DEMOGRAPHIC MONITORING OF *PRIMULA ALCALINA* (ALKALI PRIMROSE): 1991 - 1994

by

Robert K. Moseley
Conservation Data Center

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Idaho Department of Fish and Game
600 South Walnut, P.O. Box 25
Boise, Idaho 83707
Jerry M. Conley, Director

Salmon District, Bureau of Land Management
Idaho Department of Fish and Game

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ABSTRACT

Primula alcalina (alkali primrose) is endemic to meadows at the headwaters of three spring-fed creeks in east-central Idaho. It is considered extirpated from one site in Montana. Following a conservation status survey, a demographic monitoring program was deemed appropriate to provide pertinent population data for habitat management plan development. During 1991, 155 permanently marked plots were established a eight sampling sites throughout the range of alkali primrose. Plots were read twice a year: at anthesis in late May or early June, when the plants were classified into life stages, and again during the summer following fruit maturation, to measure fruit production. The plots were read through August 1994. Plot loss was high through the monitoring period. Ninety-seven plots remained in late 1994 that yielded density, demography, and fecundity data. The coordinate system used in this study could not accurately track individuals from year to year in dense parts of the populations. Because of this, only 81 plots were used to calculate life stage transitions used in the population model, representing the low- to medium-density portions of the population; the model does not necessarily represent what is presumably the most vigorous part of the species distribution.

Demography data indicate that the populations are vigorous in terms of density, population structure, and fecundity. The population modeling projects an overall population decline at all sites over the next five years, although the modeling results should be viewed with skepticism because they only accurately represent the lowest-density portion of alkali primrose distribution. Based on data presented here and in other studies, cattle grazing appears not to be detrimental to alkali primrose habitat. There may, however, be long-term viability concerns due to heavy cattle grazing and its effect on alkali primrose reproduction. This study focused intensively on a single species. Cattle grazing, especially of high intensity, has an impact on other aspects of ecosystem composition, structure, and function of both terrestrial and aquatic communities. These impacts need to be assessed in light of the unique wetlands inhabited by alkali primrose. I recommend that the demographic monitoring plots be maintained and used to collect vegetation and population density and structure data in the future.

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INTRODUCTION

The primary goal of most rare plant management is the maintenance of viable populations, yet the management of natural communities containing rare plant populations poses several basic questions for land managers: Are current land management practices adequate to maintain the community or the species? What effect will specific management activities have on the rare plant on a site? What is necessary to ensure the survival of a species? Most of these questions cannot be answered by casual observation and, therefore, some level of monitoring is needed (Sutter 1986). In its simplest form, monitoring may entail periodic estimates of population size. This level of information, however, may not provide enough information to make management decisions and a deeper understanding of population dynamics is needed (Lesica 1987).

Environmental, demographic, and genetic stochasticity are major causes of extinction in habitats specifically managed to protect rare plant populations. Of these three, managers can use demographic information to predict plant population dynamics without necessarily knowing or conducting expensive studies on the environmental and genetic mechanisms (Menges 1986). In fact, demographic factors affecting population dynamics are considered a more immediate concern than population genetics in determining minimum viable populations (Lande 1988).

Demography is the study of population changes and their causes through the life cycle of a plant. Population attributes such as birth and death rates, growth, size, density and distribution are some of the characteristics measured. Demographic studies of plants have indicated that each population possesses attributes that determine local abundance and/or persistence through time. A thorough analysis of these attributes is of primary importance in the management of rare and endangered plant populations, simply because abundance and persistence are at the center of all conservation efforts (Pavlik and Barbour 1988). Demographic monitoring studies can help determine factors that control the abundance and distribution of a species and can generate data useful in predicting the future size and age structure of a population.

Although more costly than simple inventories, demographic studies and related monitoring methods provide managers with a vastly superior understanding of a species life history and greater ability to predict population trends (Larkin and Salzar 1992). In conservation management for instance, it is necessary to determine the greatest threats to a species' survival. Demographic stochasticity causes population fluctuations and is an important threat to extinction when populations are very small. Since most rare plants occur in small populations, we should assume that demographic variation is a formidable threat (Larkin and Salzar 1992).

Demographic monitoring of rare species has become increasingly important as the efforts of natural resource agencies has evolved from an emphasis on the inventory and status determination of rare species to active protection efforts. Such is the case of *Primula alcalina* (alkali primrose; Cholewa and Henderson 1984). A status survey was conducted in 1988 by the Conservation Data Center (Moseley 1989), which found that extant populations were restricted geographically to the headwaters of three spring-fed creeks in east-central Idaho. One population is known to be extirpated.
Alkali primrose is currently a category 2 candidate for federal listing (U.S. Fish and Wildlife Service 1993), but is recommended for category 1 status when the next Federal Register list is published (Idaho Native Plant Society 1994; Conservation Data Center 1994). It is also a Forest Service Region 4 Sensitive Species and an Idaho BLM Special Status Species (Conservation Data Center 1994).

In my status survey report (Moseley 1989), I recommended that population monitoring was necessary to allow land management agencies to make informed decisions regarding the maintenance of alkali primrose. In 1991, Patricia Muir of Oregon State University was funded by the Salmon BLM to design and establish such a demographic monitoring program. She established and read the plots in June 1991 (Muir 1992), but was not interested in continuing the field monitoring. During the summer of 1991, the BLM asked the Idaho Conservation Data Center to continue the monitoring. Having never seen a study plan for the project, I'm not sure of the specific objectives, but the BLM funded the CDC to do the following:

1. Continue collecting demographic information on *Primula alcalina* from permanent plots, twice yearly, from September 1991, through August 1994;

2. Summarize population structure and fecundity data for alkali primrose from the four-year monitoring period; and

3. Construct a stage-structured demographic model of population dynamics for use in development of a Conservation Strategy.

LIFE HISTORY AND MORPHOLOGY OF ALKALI PRIMROSE

Alkali primrose is a scapose perennial forb emanating from fibrous roots. The basal rosette of light green, wavy-margined leaves ranges from 2- to 8-cm in diameter. A single, naked scape originates from the center of the rosette and is from 6- to 24-cm tall. The terminal inflorescence is comprised of from 2 to as many as 15 flowers, although 3 to 10 is the typical range. The flowers occur on short pedicels making for a compact inflorescence at anthesis. As fruits mature, however, the pedicels elongate greatly, to as much as 3 to 4 times its length at anthesis. Alkali primrose is a diploid, distylous obligate outcrosser that does not reproduce vegetatively (Cholewa and Henderson 1984; Moseley 1989; Kelso 1991; Muir and Moseley 1994).

Alkali primrose begins growth very early in the season, before or immediately after snow-melt. This probably occurs sometime in April, but may begin during May under cooler weather patterns. Growth is probably slow at first, but flowering usually occurs by late May, again varying from year to year depending on weather patterns. Most plants are in fruit by the end of June. Fruits mature rather quickly and seeds disperse by mid- to late July. Leaves stay green throughout the growing season. The onset of dormancy takes place in the fall, probably late September or October.

