APPENDIX D. GARP POWER OF PREDICTION ANALYSIS

DETAILS OF HOW GARP POWER OF PREDICTION ANALYSIS WAS USED

If environmental conditions within a particular region of the Great Lakes differ from those near a species' currently occupied range, then a prediction about the suitability of habitat cannot be made (null prediction). A prediction cannot be made because no information exists to predict whether a species under these novel conditions will or will not find suitable habitat. Unfortunately, the Genetic Algorithm for Rule-set Production (GARP), along with most species distribution models, simply predicts environments that are non-analogous to the environments found near the species' currently occupied range to be unsuitable. But, in reality, such "null" areas may actually be habitable by the species. GARP power of prediction analysis was conceived to distinguish areas that do not provide suitable habitat (predicted absence) from areas for which a prediction cannot be made (null prediction). More details about the theoretical basis for using GARP power of prediction analysis are provided in Section 3.5. The remainder of Appendix D presents the specific application of GARP power of prediction analysis to this study.

Power of prediction analyses were performed for 11 of the 14 species to help distinguish the regions for which a prediction could be made from regions where a prediction could not be made for each species. Power of prediction analysis was not performed for two of the invasive species already established in the Great Lakes, quagga mussel (*Dreissena bugensis*) and round goby (*Neogobius melanostromus*), because of a lack of occurrence data outside the Great Lakes (i.e., these species had no distribution data describing their home range, the basis for a power of prediction analysis). Also, because GARP models predict that the blueback herring (*Alosa aestivalis*) may potentially find the entire Great Lakes region as suitable habitat, no power of prediction analysis is needed, because power of prediction analyses are only concerned with areas of predicted absence.

Power of prediction analyses for species can be grouped if they share a similar home range region, eliminating the need to perform separate power of prediction analysis for each species studied. The 11 species had home-range occurrence data originating from one or more of four large regions: the northwest Pacific coast of North America, the northeast Atlantic coast of North America, the southeastern coast of Australia, and a large region comprising the northern coast of Europe and Northern Africa. Thus, we performed four power of prediction analyses.

As discussed, power of prediction analyses are only concerned with areas of predicted absence. Therefore, no power of prediction analyses were required for those species originating from southeast Australia and the Atlantic U.S. regions because the models developed for species from these regions predicted the entire Great Lakes region as suitable habitat. Similarly, no power of prediction analysis was performed for the U.S. Pacific coast region because (1) only the New Zealand mud snail, (*Potamopyrgus antipodarum)* had occurrence points within this region and (2) this species was already predicted to be fairly widespread within the Great Lakes. Thus, only Europe and North Africa remained as regions on which to focus power of prediction analyses. This complex region was subdivided into three sub-regions: the United Kingdom and northern Europe (designated UK) shoreline, the Baltic Sea, and the Ponto-Caspian Sea. GARP power of prediction analyses were performed on combinations of these regions. The gray shaded regions in Figures 7–17 and 24–27 reflect the results of the GARP power of prediction analysis.

Reverse power of prediction analysis, which processes in the opposite direction from invaded range to home range, was also performed, but these results are not included here. When we looked globally for places with conditions similar to those in the Great Lakes, we found largely salt-water environments at homologous latitudes. This result is not surprising because the vast majority of the earth's surface waters are oceanic. Assuming that salinity represents a dispersal barrier, most species found in these saline, but otherwise similar aquatic environments, would not be able to survive in the freshwater of the Great Lakes.

GROUPED RESULTS FOR 11 SPECIES

Figures D1 through D3 show the results of the GARP power of prediction analyses. Multiple species are shown in most figures because the species are grouped according to the presence of species occurrence points in each sub-region. Each of the 11 species collectively shown in D1 through D3, can be associated with a corresponding GARP figure (Figures 8-17 and 31-34). Similar to the GARP predictions, the power of prediction analyses produced a continuous measure of the ability to predict by adding the binary presence/absence outcomes from the best 100 GARP models out of 1,000 total models constructed. For clarity, we simplified the figures by converting these continuous predictions into two areas: areas where prediction is possible (shown in red) and areas where prediction is not possible (shown in black). Red areas represent location where more than 50 percent of the models have predictive power and black areas depict locations in which less than 50 percent of the models could predict presence or absence.

