Modeling the risk of introduction of non-native species by biofouling on ships' hulls: case study of Arzew port (Algeria)

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Research Article

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Abstract

Biofouling of ship hulls is considered as one of the oldest vectors for the transfer of aquatic invasive species. However, the introduction of non-native species by ballast water has received much more research attention. In this study, an alternative approach to dealing with biofouling was proposed for the port of Arzew, based on ship characteristics and transit routes. The strategy consisted of calculation of the surface area of biofouling of all ships calling at the port of Arzew during the period (2013–2016), to which was added spatial modeling using a Geographic Information System to highlight the most relevant information. We identified the areas that represented a high risk of species introduction according to their respective ecoregions of origin; those areas that constituted a minor risk, the type of ship that most likely promotes the establishment of non-native species by comparing the environmental similarity of the ecoregions assigned to the different ships with the environmental characteristics of the port of Arzew obtained by satellite imagery. The study showed that over a period of four years, 5,733 ships called at the port of Arzew, accumulating a total surface area of 35 million square meters. These results can be used for invasive species management purposes; such as: the application of specific regulations on ships of a certain tonnage that most promote the transfer of non-indigenous species, as well as their ecoregions of origin that present a great environmental similarity with the western Mediterranean, in order to minimize the transfer of aquatic invasive species.

1 Introduction

Biofouling of commercial vessel hulls is widespread and recognized as a dominant vector for the transfer and introduction of marine species beyond their natural and evolutionary range by the transfer of living organisms clinging to the hull and occupying niche spaces of ships (Fofonoff et al., 2003). In this study, we test a strategy to identify the problem of biofouling invasive species by calculating the wetted surface area of the hull that serves as potential habitat for these species, with the goal to better understand the extent of transfer of the non-native species to the Western Mediterranean.

2 Methods

To approximate the total area of biofouled ships' hulls that transited through the port of Arzew during the period from 2013–2016, we calculated the individual wet area of each of the 5,733 vessels arriving from 210 different ports (see (Bouda et al., 2017)). The second step was to use the ecoregions defined by (Spalding et al., 2007) to categorize each donor port surface. We calculated the environmental similarity between the western Mediterranean and the other ecoregions based on satellite imagery and in situ data (temperature, surface salinity).

3 Results

3.1 Wetted Surface Area by Ecoregion

The most important areas of origin of ships that have passed through the Arzew ports are in the Mediterranean basin, in the ecoregions MED-30 to MED-36, represented respectively by: the Aegean sea ecoregion with 14.96%, the Alboran Sea (MED-36) with 10.46%, the Tunisian Plateau/Gulf of Sidra with 3.20%, the Levantine Sea with 2.69%, the Adriatic Sea (0.83%) and the Ionian Sea ecoregion from Italy and the island of Malta (Fig. 1)

3.2 Risk of species introduction and survival

We have defined five arrival levels, which are classified according to the wet surface from each ecoregion. The risk level for each ecoregion is assigned based on a factor proportional to the wet surface (Fig.1). The most likely arrivals in terms of introduction are distributed between the North Sea Ecoregion (NES-25) and the Aegean Ecoregion (MED-31) with 5.7×10^6 m² in 606 trips during the 2013–2016 period (Fig. 2).

Ecoregions with a high environmental similarity to the Western Mediterranean are distributed in all the world’s seas and oceans, including the Japan Sea Ecoregion (CTNP-49), the East China Sea Ecoregion (WTNP-52) in the North Pacific; these areas pose a major threat to indigenous ecosystems as maritime transport increased to and from the Asian seas. The Mediterranean bioregions (MED-30, MED-32, MED-34) are secondary introduction risks, both from their great similarity to the Mediterranean West and the coastal navigation of ships coming from these areas as well as contact with the Red Sea, which shares the same climatic conditions in the Mediterranean West, promotes bio-invasion (Figs. 3, 4).

