Predicting the potential distribution of a new Caribbean invader using a species distribution model

Predecir la distribución potencial de un nuevo invasor caribeño utilizando un modelo de distribución de especies

Prédire la distribution potentielle d'un nouvel envahisseur des Caraïbes à l'aide d'un modèle de distribution des espèces

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EXTENDED ABSTRACT

Alien species represent a major threat to biodiversity worldwide through a myriad of effects such as altering fundamental ecological processes, transforming habitats, and changing community structure through competition, predation, and grazing (Mack et al. 2000, Molnar et al. 2008). Successfully established marine alien species have resulted in economic losses to fisheries and tourism (Pimental et al. 2005) and ecological effects including a shift in benthic community and composition (Lowe et al. 2000) and a decrease in the abundance and diversity of recipient communities (Gallardo et al. 2016). Managing marine alien species has several obstacles. The largest issue is that the ocean is a highly connected system that allows for vast dispersal of species through swimming or a passive larval stage. Examples of eradication in marine environments are rare, and therefore, management goals should focus on the prevention of introductions and reducing population sizes of already established species to levels that minimize ecological impacts (Green and Grosholz 2020).

Neopomacentrus cyanomos (regal demoiselle; referred to as 'regals' from here on), an Indo-Pacific native, was first observed in the Gulf of Mexico on several reefs near Coatzacoalcos, Mexico in 2013 (González-Gándara and de la Cruz-Francisco 2014) and has rapidly spread throughout the northern coastal regions with its invasion front now near the Florida Panhandle. In addition to the spread in the Gulf of Mexico, a second point of introduction was discovered in Trinidad in 2019 (Robertson et al. 2021a, Robertson et al. 2021b) followed by observations of individuals around the island of Aruba shortly after. With little known about the ecology of this species, trying to understand their distributional patterns and habitat requirements can help identify potential impacts and aid in the development of a management strategy to limit or slow range expansion.

The geographic range of a species is often determined by abiotic environmental conditions, biotic interactions, and dispersal limitation. Species distribution models (SDMs) are a valuable research tool that correlates a species occurrence or abundance with these drivers to predict that species' suitable habitat in response to climate change, invasion, or tropicalization (Franklin 2009). When created for an alien species, these models require geospatial occurrence data from both the native and invasive ranges for the species of interest and environmental variables to make the best prediction of the species' potential distribution or future invasion (Jiménez-Valverde et al. 2011). SDMs can aid resource managers in time-efficient and cost-effective monitoring and removal of alien species in areas predicted to have highly suitable habitat for the focal species. Here, we used an SDM to examine which environmental conditions determine the presence of regals and predict where in the Greater Caribbean they are likely to invade next to provide vital information to conservation managers.

Using the Software for Assisted Habitat Modeling within the VisTrails software (Freire et al. 2006), we tested four model algorithms to forecast potential range expansion of the new Caribbean invader, the regal damselfish. Models were built using independent training and testing data that contained presence and absence points observed in both the native and invasive ranges and a suite of environmental predictors (e.g., maximum sea surface temperature, average pH, water depth) collected from online databases. Native occurrence points included extensive distributional data sets from collaborators (Australian Institute of Marine Science and the Wildlife Conservation Society) for regals along the entire Great Barrier Reef and east coast of Africa, as well as publicly available datasets and peer-reviewed literature all of which provided broad-scale habitat preference for this species within their native range. Invasive range occurrence points included data that was personally collected by the lead author, sightings reported to the U.S. Geological Survey non-indigenous aquatic species database, and surveys from peer-reviewed literature. We compared models developed using only native occurrences, only non-native occurrences, and a final model incorporating all occurrence points to determine if different variables were driving regal distributions in the separate ranges. Lastly, the top performing model algorithms were projected over the Greater Caribbean to visualize the areas regals are most likely to invade next and the entire potential extent of their invasive range.

