Review of the CalCOFI Research Program

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Preface

The National Oceanic and Atmospheric Administration (NOAA) requested a review of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program to assess how well it meets the changing societal mandates for marine management and the need to assess the ecosystem impacts of climate change. Review panelists were Drs. Anne B. Hollowed (NOAA, Alaska Fisheries Science Center), Robert Cowen (University of Miami, Rosenstiel School of Marine and Atmospheric Science), Enrique Curchitser (Rutgers University, New Jersey), Anthony J. Richardson (Commonwealth Scientific and Industrial Research Organisation (CSIRO) and University of Queensland, Australia, and Michael Sinclair (Former Director of the Bedford Institute of Oceanography, Department of Fisheries and Oceans, Dartmouth, Canada). The following report provides the comments and recommendations of the Review Panel.

The panel met at the Scripps Institution of Oceanography (SIO) on March 2-4, 2010. Scientists from the Southwest Fisheries Science Center (SWFSC), SIO and the California Department of Fish and Game (CDF&G) provided oral presentations on a broad range of topics (Appendix 1). The Panel notes that these presentations were of high quality and very helpful in providing a comprehensive view of the CalCOFI research program.

The terms of reference for the review were:

(1) Provide an assessment of the performance of the CalCOFI program in meeting the stated mission and objectives;
(2) Review the existing mission of the CalCOFI program, and consider changes, as appropriate, given the current priorities of the three partner institutions and the needs for long-term monitoring of climate and fisheries assessment in the California Current Ecosystem (CCE);
(3) Make specific recommendations on the scope, scale, intensity and priorities for future activities to be conducted under CalCOFI, given the review of the existing program performance and potential changes to its mission and objectives;
(4) Provide guidance on the mix of observations, synthesis and forecasting activities and priorities consistent with revised or re-validated missions and objectives.

Dr. Anthony Koslow (SIO) provided the Review Panel with the following statement of the current mission of the CalCOFI:

(1) Provide a scientific understanding of human impacts and the influence of variability and climate change on the living marine resources of the California Current;
(2) Provide fishery-independent data to assess key commercial species in the California Current, such as sardine and anchovy; and
(3) Provide opportunities for scientific research and training related to the physical and biological dynamics of the California Current Ecosystem.

This report first provides an overview of CalCOFI, before detailing responses of the Review Panel to the TORs. We respond to TORs 1 and 2 comprehensively, and TORs 3 and 4 partially by providing indications of some of the priorities for a new CalCOFI program. However, we consider that a more detailed response to TORs 3 and 4, and to some more specific questions that were posed (e.g. those on p. 31 in the CalCOFI Review

Booklet) are more operational than strategic and as such would be better answered through the involvement of the CalCOFI community. We have proposed general mechanisms to address these operational issues, specifically a Scientific Steering Committee and a Workshop on survey methods. Panel recommendations are highlighted in bold print. Table 1 provides a summary of the major recommendations of the Panel.

Program Overview

The California Cooperative Fisheries and Oceanic Investigations (CalCOFI) program was established in 1949 with the primary aim of understanding recruitment variability in the California Current sardine population. The program was founded as a partnership between the California Department of Fish and Game (CDF&G), Scripps Institution of Oceanography (SIO) and the Bureau of Fisheries (now NOAA Fisheries). Since its inception, the program has facilitated world-class interdisciplinary research focused on improving our understanding of the California Current System and the responses of fish and invertebrates to ecosystem change. The core component of the program has been the systematic collection of plankton and oceanography data within the California Current. The temporal and spatial coverage of the survey has varied considerably over the 60 year history of the program (Hewitt 1988). Historically the survey was conducted monthly between Baja California and the Canadian border along parallel transect lines running perpendicular to the coast, but the present day survey grid is restricted to quarterly surveys in the Southern California Bight.(Figure 1). Numerous ancillary research programs bring added value to the core CalCOFI program (Figure 1).

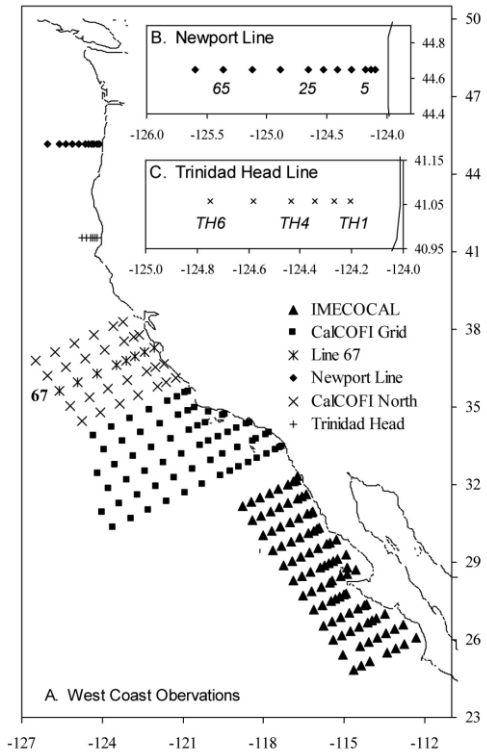

Fig. 1. CalCOFI survey transect lines and station grid for IMEOCAL, CalCOFI, grid Line 67, Newport Line, CalCOFI North and Trinidad Head Line.