4 Discussion

The WSA of the fleet of 5,733 vessels that called at the port of Arzew between 2013 and 2016 was 3.57×10^7 m². To put this value in context, it is equivalent to 34% of the size of Paris. Spatial analysis of the risk of arrival and survival of non-native species from 38 ecoregions in 3,173 trips; shows that the most likely arrivals in terms of introduction are distributed between the North Sea Ecoregion (NES-25) and the Aegean Ecoregion (MED-31) The environmental similarity between these ecoregions and the western Mediterranean is high, and non-native species from these areas have a high chance of survival if they are not eliminated during the journey (Figs. 3, 4).

5 Conclusions

The implementation of environmental parameters in this study, as well as the shipping routes linking the ecoregions to the port of Arzew, allowed us to analyze on average the capacity of species to resist the stress generated by the voyage and their ability to adapt. The results are in line with Zenetos studies on the Mediterranean Sea (Zenetos et al., 2012), and with observations by (Grimes et al., 2018) and (Bensari et al., 2020) and other reports of introductions into the Mediterranean Sea. At the end of this study, we can suggest the introduction of specific regulations on the refit of the two categories of ships: OIL/CHEMICAL TANKER and LPG TANKER. We also recommend the passage of ships coming from the coastal ecoregions "MED-30 to MED-34, L-29, L-28 and L-27" through leaching areas that cause great

environmental stress to fouling species, such as the "Black Sea" in order to minimize the biofouling of their hulls.

Declarations

Conflicts of interest/Competing interests:

The study does not present any conflict of interest.

Authors' contributions:

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Adel KACIMI, Abderrahmane BOUDA, Bilel BENSARI, Nour El Islam BACHARI and Fouzia HOUMA. The first draft of the manuscript was written by Adel KACIMI and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

