U. S. Air Force
Air Combat Command

POPULATION MONITORING OF *LEPIDIUM DAVISII* (DAVIS' PEPPERGRASS), SMALL ARMS RANGE, MOUNTAIN HOME AIR FORCE BASE, IDAHO: 1991 - 1995

FINAL REPORT

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SUMMARY

Lepidium davisii (Davis' peppergrass) is a regional endemic restricted mainly to Ada, Elmore, and Owyhee counties, Idaho, and small parts of Twin Falls County, Idaho, Elko County, Nevada, and Malheur County, Oregon. In addition to a narrow distribution, it is also restricted to a very narrow set of habitat conditions: flat, hard floors of dry lake beds known as vernal pools or playas. These small, isolated habitats are subjected to numerous and varied disturbances on the Mountain Home Desert. For these reasons it is a category 2 candidate for federal listing.

Four populations are managed by the Mountain Home Air Force Base, one on the base and three on the associated Small Arms Range. The goal of this study is to provide pertinent population data for habitat management, in general, and development of a conservation strategy, in particular. During June and July, 1991, six permanent monitoring transects were established in the largest population on the Small Arms Range. After a hiatus in 1992, four more permanent transects were established in 1993 in two adjacent, smaller playas. All plots were sampled in 1993, 1994, and 1995. A total of 301 plots were used to collect density, population structure, and fecundity data for Davis' peppergrass. We also gathered data on sedimentation rates in the playas and the effect of exotic species on population viability.

We made 3967 observations of mapped plants during the four years of study. There was a 10% decline in the number of plants in our transects during the four years of observation. Much of the loss took place between 1991 and 1993, probably as a result of the 1992 drought. The population structure is heavily skewed toward the reproductive stage, averaging 84.5% of the population through the observation period, although it varied from 98% of the population to 73%. Nonreproductive individuals comprised the next largest category with 10% of the population. Seedlings were scarce, comprising just 2%. Reproductive output varied from year to year, with flower production correlated with winter and spring precipitation. This pattern does not hold true, however, for the number of seeds actually produced from those flowers. No seeds were produced on plants in the transects during 1991 and 1993, and very few in 1994. In 1995, an extraordinary number of flowers were produced and most inflorescences produced some viable fruit

We saw no difference in population density or fecundity within the weeded transects during the monitoring period. There was, however, a difference in the projected equilibrium growth rates between the weeded and unweeded transects; the weeded transects were stable while the unweeded transects were projected to decline. No sedimentation was measured during the four years of observation.

The projected equilibrium growth rate for the populations indicated that Davis' peppergrass is expected to decline in the future. Two main factors are probably contributing to this projected decline: low seedling survival and a relatively high mortality rate of mature individuals. In other words, recruitment of new individuals into the population is not replacing the death of mature plants.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 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; Owen and Rosentreter 1992). 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 germination 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 can be an important threat leading to extinction when populations are 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 have evolved from an emphasis on the inventory and status determination of rare species to active protection efforts. Such is the case of *Lepidium davisii* (Davis' peppergrass). Although currently a category 2 candidate for listing under the Endangered Species Act (U.S. Fish and Wildlife Service 1993; Conservation Data Center 1994; Idaho Native Plant Society 1995), Moseley (1995a) recommended that it be upgraded to a category 1 candidate due to the documented extirpation and declines in populations and habitat in the Mountain Home Desert portion of its distribution. While it is apparently stable and more or less secure in five of the six distribution centers it occupies, the entire disjunct segment of its distribution on the Mountain Home Desert is in jeopardy. Preliminary evidence indicates that there may be genetic differentiation between populations and distribution centers, and the fact that the Mountain Home Desert populations occupy the elevational and aridity extremes for the species as a whole, makes these populations an important evolutionary unit whose conservation must be addressed. Moseley (1995a) recommended that the Idaho Department of Parks and Recreation, the state agency responsible for rare plant conservation, pursue a Conservation Agreement with the Lower Snake River District BLM, Idaho Army National Guard, Idaho Department of Lands, and Mountain Home Air Force Base to maintain viable populations of Davis' peppergrass on the Mountain Home Desert.

Thompson (1990) conducted a rare plant survey of the Mountain Home Air Force Base in 1990, discovering three populations of Davis' peppergrass on the Small Arms Range (Conservation Data Center occurrence number 084; Moseley 1995a) and one on the Base (occurrence number 087). A long-term monitoring program was established for the largest population on the Small Arms Range in 1991 (Bernatas and Moseley 1991). Although monitoring lapsed in 1992, it was resumed in 1993 and expanded to the other two populations on the Range (Bernatas and Moseley 1993). All three populations were sampled again in 1994 (Bernatas *et al*. 1994) and 1995. Our demographic approach compliments the Davis peppergrass population monitoring being conducted by the Bureau of Land Management on the Mountain Home Desert. They are monitoring a greater number of populations, but collecting only population density and frequency data (Rosentreter 1994; Taylor-Grant and DeBolt 1995).

The goal of our monitoring study on the Small Arms Range is to help meet management and monitoring requirements for any future Conservation Agreement between the State of Idaho, U.S. Air Force, and U.S. Fish and Wildlife Service for conservation of Davis' peppergrass, as recommended by Moseley (1995a). The results of this study will provide important data for management plan development. Specific objectives of this study are to:

1. Initiate demographic monitoring of populations of Davis' peppergrass on the Small Arms Range;

2. Measure sedimentation rates in the playa habitats;

3. Collect seeds from an appropriate number of plants and to deposit them in a long-term seed storage facility; and

4. To determine the effect of exotic species invasion on the population viability of Davis' peppergrass.

2.0 DISTRIBUTION, LIFE HISTORY AND MORPHOLOGY OF DAVIS' PEPPERGRASS

Davis' peppergrass is a regional endemic, known to be extant at 293 populations, and extirpated from at least two others. The populations are scattered throughout an area of southwestern and south-central Idaho, north-central Nevada, and southeastern Oregon that is approximately 180 miles long by 90 miles wide. Within this area, populations occur in six distinct clusters or distribution centers: Mountain Home Desert (Idaho), Bruneau Desert (Idaho), Salmon Falls Creek (Idaho), South Fork Owyhee River (Idaho, Oregon, Nevada), Alvord Desert (Oregon), and Barren Valley (Oregon). It's habitat is a unique wetland community; a vernal lake or playa, that can be filled with water in the spring and dry as hard as concrete in the summer. Davis' peppergrass populations in the Mountain Home Desert distribution center show a decline and are the most vulnerable to extirpation. The overall cause of the decline is the poor ecological condition of the sagebrush-steppe ecosystem on the western Snake River Plain. There is no reversal in this trend seen in the near future. Populations in the other five distribution centers appear stable (Moseley 1995a).

