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Aster Curtus: Current Knowledge of Its Biology and Threats to Its Survival

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Abstract

Aster curtus Cronq. , a taxon in the family Asteraceae, is a rhizomatous, herbaceous perennial endemic to the remnant prairies of Oregon, Washington and Vancouver Island, British Columbia. The current population center is located on Fort Lewis Military Base in Pierce and Thurston counties of Washington State. A "species of concern" under the Endangered Species Act, its current listing in Washington is "Sensitive". *Aster curtus* cover is highest on prairies with low exotic species invasion and competes poorly with associated native and exotic species at the seedling stage. Under field conditions, recruitment by seed appears to be low, and persistence of this species is achieved primarily through clonal growth. *Aster curtus* is self-compatible, though putative out crossing appears to result in more filled seeds. Industrial, residential and agricultural developments are the largest threats to its survival. Considering the degree of habitat degradation that has already occurred throughout the range of *A. curtus*, the long-term survival of this species will depend on how well we understand its autecology and how well we protect its habitat. This paper summarizes past and present information that can be applied to the conservation efforts of this species.

Introduction

Aster curtus is endemic to the Willamette-Puget lowlands of the Pacific Northwest. Its present range extends from lower Vancouver Island, British Columbia to Lane County, Oregon, with the largest populations found on Fort Lewis Military Base in Pierce and Thurston counties, Washington (Gamon and Salstrom; 1992). Over the past 20 years, more than 70 new populations of A. *curtus* have been reported, however these discoveries have largely occurred in counties where the species was already known to be extant (Gamon and Salstrom; 1992). The distribution of *A. curtus* is not continuous throughout its range, as evidenced by the lack of current records for populations between Pierce/Thurston counties, Washington and Vancouver Island, British Columbia. Additionally, no populations are presently known to exist between these two Washington counties and Clackamas County, Oregon (Gamon and Salstrom; 1992). The reasons for this patchy distribution are unknown, but conversion of grasslands to pasture and commercial/ residential development have likely been major factors. Despite much attention give to *A. curtus* over the past 15 years (Alverson, 1983; Clampitt, 1984; Giblin, 1997) many questions remain regarding the reasons for its rarity.

Taxonomic Status

Aster curtus Cronq., was originally described as *Sericocarpus rigidus* Lindl.in 1834 on the basis of collections made by Scouler along the Columbia River. Cronquist changed *S. rigidus* to *Aster curtus* (Hitchcock et al., 1955), and more contemporary taxonomic work has placed *Sericocarpus* as a subgenus of *Aster* (Jones, 1980; Semple and Brouillet, 1980). This subgenus is comprised of the western U.S. species *A. curtus* and *A. oregonensis,* the eastern U.S. species *A. paternus, A. solidagineus,* and *A. tortifolius*, and the Asian species *A. baccharoides*. Only *A. curtus* is a grassland native with the remaining species typically inhabiting the forest under story. The common name of *A. curtus*, white-topped aster, derives from the effect produced by the pappus which expands just prior to seed dispersal.

The ranges of *A. curtus* and *A. oregonensis* overlap from southern Washington through central Oregon, however the two species are separated on the basis of habitat preference as well as reproductive and vegetative morphology. Most notable, the woodland species *A. oregonensis* has four ray flowers and over winters as a stout caudex, whereas the grassland dweller *A. curtus*, typically has two ray flowers and is strongly rhizomatous (Hitchcock et al., 1955). The other five *Aster* species of the subgenus *Sericocarpus* have a haploid chromosome number n=9, and this is the presumed condition for *A. curtus* (Clampitt, 1984; Jones, 1980; Semple and Brouillet, 1980).

Legal Status

As a federal level, *A. curtus* is listed as a species of concern (USFWS, 1996). This classification is given to those species for which more information is needed before formal listing as endangered or threatened (Thomas and Carey, 1996). The Washington Natural Heritage Program downgraded *A. curtus* from its original listings as “Threatened” to “Sensitive” (Washington Natural Heritage Program, 1990), undoubtedly the result of more populations having been located since earlier versions of the list. The state of Oregon lists *A. curtus* as “Threatened”, and this guarantees legal protection for this species on all state-owned or state-leased property (Oregon Natural Heritage Plan, 1993). British Columbia lists *A. curtus* as “critically imperiled” because of extreme rarity (Argus and Pryer, 1990).

