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DECEMBER 2020

LEVERAGING THE LEGACY OF THE CALCOFI MONITORING PROGRAM:A SUMMARY FOR WEST COAST FISHERY AND OCEAN RESOURCE MANAGERS

by

Laura Engeman, Erin Satterthwaite, Andrew Thompson, Natalya Gallo, Noelle Bowlin, Ralf Goericke, Briana Brady, Travis Buck, and Brice Semmens

ADMINISTRATIVE REPORT LJ-21-02
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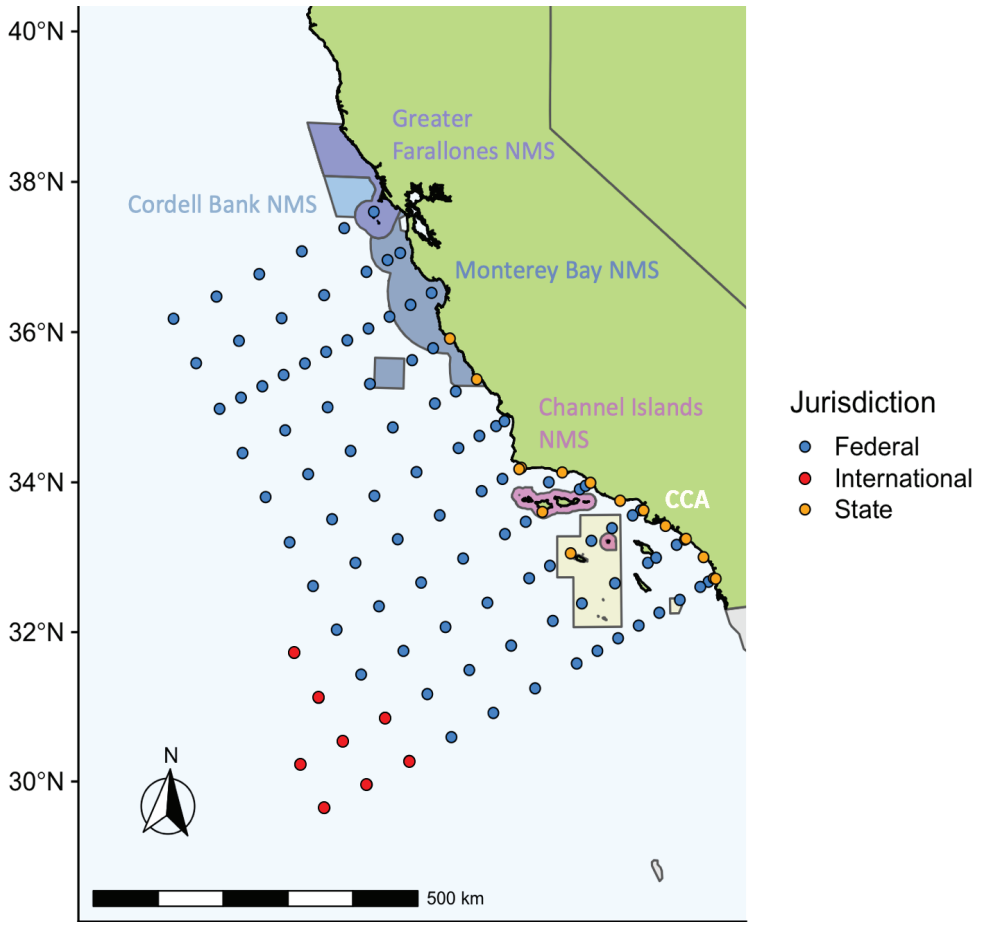
Leveraging the Legacy of the CalCOFI Monitoring Program

A summary report for west coast fishery and ocean resource managers

Figure 1: CalCOFI Stations

Map of the 113 CalCOFI stations, color-coded by state (orange), federal (blue), or international (red) waters. Certain CalCOFI stations sample within marine conservation zones, such as the National Marine Sanctuaries (NMS) and the Cowcod Conservation Area (CCA).



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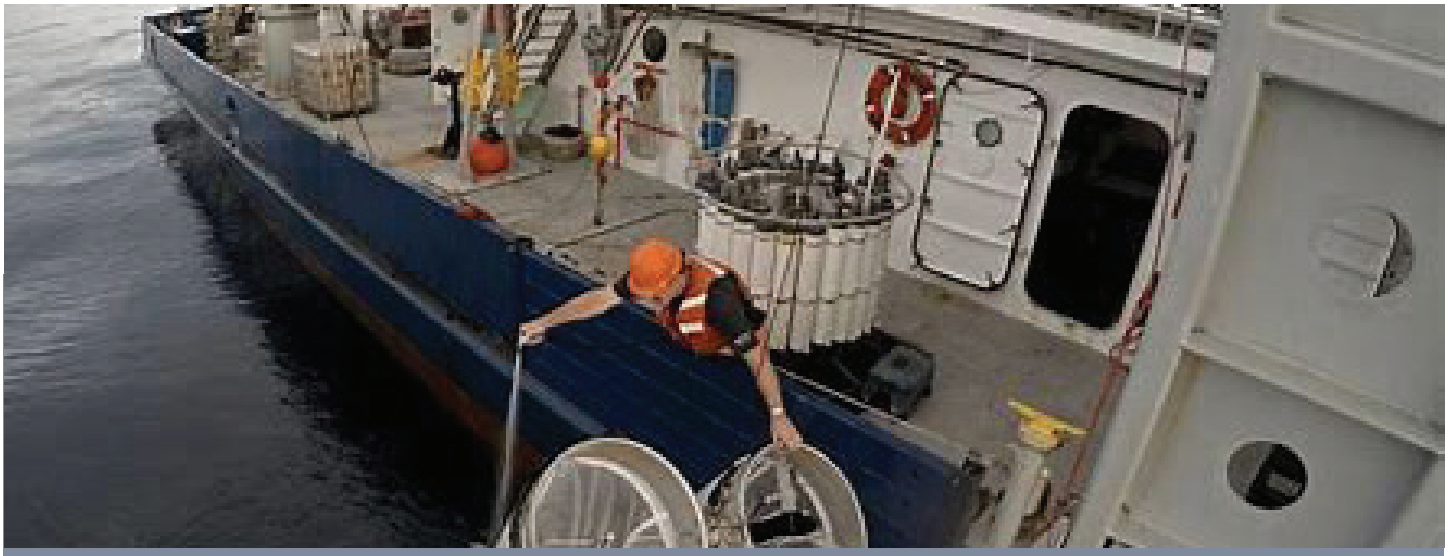

