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QUANTIFYING LIFE HISTORY PATTERNS FOR MANAGING RARE PLANT POPULATIONS: AN EXAMPLE OF A SERPENTINE SEEP THISTLE

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ABSTRACT

Comprehensive demographic data are essential to the management and conservation of rare species, especially those confined to patchy or fragmented habitats. We tested a series of related hypotheses about the life history of *Cirsium fontinale* var. *campylon*, a rare endemic perennial thistle restricted to serpentine seeps, to identify potential biological and environmental constraints to recruitment. Primary seed dispersal was concentrated within the wetland, while secondary dispersal due to hydrochory resulted in considerable movement of seed to adjacent upland areas or to downstream wetlands during flood events. Effects of seed predation indicated some pre-dispersal loss, presence of the introduced flowerhead weevil *Rhinocyllus conicus*, and considerable post-dispersal predation by mammals. While the majority of seedling recruitment occurred in the wetland, some recruitment occurred in the adjacent upland but was followed by heavy seedling mortality due to moisture stress. These potential limiting factors do not appear to significantly affect population persistence. The large seed rain, high viability, germinability, and probable lack of seed dormancy appear to ensure successful regeneration of *C. fontinale* var. *campylon* as long as suitable habitat exists. Such seed characteristics may be components of a 'cooperative' demographic syndrome that promotes restoration success. Minimizing fragmentation and maintaining high quality of existing serpentine seep habitat will maximize the potential for long-term persistence. Results of this demographic study may be applicable to the conservation and management of two closely related, endangered taxa: *C. fontinale* var. *fontinale* and *C. fontinale* var. *obispoense*; however, the persistence of these taxa in smaller fragments of habitat and threats by invasive species pose particular challenges.

Key words: California, *Cirsium fontinale* var. *campylon*, demography, management, rare plants, recruitment, restoration, serpentine seep, thistle.

INTRODUCTION

Many plant species are confined to naturally patchy habitats and exist in small populations based on response to factors such as topography, geomorphology, soils, climate, and hydrology. Species rarity reflects geographic range, habitat specificity, local population size, or any combination of these factors (Rabinowitz 1981). Restoration of rare plant populations is multi-dimensional and in particular requires an assessment of both habitat factors and demographic characteristics. But while habitat factors tend to be well studied, often less attention is given to population demographics.

Plant demography is fundamental to a basic understanding of both ecological and biological factors that shape population establishment, persistence and distribution, and comprehensive demographic data are essential to the management and conservation of rare species (Lande 1988; Menges 1990; Schemske et al. 1994; Bevill and Louda 1999). Demographic studies can be useful to uncover stages in life history that represent potential limiting factors or bottlenecks to population persistence or recovery. However, a thorough understanding of basic life history stages of rare plants is often the information most lacking in federal recovery plans and is the greatest inhibitor to effective management and conservation of rare plant populations. Demography may be especially important in the dynamics of fragmented species, whether naturally fragmented or as a result of anthropogenic fragmentation.

A basic diagram of major plant life history stages shows that any stage can represent a limiting factor to population persistence, and sequential interactions in life history can be cumulative in their effects, affecting plant population density and subsequent distribution and abundance (Fig. 1). Exploring these potential constraints through research on crucial processes of a closely related, analogous species has been used to guide management of threatened and endangered plants elsewhere (Louda 1994; Maron et al. 2002).

Many rare *Cirsium* Mill. species (Asteraceae) in the United States have been the focus of demographic studies, the majority of which have emphasized seed predation. Results have been mixed but the majority found a significant effect of seed predation, especially pre-dispersal seed predation, on population establishment and persistence (Louda 1982a, 1982b; Louda et al. 1990; Louda and Potvin 1995; Bevill et al. 1999; Russell and Louda 2004). Flower and seed feeding insects have a significant effect where plant regeneration is limited by seed numbers (Fenner and Thompson 2005). *Cirsium canescens* Nutt., for example, a native Nebraskan thistle, exhibited significant pre-dispersal predation by inflorescence-feeding insects, with effects that were magnified in successive life history stages (Louda et al. 1990; Louda and Potvin 1995). Effects of seed predation were compounded by a low germination rate, small seed rain and seed dormancy. Post-dispersal seed predation, however, did not have an obvious overall effect. Results of work on other thistles have been mixed. Insecticidal exclusion of pre-dispersal predators of *Cirsium occidentale* (Nutt.) Jeps. did not result in a significant effect on seed production (Palmisano and Fox 1997), while exclusion of insect predators from the federally threatened *Cirsium pitcheri* (Torr. ex Eaton) Torr. & A.Gray did result in an increase in total estimated seed production (Bevill et al. 1999).