The CalCOFI program's nearly continuous archives of plankton and oceanographic data collections provide a permanent record of ecosystem changes over the past 60 years. This unique dataset is a national treasure of great historical value. One that will continue to increase in value as the time series grows. CalCOFI samples continue to provide valuable information that was unforeseen at the time the samples were collected. These samples are expected to be of increased value as scientists seek to gain an understanding of the implications of future climate change on the CCE.

Valuable technological developments were designed and tested through ancillary research that used observations from the CalCOFI surveys to verify new sampling methods. CalCOFI observations continue to be used by researchers to ground truth remote sampling devices including autonomous vehicles.

The CalCOFI program grew out of a partnership between government and academic institutions. This collaboration has broadened the perspective of scientists and left a long legacy of classic research papers. Students who were trained in this environment emerged as leaders in the field of fisheries oceanography throughout the world (Ohman and Venrick 2003). CalCOFI surveys continue to provide the backbone for innovative ancillary research and collaborations.

CalCOFI researchers have gained international prominence through innovations that have emerged from the availability of a long historical data set and sustained interdisciplinary collaborations. CalCOFI researchers have advanced our understanding of the role of eastern boundary currents in ocean production and the responses of small pelagic fish to changes in upwelling. CalCOFI scientists formed the nucleus of people that introduced comparative research projects throughout the world [e.g. the GLOBEC SPACC (Small Pelagics and Climate Change) program].

The quality and longevity of the CalCOFI sampling program has had unforeseen benefits. For example, NOAA Fisheries recently selected the CCE as the region for the development of a pilot program for an integrated ecosystem assessment. Selection of the CCE region for the NOAA pilot study serves as a testament to the quality and quantity of information available and the understanding of the ecosystem structure and function that are needed to produce assessments useful for managers.

Panel Recommendation: For all of the reasons above, the Panel members recommend that the core CalCOFI Program should be continued for the foreseeable future.

TOR 1: Provide an assessment of the performance of the CalCOFI program in meeting the stated mission and objectives;

Mission 1: Provide a scientific understanding of human impacts and the influence of variability and climate change on the living marine resources of the California Current

The CalCOFI program has improved scientific understanding in many disciplines including physical oceanography, biological oceanography, fisheries and technological development. The CalCOFI report series provides an appropriate vehicle for rapid dissemination of research results. This rich legacy of improved understanding is partially summarized in Ohman and Venrick (2003). **The Panel recommends that a more complete review paper or book be prepared to document the major scientific advances that stemmed from CalCOFI monitoring and research.**

Based on the Review Panel's collective memory, their familiarity with the CalCOFI literature, and their knowledge of the CCE, we were able to develop a partial list of some of the major scientific contributions of the CalCOFI program. We recognize that this list is incomplete, although it does serve as a basis for our response to TOR 1. We also recognize that the CalCOFI research community is often broader than the scientists working at the SWFSC, CDF&G and SIO. Historically, the CalCOFI research community included researchers housed in institutions all along the west coast. For this report, we have limited our examples to key discoveries linked to the three sponsoring research institutions.

CalCOFI researchers were responsible for many of the seminal papers that have improved our understanding of biophysical impacts of interannual and decadal-scale climate variability in the CC. In particular, CalCOFI researchers were among the first to recognize impacts of El Niño events in the Northern Hemispheres (El Niño North), coastal upwelling (Bakun 1973) and the role of interannual and interdecadal variations in the west wind drift on the strength and intensity of the CC (Chelton et al., 1982). Di Lorenzo et al. (2008) further advanced our understanding of linkages between climate scale forcing and regional ocean conditions through a combination of modeling and statistical analyses. His studies helped to distinguish the pattern of the Pacific Decadal Oscillation (PDO, Mantua et al. 1997) from the North Pacific Gyre Oscillation (NPGO).

Oceanographers associated with the CalCOFI program were able to discern the bio-geo-chemical pathways governing the CCE. Observed signals within the system range from a secular warming trend to changes in the circulation of the North Pacific gyre. More recently, these historical collections help to set a context for observations of a shoaling of the oxygen minimum zone (McClatchie et al. In Review, McClatchie et al. 2009a) and the threat of ocean acidification (Feeley et al. 2008).

The co-location of researchers at SIO, CDF&G and SWFSC led to new research synergies and increased understanding and many of these will be mentioned briefly here.

In the early years when the full CalCOFI grid was sampled monthly, several classic papers were written that described the biogeography of fish and invertebrates in the CCE (Brinton 1962, Fager and McGowan 1963, Venrick et al. 1987, Fleminger 1975). Over time, and in response to the global recognition of interannual variability in the year class strength of fisheries, CalCOFI researchers focused attention on understanding the recruitment dynamics of commercial fish and invertebrates. CalCOFI scientists including Ruben Lasker, Ahlie Ahlstrom, Richard Parrish, Paul Smith, Geoff Moser and John Hunter led numerous projects that advanced our understanding of the coupling between environmental variability and early fish survival. These discoveries led to early attempts to incorporate ecosystem forcing in stock assessments (Bakun and Parrish 1980). These early research efforts not only led to the recognition of the field of fisheries oceanography (Wooster 1961), but later formed the mechanistic foundation for the formation of system level hypotheses on how "ocean triads (enrichment, concentration, and retention)" influence fish schools ("school–mix feedbacks") and species interactions (Bakun 1996, 2001). In addition, the monitoring and research led to the "basin" and "flow" hypotheses to account for decadal scale fluctuations in abundance of sardines and anchovies (MacCall 1990, 2009).