Davis' peppergrass is a deep-rooted, widely-spaced perennial with a low compact growth form commonly referred to as a clump or cushion. Each plant has many slender stems, mostly unbranched, terminated by an inflorescence consisting of from 10 to 40+ flowers. Although individual flowers are small, they combine to form a showy display at anthesis. No reproductive ecology studies have been conducted, but it is pollinated by insects and probably predominantly an outcrosser. Each flower is capable of producing a two-celled fruit, each cell containing a seed (Moseley 1995a).

Growth begins early in the season, probably sometime in April, but the early growth may take place slowly in highly saturated soils or even submerged in a few inches of water. Flowering occurs in May at lower elevations and continues into July at higher sites. Fruits mature soon after anthesis and seed dispersal generally takes place in late July and August. Many years, however, ovules abort and many fruits in a population never mature. Leaves stay green and succulent throughout the growing season. The onset of dormancy takes place in the fall, probably late September or October.

3.0 STUDY SITE

The three hard-bottom playas containing populations of Davis' peppergrass selected for study are located on the Small Arms Range, north of Mountain Home Air Force Base (Figure 1). All are adjacent to one another, separated by narrow bands of upland habitat. On the Small Arms Range, there is a controlled or restricted area which includes targets and other structures surrounded by a buffer. Playa A, the largest of the three, is located within the

Figure 1

restricted area, adjacent to the fence along the west side. This population is not adjacent to a target area, however. Playas B and C are located adjacent to the large playa, but outside the fenced restricted area, west of the perimeter road.

The land surrounding the three playas has been burned by repeated wildfires that have degraded the native vegetation. Cheatgrass (*Bromus tectorum*), Russian thistle or tumbleweed (*Salsola kali*), and other exotic species dominate the perimeters of the playas, with a few widely scattered Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and Sandberg's bluegrass (*Poa secunda*) also present.

Playa A has an estimated population of 7,200 plants and an area of 2,204 m^2. When not inundated, the playa has a smooth clay surface that fractures into a polygonal crack system. A few small basalt stones are scattered across the surface. The Davis' peppergrass plants are of moderate size and density. The playa is devoid of other plant species, with the exception of a few, widely scattered cheatgrass and Russian thistle plants found in the cracks. There is a large drift of Russian thistle along the east side of the fence that was deposited in the winter of 1990-1991. This drift has since turned to 'mulch' approximately 1 foot thick. Davis' peppergrass plants that were located under the drift did not survive through the first summer (1991). Our sampling did not include the mulched area.

The population and area estimates for playas B and C are 1,300 plants and 430 m^2 and 3,500 plants and 530 m^2, respectively. These two smaller playas are nearly contiguous, separated by a small strip of upland vegetation (mostly cheatgrass). The perimeters of playas B and C are more undulating, providing a greater perimeter to area ratio than playa A. The playas have a greater coverage of small stones and lacks the expansive smooth clay surface and numerous fractures of Playa A. Russian thistle and cheatgrass density is much higher and these two exotic species are codominants with the Davis' peppergrass.

The climate of southwestern Idaho is characterized as continental and is modified by maritime air from the Pacific, especially in the winter. The summers are typically hot and dry and the winters are moderately cold. Precipitation is strongly seasonal and occurs principally as snow during the winter and rain during the spring and fall. Mountain Home falls within the Southwestern Valleys Climate Region in Idaho. At Mountain Home the annual precipitation is 10.33 inches, however it is highly variable from year to year. Data for the 33 year period between 1961 and 1994 indicate that the annual precipitation ranged from a high of 18.99 inches in 1970, to a low of 6.69 inches in 1992 for the Mountain Home and Mountain Home Air Force Base weather stations (University of Idaho 1995). Summer precipitation is sparse, coming in the form of brief and occasionally intense thunderstorms. The low humidity in the summer is accentuated by high average wind speeds. Precipitation data for the five year period of study appears in Table 1. Precipitation during this study was highly variable and included the driest year recorded in the last 33 years, 1992. Two years, 1993 and 1995, are near or above normal precipitation.

• Table 1.
Precipitation data for the Mountain Home Air Force Base weather station for 1991 through 1994, and the first six months of 1995 (University of Idaho 1995).
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Year	Total Annual (inches)	January - June (inches)
1991	9.62	4.63
1992	6.69	3.92
1993	10.27	8.78
1994	7.79	3.0
1995	------	7.75

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4.0 METHODS

4.1 *SEED COLLECTION*

No thorough analysis of genetic variability of Davis' peppergrass has yet been undertaken. Preliminary evidence, however, indicates that there genetic differences between populations and especially between disjunct distribution centers, such as those populations on the Mountain Home Desert (Moseley 1995a). The isolated nature of its habitat and the location of the Small Arms Range populations at the northern edge of the species distribution, suggests that the Air Force may be managing important and unique genotypes. Although habitat preservation is the most efficient and prudent method of genotype conservation, the use of long-term seed storage facilities has recently become viable. As recommended in Thompson (1990), seed was collected from an appropriate number of plants in each playa and deposited in facilities at the Berry Botanical Garden. Berry, located in Portland, Oregon, is the Pacific Northwest regional repository for rare plant seed.

4.2 *SEDIMENTATION RATES*

Increased sedimentation in playas resulting from the degradation of the surrounding landscapes is believed to have resulted in the decline in at least four populations of Davis' peppergrass (DeBolt and Doremus 1989; Rosentreter 1994). Thompson's (1990) survey indicates that this may be a threat to populations on the Small Arms Range. To measure sedimentation input into Playa A from the surrounding landscape, we used methods developed by the Lower Snake River District, BLM. The relatively simple method involves driving rebar into selected areas of the playas and measuring the above-ground height of the bar during successive years.

Rebar (4 ft. x 0.5 in.) was driven into the playa with a sledge hammer until it was impossible to drive it further. These rebar were also used to mark the start and finish of each transect. In addition, rebar was placed at measured distances along the transects to facilitate identifying the plot locations. Four foot rebar pieces were used to avoid frost heaving effects. Table 2 identifies the rebar location and the height of the top of the rebar above the playa surface in 1991.

