



CalCOFI Conference

5-6 December 2016

Southwest Fisheries Science Center
La Jolla, CA

Hosted by:

Southwest Fisheries Science Center, NOAA

CalCOFI Coordinator: John Heine
Symposium Convener: Sam McClatchie

In association with:
Scripps Institution of Oceanography
California Department of Fish and Wildlife



CalCOFI Conference 2016
Southwest Fisheries Science Center
La Jolla, CA
Dec. 5-6

Monday, 5 December

- 12:30-1:30 Registration - SWFSC
- 1:30-1:40 **Opening of the Conference**
Welcome: Sam McClatchie, Southwest Fisheries Science Center.
- 1:40-2:25 **Session I: State of the California Current 2015-2016: comparison with the 1997-1998 El Niño**, Ralf Goericke, Scripps Institution of Oceanography.
- 2:25-3:10 **Session II: Status of the California Fisheries**. Laura Rogers-Bennett, California Department of Fish and Wildlife.
- 3:10-3:25 Break
- 3:25 **Session III: Contributed Papers (15 minutes with 5 minutes for discussion)**. Chair: Dave Checkley, Scripps Institution of Oceanography.
- 3:25-3:45 **C-1. Biogeography of the trawl-caught fishes of California and an examination of the Point Conception faunal break**. John S. Stephens, Jr.¹, **John Steinbeck**², Jay Carroll², Daniel J. Pondella, II¹ and Milton Love³. ¹ Vantuna Research Group, Occidental College, ² Tenera Environmental Inc., ³ Marine Science Institute, University of California, Santa Barbara.
- 3:45-4:05 **C-2. Zooplankton indicators of ecosystem productivity in the northern California Current: seasonal patterns and responses to recent climate forcing**. Eric P. Bjorkstedt¹, Roxanne Robertson², and William T. Peterson³, ¹Southwest Fisheries Science Center NMFS/NOAA, Humboldt State University, Trinidad, CA, ²CIMEC at Humboldt State University, Trinidad, CA, ³Northwest Fisheries Science Center NMFS/NOAA, Newport, OR.
- 4:05-4:25 **C-3. Recent Changes in Diet and Breeding Productivity for California Least Terns Breeding in Southern California**. Dan P. Robinette, Meredith Elliott, and Jaime Jahncke, Point Blue Conservation Science, Petaluma, California.
- 4:25-4:45 **C-4. Stable isotope-based nitrogen budget for the California Current Ecosystem domain during the 2014 Blob and 2015-2016 El Nino: from source nutrients to food webs**. Brandon M. Stephens¹, Lihini I. Aluwihare¹,

Scott D. Wankel², Margot E. White¹, Belli Valencia¹, ¹Scripps Institution of Oceanography, La Jolla, CA, ²Woods Hole Oceanographic Institution, Woods Hole, MA.

4:45-5:05 **C-5. Dynamics of intertidal abalone populations at San Nicolas Island: Evidence for ocean forcing of abalone recruitment patterns, and a circumstantial case for apparent linkages of ocean forcing to growth of the Island's sea otter population.** Glenn R. VanBlaricom, US Geological Survey, Washington Cooperative Fish and Wildlife Research Unit, & School of Aquatic & Fishery Sciences, College of the Environment, University of Washington.

5:05-7:00 **Reception, Pacific Room, SWFSC. Beer, wine, non-alcoholic drinks and hors d'oeuvres.**

Tuesday, 6 December

Ongoing Registration - SWFSC

8:00 **Session IV: The Symposium of the Conference: "The Next 70 Years of CalCOFI".** Chair: Sam McClatchie, SWFSC.

8:00-8:10 Introduction and overview: Sam McClatchie, SWFSC.

8:10-8:40 **S-1. Looking forward to the new CalCOFI.** Sam McClatchie, Southwest Fisheries Science Center, NMFS/NOAA La Jolla.

8:40-9:10 **S-2. A MOON Technological Transformation for CalCOFI During Its Next 70 Years.** Charles H. Greene and Erin Meyer-Gutbrod, Ocean Resources and Ecosystems Program, Cornell University. Ithaca, NY.

9:10-9:40 **S-3. The California Underwater Glider Network.** Daniel L. Rudnick, Scripps Institution of Oceanography, La Jolla, CA.

9:40-10:00 Break

10:00-10:30 **S-4. Towards Integrated and Multi-Scale Modeling Frameworks for the Coastal Ocean.** Emanuele Di Lorenzo¹, Peter J. S. Franks², and Kenneth A. Rose³, ¹Program in Ocean Science and Engineering, Georgia Institute of Technology, Atlanta, GA, ²Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, ³College of the Coast and Environment, Louisiana State University, Baton Rouge, LA.

