Developing biogeographically based population introduction protocols for at-risk plant species of the interior valleys of southwestern Oregon:

Fritillaria gentneri (Gentner's fritillary)
Limnanthes floccosa ssp. *bellingeriana* (Bellinger's meadowfoam)
Limnanthes floccosa ssp. *grandiflora* (big-flowered wooly meadowfoam)
Limnanthes floccosa ssp. *pumila* (dwarf wooly meadowfoam)
Limnanthes gracilis var. *gracilis* (slender meadowfoam)
Lomatium cookii (Cook's desert parsley)
Perideridia erythrorhiza (red-rooted yampah)
Plagiobothrys hirtus (rough popcorn flower)
Ranunculus austro-oreganus (southern Oregon buttercup)

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The following species are presented in alphabetical order: *Fritillaria gentneri* (Gentner's fritillary), *Limnanthes floccosa* ssp. *bellingeriana* (Bellinger's meadowfoam), *Limnanthes floccosa* ssp. *grandiflora* (big-flowered wooly meadowfoam), *Limnanthes floccosa* ssp. *pumila* (dwarf wooly meadowfoam), *Limnanthes gracilis* var. *gracilis* (slender meadowfoam), *Lomatium cookii* (Cook's desert parsley), *Perideridia erythrorhiza* (red-rooted yampah), *Plagiobothrys hirtus* (rough popcorn flower), and *Ranunculus austro-oreganus* (southern Oregon buttercup). 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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Fritillaria gentneri
(Gentner's fritillary)

Fritillaria gentneri. Photo by B. Tong

Fritillaria gentneri (Gentner's fritillary)

Conservation status

Fritillaria gentneri Gilkey (Gentner's fritillary), a showy red-flowered member of the lily family, was discovered near Jacksonville, Oregon, in the 1940s (Gilkey 1951; Figure 1). This perennial herb arises in early spring from a fleshy bulb, with mature reproductive plants producing a single flowering stalk, and vegetative plants consisting of a single leaf. Like most American species of *Fritillaria*, plants reproduce asexually, through the production and dispersal of rice-grain bulblets which develop on the surface of mature bulbs. As is true for many plant species, *F. gentneri* may be of hybrid origin.

Figure 1. Flowers of *Fritillaria gentneri* exhibit considerable variation in color and form. This one, at a site near Grants Pass, is deeper red, with less petal recurving than forms that occur near Jacksonville. Photo by M. Carr.

Due to habitat losses associated with rapid development in southern Oregon, and competition from exotic weeds, *F. gentneri* is listed as endangered by the Oregon Department of Agriculture (ODA), and the U.S. Fish and Wildlife Service (USFWS). Gentner's fritillary is on the Oregon Natural Heritage Information Center (ORNHIC) List 1 (endangered or threatened throughout its range), and has a Natural Heritage Network Rank of G1/S1 (critically imperiled throughout its range/critically imperiled in Oregon) (ORNHIC 2004). A Recovery Plan, including recommendations for the augmentation of existing populations and the creation of new ones, was issued by USFWS in 2003.

Range and habitat

Scattered occurrences of this rare lily are found throughout the Rogue and Illinois River watersheds in Jackson and Josephine Counties in southwestern Oregon, and a population was recently discovered in northern California (USFWS 2003). Many populations of *Fritillaria gentneri* occur within a 30 mile radius of the Jacksonville Cemetery in Jacksonville Oregon. This area is also the location of most early collections of this species. Most populations of *F. gentneri* are small, often numbering less than a dozen flowering plants, although populations at Pickett Creek, Pilot Rock, and Siskiyou Pass each contain several hundred flowering plants, with many more bulbs producing only vegetative leaves. A total of less than 2000 flowering plants are currently believed to exist throughout the species range, although the sporadic emergence of bulbs, combined with severe herbivory in some sites make accurate surveys difficult. Despite the showiness of *F. gentneri*, populations of this species have only recently been discovered - a 2001 field survey documented 22 new occurrences on lands managed by Medford District Bureau of Land Management (Brock and Callagan 2001).

Habitat for *F. gentneri* is difficult to characterize, as populations of this species occur on 16 habitat types, including woodlands dominated by *Quercus garryana*, moist riparian areas, Douglas fir forests, and serpentine sites. It has been suggested that the current scattered pattern of extant populations may be the result of widespread population losses due to historic land use (i.e. heavy livestock grazing), rather than inherent habitat specificity of *F. gentneri* (Brock 2001). Although suitable habitat for this species may

encompass a very large portion of the landscape, populations are currently most likely to be found in ecotones between forested sites and more open habitat, in open canopied forest or permanent openings in forest, and in large riparian zones with canopy gaps or deciduous tree canopies.

Populations have been grouped into three Recovery Units based on geographic distribution patterns; these units were delineated to provide a framework for maximizing the preservation of ecological and genetic variability within the species (USFWS 2003). (Four Recovery units were originally designated, but are in the process of revision in response to new population discoveries [Andy Robinson, botanist, USFWS, Portland, Oregon, personal communication]). Although the boundaries of these units may change still further as new sites are discovered and research studies are completed, Recovery Units provide guidance on the selection of appropriate genotypes for augmentation or population creation projects, as well as a framework for focusing conservation efforts.

