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Endangered, Threatened, and Sensitive Plants of Fort Lewis, Washington: Distribution, Mapping, and Management Recommendations for Species Conservation.

Abstract

The loss of native species and their habitats has increased with urban development, agriculture, and resource utilization. According to the Washington Natural Heritage Program, 20 plants listed as endangered, threatened, or sensitive are suspected to occur on the glacial outwash soils of south Puget Sound. In our study, more than 3,000 ha of prairie, wetland, and moist-forest plant communities were systematically sampled at Fort Lewis, Washington, and rare plant species, their habitats, and associated species were mapped. Four rare species, *Aster curtus, Trillium parviflorum, Carex comosa,* and *C. interrupta,* were found. *Aster curtus,* the most abundant of these four species, attained highest cover and frequency on prairies dominated by *Festuca idahoensis,* other graminoids, and native forbs. It also was present on some sites dominated by trees or non-native species. *Trillium parviflorum* was found in moist-forest communities with an overstory of conifers and hardwoods. *Carex comosa* was found on the margins of two wetlands, and *C. interrupta* was found growing on a gravel bar of the Nisqually River. Major threats to the four rare species are discussed, and recommendations are made for management of rare plant habitats with the goal of preserving the species.

Introduction

In the south Puget Sound lowlands of western Washington, prairies, shallow lakes and wetlands within a conifer-dominated landscape were formed on the coarse gravel deposits from the Vashon glacier. A high diversity of plant species and plant communities is characteristic of these habitats. However much of the Puget Sound lowland is currently used for urban development, agriculture, and resource extraction (gravel mining, timber, water). Impacts to habitat by these activities or by recreational trampling are a major threat to plants and plant communities.

One of the largest tracts of relatively undisturbed forests, wetlands, and prairies in the Puget Sound lowlands is on the Fort Lewis Military Reservation (FLMR), a U.S. Department of Army (DoA) installation located between Tacoma and Olympia, Washington. The DoA and all Federal land managers are directed by the Endangered Species Act of 1973 to protect and conserve the habitat of endangered, threatened, sensitive, and candidate (ETS) species on its reservations. The terms "endangered," "threatened," and "sensitive" used in this paper follow the designations established by the Washington State Department of Natural Resources, Natural Heritage Program (WNHP). Endangered plant status is assigned to a vascular plant taxon in danger of becoming extinct or extirpated in Washington. A threatened plant taxon is likely to become endangered within the near future in Washington if factors contributing to population decline or habitat degradation or loss continue. Sensitive plant taxa are vulnerable or declining and could become endangered or threatened in the State without active management or the removal of threats (WNHP 1994). Candidate species applies to taxon that are being considered for listing under the Endangered Species Act of 1973, as amended.

Currently, 20 species of ETS plants occur or potentially occur in the south Puget Sound lowlands (WNHP 1994). One, *Aster curtus,* is currently designated a species of concern by the U.S. Fish and Wildlife Service (1996). This designation suggests a threat to the persistence of the species but requires additional data for formal listing as threatened or endangered.

During spring and summer of 1992 and 1993, we undertook an inventory of ETS plant species at FLMR. We had five objectives:

(1) Map the distribution of ETS plant species within the FLMR;

(2) Describe the habitats and plant species associated with ETS plant species;

(3) Describe habitats and plant communities in areas that were inventoried but revealed no ETS plant species;

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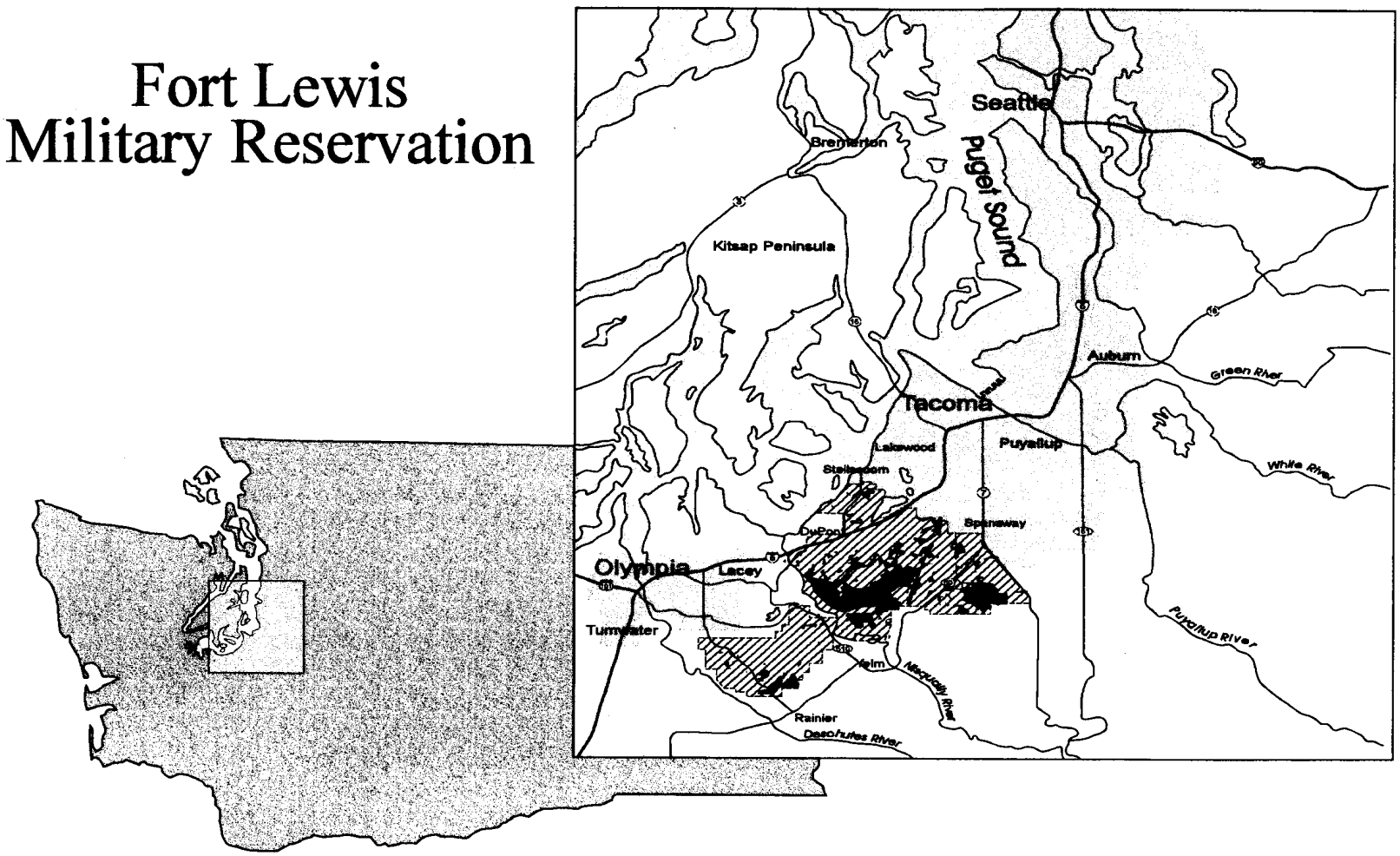

Figure 1. The location of Fort Lewis in the southern portion of Puget Sound, Washington. Prairies are shown in dark gray.

