Columbia yellowcress (*Rorippa columbiae*) in the BLM Lakeview District: Population monitoring and conservation

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Report to the Bureau of Land Management, Lakeview District

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Institute for Applied Ecology

Institute for Applied Ecology

PREFACE

IAE is a non-profit organization whose mission is the conservation of native ecosystems through restoration, research, and education. IAE provides services to public and private agencies and individuals through development and communication of information on ecosystems, species, and effective management strategies. Restoration of habitats, with a concentration on rare and invasive species, is a primary focus. IAE conducts its work through partnerships with a diverse group of agencies, organizations, and the private sector. IAE aims to link its community with native habitats through education and outreach.

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Cover photograph: Detail of Columbia yellowcress (*Rorippa columbiae*) plants at Sprague River. Photograph, and all others unless documented otherwise, by J. Christina Mitchell.

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EXECUTIVE SUMMARY

In 2022, the Institute for Applied Ecology (IAE) partnered with the Bureau of Land Management (BLM) Lakeview District to research how to maintain and restore a BLM Sensitive plant, Columbia yellowcress (*Rorippa columbiae*), and its habitat. This project involves censusing extant populations of Columbia yellowcress and quantifying the local vegetation community on Stukel Mountain, where this species exists but is not thriving. Our goals are to develop a method for effective population establishment and to improve management strategies for this species.

To this end, IAE collected Columbia yellowcress seeds from a healthy population along Sprague River in Klamath County, OR (site access facilitated by US Forest Service) and seeded 1000 plugs to grow over the winter. These plugs will be outplanted on Stukel Mountain, near Klamath Falls, OR, in April 2023, and their survival will be monitored in addition to annual censuses and vegetation community surveys. Two locations were censused on Stukel Mountain in 2022; we found 1 vegetative and 21 flowering plants and a total of 153 stems at the public site, and 6 flowering plants and a total of 12 stems at the private site.

Conservation of this species will preserve the native diversity of plants on Stukel Mountain and contribute to a better understanding of the trends, demography, and specific ecology of this uncommon species in other areas of its range.

1. INTRODUCTION

Rorippa columbiae is a low-growing perennial forb in the mustard (Brassicaceae) family and alternative common names include Columbia cress, Columbia yellowcress, and Columbian yellowcress (USDA NRCS 2016). Columbia yellowcress inhabits shoreline areas with seasonal inundations of water, including along lakes, playas, rivers, streams, and human-made ditches (Kentnesse 2017b). It is unknown exactly how long Columbia yellowcress individuals live and though it is a perennial species, some individuals behave as annuals. Plants are capable of reproduction by both seed (sexually) and rhizomes (vegetatively; Kaye 1996, Kentnesse 2017b). Populations of Columbia yellowcress appear to be healthy along the banks and within swales on the small islands in the Sprague River at an elevation of 1305 m (cover photograph). While the two populations in seasonally inundated depressions on Stukel Mountain, at 1518 m and 1545 m, do not appear as healthy (Figure 1). Previous surveys of Columbia yellowcress populations across southern Oregon suggested plant survival was threatened by human-, livestock-, and vehicle-related trampling, alteration of hydrologic regimes, and the invasion of and encroachment by nonnative plant species (Kaye 1996, Kentnesse 2017a, Kentnesse 2017b). Columbia yellowcress is not federally listed under the Endangered Species Act but is a state-listed threatened species in Washington (Washington Natural Heritage Program 1997), considered rare or endangered in California by the California Native Plant Society (California Native Plant Society 2023), and is a candidate species in Oregon (Oregon Department of Agriculture 2023).

Figure 1. Columbia yellowcress (*Rorippa columbiae*); pond site at Stukel Mountain.

It is expected that water availability and hydrology regimes, together with availability of bare ground and thatch, are the primary drivers of Columbia yellowcress distribution. At Sprague River, we observed Columbia yellowcress mainly growing in bare ground, in thatch under and near sagebrush (*Artemisia tridentata*), and amongst dense plants (including reed canary grass, *Phalaris arundinacea*). We also observed Columbia yellowcress occurring in low, but not typically the lowest, lying swales among other plants and thatch, at mid-elevation areas along "shorelines", and in bare ground both with and without evidence of trampling. When we returned to collect seeds in mid-August, one of the densest patches of Columbia yellowcress had most flowering tops consumed by a presumed herbivore (Figure 2a; 2b). At each site we visited, we saw various insects visiting Columbia yellowcress flowers, feeding on its plant tissues, or otherwise associating with it (Figure 2c).

