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Habitat Characteristics and Morphological Differences of *Trifolium thompsonii* Populations

Abstract

Trifolium thompsonii (Morton) is a rare and threatened legume of the Eastern Cascades previously known only in Swakane Canyon of Chelan County, Washington. Recent wildfire disturbances and new population sightings prompted investigation of the habitat characteristics of this taxon. Transect sampling and cluster analysis identified *T. thompsonii* occurrence in four plant associations: *Pseudotsuga menziesii/ Calmagrostis rubescens* (PSME/CARU), *Pinus ponderosa/ Agropyron spicatum* (PIPO/AGSP), *Artemisia tridentata/ Agropyron spicatum* (ARTR/AGSP), and *Artemisia tridentata-vaseyana/ Agropyron spicatum* (ARVA/AGSP). Thompson's clover occurs in a mosaic pattern characteristic of fire disturbed and grazed communities with 24-69 percent cover of forbs and grasses and 0-36 percent cover of trees and shrubs. Morphological expression of *T. thompsonii* ranged from tall (32 cm) multifloral stands in mesic PSME to relatively small (25 cm) individuals with only one flowerhead in the xeric ARTR. In contrast, plant density was low in PSME at 0.6 plants-m^{-2} but high in ARTR at 6.4 plants-m^{-2}. This study confirms *T. thompsonii* to be a vigorous and dominant forb component of early seral communities in the ponderosa pine-shrub steppe ecotone.

Introduction

Trifolium thompsonii (Morton) is one of 12 plant species listed as threatened along the eastern slope of the Washington Cascades. The taxon is among several under study in the Wenatchee area where about 15 percent of the threatened, endangered and sensitive species of Washington state occur (Washington Natural Heritage Program 1994). J.W. Thompson first reported its occurrence in 1933 on the slopes of Swakane canyon at the edge of *Pinus ponderosa* forests and into the *Artemisia tridentata* shrub steppe adjacent to the western shore of the Columbia River (Hitchcock et al. 1969). Work by Canfield (1977) and Tiedemann et al. (1977) expanded knowledge of this species and documented 10 additional stands, the largest located within the 80 ha Thompson's Clover Research Natural Area. Survey work reported by Gamon and Sprague (1988) further recorded the Chelan county occurrences of *T. thompsonii* in canyons near the Entiat River. They also reported on a stand east of the Columbia River, about 6 km southeast of the Thompson's Clover Research Natural Area.

These new sightings suggest a wider range potential and perhaps a different ecological amplitude than previously described (Kennison and Taylor 1979). The purpose of this study was to clarify the habitat characteristics of *T. thompsonii* and describe plant responses of this species to habitat changes among its associated plant communities. The objectives of this research were: 1. To document the vegetative communities and site factors associated with *T. thompsonii*; and 2. Compare morphological features and plant density of *T. thompsonii* populations among these vegetative communities.

Methods

Study Area

The known range of *T. thompsonii* is the area north of the Wenatchee River (47°23'43"N, 120°19'23"W) to the Entiat River (47°39'51"N, 120°13'23"W) and within 4 km of each side of the Columbia River. The nearest climate station at Wenatchee, Washington (elevation 343 m), has a mean January temperature of -3°C and a mean July temperature of 22°C. Annual precipitation is about 220 mm occurring mostly as snow between November and April. This taxon was reported to occur at elevations ranging 345 m to 1146 m (Canfield 1977, and this study). Using the normal lapse rate of 2°C per 300 m, the mean temperature on the study sites would be -8°C for January and 17°C for July. At these elevations, winter snowpack could remain for up to 60 days longer than in the valley floor and would delay bud emergence for *T. thompsonii* and other species (Gamon and Sprague 1988).

Disturbance History

Fire has been an historical disturbance agent in this region (Agee 1993) and was evident by fire-scarred tree stems and bunchgrass culms on the Chelan county portion of the study area. Figure 1 shows the pattern of wildfire within the known range of *T. thompsonii* (Canfield 1977, WNF 1990). The most recent fire event among *T. thompsonii* populations was the 17,000 ha Dinkleman burn of July 1988. Sheep and cattle grazing occurred in this area from the late 1800s until 1965 (Dow 1964, Tiedemann et al. 1977). No known fires have recently occurred on the Douglas County study sites. However, the area is presently grazed seasonally by domestic cattle and some of the land is cultivated for wheat (E. Gutzwiler 1993, personal communication).