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Purpose

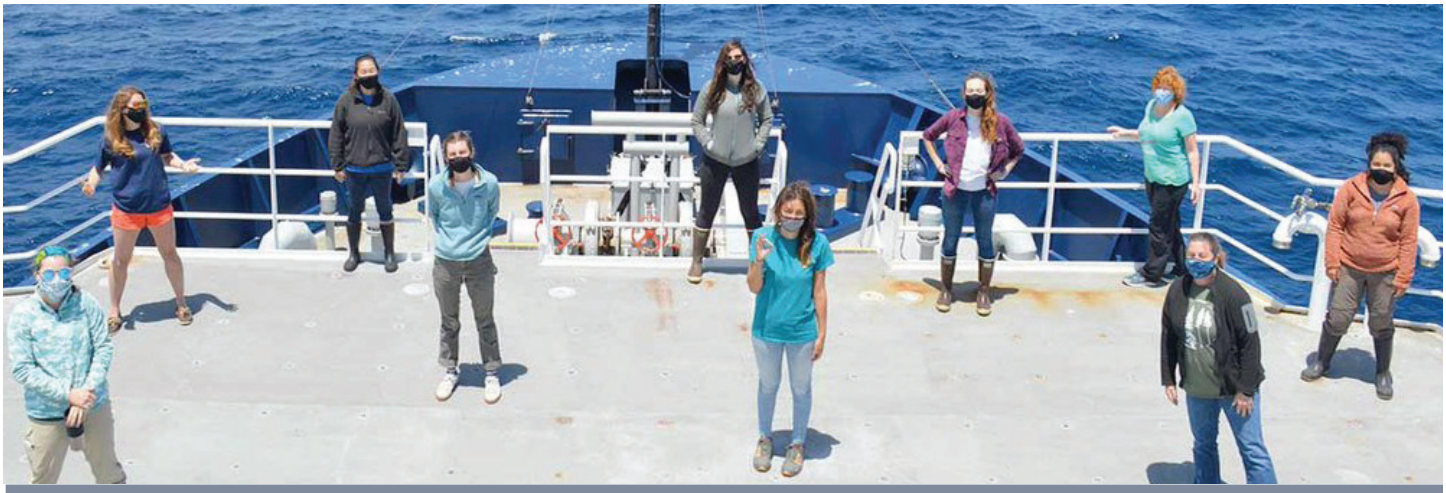
This report was written by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program for west coast fishery and ocean resource managers. It is intended to spark a dialogue about how CalCOFI's rich ocean monitoring legacy can best contribute to fisheries and marine ecosystem management priorities.

Overview

California is fortunate to have one of the world's longest-running, integrated ocean ecosystem sampling programs. Launched in 1949, CalCOFI was originally intended to investigate the oceanic conditions that drove the 1940's Pacific Sardine crash and to inform future ocean management responses. Today, it is one of a handful of ocean monitoring programs that simultaneously collects biological, chemical, and physical variables across the California Current marine ecosystem (CCE). This has proven valuable in understanding population dynamics for a variety of commercially-important marine species in addition to understanding marine ecosystem processes (e.g., biological responses to El Niños, upwelling events).

In the last decade, new questions are being asked of ocean monitoring and data as our ocean undergoes rapid, unprecedented, and profound changes. Given these emerging and expanded questions, CalCOFI partnered with California Sea Grant to explore today's ocean monitoring priorities and take a fresh look at how ocean users are leveraging CalCOFI data and products.

This report summarizes feedback from these stakeholders and identifies ways in which CalCOFI plans to mature its monitoring program, products, and partnerships to meet ongoing and future fishery and ocean ecosystem monitoring needs.



CalCOFI Today

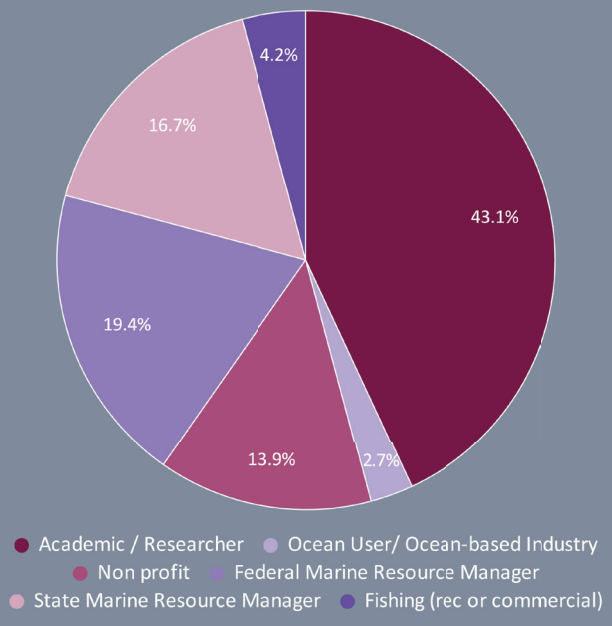
The CalCOFI 70-year time series has, and continues to, elucidate the effects of interannual and decadal scale environmental variability on the southern CCE and its fisheries. Today, CalCOFI data is also increasingly used to assess the impacts of long-term change; meet the needs of the region's marine resource managers and scientists concerned with exploited and protected species; and serves as a cornerstone data source for oceanographic and atmospheric research communities working globally and in the CCE.