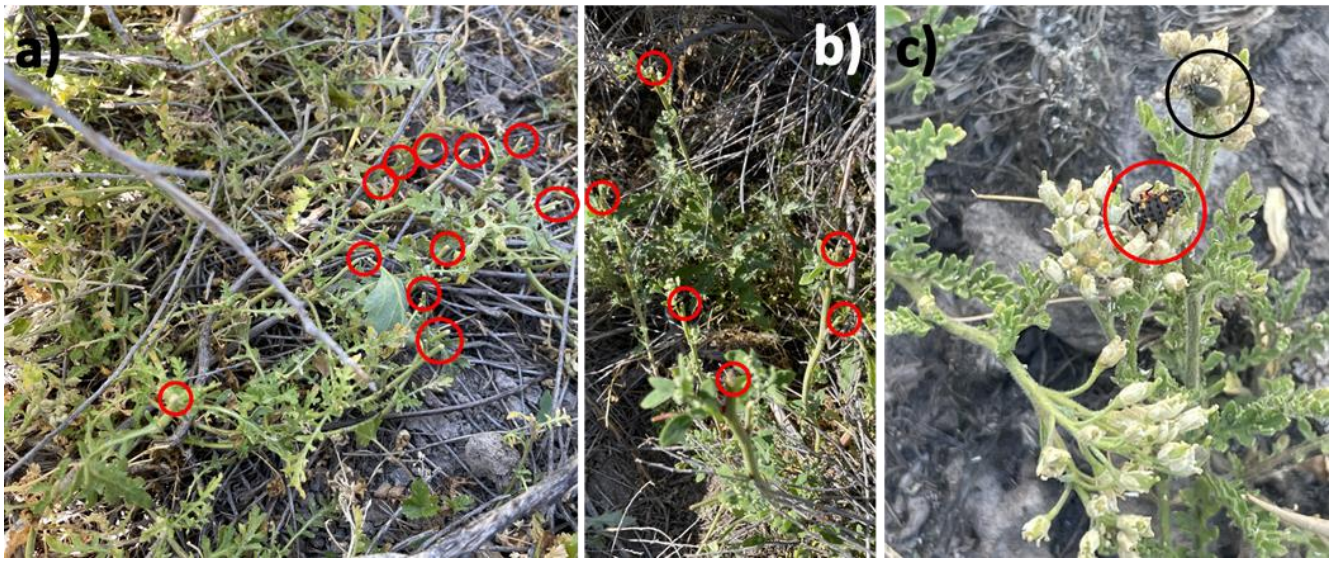

Figure 2. Evidence of herbivory damage (a, b) highlighted with red circles; insect associations (c) included ladybeetle larvae (red circle) and an aphid (black circle).

The BLM Klamath Falls Field Office, as part of the National Seed Strategy for Rehabilitation and Restoration within the Klamath Falls Resource Area, partnered with IAE in 2022 to conduct a three-year project to monitor, conserve, and augment populations of Columbia yellowcress on Stukel Mountain. In July 2022, two known populations of Columbia yellowcress plants were censused and surrounding plant communities were sampled on Stukel Mountain. One population occurs on BLM land and the other occurs on private property. In August 2022, mature Columbia yellowcress seeds were collected from populations along Sprague River. IAE began growing these seeds in the greenhouse in November 2022 and plugs will be outplanted on Stukel Mountain in April 2023. Our hope is that augmenting populations on Stukel Mountain with outsourced material will foster stable populations and improve genetics to better adapt to future perturbations.

2. GOALS AND OBJECTIVES

The goals of this project are to develop methods for effective Columbia yellowcress population establishment and to inform management strategies for conserving this species and its habitat.

Specific objectives are:

1) Census Columbia yellowcress and quantify associated vegetation communities on Stukel Mountain;
2) Collect Columbia yellowcress seeds from Sprague River populations, grow plugs in the greenhouse, and outplant plugs on Stukel Mountain to augment natural population; and
3) Monitor Columbia yellowcress on Stukel Mountain and track demography of the naturally-occurring population and outplanted plugs to determine traits of survival and inform conservation management protocols.