STUDY AREA

Extant populations of alkali primrose occur in wet alkaline meadows along the headwaters of three spring-fed creeks that run through broad, high-elevation (ca. 6500 feet) intermontane valleys in east-central Idaho. The climate is generally cool through most of the year (average annual temperature approximately 32°F), and annual precipitation is low (18-20 cm), with 30-40% falling between May and July. Soils in these meadows are alluvial, alkaline (mean pH on study sites = 8.9-9.6), fine-textured, and derived from outwash from the predominantly calcareous Beaverhead, Lemhi, and Lost River ranges. While alkali primrose occurs on creek margins, the habitat is fairly stable hydrologically, as the creeks are entirely spring fed and generally experience only minor seasonal or annual fluctuations in flows (Keller and

Burnham 1982). Thus, water flows are relatively constant and there is little channel scouring. Alkali primrose appears to be restricted to microhabitats where the soil is saturated to the surface by subirrigation throughout the growing season. It does not grow in standing water, however. Individuals occur on low, relatively level benches immediately adjacent to creeks and spring heads, often on the inside of meander loops, and also on low benches with biscuit-and-swale topography, where they are found only on the tops and sides of hummocks [see Moseley (1989); Muir (1992); and Muir and Moseley (1994) for further discussion of the study area].

Sagebrush-steppe vegetation in the *Artemisia tridentata* ssp. *wyomingensis*, *A. arbuscula*, and *A. nova* habitat types series (Hironaka *et al*. 1983) occurs on the surrounding uplands. Vegetation on benches and hummocks supporting alkali primrose is dominated by *Carex scirpoidea*, *C. simulata*, *Juncus balticus*, and *Eleocharis pauciflora*. Associated forbs are diverse, but not dominant, and often include *Dodecatheon pulchellum*, and *Triglochin maritimum*. Hummocks are often shared with shrubs, including several *Salix* species, *Betula glandulosa*, and *Potentilla fruticosa* (Muir and Moseley 1994).

STUDY SITES

We sampled alkali primrose stands from throughout habitat at the three population centers, described as follows (Muir and Moseley 1994):

SUMMIT CREEK

The Summit Creek population complex lies in the Little Lost River Valley, between the Lemhi and Lost River ranges in Custer County. Three areas of the Summit Creek complex were sampled:

> (1) Summit Creek Exclosure is a 93-ha portion of upper Summit Creek that is designated as a Research Natural Area/Area of Critical Environmental Concern (RNA/ACEC) by the Salmon District of the BLM (U.S. Bureau of Land Management 1987). Alkali primrose occurs on small terraces and hummocky areas in a relatively narrow zone immediately adjacent to the creek. Sampling was within the livestock exclosure, established in 1975 (Keller and Burnham 1982; Thomas 1986). Fencing around the exclosure was supposed to only allow access to native ungulates, such as pronghorn antelope. In my experience of over a decade of observation, cattle invariably breach the exclosure fence (annually?) and graze within the primrose population, sometimes heavily. Due its proximity to the campground (see below), there is considerable foot traffic along the banks of the creek from anglers. This trampling occurs throughout the sampled area at Summit Creek Exclosure.
>
> (2) Summit Creek Campground is also within the exclosure and RNA/ACEC, immediately downstream from the Summit Creek Exclosure sampling area, from which it is separated by a road. Similar to the exclosure site, alkali primrose occurs on low terraces adjacent to the creek. The site includes several primitive campsites maintained by the BLM. Most of the sampling areas are heavily trampled by anglers and campers, and occasionally by trespass cows.
>
> (3) Moffett Creek begins about 1 mile southeast of Summit Creek Campground and is also managed by the BLM. The drier portions of the Moffett Creek sampling area are heavily grazed by cattle during the summer. Alkali primrose was spread over a wet meadow through which numerous spring-fed small channels of Moffett Creek flow. Transects 1 and 2 (plots 1-16) have

more areas of standing water from upwelling springs than others in the Summit Creek complex, while transect 3 (plots 17-24) occurs on a site similar low terraces.

BIRCH CREEK

The Birch Creek system lies in the Birch Creek Valley, east of the Little Lost River Valley, between the Lemhi Range and Beaverhead Mountains in Lemhi and Clark counties (Moseley 1992). Four areas of the Birch Creek population were sampled, each divided by fences along ownership boundaries:

(1) Upper Birch Creek occurs on private land and is grazed by cattle at various periods throughout the growing season and fall. This site is drier than Moffett Creek, as no plots included standing water, and alkali primrose occurs on low terraces and in hummocky areas in a narrow zone immediately adjacent to the creek.

(2) Lower Birch Creek-Private is also on private land grazed by cattle. Wetter portions of this site (transect 1; plots 1-4) are reminiscent of Moffett Creek, where the primrose is widely spread throughout the stand, while most portions resemble Upper Birch Creek and Summit Creek Exclosure, where the primrose occurs on low terraces adjacent to the creek.

(3) Lower Birch Creek-Targhee is separated by a fence from Lower Birch Creek-Private and is grazed by horses during the winter. The site is managed by the Targhee National Forest. The difference in grazing regime from the preceding Birch Creek sites is evident, particularly in the uplands, where the cover of grasses, especially *Elymus cinereus*, was greater than in sites grazed by cattle. A moderate level of bank impacts from fishing pressure occurs at the downstream plots at this site, although not to the same degree as at the Summit Creek Exclosure. As with Lower Birch Creek - Private, alkali primrose largely occurs on terraces along the creek, although some sampling sites occur in more extensive wetlands where it is widely scattered throughout.

(4) Lower Birch Creek-Fish and Game occurs immediately downstream from the Targhee site at a fishing access managed by the Idaho Department of Fish and Game. It is sometimes grazed by horses in the winter, although to a lesser extent than Lower Birch Creek-Targhee, and the plots are not subject to recreational fishing impacts to the same degree as some of the Targhee plots. The primrose in transect 1 (plots 1-2) are on a low terrace adjacent to the creek, while the rest occur in a widely scattered stand in a more extensive wetland.

TEXAS CREEK

Texas Creek lies at the head of the Lemhi Valley in Lemhi County. The alkali primrose population occurs in a broad valley-bottom wetland along approximately three miles of the creek, particularly in wet meadows with interspersed hummocky areas, similar to the Moffett Creek system. This site is heavily grazed by cattle on a rest-rotation system.

METHODS

FIELD METHODS

The populations were sampled twice a season, early in the season when alkali primrose is in full bloom (late May or early June), and again late in the season (August or September) when the fruits were mature. Populations are not continuous at any site, but occur in patches; plots are located in the patches. Methods used by Pat Muir and assistants in June 1991 to locate plots varied slightly between sites (Muir 1992; Muir and Moseley 1994). At Summit Creek Exclosure and Texas Creek, they used surveying equipment to map the perimeters of patches, and they located plots by walking into the approximate centers of the patches, choosing random azimuths and numbers of paces and then locating plot centers next to the alkali primrose individual nearest each point. They located plots in consecutive patches until 24 plots had been established. At other sites, they established transects in subpopulations, placing a transect randomly through the long axis of each patch as it was encountered along stream reaches. Plots were then located by choosing a random digit ($\geq$10 and $\leq$60), walking that number of meters along the line, and centering the plot near the alkali primrose individual nearest the point on a predetermined side of the line.

Muir and crew established two to eight plots along each transect (depending on the transect length) for a total of 24 plots per site (excluding the small Summit Creek Campground and Lower Birch Creek-Fish and Game sites where they placed five and six plots, respectively). The transect lengths ranged from 10 to 96 m, with length influenced by linear dimensions of subpopulations and by the need to disperse sampling throughout the site. They marked transect ends with PVC pipe or steel reinforcing rods. Plot centers were displaced a few centimeters from the nearest alkali primrose individual, to avoid damaging it when inserting plot markers. See Appendix 1 for mapped locations of the permanent plots at the three sites.