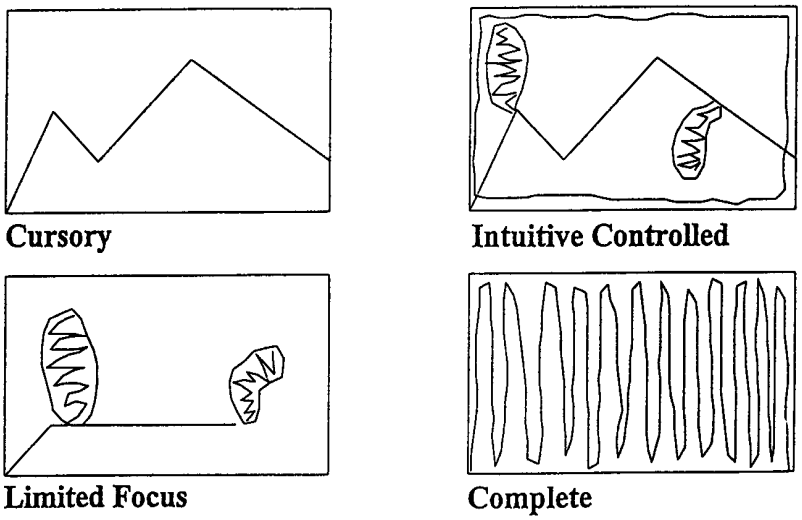

Figure 2a. Sensitive plant search methods used in 1992. Rare plant data were collected in selected habitat suspected to contain the rare species. A hierarchical approach ranging from a cursory reconnaissance of the habitat to a complete examination of the entire area and its perimeter were used to search for rare taxa.

(4) Identify the threats to ETS plant species and make management recommendations to protect populations on the FLMR;

(5) Determine future research needs.

Description of Study Area

The FLMR covers 34,818 hectares (86,000 acres) and is located in the southern portion of the Puget Trough (Figure 1). The landforms and soils of present-day FLMR were formed by the Vashon Glacier that retreated from the area 14,000 years ago and by subsequent erosion and the action of rivers (Kruckeberg 1991). Soils are derived from glacial till and drift and are well drained. The topographic relief is moderate, with elevation ranging from sea level to 173 m. Annual precipitation averages 100 cm at the Gray Airfield weather station, FLMR (unpublished data). The plant communities of FLMR are diverse. Our inventory of ETS plants included large tracts of prairie, wetlands, moist-conifer forests, and oak woodland habitat (3,036 hectares).

Methods

To determine which of the 20 ETS plant species of the Puget Trough might be present on FLMR, we examined the WHNP element occurrence database for historical records of species occurrences in Thurston and Pierce counties. We assembled data on species descriptions, habitats, phenology, and nomenclature from Hitchcock and Cronquist (1973), the WNHP Information System, local amateur and professional botanists familiar with habitats of Fort Lewis, and botanists from the USDA Forest Service, Washington Department of Natural Resources, and environmental consulting firms. Of the 20 ETS species potentially occurring on the FLMR, two were known to be associated with wetlands, four with bogs, three with moist-forests, three with riparian areas, two with forest openings, four with prairies, and two with steep, forested bluffs along Puget Sound. Then, we located these habitat types on 1:12,000 aerial photographs and transferred them to 1:24,000 USGS quad maps or orthophoto quads for field work.

During 1992, we revisited sites of historical occurrences and conducted reconnaissance surveys of prairies, wetlands, moist conifer forests, and oak woodlands by using a hierarchial approach (Figure 2a) to first identify suitable habitats and then to search for ETS plants:

(1) **Cursory**—a quick (15-30 min/ha), reconnaissance of an area to determine if it appeared to be suitable habitat or to assess the phenological development of the plants.

(2) **Limited focus**—a close examination of selected areas within potential habitats but not a search of the entire selected area.

(3) **Intuitive controlled—**a close examination of specific areas of potential habitat as well as a careful search of the perimeter of the potential habitat.

(4) **Complete—**a complete examination made by walking parallel transects throughout the entire area and its perimeter. This method was used if the area appeared to be optimal habitat for the target species.

During 1993, we systematically sampled plant species diversity with transects (Figure 2b). The four lines of the transect formed a box with three plots 50 m apart on each leg of the box. The entire box covered an area of 2.25 ha. Transects were randomly located in relatively homogeneous areas of forest, wetland, and prairie communities. Prairie communities on FLMR had been classified into three types (Rex Crawford, WNHP, personal communication): (1) prairies that had >50% total cover of native species, including > 10% cover of *Festuca idahoensis* and <10% cover of alien species (native prairies); (2) prairies that had >50% cover of native species, 10-50% cover of alien species, and <10% cover of *F. idahoensis* (mixed prairies); and (3) prairies that had >50% cover of alien species, <10% cover of *F. idahoensis* (aliendominated prairies). We categorized the prairies we sampled using Crawford's classes.

We recorded percentage cover and average height for all species found in each plot. Species cover estimates were recorded as trace = 0.5%, 1 to 10% in 1-percent increments and 15 to 100% in 5-percent increments. Height was recorded to the nearest decimeter. We used Hitchcock and Cronquist (1973) to identify plants in the field. Voucher specimens of all species encountered were collected, and identifications were confirmed at the Olympia Forestry Sciences Laboratory, Pacific Northwest Research Station (USDA Forest Service), and the Botany Department Herbarium, University of Washington, Seattle. Nomenclature used in the text and tables is from Kartesz (1994).

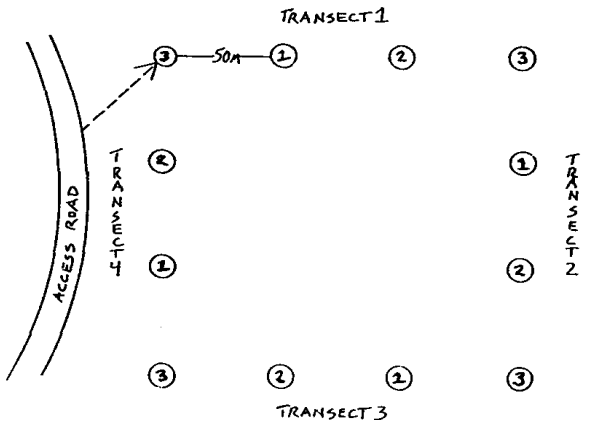

Figure 2b. Plant sampling method used for biodiversity studies in 1993. Rare plant data were collected for ETS plants that were encountered in plots, en route to plots, and on and off lines between plots. The start point for plot 1 was randomly selected.

ETS plant species found within the sampling box or while walking from one plot to the next were recorded on a ETS-plant sighting form and mapped. We also determined the number of aerial stems in the population and the area covered by the individual or population. The life-history stage of the ETS plant was recorded as vegetative, flowering, fruiting, or senescent. The pattern of distribution of ETS plants was determined to be clumped (in discrete patches), scattered-random, or scattered-even. *Aster curtus,* for example, was found clumped in numerous patches distributed over large areas. We estimated the number of individuals in each patch and the number of patches.

For each ETS plant population we found, we dug a shallow soil pit (25 cm deep) to determine the texture of the soil and the percentage of cobble and rocks. Aspect and slope were recorded.

Results

We searched for 20 potential ETS species (Figure 3) and found 97 populations (Table 1, Figures 4-8) of four ETS species during 1992 and 1993: *A. curtus, Trillium parviflorum, Carex comosa,* and *C. interrupta*. In addition to confirming historical records of *A. curtus* and *T. parviflorum* (Severinghaus and Goran 1981, Sheehan and Clampitt 1984, Gilbert et al. 1991), we found several new populations of *A. curtus* and *T. parviflorum.* Small populations of *C. comosa* and *C. interrupta,* species not previously known to occur on FLMR, also were discovered.

