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Modelling the future biogeography of North Atlantic zooplankton communities in response to climate change

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Summary

Advances in habitat and climate modelling allow us to reduce uncertainties of climate change impacts on species distribution. We evaluate the impacts of future climate change in community structure, occurrence, distribution, and phenology of 14 copepod species in the North Atlantic Ocean. To this end, historical observations from Continuous Plankton Recorder (CPR) and environmental data extracted from POLCOMS-ERSEM model have been used. Generalized Additive Models (GAMs) have been applied to relate the species occurrence with environmental variables. Selected habitat models have been projected to future (2080-2099) environmental conditions using HAMOCC (HAMburg Ocean Carbon Cycle) and MPIOM (Max Planck Institute Ocean Model) models under A1B climate scenario, and compared to present (2001-2020) conditions. Our predictions revealed a clear response to climate change with a community poleward latitudinal shift of 8.7 km/decade on average, the species seasonal peak occurs 12-13 days earlier in the seasonal annual cycle for *Calanus finmarchicus* and *C. hyperboreus*, and important changes in community structure (a high species turnover of 42.8 -78.5% has been detected at the south of the Oceanic Polar Front). These changes might lead to alterations of the future North Atlantic pelagic ecosystem.

Introduction

Plankton communities can quickly respond to climatic variability (e.g. Beaugrand et al., 2002). Impacts of global warming affect the whole pelagic ecosystem from plankton to higher trophic levels (Beaugrand & Kirby, 2010). Such impacts can result in poleward movements in species distribution (Chust et al., 2014a), shifts in phenology (Moore et al., 2011) or changes in abundance and community structure (Chust et al., 2014b). Species responses to climate change may lead to local extinction and invasions, resulting in changes in the pattern of marine species richness and trophic mismatches (Cheung et al., 2009). Therefore, assessing how these biogeographic processes will change in the future is a key prerequisite to anticipate consequences of climate change on marine ecosystems. Here, we have analyzed a zooplankton community to detect future biogeographic changes in species distribution, phenology and to identify spatial and temporal patterns of diversity. This will allow us in to project the community shifts and their consequences at the North Atlantic basin. We developed and validated habitat models in key zooplankton species using CPR survey data collected at mid latitudes of the North Atlantic to be reliably extrapolated to future climate scenarios. Subsequently, the model has been used to project species distributions, community composition and phenological changes at the end of the century under climate change scenarios.

Material and Methods

Generalized Additive Models (GAM), Mahalanobis distance algorithm and Maxent have been used to model occurrences for each of the 4 *Calanus spp*. (*C. finmarchicus, C. glacialis, C. helgolandicus, C. hyperboreus*) as a function of environmental factors (SST, salinity, pH, bathymetry) and surface phytoplankton biomass. Models were validated using independent data sets for model building and model validation. We validated the models in two ways: (1) k-fold random resampling and (2) temporal cross-validation. North Atlantic regime shift has been taken into account to perform a temporal cross-validation of the model. To this end, a subset of each of the 4 Calanus spp. between 1970 and 2004 have been used, comparing cold (1970-1986) with warm (1987-2004) regimes. In order to predict *Calanus spp*. and the other set of non calanus copepods response to climate change, selected habitat models have been projected to future climate conditions (2080-2100) under A1B scenario. Thus, latitudinal shifts, species turnover rates and phenology changes have been assessed.

Results and Discussion

Projections of 14 main copepod species in the North Atlantic by the end of the century under climate change scenarios indicate: 1) a prevailing poleward shift of most of the studied species (Fig.1), with a poleward community shift of 8.7 km/decade on average, and important species range variation from -15 to 18 km per decade; 2) an area characterized by high species turnover of local colonization and extinction located south of the Oceanic Polar Front where SST is projected to increase by the end of century; and 3) an earlier seasonal peak of copepods in response to the ocean warming trend. All these changes may propagate higher up in the food web.

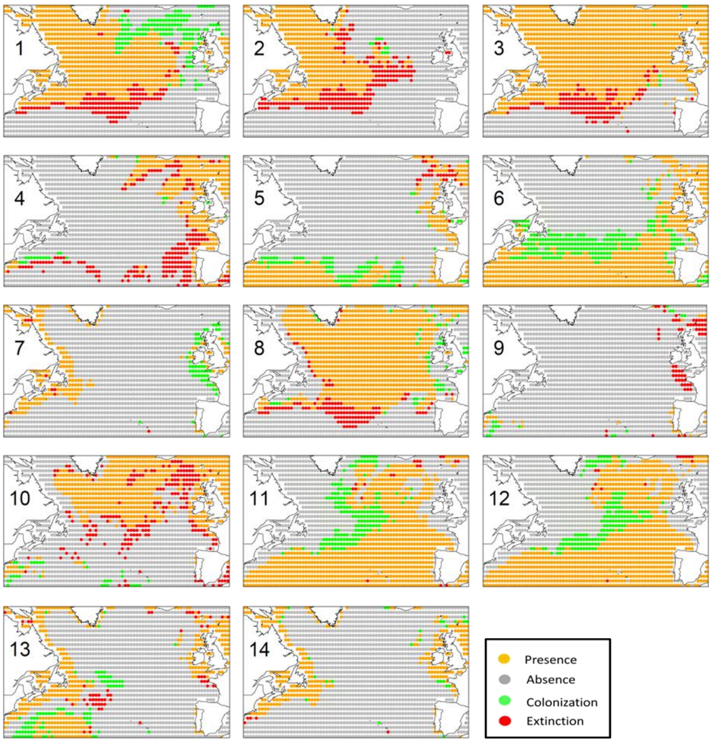

Fig.1. Habitat suitability models for each of the species at present (2001-2020) and future conditions (2080-2099). Green: colonization area, species is absent in present and present in future. Red: extinction area, species is present at present and absent in future. Orange: Present at both periods. Grey: Absent at both periods. 1. *C. glacialis*, 2. *C. hyperboreus*, 3. *C. finmarchicus*, 4. *C. helgolandicus*, 5. *Candacia armata*, 6. *Centropages typicus*, 7. *Centropages hamatus*, 8. *Paraeuchaeta norvegica*, 9. *Paraeuchaeta hebes*, 10. *Metridia lucens*, 11. *Pleurommama borealis*, 12. *Pleurommama robusta*, 13. *Pseudocalanus elongatus*, 14. *Temora longicornis*.

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