*Proceedings from*

# Social-ecological indicators to support marine management in a changing climate

*CalCOFI Conference 2021*
*December 1st & 2nd, 2021*

*Hosted by*: California Department of Fish and Wildlife

*In association with*: Scripps Institution of Oceanography, UCSD & Southwest Fisheries Science Center, NOAA

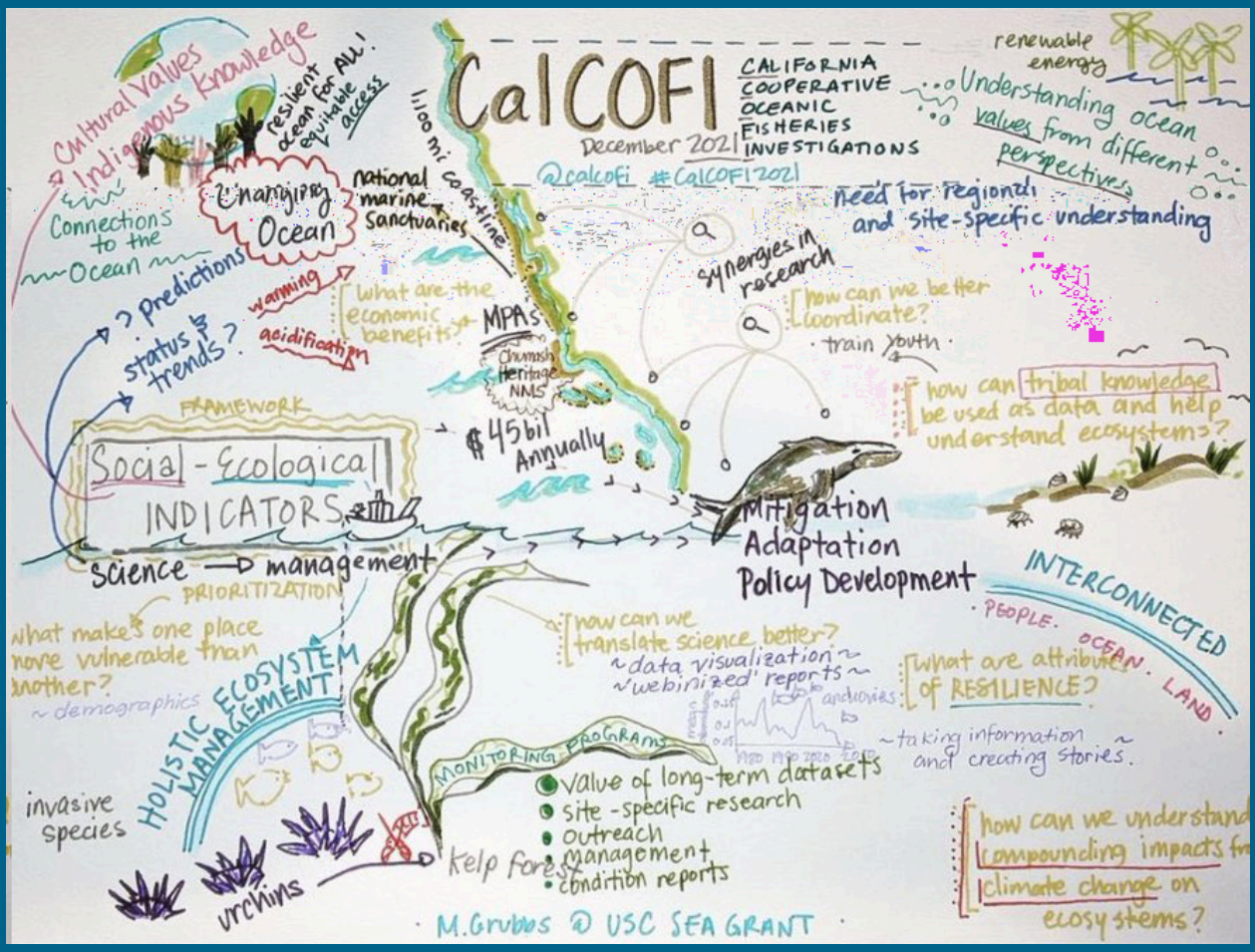
## Contents


**Introduction** **3**
**Proceedings** **4**
Overview 4
Opening session 4
Keynote: Samantha Murray, Fish and Game Commission 5
Keynote: William ‘Bill’ Douros, NOAA Sanctuaries West Coast Region 6
Panel: How can ocean observations support environmental, ecological, and socioeconomic indicators in the California Current? 7
Roundtable sessions 9
Exploring Technological Advances to Monitor Ecosystem Health in the California Current 9
Incorporating Climate Change into Regional Monitoring Programs 10
Exploring Integration of Social and Ecological Indicators for Adaptive Ecosystem-Based Management 10
Developing Environmental Indicators for Anchovy and Sardine Recruitment to Inform Modeling and Management for Forage Fish Species in the California Current 11
'Omics Applications and CalCOFI Samples 11
Conserving 30% of California’s Coastal Waters by 2030 12
Promoting the Use of Standards for Biological Observation Data Using a Primer 12
Assessing Ocean Societal Indicators for Oceans, Great Lakes, and Coasts 13
CalCOFI Showcase Development: Data Visualizations, Interactive Dashboard and Automated Workflows 13
**Panel & Discussion Session: Navigating a Contemporary Career Path in Ocean Sustainability** **14**
Status of the Fisheries 15
CalCOFI Tribute: In Memoriam 15
State of the California Current: Report 16
State of the California Current: Community Observations 16
Contributed Talks 18
Session 1: From Monitoring to Indicators and Management 18
Session 2: Oceanography & Fisheries 20
Additional content 21
Local Social gatherings 21
Photo slideshow: Year in review 21
**Outcomes & Recommendations** **21**
**Questions** **21**
**Report Preparation & Materials** **21**

# Introduction

Healthy, productive, and resilient marine ecosystems are integral to sustainable coastal communities. Currently, anthropogenic activities and coincident changes in climate are affecting ocean ecosystems and human well-being. As these impacts increase, the need to develop commensurate management responses also grows. Developing reliable social and ecological indicators, and targets that can be monitored and adaptively managed, is central to this process. Indicators are a measurable quantity relating to the social, ecological, or environmental dimensions of the ocean ecosystem that can be used to describe or predict a more complex state such as the "health" of an ecosystem, fishery stock, or human well-being.

The 2021 CalCOFI Conference was the latest milestone in a series of conferences over the 72-year history of the CalCOFI program. The overarching aims of the CalCOFI conferences are to share information on emerging priorities, the current state, and recent changes to California's marine and coastal environment and to continue to build a community of researchers and practitioners working toward holistically understanding, mitigating, and addressing coastal and marine resource issues along the West Coast.