Habitat characterization for *F. gentneri* differs among these zones. In the Grants Pass area (Recovery Unit 2), most populations occur on peridotite soils in the ecotone of forests of mixed species (*Pseudotsuga menziesii*, *Quercus kelloggii*, *Q. garryana*, and *Arbutus menziesii*). In the Jacksonville and Sam's Valley areas (now combined into one Unit), *F. gentneri* populations are generally found near *Quercus garryana* in a very broad range of habitat types. In the Cascade-Siskiyou Monument area (Unit 4), most populations occur in riparian transition zones on clay loam and gravelly clay loam soils at higher elevations than in other Units (Brock 2001).

Throughout the range of the species, populations occur at elevations of 306 -1544 meters (1004 -5064 ft), and are associated with a wide range of trees (*Arbutus menziesii*, *Pinus ponderos*, *Psuedotsuga menziesii*, *Quercus garryana*, and *Quercus kelloggi*), shrubs (*Amelanchier alnifolia*, *Arctostaphylos viscida*, *Cercocarpus betuloides*, *Ceonothus cuneatus*, *Ceonothus velutinus*, *Prunus subcordata*, and *Toxidendron diversiloba*), grasses (*Bromus ciliatus, Festuca californica*, *Festuca idoahoensis*, *Poa sandbergii*, and *Stipa lemmonii*), and herbs (*Astragalus accidens* var. *hendersonii*, *Calochortus tolmiei*,

Cynoglossum grande, *Dodecatheon hendersonii*, *Erythronium hendersonii*, *Fragaria vesca* var. *bracteata*, *Lomatium utriculatum*, *Ranunculus occidentalis,* and *Senecio integrerrimus* (Brock 2001, USFWS 2003).

Description of species

Fritillaria gentneri is a member of the lily family (Liliaceae) with showy, flowers ranging from deep red to maroon. Both flowering and non-flowering individuals occur in most natural populations, with vegetative individuals vastly outnumbering reproductive plants. The single, ovate, entire, basal leaves of non-reproductive *F. gentneri* are virtually identical with co-occurring *Fritillaria* species (*F. recurva* and *F. affinis*), making specific identification of vegetative plants difficult. Basal leaves of these three *Fritillaria* species vary considerably in size, from less than one centimeter in length for leaves produced by small bulblets, to 20 centimeters or more for leaves emerging from large vegetative bulbs (Gisler and Meinke 2002).

Flowering individuals produce single erect flowering stems 50 to 70 centimeters tall (and no basal leaves), with groups of narrow leaves arranged in several whorls around the stems. Like leaves produced by vegetative bulbs, the leaves and stems of flowering plants are glaucous. Flowers vary in color and form, with red to purplish or maroon tepals that may be slightly recurved or campanulate, and are streaked, checkered or mottled with yellow. Flowers of *F. gentneri* can be distinguished from the similar appearing *F. recurva* by the careful observation of several floral characteristics. Flowers of *F. recurva* are narrower, have more distinctly recurved tepals, shorter nectary glands, and a less deeply cleft style than *F. gentneri*, although these characters exhibit some variation within each taxon. Due to morphological variability with *F. gentneri*, it is necessary to examine all of the aforementioned traits together to accurately identify this species.

Both flowering and mature non-flowering individuals produce large numbers of small bulblets that are loosely attached to the parent individual (Pratt and Jefferson-Brown 1997, Gisler and Meinke 2002). These asexually produced bulblets are presumably

genetically identical to the parent plant, and may be the typical means of reproduction for this species.

Seed production

Although plants of *F. gentneri* have been studied intermittently at several sites for at least 20 years, documentation of seed production has largely been anecdotal. Local botanist Frank Callahan reported the collection of fertile seeds (Callahan 1985), and a few pods containing seeds with apparent embryos have been collected twice from the Beekman Woods area in Jacksonville (Bob Schroeder, board member, Jacksonville Woodlands Association, Jacksonville, Oregon, personal communication; Figure 2). *Fritillaria gentneri* was included on the Alpine Garden Society's 2002 Seed List, although the seed source, and current seed availability, were not specified (Alpine Garden Society 2002).

Figure 2. The capsule on the right, on a plant of *Fritillaria gentneri* at the Beekman Ridge site, has fully developed while the upper one (left) aborted before maturing. Photo by B. Schroeder.

Despite these anecdotal reports of pod production, more thorough monitoring studies report low or non-existent reproductive output. Knight (1991) reported flowering, but no fruit production, on nine tagged plants near Jacksonville in 1990 and 1991, and a later study documented no fruit production by 41 flowers at a BLM site near Jacksonville (Knapp 1999). No reproduction was observed during visits to this same site in 2000 and 2001 (Brock and Knapp 2001).

A more recent study also documented variable seed production among populations, and erratic fruit development in response to climatic conditions, resulting in low reproduction in most sites in most years (Amsberry and Meinke 2002). Additionally, this study suggested that most observed seed is probably the result of interspecific fertilization in response to pollination by pollen from the sympatric congeners *F. recurva* or *F. affinis*. Compared with 32 percent of manual interspecific pollinations, less than three percent of congeneric pollinations resulted in fruit production in 2002 (see "Breeding system" below).

Although few pods were produced by *F. gentneri* during the three years of this study, the pods that were produced contained a mean of 87.5 seeds; the number of seeds produced was not significantly affected by pollination treatment. A mean of 17.5 seeds per pod contained embryos, and appeared to be viable; however, the majority of seeds (mean of 70.0) were wispy bits of tissue without apparent embryos. In an earlier study, 20 seeds collected near Sam's Valley also did not contain embryos (Guerrant 1992).

