Variability of the Environmental Conditions and Fish Communities in the Altlantic Iberian Waters and its Relationship to the NAO.

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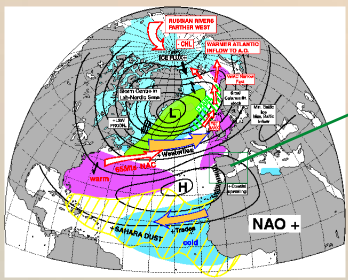


Fig. A

Fig. C

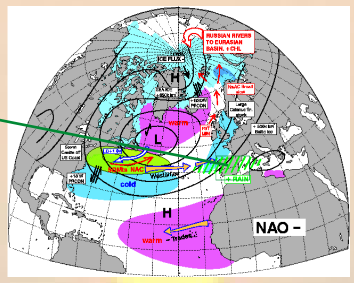


Fig. B

Figure 1 A and B: Phases of the NAO and impacts on weather and climate in the North Atlantic region (source: Dr. Dickson, CEFAS). C: Location of sampling areas in Divisions IXa and VIIIc of ICES (International Council for the Exploration of the Sea).

This study investigates the possible link between a large-scale atmospheric phenomenon, the North Atlantic Oscillation, and local fluctuations of some environmental variables, air and sea surface temperature, precipitation, wind, Ekman transport, and mean sea level, as well as time series (1975-1997) of catches and recruitment of some fish populations of commercial interest around Atlantic Iberian waters. The area of study (Figure 1) is located in the intergyre region between the subpolar gyre (North Atlantic current), the subtropical gyre (Azores Current), and the European shelf. The response of atmospheric signals to the different NAO phases in this area is different to that of Northern Europe, and follows the dipole form presented by Dickson (1997). Pérez et al (2000) compared conditions in river discharge in Scotland and Iberian rivers and found opposing conditions. Winter 1996 marked the minimum of the value of the NAO index, after a high value in 1995. However, although the simple index continued to increase returning to positive values, the actual pattern of the NAO over the ICES area did not recover to a "normal" distribution expected during high NAO years (Dickson and Meincke, 2000). This shift in the NAO index makes the new correlation, including this period, more interesting. This new change in sign in the NAO index and the response of the system is one of the aspects to be studied in this work. The time series used was from 1970 to 1997.

The NAO index (Difference of atmospheric pressure between Iceland and Azores during winter, Hurrell, 1995) indicates the state of this oscillation, a positive index corresponding to a high NAO pattern and a negative index to a low NAO pattern. Together with the winter NAO index, another oceanic index, the position of the Gulf Stream (Taylor, 1996), is used. A further index of oceanic transport provided by McCartney (1997) was also used, but due to the extension of the time-series (to 1995) correlation is not presented here. Tables I and II give the environmental variables and the fishery indices used in this work, period of time and origin.

Variable	Location	Source
Air temperature	Santander	INM
Rainfall	Santander	INM
Sea surface temperatures (SST)	Santander (45ºN, 4ºW)	COADS
U comp. Wind	Santander (45ºN, 4ºW)	COADS
V component Wind	Santander (45ºN, 4ºW)	COADS
W scalar Wind	Santander (45ºN, 4ºW)	COADS
Sea Level	Santander	IEO
Air temperature	Vigo (43ºN, 11ºW)	COADS
Sea surface temperatures (SST)	Vigo (43ºN, 11ºW)	COADS
U comp. Wind	Vigo (43ºN, 11ºW)	COADS
V component Wind	Vigo (43ºN, 11ºW)	COADS
W scalar Wind	Vigo (43ºN, 11ºW)	COADS
Sea Level	Vigo	IEO
Offshore Ekman transport	Vigo (43ºN, 11ºW)	(Lavín et al, 1991, 2000)

Table I: List of environmental variables used in this work from 1970 to 1997

Fisheries				Area	Time period	Data source
Hake	recruitment	SSB	Landings	IXa + VIIIc	1982-1997	ICES 2000 Coop. Rep No. 236,
Horse Mackerel	recruitment	SSB	Landings	IXa + VIIIc	1985-1997	ICES CM 2000/ACFM:5
Sardine	recruitment	SSB	Landings	IXa + VIIIc	1978-1997	ICES CM 2000/ACFM:5
Albacore	recruitment	Captures age2	Captures age3	Bay of Biscay	1975-1997	ICCAT*

Table II: List of fish community indices used in this work

Air Temp. Santander	-0.84
SST_Santander	-0.63
SST Vigo	-0.83
Air Temperature Vigo	-0.87
Upwelling Index Vigo	0.68

Table IV: Horse Mackerel Recruitment significant correlations

Horse mackerel correlations are shown in Table IV. Recruitment is negatively correlated with air temperature and SST in the Cantabrian Sea and in western Iberia (Figure 6). Recruitment is also negatively correlated with the yearly offshore Ekman transport. (Figure 7). The time series of horse mackerel for the existing period shows that cold temperatures due to offshore Ekman transport mainly during the winter period have a strong influence on horse mackerel recruitment. PC shows the first component to be positively related to temperature and negatively to recruitment The total variance explained is 39.26%. The second component is related to the summer upwelling index and explains 16.61%. The third is related to GULF and turbulence. The total explained variability of around 70% is a high value for biological systems. The distributions of time-series analysis as a function of the first component (recruitment) and the second (Ekman transport) are presented in Figure 8.

