Species Distribution Modelling of benthic macrofauna in the Hornsund fjord (Spitsbergen, Svalbard)

Svalbard archipelago is being considered as one of the most rapidly warming regions in the Northern hemisphere (Acia, 2005; IPCC et al., 2007). One of the main drivers of this warming is the West Spitsbergen Current (WSC). WSC is responsible for the majority of Atlantic Water (AW) fluxes, which carries heat into the central Arctic (Pavlov et al., 2013; Schauer et al., 2008; Smedsrud et al., 2010; Walczowski and Piechura, 2007). Inflows from the WSC have been noted in the fjord systems around Svalbard (Berge et al., 2005; Cottier et al., 2005; Nilsen et al., 2008, 2006; Pavlov et al., 2013; Skogseth et al., 2005; Teigen et al., 2011) and account for the instability and increasing temperatures in the fjords' waters (Pavlov et al., 2013). Atlantic water carried from a region of higher biodiversity (Norwegian Sea) may also affect the Arctic ecosystem by mediating the northern expansion of certain boreal taxa (Węslawski et al., 2009). There are first observations demonstrating that Spitsbergen fjords are becoming dominated by boreal fauna near the fjords mouths (Wesławski et al., 2011). Such effects of climate change can lead to species migrations, habitat shifts or extinction of indigenous Arctic species. Inner glacial basins of Arctic fjords are believed to suit as suitable refugia for Arctic taxa. They are known to host winter waters of very low temperatures and are isolated from the rest of the fjord by topographic sills (Svendsen et al., 2002; Weslawski et al., 2010; Wlodarska-Kowalczuk and Pearson, 2004). Norwegian fjords are known to host cold water species in the innermost basins, contrary to the outer basins that are dominated by warm water Atlantic species (Freeland et al., 1980). The same distribution of species may occur in the future in the fjords of the European Arctic. In order to asses this issue for the Horsund fjord, species distribution modelling (SDM) was performed and distribution patterns of selected benthic macrofauna species were analysed. Since benthic organisms have long life cycles and limited dispersion ability, they are believed to be better indicators of medium environmental conditions and long-term changes than pelagic communities.

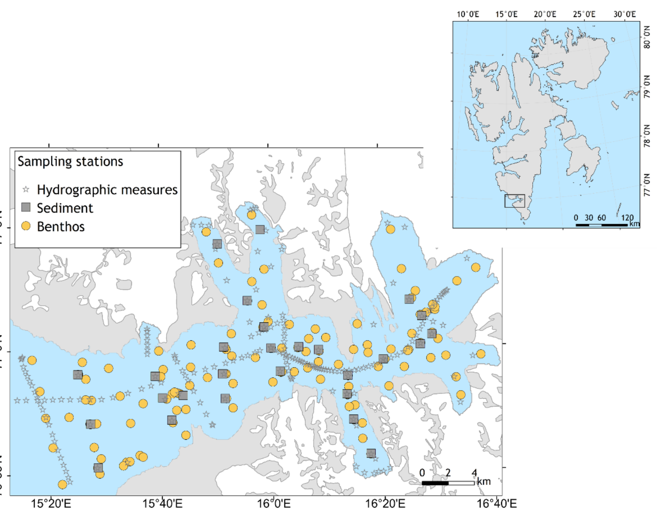


Fig. 1. Study area and sampling station design.

OBJECTIVES:

- to verify importance of individual environmental variables for benthic fauna distribution
- to predict areas of suitability for selected species
- point out potential refugia for Arctic benthos

HYPOTHESIS:

1. Benthic fauna distribution is controlled by the occurrence of cold water masses in the fjord

2. Inner basins of the fjord may serve as potential refugia for Arctic species in the changing environment

MATERIALS AND METHODS

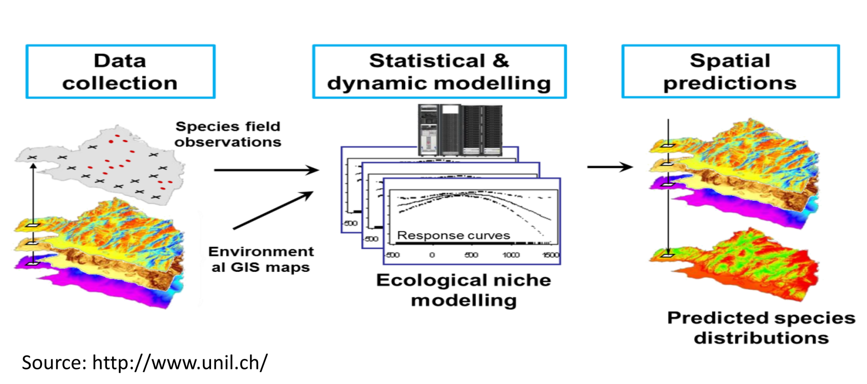
Sampling was performed in the Hornsund fjord (Spitsbergen) during routine summer R/V OCEANIA cruises performed by the Institute of Oceanology Polish Academy of Sciences in 2002, 2003, 2007, 2012 and 2014.