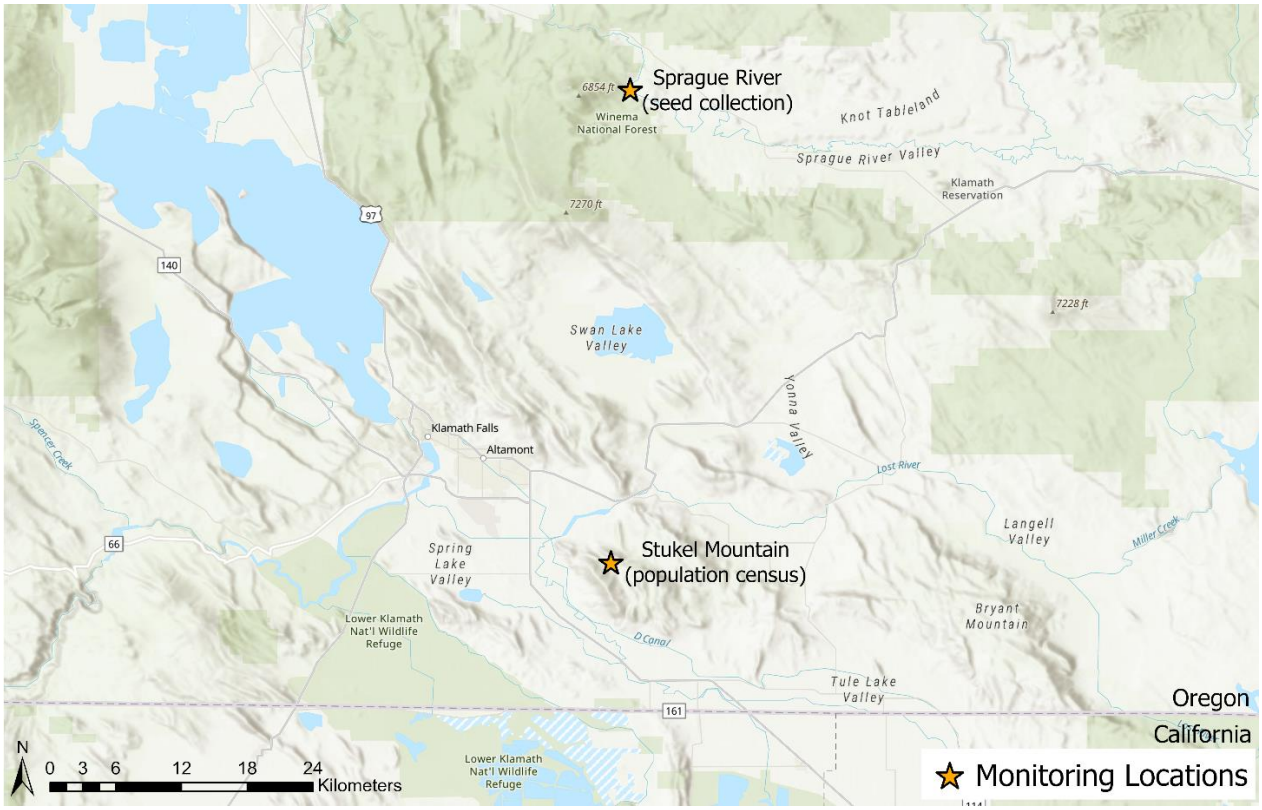

Figure 3. Locations of 2022 Columbia yellowcress seed collection (Sprague River, northern site) and population monitoring (Stukel Mountain, southern site) in Southern Oregon. Map created in ArcGIS Pro.

3. METHODS

3.1. Site Description

In 2022, we visited two known locations of Columbia yellowcress populations in Southern Oregon (Figure 3). Columbia yellowcress populations and surrounding plant communities were quantified at two locations on Stukel Mountain (Figure 4); one site owned and managed by the BLM (Stukel 1 'pond', 42.120398, -121.631561; Figure 4a) and one site owned and managed by a private entity (Stukel 2 'private'; Figure 4b). Columbia yellowcress was known to occur at these sites but populations had not been monitored since 2016 (Kentnesse 2017a).

To get an understanding of a healthy population of Columbia yellowcress, and later to collect seed, we visited an area along the Sprague River (42.510321, -121.617632; Figure 5) with permission from the USDA Forest Service.

