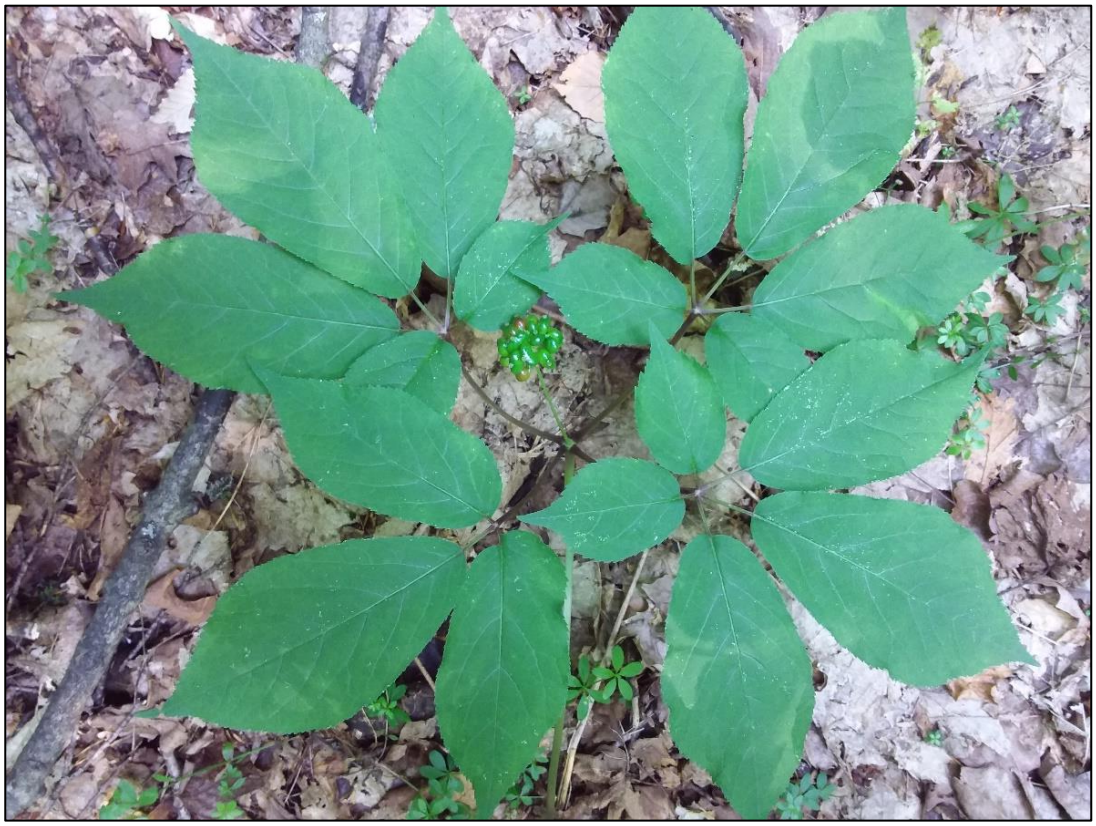
Huron-Manistee National Forest: Ginseng Restoration Project



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Cover: Ginseng (*Panax quinquefolius*) with unripe fruits in Manistee National Forest, Wexford County, Michigan (EO ID 18994) on August 6, 2020. Photograph by Rachel Hackett.

Table of Contents

List of Tables

List of Figures

Abstract

Ginseng (*Panax quinquefolius*) is a state-threatened species in Michigan. With a multitude of ethnobotanical uses, the greatest threat to ginseng populations is poaching in addition to climate change, habitat degradation, and habitat destruction. In preparation for restoration efforts in Huron-Manistee National Forest, Michigan Natural Features Inventory was contracted to update the status and collect habitat characteristics of ginseng occurrences in the forest, mine digital data sources for ginseng records in Michigan, and generate a suitable habitat model for Michigan's Lower Peninsula. The inability to locate ginseng at five of the seven locations visited in Huron-Manistee National Forest in 2020 reflects the sensitivity of this species to threats. Likely causes of the population declines include animal browse, canopy disturbance, climate change, and poaching. Anticipating and planning for these threats, especially canopy disturbance and animal browse, may improve the probability of establishing sustainable ginseng populations. The most telling habitat measurements at occupied sites were associated species, aspect (west southwest through north to east northeast) and litter depth (3.5 - 5 cm). The digital data records were used to add 20 Element Occurrence records and update documentation for 26 of the 150 ginseng records in Michigan's Natural Heritage Database. The Maxent species distribution model had an AUC training value of 0.899 and AUC cross-validation value of 0.883, indicating a good fit. The most important variables of the species distribution model included mean annual temperature, topographic position index, local relief, proportion of upland deciduous forest, and mean percent canopy cover. Using the equal sensitivity/specificity threshold method, 37% of Huron-Manistee National Forest was predicted suitable habitat with 81% of the validation points being correctly classified. District 1 in Manistee National forest was predicted to have the most suitable habitat of the four districts in Huron-Manistee National Forest at 61% suitable. Locations for restoration should take into consideration local temperature change caused by climate change and a variable terrain to provide greater number of suitable micro-habitats. The Maxent model developed here may be used to project suitable habitat into various climate change scenarios to refine best areas for introduction. Monitoring population success and growth across several microhabitats is recommended for success of the planting and improving future site selection criteria.

Introduction

Ginseng (*Panax quinquefolius*) is a state-threatened species in Michigan and is predominately found in the full-shade of mesic forests, often on slopes, and occasionally in wooded dune habitats (Swink and Wilhelm, 1994; Penskar and Higman, 1996). It is a long-lived perennial herb that does not begin reproducing until at least four years old. With a multitude of ethnobotanical uses, the greatest threat to ginseng populations is poaching in addition to climate change, habitat degradation, and habitat destruction (Penskar and Higman, 1996). It is also a species of cultural significance to many Native American tribes.

In accordance with National Environmental Policy Act (NEPA) monitoring of threatened and endangered or Regional Forest Sensitive Species, Huron-Manistee National Forest in Michigan's Northern Lower Peninsula is conducting restoration planning for ginseng on its lands. In preparation, Michigan Natural Features Inventory (MNFI) was contracted to gather data and research on Michigan ginseng populations. Specifically, the objectives were to:

1. Update the status of element occurrence records in the Huron-Manistee National Forest and collect current habitat data and leaflet samples for genetic analysis.
2. Mine digital data sources for ginseng records in Michigan to document new and update existing element occurrence records in Michigan's Natural Heritage Database.
3. Generate a suitable habitat model based on element occurrences of ginseng in Michigan's Lower Peninsula of adequate geographic accuracy.

Study area

Huron-Manistee National Forest lies in the northern Lower Peninsula of Michigan and managed by the US Forest Service. Manistee National Forest spread across nine counties (i.e., Lake, Manistee, Mason, Mecosta, Muskegon, Newaygo, Oceana, Osceola, Wexford) and Huron across five (i.e., Alcona, Crawford, Iosco, Ogemaw, Oscoda). Elevation ranges from 174 to 526 m (572-1725 ft). Pre-settlement vegetation included dry, dry-mesic, and mesic northern forests, pine and oak-pine barrens, floodplain forests, hardwood-conifer and conifer swamps and Great Lakes marsh, coastal marsh, and wet prairie near Lake Huron. Logging heavily influenced the present vegetation and land use (Albert, 1995).

Eight of Michigan's ginseng Element Occurrence (EO) records spatially intersect with Huron-Manistee National Forest property (Table 1; Figure 12). Their natural communities were described as mesic or dry-mesic northern forest, usually with sloping terrain (Michigan Natural Features Inventory, 2020).

Table 1. List of ginseng (*Panax quinquefolius* L.) Element Occurrence (EO) records in Michigan's Natural Heritage Database that intersect with Huron-Manistee National Forest Property (Michigan Natural Features Inventory, 2020). EO ID is a unique identifier for each EO record. Rank is a qualitative assessment of estimated viability of species (Appendix Table A- 1). Site indicated with *was visited by US Forest Service, not MNFI.

Site	EO ID	Rank	County	Last Observation Date
Kellogg Lake-County Line*	2184	A	Crawford	1996-08-13
Dickson Lake North	4707	B	Manistee	1986-08-26
Gauthier Creek	11029	BC	Alcona	2000-06-22
Caberfae Way Snowmobile Trail/FR-5405	18994	D	Wexford	2010-08-18
Edgewood Rd N	19849	E	Wexford	2005-08-19
USFS Rd 7504	23708	E	Wexford	2002
Peterson Creek	23709	E	Wexford	2002
Caberfae	23710	E	Wexford	2000-07-11

Methods

Element occurrence records of ginseng in Michigan

Michigan Natural Heritage Database (Biotics5) contained 130 EO records of ginseng, 120 of them mapped, at the start of this project (Michigan Natural Features Inventory, 2020; Appendix Table A- 2). Of these EO records, fifty-nine were given a qualitative viability ranking of A thru D, 32 were ranked as "extant" (E), five were ranked as "failed to find" (F), 34 were ranked as "historic" (H). For a description of the ranks, see Appendix Table A- 2.

Status of ginseng populations on federal land in Northern Lower Peninsula

Seven of the eight recorded populations of ginseng in Huron-Manistee National Forest and one population in Sleeping Bear Dunes National Lakeshore were visited in August 2020. The eighth population of ginseng in Huron Manistee National Forest was visited by Rich Corner and Grady Zuiderveen in 2020.

Meander surveys were conducted at each location. If the population had not been spatially mapped (e.g., GPS point coordinates only), an area of at least 1 hectare was surveyed with the GPS coordinates at the center. When a plant was observed, the following information was recorded: GPS coordinates, habitat description, litter depth, soil depth, soil type, soil pH, slope, and aspect. Photographs were taken of the habitat and at least one individual in the population. Leaflets were collected (no more than one per plant) for genetic analysis, organized by US Forest Service. The number of samples collected depended on the total number of plants in the population, up to 16 samples.

To prepare leaf samples for genetic analysis, leaves were folded and masticated on a Flinders Technology Associates (FTA) gene card. Cards were left to air dry until mailing. Cards were delivered to the US Forest Service Staff to manage the rest of the genetic analysis process.

Digital occurrence data search

Searches for digital occurrence records from preserved specimens and human observations were compiled from the Consortium of Midwest Herbaria (http://midwestherbaria.org), iDigBio (https://www.idigbio.org), and Global Biodiversity Information Facility (GBIF; https://www.gbif.org). Living, fossilized, and genetic material records without geographical origin information were removed. Records were filtered for location information in Michigan and for digital records without geographic information indicating another state, province, country, or continent. Duplicates indicated by identical unique identifiers were noted and removed. Additional location information was researched via online specimen images using the other information provided. Records with sufficient record information were compared with existing EO records and categorized as “Prior record [documentation] in EO”, “Update EO with record [documentation]”, or “New EO record”. Online specimen images also revealed a few records that were misidentified, and thus removed from the compilation (Figure 1).

Documentation was added to existing EO records from the compilation if the occurrence location could be reliably assessed, and new EOs were created for those not previously documented.

Ginseng species distribution model

To identify possible suitable habitat in Michigan, a Maximum Entropy (Maxent) species distribution model was generated using known, recent element occurrences of ginseng in the Lower Peninsula of Michigan and a multitude of geospatial environmental variables (Table 2). The output of the model highlighted areas likely to contain habitat similar to that of existing occurrences.

Converting the continuous Maxent probability of presence output (range 0-1) into a binary suitable/unsuitable habitat map requires the selection of a threshold value. While categorizing output from a continuous variable (range) to a binary one (i.e., 0,1) may lose some information, it is a useful product, especially for species range estimation and where an estimate of habitat area is needed. Most threshold selection methods (e.g., Fielding and Bell 1997; Phillips et al. 2006) are based on a trade-off of the levels of sensitivity (i.e., proportion of correctly predicted presences) and specificity (i.e., proportion of correctly predicted absences). Opting for a higher sensitivity will also increase the area of the study area that is classified as suitable, possibly limiting the usefulness of the output. We examined two threshold methods as a demonstration: binary threshold and 10^{th} percentile binary threshold. The binary threshold gives equal weight to sensitivity and specificity to determine the threshold. The 10^{th} percentile binary threshold captures 90% of the presence locations. For each of these methods, the Percent Correctly Classified (PCC) and the True Skill Statistic (TSS; Lawson et al. 2014) were used to evaluate the fit of the model. PCC is the sum of the correctly identified presence and absence points over the total number of points. TSS is a measure of overall accuracy corrected for accuracy expected by random chance and is not affected by prevalence (i.e., the number of presence locations divided by the number of presence plus background locations).