Species Accounts

Aster curtus

Species description. Aster curtus is an herbaceous perennial that grows from a slender, creeping rhizome and produces short (1-3 dm), erect stems with a compact, terminal cluster of flowering heads atop each stem (Hitchcock et al. 1969). Plants general-

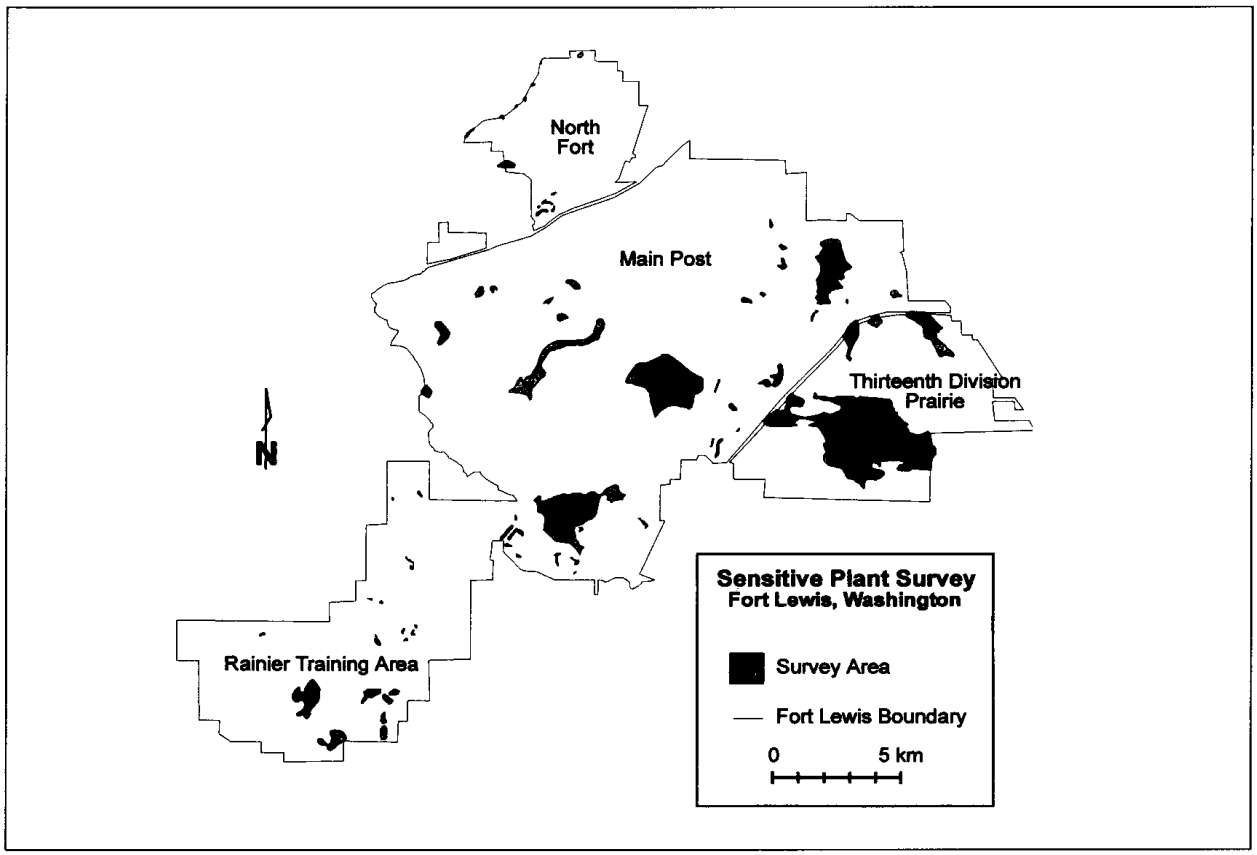

Figure 3. The location of sensitive plant surveys at Lewis, WA. A total of 3036 hectares was sampled for rare plants.

TABLE 1. Rare plant species found on Fort Lewis Military Reservation, WA. Occurrence by habitat, number of occurrences, and area (hectares) covered by each species. Rare plant searches and sampling was undertaken on 3036 hectares total.

Species	Habitat	Number of occurrences	Area (ha)
Aster curtus	Prairie, prairie-margin woodlands	73	190
Tillium parviflorum	moist forests	21	10
Carex comosa	wetland	2	0.14
Carex interrupta	gravel bar	1	0.05

ly produce flowers and fruits in August and September, although achenes may persist on some plants into October. Achenes bear a pappus of short, capillary bristles that facilitates wind dispersal of seed. A regional endemic, this species occurs only on low-elevation prairies west of the Cascade Range, from Vancouver Island and the Puget Trough south into the Willamette Valley, Oregon (Meinke 1982). *Aster curtus* is classified as sensitive in Washington (1994) and is designated as a species of concern in the 1996 Federal Register Review of Plant and Animal Taxa.

Habitat and associated species. Aster curtus occurs primarily on open to partially wooded prairies, characterized by >50% cover of native species. *Festuca idahoensis*, E*riophyllum lanatum*, *Solidago spathulata* var. *neomexicana*, and *Arctostaphylos uvaursi* had the greatest cover and were the most frequently encountered associated species (Table 2). We often found *Pinus ponderosa* and *Quercus garryana* as overstory associates; however, *A. curtus* cover was less abundant under a tree overstory than under open prairie conditions.

We also found *Aster curtus* at sites on the Fort Lewis prairies harboring non-native plant species: *Cytisus scoparius*, *Agrostis tennis*, *Hypochaeris*

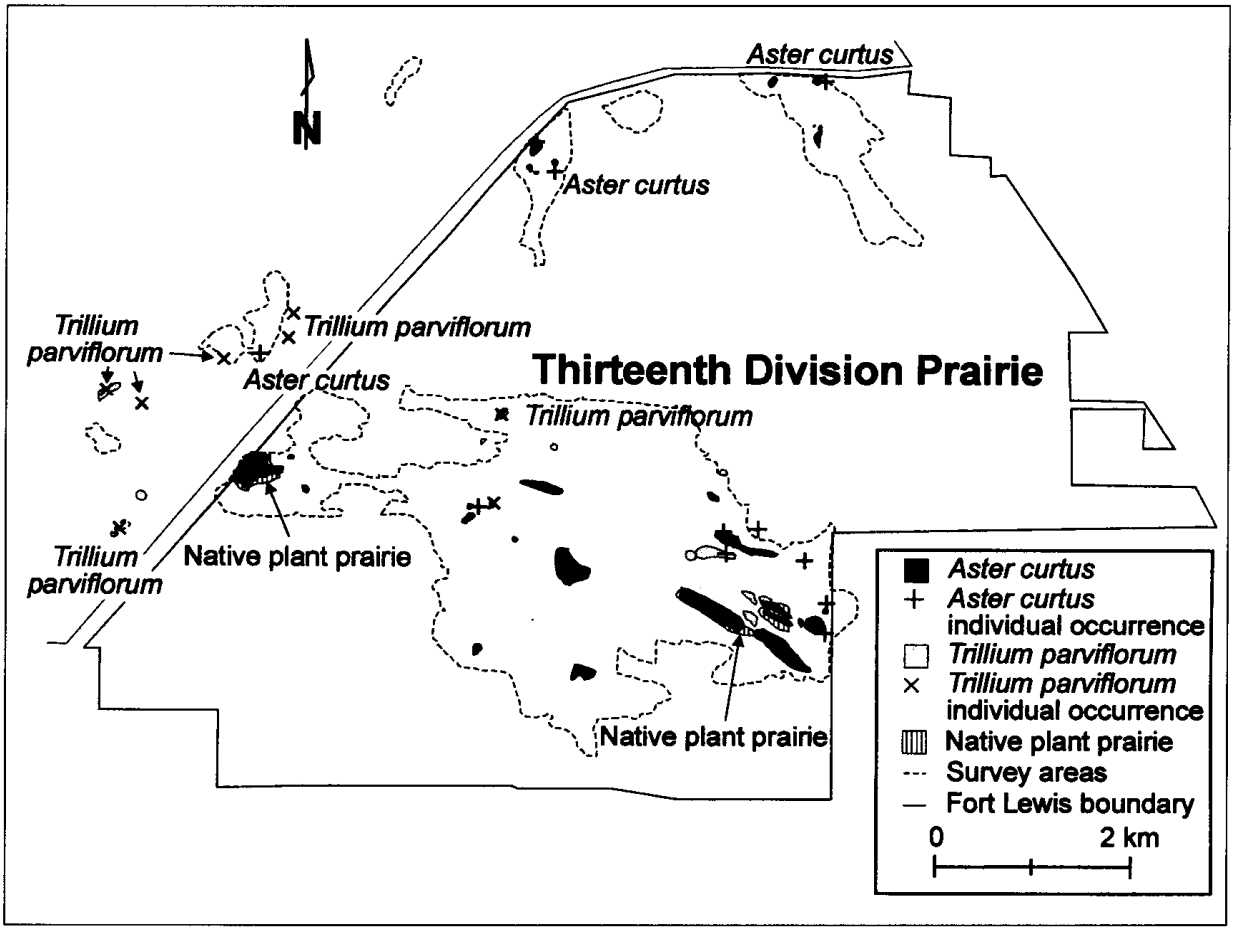

Figure 4. The location of *Aster curtus* and *Trillium parviflorum* on the 13th Division prairie.

radicata, Leucanthemum vulgare, Hypericum perforatum, and *Plantago lanceolata* (Table 3). Native species, such as *Pseudotsuga menziesii,* are invading prairie habitat as a successional process; on prairies where *P. menziesii* was found, cover of *Aster curtus* was lower than on open prairies.