The power of prediction analyses for the fishhook waterflea, the roach, the rudd, and the ruffe (see Figure D1) indicate that GARP can make predictions for these species everywhere throughout the Great Lakes except for a central deep-water portion of Lake Superior. GARP originally predicted a rather limited group of areas as susceptible for invasion by roach and rudd. Coupled with the power of prediction analysis for these two species, we can conclude that indeed, most of the areas thought to be low-risk areas are in fact predicted by the models as low-risk areas. Similarly, Lakes Erie and Ontario were predicted to be particularly suitable for invasion by both species, and the power of prediction analysis showed that the modeling approach had good predictive capabilities within these two lakes. Susceptibility to invasion by these two species in the upper Great Lakes was predicted to be limited primarily to near-shore areas, and the power of prediction analysis shows that many of the areas predicted to be not susceptible to invasion by these two species fall well within the red areas determined to be predictable by GARP. Thus, these, too, are valid predictions of low risk of invasion by roach and rudd. Therefore, the GARP model results, coupled with the power of prediction analysis, successfully identify large areas of the Great Lakes as definitely unsuitable for invasion by roach or rudd. These areas represent an opportunity for effectively focusing effort and resources for monitoring these species.

The power of prediction analysis for the zebra mussel and New Zealand mud snail indicate a large area within the Great Lakes that is predictable by GARP (see Figure D2 top panel). Much of the area that is indicated as predictable based on the power of prediction analysis is predicted to be highly susceptible to invasion by these two already-established NIS. The GARP models predict that the deep-water areas of Lake Superior should be unsuitable and, therefore, not at risk of future invasion by these species. However, the power of prediction analysis for these species indicates that this area is simply not predictable. Therefore, the risk to central Lake Superior from invasion by these two species is, at this point, undeterminable by GARP models alone. GARP predictions show parts of Lake Huron to be at low risk from the New Zealand mud snail and the power of prediction analysis shows that these areas can be well predicted by GARP.

The set of power of prediction analyses that were performed for *Corophium curvispinum*, monkey goby, tubenose goby, and tench indicate that large areas within the Great Lakes are not predictable by GARP (see Figure D2 lower panel). GARP predictability zones (red areas) are restricted to Lake Erie, the southern half of Lake Ontario, and the southernmost tip of Lake Michigan. All four of these potential invasive NIS were predicted by GARP models to encounter large areas of the Great Lakes that were unsuitable as habitat, which could be classified as immune to invasion. Many of these predicted absence areas actually fall within the black zone of the power of prediction analysis, within which no GARP prediction can be made. From the GARP predictions alone, these extensive areas would have been interpreted by managers as no-invasion-risk zones. However, the areas actually are no-prediction possible zones, meaning they might be susceptible to invasion and they might not. Without the benefit of the power of prediction analysis, this condition would not have been known from the GARP predictions alone. The power of prediction analysis prevents this critical misinterpretation.

When viewed in conjunction with the corresponding GARP power of prediction analysis figures, the results present a clearer prediction of invasion-susceptible habitat areas. Without power of prediction analysis, only 5 species (the blueback herring, the sand goby, the zebra mussel, the ruffe, and the New Zealand mud snail) are predicted by GARP models to be able to find suitable habitat throughout the Great Lakes. With the power of prediction analyses, it is possible that the entire Great Lakes region could also be susceptible to three additional potential invasive species: *C. curvispinum*, the tubenose goby, and the round goby. Managers cannot rule out much of the Great Lakes as unsuitable for these three species, as was suggested by the GARP predictions alone.