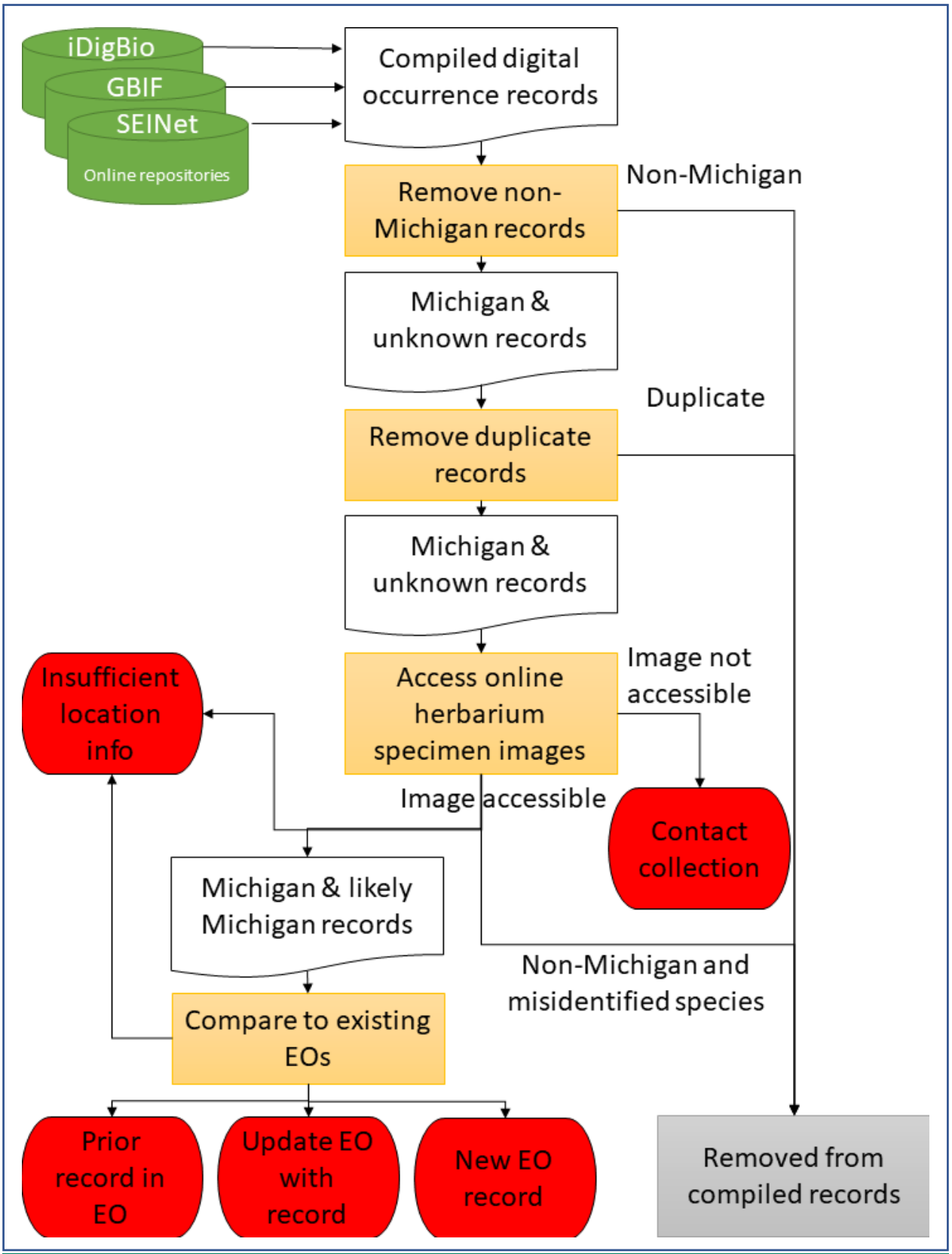


Figure 1. Generalized digital occurrence record cleaning data flow. Records were removed [grey box] or filed into one of the red categories.

Presence/Pseudo-absence points

Ginseng EO records in Michigan's Natural Heritage Database were used to create presence and pseudo-absence points for the species distribution model. Centroids of each polygon representing occupied habitat were generated for presence points, and those retained for the model met the following criteria:

- Located in Michigan's Lower Peninsula
- Last observed 1950 or later
- Area less than 3,085 acres (a point buffered by 2000 m)
- Minimum separation distance between points of 1000 m (more accurate and recent records were favored)

Presence points were visually inspected over recent aerial imagery to confirm that habitat had not been converted (e.g., converted to agriculture).

Background/pseudo-absence points were generated randomly within 3.2 km of the accepted presence points and/or other medium to high representational accuracy plant element occurrences from the MNFI database. This background point selection technique is used to account for sampling bias inherent in the presence locations (Phillips et al., 2009) The minimum distance between background points was 500 m.

Environmental Predictor Variables

Environmental variables shown to influence ginseng individual and population quality and fitness included: natural community type, canopy cover, air temperature, soil moisture, soil type, aspect, and slope (Jochum et al., 2007; McGraw et al., 2013; Souther and McGraw, 2014). We selected 39 environmental predictor variables for inclusion in the model that were proxies for these characteristics or characteristics commonly used in plant species distribution models (Table 2). Predictor variables are categorized into four types: climate, landcover, soil, and terrain, and at multiple spatial scales. Variables correlated at greater than 0.7 (Pearson or Spearman Rank) were not included in the same model. Climate variables are derived from 30 year (1980-2014) means from PRISM (precipitation) and TopoWX (temperature only) detrended datasets and had a spatial resolution of 800 m. To match the 30 m spatial resolution of the other spatial data, climate data was resampled to 30 m pixels prior to running the model.

The jackknife test of variable importance and relative contributions evaluated which variables contained the most useful information and highest relative contributions to the predictability of the model.

Model evaluation

Data independence of the model was evaluated by comparing average omission/commission and predicted area between training and test data over seven cross-validation replications. Omission rate is the percent of presence locations that were predicted absence. Commission rate is the fraction of absences predicted present. Since we have only occurrence data and no absence data "fractional predicted area" (the proportion of the study area predicted present) is used.

The sensitivity of the model was evaluated with a receiver operating curve (ROC) and its area under the curve (AUC). The standard recommendation for AUC scores is that scores between 0.9 and 1 are excellent, scores between 0.8 and 0.9 are good, between 0.7 and 0.8 are fair and anything less than 0.6 is poor (Swets, 1988). An AUC of 0.5 is a random prediction.

Table 2. List of environmental predictor variables evaluated to include in ginseng species distribution model. “BIO#” refers to the set of 19 bioclimatic variables from WorldClim: (https://www.worldclim.org/data/bioclim.html)

Type	Data source	Variable
Climate	PRISM, WorldClim	Annual Precipitation (BIO12)
		Precipitation of Warmest Quarter (BIO18)
		Precipitation Seasonality (BIO15)
	TopoWX, WorldClim	Annual Mean Temperature (BIO1)
		Mean Temperature Diurnal Range (BIO2)
		Temperature Isothermality (BIO3)
		Temperature Seasonality (BIO4)
Landcover	C-CAP 2016 Regional Landcover	Deciduous forest cover 300 m radius mean
		Deciduous forest cover 900 m radius mean
		Deciduous forest cover 3000 m radius mean
		Distance to upland forest
		Upland forest cover 300 m radius
		Upland forest cover 900 m radius
		Upland forest cover 3000 m radius
	National Landcover Dataset (NLCD) 2011	Mean percent canopy cover 300 m radius mean
		Mean percent canopy cover 900 m radius mean
		Mean percent canopy cover 1500 m radius mean
		Mean percent canopy cover 3000 m radius mean
Soil	Great Lakes Aquatic Habitat Framework	Soil Drainage Class (categorical)
Terrain	30 m Digital Elevation Model (DEM)	Aspect - Beers transformation (Beers et al., 1966)
		Aspect - TRASP transformation (Roberts and Cooper, 1989)
		Compound Topographic Wetness Index (CTI; Gessler et al. 1995)
		Hillshade (relative solar insolation) maximum azimuth value
		Hillshade (relative solar insolation) spring equinox Lansing, Michigan, USA, values
		Local relief (elevation range) 300 m radius
		Local relief (elevation range) 900 m radius
		Local relief (elevation range) 1500 m radius
		Local relief (elevation range) 3000 m radius
		Plan curvature (perpendicular to the direction of maximum slope)
		Profile curvature (in direction of maximum slope)
		Solar radiation (direct and diffuse) at equinox
		Site Exposure Index (Balice et al., 2000)
		Slope (percent rise)
		Slope Position Index Class (categorical)
		Topographic position index (TPI) 300 m radius
		Topographic position index (TPI) 900 m radius
		Topographic position index (TPI) 1500 m radius
		Topographic position index (TPI) 3000 m radius

Results

Ginseng Element Occurrences

The visits to each ginseng occurrence were described below. Occurrences that were within 1000 m were assigned the same EO identification, and they were distinguished further by town-range-section and/or a physical description of the relative location (Appendix B). Photographs were included at the end or beside of the occurrence.

Habitat data was gathered at the sites. No soil related data was gathered at Sleeping Bear Dunes National Lakeshore location because of permit restrictions. Litter depth at the HMNF sites ranged from 3.5 – 5.0 cm. Soil O-layer was 15.5 – 31.5 cm deep, pH 5.5. Aspects ranged from west-southwest (246°) to east-northeast (70°) through north (0°/360°). Slops from 0° to 40°.

Huron National Forest

Element Occurrence ID 11029 [redacted], Alcona County, Michigan. Failed to find ginseng plants on August 11, 2020, within 1.2 hectares centered on coordinates supplied by USFS (USDA Forest Service, 2020; Hackett, 2020). Our records show the last observation of this occurrence was June 22, 2000, where "30-50+ plants" were observed in a 25' by 25' area (Stebbins, 2000; USDA Forest Service, 2020).

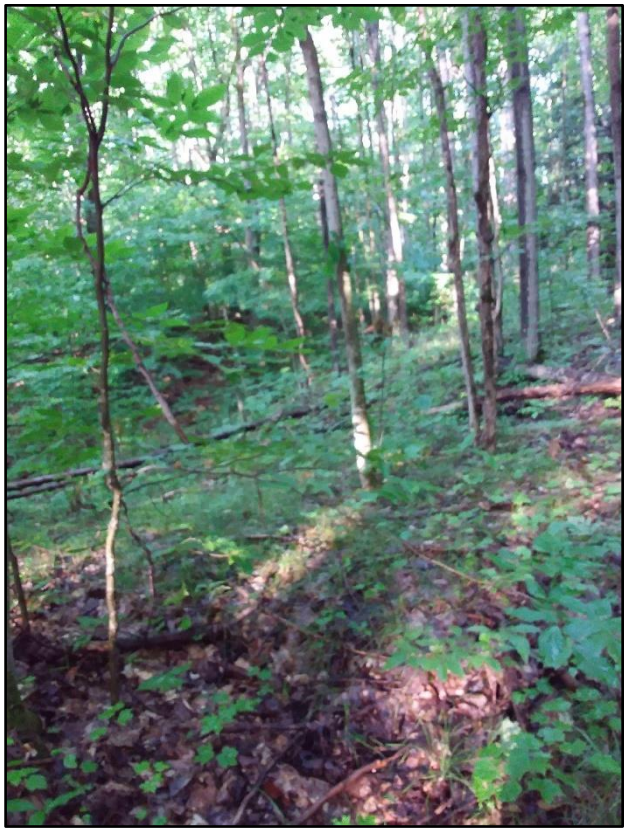


Figure 2 Habitat of Element Occurrence ID 11029, Alcona County, Huron National Forest on August 11, 2020, appeared suitable for ginseng, but no plants were found. Photograph by Rachel Hackett.

