Ichthyoplankton Response to Environmental Change in the NE Pacific Ocean

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Microstomus pacificus
Tetragonurus cuvieri
Goals

- Look for large-scale coherence in ichthyoplankton with environmental indices along North American west coast
- Focus here on central and southern CA CalCOFI time series
- Focus here on PC1’s
Study Area

- 1951-2015
- Spring cruises
Methods

• Included only “species” present >50% y
• PCA
• Annual environmental variable indices
• Spatial correction (Voronoii tessellation)
Where we left off...

  - 1951-2008
  - S. CA only
- PC1 strongly linked to deep oxygen
- Commonality between PC2 and Power Plant Intake time series
  - 6/7 most abund. species

![Graph showing PC1 and mean oxygen concentrations](image_url)

**Glyptocephalus zachirus**
Overall Abundance

- CPS dominant off S. CA
- Mesopelagics dominant off C. CA
- Fewer species off C. CA (205:281)
- Lower abundance off C. CA
PC1

- **S. CA significant loadings**
  - Most demersal and mesopelagic species
  - Warm water affiliated species

- **C. CA significant loadings**
  - Most demersal and mesopelagic species

**Correlation**

\[ R = 0.577, \ p < 0.001 \]

**Variance**

- **S. CA PC1**: 19%
- **C. CA PC1**: 21%

**Graphs**

- Scatter plot showing correlation between S. CA PC1 and C. CA PC1 with correlation coefficient and p-value.
- Line graphs showing time series data for S. CA PC1 and C. CA PC1 from 1950 to 2010.

**Image**

- Image of *Citharichthys sordidus*
### Changes from 1951-2008 analysis (Koslow et al. 2011)

<table>
<thead>
<tr>
<th></th>
<th>PC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEI</td>
<td>0.339*</td>
</tr>
<tr>
<td>PDO</td>
<td>0.438*</td>
</tr>
<tr>
<td>NPGO</td>
<td>-0.222</td>
</tr>
<tr>
<td>temp</td>
<td>0.208</td>
</tr>
<tr>
<td>sal</td>
<td>-0.321*</td>
</tr>
<tr>
<td>deep O2</td>
<td>0.159</td>
</tr>
</tbody>
</table>

* $p < 0.05$

C. CA seems to be holding to the “old pattern”

### C. CA

<table>
<thead>
<tr>
<th></th>
<th>PC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEI</td>
<td>0.562*</td>
</tr>
<tr>
<td>PDO</td>
<td>0.544*</td>
</tr>
<tr>
<td>NPGO</td>
<td>-0.272</td>
</tr>
<tr>
<td>temp</td>
<td>0.343*</td>
</tr>
<tr>
<td>sal</td>
<td>-0.506*</td>
</tr>
<tr>
<td>deep O2</td>
<td>0.416*</td>
</tr>
</tbody>
</table>

* $p < 0.05$
PC1

<table>
<thead>
<tr>
<th>Ecological group</th>
<th>Abund. Corr. To PC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>All larvae</td>
<td>0.14</td>
</tr>
<tr>
<td>Epipelagic/CPS</td>
<td>0.02</td>
</tr>
<tr>
<td>Demersal/coastal</td>
<td>0.07</td>
</tr>
<tr>
<td>VM mesopelagic</td>
<td>0.35*</td>
</tr>
<tr>
<td>NM mesopelagic</td>
<td>0.83*</td>
</tr>
</tbody>
</table>

*p < 0.05

![Nannobrachium bristori](image1.png)

![Rosenblattichthys volucris](image2.png)
What happened with oxygen and PC1?