**Sketchnote overview of CalCOFI Conference Day 1 (*Credit: Melodie Grubbs*)**

# Proceedings

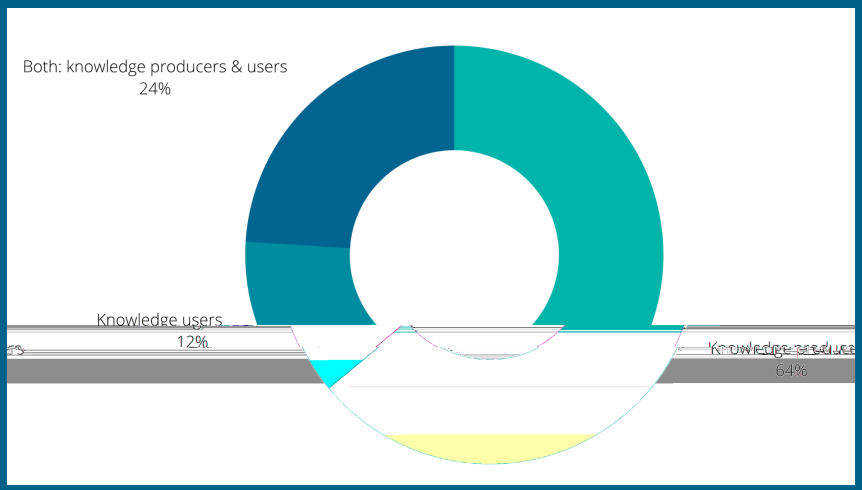
## Overview

The goal of this year's conference, *Social-ecological indicators to support marine management in a changing climate*, was to explore and refine existing social, ecological, and environmental indicators within the California Current Ecosystem. The theme was selected based on the previous year's conference registration survey of over 500 stakeholders from the CalCOFI community who indicated ecosystem and climate change indicators as the most interesting topic to explore. Speakers reviewed existing indicators, described their strengths and weaknesses, provided examples of how they are currently being used to inform ocean management, and provided suggestions for new indicators that could be developed. The conference provided perspective on where we've been, where we need to go, and what new innovations are needed with regard to environmental, ecological, and socioeconomic indicators in a time of rapid environmental change.

The virtual 2021 CalCOFI Conference consisted of keynotes, panels, roundtables, and contributed talks related to ocean observing data in support of environmental, ecological, and social indicators, ocean management, and understanding the State of the California Current Ecosystem. Additionally, there was an ocean science and sustainability career panel and local, informal social gatherings following the conference.

There were 443 registrants for the CalCOFI Conference 2021 and there were over 270 people at peak attendance from 131 different organizations and institutions across academic, government, civil society/non-profits, industry, and foundations. Nearly two thirds (64%) of conference registrants were knowledge producers (e.g., researchers), 12% knowledge users (e.g., policy-maker, manager, decision-maker, practitioner), and a quarter (24%) to be both knowledge producers and users. Registrants worked from local (city/county) to international scales, with most working along the U.S. West Coast.

Nearly half (48%) of the registrants considered themselves early career professionals, so within 8 years of completing professional training, which suggests that the CalCOFI program is reaching the next generation of ocean leaders through its annual meeting. Nearly half (45%) indicated that this was their first CalCOFI conference, which suggests that this year's conference brought in many new members to the CalCOFI community, while retaining participation from past members.



## Opening session

The conference was opened by Julia Coates from the California Department of Fish and Wildlife and this year's conference host. Coates provided an overview of the CalCOFI program and acknowledged the people that are part of CalCOFI including the technical teams, data collections and management, ship crew and operations, and CalCOFI Committee.

Coates also explained that the topic for the conference was chosen based on the topics that were most highly rated from the CalCOFI community in 2020. In addition, she described the demographics of the conference participants and gave an overview of the conference agenda.

## Keynote: Samantha Murray, Fish and Game Commission
## Framework for assessing coastal human communities

Samantha Murray, the Executive Director of the Marine Biodiversity and Conservation and the Vice President of the Fish and Game Commission presented *Social-ecological indicators to inform marine management in a changing climate*. Murray discussed the fact that every inch of California's coast is valued and the California Fish and Game Commission manages some of these human uses. As such, social ecological indicators informed by long-term observation and monitoring data can support decision making and management. The most useful data for the commission is information that has been packaged and presented in an accessible and understandable way and includes the importance ('so what').

> "It's about the *wildlife* and, it's very much, about the *people*"
>
> ~*Samantha Murray, Fish and Game Commission*

*Climate change social & ecological indicators*. Murray suggested that we are in need of climate change indicators to help predict unforeseen changes. Our response to climate change is going to be a defining theme in the decades to come. We anticipate we will observe changes, such as range shifts, changes in migratory patterns, new species, and new technologies. In order to respond to these changes, we will need to be thoughtful and deliberate and include humans as part of the ecosystem studied. As such, social-ecological indicators will be important.

*Ecosystem-based management & human dimension information*. We need to continue to focus on ecosystem health and ecosystem-based management to have a more holistic understanding that attempts to balance multiple dimensions of marine resource management. For example, the Marine Protected Area (MPA) process was informed by abundant biological and habitat data, some information on economic impacts to consumptive users, but had limited data on non-consumptive uses and benefits. This lack of social information is still a gap in our understanding, such as related to non-consumptive values and economics of coastal communities.

*Framework for assessing coastal human communities*. Since one goal is to have healthy and resilient coastal communities, we may need a framework that includes several indicators to holistically evaluate the vulnerability of coastal communities within California and along the West Coast. A framework could help to prioritize work in specific communities dependent on the coast and ocean and inform mitigation and adaptation strategies.

Murray closed with a few key points: include human dimensions and social indicators in research, policy, and management; recognize cultural value and respect indigenous knowledge; and close the nature gap through inclusion, access, and ocean justice.

## Keynote: William 'Bill' Douros, NOAA Sanctuaries West Coast Region

Bill Douros, the Regional Director of the National Oceanic and Atmospheric Administration (NOAA) Sanctuaries West Coast Region, presented on *The value of monitoring data to the West Coast National Marine Sanctuaries*. He started off by sharing an overview of the NOAA Sanctuaries program and the importance of long-term management to the Sanctuaries.

There are 5 National Marine Sanctuaries (NMS) off of California, along with the proposed Chumash Heritage NMS. Long-term data and monitoring are critical to place-based management, such as within the NMS. But the long-term data collection is varied, such as in different habitats, and contexts, and relies on extensive partnerships. Some of the long-term programs that are important to the NMS along the U.S. West Coast include: CalCOFI, Applied California Current Ecosystem Studies (ACCESS), Multi-Agency Rocky Intertidal Network (MARINe), and Rockfish Recruitment and Ecosystem Assessment Survey (RREAS).


*Long-term data used for Condition Reports & research.* Long–term observing data are used immensely in the NMS Condition Reports, which are comprehensive documents on the monitoring ecosystems within the sanctuaries. These reports assess the NMS resources, along with the ecosystem status and trends. In addition, long-term data are used by research coordinators to help a site understand oceanographic or ecological conditions.

