

Impacts of climate change on coastal benthic ecosystems in the NW Mediterranean coastal areas: assessing potential risk of mortality from field, laboratory and numerical experiments

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Abstract

In order to assess the potential impact of climate change on coastal benthic ecosystems by the end of the 21st century at sub-regional scale in the North Western Mediterranean Sea, we developed an original strategy for the definition of warming scenarios in coastal habitats and their potential sub-lethal to lethal impacts on key benthic species. This was achieved by combining high resolution numerical simulations under IPCC scenarios with field observations and thermo-tolerance experiments. First, a model validation was conducted for the period 2001-2010 in contrasted sensitive coastal areas. Then, forecasts run were performed under IPCC scenarios in order to explore the expected changes in the stratification. These simulations were qualified with species distribution and thermo-tolerance functions to explore the present risk level and potential impacts by the end of the century. This work was made in the framework of the CLIMCARES project funded by the TOTAL foundation and the MISTRALS-MERMEX project.

Introduction

The Mediterranean Sea is highly responsive to climate change. Dramatic impacts are expected to occur in benthic coastal ecosystems which are among the most exposed to the warming trend and to the increase in magnitude and frequency of extreme events [1]. In this semi enclosed microtidal sea with seasonal stratification up to 15°C, the influence of (sub)meso scale dynamics (eg. upwelling, downwelling) is crucial in modulating local thermal regimes and potential impacts of climate change at local scale [2,3]. Developing more precise/realistic scenarios of coastal habitats warming and potential impact on ecosystems is crucial for setting up sound management and conservation plans of the rich Mediterranean biodiversity. It is recognized as a priority theme of international programs (eg. CIESM, MEDPAN, MERMEX). Within the CLIMCARES project (<http://climcares.medrecover.org>), we specifically addressed the risk of mass mortality outbreaks driven by thermal stress in rocky benthic ecosystems of the NW Mediterranean [4,5].

Materials and methods

We conducted a multidisciplinary approach combining hydrodynamic simulations, physical and biological coastal observations, and thermo-tolerance experiments.

Temperature profiles (5-40m) have been monitored hourly over the past 10 years in different coastal areas of Spain, France and Corsica (T-mednet initiative, <http://www.t-mednet.org>). Observations from 10 contrasted stations were compared with simulations for the last decade for two different models: the high resolution hydrodynamical model addressing (sub)mesoscale processes MARS3D/MENOR (horizontal resolution of 1.2 km) and NEMO-MED8 (resolution of 13 km) [6]. We evaluated statistically bias and errors to qualify the models and define local corrections. Forecast simulations were run under the IPCC A2 scenario for both models.

Upper thermo-tolerance limits of key benthic species were compiled from *in situ* temperature records obtained during 1999, 2003 and 2006 mass mortality events, allowing correlation analysis of the degree of mortality and temperature conditions. Additional thermo-tolerance experiments were conducted on some of the affected species. Finally, a data base on species distribution and upper distribution limit was compiled.

The vulnerability scenarios were obtained by combining warming scenarios, biological responses to warming and upper distribution limit as described in [3].

Results and Discussion

Models comparison with coastal temperature series for 2001-2010 showed good MENOR model performances (bias, RMSD and correlation), even if extremes were underestimated in subsurface layers. The regional model also yielded good performances for monthly to seasonal statistics. Thus both approaches - local correction of regional model and high resolution downscaling with MENOR - were used to explore respectively long term trends in stratification and extreme events by the end of the century. The thermo-tolerance response functions to warming compiled from field observations and experiments shared the same pattern for the sponges, anthozoans and cnidarians tested: mortality arose after sustained "moderate" increase in temperature (24-26°C) during several weeks or stronger short overheating (27-28°C) lasting for a day.

The modeled temperatures were extracted along the NW Mediterranean coastlines and combined with thermo-tolerance and upper distribution limit of populations. This information was used to build risk and potential impact models. First results were based on hindcasts to evaluate species and areas of high conservation concern in the NW Mediterranean [3], highlighting the concomitant and/or repeated occurrence of a range of (sub)lethal conditions depending on the area considered during the past decade (Figure 1). Then the methodology was applied on forecasts to explore potential impacts of climate change by the end of the century.

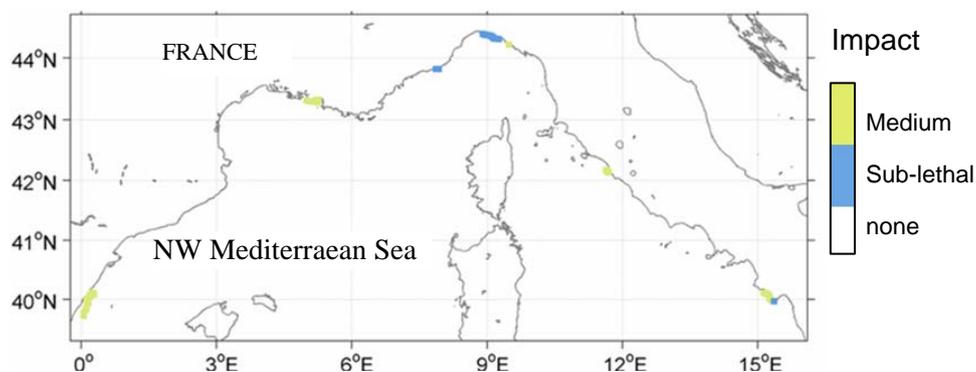


Fig1. Map of risk of mortality under thermal stress for benthic species at a depth of 30 m along the coastline of the NW Mediterranean.

References

- [1] The MerMex Group, 2011. Marine ecosystems' responses to climatic and anthropogenic forcings in the Mediterranean. *Prog. Oceanogr.*, 91:97-166.
- [2] Bensoussan N., Harmelin JG., Romano JC., Garrabou J., 2010. High resolution characterization of Northwest Mediterranean coastal waters thermal regimes: to better understand responses of benthic communities to climate change. *Estuar. Coast. Shelf Sci.*, 87:431-441.
- [3] Pairaud I., Bensoussan N., Garreau P., Faure V., Garrabou J. Impacts of climate change on coastal benthic ecosystems: assessing potential risk of mortality outbreaks on the NW Mediterranean coastal areas. *Ocean Dyn.* (in revision).
- [4] Garrabou J., Coma R., Bensoussan N., et al., 2009. Mass mortality in NW Mediterranean rocky benthic communities: effects of the 2003 heat wave. *Glob. Change Biol.* DOI: 10.1111/j.1365-2486.2008.01823.x
- [5] Crisci C., Bensoussan N., Romano JC., Garrabou J., 2011. Temperature anomalies and mortality events in marine communities: insights on factors behind differential mortality impacts in the NW Mediterranean. *PLoS ONE* 6(9): e23814. doi:10.1371/journal.pone.0023814
- [6] Somot S., Sevault F., Déqué M., 2006. Transient climate change scenario simulation of the Mediterranean Sea for the 21st century using a high-resolution ocean circulation model. *Clim. Dyn.*, 27(7-8): 851-879.