• Table 2. Rebar location and height of rebar above the playa surface in 1991.

Transect	Rebar Identifier	Distance Along Transect (m)	Height Above Playa Surface (mm)
1	A	0	337
	B	11	320
	C	22	310
	D	34	383
	E	40	361
2	A	0	329
	B	11	370
	C	22	396
	D	37	386
	E	52.4	495
3	A	0	288
	B	11	356
	C	22	527
	D	39	325
4	A	0	370
	B	11	412
	C	22	574
	D	32	378
	E	38.8	384
5	A	0	370
	B	11	339
	C	22	472
	D	30.6	346
6	A	0	286
	B	11	417
	C	22	655
	D	31	538
	E	37.7	429

4.3 *POPULATION DEMOGRAPHY AND FECUNDITY*

For recording Davis' peppergrass demographic data we used methods developed by Lesica (1987). The technique employs a contiguous, subdivided belt transect that has been found to be useful for nonrhizomatous perennial plants with low to moderate density.

Six transects were located in 1991 in playa A. In 1993, four additional transects were added to the study in playas B and C (2 transects in each). Rebar was placed at the start and end of each transect and at intermediate locations to facilitate relocating the plots (Table 2). A fiberglass tape was stretched along the transect and aligned with the rebar. Plots were placed in a continuous belt along the east side of the transect on playa A, along north side in playa B, and along the northeast side of the transect in playa C.

A transect consists of adjacent 1 m^2 quadrats placed along one side of the tape. The quadrat is graduated in 1 cm increments along the x and y axes to be used for establishing a coordinate locator for each target plant encountered. For each quadrat along the transect there is a corresponding box on the data form where the location of each plant is mapped. Coded life history data for each plant are written next to the corresponding mark on the data form.

Lesica (1987) found that life history codes have to be developed on a case by case basis. Following are the life stage classes and their codes that were used for Davis' peppergrass.

S Seedlings - very small plants with one rosette of leaves. Attributes recorded: presence/location.

N Nonreproductive - plants greater than one rosette that are not producing inflorescences. Attributes recorded: presence/location.

R Reproductive - plants that have one or more inflorescences. Attributes recorded: (1) presence/location; (2) reproductive classes as described below:

> Number of inflorescences per plant.

> Number inflorescences per plant where all fruits were aborted.

> Number of inflorescences per plant removed by predation.

Size of each plant was calculated by measuring the diameter of each plant and averaging the longest and shortest dimensions of the living portion of the cushion, in centimeters.

4.4 *EXOTIC SPECIES COMPETITION*

To determine the long-term effects of exotic species competition on Davis' peppergrass, half the transects in playas B and C (transects 8 and 9) were weeded of all exotic species in 1993, 1994, and 1995. Playa A is largely weed free. Playas B and C had considerable cover of weeds, the density of which was greater than Davis' peppergrass. The resulting appearance of transects 8 and 9 was a noticeable narrow, weed-free strip 1 m wide. Care was taken to avoid disturbing Davis' peppergrass plants while weeding.

4.5 *POPULATION MODELING*

Field data were entered into LOTUS 1-2-3 files where descriptive statistics were computed (Appendix 1). These statistics, relating to the demography of the Davis' peppergrass population, were used to construct population models. Population modelling 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 modelling using transition matrices. Four years of data, representing three transitions (*i.e.*, 1991 to 1993, 1993 to 1994, and 1994 to 1995) 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).

5.0 RESULTS AND DISCUSSION

5.1 *SEED COLLECTION*

In 1991, 1993, and 1994 no seeds were collected because fruits did not mature and seed production was extremely low or nonexistent. In 1995, however, there was tremendous flowering and fruiting, resulted in high seed production. In late July, seeds were collected from all three playas, away from the transects to avoid biasing the potential for recruitment. Seed were sent to the Berry Botanical Garden for long-term storage. A portion was also sent to two researchers working on the biology of two rare *Lepidiums* in southwestern Idaho, *L. davisii* and *L. papilliferum*, in conjunction with the Idaho Army National Guard: (1) Dr. Timothy Lowery, University of New Mexico, Albuquerque, who has an ongoing study to elucidate genetic variability of the species, and (2) Dr. Susan Meyer, USFS Intermountain Research Station, Provo, Utah, who is working on seed and seedling ecology. Also included with seed from the Small Arms Range was seed we collected from a population along the South Fork of the Owyhee River.

5.2 *SEDIMENTATION RATES*

There was no measurable sedimentation into playa A during the four years of observation. The surrounding vegetation is in stable, although degraded condition. The cheatgrass and Russian thistle are dense and there is some Sandberg's bluegrass and Wyoming big sagebrush in the surrounding vegetation which may provide some soil stability.

5.3 *POPULATION STRUCTURE AND FECUNDITY*

Table 3 displays selected metrics relating to the population structure and fecundity of Davis' peppergrass on the Small Arms Range between 1991-1995. Data collected at each plot, as well as some summary statistics, appear in Appendix 1. We made 3967 observations of mapped plants during the four years of study, including 875 plants in 1991, 1092 plants in 1993, 1023 plants in 1994, and 977 plants in 1995. The increase in observed plants between 1991 and 1993 resulted from the addition of four transects in 1993.

The average density of all plots over the four years was 3.7 plants/m^2 (Table 3). Transect 3 represents the lowest density portion of the population with 2.0 plants/m^2, and Transect 9 the highest, with 8.9 plants/m^2. There was a 10% decline in the number of plants in our transects during the four years of observation. This decline varied between playas and between transects. Plants in playa A (transects 1-6) declined by 17.2% from 1993-1995, while those in playas B and C (transects 7-10) declined only 3.3%. If 1991 data is used for playa A, the decline is 23.5%. Most of the mortality occurred between 1991 and 1993 (probably during the 1992 drought). Variation in transects ranged from an increase of 9% in transect 1 to a decline of 52% in transect 6. The three transects on the eastern end of playa A, transects 4-6, declined 30%, 50%, and 52%, respectively, while the three transects on the

Table 3. Population structure and fecundity data for Davis' peppergrass on the Small Arms Range at Mountain Home Air Force Base, Elmore County, Idaho, 1991-1995.