*Long-term data used for outreach & enforcement*. Some research and monitoring are used to guide outreach and connect to the public through exhibits in visitor centers. In addition, long-term data from CalCOFI have supported enforcement actions related to illegal cruise ship discharges. One question Douros proposed in his talk was related to figuring out how we can help to make long-term observing data more useful to managers (e.g., Sanctuary superintendents) and not only useful to the science staff that helps to advise them.

*Opportunities for long-term data & human dimension of the proposed Chumash NMS*. Douros closed with some of the upcoming opportunities related to linking observing and monitoring data to the NMS. For example, with the proposed Chumash NMS, there is an opportunity to better understand the ecosystem and what the tribal uses and cultural values are in the area. This provides a great opportunity to showcase Native American ocean use and marine sustainability.

*Partnership among CalCOFI & NMS for enhanced monitoring*. Douros shared that CalCOFI and the NMS are partnering to explore the option of using time on large NOAA vessels to add CalCOFI stations in order to cover the original spatial extent of CalCOFI and to add sites within Channel Islands National Marine Sanctuary and Monterey Bay National Marine Sanctuary, and possibly the Chumash National Marine Sanctuary. In addition, they are working towards a webenized Condition Report, which is a living, online document that can be updated faster than the 5 year reports. This would be a resource where a user can click on components of the ecosystem and find out the general information and trends.

A closing recommendation by Douros was to consider using the term 'human use' instead of 'social- ecological'.

## Panel: How can ocean observations support environmental, ecological, and socioeconomic indicators in the California Current?

This session was structured as a panel discussion with Brice Semmens, Scripps Institution of Oceanography (SIO) CalCOFI Director, as the moderator. The panelists included: Mia Lopez (Vice Chair, Coastal Band of Chumash Nation), Rosemary Kosaka (Economist, NOAA Southwest Fisheries Science Center [SWFSC]), Donna Schroeder (Marine Ecologist, Bureau of Ocean Energy Management [BOEM]), Rachel Seary (Postdoctoral Scholar, University of California, Santa Cruz [UCSC] & SWFSC), and Merrick Burden (Executive Director, Pacific Fishery Management Council [PFMC]). The panelists provided introductions and opening remarks followed by a question and answer session.

Following opening remarks, the discussion centered around a series of questions related to ensuring the relevance and use of social information, cultural heritage, as well as developing and communicating using indicators.

*Ensuring relevance of social science data for management in a changing climate*. The first question was related to ensuring that social science data that are collected is useful for managers, specifically related to the PFMC. Merrick Burden mentioned that it is important to connect directly to what the Councils need to do or are trying to do. For example, studies could link directly to the National Standard Guidelines on the topics related to social issues and equity or could link to the specific objectives of fishery management plans. One of the main takeaways from this discussion was that we will have to start thinking about things differently in the context of climate change, specifically thinking beyond the first order impacts to understanding how the ecosystem or community respond to those impacts.

*Ensuring relevance of scientific data to cultural heritage*. The next question was related to exploring ways that scientists can collect data that would be useful for cultural heritage. Mia Lopez said that tribes utilize scientific knowledge, even though it is collected in a different way. She also mentioned that the information can be slightly disconnected from the broader relevance and context of the importance of the information. This is one reason why it is important to include

> "We are doing a good job of understanding ocean dynamics and ocean change, but perhaps where we are not taking advantage of the information is in relating it to social-ecological changes and the implications of those changes"
>
> ~*Rachel Seary,*
> *Postdoctoral Scholar, UCSC & SWFSC*

different perspectives in understanding longer term changes, especially related to climate change. Related to this, Rachel Seary added that the data and observing information on the West Coast is quite impressive and that we have lots of information to understand ocean dynamics and ocean change. Yet, where we are not taking advantage of this extensive amount of information is in relating it to social ecological changes in the area. Rosemary Kosaka said that there is a need for both ocean use and non-use data, such as cultural value, citing an example of a past study where they explored valuation of MPAs by ocean users and the public.

*Distill observing information into sustainable resource management*. The discussion proceeded with a question on how we take the vast quantity of information we have and distill that information into sustainable resource use. Merrick Burden remarked on this from a fisheries and climate change perspective. He said that in the context of climate change this question has two components. The first is based on what we can anticipate and plan for so that it relates to our predictive capacity, expectations, and adaptive management. For example, for adaptive fisheries management, goal setting may be changed to account for anticipated changes. The second is, even in spite of all the information we have, there is a lot that we likely will be unprepared for, so relates to our ability to respond and build resilience. This hinges on ensuring that people and places have a diversity of responses, so are able to recover when shocks happen.

*Making social indicators useful for management and ocean literacy*. The next questions were related to the challenges and opportunities of making indicators useful as well as linking social and ecological indicators. The first was posed by Rosemary Kosaka and was related to exploring what indicators would be needed and useful for policymakers right now. The discussion centered around attributes of resilience and storytelling. For example, some attributes of resilience that have been explored are related to aspects of biodiversity, functional redundancy, capacity for innovation, and governance. In addition, it was highlighted that the most relevant indicators are those within a particular context (e.g., the U.S. West Coast), those that can be tracked, and those which scale up to a story for decision makers that describes capacity for resilience and adaptive potential. Thus, one of the things that is important in the framework of indicators is not just the metric of the indicator but the story that envelops the indicator to contextualize it and make it relevant to people that can make decisions about how we interact with and use resources. Along these lines, indicators can be project specific, but it is important to work with sociologists and other social scientists to determine more general indicators that can be useful for outreach and community engagement.

In addition, in the context of BOEM, changes within the system are linked to the human dimension (e.g., impact → physics → biology → human dimension), because it is important for managers and the public to understand the entire process for impact analyses. In order to link physical and biological changes to social and ecological impacts, datasets must be integrated across programs. The Marine Biodiversity Observing Network (MBON) provides a good example of an observing network that has successfully integrated observing data used by BOEM for impact assessments.

A few themes and recommendations emerged from the panel discussion which included:

- *Engage tribes and local knowledge holders in long-term observations*. Science, local knowledge, and traditional wisdom can further support and enhance each other. In addition, engaging people from different disciplinary perspectives and worldviews can help toward achieving shared conservation and sustainability goals.

- *Understand climate change trends*. Long-term physical, biological, and social data can be linked to understand 'baseline' conditions, the general productivity of an environment, as well as future climate change trends.
- *Relate ecological information to the human dimension*. Observing data can be better connected to the human dimension of linked environmental and social changes. This requires connecting multiple long-term datasets across larger scales and working with social scientists to understand which metrics are the most important for outreach and communication.
- *Understand vulnerability of coupled social-ecological systems*. The vulnerability of coastal communities and ecosystems to changing conditions is important to explore, especially in relation to their capacity to adapt and recover, and may rely on identifying the correct level of aggregation of social data for coastal communities.
- *Tell compelling stories with indicators*. One of the things that is important in the framework of indicators is not just the metric of the indicator but the story that envelops the indicator to contextualize it and make it relevant to people that can make decisions about how we interact with and use resources.