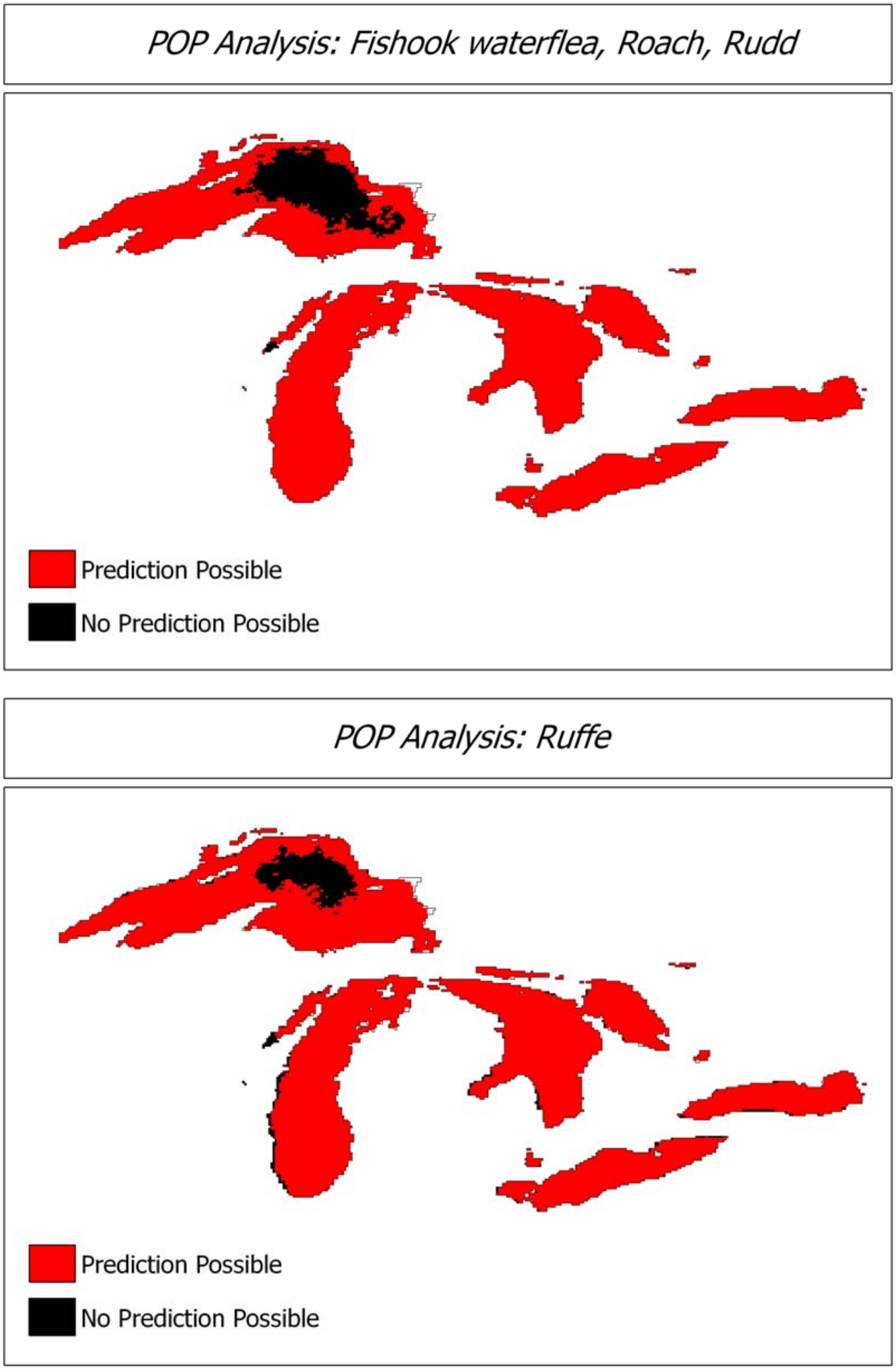