In 2020, the habitat appeared suitable except for more aspen (*Populus* spp.) than usual in the canopy and the lack of sweet-cicely (*Osmorhiza* sp.), a common ground layer associate (**Error! Reference source not found.**). The ground cover layer included wild sarsaparilla (*Aralia nudicaulis),* sedges (*Carex* spp.), American beech (*Fagus grandifolia*) saplings, Canada mayflower (*Maianthemum canadense*), ironwood (*Ostrya virginiana*), bracken fern (*Pteridium aquilinum*), and star-flower (*Trientalis borealis*). Disturbances and threats included a two-track, canopy threats of emerald ash borer and beech bark disease (in progress) and browsing. The exotic orchid helleborine (*Epipactis helleborine*) occurred uncommonly in ground cover layer.

Manistee National Forest

Element Occurrence ID 23709 ([redacted]), Wexford County, Michigan. Failed to find ginseng plants on August 5, 2020, within 1 hectare centered on coordinates supplied by USFS (USDA Forest Service, 2020; Hackett, 2020). MNFI records show the last observation of this occurrence was in 2002, but no population details were provided.

In 2020, the terrain was difficult to transverse with two-five layers of downed canopy trees (e.g., white ash (*Fraxinus americana)*, basswood (*Tilia americana*) and dense blackberry bushes (mostly *Rubus allegheniensis*; Figure 3). Some mesic forest ground cover species hidden under shrubs and saplings included: wild sarsaparilla, wild leek (*Allium tricoccum*), sedges, fringed false buckwheat (*Fallopia cilinodis*), sweet cicely, red-berried elder (*Sambucus racemosa*), and maple-leaved viburnum (*Viburnum acerifolium*).

Figure 3. Habitat of Element Occurrence ID 23709, Wexford County, Manistee National Forest, Michigan, on August 5, 2020, was no longer suitable for ginseng. Left – ginseng is not found in forest with large canopy gaps. Upper-right – dense shrubs, mostly blackberry bushes (*Rubus allegheniensis*) carpeted the forest floor. Lower-right – several layers of fallen trees made the terrain difficult. Photographs by Rachel Hackett.

Element Occurrence ID 23710 ([redacted]) [redacted], Wexford County, Michigan. Failed to find ginseng plants on August 5, 2020, within 1.5 hectares centered on coordinates supplied by USFS (USDA Forest Service, 2020; Hackett, 2020). MNFI records show the last observation of this occurrence was in 1990, but no population details were provided (USDA Forest Service, 2020).

In 2020, the habitat appeared suitable (Figure 4). The canopy was mostly intact despite progression of beech bark disease with few fallen canopy trees. The ground cover layer included wild sarsaparilla, sedges, fringed false buckwheat, sweet cicely, and maple-leaved viburnum. Disturbances and threats included emerald ash borer and beech bark disease in the canopy and browsing.

Figure 4. Habitat of Element Occurrence ID 23710, [redacted], Wexford County, Manistee National Forest, Michigan, on August 5, 2020, appeared suitable for ginseng, but no plants were found. Photographs by Rachel Hackett.

Element Occurrence ID 23710 ([redacted] Wexford County, Michigan. Failed to find ginseng plants on August 5, 2020, within 1 hectare centered on coordinates supplied by USFS (USDA Forest Service, 2020; Hackett, 2020). MNFI records show the last observation of this occurrence was on July 11, 2000, but no population details were provided (USDA Forest Service, 2020).

In 2020, the habitat appeared suitable (Figure 5). The canopy was mostly intact despite beech bark disease and fallen ash and basswood. Beech and ash saplings were abundant. The ground cover layer included wild leek, wild sarsaparilla, jack-in-the-pulpit (*Arisaema triphyllum*), northern shorthusk (*Brachyelytrum aristosum*), sedges, bottlebrush grass (*Elymus hystrix*), fringed false buckwheat, and sweet cicely. Disturbances and threats included canopy loss, old road with common invasive plant species, and exotic helleborine throughout area.

Figure 5. Habitat of Element Occurrence ID 23710, [redacted], Wexford County, Manistee National Forest, Michigan, on August 5, 2020, appeared suitable, but no plants were found. Photographs by Rachel Hackett.

Element Occurrence ID 19849 [redacted], Wexford County, Michigan. A total of one sterile plant was found on August 6, 2020, in the two-hectares surveyed (Figure 6). MNFI records show the last observation of this occurrence was on August 19, 2020 where 12 ramets and three genets were observed (Davis and Henne, 2005). The rank was changed from “E - Extant” to “D – Poor estimated viability.”

In 2020, the habitat was mesic northern forest with some swampy areas. The ground cover layer included sedges, enchanters-nightshade (*Circaea canadensis*), and rough-leaved rice-grass (*Oryzopsis asperifolia*). The single plant was found in an area of loamy sand with litter depth 5.0 cm; organic layer 15.5 cm; aspect 276°; slope 20°. Disturbances and threats included emerald ash borer, beech bark disease, basswood death, and the presence of non-native helleborine, autumn-olive (*Elaeagnus umbellata*), and common speedwell (*Veronica officinalis*).

Figure 6. Habitat and one ginseng plant found at Element Occurrence ID 19849, Wexford County, Manistee National Forest, Michigan, on August 6, 2020. Left – habitat where ginseng was found. Plant is in the lower center of photo. Right – ginseng found was sterile with two leaves. Photographs by Rachel Hackett.

Element Occurrence ID 18994 [redacted], Wexford County, Michigan. A total of 17 plants were found (3 flowering, 4 fruiting) on August 6, 2020, in the one-hectare area surveyed based on a MNFI report from 2010 (Figure 8; Figure 8). MNFI records show the last observation of this occurrence was on August 18, 2010, where one fruiting plant was documented (Dister, 2010).

In 2020, the habitat was mesic northern forest with a ground cover layer including wild leek, wild sarsaparilla, spikenard (*Aralia racemosa*), sedges (including *Carex deweyana*, and *C. intumescens*), bottlebrush grass, fragrant bedstraw (*Galium triflorum*), sweet cicely, downy solomon seal (*Polygonatum pubescens*), wild gooseberry (*Ribes cynosbati*), and dwarf raspberry (*Rubus pubescens*; Figure 7). The ginseng plants were found in areas of loamy sand soil with an organic layer of 31.5 cm and pH 5.5; A-layer of pH 5; litter depth ranging from 3.5 – 4.5 cm; aspects of 290°, 246°, and 0°; slopes of 6°, 4°, and 0°. Disturbances and threats included fallen trees, emerald ash borer, and beech bark disease in the canopy, browsing, and exotic helleborine.

Figure 7. Occupied habitat found at Element Occurrence ID 18994, Wexford County, Manistee National Forest, Michigan, on August 6, 2020. Photographs by Rachel Hackett.

Figure 8. Ginseng plants found at Element Occurrence ID 18994, Wexford County, Manistee National Forest, Michigan, on August 6, 2020. Left – ginseng with a few flowers remaining. Right – ginseng fruit. Photographs by Rachel Hackett.

Element Occurrence ID 4707 ([redacted]), Manistee County, Michigan. Failed to find on August 6, 2020, in the 2.8-hectare area mapped out from a previous MNFI survey and area centered on coordinates supplied by USFS (Host, 1986; USDA Forest Service, 2020; Hackett, 2020). MNFI records show the last observation of this occurrence was in 2001, but no population details were provided (USDA Forest Service, 2020).

The MNFI survey in 1986 described a mesic northern hardwood forest on loamy sand with approximately 50 plants scattered over 3 acres. The report mentioned a thinning of the overstory in 1985 (Host, 1986). In 2020, the community was dry-mesic forest, dominated by oaks (*Quercus* spp.).

Element Occurrence ID 23708 ([redacted]), Wexford County, Michigan. Failed to find on August 7, 2020, in the 2.4-hectare area centered on coordinates supplied by USFS (USDA Forest Service, 2020; Hackett, 2020). MNFI records show the last observation of this occurrence was in 2001, but no population details were provided (USDA Forest Service, 2020).

In 2020, the community was mesic forest, but the understory did not resemble that where ginseng has been found previously. There was little understory besides saplings of beech, sugar maple (*Acer saccharum*), and ironwood, and star-flower. Disturbances and threats included significant canopy loss caused by beech bark disease, and an old road.

Element Occurrence ID 23708 ([redacted]), Wexford County, Michigan. Failed to find on August 7, 2020, in the 2.5-hectare area centered on coordinates supplied by USFS (USDA Forest Service, 2020; Hackett, 2020). MNFI records show the last observation of this occurrence was in 2002, but no population details were provided (USDA Forest Service, 2020).

In 2020, the community was mesic forest, but the understory did not resemble that where ginseng has been found previously (Figure 9). There was little understory besides saplings of beech, sugar maple (*Acer saccharum*), and ironwood. Disturbances and threats included canopy loss caused by emerald ash borer and beech bark disease.

Figure 9. Habitat of Element Occurrence ID 23708, Wexford County, Manistee National Forest, Michigan, on August 7, 2020, appeared suitable, but no ginseng was found. Left – eastern location in NWSE quarter. Right – western location in SWSW quarter. Photographs by Rachel Hackett.

Sleeping Bear Dunes National Lakeshore

Element Occurrence ID 5687 ([redacted], Leelanau County, Michigan. A total of 33 plants were found (9 flowering, 13 fruiting) on August 14, 2020, in the 1-hectare area surveyed (Figure 11). All suitable habitat was not surveyed since the primary goals to visit this site were to collect habitat data and leaf samples for genetic analysis, so it is likely that more plants were present. MNFI records show the last observation of this occurrence in 1978 but Sleeping Bear Dunes National Lakeshore has more recent records of the population (Julia Gehring, *personal communication*).

Figure 10. Occupied habitat found at [redacted] Occurrence ID 5687, Leelanau County, Sleeping Bear Dunes National Lakeshore, Michigan, on August 14, 2020. Photograph by Rachel Hackett.

In 2020, the habitat was mesic northern forest with an intact canopy of a few beech and dead ash. Ground cover layer included dolls-eyes (*Actaea pachypoda*), maidenhair fern (*Adiantum pedatum*), wild leek, wild sarsaparilla, spikenard, northern shorthusk, enchanters-nightshade, marginal woodfern (*Dryopteris marginalis*), fragrant bedstraw, sharp-lobed hepatica (*Hepatica acutiloba*), sweet cicely, lopseed (*Phryma leptostachya*), twisted-stalk (*Streptopus amplexifolius*), and violets (*Viola* sp.). The ginseng plants were found in areas with aspects of 42°, 52°, and 70°; and slopes of 30°, 32°, 34°, 38°, and 40°. Disturbances and threats included fallen trees, emerald ash borer, and beech bark disease in the canopy, and browsing. Larger plants not hidden by other ground vegetation were most damaged by browsing of leaves and fruit (Figure 12). No measurements of soil or litter were taken because soil disturbance was not included in permit.

Figure 11. Habitat and ginseng plants found at [redacted] Element Occurrence ID 5687, Leelanau County, Sleeping Bear Dunes National Lakeshore, Michigan, on August 14, 2020. Photographs by Rachel Hackett.

Figure 12. There was heavy browsing pressure on ginseng populations in Sleeping Bear Dunes National Lakeshore (EOID 5687) as illustrated in photos. Both leaves and reproductive bodies were browsed. Photographs by Rachel Hackett.

Element Occurrence ID 5687 ([redacted]), Leelanau County, Michigan. A total of 6 plants were found (2 flowering, 2 fruiting, 2 sterile) on August 14, 2020, in 0.3-hectare area surveyed. All suitable habitat was not surveyed since the primary goals of this site-visit were to collect habitat data and leaf samples for genetic analysis, so it is likely more plants were present in area. MNFI records show the last observation of this occurrence in 1978 but Sleeping Bear Dunes National Lakeshore has more recent records of the population (Julia Gehring, *personal communication*).

In 2020, the habitat was mesic northern forest with an intact canopy of occasional beech and dead ash. Plants found in the canopy gaps in maidenhair ferns. The ground cover layer included dolls-eyes, maidenhair fern, wild leek, jack-in-the-pulpit, enchanters-nightshade, spinulose woodfern (*Dryopteris carthusiana*), twisted-stalk, and violets. Ginseng plants were found in an area with an aspect of 358° and slope of 28°. Disturbances and threats included emerald ash borer, beech bark disease and browsing. No measurements of soil or litter were taken because soil disturbance was not included in permit.

Figure 13. Habitat and ginseng plants found at [redacted] Element Occurrence ID 5687, Leelanau County, Sleeping Bear Dunes National Lakeshore, Michigan, on August 14, 2020. Photographs by Rachel Hackett.

