



Original Articles

Presence-only modeling is ill-suited for a recent generalist invader, *Anthidium manicatum*

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ABSTRACT

Anthidium manicatum, the European wool-carder bee, is an invasive species of concern given its worldwide invasion and aggressive behavior towards native pollinators. Predicting habitat suitability for this species is imperative for estimating threat to native species, and predicting future spread. Previous habitat suitability models used bioclimatic variables to make predictions across a broad geographic region, but these showed little utility at predicting risk at the local habitat scale. Therefore, we created a model using environmental inputs that vary across a regional scale (land cover type and percent impervious surface) and focused within a more restricted geographic region, the Northeastern (NE) US. Occurrence records were aggregated from open-sourced data and published records, and maximum entropy methods were used to create the model. We created a second model using bioclimatic variables (temperature and precipitation), to compare utility of both model inputs. We then tested the accuracy of both models by performing weighted random sampling and stratified random sampling across the NE to obtain presence and absence data for *A. manicatum*. Given previous predictions of widespread habitat suitability, it was surprising that out of 140 sampled locations, *A. manicatum* were only found at seven. When comparing model accuracy (Cohen's Kappa), both models showed low accuracy (land use variables KHAT = 0.023; bioclimatic variables KHAT = -0.094). Models were also not significantly different from each other ($Z = 0.548$). Therefore, presence-only modeling may not be suitable for this system, either because these variables are not capturing factors restricting *A. manicatum*'s range, or it is too early in the invasion process. Additional probability sampling is suggested to refine predictive models.

1. Introduction

Bees provide valuable pollination services to wild plants and crops worldwide (Brown and Paxton, 2009; Klein et al., 2007; Potts et al., 2010). Bee abundance and diversity increases ecosystem services and resilience to disturbance (Garibaldi et al., 2013; Russo, 2016; Winfree et al., 2007). Exotic bee introductions have seen a prolific increase within the past 100 years, however, and this addition of species generally does not incur the same benefit as an increase in native bee diversity (Russo, 2016). We aim to garner a better understanding of the current distribution and habitat suitability of an exotic bee quickly reaching worldwide distribution, *Anthidium manicatum* (the European wool-carder bee) (Gibbs and Sheffield, 2009; Miller et al., 2002; Russo, 2016; Strange et al., 2011).

The range expansion of *A. manicatum* has been noted as particularly troubling among invasion ecologists and bee researchers due to its rapid rate of spread and the species' potential impact on native species (Colla, 2016; Russo, 2016; Strange et al., 2011). Native to Europe, western Asia

and northern Africa, *A. manicatum* is now established in northeastern Asia, North America, South America, and New Zealand. *A. manicatum* was first recorded in North America in 1962 near Ithaca, NY (Jaycox, 1967). Until 2001, the species seemed restricted to the northeastern United States, but soon after, *A. manicatum* were recorded in Canada and on the western United States coast (Gibbs and Sheffield, 2009). In the following years, there was a rapid increase in *A. manicatum* sightings across the United States and southern Canada (Fig. 1). While this rapid spread alone is concerning, its behavior makes it a particularly noteworthy invader (Colla, 2016; Maier, 2009; Russo, 2016; Strange et al., 2011).

Anthidium manicatum males aggressively defend patches of floral resources to decrease resource competition with heterospecific pollinators and mate competition with conspecific males (Haas, 1960; Pechuman, 1967; Severinghaus et al., 1981; Starks and Reeve, 1999). They use spines at the base of their abdomen to puncture or fracture the wings of territory intruders. These aerial altercations often result in severe injury or death to attacked bees (Wirtz et al., 1988). While

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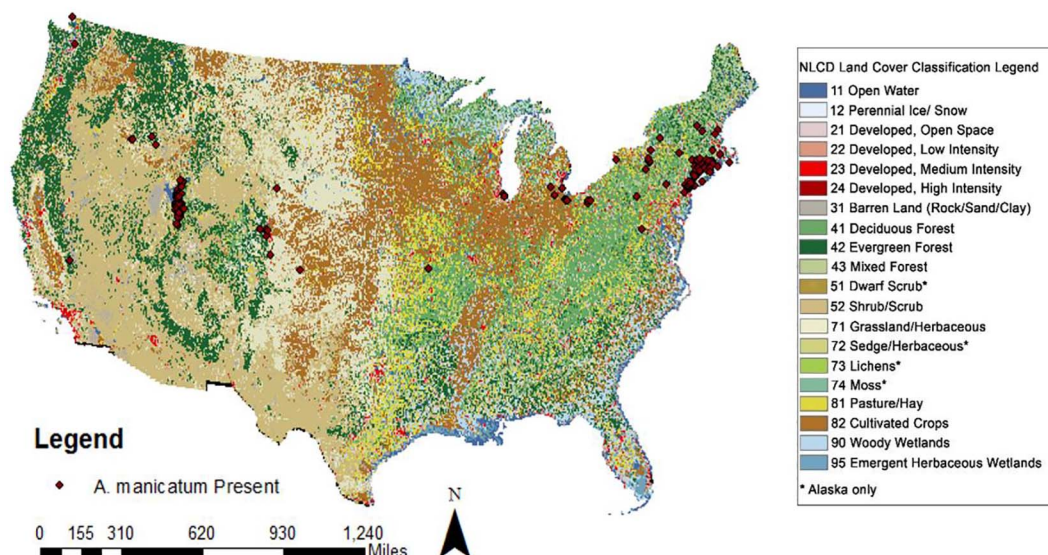