During the early-season reading, plants were located within circular plots [45.7 cm diameter (1642 cm^2)] using a polar coordinate system (Muir and McCune 1992). We classified the life stage of each plant in the plot into one of three categories: (1) "reproductive" plants, which had flowers; (2) "nonreproductive" plants, which included basal rosettes without flowers; and (3) "seedlings," which included basal rosettes $\leq$0.5 cm (we used this threshold after looking at a range of small plants in the population; we determined that checking for cotyledons on every small plant in a plot was too destructive). Coordinates were recorded for the location of all reproductive and nonreproductive individuals in the plot. We also counted flowers on reproductive individuals. A simple tally of the total number of seedlings was made for each plot.

In August or September, during the late-season reading, we relocated the plots and recorded numbers of mature fruits on each of the reproductive plants (for estimation of fruit and seed production) and again tallied the number of seedlings occurring in the plots (for estimation of seedling survival rates through the growing season).

POPULATION MODELING

Field data were entered into LOTUS 1-2-3 files where descriptive statistics were computed (Appendix 3). These statistics, relating to the demography of the alkali primrose population, were used to construct population models. Population modeling can be an effective way to use demographic information to project future population trends and to assess the effects of various management activities on population dynamics (Menges 1986). The computer program RAMAS/stage (Ferson 1991) was used to execute a type of population modeling using transition matrices. Four years of data, representing three transitions (*i.e.*, 1991 to 1992, 1992 to 1993, and 1993 to 1994) are insufficient to make strong conclusions about projected population changes, but transition matrix models are generally sensitive to small changes in the matrix (*i.e.*, demographic) components, and are therefore useful for identifying life-stage aspects of the population crucial to population growth and decline. For example, the models are useful in identifying the life-stage most responsible for the decline or growth of a population (Ferson 1991). As additional years of data become available, the model can be updated and its usefulness as a tool in projecting population trends and predicting the effects of various management options will improve (Kaye 1992).

Transition matrix models are so named because they are matrices of transition probabilities, that is, the rates at which one life stage makes the transition to another stage. Once the transition matrix is constructed, the RAMAS/stage program repeatedly multiplies it by a vector representing the abundance of individuals in each stage category (Kaye 1992). After these calculations are iterated a sufficient number of times, this method can be used to calculate the equilibrium population growth rate (commonly referred to as "lambda"), which is the rate at which a population will grow or decline. In multivariate statistics parlance, lambda is the dominant eigenvalue (see Caswell 1989 and Ferson 1991 for further discussions related to calculating lambda). If lambda is greater than one there is a positive growth rate indicating a demographically healthy population. Conversely, if lambda is less than one, the population is projected to decline (Menges 1986; Kaye 1992). In RAMAS/stage, lambda is calculated as the dominant eigenvalue.

RESULTS

CHANGES IN SAMPLE SIZE

For various reasons, the number of plots declined steadily through the sampling period. Pat Muir and crew established 155 permanently-marked plots at the eight study sites in June 1991, and by August 1994, only 97 plots (63%) remained (Appendix 2). Most plot stakes were maliciously removed, especially at sites with high recreational use, such as Summit Creek Exclosure, Summit Creek Campground, and Lower Birch Creek-Targhee. In fact, all but one plot was removed at Summit Creek Campground within two years (Appendix 2), and the one that remained had no primrose after the first year. These five plots at Summit Creek Campground were not used in any calculations or modeling. By 1993, most of the plots were missing from Lower Birch Creek-Private, a site where little recreation use occurs, yet the center stakes were obviously pulled from the ground and tossed aside. By 1994, three plots were missing from both Upper Birch Creek and Texas Creek, possibly due to livestock, as little recreational use occurs at these sites.

Aside from the disappearance of plot center stakes, it also appeared that some stakes may have been moved, as the plant coordinates did not match between two years. This included five plots at Summit Creek Exclosure and one plot at Lower Birch Creek-Targhee (Appendix 2). These plots were not usable for any calculations or modeling.

Primrose were killed in seven plots at Lower Birch Creek-Targhee by flooding in late-1993 and 1994, rendering them unusable during the last year of study (Appendix 2). All the plots (transects 4 and 5, and plot 24) occur along the same tributary channel of Birch Creek where an obvious increase in water level was observed during August 1993. The water was at the previously observed "normal" level in May 1993. The increase in water level was due to an obvious increase in flow in this channel and not to damming by a beaver and change in channel morphology. It was certainly not attributable to an increase in precipitation, because only this channel at this site was affected. Water levels and discharge rates in adjacent channels appeared unchanged. It appears that the increase in flow originates from the source spring, but these observations need further investigation.

The six plots in transects 4 and 5 occur on a low bench next to the channel and were affected by flooding immediately. Plot 24 occurs farther upstream and on a higher bench consisting of ridges between marl pools. In August 1994, there was a noticeable increase in standing water on this bench system containing transects 6 and 7, but only plot 24 (in transect 7) was immediately affected by the change. I believe that it is only a matter of time before other plots in these two transects are affected if the water levels remain high. Plots 1 and 2 of Lower Birch Creek-Fish and Game appeared wetter in 1994 than previous years and have lost all primrose plants. These creekside plots may be affected by the increased flows. By August 1994, some plots were under as much as 20 cm of flowing water and covered by 1 cm of silt. The plot center stakes remain in place and can be used to observe future fluctuations in water level and possible recovery of the vegetation and plant populations. Unfortunately, I observed no groundwater observation wells established by Mansfield and Miyasaki (1993) near transects 4 and 5. These would have provided pre-flooding water levels. I think there are some in the vicinity of transects 6 and 7, however.

While the method of mapping individual plants employed in this study works well with low- to medium-density populations, it does not work well with high-density populations. As we discovered in our study of the Stanley Basin endemics (Moseley and Mancuso 1990; 1992; 1993), and rediscovered here, the coordinate system of identifying and tracking individuals in plots is not accurate enough to locate and return to individual plants when they occur in dense patches. A combination of several factors, including relatively small size of the plant, irregular ground surface adding the third dimension of depth, dense vegetation, and the sampling apparatus, give an accuracy of one to two centimeters for locating a plant in the plot. Because of this, it became impossible to track individuals in plots with greater than about 25-30 plants (one plot had over 140 mature individuals!). These plots provided data on density, population structure and fecundity rates, but I was unable to use them in the population modeling. The number of plots at the site usable for modeling was consistently 84-85% of those used for population density, structure and fecundity calculations, although the number for both decrease over time. Plots that were too dense are noted in Appendices 2 and 3. The status of plots in August 1994, is summarized in Appendix 2 and Table 1.

Table 1. Changes in sample sizes for population density, structure and fecundity calculations (Density/Fecundity) and transition matrix modeling (Model) during the four-year study period. See text for explanation of differences. This summary does not include the five plots from Summit Creek Campground that were lost early in the study.

	1991	1992	1993	1994
Density/Fecundity	145	141	112	94
Model	124	121	96	81

The take home message from this discussion and from Table 1 is this: because high density plots could not be used in the modeling, the demographic modeling results reported in a later section apply to the lower density portions of the species range. In other words, I was not able to capture what are presumably the most vigorous portions of the population in the modeling exercise. For this reason I suggest that conservation and management recommendations and decisions be made largely on the basis of the population structure and fecundity data reported in the following section.