Data mining Michigan occurrences

The digital occurrence record search of Consortium of Midwest Herbaria, iDigBio, and GBIF resulted in 701 unique records, with 454 in unknown locations prior to further research. After the cleaning and research process (Figure 1), 31 records had unknown or withheld locations, requiring contacting of the collection. Ninety-six were records in or likely in Michigan, including 54 with further location information unknown or withheld location requiring contacting of the collection. Twenty-nine records had insufficient geographic information to determine location beyond state or county level.

After contacting the University of Michigan Herbarium/MichiganFlora.net, 45 records were updated with more detailed information and 18 additional records were added for a total of 105 records in Michigan. Correspondence with other collections resulted in additional information for 14 records and 3 records recategorized from 'unknown or withheld locations', to 'not in Michigan'.

We linked 72 records to existing EO records: 28 records were already fully documented in the EO records in the Michigan Natural Heritage Database, 44 were used to update existing EO records with additional documentation, and 19 were used to create new EOs. Additional information from collections on 2 records was never received. Michigan's Natural Heritage Database now contains a total of 150 ginseng EOs in Michigan: 26 records (17% of EO records) were updated and 20 records (13%) were newly created from this mining effort (Appendix Table A- 2). No new records that were mined were geographically linked to Huron-Manistee National Forest.

After incorporating the digital data records and information gathered from visiting Huron-Manistee National Forest EOs in 2020, the counts of EO rankings have changed (Table 3):

Table 3. Element occurrence counts of each rank. Comparison of counts before and after data mining effort. Descriptions of ranks can be found in Appendix Table A- 1

Rank	Count before data mining	Count post-data mining
A	3	3
AB	0	0
B	10	9
BC	4	3
C	22	23
CD	14	14
D	6	7
E	32	32
F	5	10
H	34	49
X	0	0
Total	130	150

Ginseng Species DIstribution Modeling

Presence/Pseudo-absence points

The extent of the model was confined to the lower peninsula of Michigan. Of the 150 element occurrences of ginseng in Michigan's Natural Heritage Database, only 95 polygon centroids met criteria to use in the species distribution model (Michigan Natural Features Inventory, 2020; Figure 14). From those 95 presence points, 10,881 background/pseudo-absence locations were randomly generated.

Model evaluation

In the omission and predicted area plot, the test omission line was well above the predicted omission line indicating that the test data averaged over replicate runs is a good match for the predicted omission rate (Figure 15). The test and training data were independent and showed no sign of spatial autocorrelation.

In the ROC, the mean AUC from seven cross-validation replications is 0.883 with a mean standard deviation of 0.039 (Figure 16). The mean AUC value indicated a good fit for the model (Swets, 1988).

Maxent Model

The Maxent model had an AUC training value of 0.899 and AUC cross-validation value of 0.883 (Figure 17). The binary threshold of equal sensitivity and specificity method predicted suitable habitat at 13% of the Lower Peninsula (Figure 18). PCC was 81% (sensitivity = 0.84; specificity = 0.81, TSS = 0.65). The 10^{th} percentile binary threshold method predicted more area at 21% of the Lower Peninsula. The PCC was lower at 71% with a sensitivity of 0.90, the specificity at 0.71, and the TSS dropping slightly to 0.61.

Using the equal sensitivity/specificity threshold method, 37% of Huron-Manistee National Forest was predicted suitable habitat (Figure 19). District 1 in Manistee National forest was predicted to have the most suitable habitat of the four districts in Huron-Manistee National Forest at 61% suitable.

The top five variables determined by the jackknife test of variable importance and relative contributions to the Maxent model were mean annual temperature, mean percent canopy cover in a 300 m radius, upland deciduous forest landcover in 300 m radius, local relief within a 300 m radius, and TPI 300 m radius (Figure 20; Table 4). The jackknife test of variable importance showed the local relief (elevation range) in a 300 m radius was the environmental variable with the greatest gain when used in isolation. The variable annual mean temperature showed the greatest decrease in gain when it is omitted, indicating that it has the most information that is not present in other variables. Variables are individually plotted in Figure 21.

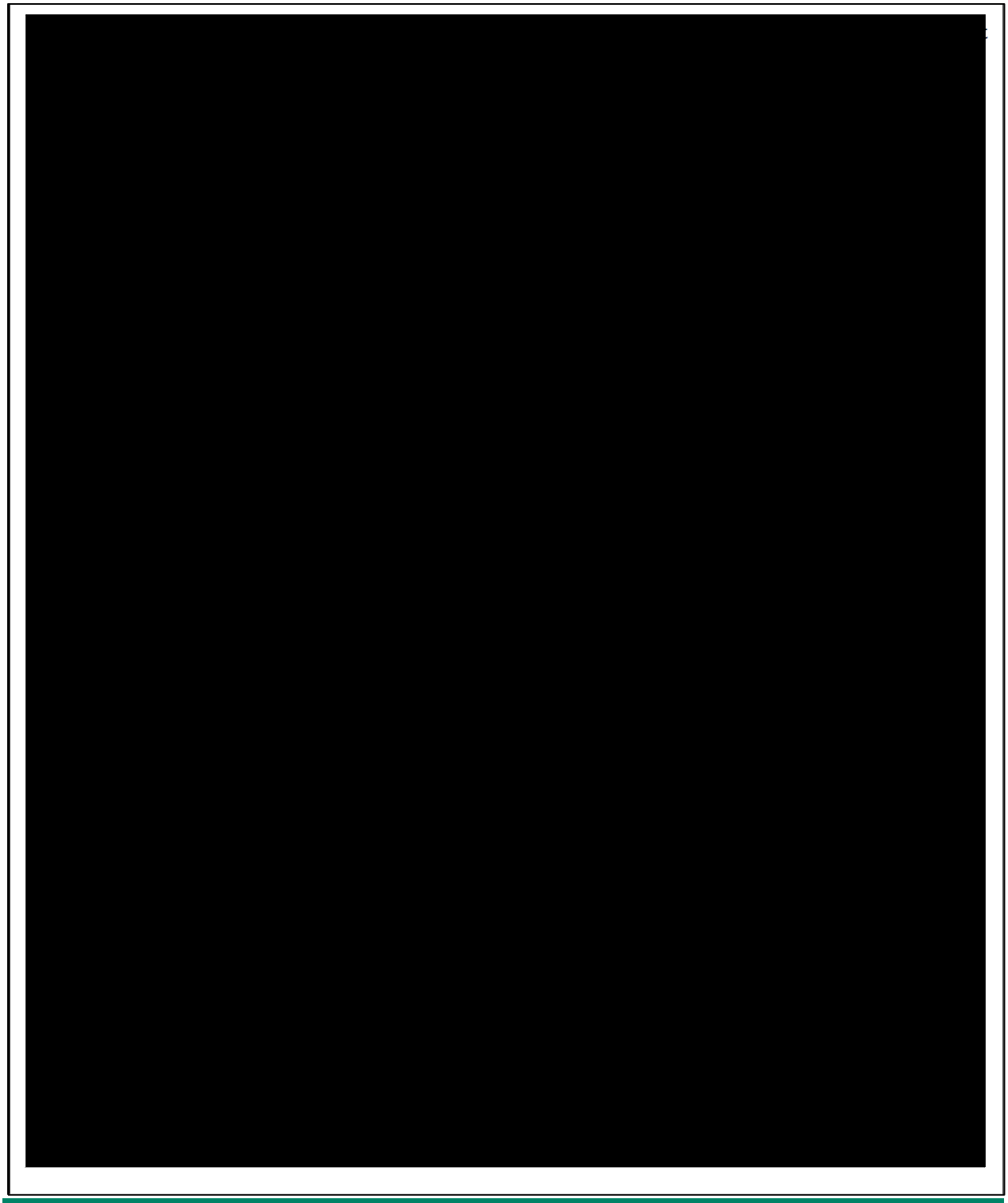


Figure 14. The 95 ginseng element occurrence points in Lower Peninsula Michigan, USA, that fit the criteria used for presence points in the species distribution model (Michigan Natural Features Inventory, 2020). Black triangles represent “failed to find” locations visited in 2020. Huron-Manistee National Forest lands are shown in green.

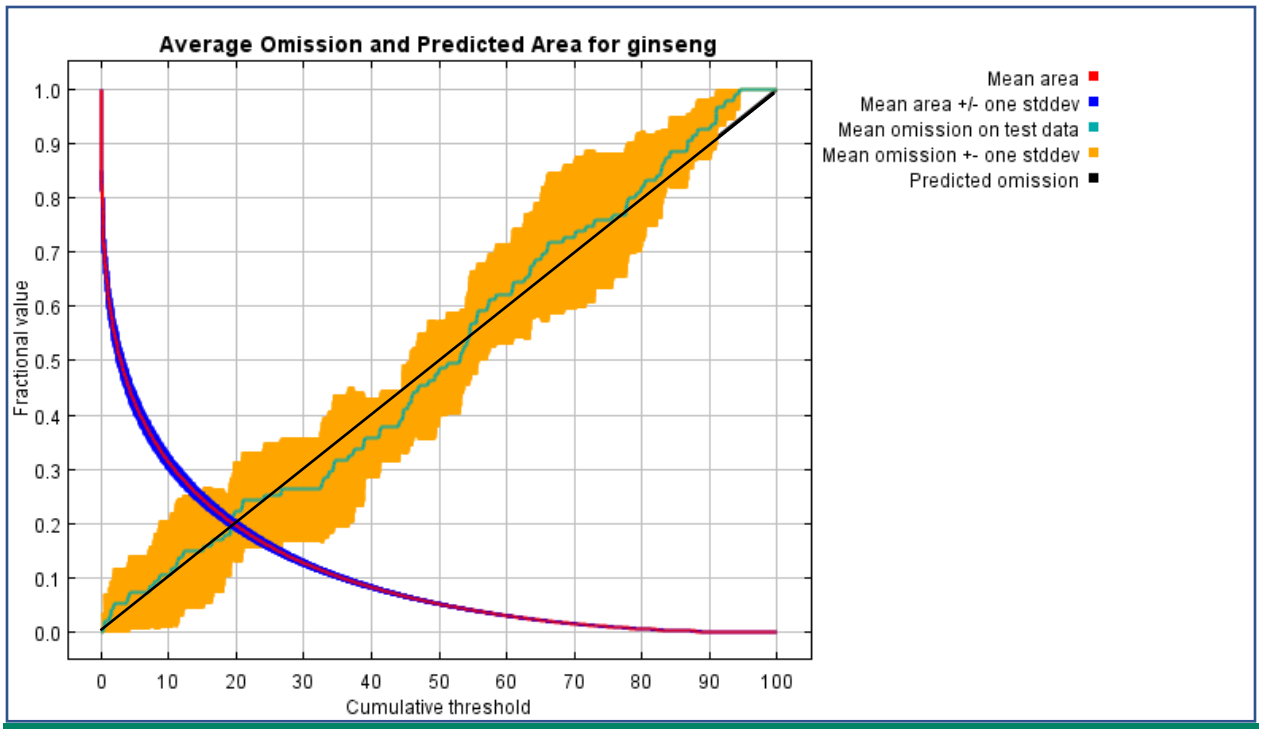


Figure 15. Omission and predicted area plot of ginseng species distribution model. Omission test data is cyan with standard deviation in gold and predicted omission rate is, by definition, the black line with a slope of 1.

