Developing biogeographically based population introduction protocols for at-risk Willamette Valley plant species:

Agrostis howellii (Howell's bentgrass)
Aster curtus (white-topped aster),
Aster vialis (wayside aster),
Delphinium leucophaeum (hot rock larkspur),
Delphinium pavonaceaum (peacock larkspur),
Erigeron decumbens var. *decumbens* (Willamette daisy),
Horkelia congesta ssp. *congesta* (shaggy horkelia),
Lomatium bradshawii (Bradshaw's desert parsley),
Lupinus sulphureus ssp. *kincaidii* (Kincaid's lupine),
Montia howellii (Howell's montia),
Sidalcea spp. (Willamette Valley checkermallows)

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Report format:

The following species are presented in alphabetical order: *Agrostis howellii* (Howell's bentgrass), *Aster curtus* (white-topped aster), *Aster vialis* (wayside aster), *Delphinium leucophaeum* (hot rock larkspur), *Delphinium pavonaceaum* (peacock larkspur), *Erigeron decumbens* var. *decumbens* (Willamette daisy), *Horkelia congesta* ssp. *congesta* (shaggy horkelia), *Lomatium bradshawii* (Bradshaw's desert parsley), *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's lupine), *Montia howellii* (Howell's montia), *Sidalcea* sp. (Willamette Valley checkermallows). Each species' section consists of segments covering Conservation Status, Range and Habitat, Species Description, Seed Production, Seed Germination, Vegetative Reproduction, Breeding System, Hybridization, Cultivation, Transplanting and Introduction Attempts, Population Monitoring, and Land Use Threats and other Limitations, followed by a final segment outlining a specific Population Introduction/Augmentation Strategy.

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Developing biogeographically based population introduction protocols for at-risk Willamette Valley plant species:

Erigeron decumbens var. *decumbens* (Willamette daisy)

Erigeron decumbens var. *decumbens* (Willamette daisy)

Conservation status

Long thought extinct, *Erigeron decumbens* var. *decumbens* (Figure 18) was rediscovered in 1980 and is currently known from fewer than 30 small native prairie sites, all occurring in the Willamette Valley of Oregon. This rare daisy is listed as Endangered by both the U.S. Fish and Wildlife Service and the State of Oregon, is on the Oregon Natural Heritage Program List 1 (threatened or endangered throughout its range), and has a Natural Heritage Network Rank of G4T1/S1 (the variety of this species is critically imperiled throughout its range/critically imperiled in Oregon) (ONHP 2001).

Figure 18. *Erigeron decumbens* var. *decumbens*. (Photo by Steven Gisler.)

Widespread loss of native Willamette Valley prairie habitat to agricultural and urban development is the primary threat to *Erigeron decumbens* var. *decumbens*. As with many other rare prairie species treated in this manual, *E. decumbens* var. *decumbens* faces the additional threats of successional encroachment of prairie habitat by trees and shrubs, competition with invasive weeds, and possible inbreeding depression arising from small population sizes (Kagan and Yamamoto 1987, Clark et al. 1993, Federal Register 1998, ONHP 2002).

Range and habitat

Herbarium collections from such notable early botanists as Louis Henderson, Thomas Howell, Morton Peck, James Nelson, Wilhelm Suksdorf, Thomas Nuttal, and J.W. Thompson collectively indicate that *Erigeron decumbens* var. *decumbens* was once fairly common and widely distributed in the wetland and upland prairies of Oregon's Willamette Valley (OSU herbarium records and ONHP 2002). Subsequent to 1934, however, the species was not collected and was believed extinct until it was finally relocated near Eugene, Oregon, in 1980 (Clark et al. 1993). Currently, the Oregon Natural Heritage Program lists historic records for 36 *Erigeron decumbens* var. *decumbens* populations, but currently only 28 of these are believed extant, distributed in Benton, Lane, Linn, and Marion Counties, Oregon (ONHP 2002). Historic populations in Clackamas, Washington and Yamhill Counties have never been relocated.

Habitat for *Erigeron decumbens* var. *decumbens* consists of undeveloped native wetland and upland prairies (Figure 19) at elevations ranging from 235-950 ft (ONHP 2002). Commonly associated prairie species include: *Achillea millefolium*, *Allium amplectens*, *Anthoxanthum odoratum*, *Aster hallii*, *A. curtus*, *Brodiaea hyacinthina*, *Bromus carinatus*, *B. japonicus*, *Carex* spp., *Camassia leichtlinii*, *Crataegus douglasii*, *Danthonia californica*, *Deschampsia caespitosa*, *Elymus glaucus*, *Eriophyllum lanatum*, *Festuca arundinaceae*, *F. roemeri*, *Fragaria virginiana*, *Fraxinus latifolia*, *Grindelia integrifolia*, *Holcus lanatus*, *Juncus* spp., *Lomatium bradshawii*, *Panicum occidentale*, *Poa nevadensis, Potentilla gracilis*, *Prunella vulgaris*, *Quercus garryana*, *Ranunculus occidentalis*, *Rosa* spp., *Saxifraga integrifolia*, *Sidalcea campestris*, and *Spiraea* *douglasii* (Kagan and Yamamoto 1987, Clark et al. 1993, 1995, Federal Register 1998, ONHP 2002).

