Recognizing Multiple *Lomatium* Species Using Morphologic, Geographic, and Climatic Data: Case Study in *L. dissectum*

Ian Clifford, Dr. Don Mansfield

PENA Background

The PENA (Perennial Endemic North American) clade in the flowering plant family Apiaceae is one of the largest clades in the American west (1). Within the clade, two of the most diverse genera are *Lomatium* and *Cymopterus* (1). Recent research has found that existing species names in these genera often conceal multiple species, as was the case with *L. ravenii* and *L. bentonitum* (2). Due to high levels of intraspecific variation in the *L. dissectum* species complex, the research goal is to discern whether there are additional species nested within this complex.

Methods

For multiple reasons, the biological species concept is inadequate for studying plants. Instead, plant biologists use combinations of species concepts. Here we use morphologic, geographic, ecologic, and genealogic species concepts.

Morphologic Concept Tests: The morphologic species concept uses measurements of plant characteristics to find any discontinuities between the physical forms of plants. Analyzing sets of measurements (such as leaf length, bract length, etc) using Principal Components Analysis (PCA) in Paleontological Statistics (PAST4.04) software illuminates discontinuities, which could indicate different species or varieties.

Geographic Concept Tests: The locality field notes made by collectors were used to map specimen locations in Google Maps and investigate whether there are geographic separations between ranges of morphologically distinct groups.

Ecologic/Climatic Concept Tests: Using 19 bioclimatic variables retrieved from the Worldclim database for each specimen's lat/long coordinates, we analyzed climate variation among plant populations using RStudio. A PCA of these variables tests for different climatic niches. Predicted geographic distribution can be modeled from the data.

Genealogic methods: Colleagues at Boise State University have been conducting DNA sequence analysis on multiple specimens within the *L. dissectum* groups to discern genetic relationships among them.

Morphometric Results

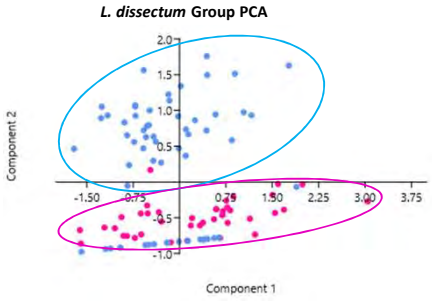

Figure 1. There are two putative *L. dissectum* species in this group: *L. dissectum* (D) circled in pink, and *L. multifidum* (M) in blue. This figure shows the morphometric data of 101 specimens in the Harold M. Tucker Herbarium and the Pacific Northwest Herbaria database. Characters included in the PCA are leaf area, leaf width, leaf length, and fruiting pedicel length.
(Note: The row of blue *multifidum* specimens at the bottom of the *dissectum* grouping is likely due to missing character values, which can be accounted for relatively simply in future PCAs)

Geographic Results

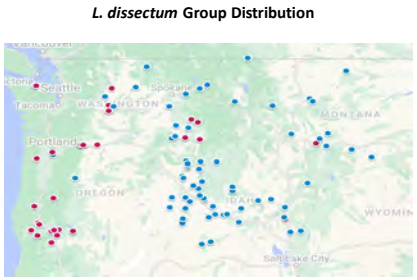

Figure 2. Geographic distribution of *L. dissectum* group across the Pacific Northwest. The two morphologically distinct groups have different geographic ranges, as expected for different species (pink is *L. dissectum,* blue is *L. multifidum*).

Climatic Results

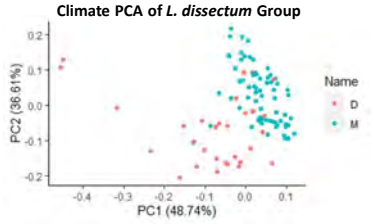

Figure 3. Climate PCA of the two putative *L. dissectum* species: *L. multifidum* (blue) and *L. dissectum* (pink). The two morphologically distinct groups appear to have evolved to different climatic niches. In order to conduct these PCAs, the latitude and longitude coordinates of each of the 101 specimens (each representing one population) were connected to the specific climatic conditions of that square kilometer. The PCA compares those climatic conditions to find differences between all of the points.

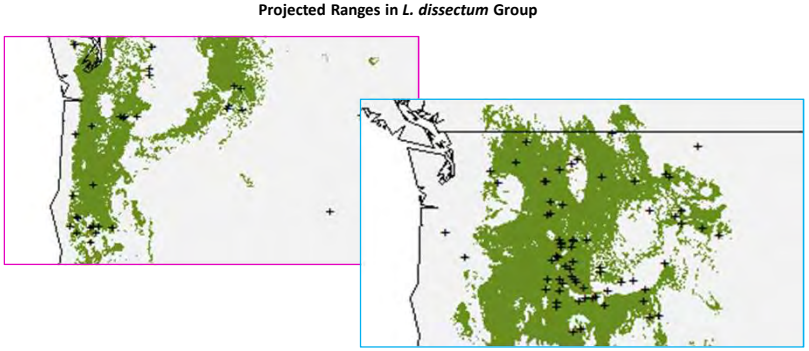

Figure 4. Modeled predicted ranges *of L. multifidum* (blue outline, top) and *L. dissectum* (pink outline, bottom) based on current climate data. These maps show the climatic conditions that are predicted to be favorable for the species' existence in the highlighted (green) areas. Black points (+'s) represent the actual localities of plants.

Conclusions/Next Steps

Morphometric, geographic, and climatic data all support separation of *L. dissectum* into two species.
Next Steps

- Soils analysis
- Additional climate analysis of the species, including future models
- Conducting different PCAs/FAMDs
- Combining data with phylogenetic results from DNA sequence analyses found by Dr. Smith and colleagues at BSU

Figure 8. Both of the above images are considered *L. dissectum* in the broadest sense. However, the one on the right is glaucous (covered in blue epidermal scales) with purple flowers, while the one on the left is green with yellow flowers. Are they different species?
Images courtesy of Cody Hinchliff (3).

References

1. George, Emma E., et al. "Phylogenetic Analysis Reveals Multiple Cases of Morphological Parallelism and Taxonomic Polyphyly in Lomatium (Apiaceae)." *Systematic Botany*, vol. 39, no. 2, 2014, pp. 662–675., https://doi.org/10.1600/036364414x680843.
2. Carlson, Kimberly M., et al. "A New Species in the Lomatium Foeniculaceum (Apiaceae) Clade Revealed through Combined Morphometric and Phylogenetic Analyses." *Systematic Botany*, vol. 36, no. 2, 2011, pp. 495–507., https://doi.org/10.1600/036364411x569688.
3. https://www.flickr.com/photos/codiferous/8387222648/in/album-72157632539419920/

Acknowledgments

Many thanks to Dr. Mansfield for his expertise and guidance; to Reina Watkins for her support; to Beth Corbin for her fieldwork help; to Dr. Jim Smith and the BSU DNA analysis team; and to Mark Darrach, Barbara Wilson, and Barbara Ertter for additional help. This project is generously funded by a National Science Foundation grant.

NSF THE COLLEGE of IDAHO