NAO related small pelagic fisheries fluctuations off Morocco and Senegal

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INTRODUCTION

- Small pelagic fish → very important resource in NW African coast
- Shared by different countries
- Artisanal and industrial fleets
- *Sardina pilchardus* (Morocco) and *Sardinella spp* (Senegal): + 80% total catches
- Statistical data → ecological time series to compare with dynamics of the climatic systems

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INTRODUCTION

Hydroclimatic regime

- Large-scale fisheries supported by an important productive marine region: the Canary Current Ecosystem
- Permanent upwelling induced by trade winds (north-south) (Belvèze and Erzini, 1983)
- “Contrasted hydroclimate” seasons: cold-waters in winter, warm-waters in summer and two transition periods between both seasons
- Important transition zone: between warm “equatorial” region and “Canary” or “subtropical” cold region
- Upwelling $\rightarrow$ high productivity $\rightarrow$ great abundance small pelagic $\rightarrow$ intermediate trophic level
- Little knowledge about climate effects on this ecosystem
INTRODUCTION

Proxy NAO

- **North Atlantic Oscillation (NAO):** The most robust pattern of recurrent atmospheric behaviour in the North Atlantic region (Hurrell & Dickson, 2003). The fluctuations are widest during the colder months (Hurrell *et al.*, 2003; Stenseth *et al.*, 2003)

- **NAO ~“weather package”**. The proxy reduces in simple measures the time-space variability of its relationship with prevailing winds and atmosphere and sea temperature

- Most studies of the NAO proxy has been made in the North Atlantic: explains a great part of the climate variability. Few studies in NW Africa
Effects of NAO in NW Africa

- **NAO +**: Intensification trade winds and the upwelling. Increases the presence of the colder waters.
- **NAO -**: Weakening trade winds and the upwelling. The waters are warmer.

(Hurrell, 1995; Hurrell & Dickson, 2003; Stenseth et al., 2003)
Wind stress

Predominance of trade winds (northeast). In winter 25°N-10°N. In summer 32°N-20°N

The wind stress north-south component ($\tau_y$) correlates significantly with the winter NAO index in most of the Atlantic basin (Visbeck et al., 2003)
Wind stress

- NAO influence in the study area (Meiners et al., 2010)
  - Between 21°N-15°N and 1960-2004
  - Wind stress shows changes with opposite NAO phases
  - Related to upwelling extension and intensity, although with local-scale high variability

Negative signs indicate the north-south component direction. Black frame indicates the selected area for wind stress time series.
Wind stress

- NAO influence in the study area (Meiners et al., 2010)

- Synchrony between NAO index and wind stress (time t)
- Positively and significantly correlated (p<<0.001)
- NAO explains 53% of wind stress variability
**Upwellings**

- NAO explains 50% of SST annual variability in the open sea (Helmke, 2003)

- Upwelling extension controlled by trade winds influence, largely determined by NAO

- Maximum extent in winter and spring, minimum in summer

- 25°N-20°N: permanent, south 20°N in winter-spring

- NAO explains high % of variability of winds and upwelling indices, and are positively related to 21°N (Meiners, 2007)
**Primary production**

- High productivity due to constant and vertical nutrients inputs (upwelling) and retention processes in surface waters (mesoscales features)

- Seasonality controlled by large-scale hydroclimatic processes (Abrantes et al., 2002), rather than local variables (Carr and Kearns, 2003)
- “New production” system in subtropical and tropical latitudes (Mann and Lazier, 1991)
- This great productivity is exported to 700 miles offshore (Neuer *et al.*, 2002)
- Maximum: at 28°N in summer and autumn, 20°N-15°N in winter and spring (>10 mg Chl m-3). At 20°N the productivity is triple than at 30°N (Carr & Kearns, 2003)
- Relationship between $\tau_y$ and SST with NAO→ impact of climatic variability on the system production
OBJECTIVE

• Considering that the knowledge of the influence of climatic variability on the ecological response of resources is very important in fishery management and,

• recent studies in the area have showed that wind-induced upwelling ($\tau_y$) and primary production are related in high % with the NAO, as well as a significant relationship between hakes abundances and NAO index, (Meiners, 2007; Meiners et al., 2010).