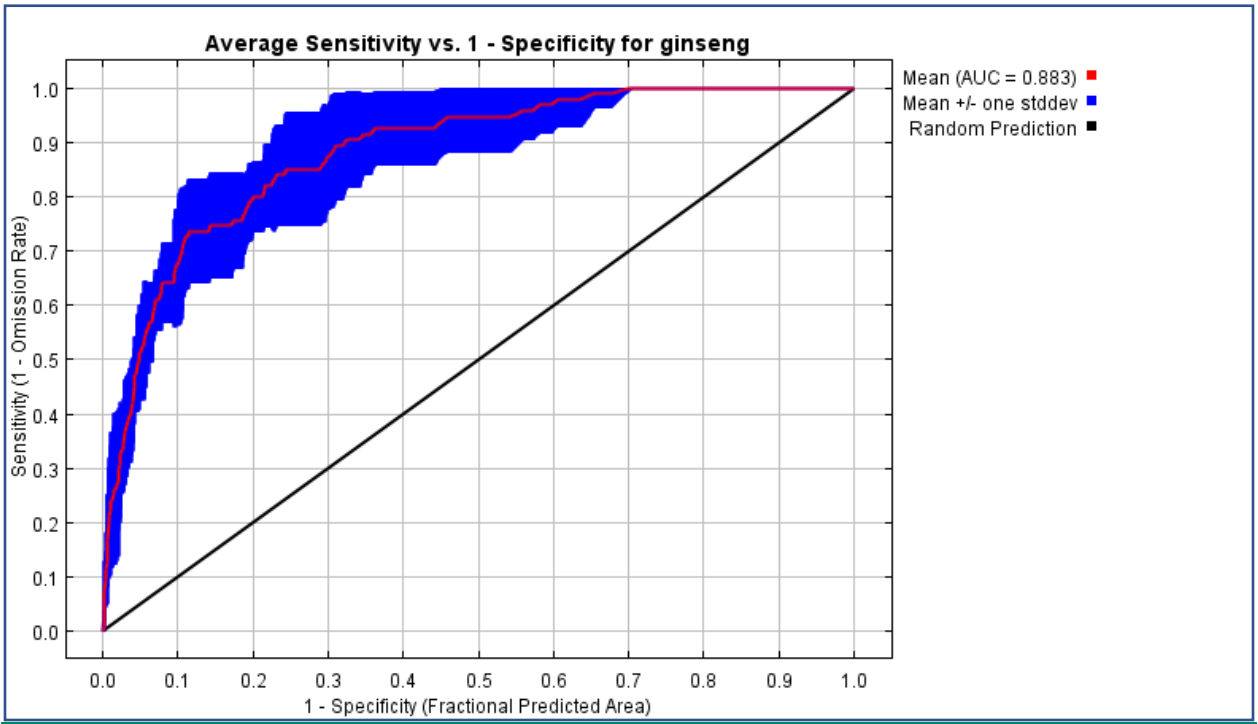


Figure 16. Receiver operating curve (ROC) of ginseng species distribution model. The mean area under the curve (AUC) is 0.886 shown in red with one standard deviation in blue.

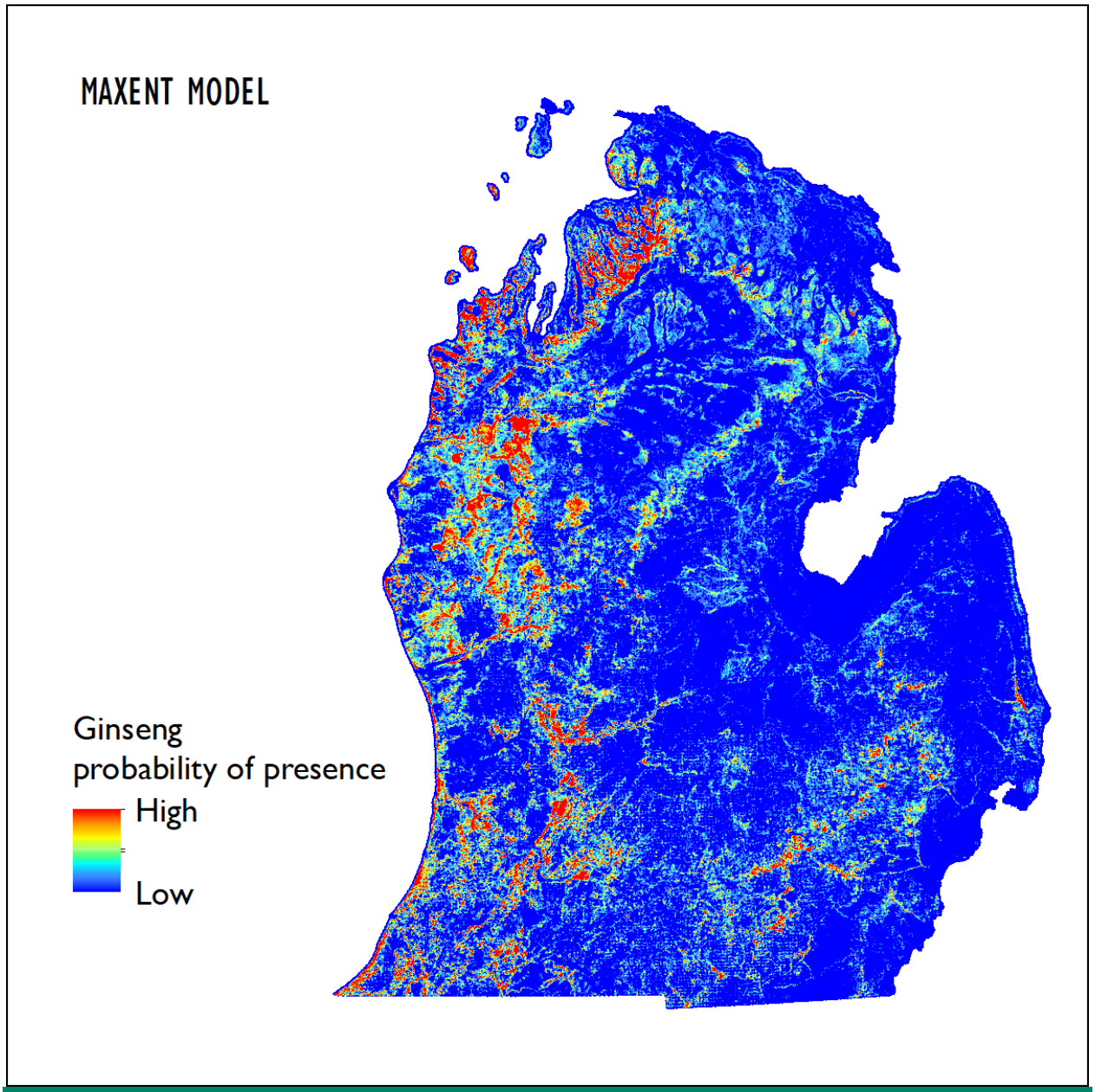


Figure 17. Maximum entropy (Maxent) model of species distribution of ginseng in the Lower Peninsula of Michigan, USA.

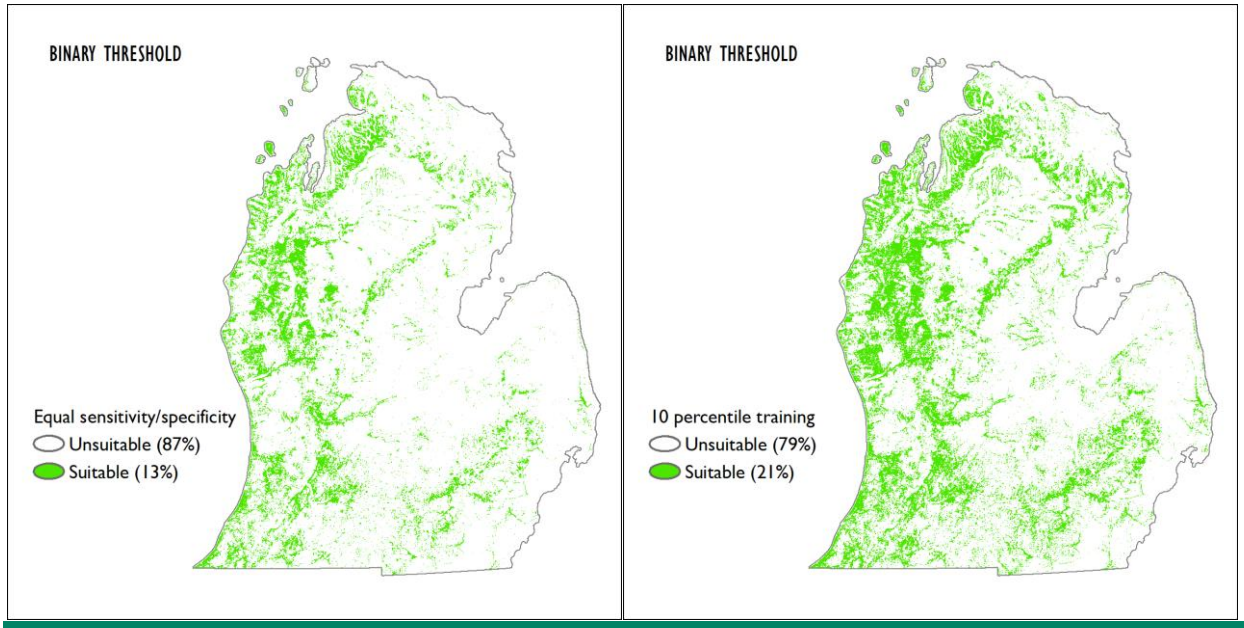
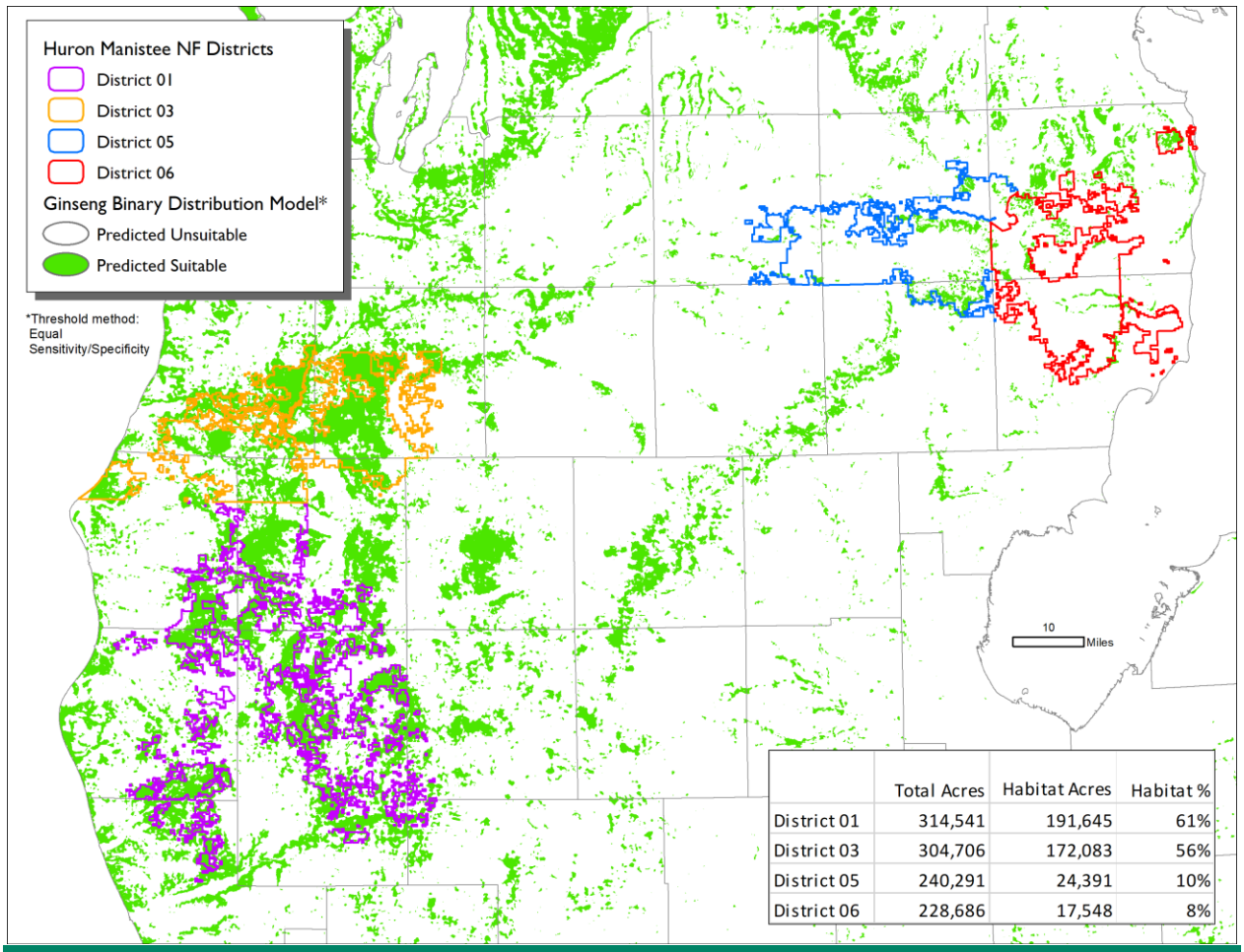


Figure 18. Binary threshold maps of suitable and unsuitable ginseng habitat in the Lower Peninsula of Michigan, USA. Left – threshold at equal sensitivity/specificity had 81% correctly classified (PCC). Right – threshold at 10th percentile training presence had 71% PCC.