Pattern of abundance. We always found *A. curtus* at lower cover and frequency on alien-dominated prairies than on native or mixed-composition (native and alien) prairies (Tables 2 and 3). Because of its rhizomatous habit, *A. curtus* always occurred in clumps. It was found in trace amounts on alien-dominated prairies but had a frequency of >25 % on prairies dominated by Hypochaeris radicata/Plantago lanceolata/litter *and Agrostis tenuis/Cytisus scoparius/cryptogam* plant communities. Canopy cover above *A. curtus* ranged from full sun on open prairies to 30% shade from shrubs or overstory trees on prairies invaded by non-native shrubs or *P. menziesii*.

On the native-species-dominated prairies, *A. curtus* was found in scattered patches containing 16 to > 10,000 stems per patch. Patch size ranged from 1 to 40 m^2, with an average patch size of 10 M^2. On portions of two near-pristine prairies (13th Division, Figure 4; and Johnson Prairie, Figure 8), more than 30 distinct patches of *A. curtus* with total stem counts of >200,000 shoots were found. On Johnson Prairie and the far west portion of 13th Division Prairie, *A. curtus* covered about 1 % of the total prairie habitat, with cover up to 21 % in some sampling plots.

Topography and soils. All populations of *A. curtus* occurred on relatively broken topography (mounds, small rises, and swales). This feature is uncommon to most FLMR prairie topography, which was usually flat or gently undulating. Soils had deep (20-50 cm) organic horizons over welldrained, gravelly, glacial outwash.

Phenology. Fruits and flowers were observed on about 30% of the stems in each patch. Reproductive structures were not found on stems under 10 cm in

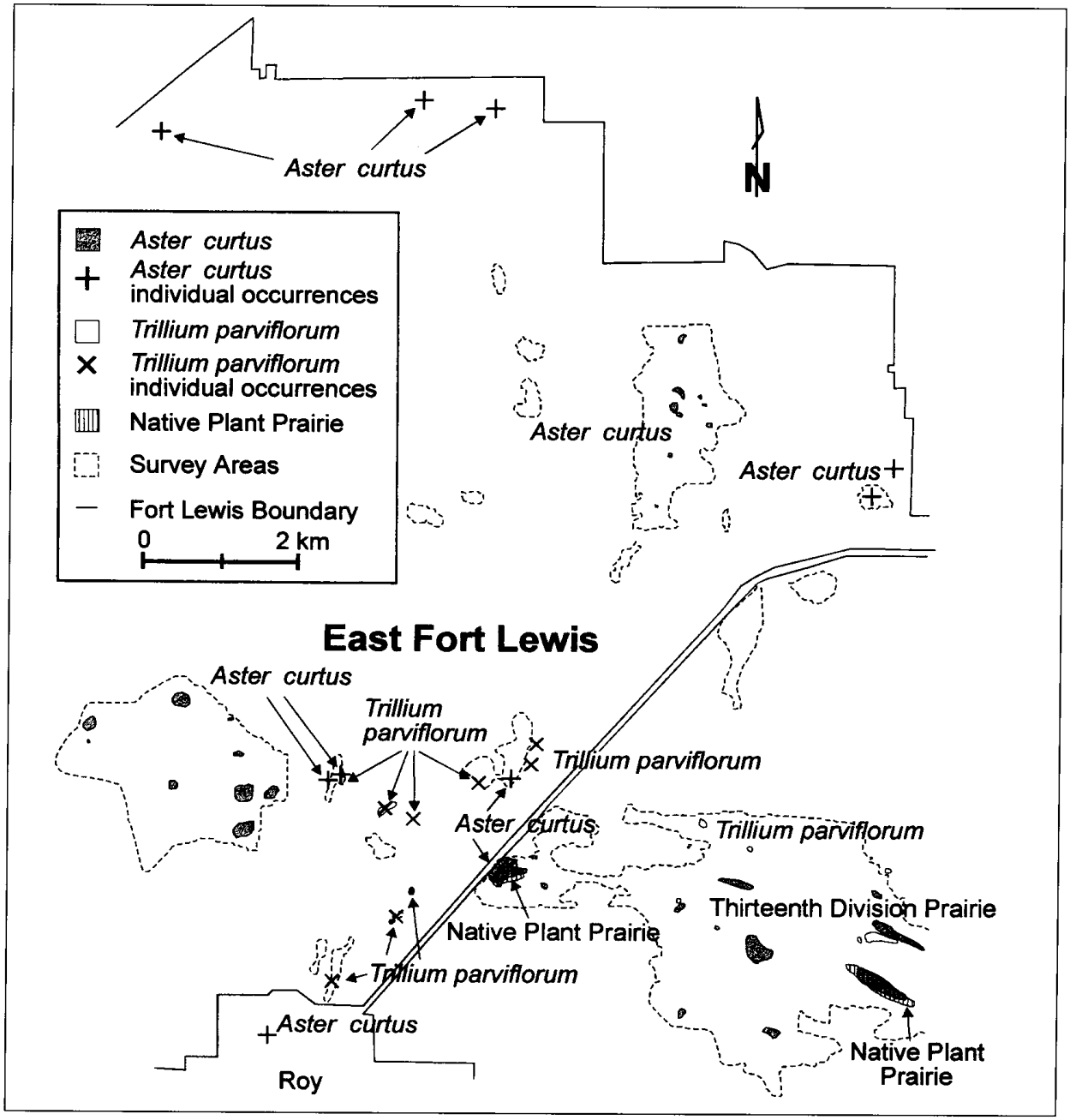

Figure 5. The location of *Aster curtus* and *Trillium parviflorum* populations and individual plants on East Fort Lewis.

eight. A trace (<1%) of observed stems appeared senescent (all leaves brown and withered), and the majority (70%) were found in vegetative stage.

Trillium parviflorum

Species description. Trillium parviflorum is a perennial herb that produces a single, erect annual stem from a short, stout rhizome. The stem is naked, with three ovate, round-tipped, green bracts atop the stem and a sessile, pearly white flower. The short (3-4 cm), upright petals are rounded at the tip and lanceolate in outline. Flowering season ranges from late March through mid May. Some plants bear mottled bracts, and immature specimens may possess only one or two bracts.

A regional endemic, *T. parviflorum* ranges from Pierce and Thurston Counties in Washington to northern Oregon (Soukup 1980). It is found in moist