- 10:30-11:00 S-5. **Whither CalCOFI?** Steven Bograd, NOAA/NMFS, Southwest Fisheries Science Center, Environmental Research Division, Monterey, CA.
- 11:00-11:30 S-6. Anthony Richardson.
- 11:30-12:00 S-7. **Advances in technology will take CalCOFI biological sampling to amazing places over the next 70 years.** Andrew R. Thompson, Dovi Kacev, Rasmus Swalethorp, and William Watson, Southwest Fisheries Science Center, NMFS/NOAA, La Jolla.
- 12:00-1:00 **Lunch**
- 1:00-1:30 S-8. **Autonomous and Attended Ocean Measurement Systems: the Future of CalCOFI.** Mark D. Ohman, California Current Ecosystem LTER site and SIO Pelagic Invertebrate Collection, Scripps Institution of Oceanography, UCSD, La Jolla, CA.
- 1:30-2:00 S-9. **One Perspective on the Future of CalCOFI.** David M. Checkley, Jr., Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA
- 2:00-2:30 S-10. Uwe Send.
- 2:30-2:50 Break
- 2:50-3:20 S-11. **Peering into sampling technologies with an eye on imaging and the future of zooplankton sampling.** Robert K. Cowen, Hatfield Marine Science Center, Oregon State University.
- 3:20-3:50 S-12. **Ecological time series: the jewel in the crown.** Tony Koslow, Scripps Institution of Oceanography, UCSD La Jolla, CA.
- 3:50-4:20 S-13. **How changes in spatial domain, frequency, and sample processing affect time series data.** Noelle M. Bowlin, Andrew R. Thompson, William Watson, Southwest Fisheries Science Center, NMFS/NOAA, La Jolla.

Panel Discussion and Poster Session, Martin Johnson House, T-29, SIO campus.

- 5:00-6:00 **Panel-led Open Discussion on the future of CalCOFI (Panel members TBD)**
- 6:00-8:00 **Poster Session. Beer, wine, and non-alcoholic beverages, hors d'oeuvres, and dessert.**

P-1. Temperature-dependent incubation rate in Pacific Sardine eggs and comparison with historical estimates of incubation rate. Megan H. Human, Noelle M. Bowlin, Andrew R. Thompson, William Watson, Ed D. Weber, Southwest Fisheries Science Center, NMFS/NOAA, La Jolla.

P-2. Temporal Trends in Ocean Temperature and Dissolved Oxygen in Coastal Waters off Point Loma, San Diego, California: 1991 - 2015. Wendy Enright, Ami Latker, Adriano Feit, Greg Welch, Tim Stebbins, City of San Diego Marine Biology Laboratory, Public Utilities Department, San Diego, CA.

P-3. INVASION - The pelagic red crab *Pleuroncodes planipes* takes over the continental shelf off San Diego, California! Robin Gartman, Ami Latker, Allison Brownlee, Wendy Enright, Tim Stebbins, City of San Diego Marine Biology Laboratory, Public Utilities Department, San Diego, CA.

P-4. Distribution and Abundance of Dungeness crab (*Metacarcinus magister*) megalopae in the California Current. Angela D. Klemmedson¹, Dr. Laura Rogers-Bennett², ¹California Department of Fish and Wildlife, San Diego, ²California Department of Fish and Wildlife, Bodega Bay.

P-5. Aerial survey of small pelagic species in the Southern California Bight. Kirk Lynn, Dianna Porzio, Laura Ryley, California Department of Fish and Wildlife.

SYMPOSIUM ABSTRACTS

The Symposium of the Conference

The next 70 years of CalCOFI

CalCOFI began regular surveys in 1951. The goals of the program have shifted to focus on the ecosystem, climate trends and variability rather than small pelagic fisheries, and a wealth of data, analyses and literature has been produced. It is timely, as we approach the 7th decade of the program, to review options for the future. Should CalCOFI continue in its current configuration? Should it remain a shipboard program, or should the balance between ships and other sensors (gliders, AUVs, moorings and satellites) change? How can CalCOFI optimize relevance to increasing frequency of extreme inter-annual variability as climate changes? Is CalCOFI providing the data, metrics and summaries relevant to ecosystem management in a changing environment? Can we provide a coherent vision of CalCOFI leading into the next seven decades that either justifies doing more of the same, and/or provides a path to a revitalized program that will be defensible, sustainable, and relevant in the expected funding framework for long-time series in the United States.

S-1. Looking forward to the new CalCOFI

Sam McClatchie

Southwest Fisheries Science Center, NMFS/NOAA La Jolla

CalCOFI is a vibrant and productive program entering the 66th year since regular surveys began in 1951. Here I examine the program with an eye to the future, bearing in mind the increased pressure for cost effectiveness, relevance, and responsiveness of ecosystem monitoring to extreme events and climate change. Ship-based sampling for CalCOFI is becoming increasingly expensive. I present the approximate survey costs and then examine the capacity of other, cheaper, platforms to measure the key ecosystem processes we should monitor in the California Current System (CCS). The CCS is a strongly regional system and I ask which areas we need to monitor in the future, and whether this might be achieved by limiting detailed station work to indicator stations. CalCOFI has always been relevant, but there is increasing pressure to provide information in near real-time relevant to extreme events, such as the 2014-2016 marine heat wave, in addition to monitoring long-term climatic trends. To be this responsive, CalCOFI needs to modify some of its protocols for processing biological data to provide ichthyoplankton community information quickly, as is already done for hydrographic surfaces and sections. Finally, CalCOFI needs to broaden its relevance to the scientific community by making all of the data readily available on the Internet using the NOAA ERDDAP system. This need applies equally to all datasets collected using the CalCOFI platform, and not just to some data categories, as is currently the case. The survival of the program is intimately related to how many people use our data because it is relevant, timely, and essential for ecosystem monitoring.