Figure 19. *Erigeron decumbens* var. *decumbens* is known to occupy both wetland and upland prairie habitats, the latter shown here at Basket Slough NWR. *Erigeron* is present as the whitish-purple flowers in the foreground, among shrubs of poison oak. (Photo by Steven Gisler.)

Description of species

Erigeron decumbens var. *decumbens* is a taprooted perennial, with decumbent stems that are often purplish at the base and 1.5-7 dm tall. Basal leaves and some or most of the cauline leaves are triple-nerved, the basal leaves up to 25 cm long and 1 cm wide, and cauline leaves becoming only gradually reduced above. Flowering heads (Figure 20) typically number from 1-20, with 20-50 purple to pale pink ray flowers (6-12 mm long, 1-2 mm wide), yellow disk corollas (2.5-4.5 mm long), and pappus consisting of 12-16 fragile bristles (Hitchcock *et al*. 1955).

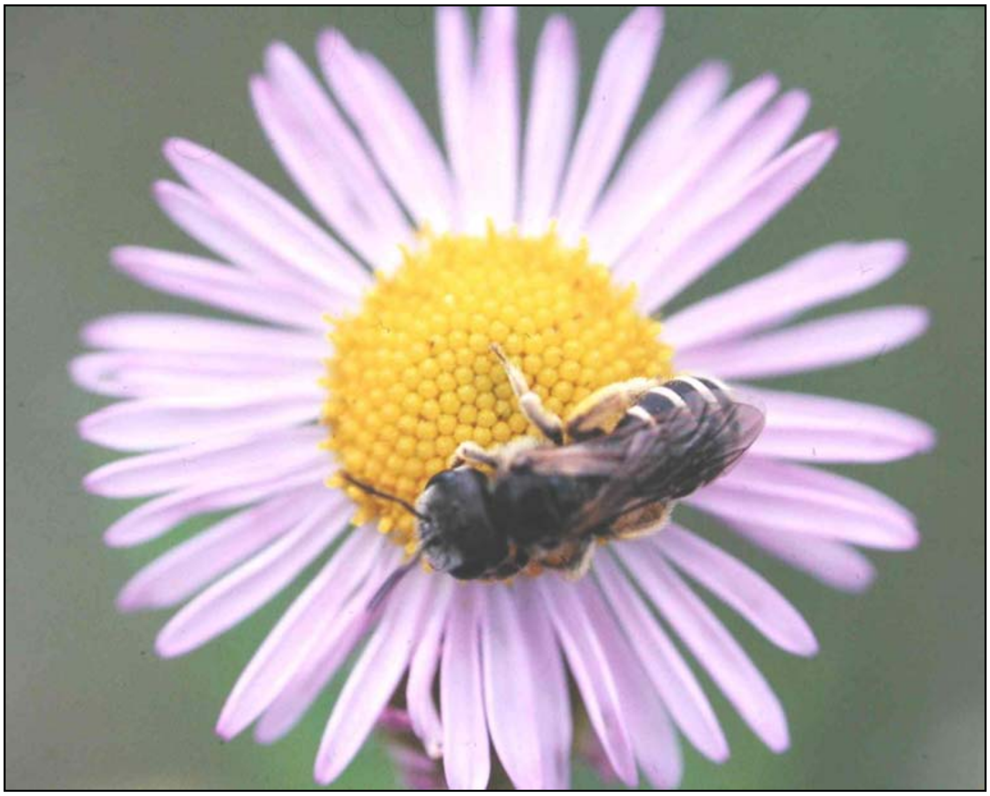

Figure 20. Flowering head of *Erigeron decumbens* var. *decumbens*, exhibiting characteristic purple-tinged ray flowers. Insect visitor appears to be the native solitary bee, *Ashmeadiella* sp.(Megachilidae). (Photo by Steven Gisler.)

According to Kagan and Yamamoto (1987), *Erigeron decumbens* var. *decumbens* is the only pink-purple rayed *Erigeron* that occurs in the grassland habitats of the Willamette Valley, and is further distinguished by its gradually reduced cauline leaves, triple-nerved basal leaves, and decumbent, spreading habit.