Habitat Characteristics

A. curtus inhabits the glacial outwash prairies and grasslands of the Puget-Willamette lowlands that were formed during the Pleistocene glaciations 15,000 years ago. Historically, high frequency, low intensity fires and periodically dry soils have kept the bunchgrass-dominated prairie system free from encroachment by forest vegetation (Hansen, 1947). *A. curtus* is typically found in open locations where cover of native grasses and forbs exceeds 50% (Thomas and Carey, 1996), but will also grow in *Quercus garryana* (Garry Oak) woodlands where light levels are high enough to support other open prairie vegetation (personal observation). Native species strongly associated with *A. curtus* include *Festuca idahoensis* (Idaho fescue), *Eriophyllum lanatum* (Woolly daisy), *Hieracium cynoglossoides* (Houndstongue hawkweed), *and Solidago spathulata* var. *neomexicana* (Thomas and Carey, 1996; Crawford et al., 1994).

The prairie soils of Pierce and Thurston counties, where the majority of populations are found, typically belong to the Spanaway series (Anderson et al, 1955; Ness, 1958). These are well-drained, gravelly sandy loams which become excessively dry between July and September. Low moisture availability during the summer months results in the dormancy of many spring flowering forbs.

Life History

A. curtus is a rhizomatous, herbaceous perennial which produces erect stems 1-3 dm in height from slender rhizomes (Hitchcock et al, 1955). New shoots emerge in March and become prominent in late spring (pers. obs.). Flowering occurs from late July through early September with individual florets being strongly protandrous. Pollen is presented in the morning and usually absent by days' end as a result of removal by bees, disruption of the inflorescence by wind, and perhaps desiccation. Stigmas appear to be receptive for up to 3 days (pers. obs). On average there are 13 disk flowers and 3 ray flowers per capitulum (Clampitt, 1984; Hitchcock et al, 1955). Only 10-30% of the ramets within a patch bear inflorescences (Gamon and Salstrom, 1992). Most seeds ripen and are wind dispersed by late September. Wind dispersal is achieved via the bristly pappus attached to the mature achene.

Effective pollination is achieved by 3-4 bee species, though butterflies do visit inflorescences during anthesis (pers. obs.). *A. curtus* is self compatible (Giblin, 1997), however pollinators increase the amount of endosperm-filled seeds produced 4-fold (Giblin, 1997; Clampitt, 1984).

A. curtus seed viability is low but not atypically so for species *Asteraceae* (Clampitt, 1984). Clampitt (1984) found that 20% of the achenes produced per plant were filled with endosperm. Of these filled seeds, only 50% proved to be viable through tetra-zolium testing (Clampitt, 1984). Greenhouse studies showed that seed germination was most favorable after 5 weeks stratification at 5 degrees C, and high light/warm temperature (30 degree C) conditions (Clampitt, 1984).

Ecology

Rabinowitz (1981) developed a classification system of rarity on the basis of geographic distribution, habitat specificity, and population size. Within this system, *A. curtus* is described as a regional endemic due to its narrow distribution, narrow habitat specificity and large population sizes. Indeed, when encountered in the field, *A. curtus* is observed to be locally abundant over a small geographical area.

Plants are divided into three groups on the basis of whether their survival strategies are ruderal, stress tolerant, or competitive (Grime, 1977). Due to its slow growth rate, ability to persist under severe competition, low stature, and allocation of resources toward clonal expansion prior to flowering, *A. curtus* is considered to be a stress tolerant species (Clampitt, 1984).

On account of its rhizomatous nature, *A. curtus* forms patches where it occurs. Patch size is extremely variable both in area and number of ramets, with native species abundance strongly influencing these factors. ON Fort Lewis prairies where native species dominated, Thomas Carey (1996) found patch area to average 10m2, though they observed patches up to 40m2. They also report ramet numbers ranging from 16 to 10,000 per patch, with a few patches containing up to 200,000 (Thomas and Carey, 1996). Seedlings are seldom observed in the field (pers. obs.), and persistence of existing populations is achieved through clonal expansion (Clampitt, 1984).