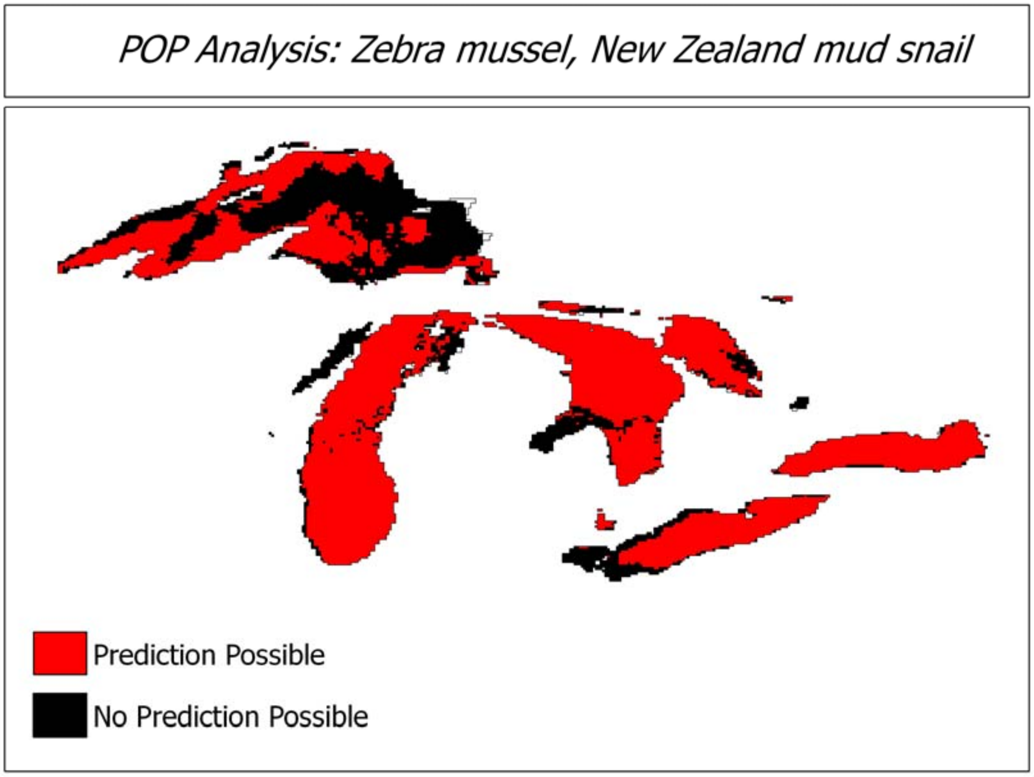