S-2. A MOON Technological Transformation for CalCOFI During Its Next 70 Years

Charles H. Greene and Erin Meyer-Gutbrod

Ocean Resources and Ecosystems Program, Cornell University.
Ithaca, NY 14853

California Cooperative Oceanic Fisheries Investigations (CalCOFI) is a ship-based, fisheries-oceanography program that will soon be entering its 67th year of studying the California Current Ecosystem. Although the time-series data sets generated by CalCOFI are of tremendous value, the program is constrained by its reliance on cruises conducted with manned survey ships. Throughout its history, CalCOFI has added new instruments and methodologies. However, the increasing expense of shiptime has reduced the program's sampling frequency and geographical extent, from monthly cruises covering nearly the entire US West Coast at its inception in 1949 to four cruises per year covering primarily the Southern California Bight at present. While CalCOFI provides a strong foundation for the ongoing evolution of an ecologically driven, ocean-observing program on the West Coast, we suggest that supplementing it with Wave Glider-based Mobile Ocean Observing Network (MOON) technology can add tremendous value to the overall enterprise.

Our vision for the future of CalCOFI is to supplement the ship-based program with a continental-scale Mobile Ocean Observing Network, consisting of a series of oceanographic lines running perpendicular to the coast and extending the full length of the US EEZ from the Canadian border to the Mexican border. Ideally, this Mobile Ocean Observing Network would sample continuously for biological, chemical, and physical data by Wave Gliders at the surface and Spray, Slocum, or comparable gliders below the surface. CalCOFI cruises currently conduct a standard set of underway observations between stations and a number of core observations at each station. In this presentation, we explore how gliders could be instrumented to collect many of the underway observations currently being made during the four annual CalCOFI cruises. MOON technology offers a cost-effective way to expand CalCOFI's spatial and temporal coverage.

S-3. The California Underwater Glider Network

Daniel L. Rudnick

Scripps Institution of Oceanography, La Jolla, CA 92093-0213

The overarching goal of the California Underwater Glider Network (CUGN) is to sustain baseline observations of climate variability in the California Current System (CCS). The CUGN uses Spray underwater gliders making repeated dives from the surface to 500 m and back, repeating the cycle every 3 hours, and traveling 3 km in the horizontal during that time. The CUGN includes gliders on three of the traditional cross-shore CalCOFI lines: 66.7, 80.0 and line 90.0. The glider missions typically last 100 days, and cover over 2000 km, thus providing 4-6 sections on lines extending 350-500 km offshore. Since 2005 the CUGN has covered 220,000 km over ground in 10,000 glider-days, while doing 97,000 dives. These data are used to produce a climatology whose products are, for each observed variable, a mean field, an annual cycle, and the anomaly from the annual cycle. The analysis includes a weighted least-squares fit to derive the mean and annual cycle, and an objective map to produce the anomaly. The final results are variables on rectangular grids in depth, distance offshore, and time. The mean fields are finely resolved sections across the main flows in the CCS, including the poleward California Undercurrent and the equatorward California Current. The annual cycle shows a phase change from the surface to the thermocline, reflecting the effects of air/sea fluxes at the surface and upwelling in the thermocline. The interannual anomalies are examined with an emphasis on climate events of the last ten years including the 2009-2010 El Niño, the 2010-2011 La Niña, the warm anomaly of 2014-2015, and the 2015-2016 El Niño.

S-4. Towards Integrated and Multi-Scale Modeling Frameworks for the Coastal Ocean

Emanuele Di Lorenzo¹, Peter J. S. Franks², and Kenneth A. Rose³

¹Program in Ocean Science and Engineering, Georgia Institute of Technology,
Atlanta, GA, USA

²Scripps Institution of Oceanography, University of California San Diego,
La Jolla, CA, USA

³College of the Coast and Environment, Louisiana State University,
Baton Rouge, LA, USA

In the late 1990's, the development of high-resolution regional ocean models enabled scientists to take a new look at the circulation and ecosystem dynamics along the California coast. By combining long-term hydrographic data from CalCOFI with this new class of regional ocean models, we have diagnosed the ocean processes by which large-scale climate variability impacts key ecosystem drivers along the west coast of North America (e.g., upwelling, alongshore and cross-shore transport, thermocline and sea surface temperatures). However, ecological observations acquired through the CalCOFI program also revealed key ecosystem processes that are not fully understood and therefore difficult to model (e.g., changes in fish and plankton assemblages, species distributions). While the integration of physical and biological models led to significant advances in the simulation of marine ecosystems and their response to climate forcing, key challenges still remain. Diagnosing and quantifying the the rich diversity of biological dynamics sampled through CalCOFI require a new class of ecological models that can combine both the compositional nature (e.g., species or functional groups) and aggregate properties (e.g., productivity, carbon export) of the ecosystem at multiple scales. There is also a growing need to incorporate top-down pressures – including human pressures – in marine ecosystem models, and to resolve finer scales of the climate-ecological-human interactions (e.g., developing social-ecological-environmental coastal models). These improved multi-scale modeling frameworks will enable the CalCOFI program to improve understanding of the physical, chemical, biological and human dimensions of climate change impacts and uncertainties in coastal environments, and position CalCOFI as a leader in detecting, monitoring and predicting global change in coastal systems.