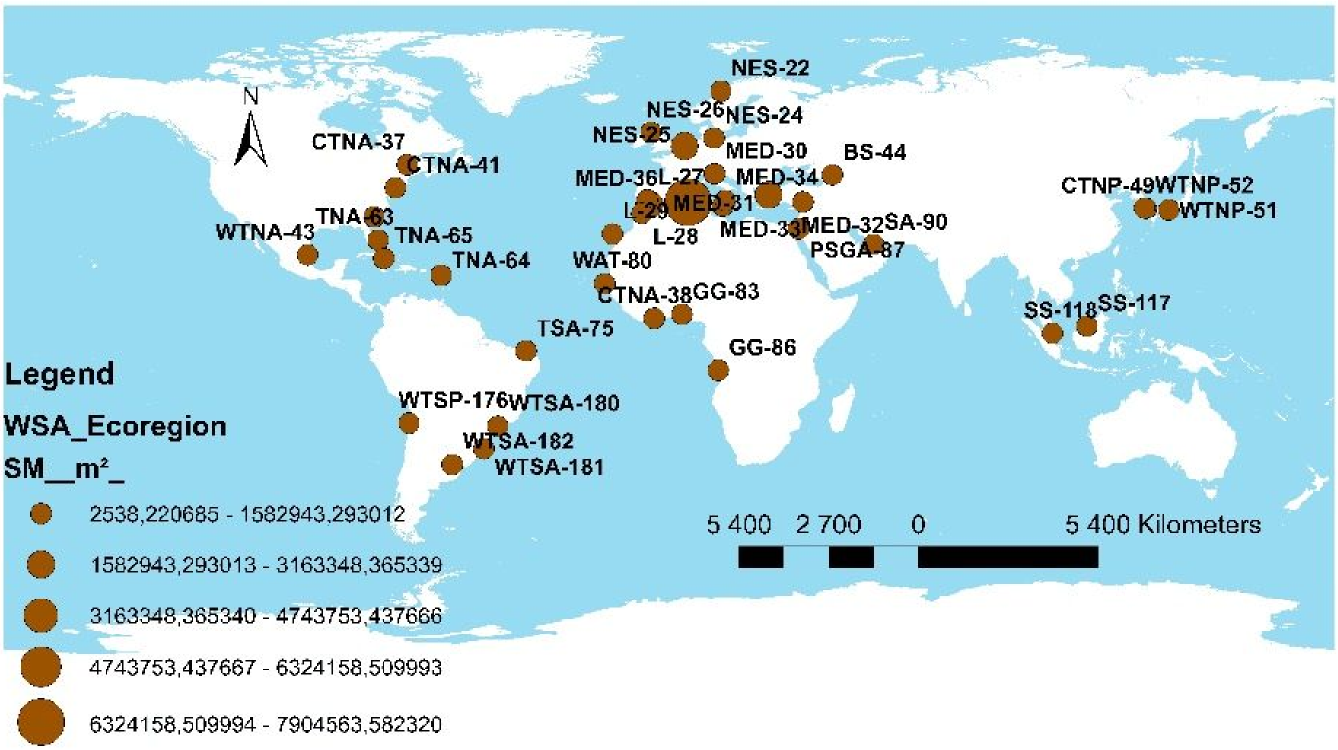

Figure 1

Map showing the wet surface by ecoregion of origin (2013-2016). Created by the author. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