The environmental background covered factors known to be important for distribution and persistence of benthic fauna- topography and geomorphology (depth, slope, and rugosity), substratum (mean grain size of sediment) and near-bottom water characteristics (temperature, salinity and their derivatives—mean and range). Additionally, distance from the glacier fronts was used as a proxy for glacier outflow. Continuous maps of environmental parameters were created with the use of ArcGIS 10.1 software. The interpolation method was chosen depending on sampling design and character of each factor as to minimalize the extrapolation error.

Species distribution modelling was performed with the use of Maxent software version 3.3.3k (Phillips et al., 2006; http://www.cs.princeton.edu/~schapire/maxent/). We adopted a 'leave-one-out' jackknife approach suggested for validating models with few occurrence records (a form of k-fold cross validation where k is equal to the number of occurrence localities in the original dataset; Peterson et al., 2011; Pearson et al., 2007). Predictive performance of the model was assessed based on its' ability to predict the single locality excluded from the training data set. For statistically significant predictions we applied a LPT threshold ('lowest presence threshold' - the lowest predicted value associated with any one of the observed presence records) that identifies sites at least as suitable as those where a species' presence has been recorded. Binary maps (suitable vs. not suitable habitat) were created in ArcGIS 10.1 software with the use of this treshold.

The importance of each environmental factor was assessed automatically in the Maxent software using a permutation importance measure that determined the contribution of each factor by randomly permuting the values of that factor and measuring the resulting decrease in model quality. A large decrease would indicate that the model depends heavily on that factor. Values were normalized to give percentages. To assess a prediction's dependence on individual factors and interpret the influence of those factors on the distribution of a species, we generated response curves. The curves plots present predicted probability of suitable conditions for a species corresponding with each factor value.

HOW DOES MAXENT WORK?



Maxent identifies geographical areas of suitable conditions for species, based on known occurrence records, by applying a maximum entropy model to estimate the species' response given a set of constraints (environmental variables).

Maxent outputs: continuous probability map of species occurrence over study area, binary classification of sites as being within or outside the species distribution, statistic and plots concerning variables' importance for model, hence for species persistence and distribution