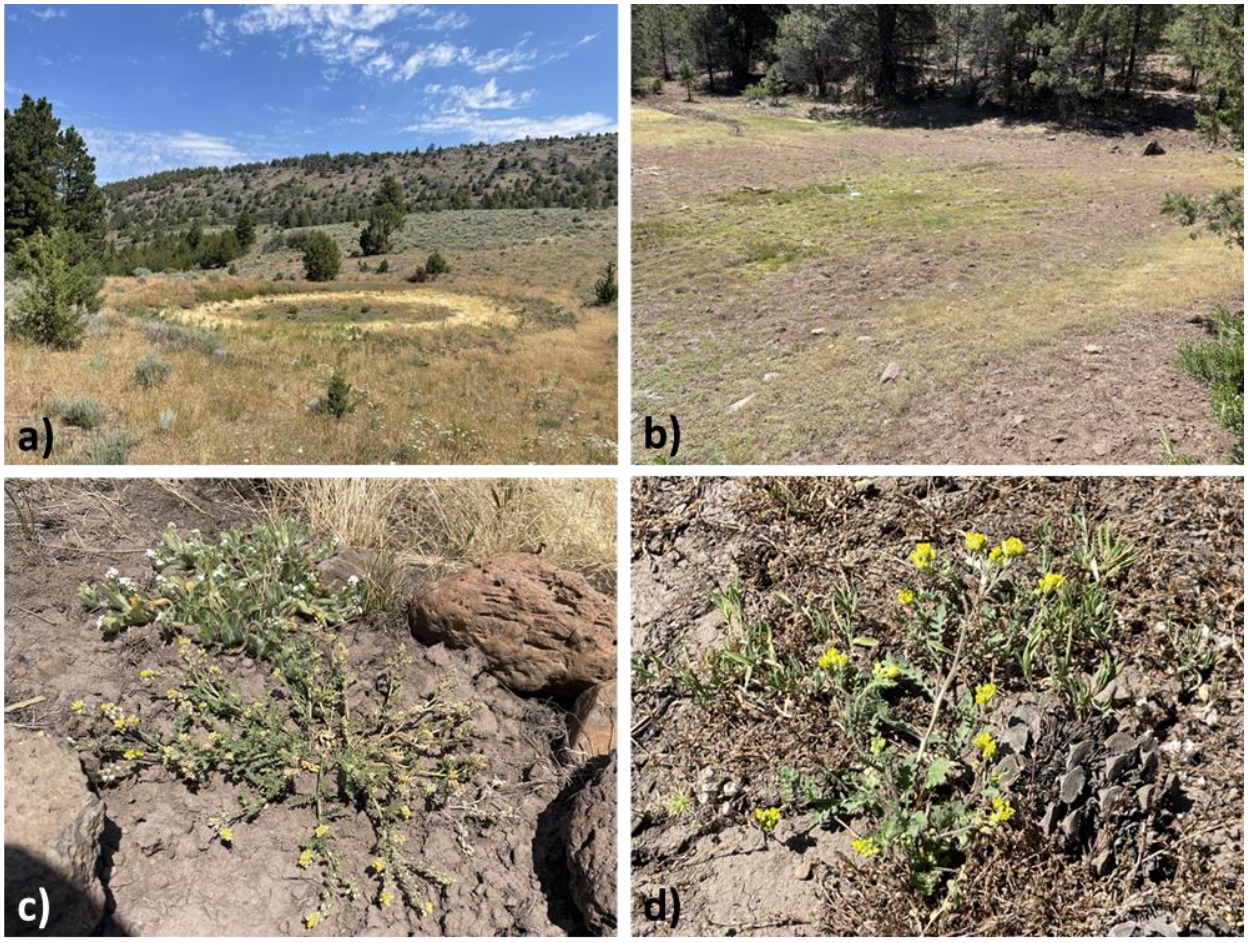

Figure 4. Stukel Mountain; contextual photographs of the pond (a) and private (b) sites displaying changes in elevation and plant communities, and two examples of Columbia yellowcress (*Rorippa columbiae)* plants and their immediate surroundings (c; d).

Figure 5. Sprague River; site of seed collection. Contextual photographs of (a) Sprague riverbank and islands, (b) Columbia yellowcress (*Rorippa columbiae*) amongst other plants, and (c) a close-up picture of flowering Columbia yellowcress.

3.2. Population Census

On July 12th and 13th 2022, each site was surveyed for all occurrences of Columbia yellowcress and plants were marked with pin flags. Locations of Columbia yellowcress were georeferenced using Field Maps software on a Samsung tablet and a Bad Elf GNSS surveyor with GPS accuracy of 1–3 meters. Populations were censused using methods based on Kaye (1996). Columbia yellowcress plants were determined to be individuals if stems at the base were 3 cm apart or greater. The total number of plants in the vegetative (no evidence of flowers or fruits) and flowering (evidence of flowers or fruit) stages were determined for each site. We then determined the following for each plant: total number of plant stems, length (cm) of the longest stem, total number of buds and flowers on the longest stem, total number of fruits (seed capsules) on the longest stem, and the total number of leaves on the longest stem.

Censusing will continue for the duration of this project to determine how Columbia yellowcress populations naturally fluctuate over time, and in response to management actions. After plugs are outplanted on Stukel Mountain, censuses will provide annual survival rates and demographic information. This will elucidate whether Columbia yellowcress plants from different source locations, Stukel Mountain or Sprague River, or reproductive strategies, naturally occurring or augmented, indicate better growth and survival.

3.3. Surrounding Vegetation Community

Understanding vegetation communities in association with Columbia yellowcress in natural populations over time can inform which species and conditions may be beneficial versus antagonistic, and inform management practices to benefit Columbia yellowcress conservation.

On Stukel Mountain, transect locations for vegetation community quadrats were based on the distribution of Columbia yellowcress and the gradient of microelevation changes at each site. Transects and quadrats covered the area of changing microelevation at each site and were placed to ensure at least one Columbia yellowcress plant would be included in the sample and that transects ran parallel to the microelevation gradient. The Stukel 1, or 'pond', site had 18 quadrats dispersed along 2 transects marked with permanent survey markers (one rebar with metal tag per transect, on north end). The Stukel 2, or 'private', site had 18 quadrats dispersed along 3 transects to account for the broader area. At Stukel 2, no survey markers were left on site (because it is private property) but locations were georeferenced so that transects can be recreated with compass and meter tape.

Each 1-m x 1-m pvc-frame quadrat was placed adjacent to the transect and the vegetation community within the area was sampled. Transect 1 at the 'pond' site ran 25-m from north to south. Transect 2 at the 'pond' was parallel to and 10-m east of Transect 1 and ran for 30-m (Figure 6a). Quadrats were placed 2-m apart and laid to the east side of the transect. The 'private' site covered a larger area than the 'pond' site and had less Columbia yellowcress plants spaced farther apart. To account for this difference, while still including Columbia yellowcress in vegetation community samples, quadrats were placed roughly 7-m apart from one another along three transects to span the site and microelevation gradient (Figure 6b). As the nature of the microevelation gradient differed between the two sites, transects at the 'private' site ran more NW to SE and quadrats were angled slightly to orient northward, matching the placement of quadrats along the transects at the 'pond' site.

