WASHINGTON NATURAL HERITAGE PROGRAM

Potential Habitat of Wenatchee Mountains checkermallow (*Sidalcea oregana* var. *calva*) and Wenatchee larkspur (*Delphinium viridescens*) for Surveys and Outplantings

Prepared by

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ON THE COVER: Typical wet meadow habitat of Wenatchee Mountains Checkermallow at Camas Meadows Natural Area Preserve

Photograph by Jesse E. D. Miller

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Introduction

Wenatchee Mountains checkermallow (*Sidalcea oregana* var. *calva*) is a perennial herb characterized by pink flowers, fleshy round basal leaf blades, and smaller stem leaves with deep palmate divisions. It occurs in montane meadows and forest edges with a high water table in the Wenatchee Mountains and surrounding areas of Chelan County, Washington, USA (Fertig 2022). It was initially collected in 1893 when John Leiberg and John Sandberg discovered it along Icicle Creek near Leavenworth and in Peshastin. Subsequently, it was only sporadically collected over the next four decades, with few records by Kirk Whited near Leavenworth in 1904 and by J. William Thompson at Camas Meadows and the slopes of Tip Top Peak in 1934-35. The taxon was officially recognized as a distinct variety, var. *calva*, by University of Washington botanist C. Leo Hitchcock in 1951, who observed unique leaf, stem, and calyx features that distinguish it from the more common *S. oregana* var. *oregana* (Hitchcock and Kruckeberg 1957).

In 1975, Wenatchee Mountains checkermallow was proposed for listing as Threatened or Endangered under the Endangered Species Act (ESA) by the US Fish and Wildlife Service (USFWS 1975). Although not listed then, it was designated as a Candidate for listing in 1980 (USFWS 1980) and recognized as a state Endangered plant by the Washington Natural Heritage Program (WNHP) in 1981 (WNHP 1981). Following USFWS's proposal in 1997, *S. oregana* var. *calva* was officially listed as Endangered on December 22, 1999 (USFWS 1997, 1999), with a recovery plan published in 2004 (USFWS 2004).

Currently, Wenatchee Mountains checkermallow is known from only four natural occurrences (Fertig 2022). One of the objectives of the recovery plan for this species is to protect or establish additional sustainable populations (USFWS 2004). However, identifying suitable habitat for this species is challenging because the wet meadows and forest edges that it requires occur sporadically amid a rugged mountainous landscape.

Habitat modeling is a tool to identify areas with suitable environmental conditions where a taxon might occur naturally or be successfully introduced based on environmental variables (such as precipitation, temperature, soil, geology, vegetation, aspect, and elevation). Here, we present a potential habitat model for Wenatchee Mountains checkermallow and another Wenatchee Mountains endemic (and state sensitive species), the Wenatchee larkspur (*Delphinium viridescens*) which often co-occurs with Wenatchee Mountains checkermallow and occupies similar montane wet meadow habitats.

After developing the models, we field-tested the Wenatchee Mountains checkermallow model to identify areas that might be suitable for establishing additional populations of Wenatchee Mountains checkermallow through transplanting plugs or direct seeding. We then revised the model based on field verification. This work will supplement ongoing efforts to conserve natural populations and improve habitat quality for introductions of Wenatchee Mountains checkermallow being conducted by the Washington Natural Heritage Program (WNHP), DNR Natural Areas Program, and University of Washington (Rare Care).

Methods

To identify potentially suitable habitat where Wenatchee checkermallow could be outplanted, we used an iterative process of field scouting and habitat suitability model development. Initial model development was informed by field scouting in 2022, when Rare Care, DNR Natural Areas, and WNHP staff scouted about 20 locations that were identified based on local field experience and satellite imagery as potentially suitable habitat. In the winter of 2023, WNHP, Rare Care, DNR Natural Areas, and US Forest Service staff held a series of meetings to discuss potential model predictor variables, based on the 2022 scouting effort as well as our existing knowledge of Wenatchee checkermallow habitat.