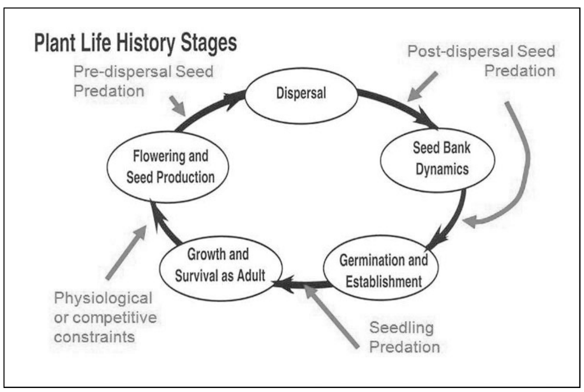

Fig.1. Basic plant life cycle, showing potential limiting factors to population establishment at each life history stage.

Cirsium fontinale (Greene) Jeps. var. *campylon* (H.Sharsm.) Pilz ex D.J.Keil & C.E.Turner (Mt. Hamilton thistle) is a rare endemic thistle restricted to serpentine seeps in Alameda, Santa Clara, and Stanislaus counties, California (List 1B; CNPS Inventory 2001; Fig. 2). This thistle is a short-lived perennial that forms rosettes the first year and typically bolts the second year. While not monocarpic, it has been known to offset after flowering (Pilz 1967; D. Kelch, University and Jepson Herbaria, pers. comm.).

Many North American species of *Cirsium* are narrow endemics and have populations characterized by few individuals (Kelch and Baldwin 2003). The distribution of *C. fontinale* var. *campylon* is extremely narrow due to its restriction not only to serpentine soils, but as an obligate wetland plant limited to seeps, springs, and edges of perennial streams, a classic example of a habitat-limited taxon. *Cirsium fontinale* var. *campylon* is one of three varieties of *C. fontinale*; the other two, *C. fontinale* var. *fontinale* (fountain thistle; San Mateo County) and *C. fontinale* var. *obispoense* J.T.Howell (Chorro Creek bog thistle; western San Luis Obispo County) are federally listed as endangered. All three taxa are characterized by distinctive nodding flower heads and glandular leaves, which separate them from other *Cirsium* taxa in California, and are restricted to serpentine seeps.

Fig. 2. *Cirsium fontinale* var. *campylon* (Mt. Hamilton thistle) is characterized by distinctive nodding flower heads, glandular leaves, and recurved involucral bracts.

In Santa Clara County, *C. fontinale* var. *campylon* is locally abundant in serpentine wetlands in the Diablo Range foothills on the east side of Santa Clara Valley and on the valley's west side in the Santa Cruz Mountains. A series of perennial seeps drain the foothills, and *C. fontinale* var. *campylon* is typically the dominant species in incised narrow canyon drainages surrounded by serpentine grassland, or in wider braided wetlands near the valley floor which intermittently flood (Fig. 3–4).

In order to characterize the early life history stages and identify potential limiting factors to establishment of *C. fontinale* var. *campylon*, we conducted a study of biological and environmental constraints on recruitment. We hypothesized that (1) the majority of primary seed dispersal is concentrated in suitable wetland habitat due to the nodding flower heads characteristic of this taxon; (2) herbivores limit seed production and/or reduce seed abundance after dispersal such that seedling recruitment is reduced;

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(3) natural seedling recruitment is concentrated in the wetland rather than adjacent upland areas; and (4) soil moisture and hydrology limit or define the localized distribution of populations. Through testing this set of hypotheses about *C. fontinale* var. *campylon* demographics, we hoped to facilitate the management and conservation not only of *C. fontinale* var. *campylon*, but also the endangered *C. fontinale* vars. *fontinale* and *obispoense.*

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Fig. 3–4. In Santa Clara County foothills, *Cirsium fontinale* var. *campylon* typically dominates narrow serpentine seeps and wetlands surrounded by serpentine upland grassland.