S-5. Whither CalCOFI?

Steven Bograd

NOAA/NMFS, Southwest Fisheries Science Center, Environmental Research Division,
Monterey, CA

Now in its 67th year, CalCOFI represents the gold standard of long-term oceanographic monitoring and research. As Warren Wooster, a Scripps graduate student when CalCOFI began in 1949, has said, the CalCOFI dataset "has become the world's richest documentation of changes over time in a substantial piece of the ocean". With its longevity, adaptability, interdisciplinary sampling, and inclusion of numerous ancillary observing programs over the years, CalCOFI has provided the framework for understanding the dynamics of the California Current System at scales ranging from seasonal to secular climate change. When thinking about the future of CalCOFI, the first and foremost consideration is that the program must continue; long oceanic time series are exceedingly rare yet are essential for detecting and understanding the impacts of climate change. However, CalCOFI must also remain flexible and adaptable as new technologies are developed and as new science questions arise. Advances in autonomous observing systems, in biodiversity monitoring through eDNA, in data archiving and dissemination, and in near-real-time applications to fisheries management, all need to be incorporated into CalCOFI's future blueprint. Here I will discuss potential changes and priorities that CalCOFI should consider, both in terms of sampling protocols and scientific focus, in order to maximize its impact on our understanding of climate change and marine ecosystem dynamics.

S-6.

S-7. Advances in technology will take CalCOFI biological sampling to amazing places over the next 70 years

Andrew R. Thompson, Dovi Kacev, Rasmus Swalethorp, and William Watson

Southwest Fisheries Science Center, NMFS/NOAA, La Jolla

CalCOFI, the world's most extensive marine ecosystem monitoring program, began in 1949, and the degree to which it was ahead of its time is staggering. Consider, for example, that the word "ecosystem" was coined by Arthur Tansley a mere 12 years prior to, and that Watson and Crick published their paper describing the double helix shape of DNA 4 years after, the inception of CalCOFI. One reason that CalCOFI is even more capable of answering pertinent marine ecosystem questions today than it was at the beginning is that the program has integrated advances in technology into its sampling techniques. From a physical perspective, utilization of instruments such as CTDs and gliders provide oceanographic information that the CalCOFI founders could only have dreamt of. As we look to the future of CalCOFI, we believe that further advances in technology will allow CalCOFI to provide ecosystem information that is beyond even the wildest dreams of its founders. Here we describe how we are beginning to use new genetic and isotopic technologies to provide novel streams of data focused on CalCOFI ichthyoplankton. From a genetic perspective, we have developed a new time-series (1998-2013) for 39 larval rockfishes by sequencing ethanol-preserved larvae collected on winter CalCOFI cruises. This new data provides evidence that rockfish production has increased during this period and that Rockfish Conservation Areas have been effective in augmenting rockfish production in southern California. At present, we are applying metagenomic techniques developed in the past decade to plankton samples with the aim of homogenizing an entire sample and genetically determining which fish are present/absent. We are also exploring the potential for metagenomics to identify fish presence from water samples (i.e., eDNA) as fish routinely slough cells from which DNA can be amplified using this powerful, new technology. From an isotopic perspective we are using recently developed compound-specific techniques to more precisely resolve perturbations within the food chain and shifts in diet of larval fishes. The goal is to identify environmental linkages to nourishment during the larval phase and determine whether this impacts recruitment. Compound-specific methodology can be used on formalin-preserved samples and hence we are able to analyze fishes from the entire CalCOFI time-series. Technological advances are currently progressing at exponential rates, and it is likely that breakthroughs over the next 70 years will allow scientists to sample the ocean in ways that are unimaginable to us now. Our challenge moving forward is to stay abreast of new technology and incorporate it into CalCOFI sampling. This will allow the CalCOFI program to continue to better reveal how the California Current Ecosystem functions.

S-8. Autonomous and Attended Ocean Measurement Systems: the Future of CalCOFI

Mark D. Ohman

*California Current Ecosystem LTER site
and SIO Pelagic Invertebrate Collection
Scripps Institution of Oceanography, UCSD, La Jolla*

Fully autonomous ocean measurement systems have exploded in the Ocean Sciences in recent years. The prospects for continued development of new ocean sensors and new autonomous vehicles and other platforms for sensor delivery are excellent. Other types of instruments are deployed from research vessels, but operate in unattended mode with minimal shipboard intervention. Still other types of shipboard measurements are fully attended and require expert technical proficiency and human judgement for proper sampling. What is the correct balance of these different measurement approaches for CalCOFI? How are the diverse objectives of the CalCOFI triumvirate, together with other interested stakeholders, going to best be met? How can continuity with the past 68 years of measurements be ensured? Can the climate-quality data for which CalCOFI is widely known and respected be sustained, uncompromised? Which biological measurements are essential to maintain, given the different paces at which physical sensors and biological-biogeochemical sensors have been developed? This presentation will provide a perspective on these issues.