	1991	1993	1994	1995	4-yr avg
TRANSECT 1					
Number of plots	40	40	40	40	40
Total plants observed	135	141	150	148	143.5
Density (plants/m^2)	3.4	3.5	3.8	3.7	3.6
Total seedlings (% population)	4 (3)	2 (1)	0 (0)	0 (0)	1.5 (1)
Total nonreproductive (%pop)	3 (2)	14 (10)	29 (19)	2 (1)	12 (8)
Total reproductive (% pop)	128 (95)	125 (89)	121 (81)	146 (99)	130 (91)
Avg#inflor/repro plant(±s.d.)	21.0 (17.9)	25.2 (28.9)	7.6 (8.6)	42.4 (38.9)	24.1
Avg # flowers/repro plant [a]	648	778	235	1310	743
Avg # fruits/repro plant (±s.d.)	0.0	0.0	0.7 (0)	36.3 (36.2)	9.3
Avg # seeds/repro plant [b]	0.0	0.0	1.4	72.6	18.5
Avg plant diameter in cm (±s.d.)	10.6 (5.3)	10.0 (6.7)	9.0 (4.3)	16.5 (7.4)	11.5

[a]Average number of flowers/reproductive plant = average number of inflorescences/reproductive plant (recorded in plots; Appendix 1) x 30.9 flowers/inflorescence (the average from 11 randomly chosen inflorescences from plants outside of the transects).

[b]Average number of seeds/reproductive plant = average number of fruits/reproductive plant x 2 seeds per fruit (Rollins 1948; personal observation).

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Table 3. Continued.

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	1991	1993	1994	1995	4-yr avg
TRANSECT 2					
Number of plots	52	52	52	52	52
Total plants observed	243	227	225	214	227.3
Density (plants/m^2)	4.7	4.4	4.3	4.1	4.4
Total seedlings (% population)	5 (2)	7 (3)	0 (0)	0 (0)	3.0 (1)
Total nonreproductive (%pop)	31 (13)	41 (18)	71 (32)	9 (4)	38.0 (17)
Total reproductive (% pop)	207 (85)	179 (79)	154 (68)	205 (96)	186 (82)
Avg#inflor/repro plant(±s.d.)	13.2 (17.3)	16.0 (23.9)	11.8 (10.6)	29.8 (36.8)	17.7
Avg # flowers/repro plant	408	494	365	921	547
Avg # fruits/repro plant (±s.d.)	0.0	0.0	0.05 (0)	29.7 (36.8)	7.4
Avg # seeds/repro plant	0.0	0.0	0.1	59.4	14.9
Avg plant diameter (±s.d.) (cm)	7.6 (5.3)	8.1 (8.3)	7.5 (4.7)	12.7 (7.9)	9.0
TRANSECT 3					
Number of plots	38	38	38	38	38
Total plants observed	80	88	61	75	76
Density (plants/m^2)	2.1	2.3	1.6	2.0	2.0
Total seedlings (% population)	0 (0)	21 (33)	0 (0)	0 (0)	5 (7)
Total nonreproductive (%pop)	4 (5)	0 (0)	16 (26)	0 (0)	5 (7)
Total reproductive (% pop)	76 (95)	68 (77)	45 (74)	75 (100)	66 (86)
Avg#inflor/repro plant(±s.d.)	22.3 (17.0)	33.9 (35.8)	not recorded	64.0 (48.8)	40.1
Avg # flowers/repro plant	689	1048	----	1978	1238
Avg # fruits/repro plant (±s.d.)	0.0	0.0	0.0	63.9 (46.0)	16.0
Avg # seeds/repro plant	0.0	0.0	0.0	127.8	32.0
Avg plant diameter in cm (±s.d.)	12.4 (4.8)	10.6 (8.7)	11.3 (4.7)	20.1 (3.8)	13.6

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Table 3. Continued.

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	1991	1993	1994	1995	4-yr avg
TRANSECT 4					
Number of plots	37	37	37	37	37
Total plants observed	141	127	110	98	119
Density (plants/m^2)	3.8	3.4	3.0	2.6	3.2
Total seedlings (% population)	1 (1)	6 (4)	0 (0)	0 (0)	1.8 (1)
Total nonreproductive (%pop)	13 (9)	11 (9)	26 (24)	0 (0)	12.5(11)
Total reproductive (% pop)	127 (90)	110 (87)	84 (76)	98 (100)	104 (88)
Avg#inflor/repro plant (±s.d.)	12.2 (10.5)	14.9 (16.7)	0.0	49.9 (43.7)	19.3
Avg # flowers/repro plant	377	460	0.0	1542	595
Avg # fruits/repro plant (±s.d.)	0.0	0.0	0.0	49.6 (43.7)	12.4
Avg # seeds/repro plant	0.0	0.0	0.0	99.2	24.8
Avg plant diameter in cm (±s.d.)	10.3 (5.1)	9.8 (7.2)	10.0 (4.9)	18.6 (7.6)	12.2
TRANSECT 5					
Number of plots	29	29	29	29	29
Total plants observed	90	71	55	45	65.3
Density (plants/m^2)	3.1	2.4	1.9	1.6	2.3
Total seedlings (% population)	0 (0)	4 (6)	1 (2)	0 (0)	1.3 (2)
Total nonreproductive (%pop)	15 (17)	10 (14)	9 (16)	0 (0)	8.5 (13)
Total reproductive (% pop)	75 (83)	57 (80)	45 (82)	45 (100)	55.5(85)
Avg#inflor/repro plant (±s.d.)	8.9 (8.3)	9.9 (13.3)	0.0	35.5 (33.1)	13.6
Avg # flowers/repro plant	275	305	0.0	1097	344
Avg # fruits/repro plant (±s.d.)	0.0	0.0	0.0	34.8 (33.3)	8.7
Avg # seeds/repro plant	0.0	0.0	0.0	69.6	17.4
Avg plant diameter in cm (±s.d.)	9.5 (4.6)	7.9 (7.3)	8.1 (4.9)	15.9 (6.7)	10.4

Table 3. Continued.