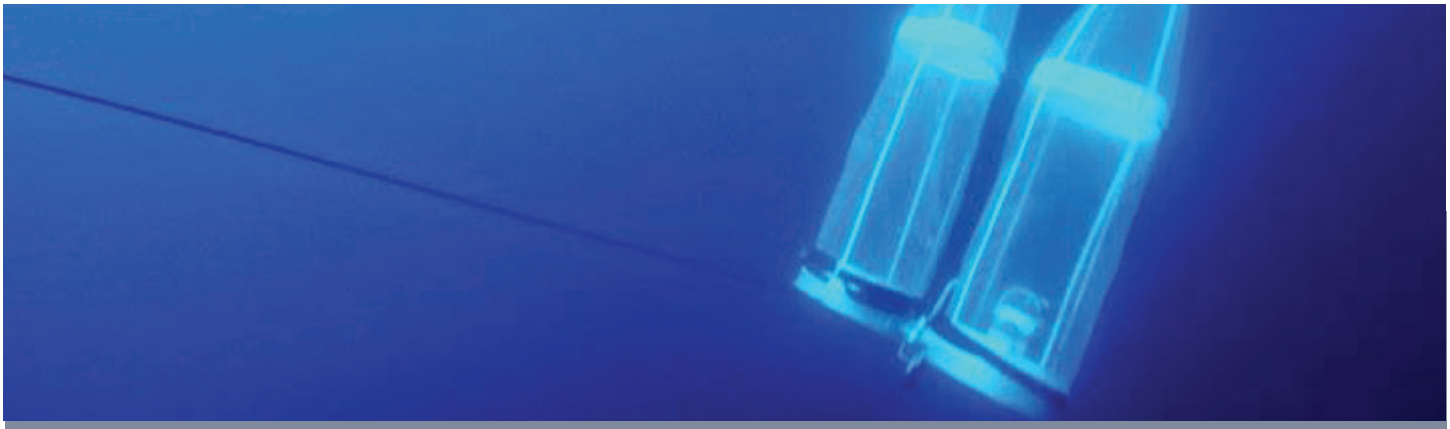
The vitality of the program is a testament to its continous efforts to evolve by augmenting or improving monitoring through the incorporation of new technologies and expanding its scope through collaborations with other monitoring programs. Today, CalCOFI and its monitoring partners serve data that support a wide range of stakeholders working to understand how changing marine ecosystem conditions affect our coastal communities now and in the future.

Stakeholder workshop

In December 2019, a workshop was held in concert with the CalCOFI Conference to capture feedback from a variety of stakeholders on how they use CalCOFI data today, current ocean monitoring questions and needs, and emerging new areas of marine management concern or research that were not being met. An online questionnaire was also sent out to CalCOFI data users. In total, input was received from 51 workshop participants and 31 additional online respondents representing a variety of ocean users. The majority of these respondents were users outside academia (Figure 2).

Figure 2: Affiliations of Stakeholder Participants





Current Monitoring Priorities

Stakeholders overwhelmingly feel that long-term and continuous monitoring is critical for understanding shifting oceanographic conditions, fluctuations in ecosystem productivity, and species range shifts. This information was also highlighted as valuable for informing fishery and marine resource management responses. Specifically, the following were identified as current ocean monitoring priorities:

1. Paired physical, chemical, and biological observations

Collecting physical oceanographic data (e.g., temperature, salinity) in conjunction with ocean chemistry (e.g., dissolved oxygen, pH) and biological samples (e.g., fish larvae, zooplankton) was expressed by many as vitally important to understanding multivariate stressors, tracking changing conditions, and validating oceanographic models. By coupling biogeochemistry measurements and performing integrated analyses, these data were identified as key to understanding how primary productivity, food web dynamics, and environmental stressors can impact commercially important and endangered species.

2. Climate change variability and associated stressors

Ocean warming, ocean acidification (OA) and ocean deoxygenation are recognized as having high potential to affect fisheries and the general health of CCE. Temperature, oxygen, carbonate chemistry and underway pH were all listed in the top ten valued measurements collected by CalCOFI. With the recent marine heat waves, historic data on ocean temperature is also seen as critical to contextualizing current temperatures and ecosystem states relative to a long-term surface and sub-surface ocean temperature trends in the CCE.

> *"A hallmark of CalCOFI has been its adaptability to new problems and approaches and willingness to accommodate ancillary research."*
> *-Dr. Ralf Goericke, Scripps Institution of Oceanography*

Current Monitoring Priorities (continued)

3. Fishery assessment information

There is wide support for CalCOFI's contribution to fishery life history data, particularly bongo net sampling, which captures planktonic organisms, including fish larvae, in the upper 200 meters of the water column. Larval fish abundance trends are considered a proxy for spawning stock biomass for fisheries species, and the consistency of these bongo samples across the CalCOFI time series provides insight into changing ichthyoplankton community composition, arrival of new species into the CCE, and recovery of previously overfished species. Stakeholders noted that integrating CalCOFI data with other monitoring programs provided expanded understanding of fishery species distribution and abundance for both federal and state managed fisheries.

4. Species distributions and range shifts

Stakeholders also place importance on CalCOFI's spatial observations of species presence/absence and relative abundance, in concert with a rich set of environmental measurements. Changing ocean conditions relate directly to changes in suitable habitat for species in the CCE. The spacially-explicit time series of these contemporaneous observations afford the ability to define species niche space, and support efforts to understand how future climate change will likely alter species composition in the CCE. As the ranges of species shift, they are likely to alter fisheries targets, which may have large consequences for coastal economies.

Emerging Monitoring Priorities

In addition to current monitoring needs, emerging areas of ocean management concern or research that stakeholders would like to see ocean monitoring help inform in the near future include:

1. Ecosystem responses to marine heat waves

Monitoring the biological response to recent marine heat waves and evaluating how these extreme events affected net primary productivity, shifts in species' ranges, and food web dynamics was a common theme. Many expressed a need to invest in more integrated analysis to understand how these events impact fish reproduction and recruitment and to help inform future management responses.

2. Environmental DNA (eDNA) analysis

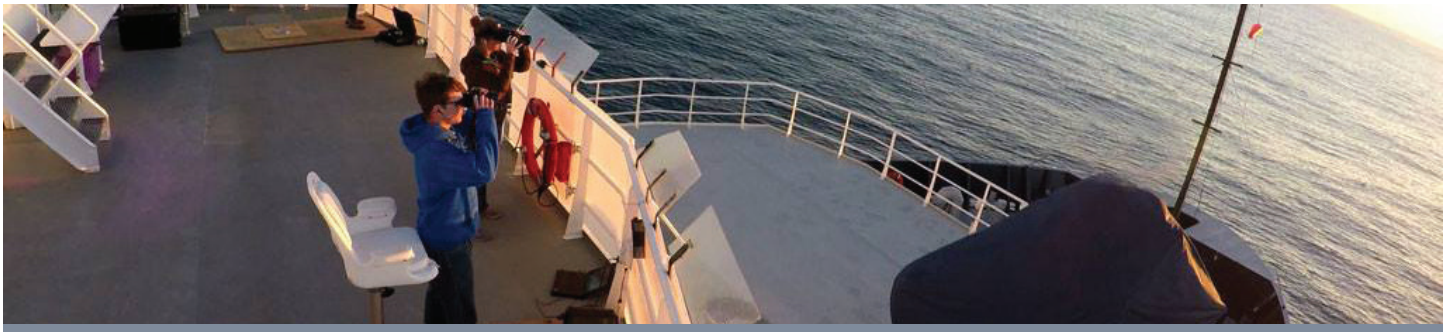
There is strong interest in advancing eDNA analysis methods for informing fisheries and biodiversity assessments and invasive species presence under climate change. The extensive archives of CalCOFI are regarded as an immensely valuable resource for testing the efficacy of using eDNA to characterize larval fish assemblages. Since 2014, the National Oceanic and Atmospheric Administration (NOAA)-CalCOFI Ocean Genomics Project (NCOG) has also used CalCOFI water samples to test cutting-edge genomic tools with the potential to provide a snapshot of the whole CCE community (from viruses to vertebrates). These genomic samples complement CalCOFI traditional net samples thus providing unique opportunities for validating and calibrating eDNA methods.

