The influence of climate on the biodiversity and community structure of fishes in the southern California Current System, 1969 – 2011

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Overview of talk

- Review of past work showing significant, coherent changes in abundance across broad groups of fish taxa and relationships with ocean forcing
- Examine how these trends in regional fish communities may have affected biodiversity: species richness and evenness/community dominance structure
The CalCOFI ichthyoplankton time series is used to assess changes to adult fish populations in the California Current Ecosystem

- **CalCOFI ichthyoplankton time series, 1951-2010**
  - Monthly/quarterly sampling
  - CTD casts to 500 m: T, S, nutrients, O$_2$, chl, O$_2$
  - Oblique net tows to 210 m depth, fish eggs/larvae removed, identified, enumerated (~500 taxa)

![Graph](image)

**Sardine** (Hill et al. 2010)

Larvae sampled primarily at prefexion stage. Their abundance is correlated with adult abundance from stock assessments.

**Anchovy** (Methot 1989)

Relationships between ichthyoplankton and stock biomass also noted for California halibut & rockfishes.
PCA indicates significant environmental impacts across broad fish communities (Koslow et al 2011)

86 taxa consistently sampled, 1951-2008 over 6 core CalCOFI transects
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 (Bograd et al 2008, McClatchie et al 2010)

Declining deepwater O2 predicted in global climate models, now observed globally, esp OMZs. Mesopelagics: dominant plankton consumers, prey of dolphins, squid, predatory fishes.
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Graph:
- Declining deepwater O2 predicted in global climate models, now observed globally, esp OMZs.
- Mesopelagics: dominant plankton consumers, prey of dolphins, squid, predatory fishes.
PC 2 (CalCOFI): declining trend of dominant fishes in CCE, mostly endemics & cool-water affinity taxa

- 72% decline in overall CalCOFI larval fish abundance since 1969
- PC 2 (CalCOFI) explains 12.4% var, 6 of the 7 most abundant species in ichthyoplankton time series loaded highly (> 0.5). 76% decline (since ~1970 (83% without sardine included):
  - Pacific hake, northern anchovy, rockfish (*Sebastes* spp.), 2 mesopelagics (myctophid (*Stenobrachius leucopsarus*) & bathylagid (*Leuroglossus stilbius*)) (+)
  - Pacific sardine (-) (Koslow et al 2013)
- PC 1 (PPI): 44% var explained for 21 nearshore fishes
  - 78% decline, 1972-83 -> 1990-2010 (Miller & McGowan 2013)
- PC 2 (CalCOFI) & PC 1 (PPI) highly correlated (R = 0.85) despite limited overlap in species, indicating decline of fishes across the CC system: nearshore & offshore fishes: epi- & mesopelagic, benthopelagic; several trophic levels, exploited and unexploited
Temporal coherence seen in an assemblage of fishes whose larvae spatially co-occur

PC 2 dominant species were identified as a ‘northern’ affinity assemblage (Moser et al. 1987)

Are these patterns local (SCB is an ecotone) or do they extend across the Pacific?

Distributions of *Stenobrachius leucopsarus* & medusafish (*Icichthys lockingtoni*) extend to Japan
Declining fish in CC system: links to climate:

Significant relations to data-assimilative ROMS output for EKE, heat content (H) and upwelling (W), spatial correlations similar to PC1 for those variables.

(-) correlation with spiciness (input of subtropical water), heat content, SST
(+) correlation with zooplankton DV, W, EKE (transport of CC)

<table>
<thead>
<tr>
<th></th>
<th>$T_{10}$</th>
<th>Spiciness</th>
<th>Log Zoo DV</th>
<th>EKE EOF 1</th>
<th>H EOF 1</th>
<th>W EOF 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PC_{fish}$</td>
<td>-0.57***</td>
<td>-0.53***</td>
<td>0.70***</td>
<td>0.40*</td>
<td>-0.42*</td>
<td>0.67***</td>
</tr>
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Species richness and mesopelagics /environment

<table>
<thead>
<tr>
<th></th>
<th>PC 1</th>
<th>PC 2</th>
<th>Deep O₂</th>
<th>T₁₀</th>
<th>W</th>
<th>MEI</th>
<th>PDO</th>
<th>NPGO</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>0.82***</td>
<td>-0.07</td>
<td>0.50**</td>
<td>0.39*</td>
<td>-0.42*</td>
<td>0.47*</td>
<td>0.44*</td>
<td>-0.48**</td>
</tr>
</tbody>
</table>
Species richness changes by biogeographic affinity

Changes in S closely linked to changes in warm-water affinity taxa

No significant change in #s of CC endemics or cool-water affinity taxa

Hypothesis: CalCOFI region is an ecotone
S sensitive to influx of warm-water affinity taxa during warmer periods: + PDO/MEI/SST and their decline during cool-water periods
# Shannon-Wiener Index (H') (~Evenness)

<table>
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<th>PDO</th>
<th>NPGO</th>
</tr>
</thead>
<tbody>
<tr>
<td>H'</td>
<td>-0.21†</td>
<td>-0.55**</td>
<td>-0.20†</td>
<td>0.39*</td>
<td>0.59**</td>
<td>-0.03†</td>
<td>-0.11†</td>
<td>0.01†</td>
</tr>
</tbody>
</table>

**Correlation Coefficient (R²): 0.37**

![Graphs showing the relationship between Shannon-Wiener Index (H') and other variables over time.](image)
Community dominance in high PC2/low evenness years (blue) and low PC2/high evenness years (red)

1 of the 11 most abundant ichthyoplankton loaded significantly on PC 2, including northern anchovy, Pacific hake, rockfishes (*Sebastes* spp), *Leuroglossus stilbius*, *Stenobrachius leucopsarus*

Their decline significantly altered the dominance structure of the fish assemblage
Summary

• CalCOFI ichthyoplankton time series indicate coherent trends in
  – mesopelagic fishes in relation to midwater $O_2$
  – Decline since 1969 of dominant cool-water and CC endemic fishes in relation to EKE (CC transport), upwelling, heat content

• Species richness (+) correlated with warm-water mesopelagic fish abundance, indicating movements of warm-water taxa in & out of the SCB but no replacement of CC endemics or cool-water fauna

• Evenness (Shannon-Wiener Index, $H'$) (-) correlated with PC 2: abundance of dominant cool-water fishes
  – Decline of dominant cool-water fishes (e.g. anchovy, hake, rockfishes, *Leuroglossus stilbius*, *Stenobrachius leucopsarus*) significantly altered the dominance structure of the fish assemblage
  – The increase in $H'$, a measure of diversity, following the decline of the dominant fish taxa in the CCE indicates that biodiversity can prove an ambiguous measure of ecosystem status
Questions?

Collaborators
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Lia Charbit-Siegelman
Pete Davison
Bill Watson
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Mike Jacox

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