Fig. 1. Presence of *Anthidium manicatum* in the continental US. Occurrence records were aggregated from open access data sources such as Discover Life (Ascher and Pickering, 2011) and published records (Griswold et al., 2014; Maier, 2009). NLCD 2011 Land Cover Type included as the background layer.

attacks are relatively indiscriminate, honey bees (*Apis mellifera*) and bumble bees (*Bombus* spp.) are the most common recipients (Maier, 2009; Miller et al., 2002; Wirtz et al., 1988).

Additionally, female *A. manicatum* are considered poor pollinators (Soper and Beggs, 2013), and cause damage to plants through collection of nesting material (Graham et al., 2017; Müller et al., 1996; Payne et al., 2011). They also compete for floral resources with native pollinators (Payette, 2001; Severinghaus et al., 1981), and are likely to compete with other native Megachilidae for nesting cavities (Barthell et al., 1998; Griswold et al., 2014; Maier, 2009).

Given the concerns surrounding *A. manicatum* behavior, estimating current range and predicting its future spread is of high priority. Habitat suitability of *A. manicatum* was modeled previously and suitable habitat was estimated to cover most of the contiguous USA and southern Canada (Strange et al., 2011). However, several factors limited the specificity of this model, including use of presence-only data which is likely influenced by sampling bias, and relatively coarse habitat inputs. Specifically, the previous model used bioclimatic variables, such as mean temperature and precipitation. These variables generally have 1 km² pixels and are not variable enough within a region to attain habitat specific predictions of suitability. Despite these drawbacks, bioclimatic variables are commonly used in SDMs for predicting invasive species habitat (Jeschke and Strayer, 2008). However, we argue that using habitat features, such as land cover type, as environmental inputs can provide greater utility for conservation planners and stakeholders who are making management decisions at a smaller, habitat specific scale. Habitat features may also be better predictors of habitat suitability.

Exotic plants and pollinators have been known to show strong associations with disturbed habitat (Burke and Grime, 1996; Hobbs and Atkins, 1988; Morales and Aizen, 2002). *A. manicatum*, in particular, is known to associate strongly with exotic flowering plants common to urban and residential gardens (Maier, 2009; Miller et al., 2002; Payette, 2001). Additionally, we expect a strong association of human activity and *A. manicatum* presence due to the predicted route of invasion – accidental human transport of *A. manicatum* nests. *A. manicatum* are cavity nesters, a life history trait highly correlated with invasion success for exotic bees (Gibbs and Sheffield, 2009; Russo, 2016). Association of *A. manicatum* with disturbed areas in North America has been noted in the past (Miller et al., 2002), but never tested.

Therefore, our objective is to propose an alternative model that

provides predictions on a finer scale, and that uses landscape variables associated with indicators of human disturbance (land cover type and percent impervious surface). We have limited the scope of the study to the region where *A. manicatum* has the longest established invasion history – the Northeastern (NE) USA (ME, NH, VT, MA, RI, CT, and NY), in order to better estimate the full breadth of suitable habitats for this species. We compare the predictions of our proposed landscape model to one created using the more traditional bioclimatic variables (modeled after Strange et al., 2011). We then tested the accuracy of both models at predicting *A. manicatum* presence/absence.

2. Methods

First, we created two predictive models for *A. manicatum* presence within the NE US using freely available presence-only data and different sets of environmental variables – landscape variables (Land Cover Model) and bioclimatic variables (Bioclimatic Model). Second, two different sampling efforts were undertaken to collect presence-absence data to test the usefulness of each model in predicting *A. manicatum* presence (Fig. 2).

2.1. Model creation

In spring 2013, we aggregated 87 distinct *A. manicatum* occurrence localities in the NE (ME, NH, VT, MA, RI, CT, and NY) available through open access data sources such as Discover Life (Ascher and Pickering, 2011) and published records (Griswold et al., 2014; Maier, 2009) (Fig. 1). Data were only included if they had detailed latitude/longitude coordinates and were from peer-reviewed publications or if identifications from open access data sources were confirmed by a bee taxonomist. This was to decrease the chances of false presences, incorrect identification, or spatial error. However, the largest drawback to using these data is the lack of consistent sampling methods used to collect the samples. For instance, some noted presences were from directed sampling efforts, while others were from convenience sampling. The 87 sample locations in no way exemplify an exhaustive sampling of the NE and do not have equal detection probabilities, but represent the best available data to date. These data were then used as training and testing locations in the model creation process.

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