3. Water quality and pollution

There was also expressed interest in better understanding microplastic and macroplastic pollution impacts on marine species. Additionally, biological monitoring coupled with nearshore nutrient and bacterial pollutant sampling was identified as an area of increasing importance for informing the management of nearshore fisheries and aquaculture, marine conservation areas, and understanding harmful algal blooms.

4. Mesopelagic data and analysis (intermediate ocean depths, 200m-1000m)

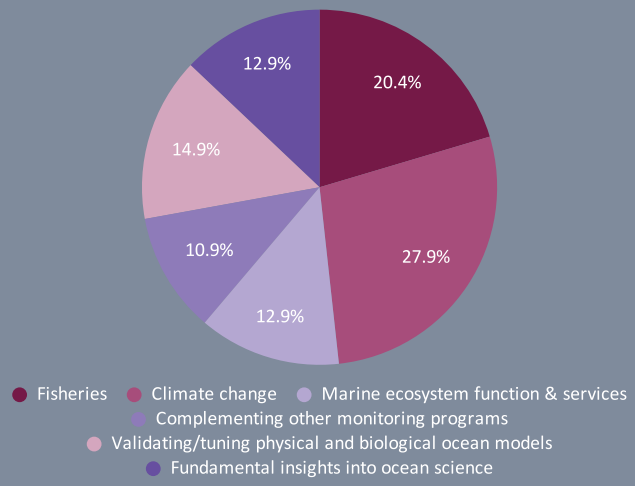
Stakeholders also identified mesopelagic monitoring data as an emerging priority. Many mesopelagic fishes, crustaceans, and cephalopods that partake in the largest daily migration on earth are residents of the CCE, but their role in the ecosystem (e.g., energy transport and forage supply) is still understudied. Taking advantage of CalCOFI bongo sampling that frequently captures mesopelagics, a focused assessment of this data could contribute to a better understanding of mesopelagic characteristics and change through space and time.



CalCOFI's Future Outlook

In general, stakeholders acknowledge that the CalCOFI monitoring program is a uniquely valuable asset for California fishery and ocean resource stakeholders. When asked to identify what areas of ocean management and research CalCOFI samples are most valuable for, the majority of participants identified climate change and fisheries. They also saw the program as valuable for understanding marine ecosystem functions and services, providing fundamental insights into ocean science and oceanic conditions, and complementing other monitoring programs (Figure 3).

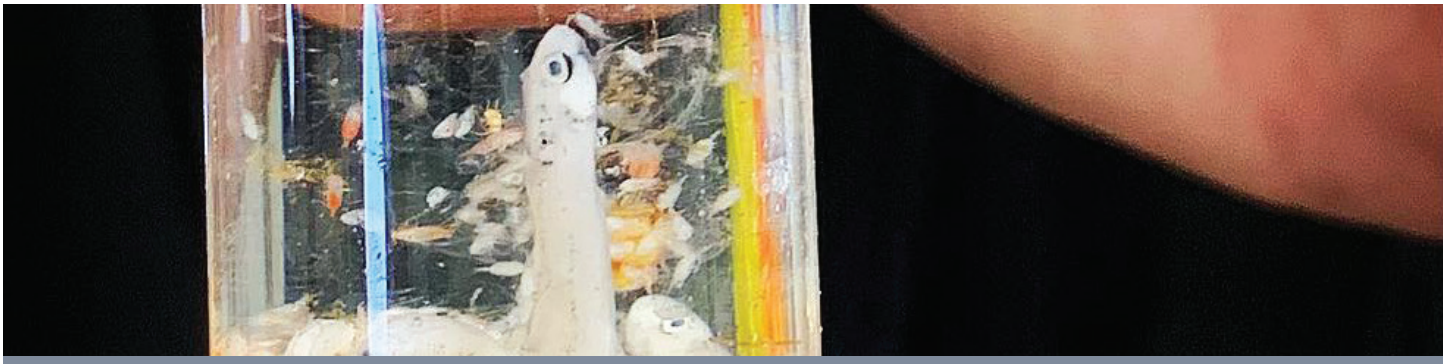
Figure 3: Areas of Ocean Management and Research CalCOFI Data Is Most Valued For



Most also expressed a strong interest in exploring ways to broaden CalCOFI's reach and partnerships to expand the use and application of its data and products. Overwhelmingly, participants believe there are opportunities for leveraging CalCOFI surveys and data to better meet their monitoring needs.

Recommendations for Moving Forward

Stakeholders recognize that CalCOFI is a foundational ocean monitoring program. However, there were a number of suggestions for how the program could evolve to further maximize its utility, particularly for west coast fishery and ocean resource managers. The following summarized recommendations will form the basis of CalCOFI strategies and priority investments going forward.



