Species Distribution Modeling of Monotropa uniflora using Maxent (a Maximum Entropy Approach)

INTRODUCTION

Monotropa uniflora, known commonly as Indian-pipe or ghost-pipe, is an herbaceous perennial with circumglobal distribution. Its global range includes temperate and boreal forests of North America, Asia, European Russia and northern South America. In North America, the species is known to occur in 11 Canadian provinces and 44 states within the continental U.S., including California, Oregon, Washington and Idaho (Figure 1). The California Native Plant Society (CNPS) currently classifies the species as a California Rare Plant Rank 2B; 2); this status acknowledges that the M. uniflora has a limited geographic range in the State, but is (globally) common elsewhere. This species is neither Federally nor Federally listed as Endangered, Threatened or Rare.

In California, M. uniflora occurs in the Sierra Nevada and northern Humboldt counties in mixed coniferous stands where Douglas-Fir (Pseudotsuga menziesii) is the dominant overstory species. Similar to other members of the Monotropaceae, M. uniflora is saprophytic, which is defined as plants with the ability to obtain carbon nutrients from associated mycorrhizal fungi which are linked to autotrophic plants. The species is distinguished by its bright white pigmentation (achlorophyllous), a unique terminus that forms a group of short, thin, and dark understory of northern temperate forests. Like most saprophytic plants, M. uniflora associates with a small range of fungal hosts of all members of Russulaceae.

During pre-harvest botanical surveys (2001-2014), M. uniflora was found at 413 locations on current GDRCo property and 5 locations adjacent to GDRCo property. In addition, the California Natural Diversity Data Base (CNDDB) contains 52 current records from Del Norte and Humboldt Counties, 35 of which are of GDRCo origin. Of the remaining 17 records, 14 were considered to be of high enough quality for this study (Figure 4). M. uniflora is commonly found in patches of one to several hundred plants distributed throughout a timber harvest unit. While these groupings are mapped as unique locations, their close proximity to one another poses a modeling risk known as spatial autocorrelation and thereby, may not be independent samples. To reduce this potential bias, a minimum separation distance of 100 meters was used to subsample the occurrence data set; this resulted in a sample size of 294 records.

In addition to entering multiple botanical surveys into the CNDDB GIS, all areas where botanical surveys are conducted are mapped in detail. These Project Surveys Areas (PSA) became important within the Maxent modeling process.

SPECIES DISTRIBUTION MODELING WITH MAXENT

Maxent is a maximum entropy based modeling approach that utilizes occurrence-only data with raster covariates to predict habitat suitability for a target species. As a thoroughly proven, well recognized, and robust species distribution modeling method, Maxent is particularly suited for small sample sizes and data sets with occurrence-only records. The Maxent program was developed by Steven J. Phillips, Miroslav Dudik, and Robert Schapire and presented in The Maximum Entropy Approach to Species Distribution Modeling: Proceedings of the Twenty-first International Conference on Machine Learning, pages 655-662, 2004.

In ordinary language, the principle of maximum entropy can be said to express a claim of indifference with regard to prior knowledge. If we have no prior knowledge about the distribution of a species, the only reasonable assumption to make is that it is equally likely to occur anywhere. The principle of maximum entropy states that the greatest degree of uncertainty (entropy) can be achieved when there is no prior knowledge. As more information is gathered, the distribution of a species can be refined, resulting in a greater degree of certainty.

To guard against the effects of multicollinearity, intra-variable correlation was assessed using Pearsons’ r for continuous variables and Cramér’s V for categorical variables. When two or more variables were found to have high intra-variable correlation, the most biologically relevant variable was retained and the others discarded. A list of the post-correlation assessed variable suite is found in Table 1.

Table 1. Post-correlation predictive variables assessed for inclusion in final model

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<th>Variable</th>
<th>Percent contribution</th>
<th>Importance</th>
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Marginal response curves illustrate the effect of each predictor variable within the model (Figure 8 - 10). In general, M. uniflora prefers lower elevations, higher precipitation, mean temperatures above 11.2°C, a maximum number of growing degree days, and a preference for the soil to be dominated by Untemperate or凉.

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