Intense warming causes a spatial shift of small pelagic fish: early warning for food security in North-West Africa

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NWA → Pelagic resources are one of the most abundant in the world. High productivity → attributed to coastal upwelling (permanent/saisonal)

Small pelagic fish are a major component in the region for food security (Ba et al. 2017).
Introduction

Small pelagic resources in North West Africa

Tropical species .......

Round sardinella

*Sardinella aurita*/Sardinelle ronde

False scad

*Decapterus rhonchus*/Chinchard jaune

Cunene horse mackerel

*Trachurus trecaei*/Chinchard noir

Flat sardinella

*Sardinella maderensis*/Sardinelle plate

bonga shad

*Ethmalosa fimbriata*/Bonga

West African Ilisha

*Ilisha africana*/Alose rasoir

Temperate species .......

Sardine

*Sardina pilchardus*/Sardine

Chub mackerel

*Scomber colias*/Maquereau

Atlantic horse mackerel

*Trachurus trachurus*/Chinchard commun

Anchovy

*Engraulis encrasicolus*/Anchois
Among several different countries of (CCLME) between Cap Roxo (Senegal) and Cap Cantin (Morocco)
What changes occurred in the spatio-temporal distribution of small pelagics during the last thirty years?

What may be the driving factors behind these changes in their dynamics?
Materials & Methods

**Data used** / Données utilisées dans l’étude

- **Fridtjof Nansen Database** (Acoustic surveys since 1995)
  - **Acoustic data**
  - **Biomasses of both sardinella (in NASC)**
  - **consistent sampling protocol**
    - Acoustic: 170,000 km
    - Biologic: 2,263 chaluts

- **Fishing data**
  - 8 species of interest en NWA

- **Satellites**
  - Méridian wind, Chlorophylle a, SST 1982 to 2015
for each Zone $Z_i$

A biomass

Estimated /year

DFN Acoustic transects ...

$Z_i$ Position (latitude, longitude)

(Sarré, 2017)
Materials & Methods

Traitements effectués :

❖ Barycentre of biomasses
Le barycentre des biomasses

❖ Northernmost limit of presence
La présence extrême nord

Analyses annuelles
The coordinates of the barycentre “$C_a$” fit the equation:

$$\sum_{i=1}^{n} B_{ai} \overline{Ca}_{ai} = B_{a1} \overline{Ca}_{a1} + B_{a2} \overline{Ca}_{a2} + \ldots + B_{an} \overline{Ca}_{an} = 0$$

(1)

The latitude “$X_a$” and longitude “$Y_a$” of “$C_a$” are:

$$X_a = \frac{\sum_{i=1}^{n} B_{ai} \cdot X_{ai}}{\sum_{i=1}^{n} B_{ai}} \quad \quad \quad \quad \quad \quad \quad \quad Y_a = \frac{\sum_{i=1}^{n} B_{ai} \cdot Y_{ai}}{\sum_{i=1}^{n} B_{ai}}$$

(2)

The barycentre indicates the mean location of the surveyed population (Woillez et al, 2009)
3 key environmental parameters are followed to address our issue:

Trois paramètres environnementaux clés, dont la couverture est synoptique pour aborder notre problématique:

➢ **Equatorial wind** / **Le vent méridional**

➢ **Chlorophyll-a** / **Chlorophyll-a**, Primary production

➢ **Sea surface temperature** / **SST**
Matériels & Méthodes

All > > from satellite remote-sensing products available from **US NOAA database**

Toutes > > *de la base de données satellitaire US NOAA*.

• **SST data** -> from the daily day-time series of the **pathfinder AVHRR** dataset version 5.2 from 1982 to 2012 at **4 km resolution** ([Casey, Brandon, Cornillon, & Evans, 2010]) and from **MODIS** (Moderate Resolution Imaging Spectro-radiometer) data for (2012-2015).

• **Meridian wind data** -> from the daily **CCMP** (Cross-Calibrated Multi-Platform) wind product V2.0 at **0.25-degree spatial resolution**, from 1988 through May 2016

• **Chlorophyll-a data** -> collected from the **AQUA-MODIS** sensor (Moderate Resolution Imaging Spectroradiometer) from 2003 to 2012.
Materials & Methods

Area of study of the environnemental parameters

5 areas ...