To model occurrences of Wenatchee checkermallow and Wenatchee larkspur, we used a maximum entropy model, which requires only presence data (and not absence data; Phillips et al. 2006). Esri's ArcGIS Pro provides their implementation of this model as "Presence-only Prediction (MaxEnt)" (Liu 2022, Esri 2024a). This tool provides many options for experimentation to determine which characteristics and variables provide the most useful model output. To provide the model with sufficient training data points, we created a set of random points within polygons representing known populations of the focal species, which we used as input presence features.

A key decision in running the MaxEnt tool is which set of basis functions to use to transform the explanatory variables. After experimenting with various combinations, for Wenatchee Mountains checkermallow we used the following combination of basis functions:

- Original (Linear) – Applies a linear basis function to the input variables and can be used when a transformation does not need to be applied.

- Smoothed step (Hinge) – Converts the continuous explanatory variable into two segments, a static segment (all zeros or ones) and a linear function (increasing or decreasing), separated by a threshold called a knot.

- Pairwise interaction (Product) – Performs a pairwise multiplication on explanatory variables.

For the Wenatchee larkspur, the use of all three produced a model that greatly overpredicted presence probability, therefore we simplified the model to only use linear and product basis functions,

Other model settings included:

- Number of Knots: 10

- Study Area: Convex hull with spatial thinning applied

- Minimum Nearest Neighbor Distance: 10 meters

- Number of Iterations for Thinning: 10

- Presence Probability Transformation (Link Function): C-log-log
- Presence Probability Cutoff: 0.25
- Validation Options:
    - Resampling Scheme – Random
    - Number of Groups - 3

We restricted the model extent to areas within Chelan and Kittitas Counties with elevations ranging from 1900 to 5000 feet for Wenatchee Mountains checkermallow and 1200 to 6000 feet for Wenatchee larkspur. Because Wenatchee checkermallow and Wenatchee larkspur typically occur in wet valley bottom areas, we confined the model extent to areas with landforms defined as flat, slope, hollow, footslope, valley, or pit based on use of the "Geomorphon Landforms (Spatial Analyst)" tool (Esri 2024b). We excluded areas of open water, cultivated crops, developed areas (high, medium, and low intensity, open space), hay/pasture, or perennial snow/ice based on National Land Cover Database (NLCD) land cover types. We derived the suite of climate variables using the ClimateNA v7.4 tool (ClimateNA 2024).

After the initial model was developed, we reviewed model output and selected sites to visit for further evaluation (Table 3). We focused on areas that were on public land or accessible private land, and areas that seemed suitable based on examination of satellite imagery. At sites selected for field scouting, we tried to visit as many predicted habitat patches as possible, recognizing that some of the characteristics that distinguish Wenatchee Mountains checkermallow habitat at a fine scale would not be represented by the model, which used relatively coarse, gridded environmental data.

Following fieldwork, we revised the model to reflect field observations. Specifically, we added three additional areas that were identified as high-quality habitat outplanting Wenatchee Mountains checkermallow by field visits as training data for the model. The model presented below is this revised version.

Results

The habitat suitability models for Wenatchee Mountains checkermallow (Figures 1-2) and Wenatchee larkspur (Figure 3) predicted numerous small areas of potential habitat in relatively low-lying areas of the landscape, with a patchy distribution across most of the model extent. Variables related to precipitation, temperature, and topographic slope had high absolute coefficients relative to other variables included in the checkermallow model, indicating that they were especially important for predicting its habitat (Table 1). In contrast, variables related to geomorphons and lithology had higher absolute coefficients in the larkspur model, indicating greater influence on the model, relative to other included predictor variables (Table 2).

Both models overpredicted habitat to some extent near the boundaries of the model extent. Because the models appeared to predict plausible habitats most accurately within the core area of existing populations—the vicinity of Camas Meadows Natural Area Preserve near Leavenworth, Washington, and the surrounding ~5-10 miles in all directions—we focus only on this geographic area hereafter (as depicted in Figure 1).

The Wenatchee larkspur model was originally included in this project to provide an alternative approach for identifying potential habitat for Wenatchee Mountains checkermallow because these two species often co-occur. It was initially hypothesized that Wenatchee Mountains checkermallow might have too few populations to train a viable model. However, because the checkermallow model provided enough predicted suitable habitat to meet our needs, and because the larkspur model appeared to overpredict habitat more than the checkermallow model, we focus primarily on the predictions of the checkermallow model hereafter.