A. curtus shows a preference for mounded areas in the prairie. Clampitt (1984) showed that *A. curtus* is most likely to occur in the middle regions of prairie mounds. My own personal observations on 13th Division and Upper Weir prairies have confirmed this association. *A. curtus* does grow in areas between mounds, but not with the same degree of predictability. The explanation for this microsite preference likely involves the ability of *A. curtus* to tolerate the droughty conditions of this location during the summer months.

Where exotic species presence is high, *A. curtus* cover tends to be low. This negative correlation is likely due to the ability of exotic species to out compete *A. curtus* for nutrients. Clampitt (1987) found that *A. curtus* seedlings competed poorly in greenhouse studies when grown with associated native and exotic prairie species. These results suggest that the recruitment of *A. curtus* requires the exclusion of other species during the seedling establishment phase. The strongly rhizomatous *Agrostis tenuis* (Bentgrass) and the fall germinating *Hypochaeris radicata* (Cat's ear) are two exotic species which can quickly colonize microsites favorable for recruitment of *A. curtus* seedlings.

Current Research

In the summer of 1996 I began researching the reproductive biology of *A. curtus*, and the influence of different disturbance regimes on seed germination and seedling establishment. Greenhouse studies are being conducted at the University of Washington's Center for Urban Horticulture, and field studies at 13th Division Prairie on Fort Lewis.

Preliminary results from greenhouse studies suggest that *A. curtus* is self-compatible. Self and cross-pollinated stigmas were harvested and examined using fluorescent microscopy techniques. Pollen grains from nearly all cross-pollinations have shown high germination percentages on the stigmatic surface and pollen tube penetration into the stylar region. Pollen grains from many of the self-pollinations showed little or no adhesion to the stigmatic surface, low germination percentages, and little stylar penetration. Nevertheless, a modest number of self-pollinations produced high germination percentages and stylar penetration. These results suggest that some genets of *A. curtus* are self-compatible.

Field pollination trials were conducted in the summer of 1996, and the results confirmed the preliminary findings of the greenhouse trials. Four pollination treatments (within-patch between-patch, exclusion, control) were applied to 20 patches of *A. curtus*. Using mesh bags to prevent unwanted pollinations, inflorescences were hand-pollinated using forceps. Inflorescences used for the exclusion treatment were bagged and received no pollinations. The control inflorescences ere covered with mesh bags after blooming. The number of endosperm filled seeds in each inflorescence was counted, and a number by the total number of seeds per inflorescence. Mean dilled seed percentages for the four pollination treatments were 39% for open, 35% for between patch, 17% for within patch and 9% for pollination exclusion. These data were arcsine transformed and analyzed using mixed model two-way ANOVA. Results showed a significant difference between treatment values at the .05 level ($F=3.14$; $p=<.001$). Multiple comparisons were run using the least significant difference test (LSD). No significant difference existed between open and between-patch treatments, or between within patch and exclusion treatments. Significant differences were detected between the two foremost and the two lattermost treatments (Table 1).

Field pollination data suggest that *A. curtus* is not pollinator limited and that self-compatibility is present. These results are important in the context of why recruitment of *A. curtus* by seed is low. One hypothesis is that low pollination rates result in low seed production, but results from between-patch pollinations discount this. A second hypothesis is that seed production is low due to the presence of a self-incompatibility mechanism. Because *A. curtus* is clonal, most pollinations occur within a patch. Self-incompatibility would inhibit seed production from such pollinations. The results suggest that seeds, though lower in quantity, can be produced from within-patch pollinations.

Table 1. Comparison of four pollination treatments applied to 20 patches of *Aster curtus* growing at 13th Division Prairie, Fort Lewis, WA. Superscript values show significant differences at alpha= .05 using LSD test.

Treatment	Arcsine Values (SE)
Open 1	.66 (.06)
Between Patch 1	.61 (.06)
Within Patch 2	.37 (.06)
Exclusion 2	.21 (.05)

Table 2. Percent of filled seeds from 20 capitula (1 capitulum per plant) of four species growing on 13th Division Prairie, Fort Lewis, WA.

Species	% Filled Seeds
Hypochaeris radicata	82
Eriophyllum lanatum	32
Aster curtus	26
Solidago spathulata	21

In separate experiment, filled seed percentage of *A. curtus* was compared to associated native and exotic species of summer-blooming composites. Twenty ripened heads were collected from *A. curtus, H. radicata, Chrysanthemum leucanthemum, E. lanatum, and S. spathulata* var. *neomexicana,* and the ratio of filled seeds to total seeds was calculated for each species. *Hypochaeris radicata* showed substantially higher mean filled seed percentage (82%) than all the other species. Filled seed percentage for *A. curtus* was comparable to those of the two native species tested. Final results for *C. leucanthemum* have not been determined, though preliminary numbers suggest a mean percentage of 50-60%. These results suggest that seed set for *A. curtus* is similar to associated exotic species (Table 2).