Review and Issues

The pioneering discoveries stemming from CalCOFI researchers provided the foundation for the development of bio-physical models that are capable of forecasting the influence of climate change and human impacts on the productivity of the CCE. **Based on this brief review, the Panel concluded that the CalCOFI program has been very responsive to the mission to provide a scientific understanding of human impacts and the influence of variability and climate change on the living marine resources of the California Current.**

While the Panel acknowledges that the CalCOFI program has exceeded expectations with respect to improving our understanding of the CCE, we did identify some issues that may be impeding the continued success of the program.

The restricted grid for the CalCOFI core survey confines sampling to the Southern California Bight. This limits holistic research because oceanographic features that govern the habitat boundaries of fish and invertebrates shift in and out of the study area.

Based on information presented during the meeting, the Panel is now aware that sample archives and databases are divided between government and academic institutions. This practice requires attention to ensure seamless linkages. Significant improvements to the database management and access have been made through recent, though limited, funding. Database development and maintenance requires an ongoing effort, therefore there is some concern about the ability to allocate future resources to this important activity.

CalCOFI researchers have been successful in acquiring ancillary funds to augment core CalCOFI research and enhance the value of the collected data. However, reliance on opportunistic funding limits a comprehensive approach to priority issues, and generates to

a certain degree a collection of loosely associated projects rather than a coordinated strategy (e.g. there is no resolution of the synoptic scales in the CC which in some theories are linked to recruitment variability). Members of the process oriented research community and the modeling community do not appear to be well linked. This partition limits the opportunity to focus research on the primary sources of uncertainty that impede successful forecasting.

Finally, the Panel notes that there is no formal process for prioritizing goals and transitioning successful new technologies or sampling protocols from research to operations. The Panel recommends that a CalCOFI Scientific Steering Committee (SSC) be formed to address this issue and others. We provide further detail on the CalCOFI SSC in our response to TOR 2.

Mission 2: Provide fishery-independent data to assess key commercial species in the California Current, such as sardine and anchovy

The CalCOFI program has focused much of its research on understanding the early life history of commercial species in California. Early contributions included an improved understanding of the timing and distribution of spawning of several small pelagic species such as Pacific sardine, northern anchovy, Pacific hake, jack mackerel, and Pacific mackerel. As documented earlier, researchers utilized CalCOFI data to evaluate mechanisms underlying recruitment variability of several small pelagic species. Based on the statistical link between successful recruitment of Pacific sardine and warm ocean conditions, stock assessment scientists proposed a harvest strategy that incorporated annual environmental conditions (Hill et al. 2007).

As the science of fish stock assessment evolved to utilize age structured stock assessments, there was a growing need for the development of a reliable measure of spawning stock size. The Daily Egg Production Method (DEPM) was developed by the CDF&G and SWFSC scientists to address this assessment need (Wolf and Smith 1986). A major innovation that expedited the production of DEPM stemmed from a technological advance, the development of the Continuous Underway Fish Egg Sampler (CUFES, Checkley et al. 1997). This device provides high spatial resolution assessments of fish-spawning habitats (Figure 2). Samples of adult sardine from trawls are needed to calculate daily specific fecundity for the DEPM (Hill et al. 2007). The SWFSC conducts an adult survey in conjunction with the CalCOFI survey to collect samples needed for the estimation of DEPM. Dr. Hill and Dr. Lo noted that when sardine spawning areas shift outside of the CalCOFI grid, some independent correction factor is needed to adjust the Total Egg Production (TEP) estimates for the fraction of the population that is not assessed.