## Roundtable sessions

The CalCOFI Conference roundtables provided a valuable, interactive opportunity to bring together the conference participants around shared interests, goals, and priority topics, build partnerships, and gather input. The roundtables were forward-looking and provided a space to discuss, interact, share, and explore together. Some roundtables included brainstorming sessions related to a seed idea, feedback or input to determine next steps for a project, consensus on a particular topic, or were intended to develop new collaborations for a grant proposal or other project. The roundtable sessions consisted of nine concurrent sessions described below.

## Exploring Technological Advances to Monitor Ecosystem Health in the California Current

The roundtable, *Exploring Technological Advances to Monitor Ecosystem Health in the California Current*, was facilitated by Alessandra Burgos (University of California, Santa Barbara [UCSB]) and co-led by Bob Miller (UCSB), Nick Nidzieko (UCSB), Erika Eliason (UCSB), Corey Garza (California State University, Monterey Bay [CSUMB]), Clarissa Anderson (Southern California Coastal Ocean Observing System [SCCOOS]), and Barbara Block (Stanford University).

The overarching goal of the Regional Ecosystem Services Observation Network is to create a framework to guide the establishment of a marine biological monitoring network in central and Southern CA. This roundtable reviewed the projects strategy to advance technology to measure ecological indicators to understand the changing ecosystem by asking participants to provide comments on the conceptual framework, and on the species the project plans to explore in more depth during the second workshop. The main points that emerged during the roundtable discussion are described below.

**Opportunities for advancing technology to measure ecological indicators through a Regional Ecosystem Services Observation Network**

- The top five taxa that participants thought this network should pursue to monitor ecosystem health in the CA current were: plankton, anchovies, sardines, kelp, & sea urchins.
- Data collected from new technologies should be interoperable with existing long-term data streams.
- Next steps could include a pilot monitoring project to test observing technology or a workshop to understand social indicators and how they relate to ecological indicators and observing data.

## Incorporating Climate Change into Regional Monitoring Programs

The roundtable, *Incorporating Climate Change into Regional Monitoring Programs*, was facilitated by Karen McLaughlin (Southern California Coastal Water Research Project) and co-led by Alex Harper (Monterey Bay Aquarium Research Institute). Since the California Current Ecosystem is predicted to undergo some of the most rapid changes due to climate change, regional long-term monitoring can be a powerful tool to characterize climate change impacts and shifting baselines in our coastal habitats. This roundtable summarized and explored efforts to incorporate climate change indicators and metrics into regional monitoring programs through a discussion of best practices for monitoring and assessment and ideas for calibrating different sampling protocols and across indicators to build towards interoperable regional datasets among monitoring programs. The key points that emerged during the roundtable discussion are described below.

**Ways to use best practices, sampling protocols, and interoperable data to incorporate climate change indicators into regional monitoring**

- Incorporate climate change indicators and metrics into regional monitoring programs, which could include an inventory of biological indicators and metrics monitoring programs are using for climate change monitoring.
- Unify best practices across monitoring programs.
- Integrate data across monitoring programs so data can be compared across agencies.

## Exploring Integration of Social and Ecological Indicators for Adaptive Ecosystem-Based Management

The roundtable, *Exploring Integration of Social and Ecological Indicators for Adaptive Ecosystem-Based Management*, was facilitated by Jessica Rudnick (California Sea Grant & Delta Stewardship Council) and co-led by Kevin Travis (California Sea Grant & Ocean Science Trust) and Kristen Goodrich (Tijuana River National Estuarine Research Reserve). Integrating social science into ecosystem-based management approaches can improve the design of programs that more effectively motivate conservation behaviors, improve learning and coordination between actors, and can improve stakeholder engagement and equity. This roundtable provided the opportunity for participants to discuss examples of where they have seen or been involved in effective integration of social and ecological monitoring systems, the benefits and challenges to integration, and what needs to be better understood in order to effectively and efficiently continue to integrate social and ecological monitoring to inform

ecosystem management. The main points that emerged during the roundtable discussion are described below.

**Examples, benefits, and challenges of integrating social and ecological indicators for adaptive ecosystem-based management**

- A comprehensive framework and exploration of existing frameworks would be helpful to better understand and synthesize the existing efforts to develop indicators on the human dimensions of ocean sustainability
- There is a substantial gap in time series data and data at finer spatial scales for indicators that represent both social, socioeconomic, and ecological factors. For example, dependency and vulnerability data are needed at a scale relevant for state managed fisheries since the data collected at a federal level can be too broad
- There is a need to understand the factors that affect social-ecological system (SES) indicators (e.g., heatwaves)
- Examples from other natural resource areas and systems (e.g., cultural ecosystem services in estuaries) could inform the development of indicators for oceans

## Developing Environmental Indicators for Anchovy and Sardine Recruitment to Inform Modeling and Management for Forage Fish Species in the California Current

The roundtable, *Developing Environmental Indicators for Anchovy and Sardine Recruitment to Inform Modeling and Management for Forage Fish Species in the California Current*, was facilitated by Desiree Tommasi (UCSC / NOAA SWFSC) and co-led by Stefan Koenigstein (UCSC / NOAA SWFSC), Barb Muhling (UCSC / NOAA SWFSC), Justin Suca (UCSC / NOAA SWFSC), Andrew Thompson (NOAA SWFSC), and Robert Wildermuth (UCSC / NOAA SWFSC). Since forage fish species serve a critical ecological and economic function in the California Current Ecosystem (CCE) and are characterized by boom and bust cycles driven by oceanographic variability, this roundtable, brought together regional experts in sardine and anchovy dynamics to review past hypotheses of drivers of sardine and anchovy recruitment as well as the latest insights from empirical and mechanistic models and isotope analyses. The main points that emerged during the roundtable discussion are described below.

**Developments in environmental indicators for sardine and anchovy recruitment**

- Food availability during larval stage is a key driver of both sardine and anchovy recruitment, but other drivers, such as parental conditioning or predation, may also play a role in any given year.
- More research is needed to characterize the prey field of larval sardines and anchovies.
- In developing recruitment indices, it is important to carefully consider which temporal and spatial scales are used since these would differ for each species and proposed mechanism.

## 'Omics Applications and CalCOFI Samples

The roundtable, *'Omics Applications and CalCOFI Samples,* was facilitated by Zachary Gold (NOAA NWFSC) and co-led by Andrew Thompson (NOAA SWFSC) and Kelly Goodwin (AOML). Since genomics approaches have opened entire new fields of research within the past decade and continue to advance rapidly, this roundtable explored the various application of genomics approaches including eDNA metabarcoding, metagenomics, qPCR/ddPCR, metabolomics, and proteomics to CalCOFI samples and how these tools can help us better understand and manage marine ecosystems in response to climate change. The main points that emerged during the roundtable discussion are described below.