	Total Acres	Habitat Acres	Habitat %
District 01	314,541	191,645	61%
District 03	304,706	172,083	56%
District 05	240,291	24,391	10%
District 06	228,686	17,548	8%

Figure 19. Predicted suitable habitat in Huron-Manistee National Forest using equal sensitivity-specificity threshold method. Percentage of acreage in each district was in the subset table.

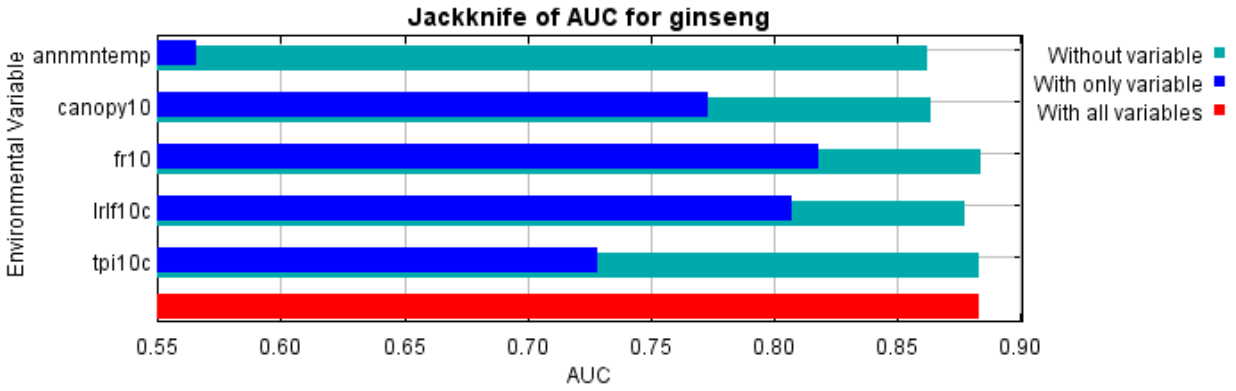
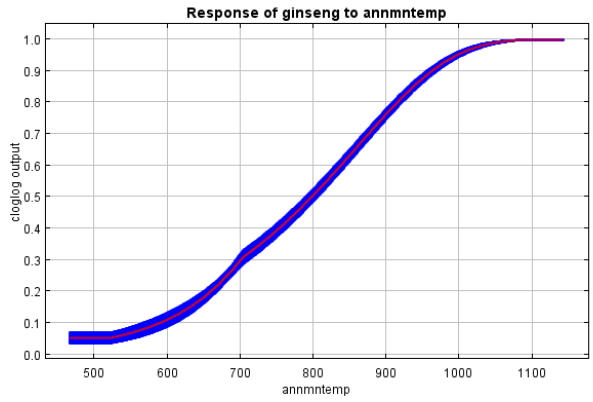


Figure 20. Jackknife test of variable importance results. The cyan bar represents the variation of the model that was explained without that variable; the blue bar represents the variation that was explained with only that variable; the red bar represents the variation explained with all variables. Variables are annual mean temperature (annmntemp), mean percent canopy cover 300 m radius (canopy10), upland deciduous forest cover 300 m radius (fr10), local relief 300 m radius (lrlf10c), and topographic position index 300 m radius (tpi10c).

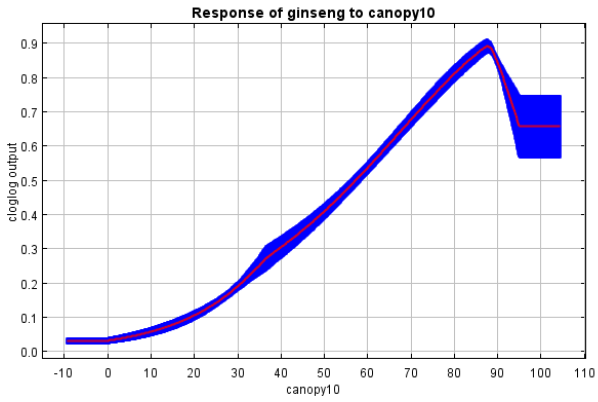
Table 4. Relative contributions of the environmental variables to the Maxent model. Permutation importance is determined by the values of that variable on training presence and background data are randomly permuted for each variable. The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages.

Variable	Percent contribution	Permutation importance
Proportion of upland deciduous forest 300 m radius	34.5	11.4
Local relief (elevation range) 300 m radius	31.6	20.7
Mean percent canopy cover 300 m radius	14.5	47.5
Mean annual temperature (30-year average)	13.9	19.3
Topographic position index 300 m radius	5.5	1.0

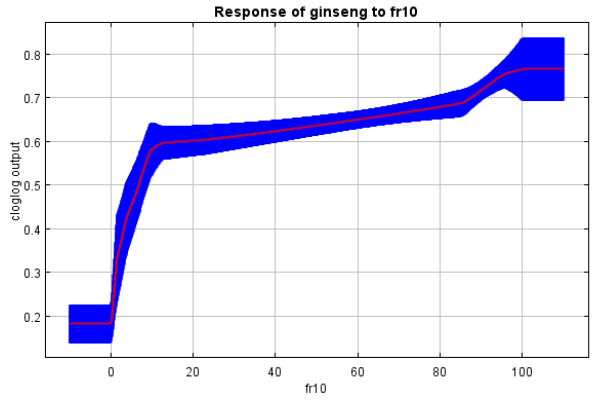
a



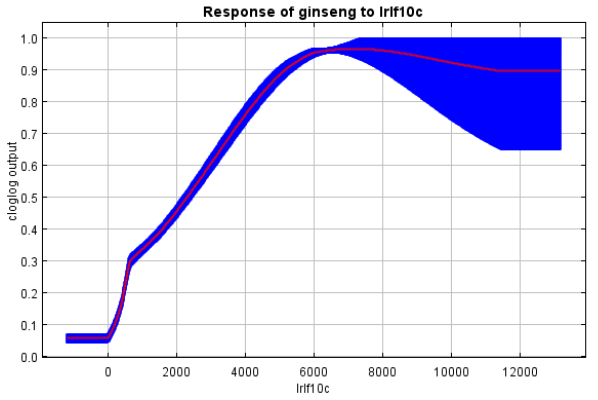
B



c



d



e

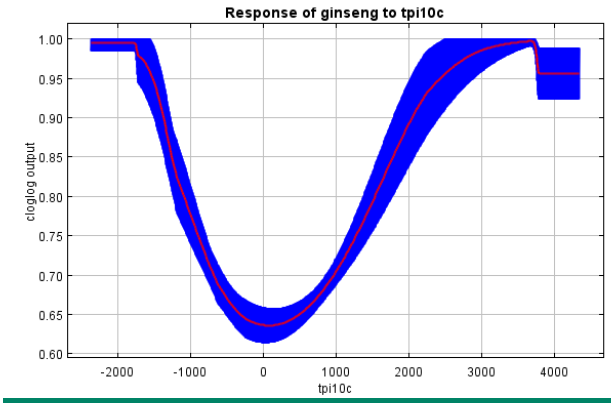


Figure 21. Plots of how each environmental variable affected the Maxent species distribution model. The red line shows the mean response of the seven replicate Maxent runs with one standard deviation shown in blue. The variables are a) annual mean temperature (annmntemp), b) mean percent canopy cover 300 m mean (canopy10), c) upland deciduous forest cover 300 m radius (fr10), d) local relief (elevation range) 300 m radius (lrlf10c), and e) topographic position index 300 m radius (tpi10c).

Discussion

In preparation for restoration of ginseng in Huron-Manistee National Forest, recently extant populations were visited in the Forest and in Sleeping Bear Dunes National Lakeshore. We hoped to learn local environmental characteristics that may inform the selection of restoration areas to increase the probability of success. The most telling measurements were associated species, aspect (west southwest through north to east northeast) and litter depth (3.5 - 5 cm). The slope and O-layer depth varied widely, so the information was not as useful. The aspect limitations can refine the suitable habitat predicted by the Maxent model to areas more likely to be successful.

There are limits to relying on solely on habitat measurements in a single point in time without recognizing population trends. Several threats such as climate change may be negatively affecting current populations but a single point in time is unable to measure the lag effects of those threats (Maschinski et al., 2012; Vitt et al., 2016). Regular population monitoring that includes plant counting or estimates will contribute to more accurate predictions and comprehension of population sustainability.

The inability to locate ginseng at five of the seven locations visited in Huron-Manistee National Forest in 2020 reflects the sensitivity of this species to threats. Two locations that no longer supported ginseng populations had significant changes in canopy and natural community type. Significant canopy changes caused by disease or thinning can make the habitat unsuitable to sustain a population of ginseng, however; these results may not be seen immediately. Anticipating threats of canopy loss may improve the probability of establishing a sustainable ginseng population. In management areas, buffers can be established to minimize deliberate canopy changes. In selecting sites, comparing possible canopy loss due to current and predicted diseases can improve restoration success.

The habitat at three locations appeared suitable, but ginseng plants could not be found approximately 20 years after their last observation. Determining the threat(s) responsible for each population's decline will contribute to the probability of reintroduction success in those locations. Threats that may have contributed to the loss of these populations were likely poaching, animal browse, climate change, or natural stochasticity affecting small populations beyond recovery (McGraw et al., 2013; Hruska et al., 2015). Restoration planners can develop best practices to combat threats of poaching and animal browse, but given the plants rooted habit, climate change threats cannot be combated after plant establishment.

The population at Sleeping Bear Dunes National Lakeshore exhibited significant animal browsing threat (Figure 12). Negative effects of browse are carried over into the following year with reduced leaf area, stalk height, reproduction, and fertility (McGraw et al., 2013). Actions to reduce the likelihood and impact of animal browse will be crucial to the success and sustainability of restored populations. Given the increasing population of browsing animals such as deer in Michigan, such precautions may need to span the existence of the restoration.

The digitization of data from large and small herbaria have contributed to more refined predictions of habitat suitability and species distribution models (Glon et al., 2017; Marsico et al., 2020). Our digital data mining effort updated 19% of EO records with new specimen-based documentation and created 20 new element occurrences. Five of the new records met the criteria to be used in our species distribution model, hence improving the model.

The evaluation statistics of the equal sensitivity/specificity threshold Maxent model support a strong model with good accuracy. The model predicted that forested areas in the Newaygo

Outwash Plain and Vanderbilt Moraines ecoregions and the dune and swale complex communities in the Traverse City and Manistee ecoregions had the most contiguous and highest probability presence of ginseng (Albert, 1995). The Newaygo Outwash Plain intersects with Manistee National Forest. Within the boundaries of Huron-Manistee National Forest, District 1 has the most predicted suitable habitat for ginseng. District 1 is also where the few remaining occurrences are documented.

Restoration of ginseng in suitable unoccupied habitat a short distance away from extant or recently extant populations is a potential useful strategy (Maschinski et al., 2012). Predicted habitat with areas of variable terrain can be successful restoration sites as well (Maschinski et al., 2012; Caughlin et al., 2019). Variable terrain produces micro-habitats that allow for more opportunities of species to self-select to the most suitable area. The importance of terrain environmental variables in the model (i.e., local relief, topographic position index), also the supports the selection of sites with variable terrain.

The importance of mean annual temperature in the model indicates that restoration planners should be aware of local climate change predictions when selecting locations. The predicted habitat suitability was based on current environmental conditions and species presence, and it does not distinguish between stable, increasing, or declining populations. Conditions could be in a state of flux with effects to the population lagging behind the environmental changes. This distinction is important for restoration planning.

The primary Maxent model developed here may be refined to be used to project suitable habitat under various climate change scenarios (Krause and Pennington, 2012). To improve the model, the model settings can be explored and evaluated for overfitting and other limitations and/or it can be compared with other models using different statistical algorithms (e.g., Boosted Regression Tree, Random Forest). A recent method of Ensembles of Small Models (ESM) has also been successfully employed for rare species (Breiner et al. 2015, Di Cola et al. 2017, Breiner et al. 2018). These techniques will further reduce the area of predicted suitable habitat and provide a more robust model to project using various climate change scenarios.