Seed germination

Although the seed of some fritillaries appears to germinate quite easily (Pratt and Jefferson-Brown 1997, King 2001), germination of seed collected from *F. gentneri* has rarely been documented. Attempts to germinate seed at Berry Botanic Garden were not successful (Guerrant 1992), and no reports of germination exist in the available horticultural literature.

In studies at OSU and in Jackson County field sites, nine seeds (out of 378 viable appearing seeds collected from plants of *F. gentneri* as part of the breeding system study discussed above) germinated into unequivocally identified *Fritillaria* seedlings in field and nursery yard plots. And additional ten apparent *Fritillaria* seedlings emerged in field plots, but early mortality made positive identification difficult, and none of the seedlings re-emerged the following year (Amsberry and Meinke unpublished, Amsberry and Meinke 2002).

Studies to identify specific requirements for fritillary germination are planned by ODA's Native Plant Conservation Program for the near future, along with further attempts to create and collect seed of known parentage from selected field sites. However, difficulties in collecting an adequate supply of viable seed of known parentage, combined with potentially poor germination and seedling survival, currently make propagation from seed a poor method for creating transplants of *F. gentneri*.

Vegetative reproduction

Fritillaria gentneri, like the majority of American fritillaries, produces small bulblets resembling rice grains on the surface of mature bulbs (Pratt and Jefferson-Brown 1997, Amsberry and Meinke 2002, Gisler and Meinke 2002, USFWS 2003, Amsberry and Meinke 2004; Figure 3). In natural sites, mature plants of *F. gentneri* are often surrounded by small leaflets emerging from these bulblets.

Figure 3. Mother bulbs can produce dozens of small bulblets (left). Each bulblet is able to produce its own leaf (right). Photos by S. Gisler (left), and R.J. Meinke, (right).

These small plantlets have the ability to increase in size over time (Kaye and Blakeley-Smith 2003), and, under suitable conditions, will eventually develop into large, reproductive plants. Because seed production in *F. gentneri* is low (see "Seed production" above), asexual reproduction through bulblet production is probably the main method of persistence and increase for this species (Knight 1990, Knapp 1999), and genetic studies corroborate speculation that populations are largely clonal (Carey and Jessup 2004). These asexually produced bulblets are presumably genetically identical to their parent plants and provide an opportunity for adapted genotypes to spread quickly into suitable habitat. Additionally, as *F. gentneri* does not generally receive frequent pollinator visits (Donham and Ferguson 2003), the constant manufacture of new bulblets allows plants to continue to reproduce in the absence of the number of pollinators needed to promote sustainable levels of seed production.

As well as contributing to population persistence in natural sites, bulblets can be collected and cultivated (King 2001, Gisler and Meinke 2002). Easily removed from the parent bulb, these subterranean vegetative propagules germinate and grow readily, making them excellent source material for creating transplants. (See "Cultivation" below.)

Breeding system

Hummingbirds and bees are reported to visit *F. gentneri*, although casual observations during the course of the breeding system study discussed above documented few visitors (Amsberry and Meinke 2002). A study looking specifically at pollination of fritillaries in southern Oregon (Donham and Ferguson 2003) also documented fairly low visitation rates, and identified the primary pollinators of *F. gentneri* as hummingbirds, halictid bees and andrenid bees. During this study, hummingbirds were noted visiting Gentner's fritillary on four separate occasions, and *Calypte anna,* (Anna's hummingbird), was photographed visiting *F. gentneri* after having visited *Fritillaria recurva.* A halictid bee, (*Lasioglossum spp*.) covered with pollen was captured inside *F. gentneri*, and andrenid bees visited both *Fritillaria affinis* and *Fritillaria recurva* during the same time period.

In order to insure visitation by hummingbirds, Donham (graduate student, Southern Oregon University, Ashland, Oregon, personal communication) suggested that *F. gentneri* restoration sites should include some plantings of *F. recurva*, a known hummingbird attractant, as well as additional native nectar sources such as *Arctostaphylos* spp. (manzanita). Andrenid and halictid bees (both "miner bees") require pollen for provisioning eggs and larvae in underground nests dug in bare patches of soil. As these bees provision their nests with pollen during the flowering season for fritillaries, they potentially provide considerable pollination services for these species - suitable habitat for "miner bees" should be included in restoration projects.

Donham and Ferguson's studies suggest that interspecific pollen transfer among species of *Fritillaria* may be occurring, and a concurrent study demonstrated that *Fritillaria gentneri* produces more pods in response to interspecific than conspecific pollinations (Amsberry and Meinke 2002). In 2000, 166 flowers of *F. gentneri* were manually pollinated with pollen from four sources: conspecfic pollen from the same flower, from 'near neighbor' flowers (within 50 m of receiving plant), from 'far neighbor' flowers (greater than 50 m from receiving plant, but within the same population), and from flowers from another population. No fruits were produced in response to any of these pollination treatments, although a pod was produced in response to one of only seven pollinations with pollen collected from *F. affinis*. In a 2001 continuation of this study incorporating pollen from *F. recurva* and *F. affini*s, as well as conspecific pollen from several source locations, 291 pollinations also produced no pods, but unusually droughty conditions during pod maturation in that year probably negatively impacted fruit production. In 2002, manual pollination of 248 *F. gentneri* flowers produced 22 fruits. Although 53% of the total pollinations completed were conspecific crosses, only three fruits with presumably "pure" *F. gentneri* seeds were produced. This species appears to experience successful sexual reproduction only sporadically, but more research is needed to identify the cause of infertility, and develop a more thorough understanding of the breeding system of this species.