Seed production

The earliest documented account of seed production in *Erigeron decumbens* var. *decumbens* is found in the federal status report for the species by Kagan and Yamamoto (1987). Here, the authors cited personal communication with Julie Kierstead of The Berry Botanic Garden, who indicated that most individuals produce 25-50 achenes per flower head. Later work by Clark et al. (1993, 1995a) indicated much higher levels of seed production, ranging from 157-182 achenes per head in three populations in 1993 and

160-220.9 seeds per head in 1994. However, subsequent analysis showed that less than 20 percent of these achenes were "robust," and the remaining 80 percent proved to be "empty or shriveled." Therefore, the mean number of filled seeds per head in three populations ranged only from 3.9-29.8 in 1994 (Clark et al. 1995a). Taking only these seeds into account, the number of seeds per head reported by Clark *et al*. (1993, 1995a) more closely align with those previously documented by Kagan and Yamamoto (1987).

With regard to the low production of filled seeds, Clark et al. (1995a) concluded, "…the small percentage of robust seeds produced means few seeds are available for germination and again emphasizes the need to adjust the number of seeds collected for restoration efforts." This point was poignantly demonstrated by Wilson et al. (2001b), who reported collecting 2,693 seeds in 1999 for cultivation projects, but only 5.7 percent of these seeds proved to be filled (i.e., presumably containing viable embryos). To get a better idea of how many filled seeds might actually be produced within populations (and therefore potentially be available for conservation efforts), Clark *et al*. (1995b) sampled two populations (Bald Hill in Benton County and Fisher Butte in Lane County) in 1994 and estimated filled seed production at 3,000 and 1,500 seeds per square meter of stems at the two sites, respectively.

Seed germination

Seed germination in *Erigeron decumbens* var. *decumbens* has been investigated by several researchers, with differing conclusions about levels of seed viability and optimal methods of breaking seed dormancy.

The earliest reference to seed germination research in *Erigeron decumbens* var. *decumbens* is found in Kagan and Yamamoto (1987), who stated, "some type of cold treatment is apparently necessary [for seed germination]." This conclusion was based upon personal communication with Julie Kierstead of The Berry Botanic Garden, who conducted research into germination of seeds collected in 1984. Kierstead found that no seeds germinated after 60 days without cold stratification, though exposure of seeds to ambient winter temperatures eventually resulted in 33 percent germination in early spring. More rapid germination was achieved by chilling seeds in a refrigerator for one week and then placing them outdoors in soil. This method yielded 22 and 24 percent germination within 2 weeks of sowing, for seeds collected in 1983 and 1984, respectively.

Subsequent research showed that cold stratification can yield even higher levels of seed germination in *Erigeron decumbens* var. *decumbens*. Kaye and Kuykendall (2001) found that germination was essentially zero percent without any cold stratification, but germination increased steadily with duration of stratification, with optimal germination achieved after 12-16 weeks of chilling. Maximum germination was 45-50 percent for seeds originating from two large populations, but was only 17 percent for seeds that came from a small population. Following cold stratification at 5°C, seeds in this study were placed in growth chambers with alternating 15°C/25°C temperatures and a 16 hour photoperiod. Slightly higher germination rates were reported by The Berry Botanic Garden (2002), with 60 percent germination for seeds that were cold stratified for 8 weeks and then placed into 20°C conditions, and 78 percent for cold stratified seeds placed in alternating 10°C/20°C conditions.

An alternative approach to germinating seeds was reported by Clark *et al*. (1995a), who stated, "The germination test showed that pre-treatment cutting or seed coat scarification is essential for promoting germination of *E. decumbens* seeds." Among the variety of seed pre-treatments investigated in Clark's study, maximum seed germination (83.3 percent) was experienced by year-old seeds that were scarified (removal of pericarp and seed coat on the cotyledon end of the seed) and treated with gibberellic acid prior to placement in a germination chamber (15°C dark/30°C light). In contrast, seeds that were cold stratified (4°C for three days) instead of scarified prior to gibberellic acid treatment had 0 percent germination. Among all successful treatments, most germination occurred within one week of seed placement in germination chambers. Seed scarification was also implemented by Wilson *et al*. (2001) to germinate seeds in 2000. Here, seeds were scarified by removing the distal end of their seed coats with razor blades, and then they were planted 3 mm below the surface of moist seedling mix. Resulting germination was 29.1 percent.

The most recent seed germination attempts in *Erigeron decumbens* var. *decumbens* were performed by Lynda Boyer (Heritage Seedlings Inc., Salem, Oregon, personal communication), who reported nearly 100 percent germination by mixing seeds with pre-moistened vermiculite inside sealed plastic bags and cold stratifying the mixture at 1°C for 13 weeks. This seed/vermiculite mixture was then sown into soil-filled flats, lightly covered with a "light dusting of soil," and most germination typically occurred within 7 days of sowing.