Figure 6. Diagram showing how two sites on Stukel Mountain, (a) Stukel 1 "pond" and (b) Stukel 2 "private", were set up with transects (purple lines) and quadrats (white squares) to survey vegetation communities associated with Columbia yellowcress (*Rorippa columbiae*). The red star indicates that at the 'private' site, quadrats were angled slightly off the quadrat line to orient northwest-ward. Satellite imagery from Google; diagrams are representative and not drawn to scale.

Within each quadrat, percent cover was estimated for each plant species and seven types of ground cover: bare ground, rocks, moss and lichen, standing water, fecal matter (e.g. cow, ungulate, rodent), woody litter (e.g. sage branches, pine cones), and non-woody litter (e.g. grasses or other herbaceous material). Cover for each of these categories was estimated independently; for example, a rock covered with lichen contributed to the total percent cover of rock, and the total percent cover of lichen. Each plant species within a quadrat was identified to the lowest taxonomic level possible. Percent cover of each plant species within a quadrat was estimated to the closest percentage point, and instances of a species covering 0.5% or less of the quadrat were considered 'trace'. Therefore, the total sum of percent cover, by ground cover types and plants, within a single quadrat could exceed 100%.

Long-term monitoring is critical to track how well natural and augmented populations establish, and to evaluate how populations respond to infrequent events (e.g., drought) or changes that may take several years to express (e.g. inbreeding depression, soil seedbank replenishment, hydrology regimes; Maschinski and Haskins 2012). Monitoring protocols will be established and used at any potential future sites.

3.4. Seed Collection and Plant Propagation

On August 15th and 16th 2022, an estimated 10,000 mature seeds were collected across the known extent of Columbia yellowcress plants at Sprague River (seed-collection permit provided by USDA Forest Service). To collect seeds, mature-looking fruit capsules were handpicked from Columbia yellowcress inflorescences and placed directly in coin envelopes, an estimated 1,000 seeds per bag (Figure 7a-b). Fruit capsules were determined mature if they began turning brown or purple instead of fully green, or if they had already started to dehisce. No more than 5% of seeds were taken from a plant or within a

given area to avoid overharvesting and to maximize genetic diversity. Fruit capsules were processed and sieved to separate seeds from other plant material and seeds were stored at room temperature (~68˚F) until sowing. Seeds looked variable in size and color when inspected under a microscope (Figure 7c), so a small trial was conducted to determine which seeds were more viable. A sample of five 'plumper, paler' seeds (Figure 7d; presumed more viable) and seven 'flatter, darker' seeds (presumed less viable) were placed in bags between moist paper towels and left in a sunny windowsill for 2 months. By trial's end, 80% of the 'plumper, paler' seeds and 29% of the 'flatter, darker' seeds successfully germinated and grew roots and shoots. We initially targeted these 'plumper, paler' seeds for plug seeding, but ended up using all collected seed.

Figure 7. Examples of Columbia yellowcress (*Rorippa columbiae*) (a) fruit, a silicle, and (b, c, d) seed.

Propagation knowledge of Columbia yellowcress is limited but work by Kaye (1996) and Kentnesse (2017a, 2017b) provided details and guidance for our process. We seeded 1000 conetainer plugs in two cohorts to allow flexible start and end dates for accommodating Columbia yellowcress' unknown growth rate and Stukel Mountain's April weather conditions.

The first cohort of 500 plugs was seeded on 11/15/22, but only 11 seedlings had emerged six weeks after seeding (Figure 8a). As part of general greenhouse protocol, large vermiculite was used to cover Columbia yellowcress seeds after sowing. Since this species depends on light for germination (Kentnesse 2017a), we believe putting large vermiculite over the seeds reduced the amount of light reaching the seeds and reduced germination. This vermiculite was removed from the plugs and placed in a seeding tray in the greenhouse, on the chance that seeds were also removed and may still germinate. On 12/30/22 plugs with no germination were overseeded with seed remaining after sowing cohort two.

The second cohort of 500 plugs was seeded on 12/30/22 using a different method than cohort one. All plugs in cohort two were filled with soil, lightly top dressed with fine vermiculite, and then Columbia yellowcress seeds were surface sown. Additionally, plugs in both cohorts were switched from traditional watering to mist watering after this date. Germination in the second cohort was much better, with 329 of 500 plugs germinated 2.5 weeks after seeding. The plants also grew better, likely a result of increased light (Figure 8b). As of 2/23/23 there were 69 plants from the first cohort, mostly lanky and without flower buds, that were sown about 14.5 weeks prior, and 426 plants from the second cohort, mostly

dense and with flowers, that were sown about eight weeks prior. Seeded plugs will continue to be monitored and hardened off to outside temperatures beginning in March, for a targeted outplanting on Stukel Mountain in mid-April. Pending knowledge of outplanting survival, we recommend future propagation efforts mimic the conditions of the second cohort, but surface sow seeds later to maximize light with longer day lengths.