**Opportunities for genomics approaches in long-term monitoring**

- 'Omics approaches, particularly metabarcoding, have the ability to unlock ethanol-preserved bongo tows and provide an untapped resource for characterizing assemblages that have been too difficult or time consuming to characterize (e.g., zooplankton and rockfishes).
- CalCOFI could benefit from the development of single species qPCR/ddPCR assays to detect key species of interest from either water samples or ethanol-preserved bongo tows including coastal pelagic fisheries targets (e.g., anchovy, sardine), key ecosystem indicator species (e.g., Northern vs. southern krill species), or harmful algal species. This could provide rapid and quantitative results for key target species.
- Careful consideration of sample preservation and storage from field to physical samples to sequencing data to bioinformatics are needed to ensure that the CalCOFI collections are best utilized using 'omics approaches. The field is rapidly evolving and methods continue to improve dramatically. Thus, standardization and thoughtful utilization and implementation are needed to ensure that CalCOFI samples are available for future 'Omics approaches. For example, if gene expression is of key interest, then samples will need to be preserved in specific RNA preserving buffers (not the current ethanol or formalin).

## Conserving 30% of California's Coastal Waters by 2030

The roundtable, *Conserving 30% of California's Coastal Waters by 2030*, was facilitated by Michael Esgro and Noah Ben-Aderet from the California Ocean Protection Council. A recent Executive Order set the goal of conserving 30% of the state's lands and coastal waters by 2030. This roundtable facilitated a scientific discussion on the major threats to biodiversity within coastal waters, especially in the face of changing ocean conditions, and what types of protections could be implemented to address those threats to inform California's 30×30 effort. The main points that emerged during the roundtable discussion are described below.

**Key considerations for discussions related to conserving 30% of California's coastal waters by 2030**

- The definitions of conservation and protection will be very important to clarify in conversations related to conserving 30% of California's coastal waters by 2030.

- The major threats to coastal and ocean biodiversity in California were considered to be: coastal runoff, kelp forest reduction, marine heat waves, oil spills, sea level rise including rocky intertidal, erosion, turbidity, loss of marshland, and plastic pollution
- Some ideas to address the threats listed above were protecting spawning habitat, using genetics to test for resilience for changed conditions, and determining how to create a regulatory framework for non point source pollutions
- The effectiveness of biodiversity protections could be monitored and evaluated to support successful outcomes for biodiversity conservation by having clear questions and goals for the short term and long term as well as building partnerships and working together

## Promoting the Use of Standards for Biological Observation Data Using a Primer

The roundtable, Promoting the Use of Standards for Biological Observation Data Using a Primer, was facilitated by Abby Benson (USGS), Diana LaScala-Gruenewald (MBARI & CenCOOS), and Robert McGuinn (NOAA Affiliate). In order to understand changes in biodiversity over time, biological data need to be able to be combined. This requires biological data standards, yet several different standards exist for biological data, metadata, and taxonomic standards, which makes it confusing for data managers and data users to navigate. The Earth Science Information Partners (ESIP) Biological Data Standards Cluster has been working on a primer for data managers new to biological data standards. The purpose of this session was to share the Biological Data Standards Primer and gain feedback and insight on next steps from a broader community. The main points that emerged during the roundtable discussion are described below.

**Recommendations on promoting the use of biological data standards**

- More work needs to be done to communicate the importance of adopting standards and to alter the perception that utilizing data standards is too much work and doesn't result in much benefit to the data provider.
- From a data user perspective there is lots of time wasted on data discovery as well as data wrangling relative to conducting the data analysis.
- A way to engage people in standards along the entire spectrum, from data managers and contributors to data users would be helpful.

## Assessing Ocean Societal Indicators for Oceans, Great Lakes, and Coasts

The roundtable, *Assessing Ocean Societal Indicators for Oceans, Great Lakes, and Coasts,* was led by Kim Marshall McLean (BOEM & Interagency Ocean Observation Committee [IOOC] Ocean Societal Indicators Task Team) and co-led by Rachel Seary (UCSC/SWFSC). Since ocean observations should be connected to social and socioeconomic indicators to ensure relevance to society, this roundtable provided a brief overview of the goals of the task team as well as soliciting feedback on a survey that the task team is sending to a diverse array of stakeholders including social scientists, NEPA practitioners, biologists, and policy professionals to help identify existing societal indicators or suites of indicators with links to physical, chemical, and biological datasets about the ocean, coasts, and Great Lakes. The main points that emerged during the roundtable discussion are described below.

**Considerations for assessing ocean societal indicators**

- Social indicators serve as a way to more fully understand ecosystem services, and especially cultural ecosystem services
- Collecting social data is relevant especially in cases where understanding ecosystem services is mandated
- The context surrounding specific societal indicators, such as what they might be used for and how they might be useful, was considered most important to focus on in synthesizing the indicators (i.e., indicators for understanding climate change impacts or indicators for vulnerability assessments)

## CalCOFI Showcase Development: Data Visualizations, Interactive Dashboard and Automated Workflows

The roundtable, *CalCOFI Showcase Development: Data Visualizations, Interactive Dashboard and Automated Workflows*, was facilitated by Ben Best (EcoQuants LLC) and co-led by Brice Semmens (Scripps Institution of Oceanography & CalCOFI), Chris Caldow (NOAA Sanctuaries), Jennifer Brown (NOAA Sanctuaries), and Pike Spector (NOAA). CalCOFI and other long-term surveys provide a long-term baseline to assess the ecological state of the California Current. This roundtable sought input from the community to prioritize data visualizations, automated workflows and dashboard functionality. The main points that emerged during the roundtable discussion are described below.

**Considerations in developing data visualization, interactive dashboards, and automated workflows with**

- *Identify the audience*. It is important to identify the focal audience, which could be scientists or general ocean users.
- *Automate long-term data pipelines*. Further develop automated data workflows of long term observing data, like CalCOFI data, to streamline the generation of updated indicators with minimal delay. In addition, it is important to understand the existing indicators and visualizations to ensure that new efforts are supportive and not duplicative.
- *Storytelling with data*. Tell unique evidence-based stories with a variety of long-term observing data.

# Panel & Discussion Session: Navigating a Contemporary Career Path in Ocean Sustainability

In recent years, collaboration and integration of the ocean science and sustainability workforce has increased across sectors and disciplines. This collaborative approach has led to new and reimagined career pathways that are cross-cutting and integrative in how we gather data, cultivate knowledge, and

apply ocean science. Navigating a contemporary career in ocean science and sustainability can be complex with variable positions, pathways, and opportunities, which can be visualized as a braided river.

The panel was moderated by Kevin Travis, a CA Sea Grant State Fellow with California Ocean Science Trust. The panel consisted of ocean professionals from various career stages, paths, and sectors including: Alfredo Giron (André Hoffmann Fellow at the Stanford Center for Ocean Solutions & World Economic Forum Centre for the Fourth Industrial Revolution), Sonia Batten (Executive Secretary of the North Pacific Marine Science Organization), Anna Zivian (Senior Research Fellow at the Ocean Conservancy), and Shauna Oh (Director of California Sea Grant). During this session, panelists shared their career journey and participants engaged in a Question & Answer session with the panelists to discuss diverse careers in ocean science and sustainability, including the challenges and opportunities for creating a more connected and inclusive ocean professionals community.

