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Conference Abstract

Climate change may constrain rather than promote invasion: high-resolution forecasting of *Vespa crabro* in a Mediterranean island hotspot

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Abstract

Whether climate change will facilitate or constrain invasive alien species (IAS) remains a central unresolved question in invasion science, particularly in Mediterranean biodiversity hotspots where warming and aridification may alter invasion trajectories in non-linear ways. Robust local-scale forecasts are often limited by coarse environmental data, heterogeneous sampling effort, and spatial autocorrelation, reducing their reliability for management applications.

Here, we developed a high-resolution climatic suitability forecasting framework for the alien European hornet *Vespa crabro* in Sardinia (Italy) (Pusceddu et al. 2019; Pusceddu et al. 2022), a Mediterranean island where the species was introduced in 2010 and currently shows a limited but expanding distribution in the northern sector. We integrated 303 spatially filtered and validated citizen-science occurrences, 40-m island-specific bioclimatic predictors, kernel density-based bias surfaces for pseudo-absence selection, spatial block cross-validation, and three tuned machine-learning algorithms (Artificial Neural Network (ANN), Gradient Boosting Machine (GBM), Random Forest (RF)) replicated across pseudo-absence sets and spatial folds (150 individual models) (Phillips et al. 2009; Barbet-Massin et al. 2012; Hijmans 2012; Roberts et al. 2017; Valavi et al.

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2019). Individual models were filtered using performance thresholds (Receiver Operating Characteristics (ROC) and its Area Under the Curve (AUC), AUC ≥ 0.7; True Skill Statistic, TSS ≥ 0.4), then weighted by validation performance and averaged into an ensemble forecasting model to project current and future suitability under SSP2-4.5 and SSP5-8.5 scenarios for 2040 and 2060. The obtained ensemble model was evaluated using the above-mentioned evaluation metrics and plotting the ROC curve.

The final ensemble achieved high predictive performance (ROC = 0.95 ± 0.02; TSS = 0.78 ± 0.06), with Annual Mean Temperature and Precipitation of the Driest Month accounting for 61% of model contribution. Current projections identified extensive climatically suitable habitats across northern Sardinia, most coastal areas, surrounding small islands, and several inland mountainous sectors not yet colonized. In contrast, all future scenarios predicted strong range contraction, with climatically suitable habitat declining by 91.02–98.98% depending on scenario and time horizon, primarily through loss of coastal suitability.

These projections suggest that future Mediterranean warming and altered precipitation regimes may progressively exceed the favorable climatic envelope of *V. crabro*, likely constraining rather than promoting its long-term persistence and spread in insular Mediterranean systems (Fig. 1). More broadly, our findings challenge the widespread assumption that climate change universally enhances invasion risk and highlight the need for species-specific, fine-resolution forecasting to support adaptive surveillance, prioritization, and management of invasive species under climate change.

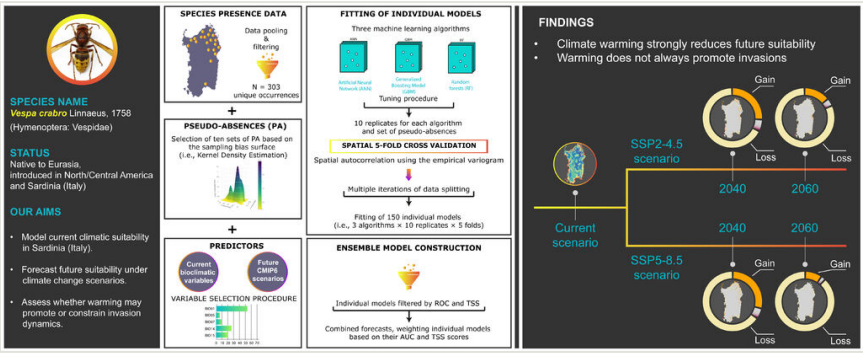

Figure 1.

Flowchart showing the approach adopted to predict Vespa crabro distribution under current conditions and two climate and socio-economic scenarios for twotemporal horizons (2040 and 2060), using an ensemble framework with three machine learning algorithms: Artificial Neural Network (ANN), Generalized Boosting Model (GBM), and Random Forest (RF)

Beyond this case study, the proposed workflow demonstrates how citizen-science data, bias-aware pseudo-absence generation, spatially explicit validation, and ensemble forecasting can be integrated into reproducible invasion-risk assessment frameworks for operational decision support.

Keywords

Alien species, Climate influence, European hornet, Mediterranean island, Social wasp, Climatic suitability models

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Conflicts of interest

The authors have declared that no competing interests exist.

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