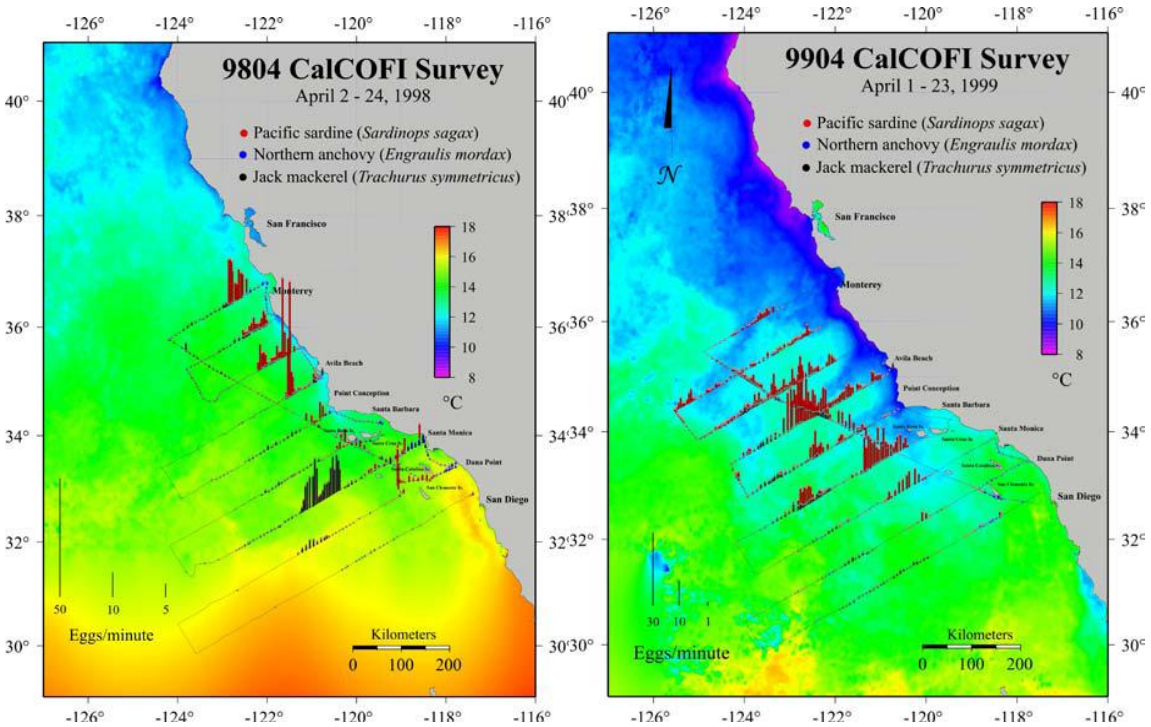

Fig. 2. CalCOFI survey transect lines for 1998 (Left) and 1999 (Right) showing results of the Continuous Underway Fish Egg Sampler (CUFES, Checkley et al 1997) for sardine, northern anchovy and jack mackerel (vertical bars) and sea surface temperature (background) derived from satellite.

Dr. Demer informed the panel that since 2000, the SWFSC has augmented CalCOFI surveys with multi-frequency-acoustic sampling to estimate the abundance of mid-trophic level species (e.g. myctophids, euphausiids, and small pelagics). The R/V David Star Jordan is equipped with four echosounders that operate at 38, 70, 120 and 200 kHz. S_A (defined in MacLennan et al. 2002) values are converted to biomass densities using combined target strength-to-length and length-to-biomass conversions developed for Atlantic species (McClatchie 2009b). Length samples were collected using surface trawls. Sardine school at depth during the day and can be assessed with acoustics.

The lead author for the sardine assessment, Dr. Hill (SWFSC), reported that recent Stock Assessment Review panels have raised concerns about the differences in abundance and trend between biomass estimates derived from the DEPM and aerial surveys supported by the industry.

Dr. Demer presented preliminary results from some experimental methods for stock assessment. The SWFSC's Advanced Survey Technologies Group derived an index of sardine biomass, without the requisite trawl samples, using a combination of estimates of preferred sardine habitat derived from satellites, CUFES egg densities, multi-frequency and multibeam acoustic instruments, and a towed stereo camera (FasTowCam).

CalCOFI larval distributions have been used to address fisheries management issues. CalCOFI samples provide an archive of 490 species of fish species and 22 species of cephalopods. These samples have been mined in ways that were not originally envisioned. For example, larval distributions were used to identify potential "no trawl zones" to protect the spawning habitats of cowcod. Similarly, the CDF&G reported that CalCOFI data are often used for assessments of developing fisheries. For example, squid para-larvae were extracted from CalCOFI samples and the data were used to assess the distribution and abundance of this group, and similar efforts are underway with larvae of the California spiny lobster, *Panulirus interruptus*.

Review and Issues

Based on this assessment, the Panel concludes that the CalCOFI survey does produce information that is responsive to the mission to provide fishery-independent data to assess key commercial species in the California Current, such as sardine and anchovy.

The Panel identified the following concerns with the current use of CalCOFI data in stock assessments. A thoughtful analysis of assessment methods was outside the scope of this CalCOFI review, but given the close relationship between the two programs (monitoring and stock assessments) we make some comments.

The Panel recommends that a workshop be convened to thoroughly assess the strengths and weaknesses of each of the three survey methods: aerial surveys, acoustic surveys and the DEPM. We recommend that the lead stock assessment author be fully engaged in this workshop to ensure that the needs for his assessment are communicated to the scientists responsible for the surveys.

The Panel is skeptical that an acoustic survey could be conducted without trawl validation of targets. While we support the continued exploration of new methods for estimation of abundance, including acoustic methods, we do not recommend the elimination of trawls for the verification of targets until the method has been conducted over an extended time period. We are concerned that there may be some years when different species of pelagic fish are co-located. We also note that the length composition of the aggregation is an important input to the target strength to length conversion. **The Panel recommends that additional work be conducted to confirm that cameras and 3-dimensional imaging provide accurate depictions of the length composition of the aggregation.**

The Panel notes that if acoustics become part of the assessment tool box, then an effort to develop target – strength relationships for Pacific sardine and northern anchovy should be conducted. While the target strength-to-length and length-to-biomass conversions developed for Atlantic species probably represent a good approximation of the reflectivity of Pacific species, the researchers should test this assumption.

The Panel recommends that the stock assessment authors should examine the relationship between sardine size at age and indices of prey availability, and the species composition of the diet relative to available prey. This type of analysis could be useful in determining relationships between prey availability and sardine grazing rates that might be useful in understanding stock size variability, distribution and growth. These could inform coupled biophysical models.