In addition to the germination studies that have been performed under controlled conditions, research has also been conducted on levels of seed germination/seedling recruitment under real and/or simulated field conditions. Clark *et al*. (1995a) described sowing seeds (once in early winter and again in late winter) into pots that were filled with soil from a natural population and buried outdoors, in the ground. The results of this study (reported in Clark et al. 1997) showed that although no germination was detected in the early winter pots, in the late winter pots most seeds germinated from mid-April through May, with a mean 33.5 percent seedling establishment by the end of June. These recruitment rates were much higher than those reported by Kaye et al. (2001), who sowed 3000 seeds into field plots at a restoration site near Eugene, Oregon, in November, 1999. Resulting recruitment rates were less than 0.7 percent after one year, with seedling numbers too low to allow statistical comparison between seed plot treatments. Similarly, Wilson et al. (2001) reported less than 2 percent seedling recruitment from seeds sown in burned, mowed, and unmanipulated control plots.

Vegetative reproduction

The earliest reference to vegetative reproduction in *Erigeron decumbens* var. *decumbens* is found in Kagan and Yamamoto (1987), who stated, "The plants have rhizomes and are decumbent; however, no vegetative reproduction has ever been noted in this taxon. All reproduction occurs sexually, through flowers and seeds." All subsequent references to this species, however, indicate that the species is in fact capable of clonal growth. For example, Clark *et al*. (1995a) concluded, "*Erigeron decumbens* var. *decumbens* appears to spread vegetatively, forming large clumps. Generally, seedlings and vegetative sprouts cannot be distinguished in the field." This sentiment was later echoed in the Federal Register (1998), and most recently, Kaye (2000) concluded that the species reproduces by seeds and, "also appears to spread vegetatively over very short distances (<10 cm)."

Breeding system

Erigeron decumbens var. *decumbens* attracts numerous insects that are believed to serve as pollinators for the species. Kagan and Yamamoto (1987) and Federal Register (1998) both stated that a variety of insects have been observed visiting *E. decumbens* var. *decumbens*, including butterflies, solitary bees, bumblebees, flies, and introduced honeybees. More specifically, Clark *et al*. (1993) reported observing four different species of solitary bees (*Ceratina* sp., *Megachile* sp., *Nomada* sp., and *Halictus ligatus*), two beetle species (*Meligethes nigrescens* and *Acanthoscelides pauperculus*), and two flies (*Toxomerus marginata* and *Tachina* sp.). Additional pollinating insects were reported by Jackson (1996), who found the most common floral visitor (46.3 percent of visits) to be the native butterfly, *Phyciodes campestris*. Two species of bees in the family Halictidae accounted for 31.6 percent of visits, and a syrphid fly, *Toxomerous occidentalis*, accounted for 12.4 percent of visits. Remaining visits were performed by 4 unidentified fly species and one unidentified beetle species. Based upon pollinator flight data, Jackson estimated neighborhood area (the area in which random breeding is expected to occur) to range from 36 to 86 square meters. As seen in Figure 20, *Erigeron decumbens* var. *decumbens* is also visited by a solitary bee (*Ashmeadiella* sp.) in the Magachilidae family, adding yet another taxon to the list of potential pollinators of this species.

No information was found for *Erigeron decumbens* var. *decumbens* regarding respective levels of selfing and outcrossing, the degree of self-incompatibility, or levels of seed set in the absence of pollinators. Deborah Clark (Dept. of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon, personal communication), and Thomas Kaye

(Institute for Applied Ecology, Corvallis, Oregon, personal communication), who have experience researching this species, reported having no knowledge of any previous work in these areas. Given the preliminary evidence of low seed production and progeny performance from small source populations compared to larger ones (Kaye et al. 2001), additional information on self-compatibility and inbreeding depression would be valuable for developing future conservation and population management plans.

Hybridization

According to Kagan and Yamamoto (1987), no natural hybrids involving *Erigeron decumbens* var. *decumbens* are known or suspected, and they stated, "there are no similar species which occur within the range of this taxon, so hybridization is not a threat or concern." Similarly, Clark *et al*. (1993) reported,

> "*Erigeron decumbens* var. *decumbens* does not co-occur with any other members of the *Erigeron eatonii* complex. *Erigeron decumbens* var. *robustior* is restricted to northern California, *E. eatonii* var. *plantagineus* occurs in south-central Oregon and northeastern Calfifornia, and *E. eatonii* var. *villosus* grows in central and eastern Oregon. Naturally occurring hybridization is highly unlikely."

Cultivation

Erigeron decumbens var. *decumbens* has been successfully cultivated in the greenhouse from both seeds and vegetative cuttings. The first reference to cultivation attempts in this species is found in Clark *et al*. (1995a), who described propagation trials using two types of vegetative stock: stem cuttings (12-16 cm long) and rhizome cuttings (stems with 1.0-2.5 cm segments of rhizome tissue). Cuttings were dipped in rooting solution (Indole-3-butyric acid) and placed 1-2 cm deep into pots filled with vermiculite. After 11 weeks, surviving cuttings were moved to 10 x 10 cm pots containing sterilized potting soil and field soil, at which time many cuttings had developed extensive root systems. Results of these propagation trials indicated that rhizome cuttings were more successful than stem cuttings; only six percent of stem cuttings survived after 26 weeks, compared to 33 percent survival of rhizome cuttings.