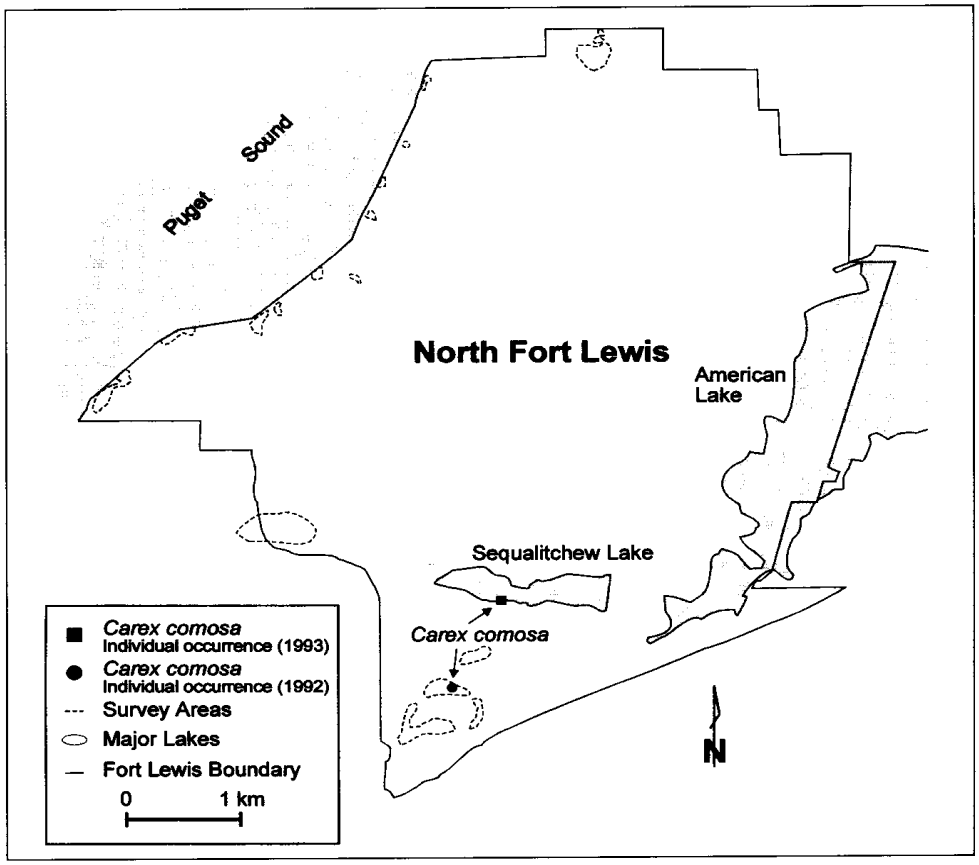

Figure 6. The locations of *Carex comosa* clumps on North Fort Lewis.

woodlands, often with a well-developed shrub understory. The species is classified as sensitive in Washington (WNHP 1994).

Habitat and associated species. We found *T. parviflorum* on sites dominated by shrubs with cover ranging from 25 to 95%. Tree cover ranged from 20 to 55% with the understory composed of moderate to high cover (50-70%) of forbs, grasses, and mosses (Table 4). The most common and abundant associated species were *Q. garryana*, *Fraxinus latifolia*, *Oemleria cerasiformis*, *Holodiscus discolor*, *Crataegus douglasii*, *Symphoricarpos albus*, *Pteridium aquilinum*, and mosses (*Kindbergia oregana*, *Rhytidiadelphus triquetrus*, *Hylacomium splendons*). Understory forbs included the non-native species *Hypericum perforatum*, *Solanum dulcamara*, and *Cirsium arvense*; and disturbance-adapted natives such as *Urtica dioica*.

Pattern of abundance. Although we found apparently extensive, suitable habitats at several survey locations, less than 10% were occupied by *T. parviflorum*. Single, scattered plants were found in some areas, and large populations (5001000 individuals) were observed at two locations. In these areas, plants occurred singly or in compact clusters.

Topography and soils. Plants were found on flat to gently sloping ground adjacent to lakes and streams. Substrate at all observed *T. parviflorum* sites consisted of leaf litter (1-3 cm deep) and a layer of dark, moist organic soil (5-25 cm deep) atop gravelly, glacial outwash.

Phenology. We found flowering plants in all populations, with an average of 60% flowering and 40% in the vegetative stage. All age classes, from juveniles with one or two bracts to robust, flowering adults, were represented at sites with large populations (over 50 plants), but some populations were composed of very few, widely scattered individuals.

Carex comosa

Species description. Carex comosa is a perennial wetland plant that produces dense clusters of stems from

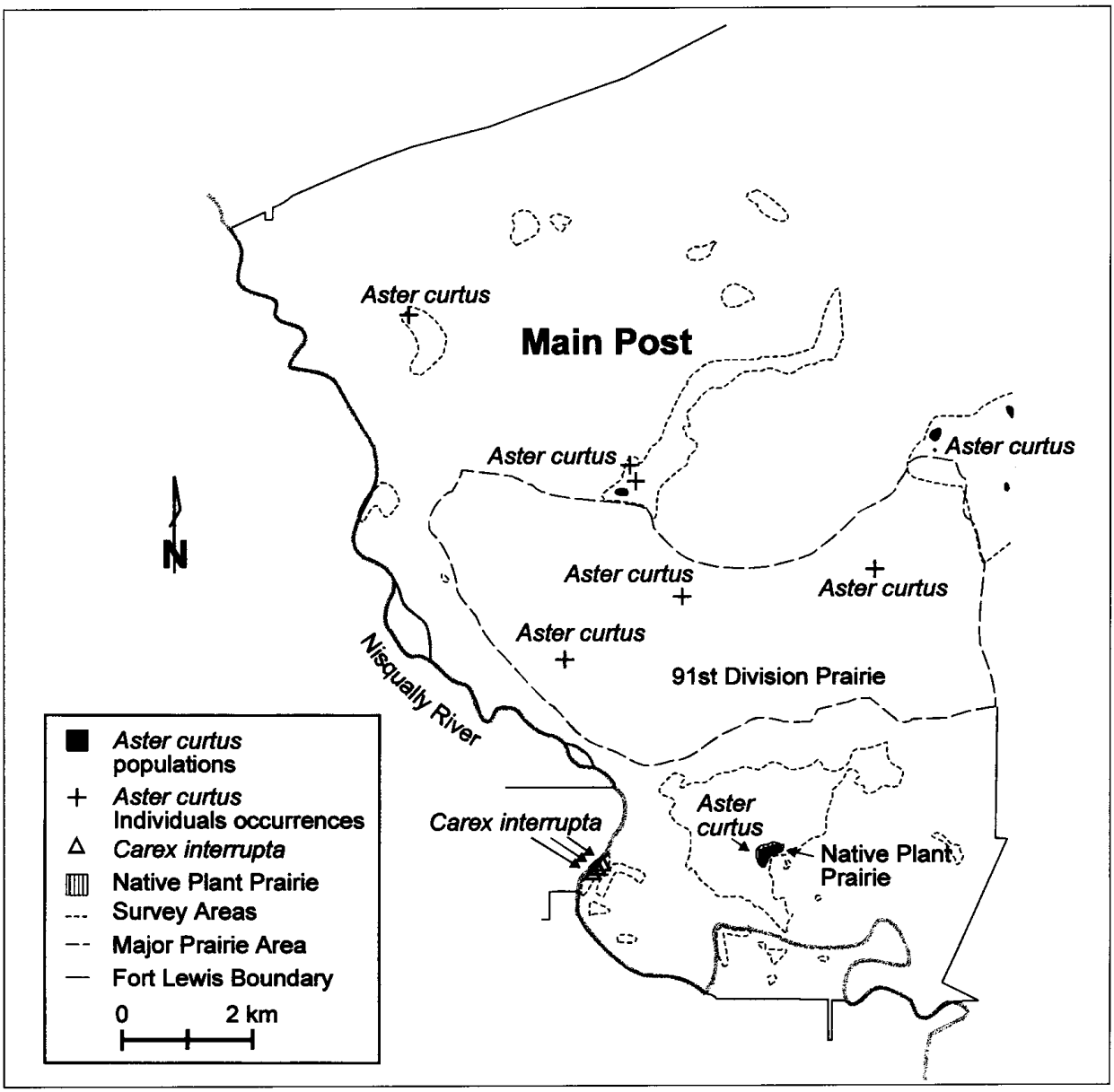

Figure 7. The location of *Carex interrupta* individuals and *Aster curtus* populations on the main post, Fort Lewis.

a short, stout rhizome. Individual plants occur in clumps, rooted in wet soils or on hassocks of other sedges (WNHP Information System). With coarse, bright-green blades, 5 to 10 dm tall, and prominent, cylindrical pistillate spikes on slender, nodding peduncles, this species can be distinguished from common, associated sedges at a glance. The perigynia also are distinctive-green when young, becoming reddish or straw colored at maturity, and prominently beaked with arching, divergent teeth (Hitchcock et al. 1969). Flowers and fruits are produced from late May through August.

Carex comosa ranges from Quebec southward to Florida and Louisiana, with scattered, disjunct populations in Washington, Oregon, California, and northern Idaho (Hitchcock et al. 1969). Although somewhat common east of the Rocky Mountains, it is rare in western states and is listed as sensitive in Washington (WNHP 1994). Confirmed *C. comosa* sites in Washington State include swamps, lake margins, and ditches (WNHP Information System).

