Inverse Relationships Between NAO and *Calanus Finmarchicus* Populations in the Western N. Atlantic (Gulf of Maine) and the Eastern N. Atlantic (North Sea)

A. Conversi¹, S. Piontkovski¹, S. Hameed¹, P. Licandro², F. Ibanez², S. Vignudelli³

¹ MSRC, State University of New York at Stony Brook, USA
² Observatoire Oceanologique, Villefranche-Sur-Mer, France
³ CNR, Istituto Elaborazione Informazione, Pisa, Italy

conversi@goased.msric.sunysb.edu
Abstract

The Continuous Plankton Recorder, SST, and the North Atlantic Oscillation index are used to study the temporal dynamics over 30 years of the *Calanus finmarchicus*. In the Gulf of Maine the NAO index is positively correlated to the winter SST, leading it by two years, and SST is positively correlated with *Calanus finmarchicus* (leading it by two years). Three major components of temporal dynamics in *Calanus* abundance are analyzed: seasonal cycle, interannual, and interdecadal variability. They all indicate a POSITIVE relationship with the NAO. *C.f.* abundance and NAO index are positively cross-correlated, with NAO leading by four years. The seasonal cycle of *C. finmarchicus* abundance becomes more pronounced, showing higher overall abundance, during high NAO years. This relationship is opposite to that found between NAO and *Calanus finmarchicus* in the eastern North Atlantic (Fromentin and Planque, 1996). The comparison of the interannual variations of *Calanus finmarchicus* in the eastern and western Atlantic shows a remarkable inverse phase relationship: when one species increases in the Gulf of Maine, it decreases in the North Sea, and vice versa. These results suggest that large scale physical/climatological factors dominate the interannual variability of this species: local factors, such as predation or food availability, cannot in fact sustain a decadal phase association across the ocean.
Contribute to the understanding of the relationship between plankton and climate variations

Questions:
• What is the relationship between Calanus finmarchicus (C.f.) in the Gulf of Maine (GOM) and the NAO index?
• How does it compare with the relationships found in the North Sea (area A2 in Fig.1)?

Purpose of the research
(a US-Globec, Georges Bank study)

photo from http://calanus.nfh.no
The Data

Zooplankton – C.f. c.5-6 abundance. Continuous Plankton Recorder (CPR) data [$ln \left( \text{counts/10n.miles} \right)$]: continuous (night and day) horizontal tows at 10 m depth, by merchant and ocean weather ships along regular routes. GOM data from NOAA-Narragansett. North Sea data from SAHFOS. Same methodology.

GOM SST ($^\circ C$): from the Comprehensive Ocean-Atmosphere Data set.

NAO index: Sea level pressure ($mB$) from the Comprehensive Ocean-Atmosphere Data set. Index calculated as the difference between the Azores Islands region (Ponta Delgadas) and the Icelandic region (Akureyri)

Fig. 1. Location of sampling areas
Results 1 – *C.fin.* in GOM and NAO

We found a positive relationship between *Calanus f.* abundance in the GOM and the NAO index at several scales:

- **Seasonal:** *C.f.* abundance is overall higher and the seasonal cycle is more defined during years with higher NAO index (Fig. 2)
- **Multidecadal:** an increasing trend in *C.f.* abundance accompanies the well known increase in the NAO index (and in GOM SST temperature) of the same period (Fig. 3)
- **Interannual (detrended values):** higher than usual NAO fluctuations are significantly correlated with higher than usual SST 2 years later, and higher than usual *C.f.* abundance 4 years later (Fig. 4)

About 58% of the total variance of the *C.f.* summer abundance residuals can be calculated from 3 physical parameters: winter SST, summer SST and NAO (Fig. 5)
Fig. 2. *Calanus f.* annual cycle (GOM) vs. NAO

<table>
<thead>
<tr>
<th>30 year average</th>
<th>HIGH NAO years average</th>
<th>LOW NAO years average</th>
</tr>
</thead>
</table>

HIGH NAO years: 1961, 73, 74, 81, 83, 84, 89, 90; LOW NAO years: 1963, 64, 65, 66, 69, 77, 78, 79

(Conversi et al., 2001, in press)
Fig.3. Trends in GOM, 1961-1991

Top to bottom: SST (C), C.f. (log10 (#/100m3)), NAO index.