POPULATION STRUCTURE AND FECUNDITY

Table 2 displays selected metrics relating to the population structure and fecundity of alkali primrose at the seven study sites measured between 1991-1994. Data collected at each plot, as well as some summary statistics, appear in Appendix 3. We made 7047 observations of mapped plants during the four years of study, including 2129 plants in 1991, 2263 plants in 1992, 1412 plants in 1993, and 1243 plants in 1994. The decrease in observed plants resulted from the loss of plots explained above.

The average density of all plots over the four years was 82.7 plants/m^2 (Table 2). The plots at Lower Birch Creek-Private have the highest density of plants with a four-year average of 137 primrose/m^2, while those at Lower Birch Creek-Fish and Game have the lowest density with an average of 31 plants/m^2 (Table 2). A caveat in interpreting these data is that the plots were randomly chosen at a site and not habitat-stratified to proportionally estimate the density over entire sites (see Methods section and Muir and Moseley 1994).

There is an even bigger caveat in interpretation, that is, the effect of the loss of plots through the sampling period on population density estimates. This is clearly illustrated at Summit Creek Exclosure where plant density fluctuated wildly during the four years (Table 2; 87.8, 131.8, 50, 31 for 1991, 1992, 1993, and 1994, respectively). The decline in density from 1992 to 1993 and 1994 is easily explained by the loss of the highest density plots from the low benches (the plot stakes were less visible in the lower density hummocky areas and, therefore, were not ripped out as frequently). We were unable to match four plots between 1991 to 1992 (Appendix 2), plots mostly from hummocky areas, and this probably caused the big increase in density in this transition. Sites that lost few or no plots (e.g., Lower Birch Creek-Targhee for 1991-1993 and Moffett Creek) had densities that remained relatively stable throughout the sampling period. An anomalous flux in density took place at Lower Birch Creek-Fish and Game, a site that lost not plots through the sampling period. Plant density in 1993 was a third of what it was in 1991 and 1992, then appeared to recover to previous levels in 1994 (Table 2). This site has only six plots and a drastic reduction in mature individuals in Plots 5 and 6 in 1993 caused the flux (Appendix 4). It appears that either some plants did not come up in 1993 or that we misread the plot (see Appendix 4 for history of individual plants in these plots during the sampling period).

The population structure at all seven sites is heavily skewed toward the nonreproductive stage, averaging 63% of the population over the four years of data collection. Reproductive individuals comprised the next largest category with 32% of the population. Seedlings were generally scarce at the seven sites throughout the four year period, comprising just 5% of the population. This population structure is similar to that observed in other rare perennial plants of the region (Lesica and Elliott 1989; Lesica and Shelly 1992; Larkin and Salzar 1992; Kaye 1992; Moseley and Mancuso 1993; Kaye et al. 1994) and may indicate that the populations are actively recruiting new individuals. Two sites, Lower Birch-Private and Lower Birch Creek-Fish and Game, were more heavily skewed toward the nonreproductive class than other sites, with only 10% and 21% in the reproductive class, respectively.

Reproductive output varied from year to year within the seven study sites. While the average number of *flowers/reproductive* plant remained steady across the sites through time, the average number of *fruits/reproductive* plant varied widely in space and time. Calculation of the *average number of seeds/reproductive plant* used the number of *fruits/reproductive* plant and, therefore, varied similarly in the two dimensions. Abortion of ovules is represented in Table 2 as the difference between the *average number of flowers/reproductive plant* and the *average number of fruits/reproductive plant*. Although aborted fruits are included, most of the decline reflected in the *fruit loss rate* metric in Table 2 is due to herbivory. Fruits appear to mature, ripen, and disperse seeds rather quickly after our early-season reading, probably in June and possibly early July. By the time we read the plots again in August and early September, herbivory of fruits (actually whole scapes) by rodents(?) and especially cattle, accounted for the large differences in total flowers and fruits in a plot during the year. I am unsure, however, to what extent this attribute actually reflects a loss of reproductive output. I have no way of knowing if mature seeds dispersed prior to the scape being eaten. This information could be gathered by altering the sampling design to include frequent plot visits (weekly?) throughout June and early July.

Most late-season herbivory was clearly attributed to cattle, indicated by the mowed nature of vegetation in the plot. In addition, we also found many scapes that were consistently and apparently selectively cut ca. 1-2 cm above the ground. This occurred at all study sites, including those ungrazed by livestock. Scape cutting generally occurred between the early and late readings; only infrequently prior to the early observation. It appears, that a small rodent may be selectively cutting primrose scapes during June and July in pursuit of ripe seeds. Although it was difficult to accurately discern if a missing scape had (1) been clipped by a rodent, (2) simply broken off and blown away due to its brittle nature in late summer, or (3) was a plot partially grazed by cattle, we noted obviously clipped scapes on the late-season field data forms (on file at the Conservation Data Center, Boise, and the Salmon BLM office, Salmon). Due to the difficulty mentioned above, we were unable to quantitatively assess the contribution of these three methods to *fruit loss rate*.

There was a decline in seedlings between the early and late readings on nearly every site over the four years of observation. The difference in the two totals is displayed as a percent *annual seedling mortality* in Table 2 (at some sites during some years, however, there was an increase in seedlings observed through the growing season). I believe that overall, this metric reflects the actual seedling mortality through the growing season. One possible confounding factor, however, is the method we used to identify seedlings, that is, as a size cutoff of plants with a rosette of less that 0.5 cm in diameter. A seedling that became greater than 0.5 cm in diameter through the growing season would have changed life stages from seedling to nonreproductive between the two readings and we would have overestimated seedling mortality. Because the sampling was not designed to track the location of individual seedlings in a plot, they were counted as a per plot total, there is no way to determine if seedlings advanced to the nonreproductive class during the summer.

As discussed by Muir and Moseley (1994), the intensity of livestock grazing was different between the seven study sites. Some sites were in pastures that were heavily grazed by cattle at various times through the grazing season, such as Texas Creek, Lower Birch Creek-Private, Upper Birch Creek, and Moffett Creek, while Summit Creek Exclosure received intermittent heavy grazing, and Lower Birch Creek Targhee-Targhee and Lower Birch Creek-Fish and Game had little grazing pressure (Muir and Moseley 1994). Within the sites that are grazed by cattle, it was observed that not all habitat occupied by alkali primrose is grazed equally; quaky, unstable substrates (peat) are generally not grazed as heavily as those with stable mineral substrates, however, this was not universal and varied both within sites and between sites. For example, under extraordinarily heavy grazing pressure, such as at Lower Birch Creek-Private, cattle grazed plots on very unstable peat, a habitat that was not grazed under less intense pressure at other sites, such as portions of the Texas Creek and Moffett Creek sites. This intrasite habitat difference in grazing intensity was not accounted for in the sampling protocol.

The three sites with the greatest grazing intensity, Upper Birch Creek, Texas Creek, and Lower Birch Creek-Private, had above average population densities. Summit Creek Exclosure and Lower Birch Creek-Targhee had population densities that were about average, while Moffett Creek and Lower Birch Creek-Fish and Game were well below average (Table 2). The population age class structure is similar among grazed and ungrazed sites, with most being close to the average for all sites (Table 2). The exceptions, noted above, include the heavily grazed Lower Birch Creek-Private, with the lowest reproductive age class, and the ungrazed Lower Birch Creek-Fish and Game, which has the second lowest reproductive age class.