Use of vegetative cuttings in *Erigeron decumbens* var. *decumbens* propagation is also reported in Wilson et al. (2001). Here, 114 rhizome cuttings were collected, transported in coolers from the field to the greenhouse, rinsed with mild bleach solution, and treated with a rooting hormone prior to planting. Cuttings were initially propagated in pots filled with 80 percent perlite, 20 percent peat moss, and a slow-release fertilizer. Pots containing the cuttings were placed inside a misting chamber and watered for 5 seconds every 8 minutes. After 3 months the cuttings were removed from the chamber, transplanted into commercial potting soil, and kept in the greenhouse until subsequent transplanting into field locations. Mortality of cuttings was reportedly high, with only 13.2 percent (15 plants) survival to time of transplanting.

The earliest attempt to cultivate *Erigeron decumbens* var. *decumbens* from seed is described in Clark et al. (1995a). Here, two methods were investigated: germinating seeds in Petri dishes and then transplanting them into pots filled with standard potting mix, and germinating seeds directly in potting mix, to avoid potential seedling damage during transplanting from Petri dishes. Pots for both treatments were placed in growth chambers (15°C/25°C and 12 hour photoperiod) and watered as needed. Neither method yielded successful establishment of seedlings, with most mortality attributed to fungal infection (i.e., damping off).

Fortunately, subsequent attempts to cultivate *Erigeron decumbens* var. *decumbens* from seed have been more successful. Wilson et al. (2001) reported 18.6 percent survival among seedlings that were initially grown in the greenhouse and then moved outside to await later transplanting into field locations. Even higher survival rates were reported by Kaye and Kuykendall (2001). Here, among seedling cohorts ranging in age from 4 to 8 weeks, mean survival in the greenhouse was 50-100 percent, depending on cohort age and seed source. All seedlings were cultivated in a soil mix consisting of one part peat, one part loam and two parts pumice, and plants were watered twice weekly and fertilized once a week using 20:20:20 fertilizer.

The most recent attempts to cultivate *Erigeron decumbens* var. *decumbens* were reported by L. Boyer (personal communication). As described in "Seed germination," above, seeds were mixed with pre-moistened vermiculite and cold stratified (at 1°C) inside sealed plastic bags for 13 weeks. This seed/vermiculite mixture was then sown into flats filled with a planting medium consisting of bark, compost, peat, perlite, and Philip's pre-mix (crabmeal, 3 kinds of lime, micronutrients, Actino-iron, and a wetting agent). Following establishment in flats, seedlings were transplanted into 5 inch x 2 3/8 inch pots. Boyer reported that although seedling establishment and survival were very high (nearly 100 percent), seedlings were nevertheless "not very robust" after 75 days.

Transplanting and introduction attempts

Recent attempts at introducing *Erigeron decumbens* var. *decumbens* to new locations indicate that transplanting of cultivated plants works much better than sowing seeds directly. Kaye et al. (2001) reported less than 0.7 percent seedling recruitment from 3000 seeds sown at a restoration site near Eugene, Oregon, whereas survival of individuals transplanted from the greenhouse ranged from 33 to 71 percent after 6 months. Other data from this study indicated that seedling recruitment was slightly improved by removing vegetation from seed plots prior to sowing, and transplant survival was significantly improved by fertilizer application at the time of planting (71 percent survival for fertilized transplants compared to 55 percent survival without fertilizer). Kaye *et al*. also noted that transplant survival varied in relation to seed source, with only 33 percent survival from one small population compared to 64 and 70 percent survival from two larger populations, respectively.

In another study, Wilson et al. (2001) reported less than 2 percent seedling recruitment from direct sowing of seeds into burned, mowed, and unmanipulated control plots. Cultivated seedlings and larger plants from cuttings were also transplanted into plots, but survival data was not yet available upon submission of this report.

Population monitoring

Population monitoring for *Erigeron decumbens* var. *decumbens* has been undertaken by various individuals and organizations at numerous sites, including The Nature Conservancy's Willow Creek Preserve and Fern Ridge Lake (Kagan and Yamamoto 1987), Baskett Slough National Wildlife Refuge, Bald Hill and Fisher Butte (Clark *et al*. 1995b, Finley and Ingersoll 1995, Finley 1998), and the Eugene BLM's Oxbow West site (Kaye 2000). Monitoring of these populations has generally been carried out in a consistent manner, with the establishment of permanent monitoring plots within which individuals have been censused and/or mapped, and typically measured for number of flowering stems, basal area, and plant height. Plot sizes have ranged from 0.5m x 0.5 m (Finley 1998) to 10m x 10m (Kagan and Yamamoto 1987) to 15m x 40m (Kaye 2000).