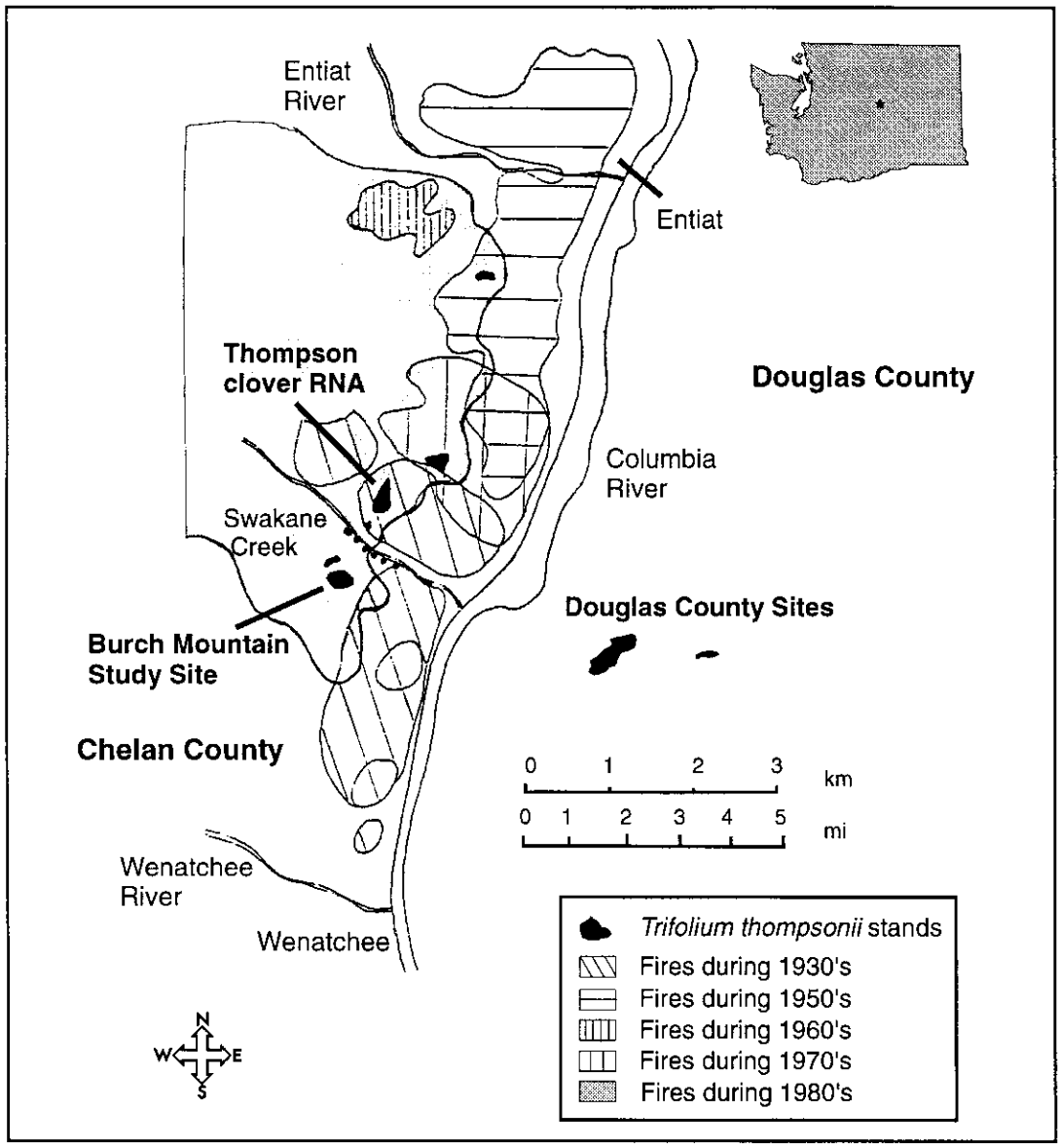

Figure 1. Present known stands of *T. thompsonii* in Chelan and Douglas Counties, Washington and known areas of fire disturbance in *T. thompsonii* range since 1930 (adapted from Canfield 1977 and WNF 1990).

Field Sampling

Study sites were selected from maps of known *T. thompsonii* locations (Gamon and Sprague 1988). We sampled in five of the eight known locations including a newly discovered site in Douglas County. Populations at two of the remaining stands (Tenas George and Keystone Point) were not located and we could not access the last location (Keystone canyon) due to road closure. The criterion for sample site selection was the presence of a stand of this taxon greater than 50 m diameter. The locations sampled were one site at Thompson's Clover Research Natural Area, two sites on Burch Mountain, and two sites on private property in Douglas County (see Figure 1). These five areas were distinct in physical characteristics and disjunct such that selection of one area was independent of another.

Vegetation was systematically sampled in each study area by placing a 50 cm x 20 cm wire frame in a 4 by 5, 20 frame block at three positions (0, 30, 50 m) along a randomly placed 50 m tape transect running through *T. thompsonii* patches (Brower et al. 1990 and see Figure 2). The three blocks together constituted sampling of a patch of *T. thompsonii* for a total of 20 patches among the five locations studied. The vertically projected canopy cover (Daubenmire 1959) of each species encountered in the plot frame was recorded. Plant species identification followed Hitchcock and Cronquist (1973) and a list of plant names of Washington (USDA-SCS 1983). Soil surface condition was sampled at 10 painted points equally spaced on the plot frame as either litter, bare soil, plant presence, cryptogamic crust, wood pieces, or rocks. The density of *T. thompsonii* was recorded by counting individuals within 10 one-m^2 plot frames that were arranged in a block of two rows of five which overlayed the block of 20 vegetative sample plot frames (Figure 2). From each sample block at least 10 *T. thompsonii* individuals were selected and measured for morphological features that included height, leaf number, shoot number, flowerhead number and root crown diameter.

