HYPOTHESES ON A MEDITERRANEAN SEA REGIME SHIFT IN THE LATE 1980S

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Abstract

A comparative study of biological and physical time series in the eastern and western Mediterranean Sea for the period 1960s to 2005, combined with a literature review, finds that all point out to an abrupt period of change in the late 1980s that involved circulation and pelagic systems. We show, using regime shift detection methods, evidence that the Mediterranean Sea underwent a climate shift in the late 1980s. An extension of this analysis to larger scale climate indexes (NHT and NAO), shows that they changed around that time. We hence hypothesize that the Mediterranean shift is part of a larger, hemispheric change, and is related to other shifts recorded during the same period in all other European seas.

Keywords: Global Change, Ligurian Sea, Adriatic Sea, Time Series, Zooplankton

Introduction

Abrupt shifts involving both the physical and the ecological systems, called regime shifts [1,2] have been the focus of recent attention. Marine regime shifts hold particular relevance, because they encompass a multitude of physical properties and ecosystem variables, and subsequently can have major impacts on all trophic levels of marine food webs and the associated biogeochemical cycles. Our initial work in the Gulf of Trieste, North Adriatic, eastern Mediterranean, identified two periods, based on winter SST patterns: 1970-1987 and 1988-2005 [3]. Our analyses of the 36-year copepod abundance time series in the Gulf of Trieste, showed that the second period was characterized by ecosystem-wide changes: the arrival of new species, the rise or decline of several taxa, and changes in the phenology in several species [3]. In this work we extend these analyses to the western Mediterranean, including biological and physical properties over different geographical scales, as well as climate indices, and find that all point out to a period of change in the late 1980s.

Methods

In this study we have utilized the following monthly times series over the 36 year period January 1970 – December 2005, unless otherwise stated: total copepod abundance Gulf of Trieste, Adriatic, Eastern Mediterranean; northern Adriatic mucilage events time series (episodes); northern Adriatic red tides time series (episodes); Adriatic anchovy stock biomass (yearly, 1976-2001); zooplankton abundance, Point B, Ligurian Sea, West Mediterranean (weekly, November 1966 - December 1993); SST, Gulf of Trieste; SLP, Gulf of Trieste; SST, Ligurian Sea; SLP, Ligurian Sea; SST, Mediterranean Sea; SLP, Mediterranean Sea; North Hemisphere Temperature (NHT) index; North Atlantic Oscillation (NAO) index. These data have been analyzed using two regime shift methods: the cumulative sums, and the sequential t-test analysis of regime shifts (STARS). The cumulative sum technique consists of plotting the cumulative sum of standardized values over time, to which is subtracted the mean of time series [4]. The STARS method calculates a Regime Shift Index (RSI), which represents a cumulative sum of normalized anomalies relative to a critical value and provides a probability level for the identified year of regime shift, based on the Student's t-test [7].

Results

All Adriatic biological series investigated in this work (copepods, anchovy biomass, and the mucilage-red tide alternance) over 36 years show a step-like period of change in the late 1980s. The 27 year mesozooplankton series in Villefranche Bay, western Mediterranean, shows a step-like change in the late 1980s as well. To support the hypothesis that these changes in the pelagic system are accompanied by changes in the physical environment, we analyse available hydrographic properties (SST e SLP) at different geographical scales: local/regional (northern Adriatic and NW Mediterranean), and basin (Mediterranean), and compare with climate indices (NHT, NAO - hemispheric scale). We find that they all show a main period of change in the late 1980s Although the time serie are on the order of a few decades, and thus a persistent state cannot yet be assessed with certainty, it is the synchronicity of the period of change, involving biological and physical properties, different trophic levels in both Mediterranean sub-basins, which indicates the presence of a major reorganization in this sea.

Conclusions

Our results suggest that the Mediterranean Sea underwent a major change at the end of the 1980s that encompassed atmospheric, hydrological, and ecological systems, for which it can be considered a regime shift. We provide evidence that links local, regional, and basin scale hydrological properties with two major indicators of large scale climate, the North Atlantic Oscillation index and the North Hemisphere Temperature index, suggesting that the Mediterranean shift is part of a larger scale change in the northern hemisphere. We hypothesize that the shifts that affected the North, Baltic [5], Black [6], and Mediterranean (this work) seas at the end of the 1980s, so far only partly associated, are all linked as part of a northern hemisphere change.

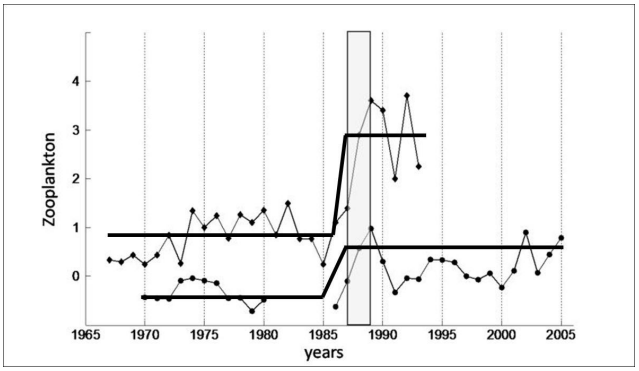

Fig. 1. Interannual variability of zooplankton abundance off Villefranche, Ligurian Sea (diamonds), and of total copepod abundance in the Gulf of Trieste, Adriatic Sea (circles), standard units. The black horizontal lines represent the stepwise trend showing the regime shift in the mean detected by STARS method. T-test, cumulative sums, and the STARS methods, all identift a period of change circa year 1987 (vertical bar).

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