Several clusters of model-predicted habitat that seemed promising based on satellite imagery analysis and our field experience in the region were selected for field visits (Table 3). During field visits, we discovered that many areas predicted as habitat by the model seemed too dry to support Wenatchee Mountains checkermallow. For example, all predicted habitats on the US Forest Service-owned portion of Dick Mesa consisted of seasonally moist draws (along with one vernal pool) without distinctive wet meadow vegetation that is often associated with Wenatchee Mountains checkermallow in the wild (e.g., *Veratrum* and *Wyethia*). However, three areas of high-quality potential Wenatchee Mountains checkermallow habitat were identified during field visits (see Table 3 as well):

1. A site southwest of Horse Lake near Wenatchee
2. A site adjacent to Allen Road
3. A site in the vicinity of Deer Park Springs

These sites are now being considered for outplanting efforts by the UW Rare Care Program; a planting has already been planned for fall 2024 at the Deer Park Springs site.

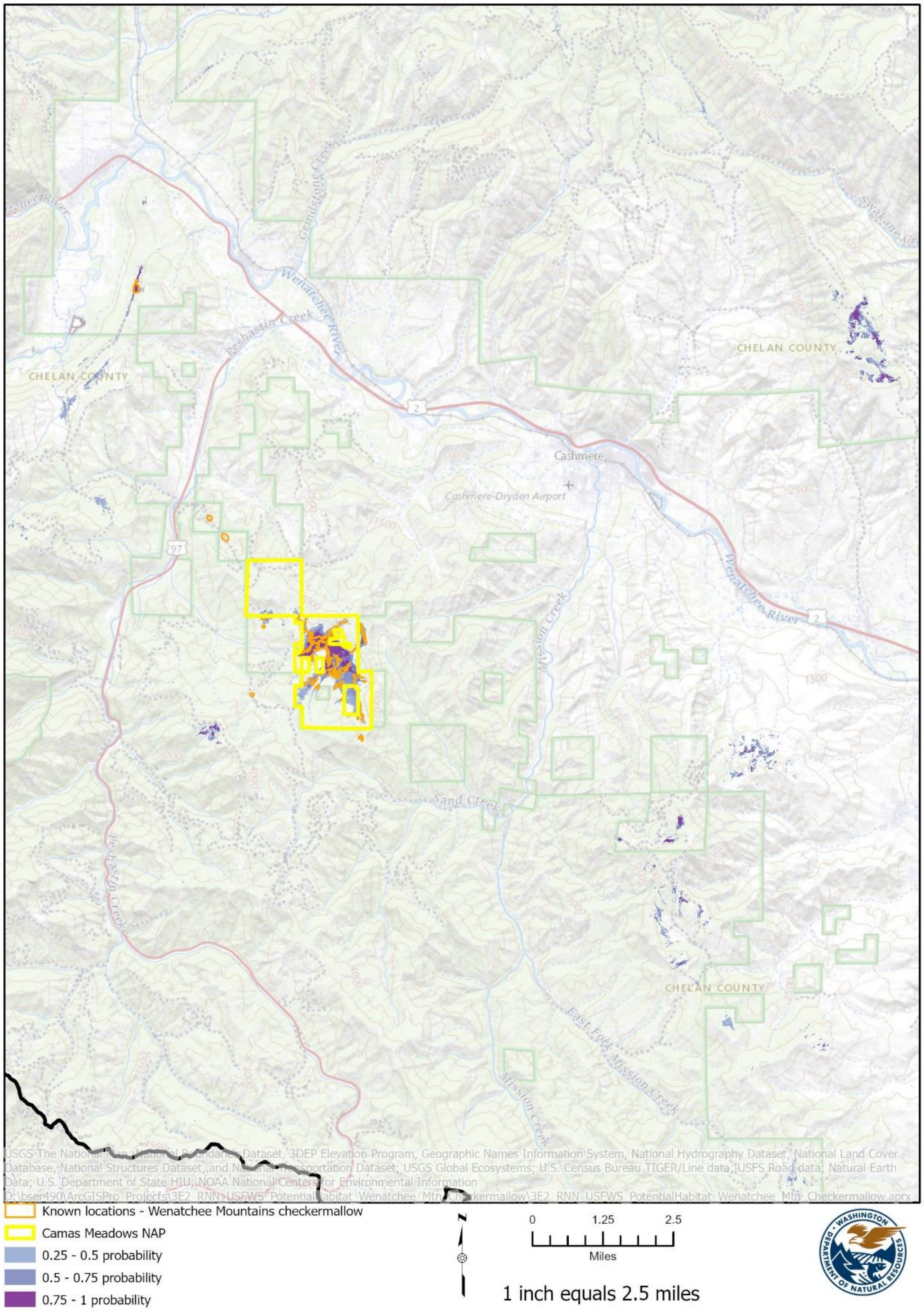

Figure 1. Model results of habitat suitability model for Wenatchee Mountain checkermallow.

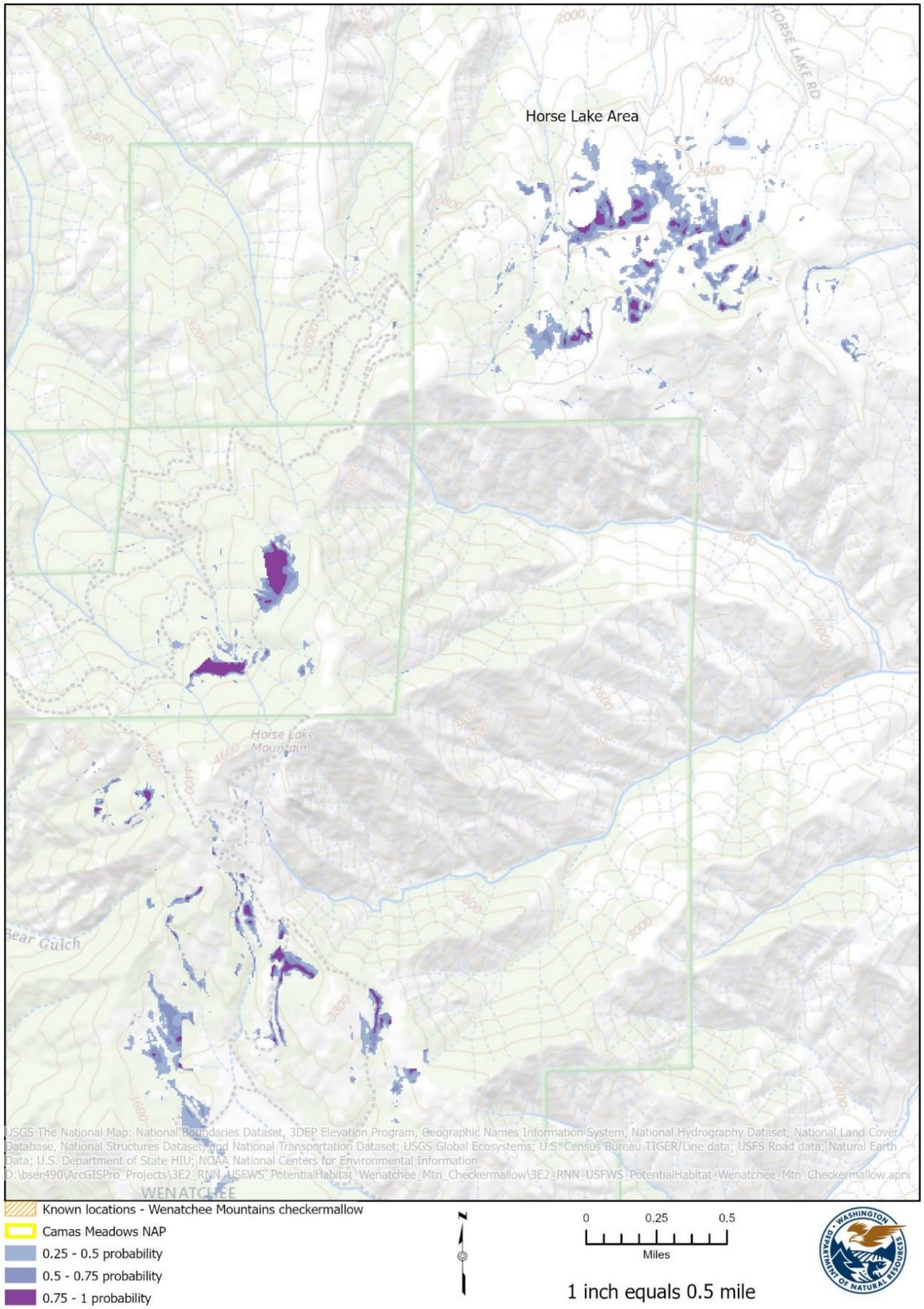

Figure 2. Detail of model results of habitat suitability model for Wenatchee Mountain checkermallow in the vicinity of Horse Lake.