RESULTS AND DISCUSSION

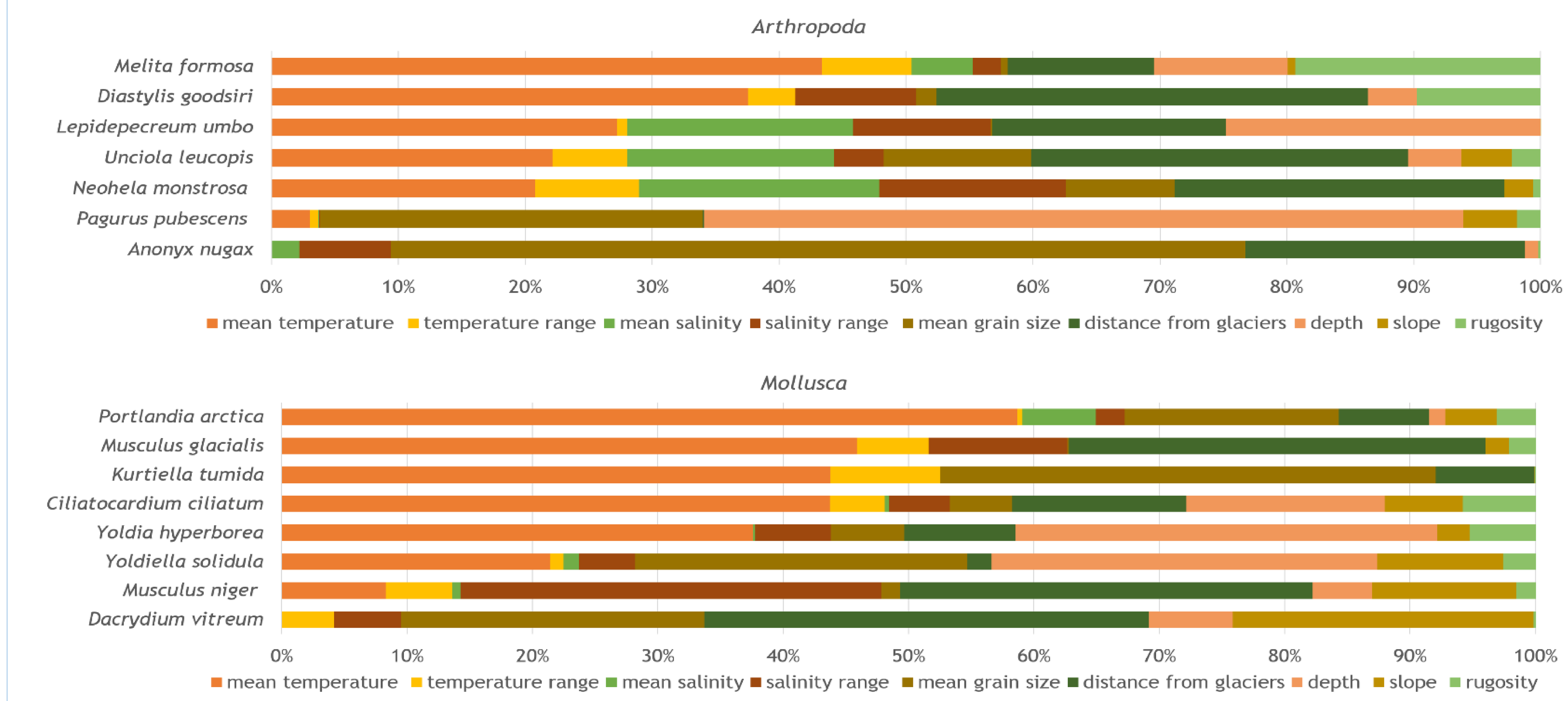


Fig. 2. Environmental factors potentially affecting benthic species collected in the Hornsund fjord and those factors' percent contribution to species distribution, as determined in the Maxent models.

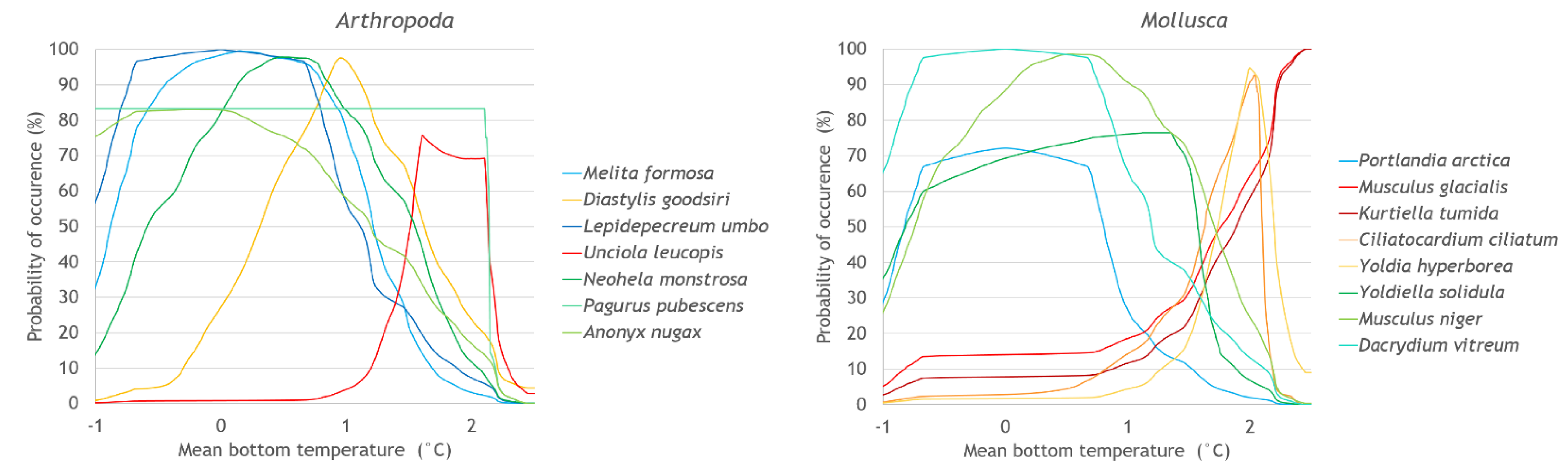


Fig. 3 Response curves of benthic species collected in the Hornsund fjord to mean bottom water temperature (derived in Maxent).