Several scientists noted that adjustments for sardine spawning south of the CalCOFI grid could be derived by improved coordination with the Investigaciones Mexicanas de la Corriente de California (IMECOCAL) surveys conducted in Mexico (Figure 1). The Review Panel encourages assessment authors and scientists involved with the survey to consider the feasibility of this type of coordination.

The Panel recommends that the historical data be used to assess the most parsimonious sampling grid that would minimize ship time, while preserving the data needed to monitor climate impacts on the CCS. Deployment of new technologies should be preceded by Ocean System Simulation Experiments (OSSEs), which can help determine optimal observational designs for particular research questions and instruments.

Retrospective analysis of CalCOFI data could also be conducted to identify useful ecosystem indicators for use in identifying ocean states in the region.

Mission 3. Provide opportunities for scientific research and training related to the physical and biological dynamics of the California Current Ecosystem.

SIO investigators reported that they currently depend on awards from granting institutions to provide opportunities for scientific research and graduate student training. Dr. Vetter (SWFSC) and Dr. Koslow (SIO) reported that funding to support the Marine Life Research Group (MLRG) at SIO has eroded over the years and this has limited training opportunities for young students. Dr. Murawski (NMFS) reported that NMFS recently committed funds to SIO to enhance training of young scientists at SIO. SIO plans to fill a new faculty position with an individual with expertise in stock assessment and ecosystem modeling. This new commitment will help to re-invigorate research on the CCE.

Review and Issues

The Review Panel concludes that the CalCOFI program has been very responsive to this mission. CalCOFI researchers have engaged the interdisciplinary research community for six decades through research projects and annual conferences.

The Panel notes that the restriction in geographic range of the CalCOFI grid appears to be limiting the participation of scientists from regions outside of the local area. This, in turn, reduces the intellectual capital and diversity of thinking that has contributed to key breakthroughs in the past.

The Panel also notes that it may be difficult to sustain a partnership if the participation of one institution is dependent on soft money. **The Panel recommends that some funds be secured that could be devoted annually to high priority research projects. This could take the form of graduate student stipends, or research fellowships.**

TOR 2 Review the existing mission of the CalCOFI program, and consider changes, as appropriate, given the current priorities of the three partner institutions and the needs for long-term monitoring of climate and fisheries assessment in the California Current Ecosystem;

Dr. Vetter and Dr. Koslow reported on the changing mandates and new visions of NOAA and SIO respectively. These presentations highlighted the need for CalCOFI to broaden its focus to consider implications of environmental variability, climate change, and other anthropogenic stressors on the CCE to inform marine management. Several members of the research community gave presentations on new opportunities for sampling to address emerging issues that were not envisioned by the founding institutions that formed the CalCOFI program.

Dr. Schwing gave a presentation on two NMFS initiatives: Integrated Ecosystem Assessments (IEAs) and Comparative Analysis of Marine Ecosystem Organization (CAMEO). Integrated Ecosystem Assessments provide a basis for reviewing the status and trends of ecosystems relative to the goals and objectives of managers for implementing an ecosystem approach to management (EAM). Data collected during CalCOFI surveys and the analytical products produced from these datasets represent a key component of an IEA. CalCOFI researchers are well poised to contribute to IEAs as evidenced by their contributions to the annual CalCOFI assessment of the State of the California Current report (McClatchie et al. 2009a).

The foundation of a sound EAM is reliable information on the distribution, abundance and interactions of species at multiple trophic levels within the ecosystem. As noted earlier, the CalCOFI surveys contribute to this foundation of information.

A key element of most EAMs is the preservation of essential fish habitat (EFH). The State of California has made significant strides in this arena by establishing a network of marine protected areas to preserve EFH. The CalCOFI ichthyoplankton datasets will be useful in monitoring the impacts of these MPAs.

New modeling tools are needed to evaluate the performance of management measures relative to their intended goals and objectives. This requires two types of modeling tools: forecasting tools to enable managers to project the implications of their actions to enable them to best select a course of action, and the development of retrospective assessments of ecosystem status to evaluate performance of management actions. The CAMEO research program is providing opportunities to develop modeling tools to satisfy both of these needs.

Review and Issues

The Panel recognizes that the research priorities of academic and government agencies evolve and we conclude that leaders of the CalCOFI program have done an excellent job of accommodating these changes without compromising the value of the core time series sampling. **To formally align the mission of CalCOFI with the shifting priorities of the three partner agencies, the Panel recommends that the Mission Statement for the CalCOFI program be modified** to read:

- *(1) Provide a scientific understanding of the human impacts and influence of climate variability and climate change on living resources of the California Current in support of an ecosystem approach to management*
- *(2) Maintain the CalCOFI monitoring program through the continuation of the core time series.*

We also recommend that with the formal broadening of the mission statement of CalCOFI, the title of the program be revisited. This should be an inclusive process of the researchers from the partner institutions. We note that the, title of the program (not the acronym) should be re-visited to include ecosystems (e.g. 'California Cooperative Oceanic Fisheries and Ecosystem Investigations'). The well-recognized CalCOFI acronym should be retained, due to the strong "brand".

