CLIMATE CHANGE IMPACTS ON COASTAL BENTHIC ECOSYSTEMS IN THE NW MEDITERRANEAN SEA: ASSESSING POTENTIAL RISK FROM FIELD, LABORATORY AND NUMERICAL EXPERIMENTS

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Abstract
Our main aim was to assess the potential impacts of climate change on coastal benthic ecosystems by the end of the 21st century at sub-regional scale: 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 thermotolerance experiments. First, model validation for 2001-2010 was conducted in contrasted sensitive coastal areas. Forecasts run were performed under IPCC scenarios to explore changes in stratification. These simulations were qualified with species distribution and thermotolerance functions to explore present risk level and potential impacts by the end of the century.

Keywords: Coastal systems, Global change, Biodiversity, Temperature, North-Western Mediterranean

Introduction
The Mediterranean Sea is extremely responsive to climate change and dramatic impacts are expected to occur in benthic coastal ecosystems which are among the most exposed to the current trends and 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 and thus 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 driven by thermal stress in rocky benthic ecosystems of the NW Mediterranean (NW Med) [4,5].

Materials and methods
We conducted a multidisciplinary approach combining hydrodynamic simulations at large geographic scale, 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 1.2 km) and NEMO-MED8 (ca. 13 km resolution) [6]. We evaluated statistically bias and errors to qualify the models and define local corrections. Forecast simulations were run under the IPCC A2 scenario and both models were considered for comparison.
Upper thermotolerance 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. Besides, thermotolerance experiments were conducted on some of the affected species. Finally, a data base on species distribution and upper distribution limit was also compiled.
The vulnerability scenarios were obtained by combining warming scenarios, biological responses to warming and upper distribution limit as fully described in [3].

Results and Discussion
Models comparison with coastal temperature series for 2001-2010 showed the good model performances of MENOR (bias, RMSD and correlation) even if extremes were underestimated in subsurface layers. The regional model also yielded good performances for monthly to seasonal statistics at these very near to coast stations. Thus both approaches - local correction of regional model and high resolution downscaling with MENOR - were considered complementary and used to explore respectively long term trends in stratification and extreme events by the end of the century. The thermotolerance 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) or stronger short overheating (27-28°C), at typical time scales from several weeks to day respectively.
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 based on hindcasts to evaluate species and areas of high conservation concern in the NW Med [3], highlighting the concomitant and/or repeated occurrence of a range of (sub)lethal conditions depending on the area considered during the past decade. Then on forecasts to explore potential impacts of climate change by the end of the century at specific, but also multi-specific level.

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