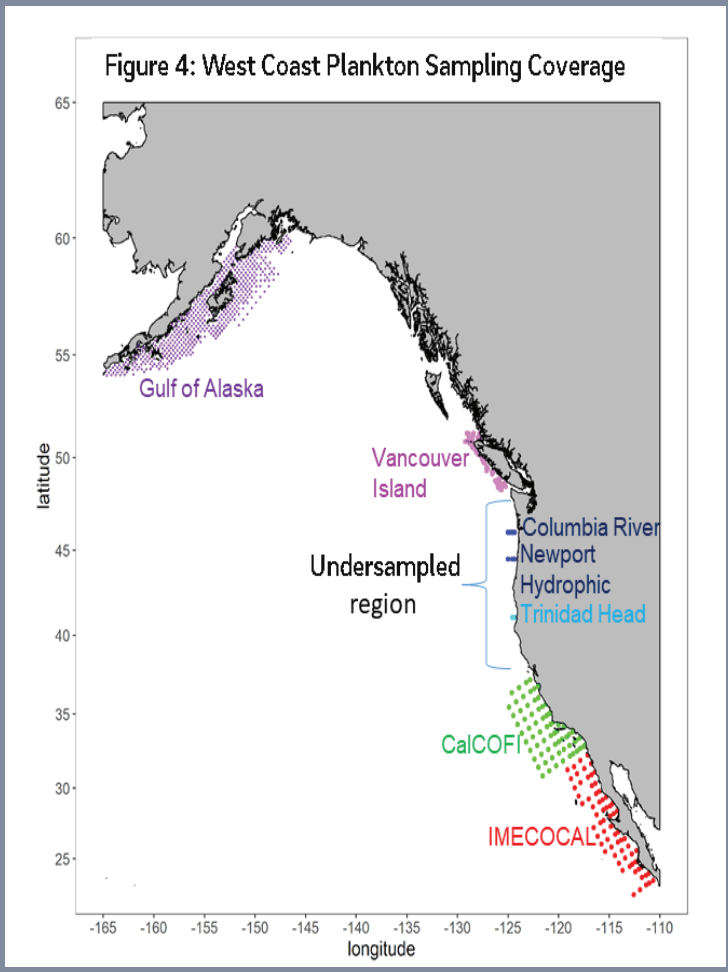
Recommendation #1:

Complete West Coast ichthyo- and zooplankton coverage

Icthyoplankton and zooplankton sampling are a hallmark of the CalCOFI monitoring program and provide unique insight into long-term trends for the distribution and composition of biological communities in the CCE. This method of sampling is currently conducted by several other partners along the West Coast, and collectively these plankton sampling programs support data products that directly inform fisheries and ocean management. However, important gaps need to be filled in order to better understand biological responses to ocean warming trends, changes in productivity, and altering ecosystem dynamics across the CCE (Figure 4).

Fill northwest gap and better integrate with Baja California's monitoring program (IMECOCAL)

Northern California up to Washington represents the most significant gap in West Coast plankton sampling, especially because this area is known to be a key region for many of the West Coast's productive fisheries (e.g., rockfish, Dungeness crab). Strategic conversations with NOAA fisheries and regional state and academic partners could identify ways to expand sampling into this area. Improving plankton sampling integration with the Investigaciones Mexicanas de la Corriente de California (IMECOCAL) in Baja California, Mexico would also facilitate enhanced understanding of ecosystem shifts in the southern end of the CCE.



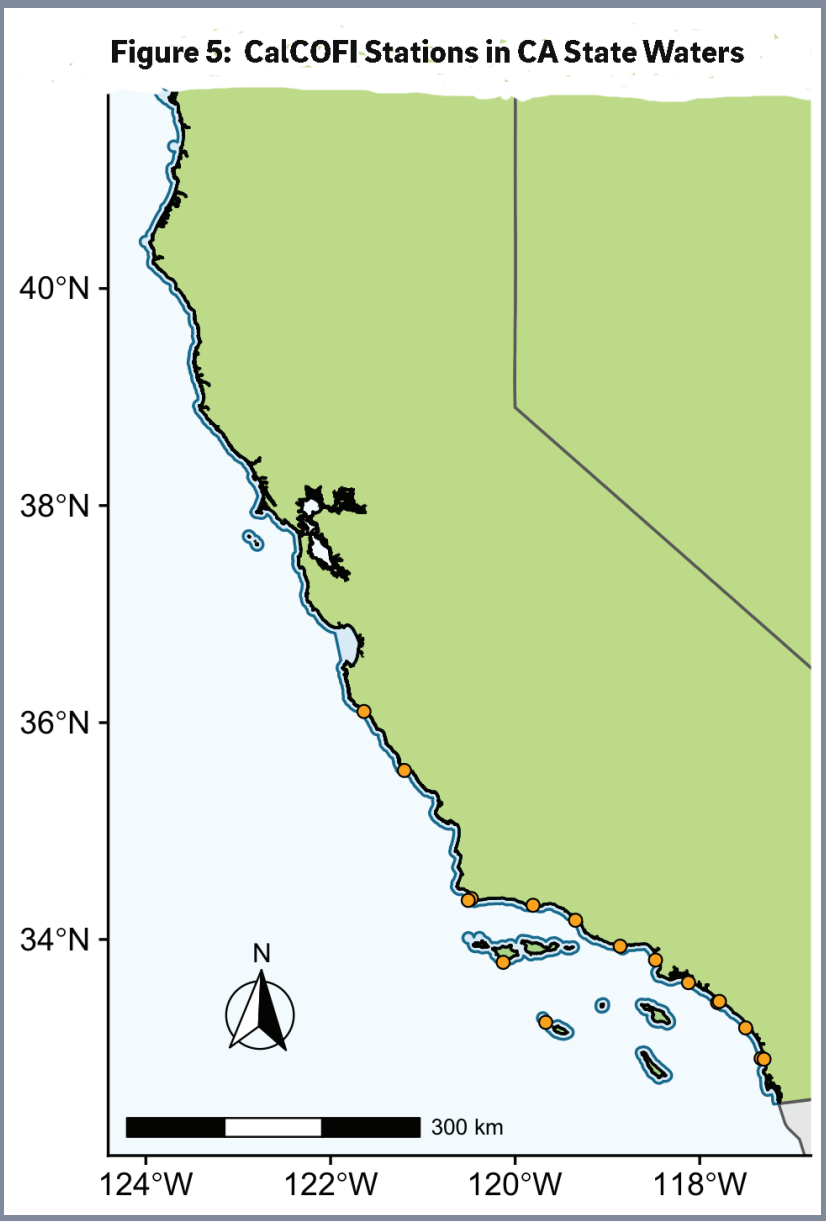
Recommendation #1 (continued):