S-9. One Perspective on the Future of CalCOFI

David M. Checkley, Jr.

Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA

CalCOFI was conceived to improve fisheries management by understanding the marine ecosystem. Over time, CalCOFI has become relevant to assessing ecosystem response to human activities. Thus, the current mission of CalCOFI is to acquire and provide information on the marine ecosystem to inform management and policy decisions regarding living marine resources and human activities. I will briefly address three questions regarding CalCOFI's future. First, what are the essential CalCOFI variables? Second, how might the use of, and hence need for, CalCOFI products be enhanced? Third, what is an appropriate strategy for CalCOFI given changes in needs, observing, and funding? I will conclude by advocating for stronger leadership by the CalCOFI Committee and the creation, and use of, an external advisory group.

S-10

S-11. Peering into sampling technologies with an eye on imaging and the future of zooplankton sampling

Robert K. Cowen

Hatfield Marine Science Center
Oregon State University

New oceanographic sampling technologies can convey significant and novel insights into physical-biological patterns and processes. In some cases, such technologies can also increase sampling efficiency, enabling either lower cost approaches, or increased effort and thereby spatio-temporal resolution. CalCOFI has a long history of sampling that has evolved as it has embraced the introduction of new technologies, but the pace of such advances is quickening and is sure to increase in the near future. Looking to the future for CalCOFI, there is a need to strike a balance between maintaining the continuity and ever-increasing value of their time-series sampling, and future costs and budgets. This includes adding value to the time series in terms of increased resolution, enabling new but comparable methodologies, and redesign of surveys to capture additional processes as they become recognized as key drivers of the California Current Large Marine Ecosystem. One exciting area of biological sampling that has evolved with considerable rapidity is *in situ* imaging technology. Optical methods, along with concurrent environmental sensors, can complement plankton net and acoustic sampling approaches. However, it may also be a means of enabling more cost-effective surveys of considerably higher temporal and spatial resolution, as well as overall (or continuous?) spatial coverage, thereby opening the door to obtain greater insight into the system. Here a brief review is provided of the current state of imaging technology available to biological oceanographers, and some of the critical trade-offs. Included in the discussion is a view on the status of image processing, which has been a major constraint to extensive use of imaging technology. Finally, recent work with the *In Situ* Ichthyoplankton Imaging System (ISIIS), and its associated automated image processing pipeline, is presented as an example of where progress has been made with imaging systems and their potential utility to CalCOFI studies.

S-12. Ecological time series: the jewel in the crown

Tony Koslow

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The overriding issue facing marine ecosystem management over the 21st century will be to manage in the face of the increasing impacts and increasing uncertainty related to climate change. It is not possible to predict how the California Current will respond to climate change: marine ecosystems are too complex and too poorly understood. The past will provide little guide: greenhouse gases and other anthropogenic forcing will subject the oceans to pressures never previously experienced. In the face of these pressures and uncertainties, CalCOFI's highest priority must increasingly be ecosystem, as opposed to single-species, management: to track ecosystem response with as much resolution as possible. Remote sensing and robotic platforms have transformed observation of the ocean's physical and chemical state; these will continue to improve. However, ecological sampling has advanced little; nets still provide the backbone of quantitative species-resolution observational data, the sine qua non of ecological time series. Despite their promise and power, acoustic, optical and genomic sampling complement but do not replace organismal sampling, and they are unlikely to do so in the foreseeable future. Ship-board sampling will continue to be required if CalCOFI is to meet its mandate. Budget pressures will no doubt persist but CalCOFI's leaders must persist as well in standing up to these pressures by marshalling stakeholder support and expanding the use and utility of CalCOFI products in marine assessments and science.

S-13. How changes in spatial domain, frequency, and sample processing affect time series data

Noelle M. Bowlin¹, Andrew R. Thompson¹, William Watson¹

¹Southwest Fisheries Science Center, NMFS/NOAA, La Jolla

We are faced with many questions regarding which direction(s) CalCOFI should pursue in the future. The transition from a focus on Pacific Sardine recruitment variability to the entire ecosystem modified the goals over time. It is important to clearly define and prioritize goals for this program. As an important part of this process we will look at the changes in spatial domain, frequency, and sample processing the program has gone through and how those changes have affected the time series. We will also consider some similar challenges that other ecosystem monitoring programs have faced and are planning for, as there may be lessons to learn from these examples. We will discuss the transitions of the MEXUS-Gulf program to SEAMAP in the Gulf of Mexico and MARMAP to EcoMon in the northeast US continental shelf region. The purpose of this talk is to add to the discussion of what we want for CalCOFI in the coming years.