Layering current and future suitable habitat predictions allows one to refine best areas for introduction. Areas where the models intersect or are adjacent would be best for introductions accounting for the threat of climate change. The predictions can vary greatly based on the climate change scenario used, so running multiple models across multiple time periods is recommended.

Stand level data could be incorporated to a GIS Multi-criteria (Malczewski and Jankowski 2020, Malczewski 2006) stand level model for HMNF to create a hybrid model geared towards a specific goal (e.g., survey, restoration) at a finer scale. Experts would choose the predictor variables, criteria, and variable weights used to score the HMNF vegetation stands in light of the specific goal. Variable records at the stand-level (e.g., browse, cover type, species list) could be incorporated into this finer scale model.

Long-term population and habitat monitoring of restoration and other planting efforts may not directly benefit their plantings, but the data lend to future restoration success (Maschinski et al., 2012). Collecting long-term data (i.e., 10 growing seasons or more) is valuable for those analyzing population viability and assessing status and sustainability. Monitoring population success and growth across several microhabitats is recommended for success of the planting and improving future site selection criteria.

Acknowledgments

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Appendix A: Element Occurrences and Rankings

Information related to ginseng (*Panax quinquefolius*) element occurrence records in Michigan Natural Heritage Database (Michigan Natural Features Inventory, 2020).

Table A- 1. Descriptions of Element Occurrence rankings for Natural Heritage Database (Biotics 5).

Rank	Description
A	Excellent estimated viability/ecological integrity
A?	Possibly excellent estimated viability/ecological integrity
AB	Excellent or good estimated viability/ecological integrity
AC	Excellent, good, or fair estimated viability/ecological integrity
B	Good estimated viability/ecological integrity
B?	Possibly good estimated viability/ecological integrity
BC	Good or fair estimated viability/ecological integrity
BD	Good, fair, or poor estimated viability/ecological integrity
C	Fair estimated viability/ecological integrity
C?	Possibly fair estimated viability/ecological integrity
CD	Fair or poor estimated viability/ecological integrity
D	Poor estimated viability/ecological integrity
D?	Possibly poor estimated viability/ecological integrity
E	Verified extant (viability/ecological integrity not assessed)
F	Failed to find
F?	Possibly failed to find
H	Historical
H?	Possibly historical
X	Extirpated
X?	Possibly extirpated
U	Unrankable
NR	Not ranked

Table A- 2. List of ginseng (*Panax quinquefolius*) Element Occurrences (EO) in Michigan's Natural Heritage Database (Biotics 5; Michigan Natural Features Inventory, 2020). Sites organized by county. Descriptions of ranks can be found in **Error! Reference source not found.**. Updated column indicates records that were either visited, had documentation added, or were created as a result of the project. No date is represented by "N.D." Element occurrences in Huron-Manistee National Forest are bolded.

EOID	County(s)	Survey Site Name	Rank	Last Survey	Updated
11029	**Alcona**	[redacted]	**F**	**2020-08-11**	**Visited**
642	Allegan	[redacted]	H	1914-09-12	
4746	Allegan	[redacted]	C	1994-05-26	
8492	Allegan	[redacted]	C	1981-06-25	
10992	Allegan	[redacted]	E	1981	
11195	Allegan	[redacted]	C	1980-06-26	
19815	Allegan	[redacted]	C	2012-08-09	
20618	Allegan	[redacted]	C	2017	Updated
23846	Allegan	[redacted]	H	1927-07-19	New

EOID	County(s)	Survey Site Name	Rank	Last Survey	Updated
1610	Allegan, Kalamazoo	[redacted]	C	2007-05-11	
3965	Antrim	[redacted]	H	1891-08-21	Updated
6694	Antrim	[redacted]	CD	1998-09-29	
10500	Antrim	[redacted]	H	1911-07-05	Updated
23835	Antrim	[redacted]	H?	N.D.	New
23837	Antrim	[redacted]	E	1993-08-29	New
6513	Barry	[redacted]	E	1979	
16254	Barry	[redacted]	CD	2006-06-17	
16885	Barry	[redacted]	B	2012-07-31	
18988	Barry	[redacted]	CD	2012-08-13	
18990	Barry	[redacted]	CD	2012-09-11	
18991	Barry	[redacted]	C	2012-08-01	
19814	Barry	[redacted]	CD	2013-08-26	
20102	Barry	[redacted]	CD	2013-07-31	
20109	Barry	[redacted]	D	2013-08-27	
20113	Barry	[redacted]	BC	2014-06-19	
14618	Benzie	[redacted]	C?	2004-04-26	
16132	Benzie	[redacted]	C	2006-09-12	
21429	Benzie	[redacted]	E	2012-08-18	
23706	Benzie	[redacted]	H	1969-07-05	New
19408	Benzie, Manistee	[redacted]	B	2012-08-23	
1104	Berrien	[redacted]	E	1979-06-11	
2206	Berrien	[redacted]	E	1980	
2986	Berrien	[redacted]	E	1980-07-22	
4427	Berrien	[redacted]	H	1932-06-19	Updated
9500	Berrien	[redacted]	E	1974-08-17	Updated
11637	Berrien	[redacted]	B	2010-08-12	
12250	Berrien	[redacted]	BC	2012-08-27	Updated
16357	Berrien	[redacted]	CD	2006-05-19	
17624	Berrien	[redacted]	C	2018-08-27	
23838	Berrien	[redacted]	H	1894-09-05	New
11539	Berrien, Cass	[redacted]	H	1916-05-15	
1386	Berrien, Cass, Van Buren	[redacted]	H	1915-08-15	
2869	Berrien, Van Buren	[redacted]	E	1980	
4710	Branch	[redacted]	E	1985-09-16	
7241	Branch	[redacted]	H	1950-05-14	Updated
23828	Branch	[redacted]	H	1989-06-21	New
16926	Calhoun	[redacted]	D	2007-05-12	
3673	Cass	[redacted]	C	2005-08-23	
5524	Cass	[redacted]	E	1979	
5525	Cass	[redacted]	E	1979	
5538	Cass	[redacted]	B	1982	Updated
6456	Cass	[redacted]	H	1905-08	Updated
12140	Cass	[redacted]	A	2010-08-12	
12277	Cass	[redacted]	E	1979	
14758	Cass	[redacted]	B	2003-06-09	

EOID	County(s)	Survey Site Name	Rank	Last Survey	Updated
23832	Cass	[redacted]	E	1987-08	New
12718	Charlevoix	[redacted]	H	1912-08-01	
2117	Clare	[redacted]	E	1982	
19730	Clinton	[redacted]	CD	2013-08-30	Updated
2184	Crawford	[redacted]	A	2007-07-20	
5907	Eaton	[redacted]	B	2001-11-01	
23833	Genesee	[redacted]	H	N.D.	New
453	Gogebic	[redacted]	CD	2001-08-19	
2888	Gogebic	[redacted]	F	1997-07-30	
5499	Gogebic	[redacted]	F	1981	
6994	Gogebic	[redacted]	F	1981	
23470	Grand Traverse	[redacted]	E	2019-07-08	
6689	Gratiot	[redacted]	H	1897-05-26	Updated
7317	Hillsdale	[redacted]	C	1985-08-29	
10612	Hillsdale	[redacted]	C	1991-09-03	
3747	Ingham	[redacted]	E	2009-06-16	Updated
9007	Ingham	[redacted]	H	1964-09-17	
11385	Ingham	[redacted]	E	1987	
23845	Ingham	[redacted]	H	1895-06-06	New
13922	Iosco	[redacted]	CD	1995	
532	Jackson	[redacted]	H	1838-07	
1727	Jackson	[redacted]	E	1979	
8040	Jackson	[redacted]	E	1975	
23843	Jackson	[redacted]	H	1838-07-05	New
483	Kalamazoo	[redacted]	H	1933-09-02	
1664	Kalamazoo	[redacted]	H	1947	
2483	Kalamazoo	[redacted]	B	2008-10-02	
2846	Kalamazoo	[redacted]	H	1947	
8412	Kalamazoo	[redacted]	H	1947	
9231	Kalamazoo	[redacted]	E	1981-08-15	
11821	Kalamazoo	[redacted]	H	1945	
11911	Kalamazoo	[redacted]	H	1933-07-17	Updated
23847	Kalamazoo	[redacted]	H	1838-07-27	New
1665	Kalamazoo, Van Buren	[redacted]	H	1947	
18996	Kalkaska	[redacted]	CD	2012-08-22	Updated
85	Kent	[redacted]	H	1896-09-01	
23839	Lapeer	[redacted]	E	2009-06-27	New
3978	Leelanau	[redacted]	E	1987-07-19	
4067	Leelanau	[redacted]	C	1984	Updated
5687	Leelanau	[redacted]	C	2020-08-14	Visited
13113	Leelanau	[redacted]	C	1982-09-16	
13199	Leelanau	[redacted]	C	2011-07-28	
17623	Leelanau	[redacted]	E	2010	
23705	Leelanau	[redacted]	E	2019-08-21	New
4323	Lenawee	[redacted]	H	1916-07-24	
10990	Macomb	[redacted]	E	1982	

EOID	County(s)	Survey Site Name	Rank	Last Survey	Updated
23840	Malcomb, Oakland	[redacted]	H	1843	New
4707	**Manistee**	[redacted]	**F**	**2020-08-06**	**Visited**
11298	Mason	[redacted]	E	1985-07-23	
9065	Monroe	[redacted]	CD	1998-08-12	
5864	Monroe, Washtenaw	[redacted]	H	1925-05-06	Updated
1124	Montcalm	[redacted]	E	1970-08-12	
20141	Montcalm	[redacted]	D	2014-07-02	
3113	Muskegon, Ottawa	[redacted]	C	2010-08-12	Updated
23834	Muskegon, Ottawa	[redacted]	H	1900-06-30	New
8000	No geography listed	[redacted]	H	1911	
5906	Oakland	[redacted]	C	2001-06-26	
7209	Oakland	[redacted]	H	1917-07-29	Updated
8855	Oakland	[redacted]	C	1985-08-27	
23841	Oakland	[redacted]	H	1916-07-30	New
23842	Oakland	[redacted]	H	1917-07-29	New
2499	Ottawa	[redacted]	H	1896-08-17	
6434	Ottawa	[redacted]	H	1914-09-12	
7232	Ottawa	[redacted]	A	1980	Updated
10023	Ottawa	[redacted]	C	1980-08-09	Updated
23829	Ottawa	[redacted]	H	1979-09-05	New
9457	St. Clair	[redacted]	H	1900	Updated
9879	St. Clair	[redacted]	H	1896-06-27	
516	St. Joseph	[redacted]	E	1967-08-08	
3834	Tuscola	[redacted]	F	1979	
5680	Tuscola	[redacted]	F	1977-09-15	Updated
7577	Tuscola	[redacted]	CD	2015-06-16	
12022	Tuscola	[redacted]	E	1979	
6433	Van Buren	[redacted]	H	1910-07-18	Updated
15873	Van Buren	[redacted]	BC	2005-07-16	
16482	Van Buren	[redacted]	D	2006-07-05	
5606	Washtenaw	[redacted]	E	1980	Updated
5688	Washtenaw	[redacted]	C	1992-09-20	
6594	Washtenaw	[redacted]	H	1867	
7004	Washtenaw	[redacted]	C	2012-07-15	
12301	Washtenaw	[redacted]	H	1922-09-18	Updated
12719	Washtenaw	[redacted]	H	1963	Updated
16229	Washtenaw	[redacted]	D	2005-06	
19680	Washtenaw	[redacted]	B	2011-07-03	
20144	Washtenaw	[redacted]	B	2014-10-01	
7208	Wayne	[redacted]	H	1933-07-18	
13487	Wayne	[redacted]	CD	2003-06-09	
23830	Wayne	[redacted]	H	1977-08	New
23831	Wayne	[redacted]	E	2008-06-24	New
3632	Wexford	[redacted]	H	1961-06-25	
18994	**Wexford**	[redacted]	**D**	**2020-08-06**	**Visited**
19849	**Wexford**	[redacted]	**D**	**2020-08-06**	**Visited**
23708	**Wexford**	[redacted]	**F**	**2020-08-07**	**Visited**
23709	**Wexford**	[redacted]	**F**	**2020-08-05**	**Visited**
23710	**Wexford**	[redacted]	**F**	**2020-08-05**	**Visited**

Appendix B: Maps of visited ginseng locations

Maps of the ginseng (*Panax quinquefolius*) locations in Huron-Manistee National Forest and Sleeping Bear Dunes National Lakeshore visited in August 2020 .