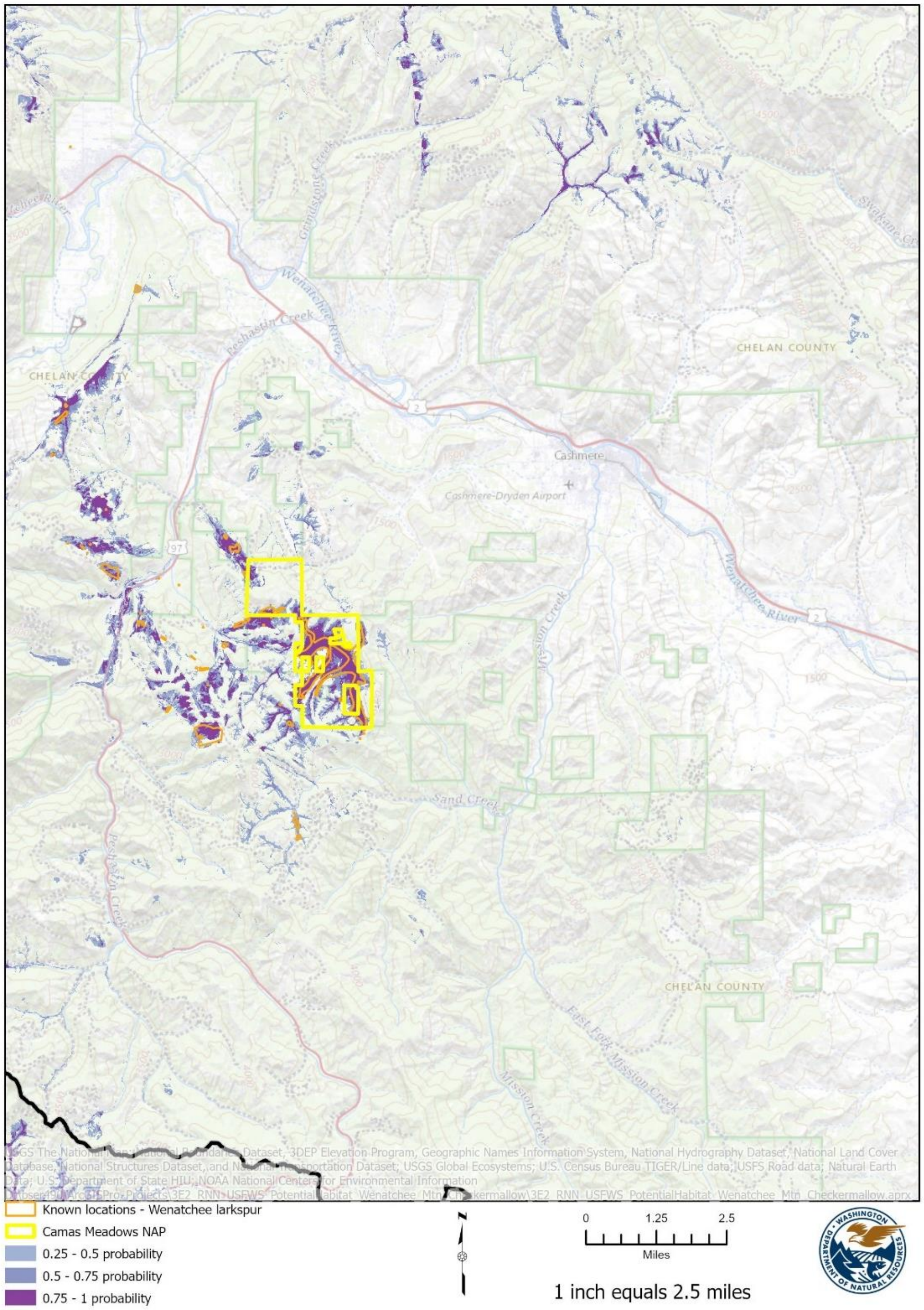

Figure 3. Model results of habitat suitability model for Wenatchee larkspur.

