CalCOFI: The Influence of Regional Ocean Climate on Coastal Habitats and Communities

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University of California, SD

Coastal Habitat Conservation in a Changing Climate: Strategies and Tools for Southern California
Outline

• Brief history of CalCOFI
• CalCOFI sampling program
• Ocean climate drivers of marine life off California
  – ENSO
  – The Pacific Decadal Oscillation (PDO)
  – The North Pacific Gyre Oscillation (NPGO)
  – Climate change: warming, hypoxia & acidification – an uncertain future
• Ocean climate and California’s fish communities
  – Hypoxia & deepwater fishes
  – California’s small pelagic fishes, sardine & anchovy
  – Nearshore and reef fishes
• New sampling technologies
• A plan for enhanced coastal monitoring to sustainably manage California’s living marine resources
The collapse of the California sardine fishery, once the largest in the western hemisphere, was the start of CalCOFI. Was it overfishing or a change in the environment? A partnership of CDFG, NMFS/NOAA/SIO to study the fishery & environment.
The initial CalCOFI station plan and sampling
CalCOFI has continued to evolve since the 1950s....
CalCOFI effort scaled back to quarterly coverage of core stations in the Southern California Bight since 1984.

Recent enhancements:
- increased sampling inshore (SCCOOS),
- increased northward sampling in spring to cover the sardine spawning distribution.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Investigator</th>
<th>Method</th>
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</thead>
<tbody>
<tr>
<td>Temp., salinity, Chl a fluorescence</td>
<td>CalCOFI</td>
<td>CTD w/ fluorometer</td>
</tr>
<tr>
<td>Irradiance (in situ profiles &amp; daily PAR)</td>
<td>CalCOFI</td>
<td>PAR meters</td>
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<td>Light transmission @ 660 nm</td>
<td>CalCOFI</td>
<td>transmissometer</td>
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<td>Oxygen</td>
<td>CalCOFI</td>
<td>CTD, auto-Winkler</td>
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<td>Nutrients (N, P, Si) - ammonium</td>
<td>CalCOFI</td>
<td>Auto analyzer</td>
</tr>
<tr>
<td>Primary production</td>
<td>CalCOFI</td>
<td>14C-uptake - POC, DOC</td>
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<td>Chl a concentration (extracted)</td>
<td>CalCOFI</td>
<td>Fluorometer</td>
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<td>Sea surface pCO2 (select stn)</td>
<td>CalCOFI</td>
<td>IR absorbance</td>
</tr>
<tr>
<td>Zooplankton, ichthyoplankton</td>
<td>CalCOFI</td>
<td>plankton net tows</td>
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<tr>
<td>Iron concentration</td>
<td>Barbeau</td>
<td>FeLume flow injection</td>
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<tr>
<td>Other bio-optical properties</td>
<td>Goericke</td>
<td>cDOM, beam c vs. λ</td>
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<td>Particulate C&amp;N, DOC, DON</td>
<td>Aluwihari</td>
<td>combustion</td>
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<td>Upper ocean currents</td>
<td>Chereskin</td>
<td>ADCP, data analyses</td>
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<tr>
<td>Taxon-specific pigments</td>
<td>Goericke</td>
<td>HPLC</td>
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<tr>
<td>Bacteria &amp; picoautotrophs</td>
<td>Landry</td>
<td>Flow cytometry</td>
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<tr>
<td>Nano- &amp; microplankton</td>
<td>Landry/Venrick</td>
<td>Microscopy, FlowCAM</td>
</tr>
<tr>
<td>Mesozooplankton, optical size classes</td>
<td>Checkley</td>
<td>OPC, LOPC</td>
</tr>
<tr>
<td>Mesozooplankton, sentinel species</td>
<td>Ohman</td>
<td>Microscopy, ZOOSCAN</td>
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<tr>
<td>Seabirds</td>
<td>Sydeman (FI)</td>
<td>Visual</td>
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<tr>
<td>Marine mammals</td>
<td>Hildebrand</td>
<td>Passive acoustics, visual</td>
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<tr>
<td>Micronekton</td>
<td>Koslow</td>
<td>Acoustics, trawl</td>
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</table>