The goal was to perform an explorative analysis to test the possible relationship between the climate variability described by the NAO index and the abundance of small pelagic fished in Morocco and Senegal.
METHODS

Fishery data

✓ CPUE data as abundance proxies from 3 commercial small pelagic species:
  ▪ *Sardinella aurita*: 1981-2005, artisanal Senegalese fleet, effort: fishing trip
  ▪ *Sardinella maderensis*: 1990-2005, artisanal Senegalese fleet, effort: fishing trip
  ▪ *Sardina pilchardus*: 1990-1999, industrial Spanish pursue seiners fleet, south to 26°N, effort: fishing day

NAO index

✓ The winter NAO index (December to March). National Center for Atmospheric Research (NCAR) [http://www.cgd.ucar.edu/cas/jhurrell/indices.html](http://www.cgd.ucar.edu/cas/jhurrell/indices.html) (Hurrell, 1995). NAO data were smoothed by running average of 3 years to reduce time-series noise.

Analysis

✓ Correlation techniques to analyze and quantify the relationships between climate variability (NAO index) and the annual yields of the small pelagic species at the same time. The statistical significance of each relation was estimated by ANOVA (F test)
RESULTS

Winter NAO Index

Maximum positive in the series

1990: 3.36

Predominantly positive
Negative
Positive

Analyzed CPUE period (1981-2005) concur with the highest values of NAO + (>2)

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RESULTS  

Sardinella aurita

Time series comparison

Extended CPUE series allowed trends comparison and use of residual CPUE, avoiding false correlations

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**RESULTS**

*Sardinella aurita*

1981 - 2005

Residuals CPUE ensure no spurious or casual correlation in long time series

- Negative quadratic dependence between abundance species and NAO index of the same year (t)
- Statistical significant regression ($p<0.05$)
- NAO explains around 32% of abundance variability of this species

\[ y = 0.327x^2 - 0.679x - 0.177 \]

\[ r = 0.567 \]

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**RESULTS**

*Sardinella maderensis*

1990 - 2005

The best adjustment of the three species

- Positive quadratic dependence between abundance species and NAO index of the same year (t)
- Statistical significant regression (p<0.05)
- NAO explains around 42% of abundance variability of this species

\[ y = -0.017x^2 - 0.01x + 0.129 \]

\[ r = 0.649 \]
**RESULTS**

*Sardina pilchardus*

1990 - 1999

The worst adjustment of the three species: very short time series (10 years)

- Negative quadratic dependence between abundance species and NAO index of the same year (t)
- No statistically significant regression (p>0.05)
- NAO explains only 14% of abundance variability of this species
- No conclusive results

\[ y = 0.018x^2 - 0.049x + 2.111 \]
\[ r = 0.376 \]

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DISCUSSION

- Winter NAO index changes are supposed to have immediate effects on fast growing species as small pelagic.
- The quadratic response may suggest an "environmental windows" defined by NAO.
- Sardinellas species: Abundances are mid to high dependent on NAO index.
  - *S. aurita*, quadratic negative: broad “environmental windows", optimal NAO values from -1 to 0 and >2, NAO could explain 32%
  - *S. maderensis*, quadratic positive: windows more limited, better NAO values between 0 and 1.7, NAO could explain 42%
  - *S. pilchardus*, quadratic negative: the widest window, although not conclusive results, series not long enough. Studies in North Atlantic showed strong dependence in oceanographic conditions (Guisande *et al.*, 2001; Santos *et al.*, 2001)
DISCUSSION

Opposite reactions between *Sardinellas* species suggest important ecological differences beside the same phenomena. Many questions come up from this behavior:

▪ Is *S. maderensis* less competitive? Less abundant?
▪ Is *S. maderensis* more “tropical” and *S. aurita* more “temperate” species?
▪ Is *S. aurita* behaviour similar to *S. pilchardus*, other “temperate species”?

Does similarity imply comparable ecological roles in both sides of the permanent upwelling?
▪ Does broad “environmental windows” in *S. aurita* and *S. pilchardus* imply greater abundances compared with *S. maderensis*? are their latitudinal distributions also wider?

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DISCUSSION

Describe and quantify relationships is helpful to consider climate factors as state variables in predictive and functional fishery models.

Also, different kinds of relationships may explain diverse features in ecological terms, showing divergent effects over species under fishing pressure in the same region.
Thank you!