METHODS

We used standard techniques in a series of experiments at five sites to examine seed dispersal of *C. fontinale* var. *campylon* in wetland and adjacent upland habitat; pre- and post-dispersal seed predation; seedling recruitment in wetland and adjacent upland habitat; and seedling germination under different moisture regimes in wetland and adjacent upland habitat. To examine pre-dispersal seed predation, we randomly bagged inflorescences from different individuals after flowering with mesh cloth; these heads were collected as seeds matured and were examined for viable and unviable seeds, and identified insects present and those that later emerged from seed. Small seed traps erected along transects perpendicular to each seep determined rates of seed dispersal over two dispersal seasons in the wetland and adjacent upland. Seed traps were set out for 10 days each month from June through August in 2005 and every other week in 2006 (May through August). The traps consisted of shallow PVC drain pipe ends lined with hardware cloth and filled with gravel, suspended on wooden stakes approx. 0.5 m from the ground to discourage loss from predation and/or stream flow. Seed trap data (seed rain) were converted into density measurements (number of seeds/m^2) and to number of seeds/day for each sample period. Total seed rain was then calculated in the wetland and upland by summing the number of seeds/m^2 dispersed on each sample date across sites. For periods in-between samples, seed dispersal per day was extrapolated from the previous and subsequent sample period to estimate per-day seed dispersal.

For post-dispersal seed predation, seed exclosure treatments (cages) were used to estimate post-dispersal seed predation and were designed to segregate the impact of vertebrates and invertebrates. Cages contained dishes with sterile potting soil and seeds of *C. fontinale* var. *campylon* placed on the soil surface. A treatment block consisted of a wire screen cage designed to exclude vertebrate predators but not invertebrate predators, a wire frame cage designed to allow both vertebrate and invertebrate predators, and a mesh fabric cage designed for full exclosure and to function as a control. Each randomized treatment block was replicated at each site and set out for 10 days per month in July and August 2005. Average rates of predation were calculated for each site on different dates.

Natural seedling recruitment was assessed in small plots (20 cm × 80 cm) established along transects in the wetland and adjacent upland from winter through mid-summer at each site. Plots were censused weekly or bi-weekly from early December 2005 through late July 2006. At each census date, the number of seedlings was recorded, along with signs of seedling mortality and new germination. Seedling plot data were then converted to seedling density (seedlings/m^2). Seedling response to moisture stress was examined by a seed transplantation experiment in wetland, upland, and boundary zones. Plots were established in each zone along transects at each site. Seeds of *C. fontinale* var. *campylon* were then sown into the plots and covered with a protective wire screen until germination. After germination the seedlings were censused weekly, and after two months the plots were thinned randomly to reduce overcrowding until one seedling remained in each plot. As the spring and summer progressed, seedlings that reached the permanent wilting point were clipped at ground level, dried, and weighed. From areas adjacent to each plot, soil core samples were collected at two depths (2–5 cm deep and 10–15 cm deep), and soil moisture was then determined gravimetrically. Soil moisture samples were taken in January 2006, and then monthly from May through August 2006. For further details, see Hillman (2007).

All data were analyzed with multi-factorial 3- and 4-way ANOVAs using the SPSS statistical package, (SPSS, Inc., Chicago, IL). F-tests were adjusted for non-sphericity using G-G epsilon. Data were log transformed prior to analysis to improve normality.

RESULTS

Putting the study results in the context of a detailed life history diagram illustrates the considerable seed loss of *C. fontinale* var. *campylon* at several early life history stages, from seed dispersal in 2005 to summer 2006 seedling density (Fig. 5). In this diagram, reproductive output is constrained or reduced by potential losses such as pre- and post-dispersal seed predation, disturbance due to flood events, and seedling mortality or thinning. Seedling persistence is represented by end of season surviving recruits.