(Conversi et al., 2001, in press)
Fig. 4. Cross-Correlations in GOM: NAO, SST, *Calanus f.*

- NAO index fluctuations precede winter SST by 2 years
- Winter SST precedes *C. fin.* summer abundance changes by 2 years
- NAO index precedes summer *C. f.* by 4 years
- All positive relations: higher NAO corresponds to higher SST and higher *C. f.* abundance

*(analysis on detrended data)*
Fig. 5. Calculating *Calanus finmarchicus* summer variations

Regression equation ($r=0.76$, $p<0.01$):

$$C = -0.16 + 0.37 \text{ SST}_{w2} - 0.30 \text{ SST}_s - 0.10 \text{ NAO}_2$$

$C$ is *Calanus* abundance in summer; $\text{SST}_{w2}$ is the winter SST of two years earlier; $\text{SST}_s$ is the same summer SST, and $\text{NAO}_2$ is the NAO index of two years earlier. *Detrended series.* (Conversi *et al.*, 2001, in press)
Results 2 – *C.finmarchicus* inter-Atlantic comparison

The Eigen Vector Filtering (EVF) method, modified for application to time series with missing data (Ibanez and Conversi, Licandro *et al.*, submitted), has been applied to *C.f.* series in the GOM and in the North Sea.

The filtered series indicate that the interannual variations of the copepod’s abundance on the opposite side of the ocean are not independent: when one species increases in the Gulf of Maine, it decreases in the North Sea, and vice versa (Fig. 6).
The correlation between the filtered series (period 78-90 only) is $r = -0.48$ after detrending ($r = -0.66$ before detrending).
Conclusions

The analyses of *C.f.* show that this species’ fluctuations are dominated by interannual variability (Licandro *et al.*, submitted). The analyses of *C.f.* interannual variations in the GOM indicate a positive relationship with the NAO at several scales in this area (Conversi *et al.*, in press). This relationship is opposite to that found in the eastern North Atlantic (Fromentin and Planque, 1996). The transatlantic comparison (GOM vs. N. Sea) shown here confirms these differences, showing a remarkable inverse relationship between the interannual variations of this species across Atlantic. Such a long-distance association suggests that large scale physical/climatological factors dominate the interannual variability of this species: local factors, such as predation or food availability, cannot in fact sustain a decadal phase association across the ocean. Possible mechanisms to explain this association include NAO-induced large scale changes in the Labrador Sea (Greene and A. J. Pershing, 2001) and Gulf Stream transport and latitude (Taylor and J. A. Stephens, 1998), which favor in one side (and disfavor in the other) *C.f.* abundance.


Acknowledgements

National Science Foundation
National Oceanic and Atmospheric Administration
Sir Alister Hardy Foundation for Ocean Sciences
Kenneth Sherman (NOAA)
Jack Jossi (NOAA)
Chris Reid (SAHFOS)
Seguono extra slides (non usate)
Fig. 6. Interannual variations of Calanus f. in western (GOM) and eastern (northern North Sea) Atlantic

Raw data in GOM and North Sea

\begin{align*}
\text{In (#/10 n.miles)}
\end{align*}

- Red: F1 GOM (12)
- Yellow: Cal.fin GOM
- Blue: F1 A2
- Green: Cal.fin A2
Fig. 6. Interannual variations of *Calanus f.* in western (GOM) and eastern (northern North Sea) Atlantic

First Principal Components (EVF) of *Calanus finmarchicus*, 1961-1991, monthly data

The correlation between the filtered series (period 78-90 only) is $r = -0.48$ after detrending ($r = -0.66$ before detrending)