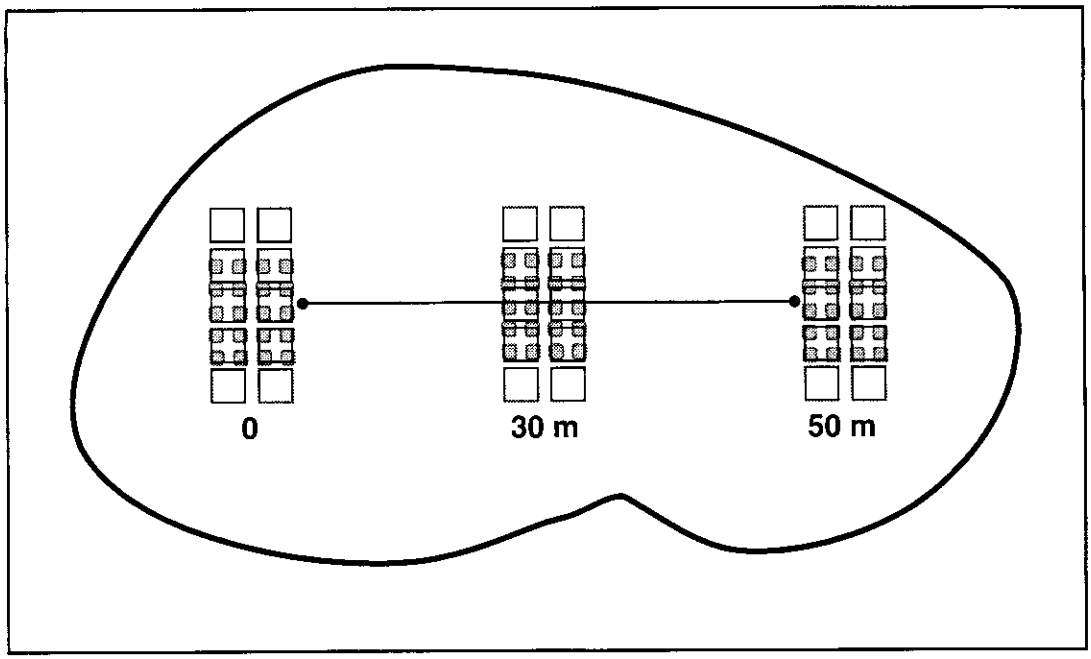

Figure 2. Pattern of sampling in a stylized sample patch of *T. thompsonii*. Canopy cover of each species was obtained by sampling in shaded blocks which are 20 plot frames, each 20 cm X 50 cm, spaced 50 cm each direction. The three block sub samples were aligned on a 50 m transect within the sample patch. Density of *T. thompsonii* was obtained by placing 10-1 meter X 1 meter plot frames in two rows of five overlaying the approximate area covered by the plot frame matrix and counting individuals.

At each sample block site the following site characters were recorded: elevation, slope, aspect, slope position, and microterrain feature (e.g., flat, convex, concave). Additional information on study area soils was from Soil Conservation Service soil survey (Beiler 1969, 1978).

Analysis

The means of species canopy cover from each block were used in a Systat Statistics cluster analysis procedure to identify major plant communities associated with *T. thompsonii* (Wilkinson and Hill 1992). We calculated mean canopy cover and frequency values for all species in each sample patch. We graphed density of *T. thompsonii* and measurements of the species' morphological features for comparison by plant community (Figure 3). The morphological features were logarithmically transformed to normalize data and subjected to analysis of variance to test for differences among community types. A regression analysis was used to examine the relationship between *T. thompsonii* density and tree density.

Results and Discussion

Trifolium thompsonii occurred in three broad vegetative settings: forest patches, steppe-like parklands, and semiarid shrub steppe. The forest patches occurring on mesic topographic settings such as gullies and northerly slopes, consisted of a layered community of trees, shrubs, grasses, and forbs dominated by *Pseudotsuga menziesii*. Steppe-like parklands were grass dominated landscapes with occasional *Pinus ponderosa* individuals. The shrub steppe consisted of the drought-tolerant, tall shrub-bunchgrass (*Artemisia tridentata/Agropyron spicatum*) vegetative associations typical of the central Columbia Basin.