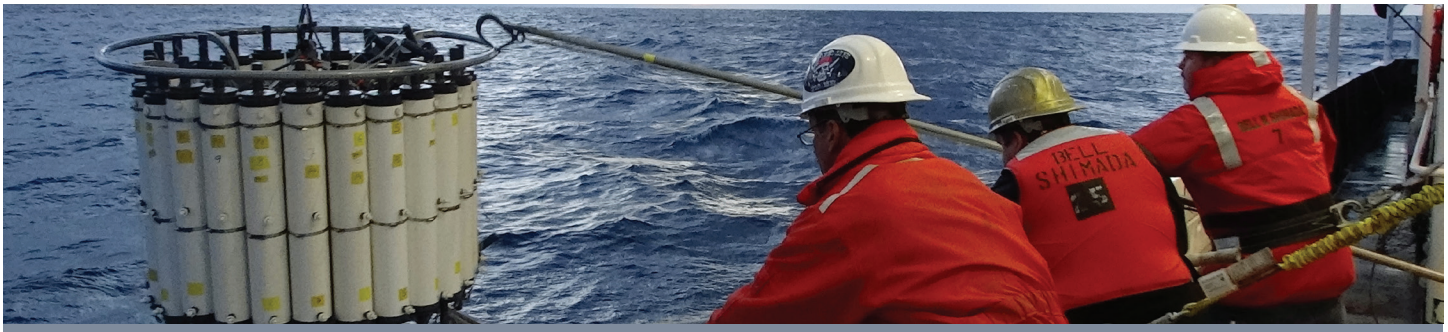
Expand nearshore coverage

Stakeholders were also interested in expanding nearshore monitoring. Nearshore plankton sampling could provide more insight for state fisheries and management of marine conservation areas. CalCOFI currently partners with the Southern California Coastal Ocean Observing System (SCCOOS) on only 9 nearshore stations that sample plankton. Expanding nearshore sampling would further capture how ocean currents, upwelling, temperature, and biogeochemistry fluxes (i.e. acidification) in the nearshore environments can affect fish productivity and survival and food web dynamics.

CalCOFI could increase nearshore monitoring value by strengthening partnerships and synchronizing efforts with state coastal monitoring programs like the Southern California Bight monitoring program (see Recommendation #2 for more detail).

Figure 5: CalCOFI Stations in CA State Waters





Recommendation #2:

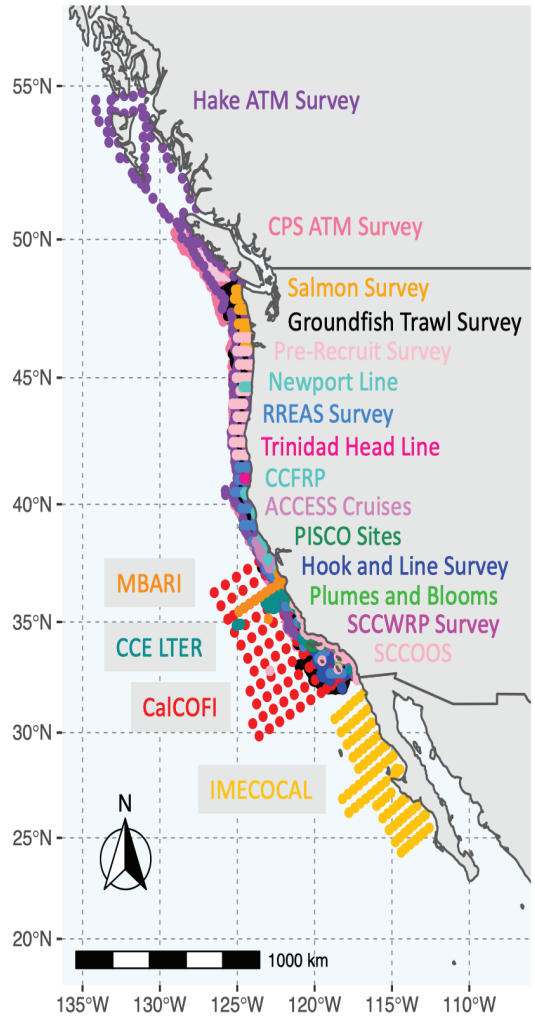
Enhance ocean ecosystem monitoring collaborations

Monitoring programs are developed to inform specific management needs and goals and often end up operating in silos, resulting in missed opportunities for data integration and collaboration across monitoring programs. In addition to plankton sampling, a number of physical, chemical and biological monitoring programs exist along the U.S. West Coast, and CalCOFI is committed to examining how these various programs can complement each other to provide a more holistic and integrated view of ecosystem health in the CCE. During the 2019 CalCOFI Conference, representatives of 21 monitoring programs on the US West Coast attended and identified several opportunities for leveraging efforts across monitoring programs (Figure 6).

California ocean ecosystem monitoring partnerships

The Southern California Coastal Water Research Project (SCCWRP) conducts comprehensive monitoring in the Southern California Bight every 5 years. CalCOFI leadership is in discussions with SCCWRP to better partner monitoring for the next Southern California Bight assessment cycle. Additionally, there are plans in the works to integrate the 2022 California Marine Protected Area Monitoring Review with the annual CalCOFI Conference to align monitoring efforts and improve data sharing.

Figure 6: West Coast Ocean Ecosystem Monitoring Programs



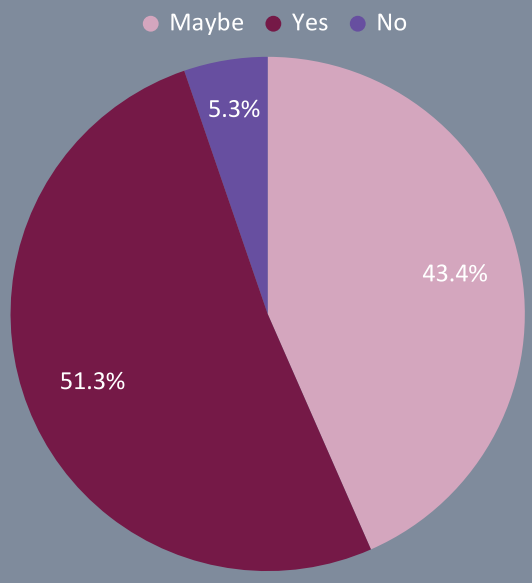
Map featuring 19 of the 21 U.S. West Coast monitoring programs. The two programs not shown are the Farallon Institute seabird surveys and the Southern California Bight Marine Biodiversity Observation Network.