While the design of the study does not allow strong inferences about the effects of livestock grazing on alkali primrose populations (Muir and Moseley 1994), density and population structure data suggest that cattle grazing is not having a major impact. Our results are similar to those of Mansfield and Miyasaki (1993) who found no evidence that grazing is deleterious to alkali primrose habitat, and that it may even increase microhabitat by opening areas for seedling establishment by eliminating competitors. This microhabitat preference has been observed to be a characteristic of related primrose species (Kelso 1987). Mansfield and Miyasaki (1993) did, however, find an inverse relationship between grazing intensity and the density of reproductive individuals at Texas Creek, Upper Birch Creek and Lower Birch Creek-Private. This suggested to them that there may be long-term viability problems related to grazing. I found this relationship only at Lower Birch Creek-Private and not at the other two sites they mentioned (see Table 2). This may suggest long-term viability problems, although the ungrazed Lower Birch Creek-Fish and Game site had the second lowest reproductive class. Long-term monitoring of *Phlox idahonis*, another federal candidate occurring in wetlands, found that populations decline under heavy cattle grazing intensity, but not under moderate levels (Moseley and Crawford 1995).

Table 2. Population structure and fecundity data for *Primula alcalina* in permanently-marked plots at seven study sites in east-central Idaho, 1991-1994.

SITE	Summit Creek Exclosure				
	1991	1992	1993	1994	4 yr avg
Number of plots	20	19	12	10	
Total mature plants observed[a]	287	411	98	51	211.8
Density (±s.d.) (plants/m^2)	87.8 (16.4)	131.8 (32.0)	50 (5.4)	31 (2.7)	75.2 (14.1)
Total seedlings - early	132	76	12	3	55.8
Total seedlings - late (% population[b])	62 (18)	11 (3)	0 (0)	3 (6)	19 (6.8)
Annual seedling mortality (%)	54	86	100	---	65.9
Total nonreproductive (% population)	188 (54)	248 (59)	64 (65)	27 (50)	131.8 (57)
Total reproductive (% population)	99 (28)	163 (38)	34 (35)	24 (44)	80 (36.2)
Avg # flowers/repro plant (±s.d.)	5.6 (2.3)	5.5 (2.8)	4.9 (2.2)	5.5 (2.3)	5.4 (2.4)
Avg # fruits/repro plant (±s.d.)	3.5 (2.5)	5.2 (4.5)	3.1 (1.5)	2.6 (1.4)	3.6 (2.5)
Fruit loss rate (%)[c]	88	93	33	98	78
Avg # seeds/repro plant[d]	82	122	72	61	84.3

[a] Mature plants = reproductive + nonreproductive.

[b] Population stage structure calculated using "total seedlings - late" to represent the seedling stage.

[c] Fruit loss rate = total # fruits/plot (late-season sampling)/total # flowers/plot (early-season reading)

[d] Average number of seeds/fruit = 23.3 (R. Fitz, Utah State University, personnel communication, 1994)

Table 2. Continued.

SITE	Moffett Creek				
	1991	1992	1993	1994	4 yr avg
Number of plots	24	24	24	24	
Total mature plants observed	221	176	227	220	211
Density (±s.d.) (plants/m^2)	56.1 (11.4)	44.5 (11.4)	58 (13.3)	56.1 (12.9)	53.7 (12.3)
Total seedlings - early	39	2	17	2	15
Total seedlings - late (% population)	9 (4)	3 (2)	0 (0)	2 (1)	3.5 (2)
Annual seedling mortality (%)	77	---	100	---	77
Total nonreproductive (% population)	118 (51)	97 (54)	135 (59)	130 (59)	95 (56)
Total reproductive (% population)	103 (45)	79 (44)	92 (41)	90 (40)	91 (42)
Avg # flowers/repro plant (±s.d.)	5.0 (2.0)	5.5 (2.4)	4.7 (2.4)	5.2 (2.7)	5.1 (2.4)
Avg # fruits/repro plant (±s.d.)	3.5 (1.4)	3.8 (1.2)	4.2 (1.5)	3.6 (1.5)	3.8 (1.4)
Fruit loss rate (%)	72	85	79	70	77
Avg # seeds/repro plant	82	89	98	84	88

Table 2. Continued.

SITE	Lower Birch Creek - Fish and Game				
	1991	1992	1993	1994	4 yr avg
Number of plots	6	6	6	6	
Total mature plants observed	36	41	12	34	30.8
Density (±s.d.) (plants/m^2)	36.6 (5.5)	41.5 (5.9)	12.2 (3.6)	34.8 (5.7)	31.3 (5.2)
Total seedlings - early	12	0	0	4	4
Total seedlings - late (% population)	2 (5)	1 (2)	3 (21)	3 (10)	2.3 (7)
Annual seedling mortality (%)	84	---	---	---	42.7
Total nonreproductive (% population)	25 (66)	25 (60)	11 (78)	34 (90)	23.8 (72)
Total reproductive (% population)	11 (29)	16 (38)	1 (1)	0 (0)	7 (21)
Avg # flowers/repro plant (±s.d.)	4.9 (1.7)	4.4 (1.4)	6.0 (0)	---	5.1 (0.8)
Avg # fruits/repro plant (±s.d.)	4 (1.7)	3 (0.7)	6 (0)	---	4.3 (0.8)
Fruit loss rate (%)	55	86	0	---	47
Avg # seeds/repro plant	93	70	140	---	101

Table 2. Continued.

SITE	Lower Birch Creek - Targhee				
	1991	1992	1993	1994	4 yr avg
Number of plots	23	23	23	11	
Total mature plants observed	295	327	282	130	258.5
Density (±s.d.) (plants/m^2)	78.1 (5.2)	86.6 (7.1)	75 (6.9)	72 (6.9)	77.9 (6.7)
Total seedlings - early	47	43	2	11	25.8
Total seedlings - late (% population)	39 (12)	14 (4)	0	11 (8)	16 (5)
Annual seedling mortality (%)	18	68	100	0	38
Total nonreproductive (% population)	215 (64)	203 (60)	159 (56)	165 (60)	186 (62)
Total reproductive (% population)	80 (24)	124 (36)	123 (44)	47 (32)	93.5 (33)
Avg # flowers/repro plant (±s.d.)	5.3 (2.3)	5.5 (2.9)	5.3 (2.6)	4.6 (1.7)	5.2 (2.4)
Avg # fruits/repro plant (±s.d.)	3.5 (1.9)	2.2 (1.3)	4.2 (2.7)	2.5 (1.2)	3.1 (1.8)
Fruit loss rate (%)	72	89	70	74	76.3
Avg # seeds/repro plant	82	51	98	58	72.5

Table 2. Continued.