Within these three settings, four plant communities were identified using cluster analysis of

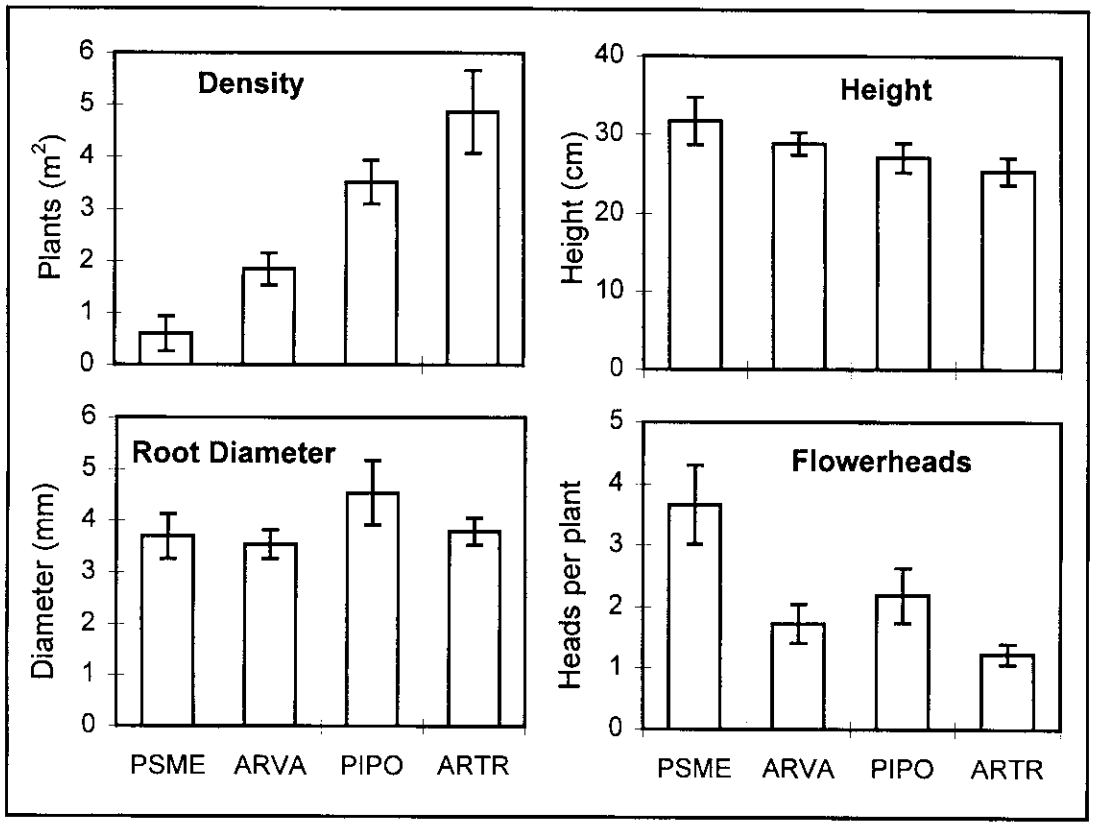

Figure 3. *T. thompsonii* population and morphological features in four community types. Vertical bars are 90% confidence intervals.

species composition and cover values from the sampling matrices. These four community types represented various successional stages of four plant associations described by Franklin and Dyrness (1973) and Daubenmire (1970). They are *Pseudotsuga menziesii/ Calmagrostis rubescens* (PSME/CARU) of the forest setting; *Pinus ponderosa/ Agropyron spicatum* (PIPO/AGSP), and *Artemisia vaseyana/Agropyron spicatum* (ARVA/AGSP) of a steppe-like setting; and *Artemisia tridentata/ Agropyron spicatum* (ARTR/AGSP) of the shrub steppe setting. These four community types are described below with reference to vegetative composition and site factor data in Tables 1 and 2 and Figure 3.

Plant Community Descriptions

The PSME/CARU community occurred on north facing steep slopes (40-50 percent) at mid to upper elevations (> 1060 m) in Chelan County. This was in the wettest and coolest settings of this study with mean annual precipitation ranging from 508 to 1016 mm and mean annual temperature of 5-6°C (Bieler 1969). *Pseudotsuga menziesii* was the overstory dominant with *Pinus ponderosa* a codominant in some sample units. *Spiraea betulifolia* and *Penstemon fruticosus* were prominent shrub layer components. The grass, *Calmagrostis rubescens,* was a significant herbaceous dominant of this community type suggesting moist upper elevation site conditions. *Balsamorhiza sagittata, Achillia millefolium* and *T. thompsonii* were the most prominent forb species. Other important herbaceous species were *Festuca idahoensis, Bromus tectorum, Poa secundi, Colinsia parviflora, Crypthantha affinis,* and *Epilobium paniculatum.* In this community, located on Burch Mountain, the 1988 Dinkleman fire destroyed the crown foliage of nearly all *Pseudotsuga menziesii* and *Pinus ponderosa.*

Soil surfaces in PSME/CARU were litter covered due to the high proportion of shrub and grass cover (Table 2 and Figure 4). The soil profile was rocky and among the shallowest of those in this study, ranging from 35 to 48 cm in depth.

The ARVA/AGSP community was located on the Thompson's Clover Research Natural Area (Figure 1). Individuals of *Artemisia vasayana,* a montane ecotype of *A. tridentata,* and *A. tripartita* represented the overstory cover of this community type. The current vegetative dominants were the grass species *Agropyron spicatum, Poa secunda, Festuca idahoensis,* ranging in mean cover from 4 to 27 percent. *T. thompsonii, Balsamorhiza sagittata, Antennaria rosea,* and *Achillia millefolium* were the major forbs. Annuals were not prominent in this community, except for a *Bromus tectorum* coverage of 4 percent, the result of ground disturbance. Charred bunchgrass clumps and shrub skeletons indicated recent (1988) fire disturbance.