The CalCOFI program has done an excellent job of leveraging external funding for ancillary research (Figure 3). However, CalCOFI cannot accommodate all requests for extra at-sea sampling. Some requests may be easily accommodated because they are well aligned with the mission and objectives of the program and require little or no additional ship time, however, inevitably, some requests will fall outside of the scope of the program and/or will be too time consuming or labor intensive. **The Review Panel recommends that a CalCOFI Scientific Steering Committee (SSC) is formed to provide strategic direction to the program.** The CalCOFI SSC would:

- Conduct periodic comprehensive reviews of priorities
- Develop a process for transitioning successful new technologies to operational use in the core CalCOFI program
- Evaluate sampling strategies
- Oversee the continued development and maintenance of a coordinated database
- Coordinate contributions to the Integrated Ecosystem Assessment
- Promote collaborations and data sharing among institutions and agencies throughout the CCE

The Review Panel recognizes that a CalCOFI SSC could play a large role in facilitating an effort to expand, integrate and coordinate monitoring within the CC LME. If the CalCOFI SSC assumes this role, they would explore opportunities for partnerships and coordination with other programs that may expand the spatial range of the survey, broaden the utility of the program, extend collaborations along the Pacific west coast and promote a larger CalCOFI research community. The Review Panel observed that CalCOFI researchers are already partially performing this task. The core CalCOFI

program serves as the foundation for a diverse suite of associated research activities (Figure 3). Therefore, acknowledging the role of the CalCOFI SSC as a key facilitator responsible for the coordination of research and surveys within the CCE, would represent a formal acknowledgement of the importance of CalCOFI researchers in the CCE.

The Review Panel recommends that the core CalCOFI surveys be considered a part of the national backbone of oceanographic sampling. Sponsoring institutions could reach out to other potential funding partners. In particular, the new NOAA Climate Services branch could be approached as a new funding partner. The next generation of global climate models will probably imbed regional coupled bio-physical models in their global models to improve the accuracy of predictions of coastal impacts of climate change. The CalCOFI program provides key information used in the development of regional models for the CCS. The Panel recognizes that there are risks associated with seeking new funding partners because they will have a new voice on the design and implementation of the CalCOFI program. Thus, if managers pursue this approach, we recommend that a memorandum of understanding be established that clearly states the core missions and objectives of the CalCOFI program.

Models that emerge to implement IEAs for EAM will require inputs to, and feedbacks from resource managers. CalCOFI researchers are in an excellent position to facilitate this exchange, as they have a long history of experience in working with State, Federal and academic partnerships. The missing link in this partnership is a strong connection to the developing science of ecosystem assessment and its proponents. **The Panel notes that the new stock assessment expert/ecosystem modeling at SIO could play an important role in facilitating this linkage.** In particular, the new assessment expert could facilitate progress by conducting research to define the ecosystem thresholds for management action. So far, most groups have focused on describing the threats and risks, but none have formally developed the forecasting tools to determine unacceptable ecosystem states. CalCOFI contributes to this by providing the information to develop multi-species Management Strategy Evaluations and ecosystem models. CalCOFI researchers can certainly contribute to this emerging new scientific concept.

When considering the plausible range of management alternatives for IEAs, we note that CalCOFI scientists can inform analysts who are developing technical interaction models that track how the existing or planned management constraints would limit the range of management actions. For example, the adoption of Annual Catch Limits for managed species will place strong constraints on the exploitation of mixed stock fisheries because catch limits of a less productive stock may limit the exploitation of the more productive species. CalCOFI contributes to this issue by providing information on the probability of overlaps between species distributions (characterization of ocean habitats), by improving our understanding of the influence of stock density and environmental variability on carrying capacity of ocean basins (e.g. MacCall 1990), and by tracing individual species abundance.

The Panel recommends that analysts responsible for gathering the information for the IEA carefully consider the content and timeframes necessary for an adequate

assessment. When considering these aspects, analysts should strive to minimize redundancy with other existing efforts (e.g. the annual CalCOFI State of the CC Report).

Finally, the Panel notes that the foundation of a sound EAM is reliable fish stock assessments and abundance estimates for other ecosystem components. If we remain uncertain about the species composition and abundance of the components of the ecosystem, it will be difficult to develop useful thresholds for EAM. Thus, the focus on developing tools to accurately assess single species and their interactions (predation, competition) in response to environmental disturbance will continue to be important. CalCOFI contributes to this foundation.