In September of 1996 I installed a randomized block experiment testing for the effect of disturbance on recruitment of *A. curtus.* Five treatments (fire, mowing, compaction, gophering, control) were replicated five times. Fifty filled seeds were sown into each treatment cell and their location marked using a quadrat frame. The fate of these 1250 seeds will be followed over the course of one growing season to determine if establishment rates differ between disturbance types.

Ongoing research also includes comparing germination rates of the seeds harvested from the field pollination trials. Difference in germination rates between within and between patch seeds might suggest the presence of inbreeding depression. The occurrence of inbreeding depression within *A. curtus* is currently unknown. Additionally, randomly amplified polymorphic DNA (RAPDs) analysis will be used to examine genetic variation of the *A. curtus* patches of the research area at Fort Lewis. Results from this analysis will provide a very general estimate of genetic similarity between these patches.

Threats to Survival of *A. curtus*

Habitat destruction is the biggest threat to the long-term survival of *A. curtus*. Conversion of prairie to agricultural production at the turn of the century has been replaced by industrial and residential development. As the Pacific Northwest population continues to grow, greater pressures are placed on the remaining pieces of this unique ecosystem. Several sources estimate that 95% of the original prairie system has been destroyed. In this context, the future of *A. curtus* is precarious. Large tracts of prairie are contained within the boundaries of Fort Lewis Military Base, so these areas are free from the pressures of development. Nevertheless, military training on these prairies can result in disturbances detrimental to the health of *A. curtus* populations. Clampitt (1993) found *A. curtus* to decline where vehicular disturbance is high, and personal observations support this finding.

Invasive exotics pose a serious threat to the long-term survival of *A. curtus. Cytissus scoparius* (Scotch broom) *Agrostis tenuis* (bentgrass), *H. radicata* (Cat's ear), and *C. leucanthemum* (Ox-eye daisy) are all aggressive colonizers of open sites on the prairie. Each of these species have proven to be outstanding competitors in this water stressed ecosystem. Recruitment and persistence of these species at both small and large spatial scales likely influence the success of *A. curtus*. Control of these invasives should be an integral part of long-term management plans for *A. curtus*.

Finally, alteration of disturbance regimes has influenced the community structure of the prairie. Removal of fire has led to encroachment by *P. menziesii* which in turns excludes prairie grasses and forbs. Decline of pocket gopher and other fossorial mammal populations has led to the loss of burrowing mounds which provided favorable microsites for the recruitment of native species. New disturbances such as soil compaction have led to increases in exotic species invasion, and as a result, declines in native species populations.

Future Research

Demography studies using stage-based projection matrices need to be conducted on patches of *A. curtus* across several prairie sites. It is currently unknown as to whether patches are increasing or decreasing in size over time. Because *A. curtus* persists almost exclusively through rhizome production, it is critical that we understand the current growth rates of these patches.

Additionally, research is needed to determine the best means of transplanting and establishing *A. curtus* in the field. Successful prairie restoration efforts will create opportunities for establishing *A. curtus* in historic locations. Presently we do not know whether transplanted rhizomes or patches of rhizomes will survive and expand. Because local populations of *A. curtus* are currently large, research conducted now would benefit from the lack of limitations on availability of experimental material.

Conclusion

Efforts need to be directed now to the conservation of *A. curtus.* Because of its apparent abundance in the field, it is often perceived as a species whose existence is not imminently threatened. Belying this perception is the fact that *A. curtus* is found in an extremely limited area subject to frequent anthropogenic disturbances and intense development pressures. Also troubling is the fact that it does not readily colonize new sites.

Too often protection is given to rare species only as they approach extinction, and such protection is often expensive and difficult. Rather than ignoring *A. curtus* on account of its abundance, conservation efforts should focus on how to best exploit this condition to ensure that long-term persistence of this species. *A. curtus*, a regionally rare species in a regionally rare habitat, represents a conservation opportunity with a high likelihood of long-term success if appropriate actions are undertaken now.

