Blue mussels Mytilus edulis L. and M. trossulus Gould in sympatry: assessment of ecological niche divergence using species distribution modeling

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## Abstract

Species distribution models (SDMs) describing the relationship between species occurrence and environmental parameters can be used to assess the ecological niche of a species. Usually applied to morphologically distinct species, SDMs are also a promising tool for describing niche partitioning in coexisting cryptic species. An example of the latter in the marine realm are blue mussels *Mytilus edulis* (*ME*) and *M. trossulus* (*MT*). Despite considerable research effort, little is known about how they share space and resources in sympatry anywhere except in the Baltic Sea. Salinity, substrate, surf and proximity to harbors have been suggested as candidate factors but no conclusion has been made. Here we assessed partial effects of these predictors on divergence of *ME* and *MT* in the White Sea littoral applying SDMs to 570 mussel samples with known taxonomic structure. We found that each of the predictors influenced spatial segregation. The most expected habitat of ME was a bottom substrate in a wind-exposed location with a “normal” salinity (24 ppt) away from ports and large rivers, while for *MT* it was an algal substrate in a wind-protected area with a lower salinity close to ports and large rivers. We also attempted to answer the question whether the species segregation by substrate was density-dependent and found that the degree of segregation positively depended on *ME* abundance, which is an indication that *ME* outcompetes MT on bottom substrates.We discuss whether the predictors used in our study can drive the segregation of these species outside the White Sea.

## Introduction

Species distribution models (SDMs) are a numerical tool describing the relationship between species occurrence and environmental parameters. Using SDMs, it is possible to predict distribution patterns of species in space and time and to assess their ecological niche in a formal way (Elith & Leathwick 2009). Joint application of SDMs to several coexisting species, i.e. a community, allows one to describe the partitioning of ecological niches between them. This is referred to as Joint Species Distribution Modeling (JSDM) (Ovaskainen & Abrego 2020). In other words, SDM/JSDMs may describe the axes in ecological space along which coexisting species are segregated. SDMs can be built using various approaches, from regular multiple regressions to advanced machine learning (Elith et al. 2006).

## Material and methods

### Study area

The study area was the Kandalaksha Bay, where all previous ME and *MT* studies in the White Sea have been conducted (Katolikova et al. 2016, Khaitov et al. 2018, Khaitov et al. 2023). The Bay, 185 km long, is funnel-shaped, with numerous islands and skerries and a highly indented coastline (Fig. 1). Climate is continental subarctic with 4-5 months of ice cover and the average monthly sea surface temperature in August of 13.8°C. Mean tidal range is about 2 m. Summer surface salinity is 24 ppt in most of the Bay (“normal” salinity for most of the White Sea) and lower in the estuarine areas (Berger & Naumov 2000). Two canals of a hydropower plant and 24 rivers with a catchment area of 141 – 12,830 km2 (Median 240 km2; see Stable ++ ) flow into the Bay, with the largest river, the Niva, entering the Bay at its very top. Due to the complex geometry of the shoreline and numerous rivers, local surf and salinity gradients are pronounced (Filatov et al. 2007).

Six ports operating oceanic vessels were functioning in the area in the 20th century (**Fig. 1**). Two of them, both at Bay’s top, are still in operation. The other four have been abandoned (Sailing directions of the White Sea 1932, Krasavcev 2011) but are occasionally visited by small ships (our observations).

Mussels are present everywhere in theow waters of the Bay. They are particularly abundant in the littoral fucoid belt (mainly *Fucus vesiculosus* L. and *Ascophyllum nodosum* L.), which is continuous 0.5-1.0 m above mean spring tide depth (Berger et al. 2001). According to the data from 2002–2013, both mussel species were almost ubiquitous in the Bay, but their ratio in settlements varied greatly, with *ME* being generally dominant (Katolikova et al. 2016).

#### Modeling data set