Hybridization

Hybrids between species of *Fritillaria* are considered to be somewhat uncommon (La Cour 1951, Beck 1953, Pratt and Jefferson-Brown 1997, King 2001), and the potential for hybridization involving *F. gentneri* was not mentioned at the time of its discovery. In the original description of *Fritillaria gentneri* (Gilkey 1951), the author stated that intermediate forms of this species do not occur, and that "the species is remarkably constant in size and color." These statements were reiterated in a later monograph of the genus (Turrill and Sealy 1980) – however, the authors admit to being unfamiliar with the species, and remarked that they had not yet seen any "authentically named" material of *F. gentneri*.

However, "intermediate forms" potentially attributable to hybridization between *F. gentneri* and *F. recurva* have been reported (Mark Mousseaux, botanist, Medford BLM, Medford, Oregon, personal communication, King 2001, Robinett 2005, in review), and putative artificial and natural hybrids between *F. recurva* and *F. affinis* have also been documented and described (Cave 1970, Guerrant 1992, Pratt and Jefferson-Brown 1997, King 2001). Intermediates and hybrids also exist among groups of *Fritillaria* species in Iran and Turkey (Rix 1997, Khaniki 1997), and in China (Zhang et al. 2001). In fritillary populations in southern Oregon, purported intermediates and hybrids exist as a range of forms, with variation occurring in tepal size and color, style length and form, and nectary morphology. Interspecific hybridization has been suggested as the mechanism for the development of *F. gentneri* (Amsberry and Meinke 2002), as well as for the morphologically similar *F. eastwoodiae* from northern California (MacFarlane 1987).

A breeding system study completed in 2000-2002 documented the production of pods and fertile seeds by plants of *F. gentneri* in response to interspecific pollinations (see "Breeding system" section above). However, as little seed is produced in most sites, and seedling recruitment is probably low (Amsberry and Meinke 2002), most plants probably develop from bulblets rather than as a result of sexual reproduction. Plants within a population are generally morphologically similar, with variation occurring among, rather than within, populations (Carey and Jessup 2004), substantiating the hypothesis that most

plants within a population are probably genetically similar. Due to this propensity for reproduction through bulblet increase, the threat of hybridization to the genetic integrity of the species is probably minimal, although further research will be necessary to fully elucidate the enigmatic breeding system of *F. gentneri*.

Cultivation

Cultivation of *F. gentneri* is not difficult, providing that conditions are suitable. Several southern Oregon residents grow plants of this species in their gardens, and Gentner's fritillary is grown ornamentally in Britain (Pratt and Jefferson-Brown 1997, David King, fritillary enthusiast, Sheffield, England, personal communication). Dozens of plants flourish in Jacksonville resident Larry Smith's yard, including a large specimen with 13 flowers; other than protection from herbivory by deer, plants of this species appear to have no special cultural requirements when cultivated within its natural range.

Plants are also relatively easily grown in pots under nursery conditions. Bulbs collected from the Jacksonville area in April 2000 have been in cultivation at OSU for over four years (Brie-anne McKernan, graduate student, Botany and Plant Pathology, Oregon State University, Corvallis, Oregon, personal communication). These bulbs were planted in a potting mix consisting of a 4:1 ratio of Northwest Best © potting mix (a mixture of peat moss, pumice, composted bark, worm casings, and mushroom compost) and clean builder's sand, and placed in the nursery yard. Bulbs thrived and increased for the first year, producing many rice grain bulblets, and one flowering stalk. (Unfortunately, this stalk was destroyed by slugs before maturity.) After 15 months, 285 dormant bulbs were transplanted into larger pots using the same potting mix, and moved to a greenhouse with standard conditions (18º C/21º C). Because plants emerged very poorly after overwintering in the greenhouse, all pots were moved back to the nursery yard. With annual fertilizing with Osmocote © timed release fertilizer, and bi-weekly watering during the late spring and summer, plants have increased in size each year and produced several flowering stalks, although slugs continue to be a problem.

In a later (2002) study at OSU, a total of 3,175 bulblets were collected from 76 reproductive or mature vegetative plants of *F. gentneri* at three populations in southern Oregon (Gisler and Meinke 2002, Amsberry and Meinke 2004). At OSU, bulblets were potted in deep pots in a custom-made potting mix consisting of 25% peat moss, 15% vermiculite, 10% organic mulch, 25% coarse sand, and 25% sandy loam. Six blocks of 80 bulblets each were randomly selected to receive one of a series of six vernalization treatments, including standard and unheated greenhouse conditions, and cultivation under a clear plastic cold-frame in the nursery yard. Bulblets overwintering in the nursery yard emerged most consistently, with leaves developing from 84% of bulblets the following spring (Figure 5). Those in the unheated greenhouse also survived well, with 64% emerging in spring. Bulblets placed in a series of experimentally controlled vernalization treatments emerged poorly, possibly because they suffered from excessive moisture loss. As in the study discussed above, very few of the bulblets grown in standard greenhouse conditions (2.5%) emerged in the spring after transplanting.

The remaining 2,695 bulblets were divided into two groups, with ½ cultivated in an unheated greenhouse, and ½ placed in the nursery yard. Bulblets from two sites (one in Recovery Unit 2, and one in Unit 1) did not differ in emergence under either of these cultivation regimes, but bulblets from the high elevation site at Pilot Rock (in Recovery Unit 4) emerged significantly better in the yard than in the greenhouse. Differing emergence rates under varying conditions may represent genetically based adaptations to local conditions, and indicate that bulbs from separate Recovery Units should not be mixed during transplant projects.