Literature Cited:

Alverson, Ed. 1983. Observations on the Occurrence and Status of *Aster Curtus* in Washington State. Unpublished Report. Washington Natural Heritage Program files, Olympia, WA. 13p. plus figures and appendices.

Anderson, W.W., A.O. Ness, and A.C. Anderson. 1955. Soil Survey of Pierce County, Washington. USDA. Soil Survey Report, ser. 1939 #7.

Argus, G. W., and K.M. Pryer. 1990. Rare Vascular Plants in Canada/Our Natural Heritage. Rare and Endangered Plants Project, Botany Division, Canadian Museum of Nature, Ottawa. 191p. plus maps.

Clampitt, C. A. 1984. The Ecological Lif History of Aster Curtus, a Grassland Endemis in a Forested Region. M.S. thesis, University of Washington, Seattle. 81p. plus appendices.

Clampitt, C.A. 1987. The Reproductive Biology of Aster Curtus (Asteraceae), a Pacific Northwest Endemic. American Journal of Botany 74(6):941-946.

Clampitt, C.A. 1993. Effects of Human Disturbance on Prairies and the Regional Endemic *Aster Curtus* in Western Washington. Northwest Science. 67:163-169.

Crawford, R.C., C. Chappell, B. Stephens, C. Soper, and D. Rolph. 1994. Inventory and Mapping of Endangered Native Ecosystems on Fort Lewis; Draft Final Report. Washington Department of Natural Resources, Division of Forest Resources, Natural Heritage Program, and The Nature Conservancy of Washington.

Gamon, J. and D. Salstrom. 1992. Report on the status of *Aster Curtus*. Washington Natural Heritage Program, Department of Natural Resources. Olympia, WA.

Giblin, D.E. 1997. The Relationship of Reproductive Biology and Disturbance to the Rarity of *Aster Curtus* (Cronq.), a Pacific Northwest endemic. M.S. Thesis,, University of Washington , Seattle.

Grime, J.P. 1997. Evidence for the Existence of Three Primary Strategies in Plants and its Relevance to Ecological and Evolutionary Theory. American Naturalist 111:1169-1174.

Hansen, H.P. 1947. Climate Versus Fire and Soil as Factors in Post-Glacial Forest Succession in the Puget Sound Lowland of Washington. American Journal of Science 245(5):365-286.

Hitchcock, C.L., M. Ownbey, and J.W. Thompson. 1955. Vascular Plants of the Pacific Northwest. Part 5: Compositae. University of Washington Press. Seattle, WA.

Hitchcock, C.L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press. Seattle, WA.

Jones, A.G. 1980. A Classification of the New World Species *Aster* (Asteraceae). Brittonia 32(2):230-239.

Ness, A.O. Soil Survey of Thurston County, Washington. USDA. Soil Conservation Service. Soil Survey Number 6.

Norton, H.H. 1979. The Association between Anthropogenic Prairies and Important Food Plants in Western Washington. NW Anthrop. Res. Notes 13(2):175-200.

Oregon Natural Heritage Plan. 1993. Natural Heritage Advisory Council to the State Land Board. Salem, OR. 158p.

Rabinowitz, D. 1981. Seven Forms of Rarity. *In* H. Synge, ed. The Biological Aspects of Rare Plant Conservation. John Wiley and Sons. New York.

Semple, J., and L. Brouillet. 1980. A Synopsis of North American Asters: the subgenera, sections, and subsections of *Aster* and *Lasellea.*

Thomas, T.B. and A.B. Carey. Endangered, Threatened, and Sensitive Plants of Fort Lewis, Washington: Distribution, Mapping, and Management Recommendations for Species Conservation. Northwest Science 70(2):148-163.

United States Fish and Wildlife Service. 1996. Endangered and Threatened Wildlife and Plants; Review of Plants and Animal Taxa that are Candidates for Listing as Endangered or Threatened Species. U.S. Code of Federal Regulations 50, Part 17.

Washington Natural Heritage Program. 1990. Endangered, Threatened and Sensitive Vascular Plants of Washington. Washington Department of Natural Resources, Olympia, WA.

Washington Natural Heritage Program. 1994. Endangered, Threatened and Sensitive Vascular Plants of Washington. Washington Department of Natural Resources, Olympia, WA.