Discussion

The small number of occurrences of Wenatchee Mountain checkermallow represents a critical vulnerability for this taxon, since a disturbance causing the extirpation of just one or two occurrences could leave it on the verge of extinction. For this reason, establishing additional populations through outplantings has been identified as an important step for its conservation (Fertig 2022; USFWS 2004). Outplantings are most likely to be successful if they are performed in ideal habitat for the taxon—wet, low-lying meadows or open woodlands. Our model identified multiple sites that appear to provide high-quality habitat for Wenatchee Mountain checkermallow, and outplanting efforts are currently being planned at one of these sites, as described above. Other apparently suitable sites we identified should be considered for future outplanting efforts.

Although we succeeded in identifying multiple potentially suitable new areas for outplanting Wenatchee Mountain checkermallow, we were not able to field verify all habitats the model predicted, and the sites we identified are not necessarily the only potentially suitable sites on the landscape. Further, habitat suitability models are never perfect, and rare plants are particularly difficult to model because their rarity leads to inherent statistical challenges--accurate models are difficult to create when limited training data are available. Most of the areas predicted as suitable habitat by our model did not appear to actually represent appropriate habitat upon exploration via satellite imagery and field visits, largely because they were too dry to support Wenatchee Mountain checkermallow.

Efforts to identify suitable outplanting sites should continue in the future, since this study likely was not exhaustive. In the future, using supervised classification of satellite imagery could be a useful approach for identifying appropriate wet meadow habitat among the many areas predicted as suitable habitat by this or other models. This approach could be used to focus on the most promising sites for field visits, reducing time spent visiting sites that are too dry to support the species.

Landscapes are dynamic, and patches of suitable habitat for Wenatchee checkermallow may shift geographically over time. A wildfire could transform densely wooded habitat to more open conditions and increase available soil water, improving conditions for the taxon. For example, the area we surveyed east of Boundary Butte appeared to have too much shrub cover to support Wenatchee checkermallow, but might provide appropriate habitat after burning. Therefore, our results represent only a point in time, and new sites should be evaluated as the landscape changes.

Establishing new populations via outplantings is most likely to lead to successful conservation outcomes if performed in tandem with other management and research efforts that promote the conservation of Wenatchee Mountain checkermallow. Landscape-scale management to promote habitat for the species should continue to be a priority; fire suppression has caused encroachment of woody vegetation that reduces habitat quality and could ultimately lead to population declines (Fertig 2022). Substantial efforts to restore habitat with prescribed fire and woody vegetation treatments at multiple Wenatchee Mountain checkermallow sites have already been undertaken (e.g., Wilderman 2015), and needs to be continued to maintain habitat. Additional research could help inform such management efforts. For example, differing fire severities can have contrasting effects on individual plant taxa and broader plant diversity patterns (Miller et al. 2020), but the effects of differing fire severities on Wenatchee Mountain checkermallow remain incompletely understood.

Further work is also needed to understand the life history of Wentatchee checkermallow, and specifically, the phases of its lifecycle where it is most vulnerable (Fertig 2022). A demographic study of this taxon where individual plants are marked and tracked over several years could provide valuable insights into its life history that would further conservation. This could identify phases of the lifecycle of Wenatchee Mountains checkermallow that are most limiting to population growth and could allow management to focus on enhancing outcomes for plants in those phases. This could ultimately lead to better outcomes for both wild and outplanted populations.

Continued research on threats to Wenatchee Mountain checkermallow remains critical because the success of outplantings could be limited by some of the same factors that constrain population sizes at existing sites. Seed herbivory is one potential issue that may affect the long-term viability of the species (Arnett and Birkhauser 2008), and further attention to this and other potential threats remains a priority. Continued monitoring of wild and outplanted populations to understand population trends and outcomes of planting efforts is also important. We envision this study as part of a cohort of multiple, intertwined efforts to sustain Wenatchee Mountain checkermallow.