Recommendation #2 continued:

Fisheries monitoring collaborations

CalCOFI is also involved in efforts to examine how data from other fisheries surveys on the US West Coast, including the California Collaborative Fisheries Research Program (CCFRP) and other NOAA Fisheries surveys, can be integrated to examine changes in abundance across different life history stages of fisheries species. For example, trends for rockfish could be examined by integrating larval rockfish data from CalCOFI net sampling, juvenile rockfish data from the NOAA Rockfish Recruitment and Ecosystem Assessment Survey, and adult rockfish data from the NOAA Groundfish Trawl Survey, the NOAA Hook and Line Survey, and the CCFRP. Together, these data streams can provide insight into how ecosystem changes, like marine heat waves, affect different life history stages of important fisheries species.

Figure 7: Percentage of Stakeholders That Saw Opportunities to Leverage CalCOFI to Better Serve Their Monitoring Needs



Recommendation #3:

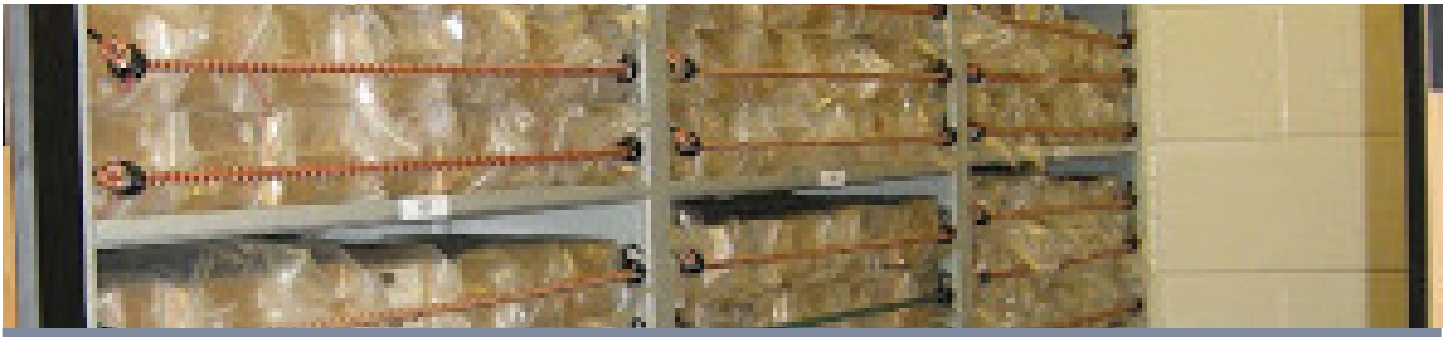
Ensure the continuity of biogeochemical sampling and analysis

Fishery and ocean resource managers are increasingly concerned about how ocean acidification, deoxygenation, and other possible climate change-related stressors may threaten the health and sustainability of west coast fisheries and marine ecosystems. CalCOFI is one of very few ocean monitoring programs that has co-located biological and chemical ocean sampling for decades; this pairing is essential in efforts to examine how changes in ocean chemistry affect marine organisms in the CCE.

The importance of biogeochemical monitoring was recently underscored by the Ocean Acidification Task Force at a June 2020 California Ocean Protection Council meeting. At this meeting, the Council highlighted the need to strengthen the continuity of long-term carbonate chemistry measurements and better connect these with biological monitoring data to interpret ocean acidification effects and develop ocean acidification water quality criteria.

Nonetheless, CalCOFI's carbonate chemistry monitoring program, one of the longest-running ocean carbonate chemistry monitoring records in the world, does not have dedicated funding. Identifying a dedicated, continuous funding source for these measurements is a high-level priority. CalCOFI leadership is working to highlight this need and identify possible solutions to continue these important measurements. At the same time, researchers are also pursuing grants to leverage CalCOFI's archival data in efforts to describe long-term acidification trends.

> *"The [California OAH Science] Task Force places high priority on ensuring the continuity of the CalCOFI survey carbonate chemistry measurements, which provide a unique historical resource dating back many decades"*
>
> *- Enhancing California's Ocean Acidification and Hypoxia Monitoring Network: Recommendations to the Ocean Protection Council from the California Ocean Acidification and Hypoxia (OAH) Science Task Force, June 2020*



Recommendation #4:

Leverage the CalCOFI archive to test emerging research questions and monitoring methods

One reason that CalCOFI is considered such a rich resource is its archived biological collection. This consists of fish eggs and larvae stored permanently in the NOAA Southwest Fisheries Science Center ichthyoplankton collection and the Scripps Institution of Oceanography pelagic invertebrate collection that houses the invertebrate zooplankton.

While stakeholders identified areas where autonomous vehicles could enhance physical and chemical monitoring, they emphasized that CalCOFI's biological sampling taken during quarterly vessel cruises cannot be automated with current technology. CalCOFI continues to support researchers in efforts to mine this archived collection in pursuit of answers to emerging research questions related to ocean ecology and resource management. For example, recent projects are using preserved CalCOFI samples to distinguish between larvae of economically valuable sea bass species (*Paralabrax spp.*) to inform California state fisheries management, and using ethanol-preserved net samples to build a sequence database for CCE fishes to support future eDNA studies.

CalCOFI's archived data and collections also serve as a valuable tool for testing and refining new monitoring techniques and technologies. There is growing interest in enhancing physical and chemical ocean sampling with autonomous vehicles (i.e. gliders). Currently, gliders are being run on CalCOFI transects to test pH sensors and capture samples outside of CalCOFI research cruise windows.

Did you know?

Archived samples from CalCOFI were used to solve the mystery of the event that inspired the Alfred Hitchcock's famous film, The Birds. In 2012, scientists examined net samples from the 1960s and found consistent evidence of Psuedo-nitzschia, a toxic dinoflagellate that produces the neurotoxin domoic acid, within the guts of preserved zooplankton. Seabirds consumed prey with domoic acid, leading to the frenzied behavoir of the birds captured in the film.