	1991	1993	1994	1995	4-yr avg
TRANSECT 6					
Number of plots	36	36	36	36	36
Total plants observed	186	121	111	89	126.8
Density (plants/m^2)	5.2	4.3	3.1	2.5	3.6
Total seedlings (% population)	1 (1)	8 (6)	1 (1)	1 (1)	2.8 (2)
Total nonreproductive (%pop)	24 (12)	25 (21)	45 (41)	0 (0)	23.5(19)
Total reproductive (% pop)	161 (87)	88 (73)	65 (58)	88 (99)	100 (79)
Avg#inflor/repro plant (±s.d.)	6.5 (7.5)	4.1 (6.8)	0.0	19.9 (19.1)	7.6
Avg # flowers/repro plant	201	127	0.0	615	236
Avg # fruits/repro plant (±s.d.)	0.0	0.0	0.0	19.8 (18.9)	4.9
Avg # seeds/repro plant	0.0	0.0	0.0	39.6	9.9
Avg plant diameter in cm (±s.d.)	7.3 (5.7)	4.6 (5.2)	5.9 (3.3)	11.5 (5.3)	7.3 (2.5)

Table 3. Continued.

	1993	1994	1995	3-yr avg
TRANSECT 7				
Number of plots	22	22	22	22
Total plants observed	58	56	53	55.7
Density (plants/m^2)	2.6	2.5	2.4	2.5
Total seedlings (% population)	4 (7)	0 (0)	0 (0)	1.0 (3)
Total nonreproductive (% pop)	2 (3)	5 (9)	0 (0)	2.3 (4)
Total reproductive (% pop)	52 (90)	51 (91)	53 (100)	52 (93)
Avg # inflor/repro plant ($\pm$s.d.)	7.8 (5.4)	0.0	12.9 (7.7)	6.9
Avg # flowers/repro plant	241	0.0	399	213
Avg # fruits/repro plant ($\pm$s.d.)	0.0	0.2 (0.8)	12.8 (7.8)	5.3
Avg # seeds/repro plant	0.0	0.5	25.6	10.5
Avg plant diameter in cm ($\pm$s.d.)	7.8 (3.7)	6.5 (2.0)	10.3 (3.7)	8.2
TRANSECT 8				
Number of plots	21	21	21	21
Total plants observed	75	74	75	74.7
Density (plants/m^2)	3.6	3.5	3.6	3.6
Total seedlings (% population)	1 (1)	0 (0)	1 (1)	0.7 (1)
Total nonreproductive (% pop)	0 (0)	7 (9)	0 (0)	2.3 (3)
Total reproductive (% pop)	74 (99)	67 (91)	74 (99)	71.7 (96)
Avg # inflor/repro plant ($\pm$s.d.)	10.6 (6.3)	not recorded	16.3 (9.1)	13.5
Avg # flowers/repro plant	328	----	501	415
Avg # fruits/repro plant ($\pm$s.d.)	0.0	0.7 (0)	16.2 (9.0)	5.6
Avg # seeds/repro plant	0.0	1.4	32.4	11.3
Avg plant diameter in cm ($\pm$s.d.)	9.0 (3.1)	6.0 (1.9)	12.8 (11.3)	9.3

Table 3. Continued.

	1993	1994	1995	3-yr avg
TRANSECT 9				
Number of plots	15	15	15	15
Total plants observed	134	133	133	133.3
Density (plants/m^2)	8.9	8.9	8.9	8.9
Total seedlings (% population)	0 (0)	1 (1)	0 (0)	0.3 (1)
Total nonreproductive (% pop)	11 (8)	34 (25)	4 (3)	16.3 (11)
Total reproductive (% pop)	123 (92)	98 (74)	129 (97)	116.7 (88)
Avg # inflor/repro plant (±s.d.)	7.2 (8.0)	not recorded	12.1 (11.9)	9.7
Avg # flowers/repro plant	222	----	374	298
Avg # fruits/repro plant (±s.d.)	0.0	0.6 (0)	11.8 (12.0)	4.1
Avg # seeds/repro plant	0.0	1.2	23.6	8.3
Avg plant diameter in cm (±s.d.)	6.6 (3.4)	5.0 (2.5)	8.2 (3.8)	6.6
TRANSECT 10				
Number of plots	11	11	11	11
Total plants observed	50	48	47	48.3
Density (plants/m^2)	4.5	4.4	4.3	4.4
Total seedlings (% population)	2 (4)	0 (0)	0 (0)	0.7 (2)
Total nonreproductive (% pop)	8 (16)	22 (46)	1 (2)	10.3 (21)
Total reproductive (% pop)	40 (80)	26 (54)	46 (98)	37.3 (77)
Avg # inflor/repro plant (±s.d.)	6.0 (5.9)	0.0	10.3 (7.2)	5.4
Avg # flowers/repro plant	185	0.0	318	167
Avg # fruits/repro plant (±s.d.)	0.0	0.0	10.0 (7.4)	3.3
Avg # seeds/repro plant	0.0	0.0	20.0	6.7
Avg plant diameter in cm (±s.d.)	5.7 (3.1)	4.1 (1.6)	7.2 (2.8)	5.6

Table 3. Continued.

SUMMARY OF ALL TRANSECTS

	1991	1993	1994	1995	summary
Number of plots	232	301	301	301	-----
Total plants observed	875	1092	1023	977	total = 3967
Density (±s.d.) (plants/m^2)	3.7 (1.0)	3.9 (1.8)	3.7 (1.9)	3.6 (1.9)	avg = 3.7 (0.1)
Total seedlings (% population)	11 (2)	54 (5)	3 (1)	2 (0.4)	2.1% (1.8 ±s.d.)
Total nonreproductive (% pop)	90 (10)	176 (16)	267 (26)	16 (1.6)	13.4% (8.9±s.d.)
Total reproductive (% pop)	774 (88)	862 (79)	753 (73)	959 (98)	84.5% (9.4±s.d.)
Avg#inflor/repro plant (±s.d.)	14.0 (5.8)	13.5 (8.9)	2.8 (4.5)	29.3 (17.4)	avg = 14.9
Avg # flowers/repro plant	433	417	87	905	avg = 460
Avg # fruits/repro plant (±s.d.)	0.0	0.0	0.2 (0.3)	28.5 (17.0)	avg = 7.2
Avg # seeds/repro plant	0.0	0.0	0.5	57.0	avg = 14.4
Avg plant diameter (±s.d.) (cm)	9.6 (1.8)	8.0 (1.8)	7.3 (2.2)	13.4 (4.1)	avg 9.6

western side remained more or less stable. The reason that the eastern transects declined is unknown, although they may represent marginal Davis' peppergrass habitat that is more sensitive to fluctuations in environmental conditions, especially precipitation. The eastern edge of the playa is not as sharply defined as the western edge, creating a diffuse border with cheatgrass extending farther into the playa.