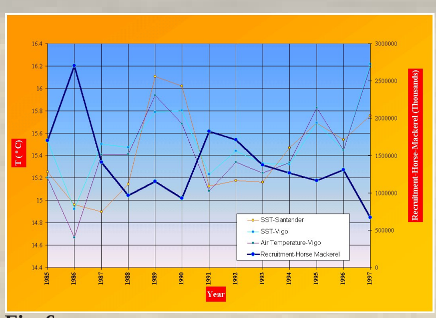


Fig. 6

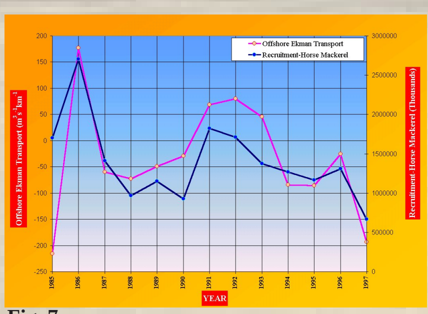


Fig. 7

Table V: Sardine correlations	RECRUIT_	SSB_SARD	LANDINGS
GULF_DEFM	**-0.47**	**0.46**	-0.34
Wind V comp. Santander	**-0.53**	0.11	-0.36
Air Temp. Santander	-0.30	-0.16	**-0.51**
SST Vigo	-0.28	-0.15	**-0.46**
Air Temperature Vigo	-0.39	-0.02	**-0.54**
Turbulence Vigo	**-0.50**	0.37	**-0.55**

(Statistically significant correlation at p=0.05 is marked in red)

Table VI: Albacore correlations	Recruitment	Landing Age 3
GULF_DEFM	-0.12	**-0.48**
Air Temp. Santander	**-0.53**	-0.19
Wind V comp. Santander	0.01	**-0.42**
SST_Santander	**-0.42**	-0.20
Air Temperature Vigo	**-0.42**	-0.28
Turbulence Vigo	-0.30	**-0.58**

(Statistically significant correlation at p=0.05 is marked in red)

Correlation between sardine recruitment, spawning stock biomass and landings in ICES Areas VIIIc and IXa from 1978 to 1997 are presented in Table V. Environmental conditions and fishing activities seem to have brought sardine to a poor state. Correlation in these conditions is poor. The low winter GULF index induces low temperatures in the western Iberia and sardine may be concentrated in this area. A high index could bring higher temperatures and lead the sardine population further north (Alheit and Hagen, 1997).

Correlations between Albacore recruitment and landings of age 3 in the North Atlantic Stock with environmental variables are given in Table VI. A statistically significant correlation between catches of age 3 and winter GULF is presented in Figure 9. This analysis was also perfomed with the oceanic index (McCartney, 1997) albeit to 1995 and the correlation is also significant. Environmental conditions induce a wide distribution of fisheries further north, and fish may be less available to the main fleets than in those with a negative influence (low temperature) when fisheries may be close to the Bay of Biscay coast and catches higher.

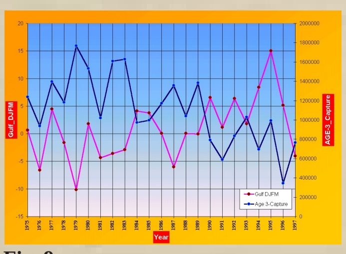


Fig. 9

The PC analysis developed for sardine and albacore shows some degree of similarity. The first component in both cases is related to offshore Ekman transport, while the second is negatively related to GULF, sardine recruitment in the first case and albacore captures of age 3 in the second. The main difference is shown in the third component related to wind in the case of albacore and with temperatures in the case of sardine, showing the oceanic and coastal behaviour of the species.

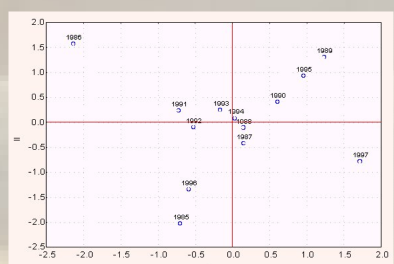


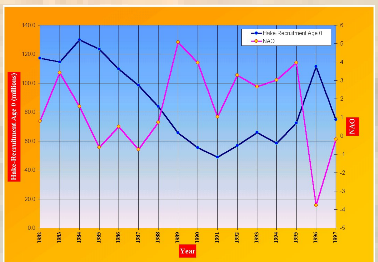
Fig. 8

Table VIII: Hake correlations	Recruitment A	SSB	Landings
NAO	**-0.52**	-0.01	0.06
Wind V comp. Santander	**-0.53**	-0.47	**-0.70**
Air Temperature Vigo	-0.45	-0.46	**-0.58**
Turbulence Vigo	-0.45	**-0.60**	**-0.62**

(Statistically significant correlation at p=0.05 is marked in red)

Hake recruitment is significantly related to NAO (Table VII). The first stages of the hake life cycle are pelagic and may be related to the environment (Figure 10), whereas later stages are demersal and the case is similar to that reported above.

