Past and future distribution of the Bay of Biscay anchovy in response of climate change

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Global climate change

Atmospheric temperature change (1950-2014) – NASA.gov Video
Global climate change

**Global sea surface temperature change**

- Historical
- RCP2.6
- RCP4.5
- RCP6.0
- RCP8.5

**Future Climate Shift**

- Current climate
- Future climate
- Less cold weather
- Increase in average temperature
- More extreme hot weather
- More hot weather

- Cold
- Average Temperature
- Hot
Anchovy (Engraulis encrasicolus)

- Fast growth
- High mortality
- High fecundity (batch spawner)
- Short life cycle
- Max. lifespan of 4 years

Good biological indicator
Anchovy distribution variations

Fisheries-independent data from International Bottom Trawl Surveys (IBTS) between 1965 to 2012

Montero-Serra et al., (2015)

Bellier et al., (2007)
Anchovy distribution future projections

Lenoir et al., (2011)
Introduction

Objectives

1. Current habitat modelling
2. Projections under RCP8.5 climate change scenario
3. Anchovy eggs distribution

PAST

- Spawning - peak
- Spawning - CoG*
- Sampling grid
- Observations
- Environmental factors
- RCP8.5 climate change scenario

PRESENT

- Stock collapse
- Trends analysis

FUTURE

- Population Center of Gravity
Peak of spawning period

1.) Data collection

2.) Gonadosomatic index (GSI) estimation

3.) Peak of spawning estimation

4.) Phenology changes?
Peak of spawning period
Peak spawning period
Spawning reconstruction model

1.) Data collection

2.) General additive models (GAM-s):

*PA = Presence/Absence
ED = Egg Density (abundance)
Introduction

Peak of spawning

Spawning CoG

PAST

Present

Future

Conclusions

Eggs density (eggs/m²)

- Absence
- [0.1, 15)
- [15, 20)
- [20, 50)
- [50, 75)
- [75, 100)
- [100, 200)
- [200, 300)
- [300, 600]
Spawning reconstruction model

1.) Data collection

2.) General additive models (GAM-s):

   \[ \text{eggs observations} \left\{ \begin{array}{l}
   \text{PA*} \\
   \text{ED}
   \end{array} \right\} + \text{Spatio-temporal variables}
   \]

   *PA = Presence/Absence
   ED = Egg Density (abundance)

3.) Population Center of Gravity estimation

   = Geographical point that describes a center-point of the region's population

4.) Correlation: CoG and variation drivers

   [Sea Surface Temperature
    Density-dependence dynamics]
Spawning distribution variations

Peak of spawning

Spawning CoG

FUTURE

PRESENT

PAST

Introduction

Conclusions
Spawnine distribution variations

![Graph showing total egg production over time with a peak in 2010 and a stock collapse.]

![Graph showing population CoG against log(total egg production) with a p-value of 5.16e-06.]

Introduction

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<th>PAST</th>
<th>PRESENT</th>
<th>FUTURE</th>
<th>Conclusions</th>
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<td>Peak of spawning</td>
<td><strong>Spawning CoG</strong></td>
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Habitat modelling

1.) Data standardization ($0.1^\circ \times 0.1^\circ$ resolution)

2.) Model: eggs observations ($PA$, $ED$) + environmental variables

3.) Extrapolation to all the Bay of Biscay
Spawning habitat modelling

**Present**

(2006-2020)

Dev. Expl.

PA: 48%

ED: 58%

Spawning habitat modelling

Eggs density (eggs/m2)

- Absence
- [0.1,10)
- [10,20)
- [20,50)
- [50,100)
- [100,200)
- [200,500)
- [500,1000)
- [1000,2000]

gam<- gam(LogEP ~ s(Lat, Long) + s(SST, k=3) + s(SSS, k=3) + MLD + s(LogChla, k=3) + s(LogBathy, k=3), family=gaussian)
Future projections

1.) Estimate changes for the future

RCP8.5 (936 CO2 ppm)

<table>
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<th>Mid-of-the-century (2040-2059)</th>
<th>End-of-the-century (2080-2099)</th>
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<tbody>
<tr>
<td>SST (°C)</td>
<td>0.52±0.28</td>
<td>1.51±0.71</td>
</tr>
<tr>
<td>SSS (psu)</td>
<td>-0.30±0.13</td>
<td>-0.57±0.35</td>
</tr>
<tr>
<td>MLD (m)</td>
<td>-7.48±8.31</td>
<td>-12.40±12.84</td>
</tr>
</tbody>
</table>

2.) Model + future environmental conditions

Present | Future | Future | ?
Spawning distribution future projections

**Mid-century**
(2040-2055)

**End-of-century**
(2080-2099)

1.53 x

2.56 x

Eggs density (eggs/m2)
- Absence
- [0, 1, 10]
- [10, 20]
- [20, 50]
- [50, 100]
- [100, 200]
- [200, 500]
- [500, 1000]
- [1000, 2000]
Spawning distribution future projections

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<th>Change (\rightarrow) Midcent</th>
<th>Change (\rightarrow) Future</th>
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<tr>
<td>All variables</td>
<td>1.53 x</td>
<td>2.56 x</td>
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<tr>
<td>All variables – MLD</td>
<td>1.51 x</td>
<td>2.40 x</td>
</tr>
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<td>All variables – LogBathy</td>
<td>1.33 x</td>
<td>2.20 x</td>
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**Total egg production (tonnes)**

- **Present:**
  - All variables: 82,614
  - All variables – MLD: 82,361
  - All variables – LogBathy: 79,223

- **Midcent:**
  - All variables: 125,984
  - All variables – MLD: 124,545
  - All variables – LogBathy: 105,634

- **Future:**
  - All variables: 211,854
  - All variables – MLD: 198,106
  - All variables – LogBathy: 174,498

**Change:**

- 1.53 x for All variables
- 1.51 x for All variables – MLD
- 1.33 x for All variables – LogBathy

- 2.56 x for All variables
- 2.40 x for All variables – MLD
- 2.20 x for All variables – LogBathy
Conclusions

Past
• No phenological changes (1987-2015)
• No population CoG shift (1989-2015)
• Population CoG variations highly correlated with density-dependent dynamics

Present
• Our model explained 58.1% of the total deviance
• Spawning is closely related to river plumes (Adour, Gironde)

Future
• ++ effects for BB anchovy spawning
• Increase 1.5 and 2.5 times (mid-century / end-of-the-century)
Thank you very much!