The elevation of this community ranged from 816-1071 m on 30-40 percent slopes facing north to southwest. Ground cover was mostly litter ranging from 37-69 percent and plant basal cover from 17-27 percent (Table 2). Estimated precipitation, soil depth and soil water availability were similar to PIPO/AGSP (Bieler 1969).

The dominant vegetation in PIPO/AGSP was an *Agropyron spicatum-Festuca idahoensis* grass understory (Table 1). *Pinus ponderosa* was present as solitary mature individuals across the Research Natural Area with canopy cover rarely exceeding 2 percent. Cover and density were higher in more mesic topographic settings of gullies and north slopes. The low shrubs, *Eriogonum heracleoides, Phlox longifolia, Haplopappus stenophyllus,* were present with less than 5 percent overall cover. No tall shrubs were recorded. The most prominent species in the forb component were *Antennaria rosea, Balsamorhiza sagittata, T. thompsonii* and *Achillea millefolium.* The annuals *Collinsia parviflora, Epilobium paniculatum,* and *Crypthantha affinis* were ubiquitous in the sample plots but had small cover values. Evidence of fire disturbance was generally in the grass shrub understory. There was no fire damage in tree crowns. The fire disturbances also explain the lack of fire-intolerant *Artemisia* spp. and *Purshia* spp. in the shrub component.

This community was sampled at elevations of 810-899 m on steep slopes with varied north to southwesterly exposures. Soil depths ranged 25-55 cm with estimated clay content of 1-4 percent (Bieler 1969).

Dominants in the ARTR/AGSP community type overstory were the tall shrubs *Artemisia tridentata* and *Purshia tridentata,* with mean canopy coverage values of 9 percent and 5 percent. The herbaceous dominants were *Agropyron spicatum, Festuca idahoensis,* and *Poa secunda* with up to 44 percent mean canopy cover. This community

TABLE 1. Constancy and mean cover values of species in four community types associated with *Trifolium thompsonii*.

	PSME		ARVA		PIPO		ARTR	
	N=2		N=3		N=7		N=9	
	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Tree								
Pinus ponderosa	100	29.0	0	0.0	P	P	0	0.0
Pseudotsuga menziesii	100	32.0	0	0.0	0	0	0	0.0
Shrub								
Artemisia tridentata	0	0.0	0	0.0	14	Tr	77	8.5
Artemisia vaseyana	0	0.0	67	1.2	0	0.0	0	0.0
Artemisia tripartita	0	0.0	67	14.0	0	0.0	11	1.0
Ceanothus velutinus	50	6.0	0	0.0	0	0.0	0	0.0
Chrysothamnus viscidiflorus	0	0.0	0	0.0	0	0.0	11	0.2
Erigeron linearis	0	0.0	0	0.0	14	0.7	0	0.0
Eriogonum heracleoides	0	0.0	100	8.5	43	2.2	55	2.6
Eriogonum niveum	0	0.0	0	0.0	14	0.4	0	0.0
Eriogonum strictum	0	0.0	0	0.0	0	0.0	22	0.2
Haplopappus stenophyllus	0	0.0	0	0.0	14	Tr	55	1.2
Penstemon fruticosus	100	11.5	0	0.0	28	0.5	0	0.0
Phlox longifolia	100	1.8	34	0.8	57	1.7	100	3.3
Purshia tridentata	0	0.0	0	0.0	0	0.0	66	4.9
Ribes cereum	50	0.4	0	0.0	0	0.0	22	0.6
Spiraea betulifolia	100	12.7	0	0.0	0	0.0	0	0.0
Symphoricarpos albus	50	1.6	0	0.0	14	0.4	0	0.0
Vaccinium occidentale	50	2.3	0	0.0	0	0.0	0	0.0
Grass								
Agropyron cristatum	0	0.0	0	0.0	0	0.0	11	Tr
Agropyron spicatum	50	0.1	100	26.7	100	26.4	100	44.1
Bromus tectorum	100	0.4	67	4.4	57	2.0	88	1.4
Calmagrostis rubescens	100	37.0	0	0.0	0	0.0	0	0.0
Festuca idahoensis	100	3.7	34	4.2	100	7.5	88	14.5
Festuca rubrua	0	0.0	0	0.0	28	Tr	0	0.0
Koeleria cristata	50	0.1	100	4.3	71	2.3	0	0.0
Melica bulbosa	50	0.0	34	Tr	14	Tr	33	1.3
Poa secunda	100	1.2	100	5.0	85	4.1	100	7.1
Forb								
Achillea millefolium	100	7.1	100	2.4	100	7.3	77	2.0
Agoseris grandiflora	0	0.0	100	1.8	57	1.5	88	6.0
Allium acuminatum	0	0.0	0	0.0	0	0.0	77	10.7
Angelica arguta	0	0.0	0	0.0	14	Tr	0	0.0
Antennaria rosea	0	0.0	34	2.5	85	17.6	0	0.0
Astragalus purshii	0	0.0	0	0.0	43	1.3	0	0.0
Balsamorhiza sagittata	100	9.9	67	3.8	100	11.7	100	17.6
Brodiaea douglasii	0	0.0	34	0.3	0	0.0	11	Tr
Castelleja lutescens	50	0.1	0	0.0	28	0.5	22	0.1
Collinsia parviflora	100	0.5	100	0.9	100	3.1	66	1.0
Cryptantha affinis	100	0.9	67	0.8	85	1.5	22	0.1
Epilobium paniculatum	100	1.6	100	1.2	100	3.2	44	TR
Geum triflorum	50	1.6	34	0.9	28	1.3	0	0.0
Helianthus petiolaris	0	0.0	0	0.0	28	2.4	0	0.0
Heuchera cylindrica	0	0.0	0	0.0	28	Tr	0	0.0
Hieracium albiflorum	50	0.8	34	0.9	57	1.5	11	Tr
Lactuca serriola	0	0.0	0	0.0	14	0.4	11	0.3
Linanthus liniflorus	0	0.0	0	0.0	14	Tr	0	0.0
Lithospermum ruderale	0	0.0	0	0.0	0	0.0	11	Tr
Lomatium nudicule	50	0.4	0	0.0	57	1.6	77	3.5