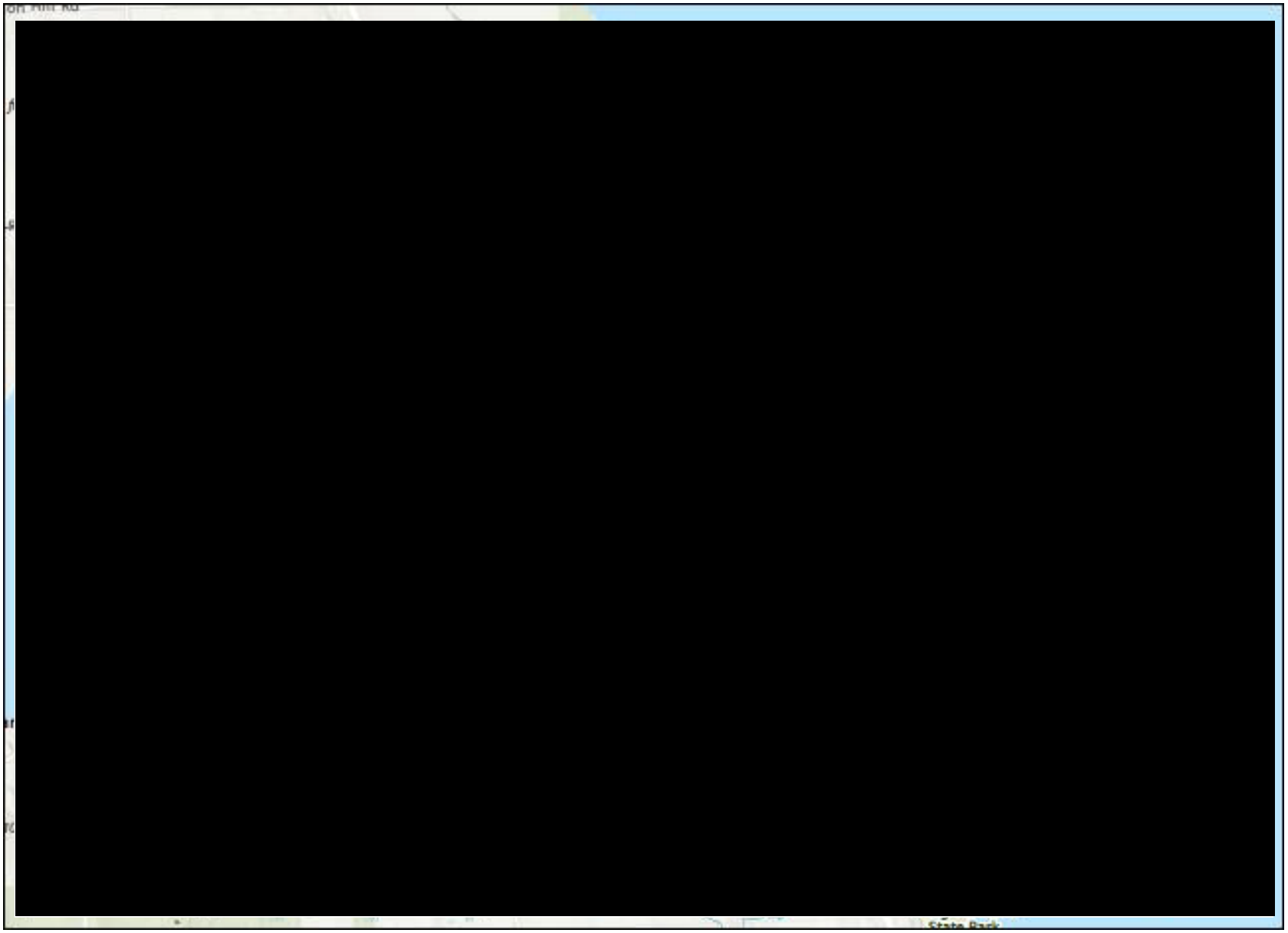

Figure B- 1 Location of ginseng (*Panax quinquefolius*) record EO ID 11029 in Huron National Forest, Alcona County, Michigan. USA.

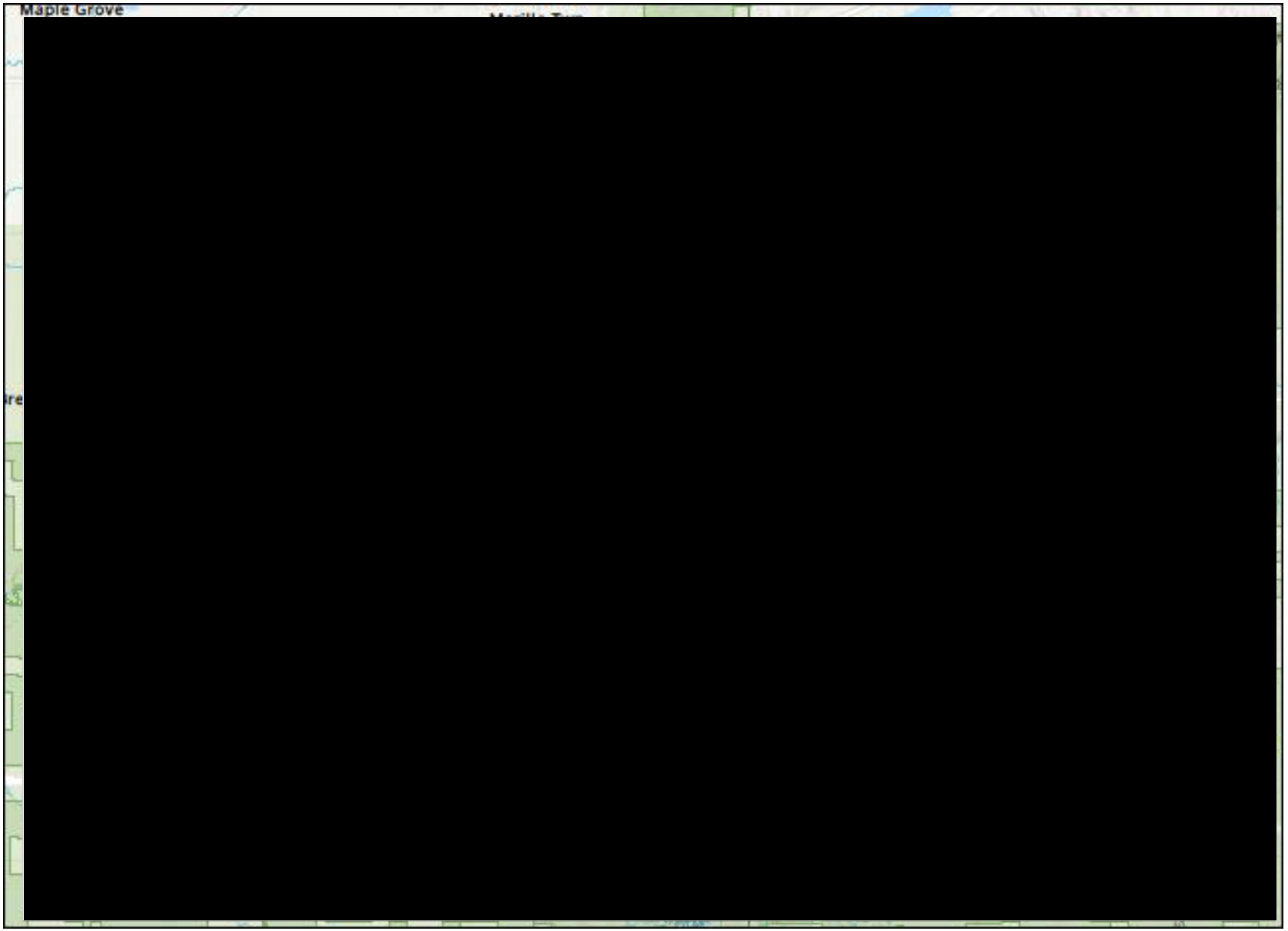

Figure B- 2. Location of ginseng (*Panax quinquefolius*) locations in Manistee National Forest, Manistee and Wexford Counties, Michigan. USA.

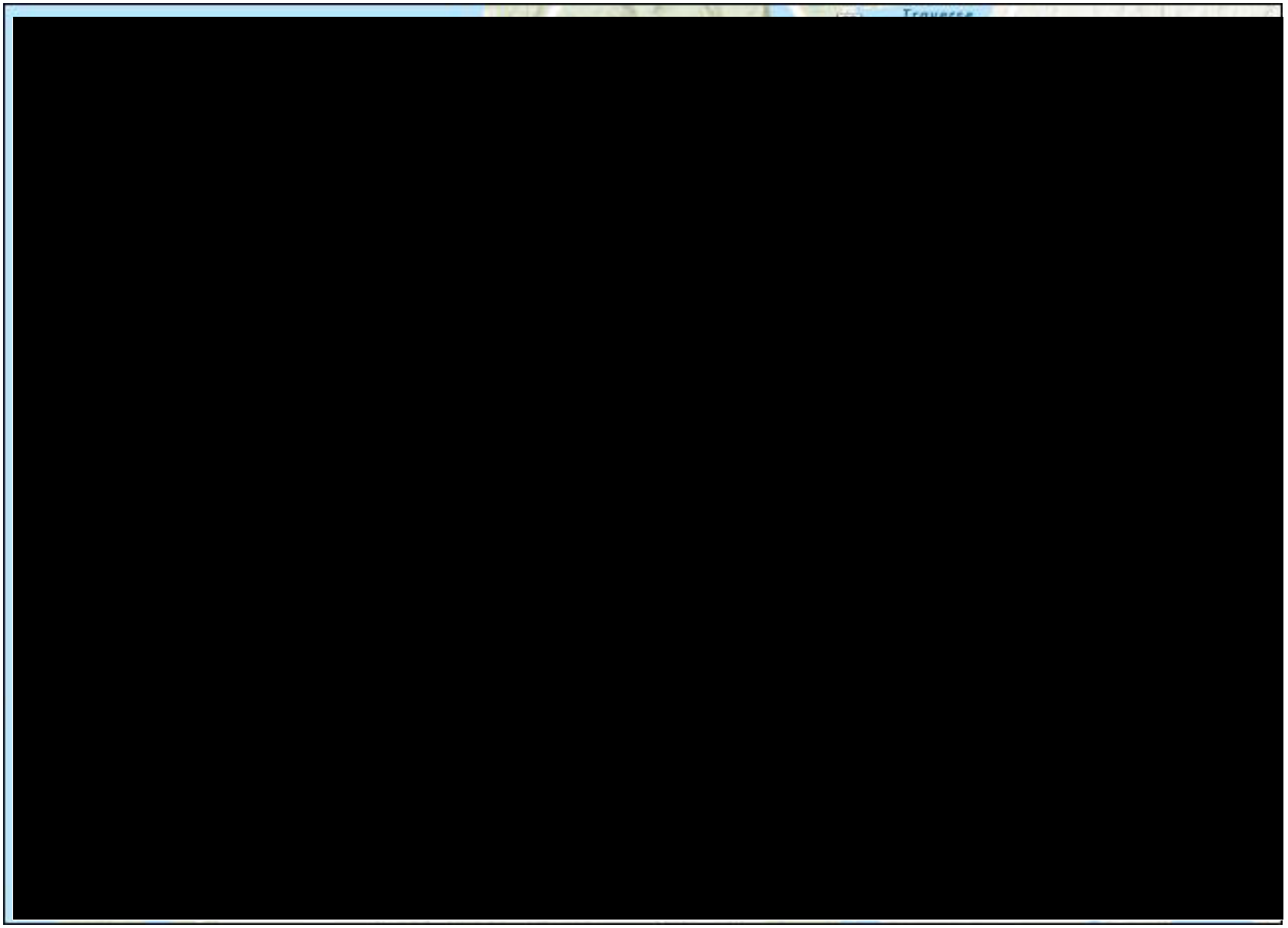

Figure B- 3 Location of visited ginseng (*Panax quinquefolius*) locations in Sleeping Bear Dunes National Lakeshore, Leelanau County, Michigan, USA.