Recommendation #5:

Improve data management and access

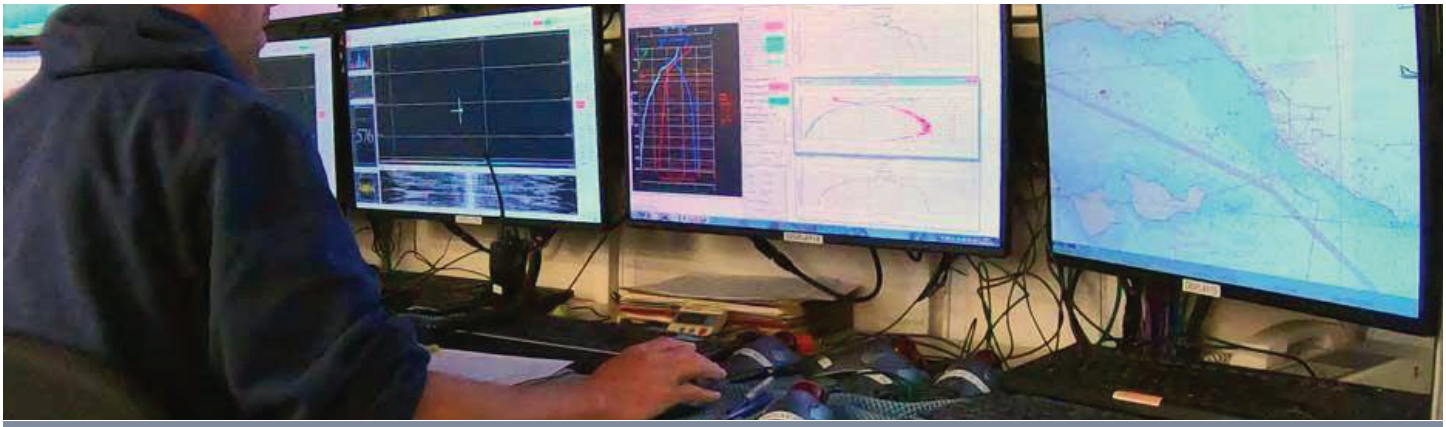
Ocean science is beginning a new era for big data; data storage, management, and processing capabilities far exceed those available when CalCOFI data systems were first established. For both CalCOFI program sponsors and affiliates, these next few years are an opportune time to invest in database upgrades, consolidation, and improved data delivery.

Broad consensus from workshop participants was that access to CalCOFI data was disjointed, making it difficult to access and use. Consolidating various monitoring information for easier access was highlighted by stakeholders as an immediate need for improving CalCOFI's utility for informing management and research topics.

In an effort to address these challenges, CalCOFI is already taking steps in 2020 to modernize the CalCOFI database and associated serving capabilities. These include enhancing database integration with NOAA Southwest Fisheries Science Center, investing in a database programmer and analysts to make improvements, and bringing on a CalCOFI coordinator who will oversee these efforts and other initiatives to improve data access and distribution.

On the horizon...

In 2021, CalCOFI intends to bring on a new data management position with support from the Southern California Coastal Ocean Observing System program. This person will support curated data views and modernization of data serving capabilities.



Recommendation #6:

Make user-friendly data products for managers and individuals

An exciting outcome of the 2019 workshop was enthusiasm and interest in potential collaborations to improve CalCOFI data delivery in formats that are easily digestable and usable by various ocean stakeholders.

Assessments of ecosystem drivers

Many stakeholders expressed interest in data integration and analysis around topics such as marine heat waves, upwelling events, and species range shifts. These would bring to light how CalCOFI data combined with other monitoring information can often inform these challenging marine resource management topics and shed light on changing conditions over seasons, years, and decades.

Fishery-focused syntheses

Participants also discussed targeted, fishery focused data syntheses that better serve both contemporary federal and state fishery management needs. With some front-end investment in developing the methods for compiling these syntheses, the resulting reports could then be regularly issued over short timeframes, or even served dynamically via a web interface. For example, California Department of Fish and Wildlife (CDFW) marine region recently expressed interest in CalCOFI's California Grunion ichthyoplankton data (1976-2014) for inclusion in the CDFW California Grunion status report. While CalCOFI staff and research associates were able to quickly collate these data and provide them, there is no doubt an improved data serving and synthesis web portal would facilitate rapid data discovery and download when such need arises.

Key findings and synthesized products from the State of California Current Report

The state of California Current Report, an annual synthesis of CCE observations, provides crucial information for the annual California Current Integrated Ecosystem Assessment Report (produced for the Pacific Fishery Management Council). Stakeholders emphasized that CalCOFI data in these reports are increasingly helpful for fishing communities, marine conservation area managers (state and federal), and general ocean stakeholders for understanding trends in the health and sustainability of the CCE. Use of this information could be enhanced by developing summaries of key findings, data visualizations, and dynamic products relevant to stakeholder needs.

Next steps

Overall, the workshop conducted by CalCOFI was hugely valuable in taking the pulse of changing ocean monitoring needs. It also provided a timely reflection on CalCOFI's assets that could be enhanced to better serve these needs.

We are excited about the identified opportunities to showcase and amplify CalCOFI's capabilities to a wider set of ocean stakeholders. Already in 2020, several steps are being taken to pursue these recommendations. For example, we have identified a new open access and peer-reviewed publication for the State of the California Current report to expand readership and use of this annual summary. Other new areas of exploration include strategic partners and investment in additional data synthesis and products, new advisory members to help guide CalCOFI's data management and products, and increased outreach to fishery and ocean resource managers to further understand their data delivery, sampling, and synthesis needs.

Thank you again to those who took time to provide input through the 2019 workshop or online questionnaire. Your feedback will define the evolution of CalCOFI going forward, and we are grateful for the enthusiastic endorsement of CalCOFI's value across a broad array of stakeholders, including ocean managers, the fishing industry, and the academic research community.

We look forward to continuing this dialogue as we all move toward a new future in ocean management together. We are up for the challenge and we also want to continue to hear from you, so feel free to reach out to us.

The CalCOFI Partnership

CalCOFI is a unique partnership that includes participation in CalCOFI research cruises, scientific research, and fishery management. It is guided by:

- **Scripps Institution of Oceanography at UC San Diego,**
- **NOAA Southwest Fisheries Science Center,** and
- **California Department of Fish and Wildlife.**

In 2004, **California Current Ecosystem Long-Term Ecological Research (CCE-LTER)** program was added to the collaboration expanding CalCOFI goals, research cruise capacity, and broadened the scope of the long-term time series.

In 2004, **Southern California Coastal Ocean Observing System** began supporting CalCOFI expanded nearshore monitoring, data integration and data serving capabilities.

In 2018, **California Sea Grant** added support, bringing outreach and communications expertise to help align CalCOFI research and findings with marine resource management priorities.

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