Habitat and associated species. We found one population of *C. comosa* in a freshwater marsh (MacKay Marsh) in June 1992. We found a second

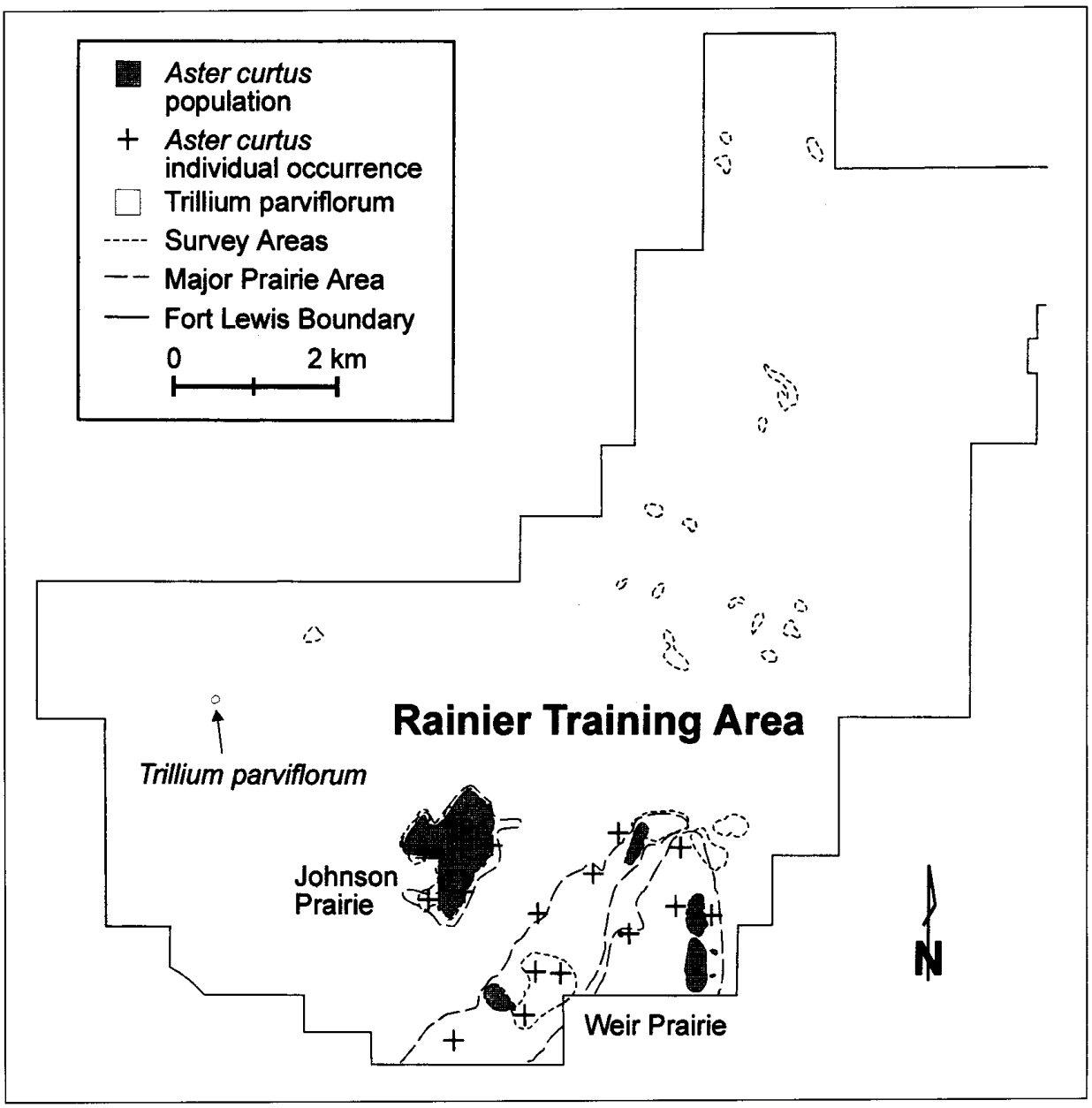

Figure 8. The location of *Aster curtus* and *Trillium parviflorum* populations on the Rainier training area, Fort Lewis.

population on the south shore of Sequalitchew Lake in August 1993. *Carex comosa* occurred in open areas dominated by wetland forbs and graminoids (cover ranged from 15 to 60%) with minor woody cover (15%) and some standing water (25%, Table 5). Dense shrub communities (over 70% cover) occurred along the margin of MacKay Marsh. *Carex comosa* was not found in these shrub-dominated areas.

Many native plant species not commonly found in Fort Lewis wetlands occurred with *C. comosa* at MacKay Marsh. We sampled 24 wetlands and found 6 species that were exclusive to MacKay Marsh and are generally characteristic of bogs: *Scutellaria galericulata*, *S. lateriflora*, *Hydrocotyle ranunculoides*, *Ledum groenlandicum*, *Drosera rotundifolia*, and *Vaccinium oxycoccos*. The following typical wetland species were present: *Potentilla palustris*, *Juncus balticus*, *J. articulatus*, *J. acuminatus*, *J. tenuis*, *Typha latifolia*, *Sparganium emersum*, *Mimulus guttatus*, *Spirea douglasii*, and *Salix sitchensis*. *Salix lasiandra*, *S. geyeriana*, and Betula

TABLE 2. Native species commonly associated with *Aster curtus* on native-dominated prairies and prairie-forest mosaic plant communities. Average cover and frequency was determined on Fort Lewis prairies that met the criteria for native-dominated plant communities, i.e., >50% cover native species and >10% *Festuca idahoensis*.

Native species	Cover (%)	Frequency (%)
Festuca idahoensis	37	75
Aster curtus	2.9	36
Erigeron speciosus var. *speciosus*	5.7	9
Poa compressa	4.1	32
Carex pennsylvanica	2.7	21
Pteridium aquilinum	2.5	20
Symphoricarpos albus	2.8	13
Lupinus bicolor	2	10
Quercus garryana	2	10
Pseudotsuga menziesii	2	26
Lupinus lepidis	1	40
Eriophyllum lanatum	1	56
Lomatium utriculatum	1	36
Lupinus albicaulis	1	31
Zigadenus venenosus	1	18
Campanula rotundifolia	1	28
Danthonia californica	1	50
Fragaria virginiana var. *platypetala*	1	27
Panicum scribnerianum	1	21
Luzula campestris var. *multiflora*	1	31
Camassia quamash	0.5	37
Viola howellii	0.5	13
Viola adunca	0.5	07
Koeleria acrantha	0.5	16
Spiranthes romanzoffiana	0.8	06
Mosses		
Racomitrium canescens	6	51
Polytrichum juniperum	3.6	36
Lichen		
Peltigera canina	1	10
Litter	4.3	30
Bare ground	7	36

glandulosa also were present along the margin of MacKay Marsh. *Phalaris arundinacea*, an aggressive, alien wetland plant, covered about 30% of this marsh and is likely to increase if allowed to persist (Hutchinson 1992).

The *C. comosa* populations (20 individuals) found at Lake Sequalitchew covered about 5% of a patch of native-dominated wetlands with an assortment of alien species in trace amounts. *Salix sitchensis*, *S. piperi*, *Alnus rubra*, *Potentilla palustris*, *J. tenuis*, *J. acuminatus*, *J. articulatus* and a moss, *Philonotis* sp., covered >70% of the area. *Phalaris arundinacea* cover was 15%, and several other alien species were present.

TABLE 3. Non-native species and common native species associated with *Aster curtus* on alien-dominated prairies and prairie-forest mosaic plant communities.