In the nursery yard, bulblets grew well throughout the spring and summer of 2003, entered dormancy in mid-summer, and emerged well again the following spring (2004). Plants were watered as soon as the soil surface dried, and fertilized twice monthly with 20-20-20 liquid fertilizer throughout the growing season. Watering was decreased as plants entered dormancy, with plants watered only when soil became very dry. Although pots were placed under a cold-frame to prevent exposure to excess moisture during their first winter in the yard, this covering was removed during the second winter with no ill

effects. A few bulbs were periodically removed and inspected for fungus infestations; roots and bulbs appeared healthy throughout the cultivation period. Most bulbs increased greatly in size, produced larger leaves in the second growing season, and developed their own new crop of rice grain bulblets. In fall of 2004, 1440 of these bulbs, along with 12,000 new rice grain bulblets, were transplanted into their sites of origin (Amsberry and Meinke unpublished; see "Transplanting and introduction projects" below).

Transplanting and introduction projects

In a 2001 study to evaluate the feasibility of creating populations of *F. gentneri*, 76 (38 reproductive and 38 large vegetative bulbs) mother bulbs were removed from the ground in three sites, and bulblets harvested from the bulb surface (Gisler and Meinke 2002). Immediately after removal from the mother bulb, 600 bulblets were transplanted at 4 or 9 cm depth in their sites of origin, with the remaining bulbs returned to OSU for cultivation studies. The following spring, 16% of transplanted bulblets returned; transplant depth did not affect bulblet emergence.

After bulblet harvest was complete, mother bulbs were also re-planted in their sites of origin. The following spring 84% of these mother bulbs re-emerged, and 52% of emergent plants bloomed, indicating that bulblet removal does not harm mother bulbs.

As a continuation of this study, 1440 large bulbs (that had developed from rice grain bulblets potted in 2002) were transplanted in their sites of origin in fall of 2004 (Figure 4). Twelve thousand new rice grain bulblets that had developed on the surface of these bulbs during cultivation in the nursery yard were also transplanted. Bulbs and bulblets were placed in rows within permanently marked plots for ease of relocation, as diligent monitoring of this large outplanting project will provide data critical to the evaluation of the feasibility of population creation projects for *F. gentneri.*

Figure 4. ODA and BLM staff planting *F. gentneri* bulbs, along with native trees and shrubs, in the Jacksonville Cemetery. Photo by B. Tong.

Population monitoring

Populations of *F. gentneri* have been formally monitored for more than almost 15 years. In 1990, Knight began a monitoring study on BLM land (T38S, R3W, S2) near the Britt Grounds in Jacksonville (Knight 1991). The site was visited five times each season in 1990 and 1991, with data collected on number of flowering stems, stem height, number of flowers, and number of mature and aborted fruits. Knight documented the time of emergence, flowering, and fruiting of *F. gentneri*, observed 100% abortion or herbivory of developing fruits, and suggested the initiation of a monitoring protocol that would include vegetative as well as reproductive plants.

In 1999, a long term monitoring project "to determine rates and modes of reproduction, plant growth rates, mortality rates and sources of mortality" was begun at another

Jacksonville site (T37S, R2W, S31) on BLM land (Knapp 1999). A total of 228 individual reproductive and vegetative plants were marked in 22 plots, and data were collected from this site in mid April and June. Monitoring of this site continued annually through 2002 – the study design was altered in this year due to "idiosyncratic" plant emergence, and difficulties in re-locating plants. Immature plants were unpredictably present or absent, prompting researchers to conclude that the length of time it takes for a plant to reach maturity, and the mortality rates for young plants, could not reliably be established. However, flowering and leaf emergence frequency for mature plants, and population fluctuations and trends, were reliably determined, and the frequency of the progression of plants from the large size vegetative class to the mature flowering class was documented (Siskiyou BioSurvey 2002a).

Beginning in 1998, a series of sites on BLM land were visited by Siskiyou BioSurvey botanists; by 2002, a total of 79 sites were known, with the majority of these monitored each year (Siskiyou BioSurvey 2002b). At a minimum, the number of flowering plants in each site was recorded – data on numbers of vegetative plants, numbers of fruits produced, and numbers of plants in each of three size classes were also collected when possible. Most populations consisted of mixed reproductive and vegetative plants, although only vegetative plants occurred in several subsequent years in some sites. Populations ranged in size from zero (in a given year – at least one plant emerged in a previous or subsequent year) to 306 flowering plants, with a range of zero to 40 small leaves associated of the parent plant (within a one meter radius). A total of three fruits were observed at all sites throughout the study period. (However, as the purpose of this study was the evaluation of population size and viability, visits were timed to allow positive identification of plants during flowering, rather than the later visits required for an accurate determination of levels of seed production.) This study also provided threat assessment and management recommendations for each site visited.

A demographic study of *Fritillaria gentneri* population on BLM land at Pickett Creek (west of Merlin – Unit 2) was initiated by the Institute for Applied Ecology in 2002 (Kaye and Blakeley-Smith 2003). In 2002 and 2003, monitoring was conducted at three

levels of intensity: a flowering plant census for the entire population, a count of reproductive and vegetative plants in nine size classes in 20 randomly selected plots, and an intensive evaluation of all plants (mapping and measuring individuals) in subplots nested within the density plot series. A total of 406 flowering plants were observed in 2003, slightly less than the 424 recorded in 2002. More plants in the two smallest size classes (those with leaves < 1 cm wide, and those with leaves 1-2 cm wide) were reported in density plots for 2003 than were present in 2002, indicating an increase in estimated population size between these two years. Additional data collection is planned for subsequent years, with the goal of developing a transition matrix and population viability analysis model for *Fritillaria gentneri* in this site.