TABLE 1. (Continued)

	PSME		ARVA		PIPO		ARTR	
	N=2		N=3		N=7		N=9	
	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Lupinus leucophyllus	0	0.0	0	0.0	0	0.0	44	1.3
Lupinus sericeus	0	0.0	34	Tr	71	1.4	66	2.8
Madia glomerata	0	0.0	0	0.0	14	Tr	0	0.0
Microsteris gracilis	100	0.4	100	1.0	57	0.2	77	1.6
Polemonium micranthum	0	0.0	34	0.2	57	0.2	100	0.6
Sisymbrium altissimum	50	0.4	67	1.2	0	0.0	22	0.1
Trifolium thompsonii	100	6.5	100	11.6	100	20.7	100	21.2

Notes: P= P. pine occurs in clusters and individuals. Aerial photo verifications indicate cover range 2- 12% on 80 ha. Tr= cover value less than 0.1 in sample plot. Community type abbreviations are: PSME= *Pseudotsuga menziesii/ Calmagrostis rubescens*; PIPO= *Ponderosa pine/ Agropyron spicatum*; ARTR= *Artemisia tridentata/ Agropyron spicatum*; ARVA= *Artemisia tridentata-vasayana/ Agropyron spicatum*

TABLE 2. Range of values for site factors in four community types associated with *Trifolium thompsonii*

	PSME	ARVA	PIPO	ARTR
Site Variables				
Elevation (m)	1115-1060	816-1071	810-899	890-1096
Slope (%)	40-50	30-40	30-60	15-50
Aspect (deg)	360	360-235	360-235	045-270
Precipit (mm)	508-1016	304-406	304-406	208-620
Temp (C)	5-6	8-10	8-10	8-10
Soil Surface				
Litter (%)	44-63	37-69	40-60	19-69
Bare Ground (%)	11	8-40	8-34	13-58
Rock (%)	1	0	0	0-26
Wood (%)	4-11	0	1	0-10
Basal Area (%)	18	17-27	11-29	17-27
Cryptogams (%)	1-4	0-1.5	1-4	5
Soil Profile				
Depth (cm)	35-48	48-56	25-55	24-75
Bulk Density (g/cc)	1.22-1.40	1.21-1.29	1.10-1.30	1.05-1.30
Available Water (cm-cm)	0.38-0.43	0.30-0.35	0.43-0.50	0.15-0.53
pH	6.5	6.4	6.4	7.1
Organic Matter (%)	2.5-4.5	2.6-3.0	2.8- 6.4	1.5-4.5
CEC (meq)	10-20	8.4-12.0	9-15	8-18
Coarse Fragments (%)	10-40	10-20	10-20	5-45
Sand (%)	72-83	67-68	65-79	33-59
Silt (%)	15-21	25-32	19-31	36-53
Clay (%)	1-3	1-6	1-4	2-13

Notes: Community type abbreviations are: PSME = *Pseudotsuga menziesii/ Calmagrostis rubescens*; PIPO = *Ponderosa pine/ Agropyron spicatum*; ARTR = *Artemisia tridentata/ Agropyron spicatum*; ARVA = *Artemisia tridentata-vasayana/ Agropyron spicatum*

was rich in forbs with 17 recorded. The most ubiquitous were *T. thompsonii*, *Balsamorhiza sagittata*, *Allium acuminatum*, *Agoseris grandiflora*, *Lomatium nudicule*, *Achellia millefolium*, and *Lupinus sericeus*. There was no field evidence or recorded documentation of recent fire in this community. However, some forbs and bunchgrasses appeared lightly grazed.