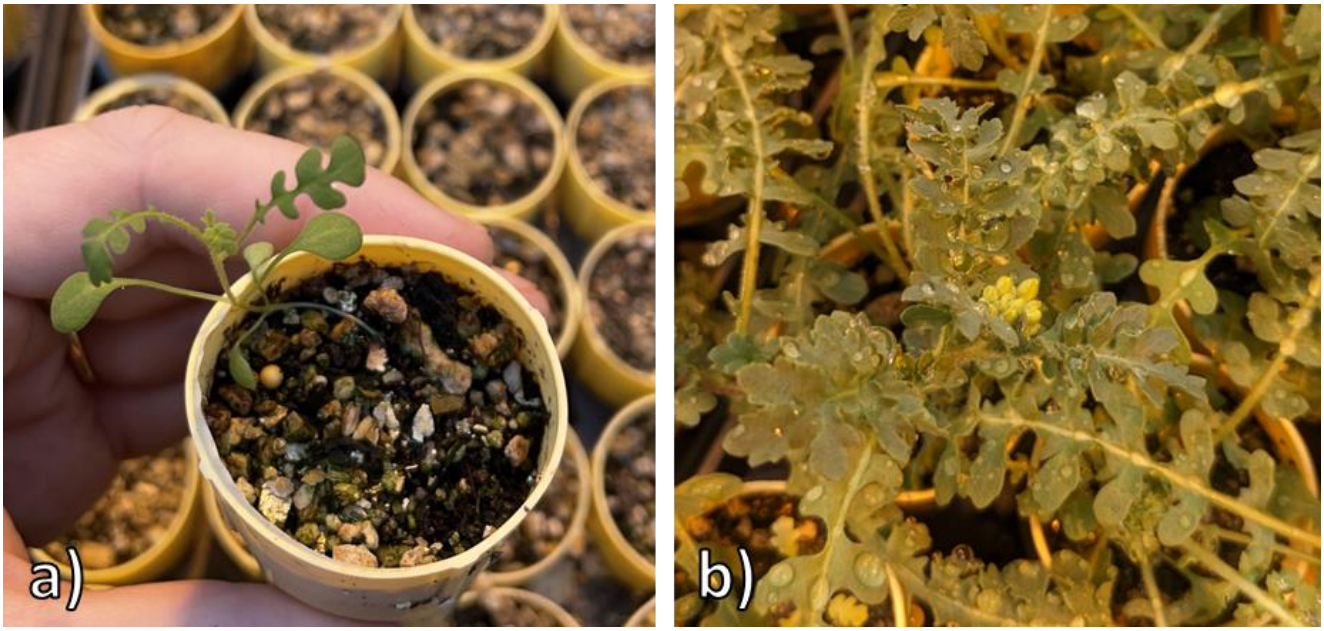

Figure 8. Columbia yellowcress (*Rorippa columbiae*) seedlings; (a) seedling from cohort 1 roughly six weeks after being sown and (b) seedlings from cohort 2 roughly eight weeks after being sown, with flower buds.

4. RESULTS

Initial field surveys were conducted in July 2022 to gather baseline data about Columbia yellowcress populations and associated plant communities on Stukel Mountain in Klamath Falls, Oregon. We surveyed 18 quadrats each at Stukel 1 'pond' and Stukel 2 'private', and summarized data by site in analyses.

4.1. Population Census

We found more Columbia yellowcress plants at the 'pond' site compared to the 'private' site (Table 1). The average number of stems per plant was greater at the 'pond' compared to the 'private' site, seven and two stems respectively, and the average length of the longest stem was greater at the 'pond'. On average, there were a similar number of leaves per longest stem. The 'pond' site had a greater average of fruits and lesser average of flowers and buds per longest stem compared to the 'private site' (Table 1). This may indicate a difference in phenology or water availability between the sites, though we only have information from a single survey and therefore cannot make any conclusions at this time.

Table 1. Census summary for populations of Columbia yellowcress (*Rorippa columbiae*), surveyed between July 12th and 13th 2022, at two sites on Stukel Mountain. One additional dead plant was found at the 'pond' site; there were six stems and the longest was 6.9 cm.

Site	Yellow yellowcress (*Rorippa columbiae*) census summary							
	Total living plants	**Total vegetative plants**	**Total flowering plants**	**Total plant stems**	**Average length of longest stem**	**Average # buds & flowers per longest stem**	**Average # fruits per longest stem**	**Average # leaves per longest stem**
Stukel 1 "pond"	22	1	21	153	12.3 cm	8	33	19
Stukel 2 "private"	6	0	6	12	9.8 cm	31	15	21

4.2. Surrounding Vegetation Community

Stukel 1 'pond' and Stukel 2 'private' had similar species richness for the categories of total annual, total perennial, total woody, total non-woody, and total native species, including grasses and forbs (Table 2). The 'pond' site had twice as many nonnative species (N = 14), including grasses and forbs, as the 'private' site (N = 7).

Table 2. Species richness in vegetation community quadrat plots at Stukel Mountain, 2022.