The generalized linear algorithm for all models performed similarly and ranked the same top three most important predictors to determine the distribution of regals: depth, minimum salinity, and the average current velocity. Our model results suggest that suitable habitat for this species is relatively shallow (<50 m), includes both brackish and normal ocean salinities (24-37 ppt), and has low to moderate current velocity (0.0–0.4 m/s). In addition, two other variables relating to temperature helped the model predict the suitable habitat of regals: maximum sea surface temperature and the annual temperature range. From these, the results suggest this species prefers warm surface temperatures (>28 ºC) and habitats that experience either small or moderate annual thermal fluctuations (0-15 ºC).

Our results suggest that regals could continue to expand their distribution into most tropical and sub-tropical coastal regions in the western Atlantic Ocean but may be bound latitudinally by temperature, especially at shallow depths in areas that experience extreme seasonal fluctuations. This species is not limited to fully marine habitats and should be monitored for in bays and estuarine systems as well. However, the distribution of regals likely excludes areas of high exposure. This may be more relevant at a finer-scale, determining which reef zone they may reside in.

Our SDM highlights that much of the Greater Caribbean is at risk for the invasion of regals. Due to the lack of extensive natural reefs, the current invasion front in the Florida Panhandle may be an effective area to slow the spread of this species to South Florida through removal of individuals on artificial reefs. If the spread continues, South Florida may act as a gateway to islands in the northern Caribbean, as seen for the invasive lionfish. These findings can be used to design efficient monitoring techniques for new populations of regals in areas our SDM predicts highly suitable habitat. Finally, our results are informative for raising awareness of this new invader and identifying Caribbean islands at risk for future range expansion.

KEYWORDS: Alien Species, Species Distribution Model, Conservation, Management

LITERATURE CITED

Franklin, J. 2009. *Mapping Species Distributions: Spatial Inference and Prediction*. Cambridge University Press.

Freire, J., C. T. Silva, S. P. Callahan, E. Santos, C. E. Scheidegger, and H. T. Vo. 2006. Managing rapidly-evolving scientific workflows. In International Provenance and Annotation Workshop. pp. 10-18. Springer: Berlin, Heidelberg.

Gallardo, B., M. Clavero, M. I. Sánchez, and M. Vilà. 2016. Global ecological impacts of invasive species in aquatic ecosystems. *Global Change Biology* **22**(1):151-163.

González-Gándara, C., and V. De la Cruz-Francisco. 2014. Unusual record of the Indo-Pacific pomacentrid *Neopomacentrus cyanomos* (Bleeker, 1856) on coral reefs of the Gulf of Mexico. *BioInvasions Records* **3** (1):49-52.

Green, S. J., and E. D. Grosholz. 2020. Functional eradication as a framework for invasive species control. *Frontiers in Ecology and the Environment* **19** (2):98-107.

Jiménez-Valverde, A., A. T. Peterson, J. Soberón, J. Overton, P. Aragón, and J. M. Lobo. 2011. Use of niche models in invasive species risk assessments. *Biological Invasions* **13**(12):2785-2797.

Lowe, S., M. Browne, S. Boudjelas, and M. De Poorter. 2000. 100 of the world's worst invasive alien species: a selection from the global invasive species database. Auckland: Invasive Species Specialist Group.

Mack, R. N., D. Simberloff, W. Mark Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* **10**(3):689-710.

Molnar, J. L., R. L. Gamboa, C. Revenga, and M. D. Spalding. 2008. Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment* **6**(9):485-492.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* **52**(3):273-288.

Robertson, D., O. Dominguez-Dominguez, M. Solís-Guzmán, and K. Kingon. 2021a. Origins of isolated populations of an Indo-Pacific damselfish at opposite ends of the Greater Caribbean. *Aquatic Invasions* **16**.

Robertson, D., K. Kingon, S. Baksh, C. Estapé, and A. Morgan Estapé. 2021b. The Indo-Pacific damselfish *Neopomacentrus cyanomos* at Trinidad, southeast Caribbean. *Aquatic Invasions* **16.**