CalCOFI measurements **red: CCE-LTER measurements; Green: ancillary programs**
El Nino impacts on phytoplankton and krill

SeaWifs Ocean Color

March 1997

March 1998

March 1999

Reciprocal krill variations

Nyctiphanes simplex

Euphausia pacifica

Kahru and Mitchell 2000

Brinton & Townsend 2003

CalCOFI
California Cooperative Oceanic Fisheries Investigations
NMFS - NOAA | CDF & G | IOD - SIO
www.calcofi.org

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The discovery of decadal scale regime shifts

The Pacific Decadal Oscillation (PDO) with breaks in 1977 & 1999
(Mantua et al. 1997)

*Nyctiphanes simplex*

The PDO index

PDO Index

Year
The PDO: links with anchovy & sardine fisheries off California & Japan
The second ‘mode’ of North Pacific climate variability: the North Pacific Gyre Oscillation (NPGO) (Di Lorenzo et al 2009)

Figure: (a) North Pacific Gyre Oscillation pattern in Satellite SSHa with superimposed ROMS model computational grid (red) at 10 km resolution. (b) Comparisons of model vs. observation time series in the CCS with CalCOFI data show that the ROMS model is able to capture the observed low-frequency variations. The NE Pacific ROMS-NPZ model hindcast from 1950-2004 was obtained using a 15 km resolution grid by Di Lorenzo et al. (2008).
Evidence of long-term climate change:
Seabird populations in the California Current

A northward shift due to climate?

Relationships with PDO & NPGO & with forage availability:
Auklets & krill
Murres & forage fish (esp rockfish)

Declines of sooty shearwaters (most abundant species), Cassin’s auklet & common murres off California

Sydeman et al 2009
PCA of CalCOFI ichthyoplankton data

(Koslow et al 2011)

86 taxa consistently sampled, 1951-2008 over 6 core CalCOFI transects
Abundance: proxy for adult spawning stock biomass
PC 1 (20.5% var explained):
24/27 taxa with loadings > 0.5 mesopelagic from 8 families:
Myctophidae, Gonostomatidae, Sternoptychidae, Stomiidae, Phosichthyidae, Scopelarchidae, Argentinidae, and Microstomatidae
Includes vertical migrators & non-migrators, plankton feeders & predators

O₂: declined 20% since 1980s

PC 1

<table>
<thead>
<tr>
<th></th>
<th>O₂ (200-400 m)</th>
<th>PDO</th>
<th>MEI</th>
<th>NPGO</th>
<th>SST</th>
<th>Upwelling</th>
</tr>
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<tbody>
<tr>
<td>R</td>
<td>0.75*</td>
<td>0.56**</td>
<td>0.47*</td>
<td>-0.23</td>
<td>0.45?</td>
<td>-0.25</td>
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</table>

Declining deepwater O₂ predicted in global climate models, now observed in global OMZs. Mesopelagics: dominant plankton consumers, prey of dolphins, squid, predatory fishes.
• **PC 2 (12.4% variance explained)**
  – Dominated by pelagic fishes: medusafish, butterfish (pompano), anchovy, hake (-), sardine (+)
  – also several rockfish: *Sebastes spp.*, *S. aurora*, boccacio

