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Acknowledging Sampling Bias in Species Distribution Modelling: Predicting Botrychium sp. Habitat in Lincoln County, Montana

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INTRODUCTION : Over 70 % of *Botrychium* in Montana are considered "Species of Concern" by the Montana Natural Heritage Program, meaning they are in jeopardy of extirpation due to habitat destruction, limited range, or small population size.[12] Thus, developing an effective conservation plan for Montana that maintains current *Botrychium* sp. diversity and preserves their distribution is critical.[5, 4] Unfortunately, *Botrychium* sp. periodically abstain from producing aboveground fronds due to their symbiosis with arbuscular mycorrhiza, complicating long-term data collection strategies.[9, 8, 4] Ergo, *Botrychium* sp. make an ideal candidate for a species distribution model (SDM) because it can provide statistical evidence linking observed distribution with environmental variables.[7, 3, 2] Frequently applied in both conservation and management activities, an SDM can predict potential distribution over an area which is pivotal to conservation planning.[5, 13] Studies have yet to employ this technique for *Botrychium* sp. and thus, there is no way to assess status or identify threats, putting *Botrychium* sp. at serious risk.[5, 12]
An SDM was used to identify environmental predictors for Botrychium sp. habitat in order to construct a predictive distribution map for Botrychium sp. in Lincoln County, Montana.
BACKGROUND : In fall 2014, a preliminary feasibility analysis focused on evaluating correction techniques to mitigate the sampling bias found in *Botrychium* sp. occurrence data from Lincoln County, Montana using MaxEnt. Maximum Entropy (MaxEnt) is an SDM that associates the spatial location of occurrence data with environmental variables to predict habitat suitability at unsurveyed locations.[13] Sampling bias arises when observation data is preferentially collected from certain areas because they are for example, more convenient to reach.[10, 2, 6] Eight explanatory variables were considered as input to the model: elevation, aspect, slope, soils, geology, mean May precipitation, mean June temperature, and land cover.[4, 14] Using techniques assembled from similar studies, sampling bias correction schemes were created that split the data into two categories of locational uncertainty, subsampled the data at two resolutions, or restricted the background sampling extent to the known distribution of *Botrychium* sp.[3, 10, 2, 6] Sampling bias was said to be resolved if the dataset exhibited a random distribution after application of a correction technique. Three optimal datasets were produced from the corrective procedures: points split based on locational uncertainty and then subsampled, points split based on locational uncertainty alone, and the complete *Botrychium* sp. dataset. The split and subsampled dataset performed poorly, creating a suitability map that grossly over-predicted potential habitat. Because the original sampling bias was so strong, this correction produced a subset of data that was no longer representative of the entire study area. Consequently, future analyses should continue to experiment with subsampling but refrain from splitting data into locational uncertainty classes.
RESEARCH PLAN :
(1) C*orrection of sampling bias in observation data:* (i) Splitting - data will not be split based upon locational uncertainty. Further scrutiny will be given to the process of eliminating redundant points; relevant data was incidentally removed during this process previously. (ii) Subsampling - there exist two main clusters of points in the survey area; limiting subsampling to only the clustered regions will be further examined. (iii) Background Extent - quantification of excluding unsuitable habitat like lakes, rivers, and roads, and high elevation sites will be examined.
(2) S*pecification of environmental variables:* Categories of environmental variables were assembled ranging from standard climatic variables, edaphic variables, and climatic variables that influence edaphic variables.

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(3) *Testing of MaxEnt's internal settings:* MaxEnt has the ability to modify the number of runs, the type of evaluation procedure, the number of background points sampled, and more. These can considerably alter results.[13]

CONCLUSION : This analysis is innovative in its application of an SDM to address deficiencies in knowledge about an enigmatic subgenus of Ophioglossaceae known as *Botrychium*. It will be one of the first studies to provide statistical support for linking environmental variables to observed *Botrychium* sp. habitat. Furthermore, this research will enhance our understanding of the ecological mechanisms behind symbiotic relationships between plants and arbuscular mycorrhiza. It will fill an important knowledge gap on the current distribution of *Botrychium* sp. in Lincoln County, MT and has potential to be expanded to other counties in Montana as well. It will help us monitor the health of this subgenus through changing disturbance and climatic regimes and create a conservation strategy that is relevant for maintaining current populations across the state.

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