All quadrats summed per site		
	Stukel 1 "pond"	**Stukel 2 "private"**
Native grass	4	6
Nonnative grass	6	3
Native forb	11	12
Nonnative forb	8	4
Total woody	2	2
Total non-woody	30	28
Total native	17	20
Total nonnative	14	7
Total annual	18	16
Total perennial	14	13
Overall species richness (N = 46)	**32**	**30**

Amounts of ground cover and summarized plant categories on Stukel Mountain varied between sites (Table 3). On average, the 'pond' site had more rock, total grass, total nonnative plant, and total annual plant cover and the 'private' site had more bare ground, woody litter, and total native plant cover. Both sites had a similar amount of moss and lichen, standing water, fecal matter, non-woody litter, total forb,

total woody, and total perennial plant cover. None of the nonnative species found at these sites had cover over 50% and no nonnative species of management concern (according to the Prairie Species Recovery Plan, US Fish and Wildlife Service 2010) had cover over 5%. When analyzed together, vegetation communities surveyed on Stukel Mountain were 50.4% native and 47.7% nonnative. When analyzed individually, the 'pond' site was mostly covered by nonnative species (66.3% ± 6.8) and the 'private' site was mostly covered by native species (67.4% ± 8.1).

Table 3. Mean percent cover for each ground cover type and summarized plant categories; standard error is included in parenthesis.

All quadrats summed per site		
	Stukel 1 "pond"	**Stukel 2 "private"**
Bare ground	21.0 (6.0)	47.8 (6.8)
Rocks	10.0 (2.7)	4.4 (1.6)
Moss and lichen	0.7 (0.4)	0.2 (0.1)
Standing water	0.0 (0.0)	0.0 (0.0)
Fecal matter (e.g. cow, ungulate, rodent)	1.8 (0.6)	0.9 (0.6)
Woody litter (e.g. sage branches, pine cones)	0.5 (0.3)	3.2 (1.5)
Non-woody litter (e.g. grasses or other herbaceous material)	24.6 (6.1)	26.7 (5.9)
Total grass	33.2 (7.2)	12.9 (5.1)
Total forb	23.0 (5.6)	18.9 (3.5)
Total woody	0.7 (0.7)	0.4 (0.4)
Total native	33.5 (6.8)	67.4 (8.1)
Total nonnative	66.3 (6.8)	29.0 (7.8)
Total annual	16.4 (3.4)	8.0 (1.6)
Total perennial	1.4 (0.3)	1.4 (0.9)

5. DISCUSSION

The Columbia yellowcress population at the Stukel Mountain 'pond' site had more individual plants, and those plants were on average larger than the plants in the population at the 'private' site. The plants at the 'pond' site seemed slightly phenologically later than the 'private' site, with a higher average of seeds compared to buds and flowers. However, the 'pond' site had twice the number of nonnative plant species compared to the 'private' site and had twice the amount of nonnative plant cover. The 'private' site had a similar number of native plant species compared to the 'pond' site, but had twice the amount of native plant cover. The 'pond' site had more rock, total grass, total nonnative plant, and total annual plant cover, while the 'private' site had more bare ground, woody litter, and total native plant cover.

This indicates there may be some underlying reason for the Columbia yellowcress population to perform better at the 'pond' site compared to the 'private' site, even though the surrounding plant community is comprised of more nonnative plants. Invasion and encroachment of nonnative plant species, along with trampling by humans, livestock, and vehicles are known threats to Columbia yellowcress survival. The invasive, nonnative species *Ventenata dubia* was present in both Stukel Mountain Columbia yellowcress populations, but averaged 23% of each quadrat sampled at the 'pond' site, and only 1% of each quadrat sampled at the 'private' site. There was clear evidence of human (footprints, trash), livestock (hoofprints, fecal material, grazing), and vehicle (rogue and path-following tire tracks) trampling at both sites, though the extent to which these actions affect Columbia yellowcress are unknown. Additionally, the full effect of microelevation gradients and variations in hydrology are unknown for Columbia yellowcress across its range. Evidence of small, vegetative Columbia yellowcress plants monitored in future years may give some indication to the conditions that promote population growth. If opportunity arises, additional means of obtaining information should be considered; perhaps experimental designs, including measuring changes in soil moisture, establishing and monitoring trampling-exclusion cages, or conducting vegetation management to reduce crowding.

In reviewing Stukel Mountain maps to create this report, areas were found through satellite imagery (Appendix A - Figure A9) that appear similar to conditions with known Columbia yellowcress populations. We propose to investigate these areas during our next visit to Stukel Mountain and determine whether they may serve as Columbia yellowcress habitats, either for population monitoring or outplanting opportunities. However, these areas may already be known to not contain Columbia yellowcress populations or experience too much vehicle traffic-related disturbance.

This agreement has expanded since its inception, and we look forward to beginning this work. We will convene a stakeholder working group of entities, knowledgeable of Columbia yellowcress historic populations and potential habitats, to meet annually and identify management needs and potential restoration sites for the species. We will also conduct field-based assessments of additional sites for future augmentation.