- Koslow et al.: high correlation between PC1 and oxygen
  - 18/20 Koslow et al. (2011) PC1 species sig. load on PC1 here
  - Koslow et al. and new PC1 are sig. correlated ($R = 0.84$, $p < 0.001$)

![Graph showing correlation between PC1 and deep oxygen](image)
Similar divergence off C. CA

- Pattern seen across many species
- Stronger to south
- May be lagged to north
Relationship between S. CA and N. CA changed ~2005

- Slope the same ($p = 0.94$)
- Intercepts differ ($p = 0.001$)
Baja CA

- Similar changes off Baja CA
- Earlier (≤ 1998)
Preliminary Conclusions

- A formerly highly-significant relationship between ichthyoplankton abundance and oxygen appears to have changed ~2005-2010
  - Other relationships seem to have changed at the same time
  - Suggestion that “state change” may be moving south-north
- Species most strongly linked to PC1 are warm-water mesopelagics
  - Cause uncertain
  - Response to regime change ~2000?
  - Influence of Blob/El Nino in 2015 uptick
  - Release from competition or reduced larval predation by collapsed CPS stocks?

*Cheilopogon furcatus*
Next steps

• More env./ecological variables
  • Includes CalCOFI euphausiid time series
• More regional fish time series
• Objective test of state change
• Use GAM to identify most important variables
• Other numerical techniques

Symbolophorus californiensis
Naucrates ductor
Support:
National Research Council
CalCOFI
Scripps Institution of Oceanography
NOAA
PC1 with more variables than years

Effect of #species

- all 113
- top 49

Tactostoma macropus
S. CA annual averages

Deep oxygen (200-400 m)

Temperature (10 m)

Salinity (10 m)

Deep temperature (200-400 m)

Diplospinus multistriatus
Bathylagoides wesethi
Are the 1950’s similar to the 2000’s?

- S. CA overall abundance similar
- CPS similar
- PC1 similar
- Oxygen similar

[S. CA abundance graph]

- S. Leuc down
- Hake, L. stil down

[1950's pie chart]
- epip 31.5
- VM 27.7
- NM 1.7

[1950's graph]

- Sardine up
- Hake, L. stil, S. leuc down

[2000's pie chart]
- epip 69.0
- VM 15.7
- NM 3.2

[2000's graph]

- sardine
- dem/coast 12.2
Coastal Pelagic Species ($\log_{10}(\text{ind. m}^{-2})$)

- **Anchovy**
  - C. CA
  - S. CA

- **Sardine**

- **Pacific mackerel**

- **Jack mackerel**
### Three PC’s

#### S. CA

<table>
<thead>
<tr>
<th></th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEI</td>
<td>0.339*</td>
<td>-0.121</td>
<td>0.233</td>
</tr>
<tr>
<td>PDO</td>
<td>0.438*</td>
<td>-0.270*</td>
<td>0.210</td>
</tr>
<tr>
<td>NPGO</td>
<td>-0.222</td>
<td>0.334*</td>
<td>-0.495*</td>
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<tr>
<td>temp</td>
<td>0.208</td>
<td>-0.198</td>
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<tr>
<td>sal</td>
<td>-0.321*</td>
<td>0.053</td>
<td>0.036</td>
</tr>
<tr>
<td>deep O2</td>
<td>0.159</td>
<td>0.021</td>
<td>0.333*</td>
</tr>
</tbody>
</table>

#### C. CA

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</tr>
</thead>
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<tr>
<td>MEI</td>
<td>0.562*</td>
<td>-0.207</td>
<td>0.012</td>
</tr>
<tr>
<td>PDO</td>
<td>0.544*</td>
<td>-0.341*</td>
<td>-0.047</td>
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<tr>
<td>NPGO</td>
<td>-0.272</td>
<td>-0.240</td>
<td>-0.299</td>
</tr>
<tr>
<td>temp</td>
<td>0.343*</td>
<td>-0.429*</td>
<td>-0.137</td>
</tr>
<tr>
<td>sal</td>
<td>-0.506*</td>
<td>0.127</td>
<td>-0.023</td>
</tr>
<tr>
<td>deep O2</td>
<td>0.416*</td>
<td>-0.159</td>
<td>0.390*</td>
</tr>
</tbody>
</table>

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*Trachipterus altivelis*