Table 1. Model results for Wenatchee checkermallow habitat suitability model

Basis Function	Variable Description	Coefficient
hinge	Slope Percent (derived from 10-meter DEM)	-9.7890
hinge	Annual Hargreaves reference evaporation (mm)	4.4427
hinge	Annual Hargreaves reference evaporation (mm)	-0.4456
hinge	Mean annual precipitation (mm)	-3.3736
hinge	Mean annual temperature (°C)	0.6514
hinge	Temperature difference between MWMT and MCMT, or continentality (°C)	-2.8786
hinge	Winter Hogg's climate moisture index (mm)	-0.0027
hinge	spring Hargreaves reference evaporation (mm)	-2.7807
hinge	spring Hargreaves reference evaporation (mm)	-5.7617
hinge	Spring precipitation as snow (mm)	-4.4738
hinge	Winter precipitation (mm)	-1.5701
hinge	Autumn mean temperature (°C)	-0.0018
hinge	Autumn mean temperature (°C)	-0.7135
hinge	Summer mean temperature (°C)	-3.4063
hinge	Winter mean temperature (°C)	3.3395
hinge	Winter mean temperature (°C)	-5.5996
hinge	Winter mean temperature (°C)	-1.2750
hinge	Winter mean temperature (°C)	-3.5414
product	Annual heat-moisture index (MAT+10)/(MAP/1000)) Winter precipitation as snow (mm)	-0.0008
product	Annual heat-moisture index (MAT+10)/(MAP/1000)) Spring precipitation (mm)	-0.0006
product	Mean annual precipitation (mm) Spring Hargreaves climatic moisture deficit (mm)	0.0000
product	Spring Hargreaves climatic moisture deficit (mm) Winter precipitation (mm)	0.0002
product	Spring precipitation (mm); Spring mean temperature (°C)	-0.0003
categorical	Geomorphon landform: Slope	-0.0177
categorical	Geomorphon landform: Hollow	0.2665
categorical	Geomorphon landform: Footslope	0.2200
categorical	Soils suborder: Aeric Fluvaquents, nearly level	0.4486
categorical	Soils suborder: Peoh silt loam	0.1475
categorical	Soils suborder: Nard sandy loam, 30 to 60 percent slopes	0.0448

Table 2. Model results for Wenatchee larkspur habitat suitability model

Basis Function	Variable Description	Coefficient
Linear	Slope Percent (derived from 10-meter DEM)	0.0000
Linear	Annual Hargreaves reference evaporation (mm)	-0.0054
Product	Slope Percent (derived from 10-meter DEM) Annual heat-moisture index (MAT+10)/(MAP/1000))	-0.0001
Product	Slope Percent (derived from 10-meter DEM) Mean annual temperature (°C)	-0.0002
Product	Slope Percent (derived from 10-meter DEM) Spring Hargreaves reference evaporation (mm)	-0.0002
Product	Slope Percent (derived from 10-meter DEM) Spring precipitation as snow (mm)	0.0003
Product	Slope Percent (derived from 10-meter DEM) Spring precipitation (mm)	0.0000
Product	Annual heat-moisture index (MAT+10)/(MAP/1000)) Winter Hogg's climate moisture index (mm)	0.0001
Product	Annual heat-moisture index (MAT+10)/(MAP/1000)) Spring precipitation (mm)	-0.0015
Product	Annual heat-moisture index (MAT+10)/(MAP/1000)) Winter mean temperature (°C)	0.0002
Product	Annual Hargreaves reference evaporation (mm) Mean annual precipitation (mm)	0.0000
Product	Annual Hargreaves reference evaporation (mm) Summer heat-moisture index ((MWMT)/(MSP/1000))	0.0000
Product	Mean annual temperature (°C) Precipitation as snow (mm). For individual years, it covers the period between August in the previous year and July in the current year.	-0.0006
Product	Mean annual temperature (°C) Summer heat-moisture index ((MWMT)/(MSP/1000))	0.0000
Product	Precipitation as snow (mm). For individual years, it covers the period between August in the previous year and July in the current year. Spring mean temperature (°C)	-0.0004
Product	Summer heat-moisture index ((MWMT)/(MSP/1000)) Spring mean temperature (°C)	0.0000
Product	Spring Hargreaves climatic moisture deficit (mm) Spring precipitation as snow (mm)	0.0010
Product	Spring Hargreaves climatic moisture deficit (mm) Spring precipitation (mm)	0.0007

