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Is the Canadian Arctic likely to be invaded by aquatic invasive species? A niche modelling study under various climate change scenarios

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Summary

The combination of global warming, resource exploitation and the resulting increase in Arctic shipping activity are expected to increase the risk of aquatic invasive species (AIS) introductions to Arctic waters in the near future. We used MaxEnt to model the potential distribution of high risk AIS into the Canadian Arctic waters. The invasive red king crab (*Paralithodes camtschaticus*) was selected to test the model performance under current environmental conditions. The predicted probability of occurrence of this species in the Canadian Arctic, particularly in Hudson Bay, resulted in a 40-60% likelihood of presence. The application of niche modelling will aid in the identification of high risk geographic locations and species to allow for more focused AIS monitoring and research efforts with current environmental conditions and also in response to climate change.

Introduction

In recent years, high-latitude areas have shown a disproportionate increase in temperature and their coasts are highly susceptible to changes in climate, hydrography, and ecology. Most aquatic invaders have gained access to North American waters through ballast water introductions and are coastal or estuarine in origin. The projected increase in Arctic shipping activity due to global warming and growth in resource exploitation are expected to increase the risk of exotic species introductions to Arctic waters in the near future (Niimi 2004; Smith and Stephenson 2013). Given that Canada has the longest coastline in the world, the majority of which is located in Arctic waters (Archambault et al. 2010), this region is at high risk of invasion (Goldsmit et al. 2014). The objectives of this study are to model species-specific potential spatial distributions and assess the probability of establishment for a subset of higher risk benthic AIS in the Canadian Arctic.

Material and Methods

An extensive bibliographic search of benthic AIS invertebrates with biological-ecological features that could potentially survive in arctic conditions and that are most likely to be introduced via ballast water was conducted. A subset of potential future high risk invaders for the Canadian Arctic were identified using the approach proposed by Ricciardi and Rasmussen (1998), where the predictions of the invasion success of aquatic organisms can be made using documented information. A total of seven species were classified as high risk: *Amphibalanus improvisus* (bay barnacle), *Carcinus maenas* (green crab), *Caprella mutica* (Japanese skeleton shrimp), *Littorina littorea* (periwinkle), *Membranipora membranacea* (coffin box bryozoan), *Mya arenaria* (soft- shelled clam) and *Paralithodes camtschaticus* (red king crab).

MaxEnt (Philips et al. 2006) was used to model the predicted distribution of these potential AIS. MaxEnt is based on the maximum entropy method for modelling species geographic distributions with presence-only data. Occurrence records of species were gathered from sources like the Global Biodiversity Information Facility (http://www.gbif.org/), Ocean Biogeographic Information system (http://www.iobis.org/) and National Exotic Marine and Estuarine Species Information System

(http://invasions.si.edu/nemesis/). Environmental data, such as sea surface temperature, salinity, bathymetry, mean open water period and ice cover presence, were collected at 1° resolution from the World Ocean Database 2013 (http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html) and the Sea Ice Index (https://nsidc.org/data/seaice_index/).

Results and Discussion

Here we present preliminary results using the red king crab (*Paralithodes camtschaticus*) as a model. *P. camtschaticus* is native to Japan seas, the Bering Sea and the northern Pacific Ocean. It was intentionally released in 1960's into the Barents Sea to create a new fishing resource, and currently has established non-indigenous populations in the Norwegian and Russian Arctic waters. In the predicted distribution map (Fig.1), the native and invaded ranges are correctly predicted, thus validating the model. The figure also shows other regions where the species would have a suitable habitat at a global scale, including Maritime region of Canada, the Gulf of St. Lawrence, Hudson Bay, Barents Sea and the South West coast of the South Atlantic Ocean. The modeled distribution of the red king crab showed medium probability of occurrence (40-60%) in Hudson Bay, specifically in James Bay region. This suggests that the Canadian Arctic currently has a region where the environmental conditions are suitable for this species. The results obtained in this study indicate that the Canadian Arctic could be at risk of invasion under current environmental conditions if this species is transported into the region. Further modelling work with future scenarios under global warming conditions is still required; nevertheless, the hypothesis is that a greater area of the Canadian Arctic will have more suitable conditions for survival of new species, increasing risk of invasion. This hypothesis applies both for the red king crab and the other potential AIS identified in this study as high risk.

The utilization of species-specific niche models will help in understanding potential risks of future AIS incursions as a result of climate change and shipping at large spatial scales. It will also provide a basis for understanding how range shifts of AIS and other species may impact the structure and functioning of marine ecosystems.

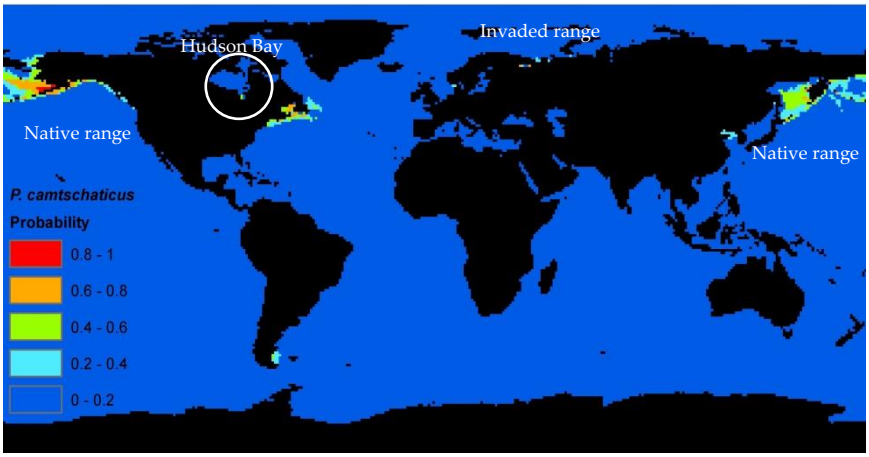

Figure 1. Global habitat suitability model for the AIS *Paralithodes camtschaticus* (red king crab) with present environmental conditions. The colors show the predicted likelihood of presence across the globe. Native and invaded ranges are highlighted. Hudson Bay region is encircled to show the area of interest.

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