This community type occurred at elevations ranging 890 to 1096 m on 15-50 percent slopes

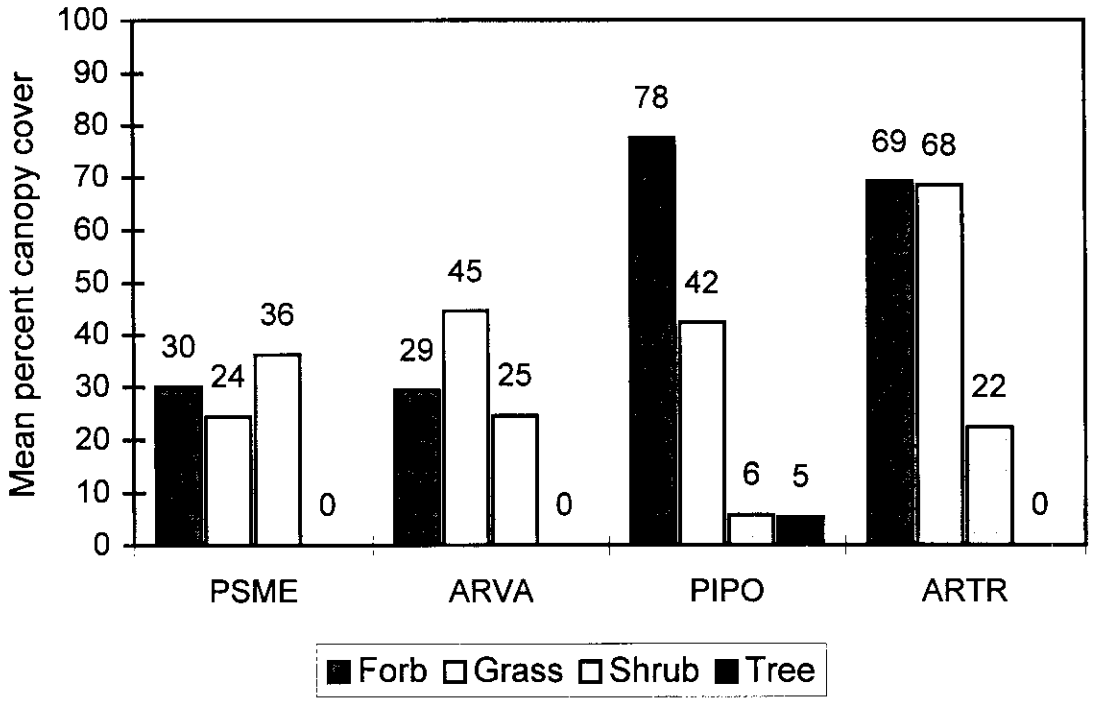

Figure 4. Canopy coverage by lifeform for four community types associated with *T. thompsonii*. No live trees on PSME due to fire kill.

with north to southwest exposures. It was the most xeric of the communities reported here. Modest clay content and varying soil depths accounted for the wide range in soil water availability values (Table 2). Soil surfaces here varied as indicated by higher proportions of bare rock surface cover.

Community Structure

Figure 4 shows vegetative structure of the four communities by layers of vegetative component. Grasses and forbs were prominent in the communities of PIPO, ARTR, and ARVA with forbs nearly equal in presence but more variable in cover and species composition among the groups. Note a relatively low value of shrub cover but high value of forb cover in PIPO/ AGSP; a probable result of recent fire disturbances since many tree boles displayed charred bark. Structure data also showed less cover of shrubs and trees and greater cover of grass and forb components from more mesic forest settings to the arid shrub steppe. This is likely the result of less precipitation at lower elevations (Table 2).

Plant Density—*T. thompsonii*

Density of *T. thompsonii* ranged from 0 to 16 plants-m^{-2} on 256 plots from within the four community types. Plant densities were significantly greater in ARVA, PIPO and ARTR than in PSME setting at 0.6 plants m^2 (Table 3). Specifically, plant density was highest in parts of the ARTR shrub-steppe of Douglas county where 1-m^2 plot frame samples contained as many as 16 plants. The ARTR

TABLE 3. Mean density (plants-m^2) of *T. thompsonii* in four community types

	PSME	PIPO	ARTR	ARVA
Density (m^2)	0.6	3.5	4.8	1.8
Standard error	0.19	0.25	0.47	0.18
p =	0.000	0.000	0.010	0.000
N =	20	99	88	49

Note: p = significance probability (<.05 is significant). N = number of plot frame samples. Community type abbreviations are: PSME = *Pseudotsuga menziesii/ Calmagrostis rubescens*; PIPO = *Ponderosa pine/ Agropyron spicatum*; ARTR = *Artemisia tridentata/ Agropyron spicatum*; ARVA = *Artemisia tridentata-vasayana/ Agropyron spicatum*

community had high grass coverages, particularly *Festuca idahoensis* with 56 percent cover (Table 1). It also had the deepest soils and highest silt content among the communities (Table 2). In contrast, plots sampled in the forested PSME were high in tree coverage and had shallow soil depths. Forest vegetation types and forest soil conditions may contribute to the low density value of 0.6 plants per square meter. Tree counts vs. *T. thompsonii* counts showed a slight negative correlation but a regression analysis of the data did not prove to be significant. We were unable to demonstrate that *T. thompsonii* stands are more suited to the heliophytic conditions of the open parks and shrub steppe within its range.