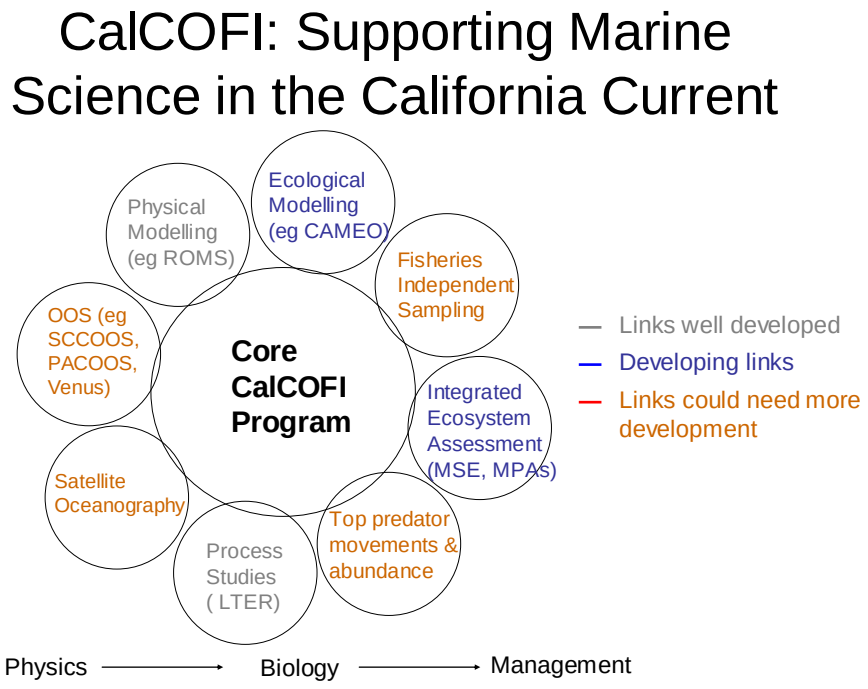

Figure 3.Reviewers' perception of the status of linkages of science supported by the existence of the core CalCOFI program. Color coding highlights what linkages are well developed (gray), where some action is underway to develop the linkages (blue), and where more extensive effort is warranted to promote strong linkages (orange).

TOR 3: Make specific recommendations on the scope, scale, intensity and priorities for future activities to be conducted under CalCOFI, given the review of the existing program performance and potential changes to its mission and objectives;

As noted earlier we recommend that a CalCOFI Scientific Steering Committee (SSC) be established to perform many of the tasks identified in TOR3. Issues regarding the Mission and Objectives were addressed in our response to TOR 2. The Panel offers the

following recommendations on issues of scope, scale, intensity, and priorities relative to potential changes in the CCE.

- **Dedicated funds are needed to maintain and modernize the database.** As more extensive linkages with ancillary databases are sought, consideration of cyber informatics may be of use.
- **Dedicated funds are needed to support research focused on applied science that would be useful in stock assessments or ecosystem assessments.**
- **The Panel suggests that SIO considers offering a course on ecosystem monitoring and assessment**
- As sampling costs escalate, continual evaluation of improving sampling efficiency is warranted. This may include coordination with other State or Federal agencies to link surveys to maximize the spatial and temporal coverage of the CCE. When considering this option, Program managers should consider augmenting existing sampling with additional underway sampling technologies including acoustics, and deploying ruggedized CTDs on trawls. If funding and timing allows we encourage the CalCOFI SSC to request that CalCOFI sampling protocols be used in other monitoring programs.
- The Panel received presentations showing the utility of augmenting CalCOFI surveys with ancillary sampling including adaptive sampling, autonomous vehicles and moorings. **The Panel agrees that the ancillary sampling programs provide added value to the CalCOFI surveys by addressing issues of spatial aggregation and seasonality.**
- When considering sampling efficiency, the Panel encourages analysts to use models to evaluate and design optimal observational strategies (OSSE) including the use of new technology such as autonomous sampling devices and moorings.
- The Panel encourages analysts to focus on contextual issues within the stock assessment within the broader conservation goals of ecosystem management. For example, analysts might consider a minimum biomass threshold to preserve the prey base for the system.
- There is an untapped opportunity to explore techniques for downscaling basin scale climate change models for use in predicting climate change impacts to fish and fisheries.
- Although scientists accept that recruitment processes are complex and predictions will continue to be uncertain, focus should be continued on improving the explanatory power of climate variability in marine fish and invertebrate production.

TOR 4: What is the proper mix of in-house and extramural modeling and synthesis?

- The Panel supports the continuation of attempts to synthesize the data to provide integrated products by both in-house and extramural researchers (i.e. in-house capacity for synthesis is important, yet partnerships are essential).
- The Panel agrees that CalCOFI investigators should continue to develop model(s) for use in evaluating the CCE through a mix of in-house and extramural modeling

and synthesis. **However, once a model is transitioned from research to use in routine operational activities, funding and staffing for this activity should be external from core CalCOFI program** but there should be tight linkages between the field and modeling activities.

- Links to websites that deliver operational data should be available from the CalCOFI website.

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Table 1. Summary of Panel Recommendations

