coastal Pelagic Species in the Northern California Current.** Elizabeth A. Daly*, Toby D. Auth, Kym C. Jacobson, Cheryl A. Morgan, Brandon E. Chasco, Brian J. Burke, and Brian K. Wells.

13:00   **New Lenses May Provide Novel Insights on Fish Recruitment.** Andrew Thompson.

13:15   **The School Trap Hypothesis Predicts the Distribution Patterns and Environmental Preferences of Pacific Sardine in the California Current Following the 2010s Collapse.** Juan P. Zwolinski* and David A. Demer.

13:30   **Preliminary Estimate of Length at Maturity for Pacific Mackerel (*Scomber japonicus*) for Consideration in the 2023 Stock Assessment.** Brad Erisman*, Kelsey James, Owyn Snodgrass, Brittany Schwartzkopf, Emmanis Dorval, and Jonathan Walker.

13:45   **Break**

14:00 **Modeling Growth of the Central Subpopulation of Northern Anchovy (*Engraulis mordax*).** Brittany D. Schwartzkopf\*, Emmanis Dorval, Dianna L. Porzio, John M. Walker, Kelsey C. James, and Brad E. Erisman.

14:15 **California Sea Lions as Samplers of Market Squid Dynamics in the Southern California Bight**. K. Alexandra Curtis\*, Emmanis Dorval, and Maya Philipp.

14:30 **Evidence of Density-Dependent, Time-Varying Processes in Pacific Sardine Stock Assessments.** Peter Kuriyama\*, Kevin Piner, Hui-Hua Lee, Kevin Hill, Paul Crone, Steve L.H. Teo, and Juan Zwolinski.

14:45 **Group Discussion: Research and Data Needs and Priorities**

15:45 **Closing Remarks & Host of the 2023 Forum.**