The population structure at all seven sites is heavily skewed toward the reproductive stage, averaging 84.5% of the population through the observation period, although it varied from 98% of the population in 1995, to 73% in 1994 (Table 3). Nonreproductive individuals comprised the next largest category with 10% of the population, fluctuating between 26% in 1994, and 1.6% in 1995. Seedlings were generally scarce at all transects, comprising just 2% of the population. This population structure is similar to that observed in other rare perennial plants of the region (Lesica and Elliott 1989; Moseley and Mancuso 1993), although many others have a population structure skewed toward nonreproductive individuals (*e.g.*, Kaye 1992; Moseley and Mancuso 1993; Kaye *et al*. 1994; Moseley 1995b).

Reproductive output varied from year to year, a pattern consistent at all transects. The pattern of flower production between 1991 and 1995 (Table 3; Figure 2) is correlated with winter and spring precipitation the same years (Table 1). The lowest precipitation year, 1994, had the lowest number of flowers produced. It's unfortunate that no data were collected during 1992, the driest year recorded for southwestern Idaho. Plant diameter is directly related to the number of flowers produced and also fluctuated with precipitation (Figure 2). As plant size fluctuates, so does the number of branches and, because each branch is terminated by an inflorescence, so does the number of flowers. This pattern does not hold true, however, for the number of seeds actually produced from those flowers (Table 3). No seeds were produced on plants in the transects during 1991 and 1993, and very few in 1994. Most ovules aborted and the fruits did not produce seeds during this period (Appendix 1). Some were also lost to predation by a beetle. In 1995, an extraordinary number of flowers were produced (almost twice the four-year average) and most inflorescences produced some viable fruit, with an average of 57 seeds being produced by each reproductive plant.

5.4 *EXOTIC SPECIES COMPETITION*

No significant differences were observed in population density and structure over the three year observation period in the weeded transects 8 and 9 (Table 3). The effect of varying precipitation patterns appears to have a greater effect, at least over the three years of observation. Reduced competition resulting from the weeding treatment may manifest itself over the long-term, however.

There was a difference in the degree of population change seen in the two treatments. The unweeded transects (7 and 10) declined by 6.5%, while the weeded transects (8-9) remained stable. Competition between Davis' peppergrass and the exotic weeds, cheatgrass and Russian thistle, may account for this difference.

Figure 2. Davis' peppergrass flower production and plant size (from Table 3) in relation to January-June precipitation between 1991 and 1995 (Table 1). Units on the right-hand Y axis are centimeters for plant diameter and inches for precipitation. Pearson's test shows that there is a 93% chance of flower production and spring precipitation being significantly correlated, but more data points are needed for an accurate test.

5.5 *POPULATION MODEL*

Matrix projections begin with the stage structure (*i.e.*, seedling, nonreproductive, reproductive) of the Davis' peppergrass 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 survivorship, fecundity, and transfer (growth) rates in order to project (model) the future dynamics of the population.

We prepared a projection matrix corresponding to the life cycle of the species using data from all transects and all years (Table 4; see also Appendix 2 for life stage transition data for the ten transects). Each number in the matrix represents a transfer from the column stage to the row stage. For example, in one year, 22% of nonreproductive individuals remain nonreproductive (column 2, row 2), while 58% become reproductive (column 2, row 3). Projection matrices were also constructed for other combinations including Transition 1 (1991 to 1993; Table 5), Transition 2 (1993 to 1994; Table 6), and Transition 3 (1994 to 1995; Table 7). These projection matrices are illustrated diagramaticly in Figures 3 - 6, where the arrows represent transfers that take place between stages each year. Because there were larger population declines in playa A compared to the two smaller ones, we prepared projection matrices for playa A (transects 1-6; Table 8; Figure 7) and playas B and C (transects 7-10; Table 9; Figure 8).

We know little about the reproductive -> seed -> seedling transitions in the life cycle of Davis' peppergrass. Our demographic monitoring skipped the seed stage entirely and little information exists from which to accurately calculate this transition. From preliminary data it appears that most seed is short-lived, with only 15% remaining viable after the second year (Dana Quinney, Idaho Army National Guard, Boise, personal communication, November 1995). For a long-lived plant such as Davis' peppergrass, however, little seed may need to survive until germination conditions become suitable for the population to remain stable of over the long-term. Because no data currently exist on the subject, we had to assume that seed predation is zero, although this is probably not the case. Due to this lack of data, we skipped the seed stage and calculated the reproductive to seedling transition for all transects by dividing the number of 1993, 1994, and 1995 seedlings by the number of 1991, 1993, and 1994 reproductive plants, respectively (Table 4; Figure 3). The reproductive to seed transfer in Transition 1 (Table 5; Figure 4) was calculated with 1991 reproductive plants and 1993 seedlings. The other two transitions were calculated similarly. This is a very simplistic method and the model will have to be refined as additional seed ecology information becomes available.

Table 4. Projection matrix for the life cycle of Davis' peppergrass using data from all transects and all years. Lambda = population equilibrium growth rate (expressed as the dominant eigenvalue by RAMAS/stage).

		FROM:		
		Seedling	Nonreproductive	Reproductive
TO:	Seedling	0.00	-----	0.003
	Nonreproductive	0.09	0.22	0.08
	Reproductive	0.06	0.58	0.83
	Mortality	0.83	0.20	0.09

lambda = 0.9025

Figure 3. The life cycle of Davis' peppergrass corresponding to the projection matrix in Table 4.

83%

Reproductive

3%

6%

8%

58%

Seedling

9%

Nonreproductive

22%

Table 5. Projection matrix for the life cycle of Davis' peppergrass using data from Transition 1 (1991 to 1993). Lambda = population equilibrium growth rate (expressed as the dominant eigenvalue by RAMAS/stage).