Species	Cover (%)	Frequency (%)
Agrostis tenuis	31	85
Hypochaeris radicata	9	79
Plantago lanceolata	5	57
Cytisus scoparius	4.7	28
Leucathemum vulgare	4	23
Cytisus scoparius (dead, burned in 1993)	3.8	21
Vicia sativa	3.8	17
Trifolium procumbrens	3	54
Poa pratensis	3.2	41
Trifolium pratense	29	36
Holcus lanatus	2.2	61
Anthoxanthum odoratum	1.8	13
Aster curtus	1.6	14
Agropyron repens	1.4	17
Bromus mollis	1	28
Aira praecox	1	48
Hypericum perforatum	1	66
Dactylis glomerata	1	29
Rumex acetosella	0.5	28
Aira caryophylla	0.5	36
Teesdalia nudicaulis	0.5	40
Mosses		
Racomitrium canescens	4.9	43
Polytrichum juniperum	3	47
Lichen		
Peltigera canina	1	10
Litter	7	54
Bare Ground	5	45

Pattern of abundance. *Carex comosa* covered less than 1 % of the MacKay Marsh location. The population consisted of six clumps (one clump equals an individual) distributed over an area of ca 1000 m^2. Distance between individual plants ranged from 5 to 100 m.

TABLE 4. Common plants associated with *Trillium parviflorum.* Plant species are listed by rank of their average % cover for each vegetation stratum. Site and species information was collected from 11 sites harboring *Trillium parviflorum.*

Species	Cover (%)	Frequency (%)
Trees		
Quercus garryana	35	55
Pseudotsuga menziesii	35	55
Fraxinus latifolia	19	27
Shrubs		
Symphoricarpos albus	49	55
Acer circinatum	24	18
Oemleria cerasiformis	20	73
Holodiscus discolor	10	9
Berberis aquifolium	2	18
Rubus procerus	4	18
Rubus ursinus	1	9
Forbs/Graminoids		
Trillium parviflorum	12	100
Galium aparine	3	55
Montia sibirica	3	45
Solanum nigra	3	18
Tellima grandiflora	2	27
Nemophila parviflora	1	45
Circaea alpina	2	18
Osmorhiza chilensis	2	18
Bromus vulgaris	1	18
Leucanthemum vulgare	1	18
Dactylis glomerata	1	18
Hyphochaeris radicata	0.5	27
Lactuca muralis	0.5	18
Arctium minus	0.5	18
Moss/Lichen		
Kindbergia oregana	25	55
Rhytidiadelphus triquetrus	5	27
Isothecium stoloniferum	4	18
Plagiomnium sp.	2	9

TABLE 5. Common plants associated with *Carex comosa.* Plant species are listed by rank of % cover, based on their occurrence at MacKay Marsh and Lake Sequalitchew. Native plants dominated the locations; alien plants are also listed.

Species	Cover (%)
Salix lasiandra	20
Salix sitchensis	20
Salix piperi	10
Salix geyeriana	8
Phalaris arundinacea	8
Spiraea douglasii	6
Potentilla palustris	5
Typha latifolia	3
Kalmia microphylla	2
Agrostis tenuis	1
Mimulus guttatus	1
*Ledum groenlandicum**	1
*Vaccinium oxycoccos**	0.5
*Drosera rotundifolia**	0.5
Juncus tenuis	0.5
Juncus acuminatus	0.5
Juncus articulatus	0.5
Juncus balticus	0.5
Eriophorum chamissonis	0.5
Cytisus scoparius	0.5
*Scutellaria galericulata**	0.5
*Scutellaria lateriflora**	0.5
*Hydrocotyle ranunculoides**	0.5
Sparganium emersum	0.5
Mosses	
Philonotis spp.	10
Spaghnum capillifolium	3
Spaghnum palustre	0.5
Spaghnum squarosum	0.5

* Species that were exclusive to MacKay Marsh.

Topography and soils. Three of the six plants were found in standing water (5-20 cm deep) at time of initial survey at MacKay Marsh (2 June 1992). All clumps were found in open areas without shade from forbs or woody plants. The substrate consisted of fine silt (10-20 cm) over gravel at MacKay Marsh. The substrate at the Sequalitchew Lake site consisted of sandy loam soils over gravel outwash.

Phenology. All the plants we observed bore fruit and appeared robust (there was no evidence of herbivory or senescence). No seedlings or immature clumps were found. Additional plants may exist, but we were unable to access interior portions of this swamp by foot or canoe. At Sequalitchew Lake, about 85% of the plants were in fruit with the remaining being in the vegetative stage.

Carex interrupta

Species description. Carex interrupta is a rhizomatous, perennial plant that forms loose clumps of stems 1.5 -7 dm tall. Flowering stalks bear 2-7 erect, slender

pistillate spikes and a terminal staminate spike. The olive-green perigynia are very small, each subtended by a purplish black pistillate scale (Hitchcock et al. 1969). Plants generally produce 3 flowers and fruits from April through July. Precise measurement and observation of the perigynia and mature achenes is necessary to distinguish *C. interrupta* from closely related species with overlapping range.

Carex interrupta favors sandy or gravelly river banks, streambeds, and open, wet areas at low to moderate elevations. Reported from areas scattered throughout Washington, the species also ranges southward into Oregon, where it can be found west of the Cascade Range (Hitchcock et al. 1969). *Carex interrupta* is classified as a monitor species in Washington (WNHP 1994). It currently is considered to be more abundant and less threatened in Washington than was previously assumed.

Habitat and associated species. We found one confirmed population of *C. interrupta* along the Nisqually River. *Carex interrupta* clumps were on sparsely vegetated, sandy banks on a gravel river bar. Forbs and graminoids comprised the dominant vegetation (35 % cover), with minor cover (5%) in the woody species, *Salix sitchensis* and *A. rubra*. Associated species include *J. ensifolius*, *Mimulus guttatus, Scirpus microcarpus, Carex* spp., *Epilobium* spp., and *Veronica* spp. Alien plants such as *Melilotus officinalis*, *Phalaris arundinacea*, and *Ranunculus repens* also were present.

Pattern of abundance. About 20 clumps (each clump comprising an individual) occurred along a 100-m section of the north bank. *Carex interrupta* occupied about 5% of the 500 m^2 area, but visual estimates of cover for this species were difficult because it intermingled with *C. sitchensis* in this location, and the vegetative portions of these species are indistinguishable.

Topography and soils. The bank slope was gentle (slope <5%), and no evidence of slope instability was observed at the site. Dry, waterborne debris was observed on the upper banks, above the *C. interrupta* clumps, which indicated that the population was submerged during high water events. Soils were composed of bare sand and a thin layer (1 cm) of organic material over sorted gravels and cobbles.

Phenology. Mature reproductive structures are required for positive identification, hence all confirmed *C. interrupta* specimens bore fruit. Among all *C. interrupta*-like sedge clumps observed at the site, 80% bore fruits, 10% had shed all seeds by survey date (9 July 1992), and 10% exhibited only vegetative growth.

Threats to rare species populations at Fort Lewis

Several threats were apparent to each of the rare species present at Fort Lewis. The threats to each species and some recommendations for species conservation are discussed below.

Aster curtus

Loss of suitable habitat and reduction in plant populations due to the successional advancement of *P. menziesii*, encroachment by non-native species such as *Cytisus scoparius*, and physical disturbance (overland vehicular traffic and military training activities) are the greatest threats at FLMR.

Fort Lewis initiated efforts to protect *A. curtus* populations in 1987. This program includes removing of *P. menziesii*, burning *C. scoparius* to maintain prairie plant communities, and prohibiting physical damage to *A. curtus* sites by posting signs to keep vehicles out of areas having large populations.

Surveys of *A. curtus* conducted in 1984 (Sheehan and Clampitt) and 1991 (Gilbert et al.) indicated significant changes in species richness and vegetative cover at permanently marked monitoring plots, but no significant change in the abundance of *A. curtus*. Even though Gilbert et al. (1991) concluded that current management activities to preserve *A. curtus* on FLMR are effective, additional research and monitoring efforts would augment assessing the long-term effectiveness of management plans.

Aster curtus is well suited to long-term demographic study at FLMR because the population is large, and substantial numbers of plants are found in a range of habitat conditions, from somewhat pristine to degraded. Of all rare plants extant at FLMR, *A. curtus* inhabits the most accessible natural areas (open prairies with good road access) and the habitat most likely to be transformed by plant succession and weed invasion. Susceptible to physical destruction and displacement by competitor species, the *A. curtus* population al FLMR merits continued monitoring.