Patterns of seed production for *C. fontinale* var. *campylon* vary from year to year. In 2005, there was a total overall average rate of pre-dispersal seed predation by insects of 26%. *Rhinocyllus conicus* (Frölich 1792), an introduced flower head feeding weevil (see Discussion for further information), was found in 18% of inflorescences sampled, with an average of 1–2 weevils per head. Primary seed dispersal principally occurred in the wetland seep habitat; total seed rain significantly exceeded 1000 seeds/m^2 in the wetland but only a little over 50 seeds/m^2 in the adjacent upland. Seed dispersal rate peaked at almost 25 seeds/m^2/day in the wetland and just over 1 seed/m^2/day in the upland. Post-dispersal seed predation in 2005 by vertebrate predators such as rodents accounted for a seed loss of over 75%, while insects were not a significant source of post-dispersal predation. Highest seedling recruitment levels also occurred in the wetland. Peak seedling density was almost 200 seedlings/m^2 in the wetland and just over 100 seedlings/m^2 in the upland. Average upland seedling density peaked in late January, while wetland seedling density peaked in late March. Due to occasional floods, seeds were secondarily dispersed (hydrochory) into upland habitat and almost twice as many seedlings recruited in the upland as were initially dispersed, while there was much lower seedling recruitment in the wetland than had been originally dispersed (almost a 40% loss within wetlands). Seedling persistence was greater in the wetland than the upland due to thinning; however, even in the wetland, seedling mortality exceeded 80%. Seedling mortality correlated with soil moisture levels in the wetland and adjacent upland. End of season surviving recruits (summer 2006) was 35 seedlings/m^2 in the wetland. Very few if any seedlings in the upland made it to the first winter rains (the last census date of 27 July 2006 indicated an average of 1.8 seedlings/m^2 in the upland).

DISCUSSION

In this study of *C. fontinale* var. *campylon,* life history stages do not appear to limit population success. *Cirsium fontinale* var. *campylon* lost a considerable number of potential recruits at several life history stages. The large bottlenecks were post-dispersal seed predation (76% loss; Fig. 5), disturbance due to flooding (39% loss), and seedling thinning (82% loss). Despite large losses, however, there appear to be few overall constraints to successful recruitment because of large rates of seed production, comparatively low pre-dispersal seed predation, and targeted seed dispersal. While the end of season surviving recruits represented only 2% of the original reproductive effort, it was still approx. 7 times the adult population density (estimated at 2–5 plants/m^2).