All researchers working on monitoring projects involving *F. gentneri* experienced similar problems regarding the difficulty in determining the specific identification of vegetative plants, and the confounding effect of erratic emergence of leaves from small bulblets. As well as making accurate data collection for research studies problematic, the inability to reliably identify and quantify vegetative population components also has the potential to obfuscate the evaluation of population creation projects.

Monitoring of flowering plants was completed at three Jacksonville sites in 2000-2002 as part of a breeding system study (Amsberry and Meinke 2002). Over the length of the study period, the number of flowering plants present within herbivory resistant study cages increased at one site, decreased at another, and remained unchanged at the third The initiation of flowering, and number of buds produced per plant also varied by site and year, with no one site consistently out producing the others (Amsberry unpublished).

Land use threats and other limitations

Throughout the range of *Fritillaria gentneri*, two of the most daunting threats to populations of this species are loss of habitat, and habitat degradation due to weed infestations. Since 1982, this species has been extirpated from at least eight sites due to road construction, agricultural disturbances, or urban development - these activities continue to threaten currently viable populations (USFWS 2003).

Often as a result of human-mediated disturbance, invasions of exotic weeds, especially *Centaurea solstitalis* (yellow star thistle), occur in several extant sites, including the Jacksonville Cemetery (Siskiyou BioSurvey 2002b, USFWS 2003). Following a fuels reduction project, the area above the Britt Grounds has also become heavily infested with both *Centaurea solstitalis* and *Cytisus scoparius* (Scotch broom). Although weed control measures have been initiated in these two sites, weed-impacted populations here and elsewhere continue to be at risk from competitive exclusion by invasive exotics.

Grazing by deer has also been suggested as a potential threat (USFWS 2003). Flowering plants are heavily browsed by deer in many sites (Siskiyou BioSurvey 2002b, Kaye and Blakely-Smith 2003), although the long term effects of this type of herbivory have not been determined. Additionally, many populations are threatened by disturbance due to off-road vehicle use, trail maintenance, and grazing (Siskiyou BioSurvey 2002b). Historic heavy grazing may have contributed to the current rarity of this species.

Population introduction and augmentation strategy

Based on this information, the following step-down procedures are recommended for *Fritillaria gentneri* population introductions:

1. Select population introduction/augmentation target sites. Inappropriate site selection is the most common cause of rare plant reintroduction failures – care in selecting suitable sites during the initial phases of planning will promote project success. Unfortunately, target sites for the successful creation of populations of *F. gentneri* are not easily characterized. This species occurs on a wide range of soil types and within many types of habitat. As discussed above in "Range and habitat", knowledge regarding habitat characterization of *F. gentneri* within the USFWS Recovery Unit in which a population creation project is scheduled to occur may help direct the optimal choice of location of a target site. *Fritillaria gentneri* often occurs with *F. recurva* – this species may provide some indication that a site is potentially suitable for *F. gentneri*. However, sympatric presence of the two species can complicate monitoring efforts.

As weed infestations can reduce transplant success and decrease population viability, sites with minimal cover of weedy species should be selected if available. Because weed control will often be necessary for populations to become established, selection of sites without serious weed infestations will reduce management costs for the new population.

Although appropriate habitat for *F. gentneri* occurs on private land, and many southern Oregon landowners are interested in the conservation of this species, establishment of rare plant populations on these lands is problematic. Neither naturally occurring nor created populations of listed plants receive administrative protection under state or federal law, creating the potential for erratic or mis-guided management of these sites. As many ecologically appropriate publicly owned sites are available (particularly on lands managed by the Medford District BLM), population creation projects should probably be limited to sites on public land. Selection and use of sites should be coordinated with pertinent public landowners to ensure administrative protection and promote adaptive management of created populations.

2. Collect bulbs/bulblets for off-site cultivation of introduction stock. As discussed above in "Transplanting and population introduction projects" bulblets can be collected from mother bulbs without damage to the donor plants. To insure the identity and viability of donor bulbs, especially in sites where multiple species of *Fritillaria* occur, reproductive plants should be located and tagged during the flowering season (April in lower elevations, and May at high elevation sites in Unit 4). Bulblets should be removed in late summer or early fall, when plants are dormant. (Although winter removal of bulblets has not been attempted, harvest at this time might also be successful.) Bulblets should be placed in plastic bags, transported on ice in coolers, and transplanted to appropriate potting mix as soon as possible.

In general, source material for a population creation project should utilize propagules collected from the extant population located nearest to the target site. As ecological and morphological differentiation among populations of this species has been documented, collection of *F. gentneri* propagules from the site in closest geographic (and/or ecological) proximity to the target site maximizes conveyance of potentially important local adaptations and increases the likelihood of successful population establishment. As this species occurs in three Recovery Units (USFWS 2003), source material for population creation projects within any Unit should be collected from the nearest site within the same Unit. However, as administrative considerations may require the selection of a site outside the current range of the species, combined collections of propagules from multiple sites may be appropriate in these situations.

Populations of *Fritillaria gentneri* probably reproduce largely through asexual bulblet production, and do not exhibit high levels of within population variation. However, to ensure that the genetic variation present in the extant donor population(s) will be represented in the newly created site, bulbs should be collected from as many individuals as possible, located throughout the population. As *F. gentneri* produces abundant bulblets in most sites, and these bulblets grow and reproduce in cultivation, one year of collection should yield an adequate amount of propagules for most population creation projects.