Trillium parviflorum

Based on field observations in 1992 and 1993, threats to *T. parviflorum* populations at FLMR appear to be minor at this time. Threats include competition with associated species, both native and non-native. There was uncertain reproductive success at sites with few, scattered individuals. Monitoring some of the populations to detect changes in the population numbers and vigor of the plants may provide evidence for a continued need for monitoring in permanent plots. Several individuals of *T. parviflorum* showed signs of seed predation; Kruckeberg (1991) observed ants eating the seeds of the *T. ovatum*. Additional work will be required to accurately assess the conservation needs for *T. parviflorum*.

Carex comosa

The environmental circumstances under which the current population of *C. comosa* developed are unclear, and no demographic information is available to indicate growth rate of the population. Specific threats are difficult to infer from a single visit to a population of six individuals, but observations from the 1992 survey do suggest factors that may influence the continued persistence of *C. comosa* at Fort Lewis.

The presence of water control structures (a head gate and human-made outlet channel at MacKay Marsh) and the abundance of reed canary grass show that the swamp is not pristine. Aerial photographs from 1981 show little open water in MacKay Marsh and no visible snags. In 1992, we encountered large areas of open water and numerous standing dead *Populus trichocarpa*, *Pinus contorta* var. *contorta*, and *Pyrus fusca* on the margins and in MacKay Marsh. Water level and woody-plant cover have fluctuated during the past decade. *Carex comosa* was not found on sites with dense cover of shrubs and trees, but woody vegetation dominates the surrounding area and may spread into the habitat of this rare species. The impact of changes in water level and woody cover on *C. comosa* should be examined.

No seedlings or small plants of *C. comosa* were found, indicating a lack of seedling reproduction under the current environmental and physiological conditions. Vegetative reproduction was not apparent for this population. The total number of reproductive adults is small and individual plants are widely scattered. Therefore, such a population may possess low genetic diversity and concomitant inability to adapt as environmental conditions change (Owen and Rosentreter 1992). Such small populations are especially susceptible to stochastic effects, including environmental disturbance (fire, drought) and chance death of numerous individuals.

Carex interrupta

Based on initial observation of *C. interrupta* at FLMR, competition from native and non-native species may be a threat. Abundant bare ground on the gravel bar of the Nisqually River is available for colonization by native and alien species, and loss of individual clumps of *C. interrupta* may be displaced by other species or physically during high-water events. Minor herbivory was observed; bracts were partially eaten from two *C. interrupta* clumps.

Management Recommendations

Each ETS plant species occurring at FLMR is restricted in its distribution by the interactions of its unique population dynamics and environmental conditions it finds favorable. No single management practice can provide the requirements for all four species. A basic monitoring protocol, tailored to each species, would provide information necessary to evaluate the efficacy of management, however. The conservation strategies, monitoring, and research endeavors summarized below are designed to protect extant populations and provide information to assess long-term viability of these populations. Because our knowledge of the species and the efficacy of the management techniques is rudimentary, management must be adaptive, incorporating monitoring and feedback to redirect management activities. Before beginning such programs however, the land manager must decide what time, funds, and personnel will be allocated to the maintenance and monitoring of ETS plant species (Owen and Rosentreter 1992) and develop management plans accordingly.

(1) *Protection*. Protect extant populations from physical damage from rubber-tired or tracked vehicles. Establish biodiversity preserves to protect and manage ETS plant populations and habitat. Emphasis should be placed on improving and maintaining critical wetland and prairie communities that contain the ETS species, high percentages of native species, and little or no evidence of disturbance from non-native species, military training maneuvers, historic grazing, or cultivation.

(2) *Rehabilitation of degraded habitat*. Control the spread of competing and non-native species or actively remove non-native species. Erosion control, maintenance of stream crossings, and maintenance of water levels in wetlands are measures that would improve the habitat of ETS species and native plant communities.

(3) *Monitoring*. Periodically review results of management plans, including the effects on plant demography and habitat quality to see if the plan is adequate or if it needs revision (Pickart 1991). Record habitat information (distribution and abundance of associated species, cover types, physical characteristics of site) and life stage, flowering, seed production, and dispersal of individuals (Dixon and Cook 1989; Menges 1990; Pickart 1991).

(4) *Propagation*. If populations decline, a program of germination or vegetative propagation, revegetation, and habitat restoration could be considered.

Research in conjunction with monitoring of management efficacy could provide additional information on the life history and habitat of ETS plants and factors limiting their populations. Additional research, experimental or retrospective, could quantify the demography of plant populations in relation to degree of disruption or manipulation that alters habitat. Genetic material from plants within and among patches throughout the of white-topped aster permanent plots on Ft. Lewis Military Reservation, Pierce Co., Washington. U.S. Fish and Wildlife Service, Olympia, WA. FLMR could be analyzed to determine the amount of variation within FLMR populations. Because lack of genetic variation can inhibit a population's ability to respond to environmental changes, such information should be considered when developing long-term management plans for ETS species (Owen and Rosentreter 1992). Research on the reproductive capability of ETS plant species is needed. Seeds could be collected, germinated, and grown under controlled conditions that simulate natural phenomena (i.e., test effect of freezing, long-term storage, or inundation of water on seed viability) (Dixon and Cook 1989).

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Literature Cited

Clampitt, C. A. 1993. Effects of human disturbance on prairies and the regional endemic *Aster curtus* in western Washington. Northw. Sci. 67:163-169.

Dixon, P.M., and R.E. Cook. 1989. Science, planning, and the recovery of endangered plants. Endangered Species Update 6(10):9-14.

Department of the Army. 1990. Procedures to protect and enhance the habitat of endangered, threatened, and/ or candidate species on Fort Lewis and sub-installations. Regulation 420-5.

Gilbert, B., T. Williams, and J. Bortorff. 1991. 1991 status Hitchcock, C.L., A. Cronquist, M. Ownbey, and J.W. Thompson. 1955-1969. Vascular Plants of the Pacific Northwest. Vol. 1-5. University of Washington Press, Seattle.

Hitchcock, C.L., and A. Cronquist. 1973. Flora of the Pacific Northwest: An Illustrated Manual. University of Washington Press, Seattle.

Kartesz, J. T. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. Second Edition. Volume 2—Thesaurus. Timber Press, Portland, Oregon.

Kruckeberg, A.R. 1991. The Natural History of Puget Sound Country. University of Washington Press, Seattle.

Meinke, R.J. 1982. Threatened and endangered vascular plants of Oregon: an illustrated guide. GPO 594-793, U.S. Government Printing Office, Washington, D.C.

Menges, E. 1990. Population viability analysis for an endangered plant. Conserv. Biol. 4:52-61.

Owen, W.R., and R. Rosentreter. 1992. Monitoring rare perennial plants: techniques for demographic studies. Natur. Areas J. 12:32-28.

Pickart, A.J. 1991. The evolution of a rare plant monitoring program: case study at the Lanphere-Christensen Dunes Preserve. Natur. Areas J. 11:187-189.

Severinghaus, W.D. and W.D. Goran. 1981. Effects of tactical vehicle activity on the mammals, birds, and vegetation at Fort Lewis, WA. Construction Engineering Research Laboratory, US Army Corp of Engineers Tech. Rep. N-116, Champaign, Illinois.

Sheehan, M., and C. Clampitt. 1984. Effects of military activities, Fort Lewis, Washington, on the white-topped

aster (*Aster curtus*). Washington Natural Heritage Program, Washington Department of Natural Resources, Olympia.
Soukup, V.G. 1980. A new trillium (Lilliaceae) from the north western United States. Brittonia 32:330-333.

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Washington Natural Heritage Program. 1994. Endangered, threatened, and sensitive vascular plants of Washington. Washington Department of Natural Resources, Olympia.
U.S. Fish and Wildlife Service. 1996. Endangered and threatened wildlife and plants; Review of plant and animal taxa that are candidates for listing as endangered or threatened species. U.S. Code of Federal Regulations 50, Part 17.