- AREA 1: 30°N
- AREA 2: 26°N
- AREA 3: 21°N
- AREA 4: 20°N
- AREA 5: 16°N

CAP BLANC AREA

Cap Blanc

Zone de transition aussi bien physique qu'écologique

WEIKERT
MARTINEZ
BINET
Résults

Sarré et al., 2017
Results

The barycentre of the biomasses and latitudinal extreme presence

Hovmoller Diagrams of the observed changes

AND WE SEE STRAIGHTAWAY THE NORWARD SHIFT OF AURITA

WHILE MADERE SHOWS A STABLE DISTRIBUTION AREA

(Sarré et al., 2017)
From 2015 Moroccan vessel assessment

This finding supports the Moroccan acoustic survey of 2015.

And also

From Russian and UE fleets catches in Morocco by industrial trawlers from the Russian Federation, and the EU. The catch data show an clear increase since 2005

(Salahedine El Ayoubi, 2015)

(FAO, 2015)
Like *S. aurita*, other small pelagic fish species showed northward trends in their distribution.

Comme *S. aurita*, d'autres espèces ont montré les mêmes signes :

(Sarré et al. 2017)
**Significance of trends**

Spearman and Bootstrap Tests on the **northernmost limit of presence**

<table>
<thead>
<tr>
<th>Year</th>
<th>S_aur</th>
<th>S_mad</th>
<th>T_tre</th>
<th>D_rho</th>
<th>B_aur</th>
<th>C_chr</th>
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<td>20.55</td>
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<td>27.95</td>
<td>26.60</td>
<td>23.80</td>
<td>18.81</td>
<td>20.97</td>
<td>20.97</td>
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<td>2011</td>
<td>27.38</td>
<td>21.72</td>
<td>23.69</td>
<td>24.59</td>
<td>20.43</td>
<td>19.64</td>
<td>17.96</td>
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<th>0.46</th>
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<th>0.55</th>
<th>0.66</th>
<th>0.43</th>
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<td>0.69</td>
<td>0.11</td>
<td>0.14</td>
<td><strong>0.04</strong></td>
<td><strong>0.01</strong></td>
<td>0.12</td>
<td><strong>0.02</strong></td>
</tr>
</tbody>
</table>
Results

Meridian component of the sea surface wind

(Sarré et al., 2017)
Slight decrease (not significant) in Senegal and Mauritania

Contrast in area 1 (26–30 °N)

(Sarré et al., 2017)
• SST displays a regular and homogeneous **intense warming** trend throughout the whole region

• especially **south of Cape Blanc** (areas 3 to 5) with cumulative increases of between 0.5 °C and 1.5 °C in the past 34 years

(Sarré et al., 2017)
At global level...

The increase in SST was evaluated in terms of northward displacement of isotherms by comparing the last 17-year period (1999-2015) with the previous one (1982-1998).

24 °C Isotherm (Dakar)

Observed displacement: 230 km

(Sarré et al., 2017)
# Results

Displacement **key small pelagic species** from 1995 to 2015 // Displacement of **isotherms**

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean latitudinal North limit (°N) 1995</th>
<th>Mean latitudinal North limit (°N) 2015</th>
<th>Shift distance (in km)</th>
<th>Isotherm (°C)</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td><strong>Sardinella aurita</strong></td>
<td>26.77</td>
<td>29.17</td>
<td>267</td>
<td>20.5</td>
<td>20.0</td>
</tr>
<tr>
<td><strong>Sphyraena guachancho</strong></td>
<td>17.24</td>
<td>20.61</td>
<td>375</td>
<td>23.0</td>
<td>20.5</td>
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<tr>
<td><strong>Trachurus trecae</strong></td>
<td>23.59</td>
<td>26.61</td>
<td>335</td>
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<tr>
<td><strong>Chloroscombrus chrysurus</strong></td>
<td>17.75</td>
<td>20.73</td>
<td>332</td>
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<tr>
<td><strong>Brachydeuterus auritus</strong></td>
<td>18.28</td>
<td>19.94</td>
<td>184</td>
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<tr>
<td><strong>Selene dorsalis</strong></td>
<td>17.98</td>
<td>19.93</td>
<td>217</td>
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<td></td>
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<tr>
<td><strong>Decapterus rhonchus</strong></td>
<td>23.72</td>
<td>24.14</td>
<td>48</td>
<td></td>
<td></td>
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<tr>
<td><strong>Sardinella maderensis</strong></td>
<td>24.10</td>
<td>24.95</td>
<td>94</td>
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</tr>
</tbody>
</table>

