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# Oceans apart, Part 2: Predicting Invasive Species from Biogeographic Patterns

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The introduction and establishment of an aquatic invader can be viewed as occurring in four discrete phases: (1) the potential invader is taken up by a transport mechanism (vector) and survives the transport, (2) the potential invader survives release into the new environment, and (3) the invader establishes a self-sustaining population at or near the locality of initial release; and for "invasive" species, (4) the potential invader undergoes a population "explosion" and expands its range into new localities. Comparisons of the spatial distributions of nonnative species within and among biogeographic regions is one approach to identifying which species have the physiological/ecologic characteristics to allow them to pass through at least the first three of these phases, and thus represent an invasion risk to other geographic areas.

In this study, we used the distributions of nonnative marine/estuarine macrobenthos in the Northeast Atlantic and Northeast Pacific to identify high-risk invaders for both of these biogeographic regions. A literature review identified approximately 80-90 nonnative macrobenthic invertebrates in marine to brackish environments of the Northeast Atlantic, including the Baltic Sea. In comparison, in our database, the Pacific Coast Estuarine Information System (PCEIS) more than 200 nonnative macrobenthic species are presently recorded for estuaries of the Northeast Pacific, defined here as California, Oregon, and Washington, U.S.A. A relatively high overlap exists among these species, such that 40-50% of the Northeast Atlantic invaders also occur in the Northeast Pacific. Rather than being donor regions for each other, the two regions share invaders from other biogeographic regions, in particular the Northwest Atlantic (U.S. east coast) and the West Pacific (New Zealand to Japan). The high overlap of invaders indicates that the environments in these two geographic regions are sufficiently similar that they can be used as “surrogates” for each other. Thus, the nonoverlapping invaders in each region represent an initial list of species that have a high potential for invading either the Northeast Atlantic or the Northeast Pacific.

To identify which nonoverlapping invaders have a greater likelihood of invasion in the uninvaded geographic region, we evaluated their present range in the invaded region. This approach assumes that invaders with larger geographic ranges have suites of characteristics that promote their transport into and establishment in new environments. To identify potential invaders for the Northeast Atlantic, we used the number of estuaries from which each nonoverlapping Pacific coast invader has been reported, as well as their latitudinal range, to exclude invaders primarily occurring in southern California. Using this approach, we identified a suite of species with the greatest likelihood of invasion into the Northeast Atlantic, including several species of spionid and ampharetid polychaetes, amphipods of the genus Monocorophium and Grandidierella japonica, and the ectoproct Schizoporella unicornis. These potential invaders include species from both the U. S. east coast and Asia. Although we have less detailed information on the distribution of invaders in the Northeast Atlantic, two widespread species that appear to be high-risk invaders for the U. S. Pacific coast are the barnacle Elminius modestus and the bivalve Ensis americanus.

We also conducted a preliminary evaluation into whether the biogeographic range of an invader in one region was a predictor of its range in another region. A high correlation among ranges would suggest that a species range in one biogeographic region could be used to predict whether it would become invasive (the fourth phase of an invasion) in a new geographic region. Specifically, we compared the extent of distributions of the overlapping species given in an analysis of North Sea invaders with the number of estuaries in which the same species have been reported on the U. S. Pacific coast. Certain invaders were widely distributed in both regions, such as the bivalve Mya arenaria. However, the correlation among ranges in the two regions showed several exceptions that may reflect differences in estuarine environments in the two biogeographic regions. Invasion history also appears to play a role. For example, a limited North Sea distribution was reported for the caprellid amphipod Caprella mutica, even though it occurs in at least 14 estuaries on the U. S. Pacific coast, ranging from San Diego in southern California to Puget Sound. However, Caprella mutica is a recent invader in the Northeast Atlantic, where its first reported occurrence was in 1995, in comparison with the mid-1970s on the U. S. Pacific coast. Recent reports of the spread of this species in the North Sea and its wide distribution on the U. S. Pacific coast suggest that this amphipod has the potential of becoming a widespread invader in the Northeast Atlantic.

As invasion biology struggles to become a more predictive science, we suggest that an analysis of regional and global patterns of invasion is one approach to identifying species with a high invasion potential (phases 1-3) and, possibly, which species will become invasive (phase 4). Combining such analyses with invasion histories and an understanding of vectors will further increase the predictive power of this approach. Additionally, incorporating habitat/niche requirements will also increase the predictive power and may help explain why an invader is widespread in one region but limited in range in another.