LARGE SCALE CLIMATE CONTROL ON OCEANOGRAPHIC AND ECOLOGICAL CHANGES IN THE LIGURIAN SEA, NORTHWESTERN MEDITERRANEAN

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Abstract
A causal chain of meteorological, hydrological and ecological processes linked to the North Atlantic climate forcing and the Northern Hemisphere temperature have been pointed out in the Ligurian Sea, Northwestern Mediterranean.

Keywords: NAO, Northern Hemisphere temperature, Ligurian Sea, planktonic copepods, hydromedusae

Introduction

During the last decades, planktonic ecosystems have experience strong ecological changes (i.e. population explosions, strong decreases, ecosystem shifts) occurred with increasing frequency, intensity, variety and range (1). A causal link between these changes and the warming trend registered in the Northern Hemisphere has been suggested (2,3).

The western Mediterranean constitutes a sensible area to large scale climate forcing from subtropical and North Atlantic sectors (4,5,6) and to global climate warming (7). However, although such relationships have been identified, the ecological consequences in this area are poorly explored.

In this work we analyse long-term variability of two distinct trophic levels, planktonic copepods and gelatinous carnivores, during the period 1967-1993. We document the contribution of the North Atlantic climate forcing and the Northern Hemisphere temperature on the oceanographic and ecological changes in the Ligurian Sea.

Material and methods

The study site is located in the Ligurian Sea (NW Mediterranean), and precisely in the monitoring station of the Bay of Villefranche/mer (43° 41'N; 7° 19' E). We analysed physical (temperature and salinity) and biological data from the long term monitoring of pelagic populations carried out by the Observatory of Oceanography of Villefranche (OOV). We also used daily records of local meteorology (air temperature, atmospheric pressure, wind speed and precipitation).

Biological time series analysed correspond to zooplankton abundance of planktonic copepods (adult stages of three free-spawning, *Centropages typicus*, *Acartia clausi* and *Temora stylifera,* and two egg-carrying species, *Oithona spp* and *Oncaea spp*) and gelatinous carnivores (*Liriope tetraphylla*, *Solmundella bitentaculata* and *Rhopelonema velatum*).

Time series were analysed in their standardised and non-dimensional form (i.e. standard deviations from the mean of the time series). Principal Component Analysis and Pearson product-moment correlation were used to explore interannual variability on local hydroclimatic and biological changes and their possible relation with large scale climate processes.

Results and discussion

A significant link between the governing climate in the North Atlantic sector and the hydroclimatic conditions in the Ligurian Sea is pointed out. This relationship appears stronger during winter. Indeed, hydroclimatic interannual variability (PC1 38.3% of the total variance) was linked with the NAO ($r = 0.69$; $p<0.01$) and the Northern Hemisphere temperature ($r = 0.45$; $0.05<p<0.1$).

The local hydroclimatic variability driven by the climate forcing during winter and linked to the NAO state (i.e. changes in heat fluxes, precipitation, wind stress and mesoscale circulation) quite have an effect on the development and/or structure of phytoplankton composition leading to a shift in species dominance.

The main signal of the whole zooplankton populations, as indicated by the first eigenvector and principal component (PC 1 55% of the total variance), results showed a strongly link to the NAO variability ($r = 0.62$; $p<0.01$) and Northern Hemisphere temperature ($r=0.62$; $p<0.04$).

The long term trend observed in gelatinous carnivores has been related to a period characterized by an increase in temperature, salinity and dry conditions (8) particularly marked during mid-late 1980's. In this study we show that such period was linked ultimately to an exceptional high NAO and tightly coupled to the Northern Hemisphere Temperature trend.

Hydroclimatic modifications occurred during the last decades in the study area quite promoted increase in food availability for gelatinous carnivores (i.e. microzooplankton production related to the flagellate dominance on the microplankton community) and favour conditions for their development (i.e. high temperatures, low water column mixing). Owing to their important increase since mid-1980s, recurrent autumn peak and their feeding proprieties (i.e. they are no satiated and can feed on a larger range of particles than copepods), the higher abundance observed suggests a multiplicative and non-linear predation pressure over copepods. Indeed, a collapse in the summer-autumn blooming copepods occurred during late 1980's.

These results provide evidence for a significant link between local changes in the Ligurian Sea (i.e. meteorology, hydrology and plankton populations) and the governing atmospheric circulation in the North Atlantic. During this time, the influence of the North Atlantic climate appears as a key control on the dynamics of hydroclimatic conditions and long term variability of planktonic populations, as indicated by decadal changes documented in both physical and biological time series.

These results when considered in the context of long term changes in planktonic groups previously reported for the same study area (salps, doliolids and other gelatinous carnivores), suggest a shift in the Ligurian planktonic ecosystem which might be related to large scale climatic processes governing the North Atlantic.

There are several implications of this study which could be useful to understanding interannual and decadal abundance variability in the planktonic populations of the Northwestern Mediterranean. The first is that these results confirmed the sensitivity of the Western Mediterranean to large scale climate processes and showed a rapid response to the forcing from the North Atlantic sector. The second is that instead of approaching long term trends in marine ecosystems as determined by local events, efforts should be directed toward investigate connections across the atmospheric circulation and ranges of influence of large scale climate variability in order to forecast and mapping possible scenarios of ecological changes in the context of the global climate change.

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