Product	Winter Hogg's climate moisture index (mm) Winter precipitation as snow (mm)	0.0000
Categorical	Geomorphon landform: Slope	-0.3403
Categorical	Geomorphon landform: Hollow	0.3434
Categorical	Geomorphon landform: Valley	0.4214
Categorical	Geomorphon landform: Pit	-0.3171
Categorical	Lithology: continental sedimentary deposits or rocks	1.3273
Categorical	Lithology: continental sedimentary deposits or rocks, conglomerate	3.6230
Categorical	Lithology: basic (mafic) intrusive rocks	0.0274
Categorical	Lithology: mass-wasting deposits, mostly landslides	2.7211
Categorical	Lithology: alluvium	1.5834
Categorical	Lithology: alpine glacial drift, Fraser-age	1.8281

Table 3. Areas of model-predicted Wenatchee checkermallow habitat that were assessed during field visits.

Owner	TRS	Watershed	Elevation (m)	Location	Description	Rapid Assessment Ranking	Notes
USFS	23N 18E S32	Peshastin Creek - Ruby Creek	3760	Deer Park Spring	Apparently suitable habitat, has DEVI	High	High priority for planting
USFS	T25N R17E S22 NW1/4	Wenatchee River	2500	Tumwater Canyon	Forested, gentle slopes	Not suitable	Heavily forested
USFS	T25N R18E S13	Eagle Creek, Wenatchee River	2250	North of Leavenworth	In valley and side drainage, FS Rd access	Not suitable	Too dry, forested
USFS	T24N R17E S25	Peshastin Creek	2500	East of Boundary Butte, upstream of CDLT outplanting	In north-running valley above Mt Home Road	Moderate to high	If site burns, it should be reassessed
USFS	T25N R21E S6, T26N R21E S31	Entiat		Dick Mesa	Seasonal drainages and a vernal pool	Not suitable	Too dry
USFS	T23N R17 E S 12	Peshastin Creek	2600	Allen Creek Rd off of Mt Home above Hwy 2	DEVI in area, much of area seems to have canopy	Moderate to high	If site burns, it should be reassessed
USFS	T24N R19E S12, T24N R20E S7	Swakane	2400	Swakane Canyon	Along creek below beaver ponds	Not suitable	Small area with dense aspen
Private (CDLT)	T23N R19E S35	Wenatchee River	2800	SW of Horse Lake	In north facing draws and slopes	High	One good habitat patch

Table 4. Predictor variables that were initially included in the Wenatchee Mountains checkermallow (SIORCA) and Wenatchee larkspur (DELVIR) models.

Variable Description	Used in final DELVIR Model	Used in final SIORCA Model
Slope Percent (derived from 10-meter DEM)	X	X
Geomorphon landforms (derived from 10-meter DEM)	X	X
Soils suborder		X
Geology (Lithology)	X	
Annual heat-moisture index (MAT+10)/(MAP/1000))	X	X
Hogg's climate moisture index (mm)		
Annual Hargreaves reference evaporation (mm)	X	X
Mean annual precipitation (mm)	X	X
Mean annual temperature (°C)	X	X
Precipitation as snow (mm). For individual years, it covers the period between August in the previous year and July in the current year.	X	
Summer heat-moisture index ((MWMT)/(MSP/1000))	X	
Temperature difference between MWMT and MCMT, or continentality		X
Summer Hargreaves climatic moisture deficit (mm)		
Spring Hargreaves climatic moisture deficit (mm)	X	X
Summer Hogg's climate moisture index (mm)		
Winter Hogg's climate moisture index (mm)	X	X
Summer Hargreaves reference evaporation (mm)		
Spring Hargreaves reference evaporation (mm)	X	X
Spring precipitation as snow (mm)	X	X
Winter precipitation as snow (mm)	X	X
Spring precipitation (mm)	X	X
Winter precipitation (mm)		X
Autumn mean temperature (°C)		X
Summer mean temperature (°C)		X
Spring mean temperature (°C)	X	X
Winter mean temperature (°C)	X	X

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