		FROM:		
		Seedling	Nonreproductive	Reproductive
	Seedling	0.11	-----	0.07
	Nonreproductive	0.00	0.25	0.08
TO:	Reproductive	0.22	0.33	0.72
	Mortality	0.67	0.43	0.20

lambda = 0.7914

Figure 4. The life cycle of Davis' peppergrass corresponding to the projection matrix in Table 5.

```
                                72%
                    ••••••••••••••
                    •Reproductive•
                    ••••••••••••••

       7%                                   33%
                    22%           8%


  ••••••••••                            •••••••••••••••••
  •Seedling•                            •Nonreproductive•
  ••••••••••              0%            •••••••••••••••••
11%                                                      25%
```

Table 6. Projection matrix for the life cycle of Davis' peppergrass using data from Transition 2 (1993 to 1994). Lambda = population equilibrium growth rate (expressed as the dominant eigenvalue by RAMAS/stage).

		FROM:		
		Seedling	Nonreproductive	Reproductive
	Seedling	0.00	-----	0.003
	Nonreproductive	0.11	0.50	0.15
TO:	Reproductive	0.04	0.32	0.79
	Mortality	0.85	0.18	0.06

lambda = 0.9080

Figure 5. The life cycle of Davis' peppergrass corresponding to the projection matrix in Table 6.

79%

Reproductive

0.3% 4% 15% 32%

Seedling 11% Nonreproductive

50%

Table 7. Projection matrix for the life cycle of Davis' peppergrass using data from Transition 3 (1994 to 1995). No equilibrium growth rate could be calculated because of no seedling survival in this transition.

		FROM:		
		Seedling	Nonreproductive	Reproductive
TO:	Seedling	0.00	-----	0.002
	Nonreproductive	0.00	0.06	0.01
	Reproductive	0.00	0.81	0.98
	Mortality	1.00	0.13	0.01

Figure 6. The life cycle of Davis' peppergrass corresponding to the projection matrix in Table 7.

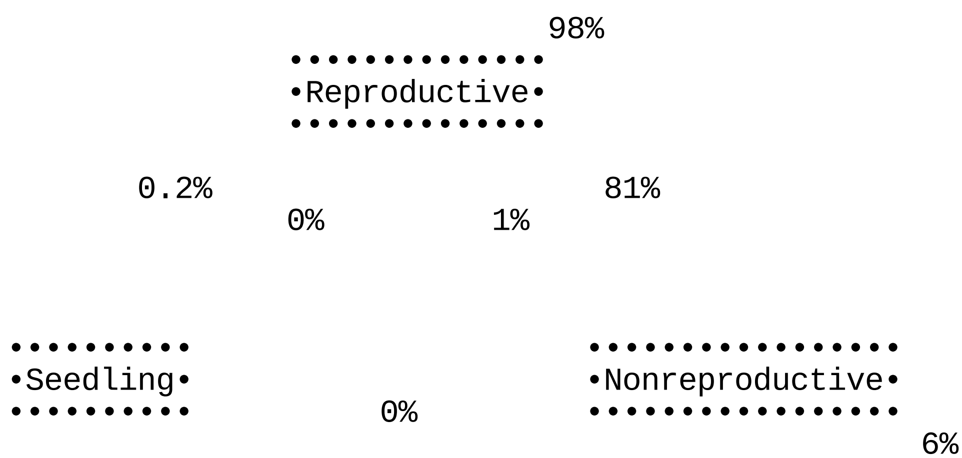

Table 8. Projection matrix for the life cycle of Davis' peppergrass using data from playa A, transects 1-6 (1991 to 1995). Lambda = population equilibrium growth rate (expressed as the dominant eigenvalue by RAMAS/stage).

		FROM:		
		Seedling	Nonreproductive	Reproductive
	Seedling	0.00	-----	0.02
	Nonreproductive	0.09	0.23	0.08
TO:	Reproductive	0.07	0.54	0.82
	Mortality	0.82	0.23	0.11

lambda = 0.8888

Figure 7. The life cycle of Davis' peppergrass corresponding to the projection matrix in Table 8.

82%

Reproductive

3%

54%

7%

8%

Seedling

9%

Nonreproductive

23%

Table 9. Projection matrix for the life cycle of Davis' peppergrass using data from playas B and C, transects 7-10 (1993 to 1995). Lambda = population equilibrium growth rate (expressed as the dominant eigenvalue by RAMAS/stage).

		FROM:		
		Seedling	Nonreproductive	Reproductive
TO:	Seedling	0.00	-----	0.004
	Nonreproductive	0.14	0.19	0.11
	Reproductive	0.00	0.76	0.88
	Mortality	0.86	0.05	0.01

lambda = 0.9856

Figure 8. The life cycle of Davis' peppergrass corresponding to the projection matrix in Table 9.

88%

Reproductive

0.4% 0% 11% 76%

Seedling 14% Nonreproductive

19%

The variation in transfer probabilities seen in Transitions 1, 2 and 3 are most likely attributed to fluctuations in precipitation and inundation. In the transition from a wet year (1993) to a dry year (1994) in Transition 2, 15% of 1993 reproductive plants did not flower in 1994, twice the four-year average. In contrast, the transition from 1994 to another moist year, 1995, only 1 percent transferred in this direction, while 81% of the 1994 nonreproductive plants flowered in 1995, and 98% of the reproductive individuals stayed in the reproductive class in 1995. Mortality of reproductive plants was almost nil in 1995, and relatively low for nonreproductive plants (the 100% mortality figure for seedlings in 1995 is based on only 2 seedlings). It appears then, that during dry years, fewer mature Davis' peppergrass plants flower than wet years and that these plants are able to flower in subsequent wet years. This pattern is similar to the biomass, flower, and fruit production seen during dry and wet years (Table 3; Figure 2). As mentioned before, it is unfortunate that no data were collected in 1992, a record dry year. The transition probabilities between 1992 and 1993, a wet year, could have been used to corroborate or contradict this pattern.

Although 1992 demographic data are missing, the 1991 to 1993 transition is instructive in at least one way. Most 1991 seedlings became reproductive individuals by 1993 (Figure 4), nearly four times the four-year average (Table 3). It appears that if seedlings survive the first year, most (all?) will flower during their second year, at least under the climatic conditions that prevailed from 1991 to 1993.

The combined matrix model for all transects, as executed by RAMAS/stage, projects that the Davis' peppergrass populations on the Small Arms Range are expected to decline if environmental conditions remain constant. The equilibrium growth rate (lambda) is 0.9025 (Table 4), indicating that they will decrease in size. The growth rate could not be calculated for transition 3 (1994-1995) because no seedlings survived. Of the two transitions that could be calculated, transition 1 (1991-1993) showed the greatest decline of all equilibrium growth rates calculated (lambda = 0.7914; Table 5). This reflects the high loss of plants during this transition, probably resulting from the drought in 1992. The population in playa A can be expected to decline more rapidly than playas B and C, with equilibrium growth rates of 0.8888 and 0.9856, respectively.