Morphological Characteristics—*T. thompsonii*

Considering mean values, a "typical" *T. thompsonii* specimen might be 27.6 cm in height, a three stem plant with five leaflets per leaf, two flowerheads and root diameter of 4 mm. A mean plant height of 31.7 cm for *T. thompsonii* in PSME was significantly (p=0.010) taller than in ARTR at 25.3 cm. There were no significant differences in height among ARVA, PIPO and ARTR. The number of flowerheads per plant in PSME was 3.6. This was significantly (p=0.000) greater than in the other community types, among which were no significant differences in flowerhead counts. Leaf and shoot counts did not significantly differ among the community types. Root crown diameters of 4.54 mm in PIPO were nominally greater than in the other community types but only significantly greater (p=0.064) than in the ARVA community at 3.54 mm.

The taller plants with more flowerheads in the PSME community suggests a slightly more robust *T. thompsonii* stand here. This may be a short-lived response to resource release since the PSME locations were burned by wildfires in 1988 and sampled in 1991. We hypothesize that *T. thompsonii* stands occurring in the PIPO community might be viewed as "typical." Plant heights of 27 cm, two flowerheads per plant, three stemmed plants and a larger root diameter suggests a greater period of site occupancy. However, it may be that the site is more frequently disturbed by wildfires and that *T. thompsonii* roots may be benefiting from the resource releases facilitated by the fires. There is an observable contrast in the smaller plants of the ARTR community of Douglas County vs. those in Chelan County, particularly the robust *T. thompsonii* of PSME on the Burch Mountain location, even though this study has not statistically substantiated this observation in all features. We suggest that precipitation availability and frequency of disturbances are likely to affect morphological differences of expression for this species among these documented habitats.

Recently Discovered Populations

In 1983 and 1993, two new populations of *T. thompsonii* were encountered in Douglas County. They were about 8 km east of the best known stands of Swakane canyon (Gamon and Sprague 1988 and this study). The landscape and terrain features of the Douglas County study area are similar to those west of the Columbia River. It features steep hillslopes rising to forested summits at 1300 m with a sharp ecotone into grass-shrub ecosystems at about 1150 m elevation. A distinct difference in the vegetative composition is the ubiquitous and relatively even coverage of *Artemisia tridentata* and *Purshia tridentata* on this landscape, indicating infrequent stand-altering fire events. The primary disturbance feature here is the agricultural activity of wheat fields and associated cattle grazing.

Trifolium thompsonii occurs here in disjunct patches ranging from 2 m^2 to about 10 ha in size, often in close proximity to *A. tridentata* individuals. Native bunch grasses are prominent vegetative cover and *T. thompsonii* is often the dominant forb. *Trifolium. thompsonii* in the Douglas county samples was typically a shorter individual with only one or two flowerheads (Figure 3). Population densities were significantly larger than those found west of the Columbia River (Figure 3). Total canopy coverage of vegetation in Douglas County plots was greater than the other sites sampled in this study (discounting the tree category in PSME, since the crown foliage was removed by fire). *Trifolium thompsonii* stands were 2-3 km from the nearest forest ecotone in the midst of well-developed *A. tridentata/ Agropyron spicatum-F. idahoensis* associations.

The *T. thompsonii* population expression in Douglas County was different from that of the Chelan County populations. The reasons for the differences are speculative. *Trifolium thompsonii* stands east of the Wenatchee river are functioning in relatively undisturbed habitat. The smaller stature of the plant may be due to the more xeric climate and soil conditions (Table 2). The smaller plant

heights could also be an effect of the greater vegetation cover of this site: a greater community biomass competing for a limited pool of resources.

Conclusions

There is increased interest by land managers in the biology and habitat conditions of rare species particularly on Wenatchee area landscapes which have been historically (and recently in 1994) frequented by large scale fires. This study clarifies that *T. thompsonii* habitat is best characterized by the plant association featuring *Artemisia tridentata / Agropyron spicatum-F. idahoensis*, as demonstrated in the mature community of the Douglas county sample sites. This habitat type association forms an integrated ecotone along the forested edge near the summits of the arid foothills near Wenatchee. *Trifolium thompsonii* is likely an ancient endemic of the *Artemisia tridentata* habitat type, however, *A. Tridentata* is often absent due to wildfire events. *Trifolium thompsonii* seems to respond to fire-caused openings in adjacent forested settings with vigorous growth and flower production, probably a physiological response to resource release. As tree or shrub canopy cover increases, *Trifolium thompsonii* vigor is reduced as indicated by the Douglas County samples. Since there are no clear explanations for the limited range of this species, new population locations are probable. New stands will likely be found in both disturbed and undisturbed *A. tridentata* habitat types and in disturbed forested settings near the shrub-grass ecotone.

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