• **PC 3 (6.8% variance explained)**
Coastal fishes & ocean environment

<table>
<thead>
<tr>
<th></th>
<th>MEI</th>
<th>PDO</th>
<th>NPGO</th>
<th>SST</th>
<th>Upwelling</th>
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</thead>
<tbody>
<tr>
<td><strong>PC 3</strong></td>
<td>0.24</td>
<td>0.23</td>
<td>-0.41?</td>
<td>0.35*</td>
<td>-0.05</td>
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<td>(18)</td>
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<tr>
<td><strong>Differenced</strong></td>
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<tr>
<td><strong>PC 3</strong></td>
<td>0.51***</td>
<td>0.32*</td>
<td>-0.43**</td>
<td>0.56***</td>
<td>-0.50***</td>
</tr>
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<td>(38)</td>
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![Graphs showing time series of PC3 and SST](image1)

![Graphs showing differenced PC3 and SST](image2)
CalCOFI & California coastal fisheries:
Fishery-independent time series from ichthyoplankton sampling

(Koslow et al in press, in prep)
CalCOFI & California coastal fisheries: Impacts of climate variability
(Koslow et al in press, in prep)

Potential to manage these fisheries with
1) fishery-independent time series based on larval sampling, and
2) Environmental input to assess the state of the environment for these species

Spiny lobster & SST (also ENSO)

Market squid predicted from ENSO, PDO
New sampling technologies: acoustics

Daytime distribution of midwater fish above OMZ
Jan 2010 CalCOFI cruise, 6 transects combined
The Continuous Underway Fish Egg Sampler (CUFES) maps the fine-scale distribution of fish eggs by species in relation to hydrography (from satellite).
Robotic gliders collect high-resolution data continuously along CalCOFI lines.

**Sensors**

- Fluorometer
- 750 kHz ADCP
- CTD
CalCOFI sampling applied to California coastal ecosystems

<table>
<thead>
<tr>
<th>Designated Ecosystem</th>
<th>Focal species monitored by CalCOFI</th>
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<tr>
<td>Kelp and shallow</td>
<td>Spiny lobster, sheephead, cabezon, blennies, gobies, seabirds, blacksmith</td>
</tr>
<tr>
<td>Mid-depth rock</td>
<td>Bocaccio rockfish, lingcod, CA scorpionfish</td>
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<tr>
<td>Estuarine and wetland</td>
<td>CA halibut, arrow goby, topsmelt</td>
</tr>
<tr>
<td>Soft-bottom subtidal</td>
<td>CA halibut, sanddab, ridgeback prawn</td>
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<tr>
<td>Deep</td>
<td>Rockfishes (cowcod, bocaccio, splitnose, Mexican, aurora, blackgill), thornyheads, sablefish</td>
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<tr>
<td>Nearshore pelagic</td>
<td>Shortbelly rockfish, sardine, anchovy, market squid, barracuda, seabirds, ichthyoplankton abundance/diversity</td>
</tr>
<tr>
<td>Consumptive species</td>
<td>Sardine &amp; anchovy, market squid, spiny lobster, Ca halibut, sand bass, croakers, silversides, rockfishes</td>
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</table>
Augmented coastal CalCOFI sampling

Sampling Approach
Augmented quarterly (winter, spring summer, fall) CalCOFI cruises to survey MPAs, other coastal habitats

Biological and Environmental Data:
- CUFES - continuous measure of eggs along survey track
- Seabird & mammal observations along survey track
- Acoustics – fish biomass along survey track
- Bongo net tows – plankton samples (eggs and larvae) on station
- CTD - oceanographic conditions
- ADCP – currents, flow
Summary

CalCOFI is the world’s oldest multidisciplinary ocean observation program – one of the only in the world to monitor the ecosystem from physics to fish, from winds to whales – and is a unique partnership of an oceanographic institution and federal and state agencies.

CalCOFI has pioneered marine ecosystem climate research: the impacts of El Nino, decadal-scale climate variability (the PDO & NPGO) and long-term climate change in the California Current impacts on regional fish communities & fisheries.

CalCOFI continues to evolve, incorporating new tools and technologies, while maintaining its core time series to further our scientific understanding and ecosystem-based management of the California Current.

CalCOFI seeks to enhance coastal sampling & relevance to coastal management.