As seed is not reliably produced by *F. gentneri*, and the parentage of open-pollinated seed is difficult to determine, cultivation of transplants from seed is not the first choice for population introduction projects. Although including transplants grown from seed in population creation projects can provide the valuable asset of increased genetic diversity in a new population, further research to establish germination requirements, expected levels of seedling mortality, and length of time needed to produce transplants is needed before propagation from seed can be considered a viable option for population creation projects for *F. gentneri*.

3. Cultivate stock for transplanting. Assuming that bulblets are transplanted promptly, and cultivated properly, *F. gentneri* can be successfully grown from these propagules under standard nursery conditions. Bulblets should be transplanted into deep four inch diameter or larger pots (multiple bulblets can be placed in each pot), with bulblets placed approximately 6 centimeters below the soil surface. Fast-draining commercial potting mix can be used, or a custom mix can be made from 25% peat moss, 15% vermiculite, 10% organic mulch, 25% coarse sand, and 25% sandy loam. Bulblets should be watered immediately after transplanting, with the soil surface subsequently allowed to dry before the next watering. Pots should be over-wintered outdoors, but protected from hard frosts by grouping them together, and surrounding them with sawdust or other insulation. (In climates colder than the Willamette Valley, bulbs should probably be over- wintered in a minimally heated greenhouse or cold frame.) Bulbs can be protected from excess moisture with a cold-frame or other cover, although care must to be taken to insure that pots do not dry completely out. Once leaves begin to emerge (in February), a fertilization regime should be initiated. Bulbs can be fertilized frequently with a liquid fertilizer, or once early in the growing season with a timed release granular fertilizer. Once leaves begin to shrivel and become discolored, (in early summer), fertilizing should be discontinued and watering should be gradually reduced. When bulbs are completely dormant, they should be watered only when soil has become quite dry. As *Fritillaries* do not like repeated disturbance, appropriately sized containers should be selected at the start of the study, and transplanting during cultivation should be avoided.

4. Introduce cultivated bulbs into the target site(s). *Fritillaria gentneri* transplants should be planted in late summer, fall, or early winter, when bulbs are dormant. If plants must be planted during the active growing season, supplemental water should be supplied at the time of transplanting and periodically throughout the growing season. Bulbs should be placed in shallow holes (5-10 cm deep for small bulblets, and 10-15 for large bulbs), with the growing tip facing upwards. Soil

should be carefully backfilled around bulbs, and pressed down lightly. Because monitoring the vegetative leaves of *F. gentneri* can be challenging, transplants should be placed in monitoring plots which allow individual emergent bulblets to be located each year. (see "5. Monitor introduced populations" below).

As removing adjacent vegetation prior to planting generally increases transplant establishment, weeding should be included in the transplant protocol if necessary. Weeds should be removed from target sites before the initiation of transplanting, and a plan for future weed control should be developed. Additionally, in sites with weed infestations, efforts should be made to enhance or re-create a plant community similar to that present in natural sites in which *F. gentneri* occurs. Planting native shrubs, grasses and forbs as part of the reintroduction project will help prevent re-infestation of these sites with aggressive exotics, provide resources for pollinators, and increase the likelihood of project success.

Deer frequently graze plants of *F. gentneri*, particularly the flowering stalks. Temporary fencing of sites for the first few years after transplanting may promote plant establishment, and would increase the accuracy of monitoring efforts, especially in areas where deer are prevalent.

5. Monitor introduced populations. Introduced populations should be monitored annually to evaluate project success. As leaflet emergence from small bulblets can be erratic, several years of monitoring data will be required to determine the success of the population reintroduction project.

   Both vegetative and flowering individuals (which should appear as bulblets mature) should be counted. To promote ease in locating and identifying transplants, bulblets should be placed in a regular array within permanently marked monitoring plots, or individually marked. At a minimum, the presence or absence of an emergent leaf from bulblet should be recorded each year, with leaf and flowering stalk size measurements included if feasible.

6. Develop an adaptive management strategy. Management strategies expected to promote establishment and expansion of created populations should be developed prior to the initiation of population creation projects. Because *F. gentneri* populations can be negatively impacted by weed infestations, management plans for created populations should include recommendations for periodic weed removal. When monitoring data are collected and reviewed each year, these plans should be evaluated, and adapted to meet the needs of the created population.

Literature cited

Alpine Garden Society. 2002. The *Fritillaria* Group Seed List 2002. http://www.fritillaria.org.uk/ms02.htm accessed December 9, 2004.

Amsberry, K., and R.J. Meinke. 2002. Reproductive ecology of *Fritillaria gentneri.* Report submitted to U.S. Fish and Wildlife Service, Portland, Oregon. Native Plant Conservation Program, Oregon Dept. of Agriculture.

Amsberry, K., and R.J. Meinke. 2004. Vegetative reproduction, propagation, and population augmentation for the endangered Gentner's fritillary (*Fritillaria gentneri*). Second year progress report to Bureau of Land Management, Medford District. Native Plant Conservation Program, Oregon Dept. of Agriculture.

Beck, C. 1953. Fritillaries: a gardener's introduction to the genus *Fritillari*a. Faber and Faber Limited, London.

Brock, R. 2001. *Fritillaria* survey and habitat analysis. Report submitted to the Bureau of Land Management, Medford District.

Brock R., and B. Knapp. 2001. *Fritillaria* demographic study plots, Jacksonville Woodland Site. Report submitted to Bureau of Land Management, Medford District.