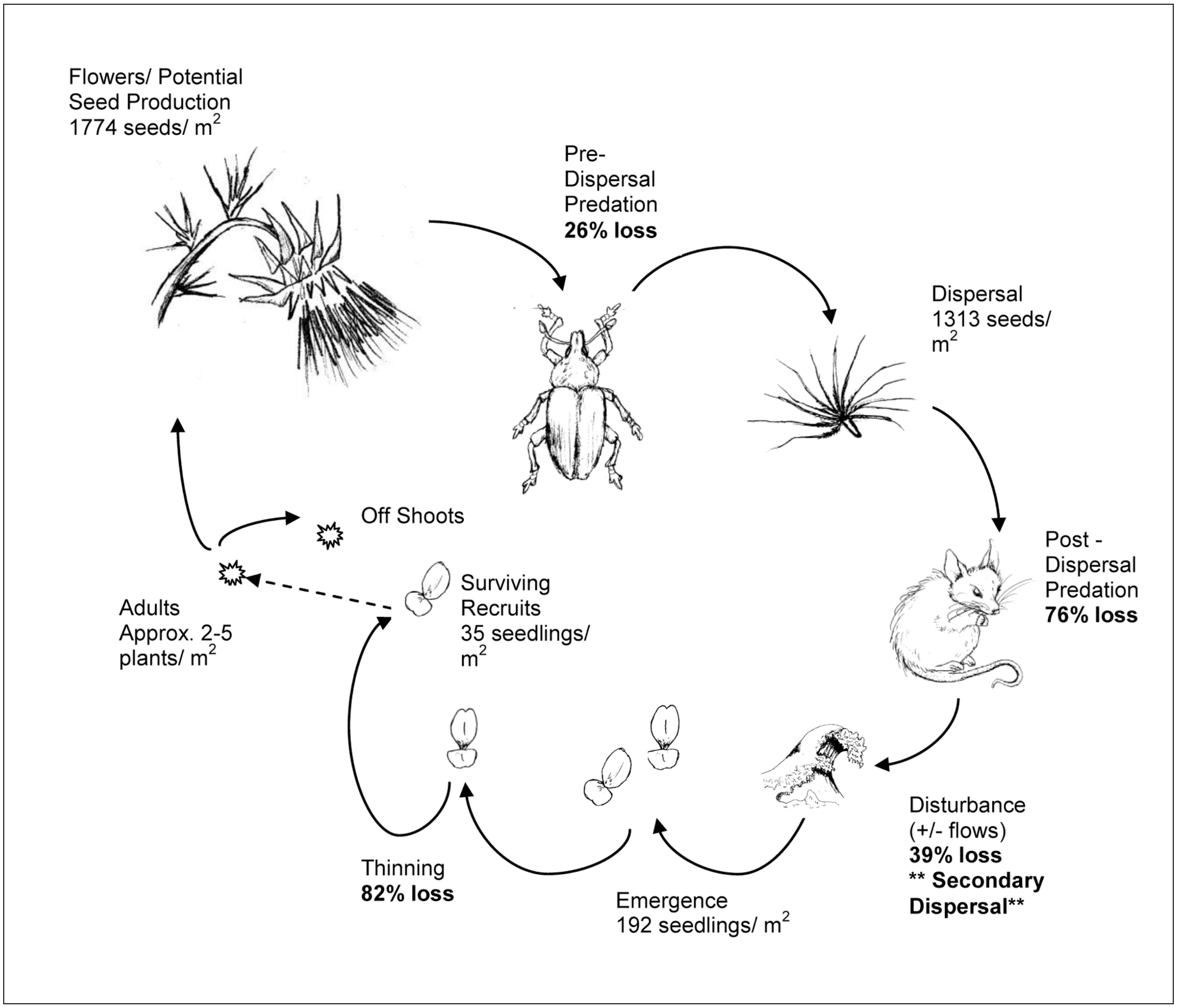

Fig. 5. Seed budget diagram for *Cirsium fontinale* var. *campylon* in wetland habitat from 2005 dispersal (average total seed rain) to 2006 seedling density (July 2006). Flowers/potential seed production represents theoretical reproductive output, while dispersal is average total seed rain for the 2005 primary dispersal season. Emergence represents the highest average seedling density recorded over the recruitment season. End of season surviving recruits are recorded as the last seedling density census in July 2006.

Because this is a habitat-limited taxon, critical adaptations such as nodding flower heads and non-persistent pappus plumes concentrate seed dispersal into suitable wetland habitat. Secondary dispersal by hydrochory can disperse seeds downstream and connect sub-populations along drainages, also facilitating population expansion. A study of *Cirsium vinaceum (*Wooton & Standl.) Wooton & Standl., a threatened thistle endemic to travertine seeps and springs in New Mexico (Craddock and Huenneke 1997), documented substantial aquatic seed dispersal that connected discrete population patches along a stream corridor. Hydrochory, the dispersal of seeds by water, is one of the primary dispersal mechanisms for plants along river corridors (Johansson and Nilsson 1993; Merritt and Wohl 2002; Jansson et al. 2005). This secondary dispersal of *C. fontinale* var. *campylon* can be seen as a source-sink dynamic, because while hydrochory moves seeds downstream to suitable habitat, it also moves them laterally into adjacent upland grassland habitat which is unsuitable since the seedlings experience mortality as flood waters recede and the upland dries. Still, in spite of the potential sink effect, secondary dispersal by water could be an important dispersal mechanism for wetland-obligate *Cirsium* taxa.

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The discovery of *Rhinocyllus conicus* in flower heads of *C. fontinale* var. *campylon* is of special interest and potential concern. First introduced in North America in the late 1960's for biological control of weedy naturalized thistles such as *Carduus* L. and *Silybum* Adans., *R. conicus* has also been found to feed on *Cirsium* (Turner et al. 1987; Herr 2000). Herr (2000) recovered *R. conicus* from rare *Cirsium* taxa in California, and found that for one taxon studied in more detail (*Cirsium hydrophilum* (Greene) Jeps. var. *vaseyi* (A.Gray) J.T.Howell) there was a predation rate of 27.4%. However, he noted that while there may be heavy seed predation early in the season, California endemic thistles typically bloom longer than the oviposition period of the weevil and thus overall, season-wide seed predation is lower (J. Herr, ARS-USDA, pers. comm.). He concluded that there was a lack of a significant effect on overall population recruitment and establishment due to lack of phenological synchronicity with oviposition pattern. In contrast, weevil density and subsequent seed reduction has been documented in other thistles that do have phenological synchrony of plant flowering with weevil oviposition period, resulting in seed loss as high as 85.9% (Louda et al. 1997; Louda 1998; Headrick and Oishi 1999; Russell and Louda 2004). The relatively low pre-dispersal predation rates in California endemic thistles such as *C. hydrophilum* var. *vaseyi* and *C. fontinale* var. *campylon* are in marked contrast to those of thistles studied in other parts of the United States.