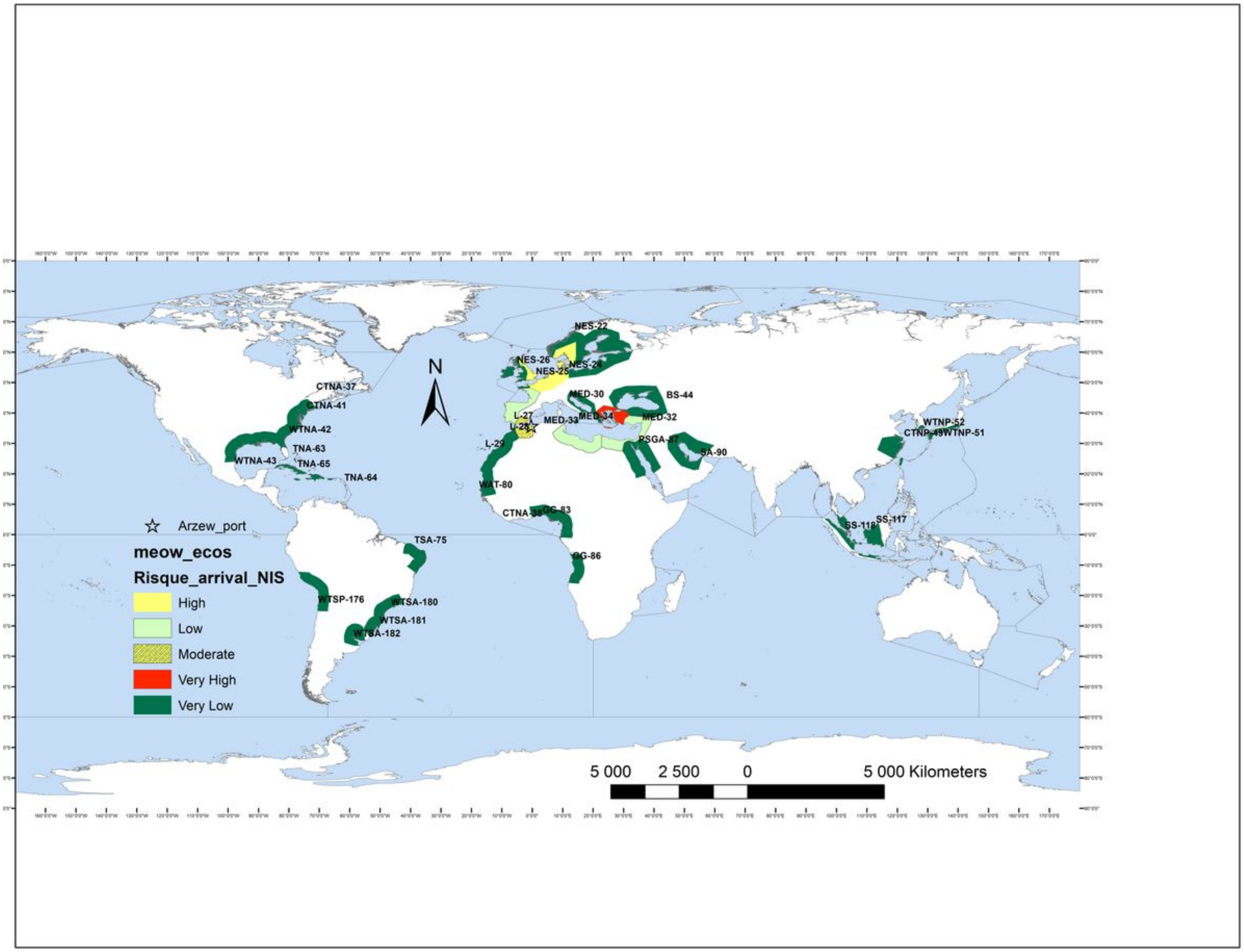

Figure 2

Map showing the risk of non-native species arriving by Ecoregion. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