Those who have performed population monitoring of *Erigeron decumbens* var. *decumbens* have reported various noteworthy complications related to the biology and life history of the species. For instance, Kagan and Yamamoto (1987) found it difficult to determine survival and mortality between years because of irregular emergence and sporadic flowering from year to year. They suggested that some plants probably lie dormant during some years, as indicated by the sudden appearance of large plants where they were not previously recorded, and the disappearance and later re-emergence of large plants within monitoring plots. In addition, Clark et al. (1993) stated that non-reproductive individuals can be very difficult to find and monitor due to their inconspicuous nature, and that the definition of individuals can be complicated when flowering clumps overlap. These sentiments were echoed by Finley (1998), who stated, "The clonal nature of the plant makes long-term attention to separating the fates of particular individual plants problematic."

Given the problems associated with discerning physiologically distinct individuals due to overlapping clusters of stems, workers have variously defined individuals (for censusing and monitoring purposes) as any stem/stem cluster separated from its nearest neighbor by at least 5 cm (Finley 1998) or 7 cm (Kaye 2000). As a possible means of avoiding the problems of defining individuals, Finley (1998) proposed that monitoring might instead focus only on number of reproductive stems, flower heads, and cover within fixed plots—measurements that would not necessarily rely on the definition and relocation of the same individuals from one year to the next.

Land use threats and other limitations

Like many native species endemic to Willamette Valley prairies, *Erigeron decumbens* var. *decumbens* is threatened by habitat loss due to urban and agricultural development, secondary successional encroachment of habitat by trees and brush, competition with non-native weeds, and small population sizes (Kagan and Yamamoto 1987), Clark *et al*. 1993, Federal Register 1998). According to the Federal Register (1998), habitat loss is occurring at 80 percent of remaining 84 remnants of native prairies occupied by *Erigeron decumbens* var. *decumbens* and another threatened species, *Lupinus sulphureus* ssp. *kincaidii*. Furthermore, it is stated that 24 of the 28 extant *E. decumbens* var. *decumbens* populations occur on private lands and, "without further action, are expected to be lost in the near future."

Although populations occurring on private lands are the most vulnerable to threats of development (state and federal plant protection laws do not apply to private lands), publicly owned populations are not immune from other important limitations to the species. For instance, Clark et al. (1993) identified four populations protected from development on public lands (Willow Creek, Basket Slough NWR, Bald Hill Park, and Fisher Butte RNA), but stated that even these appear to be threatened by the proliferation of non-native weeds and successional encroachment of brush and trees. Likewise, vulnerability arising from small population sizes and inbreeding depression may be a concern for the species, regardless of land ownership, especially among 17 of the 28 remaining sites that are less than 3.4 hectares in size (Federal Register 1998).

Given the predominance of privately owned populations, land ownership represents a serious obstacle to conservation and recovery of *Erigeron decumbens* var. *decumbens*. Efforts should be made to acquire privately owned sites and/or gain the voluntary cooperation of landowners in conserving the species before further habitat loss takes place. Meanwhile, the few remaining populations on public lands should be the focus of intensive management and conservation efforts, serving both as seed sources for off-site cultivation and target sites for re-introduction and population augmentation projects.

Population introduction/augmentation strategy

Based upon the biogeographical data compiled and described above for *Erigeron decumbens* var. *decumbens*, there do not appear to be any insurmountable ecological, life history, anthropogenic, or administrative obstacles to the successful implementation of population introduction and augmentation projects for this rare species. Although many *E. decumbens* var. *decumbens* populations face imminent threats on private lands, and native prairie habitats have been reduced to tiny remnants of their former abundance, there are still some extant *E. decumbens* var. *decumbens* populations occurring on public or otherwise secure landholdings. As such, pending interagency cooperation and funding availability, there should be several good sites available for collection of seeds and/or rhizome cuttings for use in off-site cultivation projects, and open locations should also be available for population augmentation and introduction purposes.

Perhaps the most serious environmental constraint to these much-needed conservation efforts is the proliferation of invasive weeds, which already pose a formidable threat to existing populations and limit the quality and availability of suitable introduction sites. However, while invasive species will continue to pose a challenge to habitat managers, there are still high quality prairie remnants remaining throughout the range of the species that can provide valuable opportunities for *E. decumbens* var. *decumbens* population introduction projects.

The biology and life history of *Erigeron decumbens* var. *decumbens* likewise pose no unavoidable hurdles to successful implementation of population introduction and augmentation projects. Although production of viable seeds is low in this species, seed germination rates among filled seeds generally range between 50-83 percent (when seeds are properly cold stratified and/or manually scarified), and *E. decumbens* var. *decumbens* has been successfully cultivated from both seeds and rhizome cuttings in the greenhouse.