Brock R., and R. Callagan. 2001. Site review of *Fritillaria gentneri* on BLM land: 2001 report. Report submitted to Bureau of Land Management, Medford District.

Callahan, F. 1985. Some notes on *Fritillaria*. Native Plant Society of Oregon Bulletin.

Cave, M.S. 1970. Chromosomes of the California Liliaceae. University of California Publications in Botany 57:1-48.

Carey, G., and S. Jessup. 2004. Testing the hypothesis that the southern Oregon endemic *Fritillaria gentneri* (Liliaceae) derives from hybridization between *F. affinis* and *F. recurva*. Cost share grant report to Medford District BLM.

Donham. K., and C. Ferguson. 2003. Potential pollinators and insect visitors to threatened and endangered *Fritillaria gentneri* (Liliaceae) and closely related species *Fritillaria affinis* and *Fritillaria recurva*. Page 151 in K.L. Mergenthaler, J.E. Williams, and E.S. Jules, editors. Proceedings of the Second Conference on Klamath-Siskiyou Ecology. Siskiyou Field Institute, Cave Junction, Oregon.

Donham, Kathleen. Student, Southern Oregon University, 1250 Siskiyou Blvd., Ashland, Oregon 97520, (541) 772-5044, Kdonham@prodigy.net, personal communication on April 3, 2003.

Gilkey, H.M. 1951. A new *Fritillaria* from Oregon. Madroño 11:137-141.

Gisler, S.D., and R. Meinke. 2002. Vegetative reproduction, propagation, and population augmentation for the endangered Gentner's fritillary (*Fritillaria gentneri*) First year progress report to Bureau of Land Management, Medford District. Native Plant Conservation Program, Oregon Dept. of Agriculture.

Guerrant, E.O. Jr. 1992. An electrophoretic investigation into the status of *Fritillaria gentneri* (Liliaceae): is it a 'good' species or not? Report to the Oregon Department of Agriculture and the Bureau of Land Management, Medford District.

Kaye, T.N., and M. Blakeley-Smith. 2003. *Fritillaria gentneri* population monitoring at Pickett Creek, Josephine County, Oregon. USDI Bureau of Land Management, Medford District, and Institute for Applied Ecology, Corvallis, Oregon.

Khaniki, G.B. 1997. Karyomorphological studies on *Fritillaria persica*. Phytomorphology 47:27-44.

King, D. 2001. The genus *Fritillaria.* Pages 151-171 in K. McGary, editor, Bulbs of North America. Timber Press and North American Rock Garden Society.

King, David. Fritillary enthusiast, Sheffield, England, davidking42@onetel.com, personal communication on August 13, 2004.

Knapp, B. 1999. Monitoring of *Fritillaria gentneri* at Jacksonville Woodlands. Report to the Bureau of Land Management, Medford District.

Knight, L. 1991. Baseline monitoring of *Fritillaria gentneri*. Report to the Bureau of Land Management, Medford District.

La Cour, L.F. 1951. Heterochromatin and the organisation of nulceloli in plants. Heredity **5**:37-50.

Macfarlane, R.M. 1978. On the taxonomic status of *Fritillaria phaenthera* Estw. (Liliaceae). Madroño 25:93-100.

Mc Kernan, Brie-anne. Graduate student, Department of Botany and Plant Pathology, Cordley Hall 2092, Oregon State University, (541) 737-4220, mckernab@science.oregonstate.edu, personal communication.

Mousseaux, Mark. Botanist, Bureau of Land Management, 3040 Biddle Road, Medford, Oregon, 97504, (541) 618-2200, Mark_Mousseaux@or.blm.gov, personal communication.

Oregon Natural Heritage Information Center. 2004. Rare, threatened and endangered species of Oregon. Oregon Natural Heritage Information Center, Oregon State University, Portland, Oregon.

Pratt, K., and M. Jefferson-Brown. 1997. The gardner's guide to growing fritillaries. Timber Press, Portland.

Rix, E.M. 1997. *Fritillaria* L. (Liliaceae) in Iran. Iranian Journal of Botany 1:75-95.

Robinett, G. 2005. Gentner's Fritillary – rare species or hybrid? Kalmiopsis, in review.

Robinson, Andy. Botanist, U.S. Fish and Wildlife Service, 2600 SE 98th Ave., Suite 100, Portland, Orego 97266, (503)231-6179, Andy_Robinson@r1.fws.gov, personal communication.

Schroeder, B. Board member, Jacksonville Woodlands Association, P.O. Box 1210, Jacksonville, Oregon 97530, (541) 899-1763 schroetr@jeffnet.org , personal communication on January 1, 2002

Siskiyou BioSurvey. 2002a. Demographic study plots, Jacksonville Woodlands site. Report submitted to Bureau of Land Management, Medford District.

Siskiyou BioSurvey. 2002b. Site review of *Fritillaria gentneri* on BLM lands; 2002 report Report submitted to Bureau of Land Management, Medford District.

Turrill, W.B., and J.R. Sealy. 1980. Studies in the genus *Fritillaria* (Liliaceae). Hooker's Icones Plantarum 39:1-280.

U.S. Fish and Wildlife Service. 2003. Recovery plan for *Fritillaria gentneri* (Gentner's fritillary). U.S. Fish and Wildlife Service, Portland, Oregon.

Zhang, L., Y. Zhang, and S. Ji-Zhou. 2001. A taxonmetric analysis of variation patterns of characters of *Fritillaria przewalskii* (Liliaceae). Xibei Zhiwu Xuebao 21:844-856 (abstract only).