Other biological factors also are unlikely to be limiting populations of *C. fontinale* var. *campylon*. This species has high seed viability and a high germination rate (98% and 91%, respectively) and no apparent seed dormancy. This taxon is not seed limited, in contrast to other *Cirsium* species studied, such as *C. canescens*, which exhibited a high pre-dispersal seed predation rate, small seed rain, low germination rate, and seed dormancy (Louda et al. 1990; Louda and Potvin 1995). The primary restriction for *C. fontinale* var. *campylon* is habitat availability. It is confined to spatially fragmented serpentine wetlands and fits a classical definition of rarity (Rabinowitz 1981). *Cirsium fontinale* var. *campylon* has a small geographic range (restricted to three counties in the general San Francisco Bay Area); a narrow habitat specificity (as an edaphic endemic restricted to wetlands on serpentine); and large localized populations (sub-populations along a portion of a drainage can typically contain several thousand individuals or more in a healthy population).

Seasonal environmental variation may emphasize the habitat restriction. This study area was conducted in a high-rainfall year (43.4 cm for the 2004–2005 season and 60.5 cm for the 2005–2006 season). These wetlands are a dynamic system constrained by habitat limitations. For example, while we did not collect data during the 2008–2009 season, no rainfall events were sufficiently large to cause the flooding disturbances seen in the earlier year. In wet years, seedlings are more likely to persist while in the dry years, recruitment should be further limited; but variation in flooding disturbances complicates these simple interpretations. This is because small shifts in important bottlenecks can result in large increases in mortality or survival. For example, if the pre-dispersal predation rate were tripled to a rate of predation documented in other thistles (Louda et al. 1997; Louda 1998; Headrick and Oishi 1999; Russell and Louda 2004), overall surviving recruits in this study would drop by 80% even if all the rates at other stages were the same. Similarly, using our survival rates for each life history stage, surviving recruits would drop by 50% or 75% if mortality rates for establishing seedlings were to increase, such as during a dry year, by only 10% or 14%, respectively.

Is *C. fontinale* var. *campylon* a model for other related taxa? While research on crucial processes of a closely related species has been used to guide recommendations for increasing recruitment and persistence in populations of endangered plants elsewhere (Louda 1994; Maron et al. 2002), an assumption of similar demographic patterns between rare and more common taxa may not always be appropriate or accurate (Fiedler 1987; Byers and Meagher 1997). *Cirsium fontinale* var. *fontinale* is restricted to approx. five occurrences and less than 3500 plants in San Mateo County, while *C. fontinale* var. *obispoense* is restricted to approx. thirteen occurrences and 11,000 plants in San Luis Obispo County (California Natural Diversity Database 2006). All three taxa share similar habitat specificity, confined to serpentine seeps and streams below 750 m. All three are characterized by distinctive nodding flower heads and glandular leaves, and belong to a California endemic clade of *Cirsium* determined through phylogenetic analysis (Kelch and Baldwin 2003). However, the key issue is why *C. fontinale* var. *campylon* is not limited compared to the other two critically rare taxa.

Lack of available suitable habitat and threats from invasive species appear to be the greatest limiting factors to persistence of *C. fontinale* var. *fontinale* and *C. fontinale* var. *obispoense*. In Santa Clara County, which has a total area of 3377 km^2 and the

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majority of occurrences of *C. fontinale* var. *campylon*, approx. 142 km^2 are mapped as serpentine soils and serpentine geology (ICF Jones & Stokes 2009). Of that area, only approx. 0.13 km^2, or 0.01%, is comprised of serpentine seeps. Primary habitat modeled for *C. fontinale* var. *campylon* in the draft Santa Clara Valley Habitat Plan comprised approx. 2.3 km^2 or 0.6% of the total serpentine area (primary habitat was defined as serpentine seeps, or serpentine soils or grasslands within 8 m of riverine habitat; ICF Jones & Stokes 2009). Summary calculations of serpentine soils by Arthur Kruckeberg (1984) indicated approx. 93.2 km^2 in the Santa Clara area, 40.9 km^2 in the San Luis Obispo area, and 0.8 km^2 in the San Mateo area. As is indicated by the Santa Clara County example above, only a very small subset of the total area of serpentine soils contains suitable hydrology for wetland obligate serpentine taxa such as *Cirsium fontinale*.