SITE	Lower Birch Creek - Private				
	1991	1992	1993	1994	4 yr avg
Number of plots	24	24	4	4	
Total mature plants observed	557	539	83	93	318
Density (±s.d.) (plants/m^2)	141.5 (19.4)	137.3 (25.5)	126.9 (8.3)	142.1 (15.3)	136.9 (17.1)
Total seedlings - early	290	55	0	4	87.3
Total seedlings - late (% population)	88 (14)	35 (6)	0	1 (1)	31 (5)
Annual seedling mortality (%)	70	27	---	75	64
Total nonreproductive (% population)	414 (64)	507 (88)	79 (94)	89 (95)	272 (85)
Total reproductive (% population)	143 (22)	32 (6)	4 (6)	4 (4)	45.8 (10)
Avg # flowers/repro plant (±s.d.)	5.1 (2.1)	5.1 (2.7)	5.0 (2.0)	3.0 (0.0)	4.6 (1.7)
Avg # fruits/repro plant (±s.d.)	3.3 (1.6)	6.3 (2.9)	0	0	2.4 (1.2)
Fruit loss rate (%)	80	0	0	0	20
Avg # seeds/repro plant	77	146	0	0	60.9

Table 2. Continued.

SITE	Upper Birch Creek				
	1991	1992	1993	1994	4 yr avg
Number of plots	24	23	22	19	
Total mature plants observed	345	366	335	340	346.5
Density (±s.d.) (plants/m^2)	86.8 (12.6)	97 (12.9)	92.7 (10.6)	109.2 (13.0)	96.6 (12.3)
Total seedlings - early	66	13	13	14	26.5
Total seedlings - late (% population)	18 (5)	2 (3)	13 (4)	11 (5)	11 (4)
Annual seedling mortality (%)	33	85	---	22	58
Total nonreproductive (% population)	212 (58)	196 (52)	158 (45)	180 (87)	186.5 (61)
Total reproductive (% population)	133 (37)	170 (45)	177 (51)	16 (8)	124 (35)
Avg # flowers/repro plant (±s.d.)	5.0 (2.1)	5.1 (2.1)	5.8 (2.1)	4.7 (2.0)	5.2 (2.0)
Avg # fruits/repro plant (±s.d.)	4 (0.0)	2.9 (1.1)	3.7 (1.2)	0	2.7 (0.6)
Fruit loss rate (%)	97	96	98	100	97.8
Avg # seeds/repro plant	93	68	86	0	61.8

Table 2. Continued.

SITE	Texas Creek				
	1991	1992	1993	1994	4 yr avg
Number of plots	24	22	21	20	
Total mature plants observed	338	403	353	375	367.3
Density (±s.d.) (plants/m^2)	98.8 (14.6)	111.6 (19.4)	102.5 (19.6)	114.7 (22.3)	106.9 (19.0)
Total seedlings - early	64	49	2	33	37.0
Total seedlings - late (% population)	49 (11)	2 (1)	3 (1)	33 (8)	22.3 (5)
Annual seedling mortality (%)	24	92	---	0	40
Total nonreproductive (% population)	205 (47)	195 (48)	204 (57)	305 (75)	227.3 (57)
Total reproductive (% population)	183 (42)	208 (51)	149 (42)	70 (17)	152.5 (38)
Avg # flowers/repro plant (±s.d.)	5.4 (2.5)	4.7 (2.4)	5.3 (2.1)	5.2 (2.6)	5.1 (2.4)
Avg # fruits/repro plant (±s.d.)	3.4 (1.6)	3.3 (1.1)	3.9 (1.7)	2 (0)	3.2 (1.1)
Fruit loss rate (%)	95	98	93	47	83
Avg # seeds/repro plant	79	77	91	47	73.5

Table 2. Continued.

SUMMARY

	1991	1992	1993	1994	4 yr avg
Number of plots	150	141	112	94	
Total mature plants observed	2129	2263	1412	1243	7047
Density (±s.d.) (plants/m^2)	83.7 (30.7)	92.9 (35.6)	73.9 (35.1)	80.0 (89.6)	82.7 (6.8)
Total seedlings - late (% population)	12	3	1	5	5
Total nonreproductive (% population)	60	58	57	75	63
Total reproductive (% population)	28	39	42	20	32
Avg # flowers/repro plant (±s.d.)	5.2 (0.2)	4.1 (0.4)	5.3 (0.4)	4.0 (1.8)	4.9 (0.5)
Avg # fruits/repro plant (±s.d.)	3.6 (0.3)	3.8 (1.3)	3.6 (1.7)	1.5 (1.4)	3.1 (0.9)
Fruit loss rate (%)	79.9	78.1	53.3	55.6	66.7
Avg # seeds/repro plant	84	89.6	85.6	35.7	73.5

POPULATION MODEL

As stated in a previous section, I was not able to capture the densest portions of the population in the modeling exercise due to sampling design problems. Therefore, the modeling results discussed below apply only to the low- to medium-density portions of the alkali primrose distribution, excluding what is presumably the most vigorous portion. For that reason, I explore primrose population monitoring only in a cursory way and conclusions generated from these results should not be relied upon too heavily for making management and conservation decisions.

Matrix projections begin with the stage structure (*i.e.*, seedling, nonreproductive, reproductive) of the alkali primrose populations in 1991. The stage structure then changes over one year as some individuals remain at that stage, while others grow to another stage or die. We collected data on three transitions, which were used in the model to calculate stage-specific survivorships, fecundity, and transfer (growth) rates in order to project (model) the future dynamics of the population.

I first constructed a diagram of the life history of the species (Figure 1). Arrows in Figure 1 represent transfers that take place between stages each year. These transfer rates were calculated from the 1991 through 1994 monitoring data (see Appendix 4 for life stage transition data for the seven study sites). I calculated the reproductive to seedling transition by dividing the number of 1992, 1993, and 1994 seedlings by the number of 1991, 1992, and 1993 reproductive plants, respectively. This method of calculating this transition was used because we know little about the reproductive -> seed -> seedling transitions, in other words I skipped the seed stage. There is apparently no storage in a soil seed bank (Caryl Elzinga, Alderspring Ecological Consulting, Tendoy, ID, personal communication, 1994). Because no data currently exist on the subject, I had to assume that seed predation is zero, although this is probably not the case. One odd finding was that 11% of the seedlings went on to become reproductive plants, skipping the nonreproductive stage (seedling to reproductive transfer in Figure 1). In reality, this probably does not happen in nature and these results reflect problems associated with the sampling design.

I next prepared a projection matrix (Figure 2) corresponding to the life cycle presented in Figure 1. Each number in the matrix represents a transfer from the column stage to the row stage. For example, in one year, 50% of nonreproductive individuals remain nonreproductive (column 2, row 2), while 25% become reproductive (column 2, row 3).

Figure 1. The life cycle of *Primula alcalina*. Reproductive output and transfer rates were calculated using 1991 to 1994 data from low- to medium-density plots and does not necessarily represent the densest portions of the species distribution.