**Note:** the distances that migratory pelagic fish have moved were of the same order of magnitude as those observed for the isotherms in the region (150–300 km) since 1995.
Conclusions

- It is likely that SST is the most significant environmental parameter explaining the movements of S. aurita, even though combination of physical and ecological factors contribute to this phenomenon.

- The observed variation in meridian wind cannot explain the gradual northward shift of the S. aurita population.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Area 1</th>
<th>Area 2</th>
<th>Area 3</th>
<th>Area 4</th>
<th>Area 5</th>
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<tr>
<td>WIND</td>
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<tr>
<td>Area 1</td>
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<td>0.003</td>
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<tr>
<td>Area 2</td>
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<td>0.010</td>
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<tr>
<td>Area 3</td>
<td>0.41</td>
<td>0.030</td>
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<tr>
<td>Area 4</td>
<td>0.21</td>
<td>0.280</td>
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<tr>
<td>Area 5</td>
<td>-0.53</td>
<td>0.004</td>
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<td>CHL_a</td>
<td>r</td>
<td>p-value</td>
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<td>Area 1</td>
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<td>0.779</td>
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<tr>
<td>Area 2</td>
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<td>Area 3</td>
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<tr>
<td>Area 4</td>
<td>-0.24</td>
<td>0.340</td>
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<tr>
<td>Area 5</td>
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<tr>
<td>SST</td>
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<td>p-value</td>
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<td>Area 1</td>
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<td>Area 5</td>
<td>0.77</td>
<td>7.47E-08</td>
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</table>

Effet de la température
Conclusions

- The observed northwards shifts of the *S. aurita* stock as well several tropical pelagic species *may significantly* affect *(decrease)* their abundance in the Southern part of the system, *i.e.*, South of Cape Blanc

- The specific shift of *S. aurita* has to be underlined as it *constitutes a key source of proteins* for the regional populations

*Consequently, any shift in the distribution of this stock might induce significant social instability*

*Early warning*
Thank you for your attention
Relative variation of *Sardinella aurita* biomass and environmental parameters in both sides of Cape Blanc (Sarré *et al.*, 2017)
Specific features characterize this region:

- **Permanent** Seasonal
- **Seasonal** Permanent

**Introduction**

- **First** Presence of well-protected areas from winds and currents…
- **Second** Presence of areas where upwelling is permanent, and others where upwelling is seasonal
• 8 species were followed; Species selection was based on 5 criteria

- the species must be exploited
- important for local food security
- of tropical affinity,
- frequently encountered in the catch
- their northern limit of abundance must be included in DFN coverage

*S. aurita, S. maderensis, T. trecae, D. rhonchus, Selene dorsalis, Chloroscombrus chrysurus, Brachydeuterus auritus* and *Sphyraena guachancho*.

• the related shift is estimated as:

\[ \Delta f = f(2015) - f(1995) \]
## Materials & Methods

### Species occurrence in the trawls

<table>
<thead>
<tr>
<th>Year</th>
<th>Nb. of trawls (n = 2263)</th>
<th>Species occurrence in the trawls (%)</th>
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<tr>
<td></td>
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<td>17</td>
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<tr>
<td>Moy</td>
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</table>
Also confirmed by the change in strategies adopted by Senegalese fishermen.

Observations confirmées aussi par le changement des stratégies de pêche au Sénégal.

(Fishing agreements with Mauritania)

(Thiao, 2012)