More effort will be dedicate to understanding the correlations found here and to relate them to planktonic intermediate states.



Time series (1961-1997) of some environmental variables, such as air and sea surface temperature, precipitation, wind, Ekman transport and mean sea level, as well as time series (1975-1997) of catches and recruitment of some fish populations of commercial interest, such as horse mackerel, mackerel, sardine, albacore, and hake, were studied in Atlantic Iberian waters. The area studied is located on the border between the influence of the Iceland Low and the Azores High.

The aim of this work is to determine the relationship between the variability observed during the last decades and the climate regime over this area and evaluate the usefulness of the NAO index as a proxi for the climate regime over this area of the North Atlantic.

The phases of the NAO index are reflected in the time series studied: positive NAO phase is mainly characterised by high temperature and low precipitation in this area, negative phase of NAO presents the opposite scenario.

From monthly values, the annual mean is obtained for all environmental variables. In the case of offshore Ekman transport, the April-Sepember value is also used as Upwelling Index. Turbulence is computed as the cube of the scalar wind.

The study of each of the parameters was made by using the Pearson correlation coefficient. Significance levels were $P < 0.05$, and all the variables were standardised. The Principal Components Analysis (PC) was explained with the aim of allowing the extraction of the main trends of variation which govern inter-annual differences. The varimax strategy maximizes variance on the new axes.

Correlations between the general winter NAO index (Hurrell, 1995) and the winter index of the position of the Gulf Stream (Taylor, 1996) and local environmental variables in both locations, Santander and Vigo are shown in Table III.

1970-1997	Winter NAO	GULF_DEFM
Air Temp. Santander	**0.46**	**0.40**
Precipitation	-0.35	-0.19
Sea-level Santander	-0.11	-0.14
Wind U comp. Santander	0.20	0.16
Wind V comp. Santander	0.25	0.30
Escalar Wind Santander	-0.04	0.34
Turbulence Santander	-0.05	0.33
SST Sant	0.35	0.24
SST Vigo	0.26	0.29
Air Temperature Vigo	0.34	**0.38**
Wind V comp. Vigo	0.00	0.12
Escalar Wind Vigo	0.26	**0.65**
Turbulence Vigo	0.26	**0.66**
Sea-level Vigo	-0.18	0.15
Ekman Transport Vigo	-0.06	0.25
Ekman T. Apr-Sep (-Up. Index)	0.02	0.03
Ekman T. Oct-Mar Vigo	-0.12	0.25

(Statistically significant correlation at p=0.05 is marked in red)

Table III

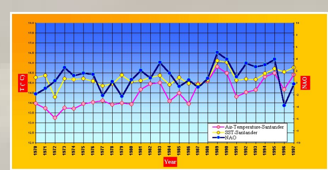


Fig. 2

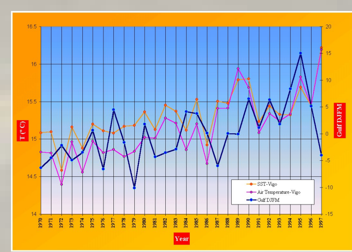


Fig. 4

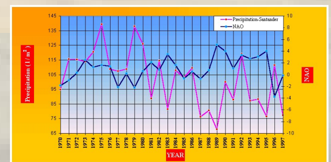


Fig. 3

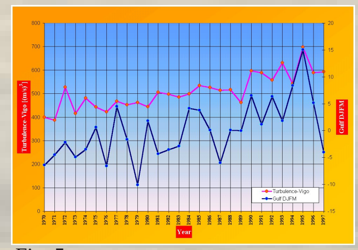


Fig. 5

NAO and air temperature in Santander show similar patterns in their long term trends as well as in their year to year fluctuations, as can be seen in Figure 2. Results indicate a statistically significant relationship between them. Sea surface temperature presents the same trend. The same is true of precipitation, but in this case with a negative trend (Figure 3). Environmental variables in Vigo, such as air temperature (Figure 4) and turbulence (Figure 5) are significantly correlated with the Gulf Stream position of the winter months.

Oceanic conditions seem to have a strong influence over the western Iberian Peninsula (the case of Vigo) and parameters are correlated with the winter GULF index. In the Bay of Biscay, atmospheric conditions represented by the NAO index have a stronger influence than oceanic ones, and so parameters are correlated with the NAO. In PC analysis, the first principal component of the system represents 40% of system variability and corresponds to air and sea surface temperatures. The second component is turbulence with 25% and the third is offshore Ekman transport and makes up 10% of variance.

ACKNOWLEDGEMENTS

We wish to thank the Centro Meteorológico Zonal de Asturias y Cantabria del Instituto Nacional de Meteorología, and COADS for the data-series on meteorological and oceanographic variables, J. Hurrell and B. Dickson, for the NAO index, A. Taylor for the latitude of the Gulf Stream index and María Jesús Garcia from the Instituto Español de Oceanografía for the sea-level time-series. J. Carranza and C. Gonzalez-Pola for their help.

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