CONTRIBUTED ABSTRACTS

C-1. Biogeography of the trawl-caught fishes of California and an examination of the Point Conception faunal break

John S. Stephens, Jr.¹, **John Steinbeck**², Jay Carroll², Daniel J. Pondella, II¹
and Milton Love³

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We analyzed fish data from 2332 trawls collected from depths between 55 and 1280 m off the coast of California that were collected from 2003 to 2010 to examine changes in composition north and south of the faunal break at Point Conception. For the 732 species known from California, including 283 species (~39% of the California ichthyofauna) in this study, very few were contained by the faunal break at Point Conception, with 21% limited from the south and only 4% from the north. Based upon trawl densities of 93 common species that were distributed across this potential barrier from three regional divisions-the Southern California Bight (SCB), the South Central Coast (SCC), and the Monterey region (MONT)-there was no effect of the barrier on 27 species, while 58 were found in significantly higher regional densities. 62% of the species showed a strong effect from this boundary. The composition from the SCC region generally had a stronger relationship with the composition for the MONT region rather than the SCB region. The samples were also classified by depth and latitude. Latitudinal changes in composition were most evident in the samples collected at depths of <200 m and less apparent at deeper depths.

C-2. Zooplankton indicators of ecosystem productivity in the northern California Current: seasonal patterns and responses to recent climate forcing

Eric P. Bjorkstedt¹, Roxanne Robertson², and William T. Peterson³

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Sampling along the Trinidad Head Line off northern California is conducted at approximately monthly intervals throughout the year to provide information on the state of the planktonic ecosystem in the context of hydrographic variability. The copepod assemblage observed at mid-shelf shows distinct seasonal pattern, reflecting the presence of different water masses as a result of variability in transport and source waters throughout the annual cycle. Similarly, seasonal pattern in the euphausiid assemblage reflect combined effects of variability in reproductive output and advection-driven cross-shelf distributions. Both assemblages exhibited strong, persistent changes in response to the marine heatwave of 2014-2016. Cold-water (typically lipid-rich) copepod species have declined in abundance and warm-water (lipid-poor) species have become more abundant, a pattern corroborated by the occurrence of warm-water copepods not previously recorded in our time series. The euphausiid assemblage experienced a similar shift, driven by apparent changes in reproductive output in *Thysanoessa spinifera* (an upwelling-dependent species), onshore shifts of more oceanic species, and the occurrence of species from offshore waters (*Euphausia recurva*) or from coastal waters to the south (*Nyctiphanes simplex*). Coincident with these changes in the euphausiid community, we have observed a persistent shift in the mean size of adult *Euphausia pacifica* towards smaller individuals. Collectively, these time series provide strong evidence of changes in the plankton community off northern California in response to climate forcing, including shifts with potentially important implications for productivity throughout the broader ecosystem.

C-3. Recent Changes in Diet and Breeding Productivity for California Least Terns Breeding in Southern California

Dan P. Robinette, Meredith Elliott, and Jaime Jahncke

Point Blue Conservation Science, Petaluma, California

The California least tern (*Sternula antillarum browni*) is a small, colonial seabird that breeds on sandy beaches along coastal California, with the majority of the population breeding south of Point Conception. Loss of breeding habitat due to coastal development and increased recreational use of beaches in the 1950s and 1960s led to a decline in breeding population and the least tern's listing on state and federal endangered species lists. Management efforts have proven successful as the population increased from <700 pairs prior to its federal listing to >4,000 pairs in recent years. However, annual breeding productivity for southern California colonies has been consistently below the long term average for the past 14 years, prompting questions about prey availability in the Southern California Bight (SCB). Here, we compare diet composition at four southern California colonies between two time periods (1999-2000 and 2012-2015) to investigate whether low prey availability is the cause of low breeding productivity. There was a decrease in the occurrence of clupeiform fishes between the two time periods for three of the four colonies. Clupeiform fishes have high caloric values and their occurrence in least tern diet has been positively correlated with breeding productivity at a colony in central California. Additionally, diets at all colonies were more diverse in 2012-2015 and showed a higher occurrence of larval fish, indicating that the least terns are depending more on alternative prey with lower caloric value in recent years. Our results suggest that important prey like anchovies have either become less abundant in the SCB or are more dispersed and thus more difficult locate. A more dispersed prey source can lead to increased time spent foraging which, in turn, can lead to less time spent defending the colony from predators and decreased chick provisioning rates. Thus, changes in prey availability are likely contributing to the low breeding productivity of least terns in southern California.