> "The braided river is not just for professional development, but to solve problems"
>
> ~ *Shauna Oh, Director, California Sea Grant*

A few key pieces of advice emerged from the Q & A discussion. These included:

*Relationship building & mentorship:* There was a strong emphasis on the importance of connecting with people throughout your career. This includes being proactive in building relationships and expanding your network across sectors and disciplines, no matter at what career stage. Informational interviews with professionals from various backgrounds can provide insight on different careers and pathways. Additionally, good mentorship is invaluable at all career stages and in many cases, it may be necessary to seek mentors out, especially for navigating challenging moments. This includes the insight that comes from peers, because they may have different, yet relevant experiences.

*Communication & novel skill building:* The ability to communicate across a diversity of people, sectors, and disciplines is increasingly important for careers in ocean sustainability. This may include effectively translating key messages between disparate sectors or communicating with people from various backgrounds. Developing these communication skills or other novel skills tend to be acquired from opportunities beyond academic education, so it is increasingly important to seek novel opportunities, whether formal or informal, that will allow you to do something different. The braided river analogy emphasizes the connectedness between sectors and pathways, so use this for diversifying your professional experience to see how marine and environmental science is conducted in different contexts and settings.

*Co-creation & Inclusivity:* There is a growing emphasis on the co-creation of ocean science knowledge and the co-implementation of solutions within ocean sustainability. This relies on working with communities, end users, and industry, as well as explicitly including social scientists & the human dimensions. It is necessary to build relationships with communities for defining environmental issues and establishing partnerships across sectors and disciplines around a common goal. These collaborative career

opportunities should be designed to bring in more voices into the workforce, especially those that have been historically excluded from Science, Technology, Engineering, and Math (STEM) fields. It is critical that organizations and institutions work to build an inclusive and equitable support system for Early Career Professionals and throughout the braided river of career pathways.

## Status of the Fisheries

In her opening remarks, Julia Coates (California Department of Fish and Wildlife CalCOFI Program Lead) described trends in landings of a few key state-managed fisheries including market squid (Doryteuthis opalescens), Dungeness crab (Metacarcinus/Cancer magister), spiny lobster (Panulirus interruptus), and California halibut (Paralichthys californicus). She examined the relationship between trends in landings and the Multivariate Ocean-Climate Indicator (MOCI) climate index within three regions of the state (southern, central, northern) and at annual or seasonal time scales depending on how each fishery operates. Three of the four species (squid, lobster & halibut) indicate a regional shift or expansion to the north in recent years. For each of these fisheries, significant correlations between landings and MOCI suggest environmental influence. Future work will examine lagged correlations to better explore the relationship between environmental conditions and stock productivity as well as incorporate the influence of economics and fishing behavior on landings trends.

## CalCOFI Tribute: In Memoriam

Roger Hewitt, Assistant Director at the SWFSC, described the contributions of Paul Smith, Rich Charter, and Jeff Moser within the context of CalCOFI history in his presentation, “In Memoriam." Roger Hewitt described the early history of CalCOFI and the initial philosophy of the program as the “oceanographic approach to fisheries research,” which we now call “ecosystem approach to fisheries management”. He also described the unique contributions of these three key CalCOFI figures to ichthyology, data management, and unique scientific findings related to recruitment and climatic events. A few common threads emerged that tie together these important CalCOFI figures: The first is that fish cannot be understood in isolation from their environment, the second is that long term monitoring can be used to better understand patterns in nature, and third that there is high value of interpersonal relationships to people.

## State of the California Current: Report

In the annual State of the California Current presentation, Juan Zwolinski, Project Scientist, at the SWFSC, described the patterns and trends of the physical, chemical, and biological conditions in the California Current from 2020-2021, many of which have signaled a return to more normal conditions, yet are still not normal compared to pre-heatwave conditions.

The physical oceanography of the past year has followed a series of heat waves and fluctuations in the El Nino Southern Oscillation (ENSO) and the warm anomalies in 2021 in the open Pacific Ocean waters did not reach the California Current due to upwelling. The major climate indices (ENSO, ONI, PDO) are mostly in cold or neutral states. The average sea surface temperature in CalCOFI region has

been returning to normal and the salinity anomalies were salty in recent years on line 90, possibly indicating the influence of water masses with unique origins.

In 2021, some Harmful Algal Blooms (HABs) occurred, but to a lesser degree than previous years. Some fisheries in Northern California were able to re-open after having been closed due to HAB events.

Both the ichthyoplankton and salmon data seemed to be returning to normal, following deviations caused by previous heatwaves. The abundance of Northern Anchovy, juvenile rockfish, and Hake increased following low numbers in the previous year with anchovy more dominant in the south, and Jack Mackerel in the north. In addition, the potential Pacific Sardine habitat in 2021 appeared more like past conditions in that it was detached from the coast off Northern California and did not reach as far north as in previous warm years.

The bird census at select locations also suggests a return to more normal conditions, compared to previous years. In addition, survival of sea lion pups fluctuates with coastal pelagic species (CPS) availability (e.g., anchovies) in recent years, such that survival is low in years with marine heat waves and high with more average conditions. There was an unusually high number of sightings of blue and fin whales as well as fur seals in the offshore CalCOFI region.

## State of the California Current: Community Observations

Following the State of the California Current presentation, there was a community discussion where the CalCOFI conference participants could share their observations of the coastal and marine environments from the past year. Andrew Thompson, Research Fisheries Biologist at the SWFSC, moderated the community discussion.

*Cooler water, abundant salps, and abundant pyrosomes in the southern part of the California Current*. Bryan Overcash, NOAA CalCOFI technician, started the discussion by sharing the observations that the ocean water had returned to a more normal state. Generally, there was a higher abundance of salps than past years and the water was slightly cooler where the salps were present. In addition, there tended to be more abundant but smaller pyrosomes in the water than past years. Emily Gardner, NOAA technician, added that they had observed pyrosomes even throughout the winter samples over the past year, which is uncommon. In addition, many pyrosomes had been present in the northern California Current (e.g., off the coast of Washington) in past summer CPS cruises, but this year there were markedly fewer up north. Many other conference participants added pyrosome observations to the discussion through the conference chat. Elizabeth Phillips added that they had similar pyrosome observations

> "We are in the ocean and see these changes on a daily basis – is there an opportunity to reach out to the commercial industry to get input on the changes we are seeing"
>
> ~ *Dick Ogg, Commercial fisherman, Bodega Bay, CA*

from the hake acoustic-trawl survey, such that there were more pyrosomes in the south than the north. Cheryl Morgan added that they did not see any pyrosomes in the daytime surface trawls off Washington and Oregon. Jennifer Fisher added that they didn't see any pyrosomes on the Newport Line in 2021 but did collect quite a few small pyrosomes off Crescent City in May 2021. Eric Bjorkstedt said that they frequently had small to medium pyrosomes off Trinidad Head over the past year. Bob Miller added that they saw large numbers of senescent pyrosomes on the bottom in coastal Southern California waters and only bat stars seemed to be eating them.