Seed production and germination rates may be lower in some small populations, possibly due to inbreeding depression. The species exhibits no unique propagation or soil symbiont requirements, and seedlings and rhizome cuttings have been reported to experience fast root development (though they have simultaneously been characterized as "not very robust"). Once mature *E. decumbens* var. *decumbens* plugs are obtained through off-site cultivation, they have demonstrated fairly high rates of survival when introduced into the wild, ranging from 33 to 71 percent (the higher survival percentage apparently boosted by fertilizer application at the time of planting). In contrast, population introduction attempts employing direct seed sowing have proven less successful.

Although *Erigeron decumbens* var. *decumbens* lends itself to vegetative propagation in the greenhouse and forms clones in the wild, efforts should be made to maximize the frequency of genetically variable individuals when creating or augmenting populations, because preliminary evidence suggests the possibility of inbreeding depression in this species, and self-incompatibility has not yet been investigated. Therefore, genetically diverse introduction stock should be used whenever possible to elevate seed production and reproductive fitness, and also ostensibly improve the odds of overall introduction success by maximizing the amount of adaptive genetic variability in the population. Interspecific hybridization does not appear to pose a serious concern for *E. decumbens* var. *decumbens*, as there are no closely related, sexually compatible species in its geographic range and habitat type.

Based upon this information, the following step-down procedures are recommended for *Erigeron decumbens* var. *decumbens* population introductions:

1. <u>Select population introduction/augmentation target sites</u>. Several primary factors should be considered when selecting target sites for *Erigeron decumbens* var. *decumbens* population introduction and augmentation projects. First, target sites should obviously contain suitable habitat. However, habitat for *E. decumbens* var. *decumbens* can vary from poorly drained, wet prairie sites, to drier, more

upland prairie habitats. As such, although the habitat descriptions in this manual can be used to provide general habitat suitability guidelines, specific population introduction target sites should ultimately be selected based upon visits to local extant *E. decumbens* var. *decumbens* populations. Such visits should impart a better idea of the kinds of microsites occupied by individuals within their larger prairie habitat type.

Given the ongoing (and expected) decline of *Erigeron decumbens* var. *decumbens* populations on private lands, inventories for suitable population introduction and augmentation sites should be focused strictly to publicly owned (or otherwise secure) lands. Selection and use of sites should be coordinated with pertinent public landowners to ensure administrative protection and management of populations following introductions.

2. <u>Collect *Erigeron decumbens* var. *decumbens* seeds and/or rhizome cuttings for off-site cultivation of introduction stock.</u> Source material for off-site cultivation of *Erigeron decumbens* var. *decumbens* should be collected from the extant population(s) located nearest to the population introduction target sites to minimize undesirable mixing of gene pools and maximize conveyance of potential local adaptations (if such intraspecific variability and adaptations exist). Given low levels of viable seed production documented in *E. decumbens* var. *decumbens*, seed collecting should be planned and implemented well in advance of cultivation projects to ensure adequate time (possibly several consecutive years) for the harvest of sufficient seed supplies. Based upon historic seed production estimates, individual *Erigeron decumbens* var. *decumbens* flowering heads can be expected to produce from 4-50 viable seeds per head, which in turn represent only a small fraction of the total number of unfilled/shriveled achenes that are produced.

   In light of suggestive evidence of inbreeding depression documented in *Erigeron decumbens* var. *decumbens*, and lack of data on levels of self-incompatibility in the species, efforts should be made to collect seeds and/or rhizome cuttings from as large a sample of genetically variable individuals as possible, in an effort to elevate seed production, fitness, and adaptive genetic variability within introduced populations.

3. Cultivate *Erigeron decumbens* var. *decumbens*. *Erigeron decumbens* var. *decumbens* has been successfully cultivated from both seeds and rhizome cuttings. If seeds are used for cultivation of introduction stock, previous studies suggest they should be cold stratified at 5°C for 8-16 weeks, and/or scarified at the pappus end of each achene, to maximize germination rates. Following pre-treatment, seeds should be expected to germinate within 2-11 days, at rates typically ranging between 40-78 percent (though rates apparently can be lower in smaller population suffering from inbreeding depression). Once seeds germinate, seedling survival can be high (50-100 percent) in the greenhouse, though high mortality rates resulting from damping off have been noted by some workers.

   Erigeron decumbens var. *decumbens* can also be cultivated using rhizome fragments. Although extensive studies of these propagation techniques have not been performed, one study indicated 33 percent survival after dipping rhizome fragments in rooting hormone and placing them for 11 weeks in flats filled with vermiculite.

4. Introduce cultivated plugs into the target site(s). *Erigeron decumbens* var. *decumbens* introductions should be performed after the arrival of fall rains, so that soils are moist at the time of planting and plugs have ample opportunity for root system development prior to summer drying. Currently we have no information about the extent to which *Erigeron decumbens* var. *decumbens* may be pollen limited in small patches, or the degree to which the species may be self-incompatible. There is preliminary evidence, however, that inbreeding depression may limit seed production and progeny performance in small populations. As such, when populations are introduced into new sites, they should probably

consist of many individuals planted in large patches to help maximize opportunities for outcrossing. However, this "patch" technique may be at odds with monitoring goals, if the latter are oriented towards tracking individuals over time (since rhizomatous/clonal growth may complicate the identification of closely planted individuals) (see #5, below).

