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# Modelling the future response of zooplankton species to climate change in the North Atlantic

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## Summary

Recent advances in habitat modelling allow us to assess 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 (sea surface temperature and salinity, bathymetry, pH, O2, mixed layer depth, surface phytoplankton biomass). North Atlantic regime shift has been taken into account to perform a temporal cross-validation of the model. To this end, a subset of 4 *Calanus spp*. (*C. finmarchicus, C. glacialis, C. helgolandicus, C. hyperboreus*) between 1970 and 2004 have been used, comparing cold (1970-1986) with warm (1987-2004) regimes. Results have shown that model accuracy is relatively good (74-85%) for the models built in cold regime and extrapolated and validated in the warm period. Therefore, species models can be used to be projected in future climate simulations with relative confidence. On a second step, it is intended to extend the analysis by comparing GAMs with Maximum Entropy model and Mahalanobis distance algorithm.

## Introduction

Many studies have provided evidence that marine plankton communities can quickly respond to climatic variability (e.g. Beaugrand et al. 2002). Environmental conditions determine the relative abundance and diversity of species in marine plankton communities (Edwards et al. 2013). Species distribution models attempt to provide detailed predictions of distribution of species by relating species occurrence to environmental predictors. Sea temperature is probably the most important physical variable structuring marine ecosystems. There is overwhelming evidence that the composition, abundance, and phenology of plankton communities are closely linked to water temperature (Richardson, 2008). Throughout the North Atlantic Ocean, a general increase in temperature has been observed in the past century (Beaugrand, 2009) and future ocean temperatures have been forecasted by coupled atmosphere–ocean general circulation models (AOGCMs). Here, we modelled the ecological niche of four copepod species in the 1970-2004 period (*C. finmarchicus, C. glacialis, C. helgolandicus, C. hyperboreus*) using habitat suitability modeling techniques (Chust et al., in press). Subsequently, we applied the best selected model on other 10 copepod species. On a second step, we will evaluate the impacts of future climate change in community structure, occurrence distribution, and phenology in the North Atlantic Ocean with model outputs corresponding to SRES A1B global warming scenario (IPCC AR4, 2007).

## 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*. 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 4 Calanus spp. (*C. finmarchicus, C. glacialis, C. helgolandicus, C. hyperboreus*) between 1970 and 2004 have been used, comparing cold (1970-1986) with warm (1987-2004) regimes. In order to predict *Calanus spp*. response to climate change selected habitat models will be projected to future climate conditions. Species potential distribution under present (1970-2004) will be projected to future climate conditions (2080-2100) under A1B scenario. Thus, latitudinal shift and temporal (phenology) changes of species suitable habitat distribution will be assessed.

## Results

Using GAMs, we identified 3 key environmental variables, i.e. temperature, salinity and depth. They were present in all *Calanus spp.* habitat models. *C. finmarchicus* and *C. hyperboreus* models included surface phytoplankton biomass and pH. Therefore, surface phytoplankton biomass seems to be a controlling factor in the probability of occurrence and distribution of these two species, but not on *C. glacialis* and *C. helgolandicus*, according to models (Fig. 1).

The temporal cross validation analysis showed that model accuracy is relatively good (74-85%) for the models built in cold regime and extrapolated and validated in the warm period. Therefore, species models can be used to be projected in future climate simulations with relative confidence.

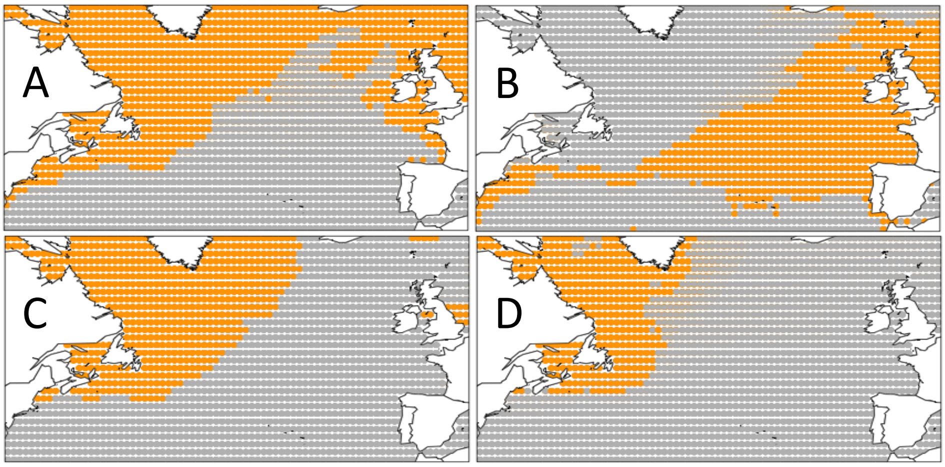


**Fig.1. Occurrence models of *Calanus spp*. in 1970-2004 period. Map key: Orange is presence and grey is absence.**

**A) *C. finmarchicus***
**B) *C. helgolandicus***
**C) *C. glacialis***
**D) *C. hyperboreus***

## References

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