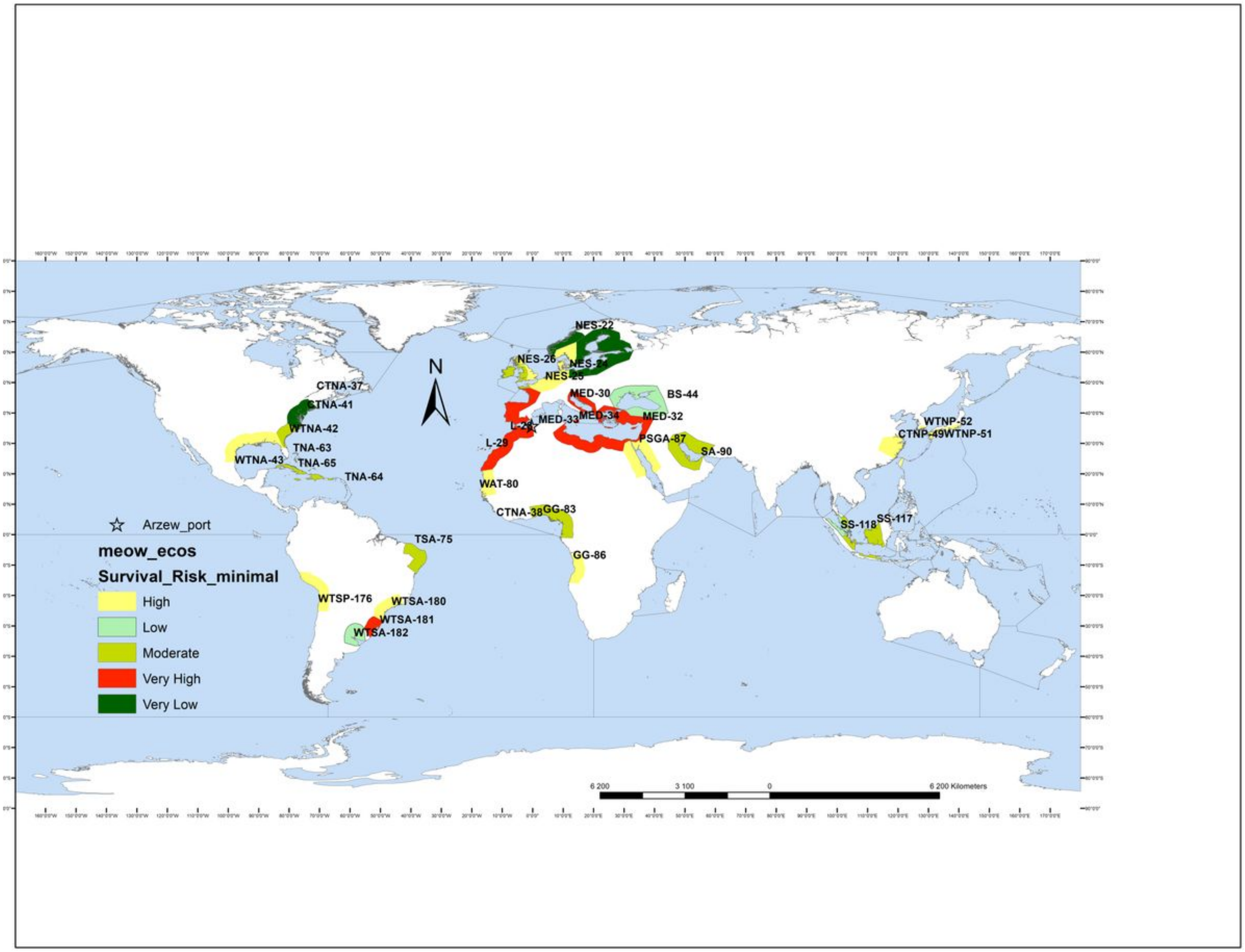

Figure 3

Map illustrating spatial pattern of all donor Ecoregions in the world, according of their category of minimal survival risk (2013–2016). Created by author. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

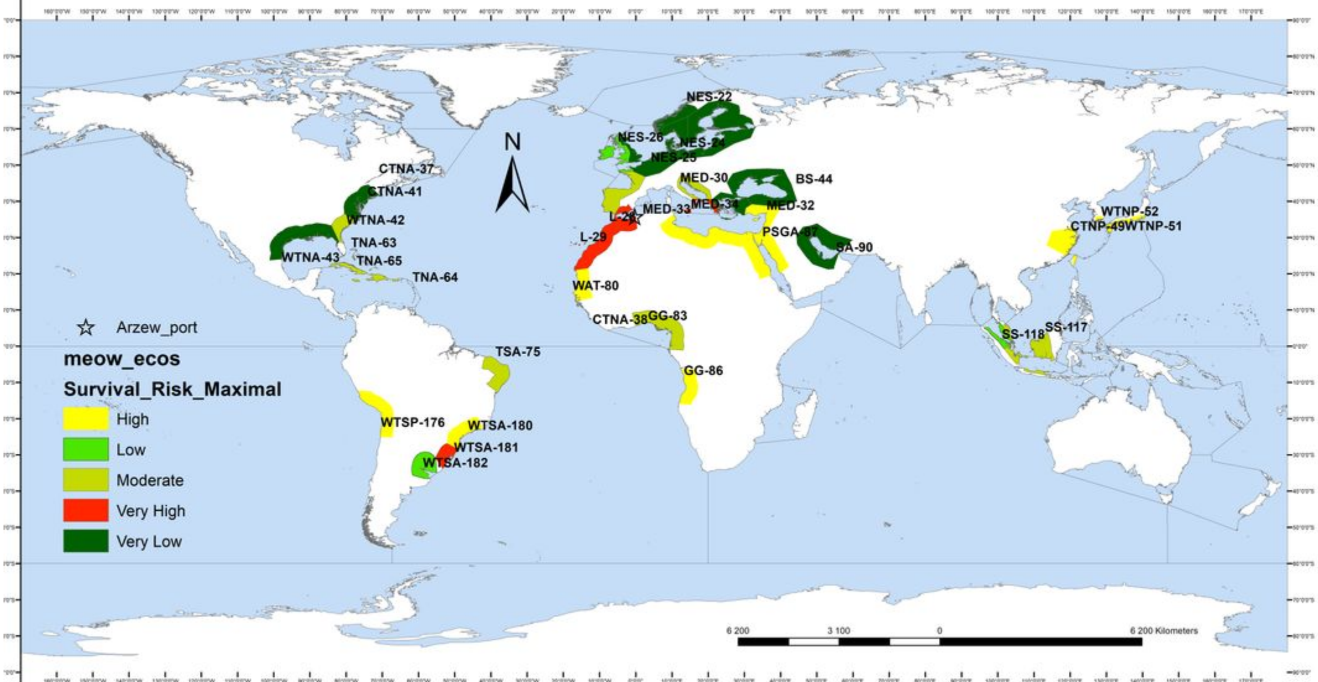

Figure 4

Map illustrating spatial pattern of all donor Ecoregions in the world, according of their category of maximal survival risk (2013–2016). Created by author. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.