C-4. Stable isotope-based nitrogen budget for the California Current Ecosystem domain during the 2014 Blob and 2015-2016 El Nino: from source nutrients to food webs

Brandon M. Stephens¹, Lihini I. Aluwihare¹, Scott D. Wankel²,
Margot E. White¹, Belli Valencia¹

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CalCOFI's long-term, spatially-expansive collection of nutrients, plankton and fish abundance, and hydrographic data have substantially improved our understanding some of the fundamental mechanisms influencing the pelagic ecosystem (e.g., Rykaczewski and Checkley, 2008), revealing clear climatological trends across food webs (e.g., Di Lorenzo and Ohman, 2013). Central to overall phytoplankton production throughout the California Current is the supply of 'new' nutrients (i.e., subsurface nitrate) into the euphotic zone (Eppley et al., 1979). Studies have also highlighted the local imbalance of 'new' nutrient supply and export, the balance of which is important not only for carbon budgets but for the support of food webs across the coastal gradient, that is reconcilable by invoking such processes as the cross-shore transport of surface particles and organisms (Plattner et al., 2005; Stukel et al., 2011). Using model analysis of the stable isotopic composition of nitrate, we estimate that euphotic zone conversion of recycled nutrients into nitrate (i.e., nitrification) may account for up to 30% of nitrate-based production. In addition to euphotic zone nutrient cycling, long-term monitoring of sub-euphotic zone nitrate stable isotopes can also be useful to estimate changes in deep source waters subject to denitrification like those of the Santa Barbara Basin (Goericke et al., 2015) or eastern Equatorial Pacific (Sigman et al., 2005) and could be useful in isolating influences on long-term pycnocline decreases in oxygen (Bograd et al., 2015). The collection of samples for nitrate isotopes requires little time and storage space, and the analysis of this nitrate isotope data throughout the water column could provide insight into processes supporting the coastal pelagic ecosystem across the CalCOFI sampling domain.

**C-5. Dynamics of intertidal abalone populations at San Nicolas Island:
Evidence for ocean forcing of abalone recruitment patterns,
and a circumstantial case for apparent linkages of ocean forcing
to growth of the Island's sea otter population**

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The nearshore marine ecosystems of San Nicolas Island (SNI) are occupied by populations of the endangered black abalone (*Haliotis cracherodii* Leach, 1814) and the threatened southern sea otter (*Enhydra lutris* [L., 1768]). A thirty-six year time series of data on dynamics of black abalone populations at SNI reveals significant effects of novel disease, ocean forcing of recruitment, and sediment inundation. Since 2001 apparent recruitment rates correlate negatively with sea surface temperatures, suggesting beneficial effects of cold-phase ocean conditions on recruitment rate. Sea otters, recognized as significant abalone predators, were restored to SNI in 1987 following local extinction from excessive hunting in ~1850. At present ~100 sea otters dwell at SNI, a level thought to be ~0.3 to 0.5 of the likely equilibrium population size sustainable by Island ecosystems. The population trend of sea otters at SNI has been positive for ~20 yrs. Given prevailing dogma regarding the ostensible trophically-based incompatibility of sea otters and abalones in time and space, it is noteworthy that estimated numbers of sea otters and abalones at SNI have been positively correlated since 2001. Both sea otters and black abalone at SNI may be responding positively to cold-phase ocean conditions. Benefits of cold-phase conditions accrue to black abalone primarily through recruitment processes, and to sea otters through augmented recruitment and growth rates of multiple species of invertebrate prey at SNI, including urchins, crabs, and snails among other taxa.

POSTER TITLES AND ABSTRACTS

P-1. Temperature-dependent incubation rate in Pacific Sardine eggs and comparison with historical estimates of incubation rate

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The Daily Egg Production Method (DEPM) is a useful tool in assessing the spawning biomass of Pacific Sardine. This method uses an exponential mortality model derived from the temperature-dependent rates of egg development established 20 years ago using eggs collected from net tow samples with an estimated time of fertilization. To determine if this relationship is still current we collected ripe male and female sardines during trawl surveys and fertilized the eggs at sea. The eggs were reared in constant temperature baths between 12°C and 21°C, collected at regular time intervals, preserved, and later staged in the laboratory. Preliminary results from the temperature-dependent egg-development model suggest eggs in our experiment developed more quickly at comparable temperatures than in previous experiments. These results may be due to differences in experimental design; we were able begin recording developmental stages upon fertilization instead of using estimates of peak spawning times. However, further experimentation is needed. This research can be used to update the temperature-dependent egg development curve used in the parameter estimation for the DEPM.

P-2. Temporal Trends in Ocean Temperature and Dissolved Oxygen in Coastal Waters off Point Loma, San Diego, California: 1991 – 2015

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The City of San Diego collects a comprehensive suite of oceanographic data from waters surrounding the Point Loma and South Bay ocean outfalls to characterize conditions off San Diego and to identify possible impacts of wastewater discharge. These data include measurements of water temperature, salinity, light transmittance, dissolved oxygen (DO), pH, and chlorophyll *a* at a large number of water quality monitoring stations arranged in grids surrounding the two outfalls and encompassing a total area of ~880 km². This project specifically looks at temperature and DO data collected over a 25 year period (1991–2015) at a subset of these stations located along the 100-m depth contour spanning the discharge site of the Point Loma outfall. Although monitoring occurred monthly from 1991 through mid-2003 and then quarterly thereafter through the present, the data for this study were limited to quarterly months for comparison purposes. Preliminary analyses included plots of ocean temperatures and DO concentrations over time for each 1-m depth bin, averaged over all stations sampled during each quarterly period, as well as raw values of DO from five different depth layers (i.e., 1-20 m, 21-40 m, 41-60 m, 61-80 m, and 81-100 m) fitted with the loess-smoothed trend of each quarterly mean for both DO and temperature. Results from subsurface (> 20 m) depth layers indicate a general decline in DO concentrations from 1998 through the beginning of 2012, after which there was a sharp increase in DO through the end of 2015. These trends in DO generally track changes observed in ocean temperatures at these deeper depths sampled off Point Loma and roughly correspond to large-scale oceanographic events such as the 1997/1998 and 2014/2015 El Niños. Additionally, it is interesting to note that increases in DO measured at depths greater than 20 m began in 2012, approximately one year prior to the first observations of the Pacific Anomaly (aka “The Blob”) off Southern California.