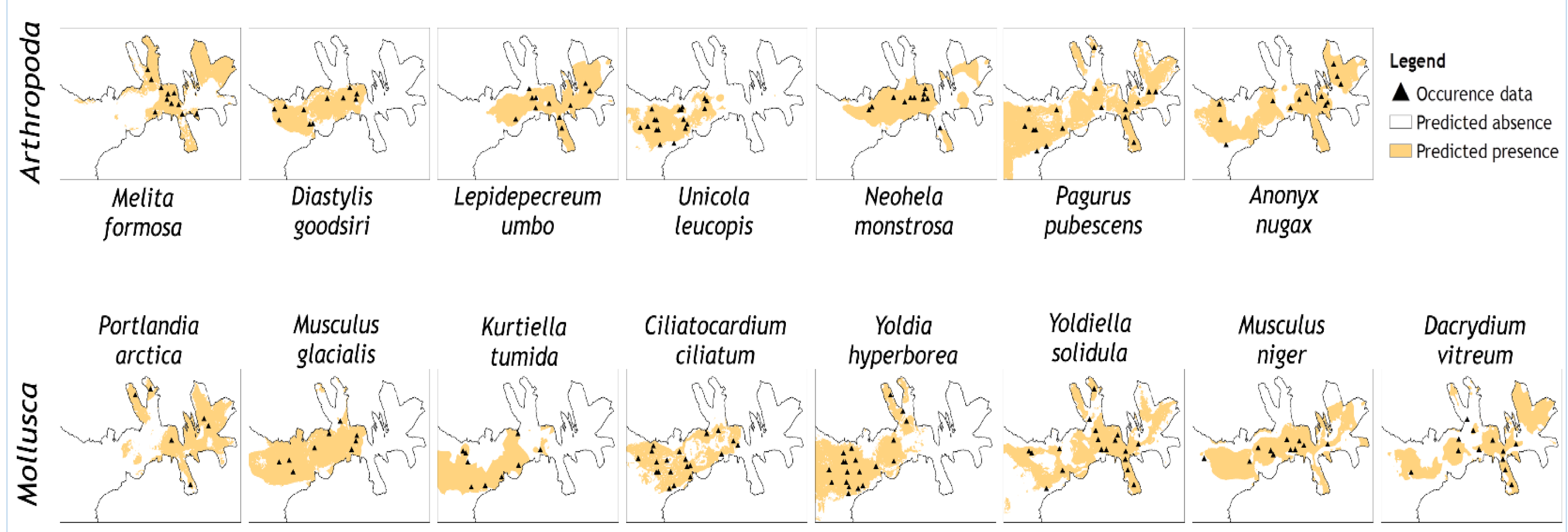


Fig. 4 Modelled distributions for selected benthic species collected in Hornsund fjord using LPT—the lowest presence threshold.

mean temperature of bottom water had one of the highest percent contribution in Maxent model creation ⇨ results confirm the importance of bottom water temperature in regulating the distribution and presence of benthic fauna in the Hornsund fjord

relationship was found between the importance of water temperature to a species distribution, the size of suitable area predicted and species response to temperature values (tolerance):

1. temperature not important, suitable habitat across most of the fjord area, broad tolerance range to temperature
2. temperature important, suitable habitat areas generally restricted to either the inner or outer basins of the fjord, narrow tolerance range to temperature - only warm (above 1°C) or cold (below 1°C) waters preferred

⇨ the preferred temperature regimes seem to be species specific and unrelated to phylum

the distribution of selected species is related to specific water masses

models predicted suitable conditions in the inner parts of the fjord for selected species ⇨ inner basins serve as potential refugia for cold water fauna threatened by the climate change-related intensification of warmer water inflows.

models predicted suitable conditions in the central and outer parts of the fjord for selected species ⇨ outer and central basins provide suitable habitats for fauna that prefers warmer waters

Results from project funded by the National Center for Science in Krakow, Poland ("Cold water benthic fauna relicts in warmed up fjords - GIS approach" - 2012/05/N/ST10/03856, "GAME" - 2012/04/A/NZ8/00661) and the Polish-Norwegian Research Programme operated by the National Centre for Research and Development under the Norwegian Financial Mechanism 2009-2014, Project Contract No DZP/POL-NOR/1876/2013 ("GLAERE").

References: Drewnik Anna, Węsławski Jan Marcin, Włodarska-Kowalczuk Maria. 2016 From the worm's point of view. II. Species Distribution Modelling of benthic macrofauna in the Hornsund fjord (Spitsbergen, Svalbard) (submitted)