*Abundant storm petrels, cargo ships, and tar balls from the Southern California oil spill*. Angela Klemmedson, SIO CalCOFI technician, added that they saw a much larger number of storm petrels during the fall cruise than has been seen in past years and they observed blue whales offshore. Also, there were hundreds of cargo ships anchored off of Long Beach, which made ship operations and sampling a bit more challenging and tar balls were found in some of the net tow samples, possibly related to the recent Southern California oil spill.

Other participants contributed additional observations to the discussion. For example, there were mostly upwelling-favorable winds in Southern California for most of the year except one period in June. In addition, some kelp returned to Northern California areas after losses due to marine heat waves. During marine heat wave years, there were a lot of different species present including more southern and northern marine species, and tuna crabs were associated with previous heat wave conditions. Scott Benson added that large Mola mola have become ubiquitous in shelf waters off central California during the past 5-7 years based on long term aerial surveys.

The discussion closed with a remark from Dick Ogg, a commercial fisherman from Bodega Bay, who said that commercial fishermen observe changes in the ocean on a daily basis (e.g., appearance/disappearance of species). Thus, there may be an opportunity to collaborate with the commercial fishing industry to share ocean observations on a more regular basis. In addition, Alan Mearns suggested incorporating daily sport fishing landings into the State of the California Current report.

An overarching question that arose from the discussion was, *"Is there a way to incorporate social science and/or citizen science data, such as observations from commercial and recreational fisherman, into the State of the California Current Report and other scientific analyses?"*

*Is there a way to incorporate social science and/or citizen science data, such as observations from commercial and recreational fisherman, into the State of the California Current Report and other scientific analyses?*

# Contributed Talks

## Session 1: From Monitoring to Indicators and Management

*The Southern California Bight Regional Marine Monitoring Program,* was presented by Karen McLaughlin. One of the key takeaways from the presentation was that coordination among monitoring programs can greatly enhance spatial coverage of ocean acidification impacts assessments.

*40 Years and Counting? A Remarkable Time Series of California Sea Lion Diet from the southern Channel Islands*, was presented by K. Alexandra Curtis. A key message of the presentation was that California sea lion scats from key rookeries on the southern Channel Islands have been collected quarterly for more than 40 years, providing a long term dataset of sea lion diets from Southern California, but the time series has an uncertain future.

*Long-term Participation in Collaborative Fisheries Research Improves Angler Opinions on Marine Protected Areas*, was presented by Erica Mason. One of the takeaways from the presentation was that the California collaborative Fisheries Research Program (CCFRP) has successfully integrated citizen science into the program and a positive opinion of MPAs was likely to occur after considerable time (7+ years) engaged with the collaborative fisheries program.

*An integrated California MPA data dashboard to support MPA assessment and research in a changing ocean*, was presented by Natalie Low. One of the main points from the presentation was that integrating climatological, oceanographic, ecological, and model output data from multiple sources can support researchers and managers in understanding short and long term drivers and patterns of change within MPAs.

*Climate informed indicators of bull kelp forest ecosystems*, was presented by Laura Rogers-Bennett. A key finding was that the winter Multivariate Ocean Climate Indicator (MOCI) values are a good early warning indicator since they predict peak kelp canopy the following summer.

*An anchovy ecosystem indicator explains foraging and reproduction of marine top predators*, was presented by Will Fennie. A key takeaway was that since northern anchovy (*Engraulis mordax*) is an important forage species whose population size can change by orders of magnitude from year to year, the anchovy ecosystem indicator (AEI) was strongly positively correlated with the diet composition of California sea lions and three seabird species; the at-sea distribution of Common murre, Brandt's cormorant, and California sea lion; and reproductive success of Brandt's cormorant and California sea lion.

*California grunion runs as indicators for beaches*, was presented by Karen Martin. A key message was that over the past 20 years, California Grunion runs have generally become less frequent and less abundant in southern California and have experienced a northward habitat shift so may be a choice indicator for sandy beach biodiversity and climate change.

*Designing an indicator to characterize the sensitivity of the predator community to prey distribution shifts in the California Current*, was presented by Pierre-Yves Hernvann. A main point was that a novel ecosystem/food web model-based approach, which integrates diet and habitat data from both CPS and their predators, can help to understand the sensitivity of marine predators to changes in CPS distribution in the California Current.

*Using climate novelty as an indicator of general ecosystem stress*, was presented by James Smith. A main finding was that even under high emissions, consistent novelty appears around 2040 and then only

in small patches, but novelty increases rapidly after 2040 (especially in warmer seasons), so that by 2090 up to 100% of the California Current Ecosystem in an average year has shifted to a novel local climate, which increases to 100% by 2090. The ecosystem could increasingly experience novel combinations of warmer temperatures, lower dissolved oxygen (especially inshore), and a shallower mixed layer (especially offshore).

*Portfolio substitution between coastal pelagic species under shifting target species distributions and policy constraints*, was presented by Felipe Quezada. This presentation explored fishing portfolios and found that there was strong substitution between market squid and Pacific sardine when both were available.

*Attributes of climate resilience in fisheries: from theory to practice*, was presented by Julia Mason. A main outcome of this work was a resilience framework to examine fishery systems across ecological, socio-economic, and governance dimensions using five resilience domains: assets, flexibility, organization, learning, and agency.

*Developing socio-ecological indicators to evaluate management strategies to mitigate whale entanglement risk within the Dungeness Crab Fishery*, was presented by Rachel Seary. This presentation described the development of socio-economic indicators related to ecosystem-based management that can successfully reduce whale entanglements while promoting healthy fisheries, such as Dungeness Crab.

*Fish Tales: The OceanView app for citizen science*, was presented by Marina Frants. This presentation showcased an interactive citizen science application that is intended to supplement existing long term observations in the California Current. The app will allow recreational fishers to upload detailed information on species they caught or observed, including species information, length, weight, and location.

*Applying your work to ecosystem management*, was presented by Brian Wells. This presentation provided a conceptual understanding of how developing qualitative networks between managed ecosystem components can help in estimating the responses of ecosystems to future climate trends and variability.

## Session 2: Oceanography & Fisheries

*Temperature and salinity extremes from 2014-2019 in the California Current System and its source waters*, was presented by Alice Ren. This presentation showed that a high-salinity anomaly and anomalously high temperatures affected the CCE from 2017-2019.

*Integrated hydrodynamics and machine learning models for compound flooding prediction in a data-scarce estuarine delta*, was presented by Joko Sampurno. This presentation showcased an integrated hydrodynamic and machine learning approach to predict compound flooding in areas with limited computational resources and observational data. A finding was that the Random Forest algorithm is the most accurate algorithm to predict flooding hazards.