Two main factors are probably contributing to this projected decline: low seedling survival and a relatively high mortality rate of mature individuals. In other words, recruitment of new individuals into the population is not replacing the death of mature plants. Keep in mind, however, that these declines are projected using only three transitions. As more data are collected and more environmental variability is accounted for, the equilibrium growth rates for this long-lived perennial may stabilize closer to 1.0.

Elasticity gives the proportional importance of demographic transitions to population growth. Elasticity matrices for the same projection matrices presented in Table 4 - 9 are presented in Table 10 (except for transition 3, which could not be calculated due to lack of seedling survival). Growth and survival of reproductive individuals was consistently important in all analyses.

Table 10. Elasticities for Davis' peppergrass stage transition matrices for which equilibrium growth rates were determined (Tables 4 - 9).

All transects all years

	Seedling	Nonreproductive	Reproductive
Seedling	0	0	0.00454
Nonreproductive	0.00254	0.02273	0.06796
Reproductive	0.00199	0.0705	0.82974

Transition 1 (1991-1993)

	Seedling	Nonreproductive	Reproductive
Seedling	0.0041	0	0.02543
Nonreproductive	0	0.02533	0.05486
Reproductive	0.02543	0.05486	0.80999

Transition 2 (1993-1994)

	Seedling	Nonreproductive	Reproductive
Seedling	0	0	0.00036
Nonreproductive	0.00024	0.1234	0.10047
Reproductive	0.00011	0.10071	0.67471

Playa A (transects 1-6)

	Seedling	Nonreproductive	Reproductive
Seedling	0	0	0.00329
Nonreproductive	0.00169	0.2388	0.06672
Reproductive	0.0016	0.6841	0.83439

Playas B and C (transects 7-10)

	Seedling	Nonreproductive	Reproductive
Seedling	0.	0	0.00049
Nonreproductive	0.00049	0.2258	0.09407
Reproductive	0	0.09456	0.78782

6.0 CONCLUSIONS AND RECOMMENDATIONS

> **Seed Collection -** In three of the four years, seed production was severely limited and no seed was collected. In 1995, however, the plants were vigorous and flower and seed production was substantial. Seed was sent to the Berry Botanical Garden for long-term storage to be available for *ex situ* conservation measures if needed in the future. Seed was also sent to the University of New Mexico and the USFS Intermountain Research Station, where studies of the conservation genetics and germination requirements of two rare *Lepidium* species are underway.

> **Sedimentation** - No sedimentation was measured in playa A during the four years of observation. Other workers have observed that when surrounding vegetation is converted to annual grasslands or otherwise disturbed, siltation often increases. The climatic event that triggers high sedimentation rates is probably episodic in nature, dumping large quantities all at once, instead of a continuous input of small amounts. The 1991-1995 monitoring period did not include such an episode and observations of sedimentation rates should continue to be made as part of an ongoing monitoring program by the Mountain Home Air Force Base.

> **Restoration of a Buffer** - To preclude the possibility of a deleterious sedimentation event, the poor ecological condition of vegetation surrounding the playas should be improved. As technology develops to restore sagebrush-grasslands, at least on a small scale, it may be prudent to restore the surrounding habitat to protect the Davis' peppergrass.

> **Population Demography and Fecundity** - There was a 10% decline in the number of plants in our transects during the four years of observation. Playa A declined the most with much of the loss taking place between 1991 and 1993, probably as a result of the 1992 drought. The population structure is heavily skewed toward the reproductive stage, averaging 84.5% of the population through the observation period, although it varied from 98% of the population in 1995, to 73% in 1994. Nonreproductive individuals comprised the next largest category with 10% of the population. Seedlings were scarce, comprising just 2%. Reproductive output varied from year to year, with flower production correlated with winter and spring precipitation. This pattern does not hold true, however, for the number of seeds actually produced from those flowers. No seeds were produced on plants in the transects during 1991 and 1993, and very few in 1994. In 1995, an extraordinary number of flowers were produced and most inflorescences produced some viable fruit.

> **Spring Precipitation** - Biomass, flower, and, to a lesser extent, fruit production is positively correlated to spring precipitation. We also found that most mature individuals will flower during wet years, while many will revert to nonflowering status during subsequent dry years.

> **Weeding Treatment** - Although we did not see a difference in population density or fecundity within the weeded transects from 1993-1995, the competitive effect of exotic weeds on the Davis' peppergrass population may not manifest itself for several years. There was, however, a difference in the projected equilibrium growth rates between the weeded and unweeded transects; the weeded transects were stable while the unweeded transects were projected to decline. As with the observations on sedimentation rates, the weeding treatment should be continued.

> **Projected Decline** - The projected equilibrium growth rate for the populations are all less than 1.0, indicating that Davis' peppergrass is expected to decline. Two main factors are

probably contributing to this projected decline: low seedling survival and a relatively high mortality rate of mature individuals. In other words, recruitment of new individuals into the population is not replacing the death of mature plants. Keep in mind, however, that these declines are projected using only three transitions. As more data are collected and more environmental variability is accounted for, the equilibrium growth rates for this long-lived perennial may stabilize closer to 1.0.

> **Continue Monitoring** - Predictions made regarding the fate of Davis peppergrass populations on the Small Arms Range will become more robust the longer monitoring data is collected. Davis' peppergrass is a long-lived species and four years of data cannot capture all the variability inherent in the population and in environmental conditions. We recommend that the population monitoring continue, but with a reduced effort. A subsample of five randomly selected plots per transect, sampled annually, would provide a suitable long-term data set.

> **Population on Base Should be Added** - The population on the Mountain Home Air Force Base, near the hospital, should be included in this monitoring effort in 1996.

> **Pre-listing Conservation Agreement** - A Conservation Agreement with the Department of Parks and Recreation and U. S. Fish and Wildlife Service, covering populations of Davis' peppergrass managed by the Mountain Home Air Force Base, would provide management protocols for protection this rare species.

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Appendix 1

Lotus 1-2-3 data files for Davis' peppergrass monitoring plots, 1991-1995.

Appendix 2

Life stage transition data for Davis' peppergrass, 1991-1995.