5. Monitor introduced populations.   Introduced *Aster curtus* plugs should be monitored annually to evaluate project success. Given the clonal nature of the species (i.e., asexual expansion via rhizomes), which can seriously complicate the definition of individuals, monitoring should probably be carried out in a way that simply estimates presence or absence, or overall *A. curtus* cover, within sampling plots. Counting the number of individual stems and/or attempting to discriminate individuals should probably only be attempted when introduced populations are very small and introduced plugs are widely spaced so that they can be reliably differentiated over time (though even in these cases stem counting may become infeasible if clones eventually become large and intertwined).

Literature cited

Berry Botanic Garden. 2002. Unpublished spreadsheet of rare plant germination data, provided at Willamette Valley recovery meeting, February, 2002, on file at Oregon Department of Agriculture.

Boyer, Lynda. Restoration Biologist and Native Materials Manager, Heritage Seedlings Inc., 4194 71st Ave. SE, Salem, Oregon, (503) 585-9835, Lboyer@heritageseedlings.com personal communication on April 3, 2003.

Clark, Deborah. Biology Coordinator, Dept of Botany and Plant Pathology, Cordley Hall 2082, Oregon State University, Corvallis, Oregon, 97331, (541) 737-1734), Deborah.clark@oregonstate.edu, personal communication.

Clark, D.L., K.K. Finley, and C.A. Ingersoll. 1993. Status report for *Erigeron decumbens* var. *decumbens*. Unpublished update of previous status report by Kagan and Yamamoto (1987), on file at Oregon Department of Agriculture.

Clark, D.L., K.K. Finley, and C.A. Ingersoll. 1995a. Regeneration biology of *Erigeron decumbens* var. *decumbens*, an endangered plant of the Willamette Valley. Unpublished report on file at Oregon Department of Agriculture.

Clark, D.L., K.K. Finley, and C.A. Ingersoll. 1995b. Demography and reproduction of *Erigeron decumbens* var. *decumbens*, 1993-1994 field studies. Unpublished report on file at Oregon Department of Agriculture.

Clark, D.L., C.A. Ingersoll, and K.K. Finley. 1997. Regeneration of *Erigeron decumbens* var. *decumbens* (Asteraceae), the Willamette daisy. In, Kaye, T.N., A. Liston, R.M. Love, D. Luoma, R.J. Meinke, and M.V. Wilson [editors]. Conservation and management of native plants and fungi. Pp. 41-47. Native Plant Society of Oregon, Corvallis, Oregon.

Finley, K.K. and C. Ingersoll. 1995. 1995 field monitoring of *Erigeron decumbens* var. *decumbens* (the Willamette Daisy), annual report. Unpublished report prepared for U.S. Fish and Wildlife Service.

Finley, K.K. 1998. Field monitoring of *Erigeron decumbens* var. *decumbens* (the Willamette Daisy), final report. Unpublished report prepared for U.S. Fish and Wildlife Service, Portland, Oregon.

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

Jackson, S.A. 1996. Reproductive aspects of *Lomatium bradshawii* and *Erigeron decumbens* of the Willamette Valley, Oregon. Master's thesis, University of Oregon, Eugene, Oregon.

Kagan, J.S. and S. Yamamoto. 1987. Status report for *Erigeron decumbens* var. *decumbens*. Unpublished report prepared by the Oregon Natural Heritage Program.

Kaye, Thomas. Director, Institute for Applied Ecology, 227 SW 6th St., Corvallis, Oregon, 97333, (541) 753-3099, kayet@peak.org, personal communication.

Kaye, T.N. 2000. Population monitoring for proposed experimental habitat manipulation of Willamette daisy, Oxbow West site, West Eugene. 2000 progress report. Prepared by Institute for Applied Ecology for Eugene District BLM.

Kaye, T.N. and K. Kuykendall. 2001. Germination and propagation techniques for restoring rare Pacific Northwest prairie plants. In Reichard, S.H., P.W. Dunwiddie, J.G. Gamon, A.R. Kruckeberg, D.L. Salstrom, editors. Conservation of Washington's Native Plants and Ecosystems. Washington Native Plant Society, Seattle, Washington.

Kaye, T.N., K. Kuykendall, and C. Nelson. 2001. Seeding and transplanting rare Willamette Valley prairie plants for population restoration. Progress report. Prepared by Institute for Applied Ecology for Eugene District BLM and City of Eugene.

Wilson, M.V., S. Leininger, and D.L. Clark. 2001. Promoting and restoring Kincaid's lupine and Willamette Daisy. Unpublished report on file at U.S. Fish and Wildlife Service, Portland, Oregon.