*A pyrosome eruption in the California Current Ecosystem in the context of the preceding 7 decades*, was presented by Laura Lilly. This presentation explored the widespread outbreak of pyrosomes that occured in spring and summer of 2021 in the California Current.

*Seasonal and interannual variation of Atlantidae (Pterotracheoidea) in the Pacific coast of Baja California, Mexico*, was presented by María Moreno-Alcántara. This presentation explored the distribution and abundance of planktonic gastropods, Atlantids, in the CCE. A key finding was that there is a higher diversity of Atlantids in winter than spring, with the most species recorded during the warm anomalies observed in the winters of 2014 and 2016, and the distribution of Atlantids in winter was mainly correlated to water masses, temperature, and salinity while in spring, their distribution was mainly correlated with hypoxic conditions and the aragonite saturation horizon depth.

*Natural mortality rate of sub-legal Dungeness crabs*, was presented by Montana McLeod. This presentation estimated the natural mortality rate of sub-legal crabs while accounting for the probability of molting and the change in size due to molting.

*Market squid fishery in Oregon*, was presented by Gregory Krutzikowsky. A key point was that market squid have been fished for and landed in Oregon intermittently since the 1980s and the highest landings on record in Oregon occurred in 2020.

*Fish scale deposition in the Santa Barbara Basin: reconstruction and climatic significance*, was presented by Tim Baumgartner. Reconstructed estimates of sardine biomass from AD 470 through 1970 using sardine scales in the sediments of the Santa Barbara Basin were presented and showed multidecadal and paleoclimate variability.

*Putting the Pacific marine heat wave into perspective: the response of larval fish off Southern California to unprecedented warming in 2014-2016 relative to the previous 65 years*, was presented by Andrew Thompson. A main conclusion was that the larval fish assemblage during the 2014-2016 marine heatwave was unusual relative to previous warm years because of the combination of record high mesopelagic abundance, species richness, the increase in anchovy, and the presence of rare northern species.

*Persistent structure and sharp transitions in larval fish assemblages off northern California: Analysis of a 12-year ichthyoplankton time series along the Trinidad Head Line*, was presented by Blair Winnacott. A key outcome of this presentation was that there was a strong increase in larval fish abundance and richness that coincided with the marine heatwave in 2015-2016, which suggests that larval fish assemblages could be indicators of ecosystem response to climate forcing in the California Current.

*Length and age compositions for the central subpopulation of the Northern anchovy (Engraulis mordax)*, was presented by Brittany Schwartzkopf. A main finding was that greater numbers of smaller and younger anchovies were caught in the trawl survey from 2015-2017, with a higher frequency of larger and older anchovies observed from 2018-2021.

*Updated estimates of length and age at maturity for the central subpopulation of the Northern anchovy (Engraulis mordax)*, was presented by Brad Erisman. This presentation provided updated estimates of length and age at sexual maturity. One finding was that the standard length at maturity (L50) of female anchovies in the Southern California Bight was 98.2 mm.

*Top-down and bottom-up effects on juvenile Chinook salmon survival off central California from an individual-based model*, was presented by Kelly Vasbinder. This presentation used a 21-year time series from 1990-2010 to explore interannual variability in growth and survival of juvenile Chinook salmon off central California under predation pressure from common murre.

*Identifying stage-specific drivers of Pacific hake (Merluccius productus) recruitment in the California Current Ecosystem*, was presented by Cathleen Vestfals. Using a 7-stage conceptual hake life-history model, multiple stage-specific mechanisms, including parental preconditioning, were found to influence hake recruitment across their early life history.

*Evaluating robustness of harvest control rules to variability in Pacific sardine recruitment*, was presented by Robert Wildermuth. A management strategy evaluation was used to assess the robustness of current and alternative environmental harvest control rules under a variety of recruitment variability scenarios for Pacific sardine. A main finding was that harvest control rules that were successful had higher mean stock biomass and catch, with low catch variability, few fishery closures, and shorter stock rebuilding periods.

## Additional content

### Local Social gatherings

Informal social gatherings occurred at local hubs along the U.S. West Coast and provided a bit of in-person connection surrounding the conference. Gatherings occurred in: San Diego, Carlsbad, Santa Barbara, Monterey, Santa Cruz, Newport, and Seattle.

### Photo slideshow: Year in review

A photo slideshow was developed to showcase field operations in 2021. The slideshow can be found at: tiny.cc/CalCOFIslideshow.

# Outcomes & Recommendations

1. Researchers in the CA Current System are looking to larval fish as indicators of ecosystem response to climate. They are also studying indicators of predator sensitivity to changing prey communities, indicators of recruitment success of commercially important species, and physical indicators of kelp productivity.
2. Recent warming events were associated with high diversity and richness in fish and gastropod assemblages and coincided with surprising increases in abundance of particular species including anchovy and sea lions.

3. Social ecological indicators are important to understand and gauge the vulnerability of human coastal communities.
4. Further data, information, and research is needed on cultural values and non-consumptive uses and benefits.
5. An overarching framework to assess and prioritize coastal human communities in need of adaptive management would be useful in California.
6. The term 'social-ecological' may not be the clearest term. The terms human dimensions, cultural or ecosystem services, or human use may be more easily understood by a wider audience.
7. An annual report on the social/human dimensions could occur as a complement to the State of the California Current Report and could include collaborations with commercial fishermen.
8. Diverse engagement, especially tribal and local engagement, is essential for ocean conservation and sustainability.
9. Coordination would be helpful among the existing ecosystem reports in the CCE (e.g., CCIEA, Sanctuary, State of the California Current Ecosystem Report).

# Questions

1. What types of human dimensions data would be most valuable for improving ocean resource management?
2. A great deal of work has been done to understand the drivers of sardine and anchovy recruitment success. Studied factors include food availability during larval stage, parental conditioning and predation. Other factors include physical conditions and their impact on metabolism, growth, and behavior. Given we cannot study drivers of recruitment success for all harvested species to this level of detail, has this body of work suggested which factors are likely to be most important and those that should be investigated first?
3. Would the high larval fish richness observed during recent warming events be maintained with more frequent or more persistent warming?
4. What are our best next steps for linking our knowledge of the frequency and duration of future novel physical characteristics in the CA Current to anticipated biological community characteristics?

# Report Preparation & Materials

This report was prepared by the CalCOFI Committee (Drs. Brice Semmens, Noelle Bowlin, Julia Coates, Ralf Goericke, Rasmus Swalethorp, Andrew Thompson, and Briana Brady) and the CalCOFI Coordinator (Dr. Erin Satterthwaite) with input and feedback from conference speakers and moderators. We are grateful to all facilitators, speakers, and participants for making this a successful conference.

To find all materials, including abstracts, associated with the 2021 CalCOFI Conference "Social ecological indicators to support marine management in a changing climate", please visit the calcofi website (*temporary address:* https://calcofi.org/conference/conference-2021/).