Figure D-1. Power of prediction analysis for fishhook waterflea, roach, and rudd (top) and ruffe (bottom)



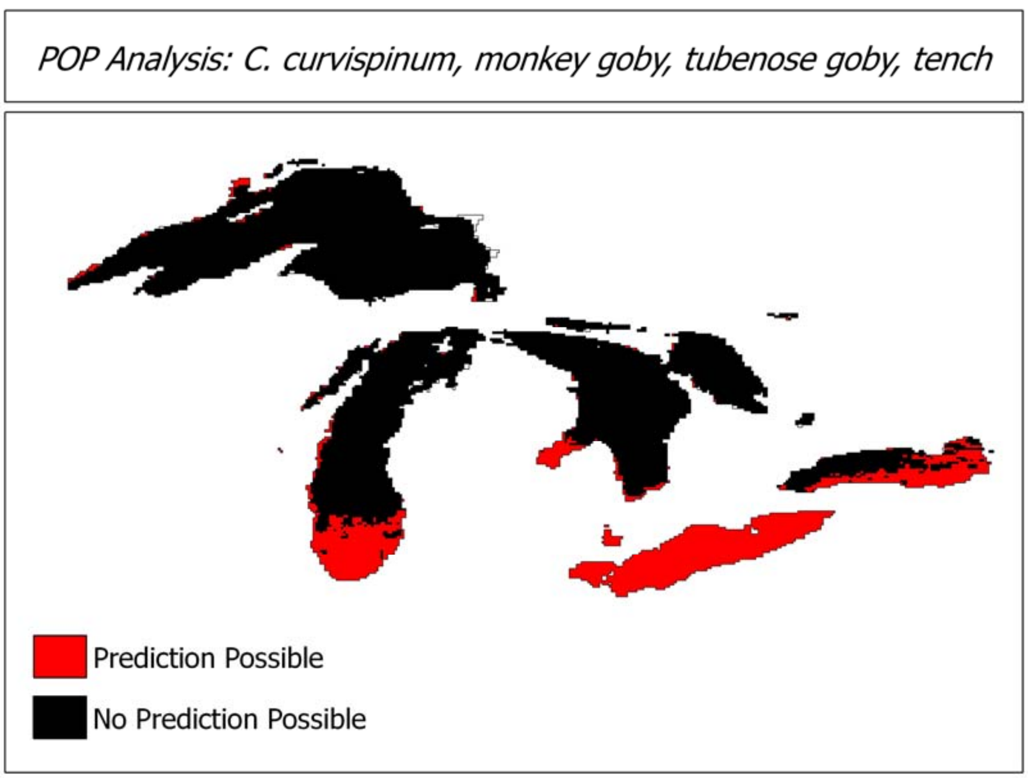


Figure D-2. Power of prediction analysis for zebra mussel and New Zealand mud snail (top) and *C. curvispinum,* monkey goby, tubenose goby and tench (bottom).

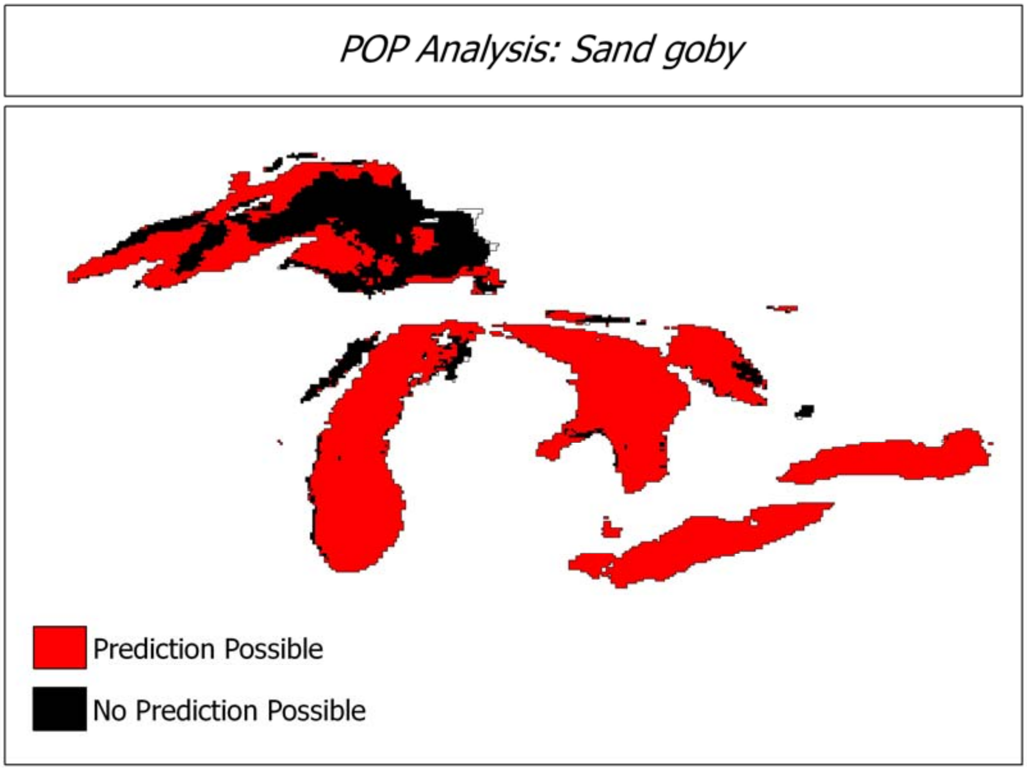


Figure D-3. Power of prediction analysis for sand goby.