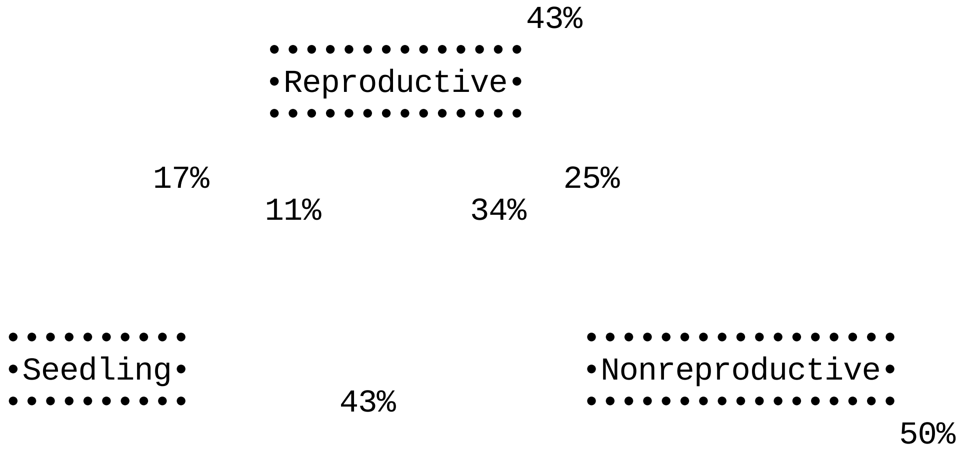

Figure 2. Projection matrix corresponding to the life cycle of *Primula alcalina* presented in Figure 1.

			FROM:	
		Seedling	Nonreproductive	Reproductive
	Seedling	0.0	0.0	0.17
TO:	Nonreproductive	0.43	0.50	0.34
	Reproductive	0.11	0.25	0.43

The combined matrix model for all seven sites, as executed by RAMAS/stage, projects that alkali primrose is expected to decline if environmental conditions remain constant. The equilibrium growth rate (lambda) of the populations was calculated to be 0.8056, indicating that the populations will decrease in size. Figure 3 shows the population decline over the next five years as projected by the model. The reason for the decline shown by the model is not entirely clear, although several demographic factors may be contributing: (1) low number of seedlings (Table 2); (2) relatively high mortality rate of seedlings (46%; Appendix 4); (3) nearly a quarter of all reproductive and nonreproductive individuals die annually (23% and 25%, respectively; Appendix 4); and (4) a high number of reproductive individuals "revert" to being nonreproductive in a given year (average 34%), and fewer nonreproductive individuals move on to the reproductive stage (average 25%; Figure 1; Appendix 4). Separate models developed for each of the seven sites show similar declines to the model developed for all sites collectively (Table 3). Lambda values range from 0.6536 at Lower Birch Creek-Fish and Game to 0.8777 at Upper Birch Creek (Table 3). The two sites that are not grazed by cattle, Lower Birch Creek-Targhee and Lower Birch Creek-Fish and Game, show the sharpest decline (lowest lambda values) (Table 3).

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Figure 3. Decline projected by the combined model of *Primula alcalina* at the seven sampling sites over a five year interval. Total number of plants (in thousands), includes seedlings, nonreproductive, and reproductive stages. This graph represents the Low- and medium density plots and does not necessarily represent the densest portions of the species distribution.

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Table 3. Equilibrium growth rates (lambda) for alkali primrose at the seven study sites (expressed as dominant eigenvalues by RAMAS/stage population modeling). Data used for this analysis is from the low- to medium-density plots and does not necessarily represent the densest portions of the species distribution.

* * *

	Lambda
Combined Model for All Sites	0.8056
Summit Creek Exclosure	0.7870
Moffett Creek	0.8314
Lower Birch Creek-Fish and Game	0.6536
Lower Birch Creek-Targhee	0.7186
Lower Birch Creek-Private	0.7565
Upper Birch Creek	0.8777
Texas Creek	0.7870

* * *

CONCLUSIONS AND RECOMMENDATIONS

1. Demography data indicate that the populations are vigorous in terms of density, population structure, and fecundity.

2. The population modeling projects an overall population decline at all sites over the next five years. Seedlings were not common in our plots and this was probably a factor that contributed to the decline shown by the model (along with the fact that the lowest-density portion of the sampled distribution was modeled). Low seedling recruitment is common in perennials and tends to skew population models developed from short monitoring periods (*e.g.*, Moseley and Mancuso 1993). Our monitoring period for alkali primrose is rather short and probably did not encompass all the demographic variability, especially in seedlings, which is the life stage most vulnerable to annual fluctuations. For example, seedlings fluctuated more than any other life stage through the four-year monitoring period (Table 2). Climatic

patterns may be at least partially responsible for this flux, although alkali primrose distribution was observed to coincide with that portion of the wetlands that were subirrigated to the soil surface throughout the growing season (Moseley 1989).

3. This study was designed and established by Pat Muir in 1991. As she stated, "the study does not allow strong inferences about the effects of livestock grazing on alkali primrose populations" (Muir and Moseley 1991). Based on my interpretation of the monitoring data and 12 years experience in primrose habitat, moderate and light levels of cattle grazing are not detrimental to alkali primrose habitat. This corroborates my pervious observations (Moseley 1989) and data collected by Mansfield and Miyasaki (1993). There may, however, be long-term viability concerns due to heavy cattle grazing and its effect on alkali primrose reproduction (as discussed in previous sections and in Mansfield and Miyasaki 1993). Studies on the reproductive ecology of alkali primrose are currently being conducted by Robert Fitz of Utah State University, under contract to the BLM. His studies will shed light on the overall appropriateness of cattle grazing, in terms of reproductive viability, and the proper timing of grazing. For now, I agree with the conclusions of Muir and Moseley (1994), that if alkali primrose populations must be grazed by cattle, it should take place before anthesis (generally prior to mid-May) or after seed dispersal (generally after late July) and should be light in intensity.

This study focused intensively on a single species. Cattle grazing, especially heaving grazing, has an impact on other aspects of ecosystem composition, structure, and function of both terrestrial and aquatic communities (Fleischner 1994). This is especially evident along the fenceline between Lower Birch Creek-Targhee and Lower Birch Creek-Private, but grazing effects have had an impact on ecosystem attributes at all study sites (*e.g.*, see Keller and Burnham 1982 and Thomas 1986 for ecological changes at Summit Creek). The impacts of even light grazing should be evaluated, given that the wetland ecosystems of Birch, Summit, and Texas creeks are rare and unique, inhabited by at least six rare plant species.

4. While demographic monitoring has proven very useful in rare plant management (Sutter 1986), emphasis must continually be placed on protection and maintenance of the natural habitats where the species live. In fact, demographic attributes, such as the fitness of an individual, may be influenced more by the ecological quality of the habitat for seedling germination and establishment than by total reproductive output (Owen and Rosentreter 1992). Therefore, some level of community monitoring should be established to measure change in compositional and structural attributes of the habitat, and possibly the functional or ecological processes operating to maintain overall habitat quality.

In this light, the demographic monitoring plots should be maintained and used to collect vegetation and population density and structure data in the future. The vegetation data can be compared to Pat Muir's baseline data collected in 1991 to assess habitat changes over time. The same goes for the population data. The monitoring interval can be increased from annually as it was with this study, to a longer interval (every five years?) to assess long-term population trends. I do not recommend tracking individual plants. The observation wells established by Mansfield and Miyasaki (1993) in 1992 should also be maintained and used to collect hydrologic information over time. They established an excellent baseline that can be used to assess future changes in hydrology and the impacts of those changes in alkali primrose habitat. It may prove very useful in measuring the changes in water flows in the channel of Birch Creek that increased flow in late 1993 and 1994 and flooded primrose habitat (discussed previously).

5. Finally, I offer the following recommendations regarding monitoring methodology:

As stated earlier, the method of mapping individual plants employed in this study works well with low- to medium-density populations, it does not work well with high-density populations. The coordinate system of identifying and tracking individuals in plots is not accurate enough to locate and return to individual plants when they occur in dense patches.