These limiting factors coupled with additional threats posed by road construction and maintenance, recreational development, destruction or fragmentation of habitat, alteration of hydrologic regime, and cattle trampling, led to these taxa being considered as highly endangered (Federal Register 1994, 1995; USFWS 1998a,b; California Natural Diversity Database 2006). Such threats are similar for populations of *C. fontinale* var. *campylon*; however, more high-quality serpentine seep habitat exists and the threat of invasive species such as *Cortaderia selloana* (Schult. & Schult.f.) Asch. & Graebn. (pampas grass) is lower. *Cirsium fontinale* vars. *fontinale* and *obispoense* occur in smaller habitat fragments with less total available habitat. They are geographically isolated, occurring in a more northerly and southerly coastal locale, while *C. fontinale* var. *campylon* is restricted to a more arid interior (Sharsmith 1939; Pilz 1967). In effect, practitioners should be cautious of model taxa and analogous comparisons, which may not always be appropriate or accurate, when making critical management decisions.

CONCLUSIONS

In this study, we tested a set of related hypotheses about life history characteristics of *C. fontinale* var. *campylon* to identify biological and environmental constraints on recruitment. Primary seed dispersal of *C. fontinale* var. *campylon* is highly restricted to local wetland habitats in which the population is found. In addition, secondary seed dispersal by water (hydrochory) amplified recruitment levels in seasonally flooded areas of the adjacent upland grassland. Hydrochory is likely beneficial in the dispersal of seeds downstream but potentially detrimental in the movement of seeds laterally into unsuitable upland habitat. Herbivores did limit seed production and abundance after dispersal; pre-dispersal seed predation was 26% and post-dispersal seed predation by mammals was 76% in this study. Potential effects of the introduced flowerhead weevil *Rhinocyllus conicus* on seed production should continue to be closely monitored but currently do not appear to pose a significant constraint on overall recruitment. The majority of seedling recruitment occurred in the wetland; however, a surprising amount of recruitment was also documented in adjacent upland habitat in seasonally flooded areas. By the end of the season in July 2006, the majority of seedling recruits in the upland had experienced mortality, indicating a source-sink dynamic. Finally, seedling mortality was correlated with soil moisture levels in the wetland and adjacent upland, indicating that *C. fontinale* var. *campylon* populations are limited by soil moisture and hydrology.

Comparison of the present study results with demographic studies of other *Cirsium* species referenced in this paper indicates some variation in the effects or importance of limiting factors such as seed germination, viability, pre- and post-dispersal seed predation, and recruitment on population establishment and persistence. In this study, an examination of early life history stages to uncover potential limiting factors for persistence of populations of this rare endemic taxon revealed that in spite of significant pre- and post-dispersal seed predation and seedling loss due to thinning after emergence, the small fraction of the original reproductive effort that does survive appears to be sufficient to ensure population viability. The concentrated primary dispersal of seeds into suitable wetland habitat, coupled with high viability, germinability and probable lack of seed dormancy, ensures a high chance of successful regeneration as long as suitable habitat exists.

Using demographic patterns of *C. fontinale* var. *campylon* as a model for closely related, endangered taxa may not be appropriate, although there are some similarities among all three varieties of *C. fontinale*. While *C. fontinale* var. *campylon* appears to successfully exploit its habitat and effectively occupy its available niche, the other two taxa are critically rare and occur in much smaller, isolated habitat fragments. However, there are restoration actions that can benefit all three taxa. We can work to (1) minimize the fragmentation of existing habitat—

serpentine seeps are naturally fragmented and we need to preserve the remaining suitable habitat; (2) conserve and manage existing hydrologic connections—this includes entire drainages and spring systems; (3) manage hydrologic processes and systems to benefit thistle populations and encourage recruitment—if new roads or construction is planned, we can incorporate culverts into the design to allow dispersal of seeds by hydrochory and keep sub-populations connected; (4) experimentally exclude livestock from wetlands to examine potential negative effects—serpentine grasslands benefit from grazing to reduce thatch and non-native grass cover, but livestock in wetlands negatively impact thistle populations due to trampling, grazing, and water quality issues; (5) remove non-native invasive species where thistle populations are threatened; and (6) we can continue to monitor for the potential negative effects of the introduced flower head weevil *R. conicus*.

From a conservation management perspective, minimizing the fragmentation of existing habitat and ensuring a continued high quality, health, and functionality of habitat is probably the best management tool for long-term persistence of *C. fontinale* var. *campylon*. Although local populations are abundant and do not appear to exhibit any significant constraints or bottlenecks to population persistence at this time, the narrow endemism of this taxon and its restriction to serpentine seeps serve as the greatest limiting factors to population distribution and geographic range and will ensure its continued rarity.

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