6. CONCLUSIONS

In summary,

- Greenhouse-grown Columbia yellowcress will be outplanted on Stukel Mountain in April 2023.
- Columbia yellowcress censusing and associated plant community monitoring will continue, to further understand the Stukel Mountain populations.
- More information, ideally experimental, is needed to determine the best growing conditions for Columbia yellowcress field plantings. Consider the use of soil moisture monitors to determine how saturated the soil should be, exclusion cages to deter against trampling, or vegetation management to reduce plant crowding.
- Investigate Stukel Mountain for areas determined with aerial imagery to be similar (water inundation) to known Columbia yellowcress habitats.
- We will convene a Columbia yellowcress stakeholder working group and determine which sites and populations should receive future augmentation.

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APPENDIX A. POTENTIAL SURVEY LOCATIONS ON STUKEL MOUNTAIN

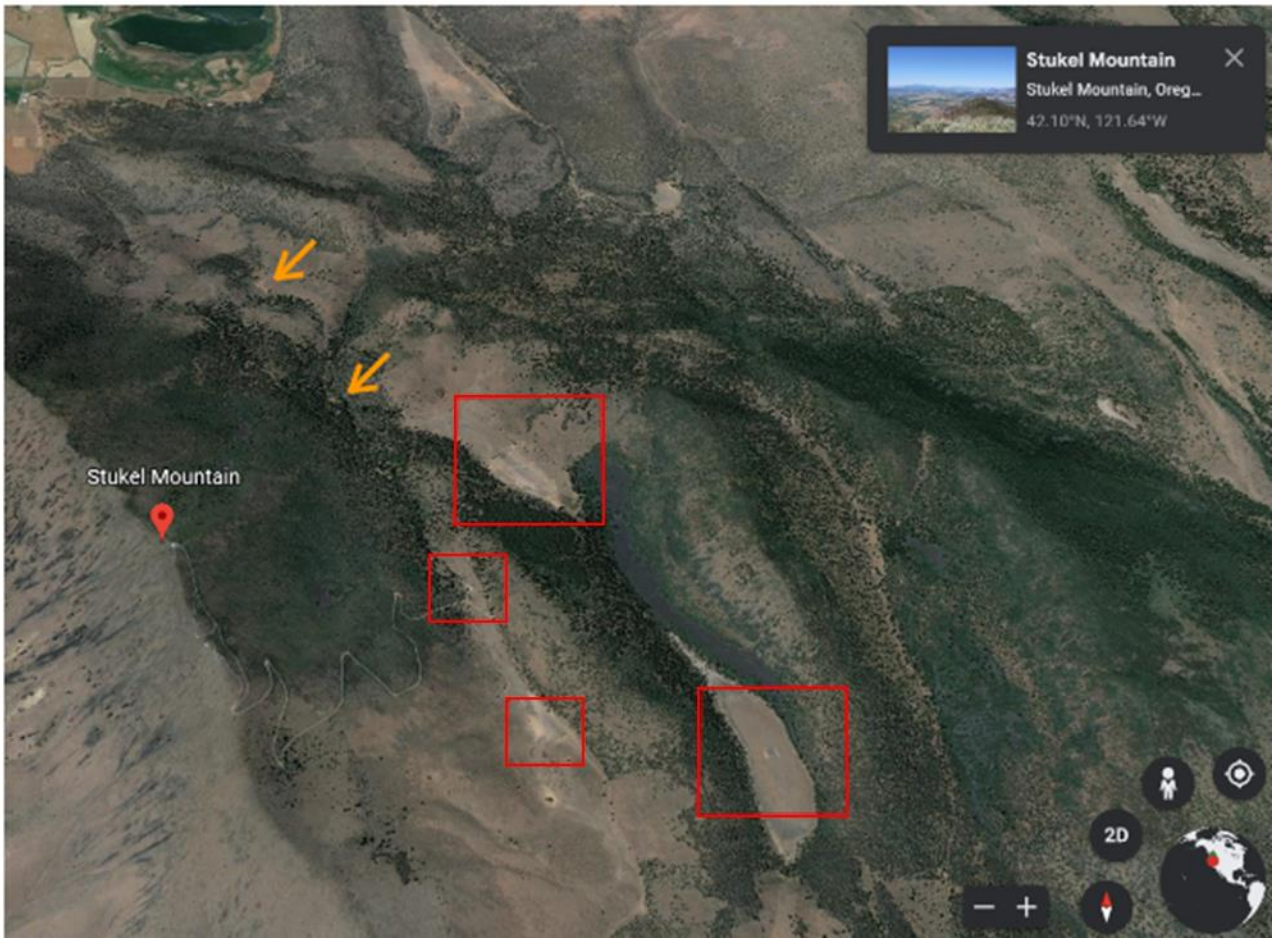

Figure A9. Orange arrows point to areas on Stukel Mountain currently monitored for Columbia yellowcress (*Rorippa columbiae*); the more northern arrow is the Stukel 1 'pond' site and the more southern arrow is the Stukel 2 'private' site. Red boxes (N = 4) outline areas with standing water in Google Earth's imagery, and potential survey locations.