The plot layout at Texas Creek is inefficient. Although a larger portion of the population may be sampled, single plots are difficult to relocate in this extensive wetland. The plots stakes are isolated and easily blocked from view by hummocks or shrub patches. We spent considerable time searching for the plots, even after having done it four years in a row. It would have been more time-efficient to place several short transects or clusters of plots throughout the population.

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Appendix 1

Maps of permanent *Primula alcalina* monitoring plots.

Map 1. Summit Creek Exclosure, Summit Creek Campground, Moffett Creek

Map 2. Lower Birch Creek-Fish and Game, Lower Birch Creek-Targhee, Lower Birch Creek-Private

Map 3. Upper Birch Creek

Map 4. Texas Creek

Appendix 2

Disposition of *Primula alcalina* monitoring plots, 1991-1994.

Definitions:

present - plot present at both early and late observations.

present-early, missing-late - plot present at the early observation, but missing during the late observation that year.

missing - center stake missing. No data were collected.

no match - plant coordinates do not match preceding or proceeding year's. No data were collected. Some plot stakes at Summit Creek Exclosure were obviously moved.

too dense - plot too dense with primrose - impossible to match plant coordinates from one year to the next. Total number of primrose, stage, and seedling data used in density and fecundity calculations, but plot data were not used in transition modeling.

flooded (Lower Birch Creek - Targhee) - plots under water. Unable to collect any information.

Lower Birch Creek - Fish and Game

All six plots present for four years.

Density/fecundity: n=6 (all years)
Model: n=6 (all years)

Moffett Creek

All 24 plots present for four years.

Three plots too dense to track individual plants:

transect 1, plot 6 (all years)
transect 2, plot 2 (all years)
transect 3, plot 1 (only 1993 & 1994)

Density/fecundity: n=24 (all years)
Model: n=22 (1991 & 1992)
n=21 (1993 & 1994)

Summit Creek Campground (not used in any calculations)

Plot #	1991	1992	1993	1994
1	present	present-early missing-late	missing	missing
2	"	present	missing	missing
3	"	present	present	present
4	"	present- early missing late	missing	missing
5	present-early missing-late	missing	missing	missing

Summit Creek Exclosure

Plot #	1991	1992	1993	1994
1	present	present	missing	missing
2	"	"	present	present
3	"	missing	missing	missing
4	"	present- early missing late	missing	missing
5	"	present	present	present
6	"	"	"	"
7	"	"	"	"
8	"	"	"	"
9	"	"	"	"
10	"	"	"	missing
11	"	"	"	present
12	"	"	missing	missing
13	too dense	too dense	missing	missing
14	no match	no match	missing	missing
15	present	present	present	present
16	no match	no match	missing	missing
17	present	present	present	no match
18	"	"	"	present
19	too dense	too dense	missing	missing
20	present	present	missing	missing
21	"	"	present	present
22	too dense	too dense	missing	missing
23	no match	no match	missing	missing
24	no match	no match	no match	no match
Density/ fecundity:	n=20	n=19	n=12	n=10
Model:	n=17	n=16	n=12	n=10

Lower Birch Creek - Targhee

Plot #	1991	1992	1993	1994
1	present	present	present	missing
2	"	"	too dense	missing
3	"	"	too dense	missing
4	"	"	present	present
5	"	"	present-early missing-late	missing
6	"	"	present-early missing-late	missing
7	"	"	present-early missing-late	missing
8	"	"	present-early missing-late	missing
9	"	"	present	present
10	"	"	"	"
11	"	"	"	flooded
12	"	"	"	flooded
13	"	"	too dense	flooded
14	no match	no match	no match	flooded
15	present	present	present	flooded
16	"	"	"	flooded
17	"	"	"	present
18	"	"	"	"
19	"	"	"	"
20	"	"	"	"
21	"	"	"	"
22	"	"	"	"
23	"	"	"	"
24	"	"	"	present-early flooded-late
Density/ fecundity:	n=23	n=23	n=23	n=11
Model:	n=23	n=23	n=20	n=11

Lower Birch Creek - Private

Plot #	1991	1992	1993	1994
1	too dense	too dense	too dense	too dense
2	too dense	too dense	too dense	too dense
3	too dense	too dense	too dense	too dense
4	present	present	present	present
5	"	present-early missing-late	missing	missing
6	"	"	"	"
7	"	"	"	"
8	"	"	"	"
9	"	"	"	"
10	"	"	"	"
11	"	"	"	"
12	"	"	"	"
13	too dense	too dense missing-late	"	"
14	too dense	too dense missing-late	"	"
15	present	present-early missing-late	"	"
16	too dense	too dense missing-late	"	"
17	present	present	"	"
18	"	"	"	"
19	"	"	"	"
20	too dense	too dense	"	"
21	present	present	"	"
22	"	"	"	"
23	"	"	"	"
24	"	"	"	"
Density/ fecundity:	n=24	n=24	n=4	n=4
Model:	n=17	n=17	n=1	n=1

Upper Birch Creek

Plot #	1991	1992	1993	1994
1	too dense	too dense	no match	no match
2	present	present	present	present
3	"	"	"	"
4	"	"	present-early missing-late	missing
5	"	"	present	present
6	"	"	"	"
7	"	"	"	"
8	"	"	"	"
9	too dense	too dense	too dense	too dense
10	present	present	present	present
11	"	"	"	"
12	"	"	"	"
13	"	"	"	"
14	too dense	too dense	too dense	too dense
15	present	present	present	present
16	"	"	"	"
17	"	"	present-early missing-late	missing
18	"	"	present-early missing-late	missing
19	"	"	present	present
20	"	"	"	"
21	too dense	too dense	too dense	too dense
22	present	present	present	present
23	"	"	"	"
24	too dense	no match	no match	no match
Density/ fecundity:	n=24	n=23	n=22	n=19
Model:	n=19	n=19	n=19	n=16

Texas Creek

Plot #	1991	1992	1993	1994
1	present	present	present	present
2	"	"	"	"
3	too dense	too dense	too dense	too dense
4	too dense	too dense	too dense	too dense
5	too dense	too dense	missing	missing
6	present	present	present	present
7	"	"	"	
8	"	"	"	
9	"	"	"	
10	too dense	too dense	too dense	too dense
11	present	present	present	present
12	"	"	"	missing
13	"	"	"	present
14	"	"	"	"
15	present-early missing-late	missing	missing	missing
16	present	missing	missing	missing
17	"	present	present	present
18	"	"	"	"
19	"	"	"	"
20	"	"	"	"
21	"	"	"	"
22	"	"	"	"
23	"	"	"	"
24	"	"	"	"
Density/ fecundity:	n=24	n=22	n=21	n=20
Model:	n=20	n=18	n=18	n=17

Appendix 3

Lotus 1-2-3 data files for *Primula alcalina* monitoring plots, 1991-1994.

Arranged by site in the following order:

Summit Creek Exclosure
Moffett Creek
Lower Birch Creek-Fish and Game
Lower Birch Creek-Targhee
Lower Birch Creek-Private
Upper Birch Creek
Texas Creek

Appendix 4

Life stage transition data for *Primula alcalina*, 1991-1994.

From: Demographic monitoring of *Primula alcalina* (alkali primrose): 1991 - 1994, by Bob Moseley, January 1995. Submitted to the Salmon District, BLM.