P-3. INVASION – the pelagic red crab *Pleuroncodes planipes* takes over the continental shelf off San Diego, California!

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The City of San Diego Ocean Monitoring Program conducts otter trawl surveys to collect demersal fishes and relatively large (megabenthic) mobile invertebrates from seafloor habitats surrounding the Point Loma and South Bay ocean outfalls to characterize conditions off San Diego and to identify possible impacts of wastewater discharge. During calendar year 2016, many of the City's trawls were dominated by the presence of the pelagic red crab, *Pleuroncodes planipes*. In order to gain perspective on the vast numbers of crabs encountered during this past year, we reviewed historical trawl data dating back to the early 1980s. Trawl data were collected from three sets of monitoring stations: 1) stations located along the 60-m depth contour spanning the original Point Loma Ocean Outfall (PLOO) discharge site (sampled 1983–2003); 2) stations located along the 100-m depth contour spanning the current PLOO discharge site (sampled 1991–2016); 3) stations located along the 28-m depth contour spanning the South Bay Ocean Outfall (SBOO) discharge site (sampled 1995–2016). A single trawl was performed at each station during each survey using a 7.6-m Marinovich otter trawl fitted with a 1.3-cm cod-end mesh net. In most cases, the net was towed for 10 minutes bottom time at a speed of about 2.0 knots. Exceptions occurred during 2016 when the 10 minute trawls resulted in exceptionally large hauls of red crabs that were too heavy to be brought onboard the ship. In such cases, one minute trawls were subsequently attempted, and even then some hauls were too large to process. Once onboard, all organisms were identified and counted. However, when the red crab abundance exceeded ~250 individuals, the number of individuals per haul was estimated by weighing and counting an aliquot of specimens and then calculating total abundance from total biomass. All red crab abundances were then converted to catch per unit effort (CPUE) in order to make data from the 1 versus 10 minute trawls comparable. Results from this study will include temporal and spatial trends found in red crab abundances, along with coincident changes in demersal fish and megabenthic invertebrate populations. We will also assess any concomitant trends in historical ocean temperature data dating back to 1991.

P-4. Distribution and Abundance of Dungeness crab (*Metacarcinus magister*) megalopae in the California Current

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The Dungeness crab fishery is one of the most valuable on the west coast, and larval dispersal is an important consideration for management. Larvae of *M. magister* hatch in the spring and progress through five zoeal stages, followed by one megalopal stage. The objective of this study is to examine spatial and temporal variability in the distribution of *M. magister* larvae in the California Current from spring CalCOFI zooplankton samples (2003-2014). Crab larvae found in CalBOBL and Manta net tow samples collected north of line 80.0 (Point Conception, CA) were counted, identified, and measured. The results suggest a strong association between megalopae abundance and near-shore continental shelf waters, especially in the vicinity of bays, particularly San Francisco and Monterey. Due to climatic variations and changing ocean conditions, it is important for fisheries managers to have information on Dungeness crab larval abundance to examine good and bad years, as well as distribution to monitor geographic shifts in the population.

P-5. Aerial survey of small pelagic species in the Southern California Bight

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California Department of Fish and Wildlife

Current survey indices used in annual stock assessments to manage the federal Pacific sardine (*Sardinops sagax*) fishery do not include nearshore sardine biomass in southern California waters. The California Department of Fish and Wildlife (CDFW), in collaboration with the California Wetfish Producers Association, has conducted aerial surveys using direct observer estimates of sardine biomass within the Southern California Bight (SCB) since the summer of 2012. Island and mainland coastal areas were surveyed during spring and summer seasons. Beginning in summer 2013, northern anchovy (*Engraulis mordax*) has also been included in the survey. Aerial identifications of fish school species have been validated using boat sampling of aerial sightings, and biological information obtained from collected samples. We observed fish primarily along coastal areas; most notably, large aggregations were seen in nearshore waters off Ventura and Santa Monica. Survey results showed declines in abundance of sardine and anchovy in 2014, with apparent increases for both species beginning in early 2016. A September 2016 study paired CDFW's nearshore aerial survey with an acoustic trawl survey that was limited to operating outside of nearshore waters to provide a better estimate of sardine in the entire SCB. Further work will provide information on sardine and anchovy abundance and distribution to account for areas not covered in present surveys. Continued data collection on sampled fish and habitat associations can add to understanding of population and stock structure.