Climate change scenario experiments predict a future reduction in small pelagic fish recruitment in the Humboldt Current system

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1 - Introduction

The Humboldt current system:

(Current) High productivity, and variability of SPF abundance at a variety of spatiotemporal scales. No clear cycles (e.g. PDO) or alternations.

Larval dynamics is a strong constraint to recruitment

Salvatteci et al. (this symposium)

→ Impact of climate change on larval survival (retention in nursery area)?
Changes in Equatorial atmospheric circulation: the Walker cell

Current increase in coastal wind (e.g. Bakun, 1990; Sydeman et al., 2014)

But models predict that Global warming should weaken the Walker cell

Vecchi et al. (2006), Vecchi and Soden (2006)

Weakening of coastal winds along the Peruvian coast?
Introduction

Climate change in the Humboldt Current System: Physical forcings

• Changes in longitudinal atmospheric circulation: the Hadley cell

Current Climate

Global warming: poleward shift of the Hadley Cell (Falvey and Garreaud, 2009; Goubanova et al., 2011)

Futur Climate

→ Southward extension of the upwelling area?
2 - Regional downscaling of a numerical simulation

Global Model IPSL-CM4 (resolution ~200 km)

Regional Model ROMS/PISCES (resolution ~20 km)

Initial and border conditions for physics and biogeophysics
Regional Downscaling

Choice of the climate projection scenario

**GFDL CM2.0 Experiments**

- **Control scenario (no climate change):** CO2 constant at the preindustrial level: \( \text{PI} \)
- **Moderate climate change (\sim 2050):** CO2 x 2 compared to preindustrial level: \( \text{2CO2} \)
- **Extreme scenario (Trump) (\sim 2100):** CO2 x 4 compared to preindustrial level: \( \text{4CO2} \)

- **Stabilized @ 2000 (s2):**
- **Historical (h1):**
Regional Downscaling
Changes in Currents and Stratification

Surface currents:
Changes in Eddy Kinetic Energy
(= intensity of 50-100 km radius eddies)

→ strong warming → increase stratification
→ Changes in currents and mesoscale activity

Echevin et al. (2012), Oerder et al. (2014)
Regional Downscaling

Changes in Primary production

Changes in nutrients contents (0-200 m) and surface Chla in IPSL-CM4:

Changes in Chla in ROMS-PISCES:

Climate change impacts are stronger (better resolved) in the regional model
3 - Impacts on SPF nursery

- Lagrangian IBM tool *Ichthyop* *Lett et al.*, 2008)

- Horizontal movements: passive transport by the currents
- Vertical movements: Buoyant (eggs), passive (yolk-sac), and active larvae (DVM)

- Mortality:
  - if $T<T^s$ and $O_2<O_2^s$ (i.e. below from the surface layer)
  - if transported outside nursery area

- «Recruitment» = % larvae that survived at 30 days
Impacts on SPF nursery

Changes in retention rate over the continental shelf

**Good news**

*Increased larval retention over the continental shelf*
Impacts on SPF nursery

Changes in retention rate over the continental shelf

Increased larval retention over the continental shelf

Why? The cause differs according to the area

Zone 1 & 2: changes due to stratification:

Vertical distribution 0-30m

2CO2, 4CO2

larvae under the Ekman layer are transported towards the shore
Impacts on SPF nursery

Changes in retention rate over the continental shelf

Increased larval retention over the continental shelf

Why? The cause differs according to the area

Zone 3: changes due Eddy activity

<table>
<thead>
<tr>
<th>Rate of retention (%)</th>
<th>% increase (+) or decrease (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>4 × CO2</td>
</tr>
<tr>
<td>Normal 5.0</td>
<td>6.5</td>
</tr>
<tr>
<td>No « eddy » 3.00 (-40%)</td>
<td>1.50 (-76%)</td>
</tr>
</tbody>
</table>
Impacts on SPF nursery

Changes in offshore extend of the nursery area

Bad news

Strong Reduction of the offshore extend of the productive area...

... not fully compensated by the increase in retention rate on the continental shelf

→ Global negative impact

Decreasing rate of retention in the plankton rich area
Hypothesis: mean oxycline depth shift from 30 m to 15 m

Impact on the larvae vertical distribution?

Combined effect of nursery area reduction and oxycline shoaling on larval survival:

Further reduce the larval retention in the nursery
Conclusions

Predicted impact of climate change in the Humboldt…

...in physical forcings:
- Weak changes in wind forcing in Peru
- Increase of upwelling winds in Chile
- Strong increase of stratification in the entire HCS

...in biogeochemical dynamics:
- Strong reduction in primary productivity (to be confirmed)
- Scenario of oxycline shoaling to be confirmed

...in SPF reproduction success:
Antagonist effects on larval retention/survival of:
- positive effect of the stratification (Ekman/Eddies)
- Negative effect of the production reduction (in IPSL-CM4)
- Strong reduction in larval survival in Peru, moderate effect in Chile

... overall negative effects for SPF
Conclusions

Limits of the study:

Simplified larval model (no predation and growth)
No submesoscale eddies and filaments due to spatial resolution (~20 km)
Missing processes such as tides, coastal winds, rivers…
Only one climate model (IPSL-CM4) and extreme scenarios (PI, 4xC02)
Oxygen is not well simulated in climate models, with no clear trends
Thank you

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