Term of Reference	Recommendation
General	The core CalCOFI Program should be continued for the foreseeable future.
TOR 1, Mission 1	A more complete review paper or book should be prepared to document the major scientific advances that stemmed from CalCOFI monitoring and research.
TOR 1, Mission 1	A workshop should be convened to thoroughly assess the strengths and weaknesses of each of the three survey methods: aerial surveys, acoustic surveys and the DEPM.
TOR 1, Mission 2	Additional work should be conducted to confirm that cameras and 3-dimensional imaging provide accurate depictions of the length composition of the aggregation.
TOR 1, Mission 2	If acoustics become part of the assessment tool box, then the assumption that target – strength to length relationships for Atlantic stocks are suitable for Pacific sardine and northern anchovy should be evaluated.
TOR 1, Mission 2	The stock assessment authors should examine the relationship between sardine size at age and indices of prey availability, and the species composition of the diet relative to available prey.
TOR 1, Mission 2	The historical data should be used to assess the most parsimonious sampling grid that would minimize ship time, while preserving the data needed to monitor climate impacts on the CCS.
TOR 1, Mission 3	Some funds should be secured that could be devoted annually to high priority research projects. This could take the form of graduate student stipends, or research fellowships.
TOR 2	To formally align the mission of CalCOFI with the shifting priorities of the three partner agencies, the Panel recommends that the Mission Statement for the CalCOFI program be modified.
TOR 2	If the mission statement is broadened to encompass ecosystems, the title (not the acronym) should be revisited.
TOR 2	A CalCOFI Scientific Steering Committee (SSC) should be formed to provide strategic direction to the program.
TOR 2	The core CalCOFI surveys should be considered a part of the national backbone of oceanographic sampling.
TOR 2	The new stock assessment expert/ecosystem modeling at SIO should play an important role in facilitating a link between resource managers the developing science of ecosystem assessment.
TOR 2	When considering the plausible range of management alternatives for IEAs, CalCOFI scientists can inform analysts who are developing technical interaction models that track how the existing or planned management constraints would limit the range of management actions.
TOR 2	Analysts responsible for gathering the information for the IEA should carefully consider the content and timeframes necessary for an adequate assessment.
TOR 3	Dedicated funds should be identified to maintain and modernize the database.
TOR 3	Dedicated funds should be identified to support research focused on applied science that would be useful in stock assessments or ecosystem assessments.
TOR 3	Ancillary sampling programs should be encouraged because these programs provide added value to the CalCOFI surveys by addressing issues of spatial aggregation and seasonality.
TOR 3	SIO should consider offering a course on ecosystem monitoring and assessment
TOR 4	Once a model is transitioned from research to use in routine operational activities, funding and staffing for this activity should be external from core CalCOFI program

TUESDAY, MARCH 2ND

Scripps Seaside Forum – Ted Scripps Room

9:00 **Welcome and Introduction**
Tony Koslow, Scripps Institution of Oceanography
Usha Varanasi, Southwest Fisheries Science Center
Russ Vetter, Southwest Fisheries Science Center
Laura Rogers-Bennett, California Department of Fish and Game

CalCOFI – The Past

9:30 **History of CalCOFI**
Paul Smith, Southwest Fisheries Science Center, retired

10:00 ***Coffee break***

CalCOFI – The Present

10:15 **CalCOFI Climate Research: Biophysical Oceanography**
Tony Koslow, Scripps Institution of Oceanography
Steven Bograd, Southwest Fisheries Science Center

11:00 **Applications of Ichthyoplankton Data to Fisheries and Climate**
Sam McClatchie, Southwest Fisheries Science Center
Nancy Lo, Southwest Fisheries Science Center
William Watson, Southwest Fisheries Science Center

11:45 **CalCOFI Ancillary Programs: The New CalCOFI**
Ralf Goericke, Scripps Institution of Oceanography

12:15 ***Lunch***

1:15 **CalCOFI and State Fisheries/Marine Management**
Laura Rogers-Bennett, California Department of Fish and Game

1:45 **CalCOFI and Biophysical Modeling**
Art Miller, Scripps Institution of Oceanography

2:15 **Complementary to CalCOFI (CCE-LTER, gliders, and coastal moorings)**
Mark Ohman, Scripps Institution of Oceanography
Uwe Send, Scripps Institution of Oceanography 2

3:00 **Data Management and Data Delivery**
Ed Weber, Southwest Fisheries Science Center
Karen Baker, Scripps Institution of Oceanography

3:30 ***Coffee break***

4:00 **Discussion**

5:00 – 7:00 **Reception**
Scripps Forum Terrace

THURSDAY, MARCH WEDNESDAY, MARCH 3RD

Scripps Seaside Forum – Ted Scripps Room

CalCOFI - The Future

9:00 **Advanced Survey Methods for Stock Assessment**
David Demer, Southwest Fisheries Science Center

9:30 **Use of Acoustics for Ecosystem Studies**
Tony Koslow, Scripps Institution of Oceanography

10:00 ***Coffee break***

10:30 **Molecular ID of plankton**
John Hyde, Southwest Fisheries Science Center

11:00 **Biogeochemistry**
Ralf Goericke, Scripps Institution of Oceanography

11:30 **CalCOFI and IEAs/Ecosystem modeling (CAMEO)**
Frank Schwing, Southwest Fisheries Science Center
Tony Koslow, Scripps Institution of Oceanography

12:15 ***Lunch***

1:15 **Mandates, Measurements and Minds (Summary)**
Laura Rogers-Bennett, California Department of Fish and Game
Russ Vetter, Southwest Fisheries Science Center
Tony Koslow, Scripps Institution of Oceanography

2:00 **Discussion**
Q & A between panel and participants 3

3:30 ***Coffee break***

4:00 **Panel Meeting**

THURSDAY, MARCH 4TH

Scripps Seaside Forum – Ted Scripps Room

9:00	**Final Day Opening remarks** Tony Haymet, Scripps Institution of Oceanography
9:15	**Panel drafts Report**
10:30	***Coffee break***
11:00	**Panel reports preliminary conclusions**
12:00	**End of Review** Steve Murawski, NOAA Fisheries