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THE ECOLOGY OF *Arabis fecunda*: LONG-TERM MONITORING, KNAPWEED REMOVAL, AND SOIL CRUST ECOLOGY STUDIES.

1988 PROGRESS REPORT

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INTRODUCTION

In order to adequately protect populations of an organism, it is necessary to understand its life history and population dynamics (Massey and Whitson 1980; Sutter 1986; Palmer 1987). In addition, many rare species are threatened by interactions with non-native species that have been introduced into their habitat (Drake 1988). It is important to understand the nature of these interactions in order to protect populations of rare species from extinction.

Arabis fecunda Rollins (Sapphire rockcress) is a rosette-forming perennial in the mustard family (Brassicaceae). This recently described species (Rollins 1984) is endemic to highly calcareous, azonal soils in the foothills of the Sapphire and Pioneer mountains in Ravalli, Beaverhead and Silver Bow counties, Montana (Lesica 1985; Schassberger 1988). *Arabis fecunda* occurs on eroding slopes with low vascular plant density but a relatively high cover of cryptogamic soil crust. Populations of *A. fecunda* are thought to be threatened by livestock grazing and encroachment by *Centaurea maculosa* Lam. (spotted knapweed), an aggressive exotic weed (Lesica 1985; Schassberger 1988).

This paper is a progress report on three studies being conducted on populations of *A. fecunda* in Ravalli County. The studies and their purposes are:

1. Long-term monitoring of *A. fecunda* populations in order to determine important life history attributes and trends in overall recruitment and mortality.

2. Spotted knapweed removal study, in order to determine the effects of knapweed competition on the performance of *A. fecunda*.

3. Soil crust ecology study, in order to assess the importance of soil crust to the establishment and survival of *A. fecunda* plants.

METHODS

Study Areas

Studies were conducted at two *Arabis fecunda* sites in Ravalli County, Montana: Charleys Gulch and Birch Creek. The Charleys Gulch site is on a steep, eroding, southwest-facing slope along the drainage at an elevation of ca. 1524 m. (5000 ft.) (T6N R19W S29, NW1/4). The Birch Creek site is on a steep, eroding, southeast-facing slope above the creek at an elevation of ca. 1433 m. (4700 ft). (T7N R19W S16, NW1/4). Complete descriptions of the study sites can be found in Lesica (1985) and Schassberger (1988).

Long-term Monitoring Study

In May, 1987, we established permanent belt transects of 12 adjacent 1 m^2 plots at both sites following the methods outlined in Lesica (1987). Individual A. fecunda plants were mapped and recorded using the following system:

S = seedling
R = the number of rosettes per plant
I = the total number of inflorescences (stems) per plant
F = the total number of fruits produced by the plant

Thus, a plant with two rosettes, three stems and a total of nine fruits would be recorded as R1-I3-F9. Seedlings were recognized by their small size and the absence of leaves from the previous year. In addition, we noted the presence of recently disturbed soil and evidence of livestock trampling. We did not record seedlings at the Birch Creek site in 1987. The transects were read on May 19-20, 1987 and 1988.

Knapweed Removal Study

In May, 1987, we established permanent belt transects consisting of 10 adjacent 1 m^2 plots at each of the study sites following the methods of Lesica (1987). Transects were placed in areas with relatively heavy knapweed infestations. Individual A. fecunda plants were mapped and recorded as in the long-term monitoring study. For each transect, we removed the knapweed from five randomly selected plots by carefully cutting the plants below the root crown with a sharp knife. Knapweed was removed from plots 2,4,5,8, and 9 at Birch Creek and from plots 1,4,5,8, and 9 at Charleys Gulch. We did not record seedlings at the Birch Creek site in 1987. The transects were read on May 19-20, 1987 and 1988.

Soil Crust Ecology Study

In order to determine whether there is an association between intact cryptogamic soil crust and the distribution of A. fecunda, we estimated cover of soil crust and bare ground in belt transects consisting of adjacent 1 m^2 plots. These transects were chosen to be representative of the steep, highly erodible slopes where A. fecunda is most frequent. We measured cover of bare ground and soil crust using a point-frequency frame (Mueller-Dombois and Ellenberg 1974, p. 86). The frame was 1 X 1 m with 20 equally-spaced pins. In each plot, the pins were dropped to the surface and the number of hits on bare soil and soil crust was recorded. Hits on exposed rock were not included in subsequent analyses. The diameter of the pins was approximately equal to the diameter of a taproot of A. fecunda (ca. 0.1 in). In addition, we recorded the number of A. fecunda plants rooted in the soil crust and the total number of A.

fecunda plants in each 1 m^2 plot. At Charleys Gulch, we read two transects (10 and 12 plots), and at Birch Creek, we read one transect (22 plots). All of the transects were located in areas subject to livestock grazing. Transects were read on May 19-20, 1988.

RESULTS AND DISCUSSION

Long Term Monitoring Study

A summary of the data from two years of the long-term monitoring study is presented in Table 1. At both sites the density of plants was slightly lower in 1988 than in 1987. In addition, the number and percentage of fruiting plants was appreciably lower in 1988 than in 1987. At both sites, however, the total number of fruits per fertile plant, and the number of fruits per inflorescence, was greater in 1988. These results probably indicate various stress responses to the drought conditions that began in 1987 and continued into 1988.

Size and fecundity data for individual Arabis fecunda plants over the two-year period are presented in Appendix A. These data are summarized in Table 2. It is too early in the study to determine whether these populations are stable, growing or declining; nonetheless, it is worth noting some trends. At Charleys Gulch, where only one plant was lost to apparent soil slumping, recruitment and adult mortality were approximately equal in both years. At Birch Creek, where 15 plants were lost to soil slumping, adult mortality was appreciably higher than recruitment. In most cases of soil slumping at Birch Creek, we observed hoof prints of cattle in the slumped areas. If these 15 plants had not been lost, mortality and recruitment would have been approximately equal. At Charleys Gulch, apparent seedling survival was greater than seedling mortality. However, these results have limited meaning because appreciable seedling mortality may have occurred prior to reading the transects in late May.

Knapweed Removal Study

One year after removing spotted knapweed plants from the experimental plots, its cover was approximately equal to that in the control plots (Table 3). This result can be explained in part by new recruitment of seedlings and in part by a failure to completely eradicate all plants in 1987. Nonetheless, the competitive ability of knapweed in the removal plots should have been reduced during at least part of the 1987 growing season.

Table 1. Population density and fecundity data for *Arabis fecunda* in long-term monitoring transects, 1987-1988.

		Birch Creek	Charleys Gulch
Density (plants/m^2)	1987	5.0	6.3
	1988	4.6	5.2
# plants fruiting	1987	17	26
	1988	7	10
% plants fruiting	1987	34%	41%
	1988	11%	14%
# fruits per fruiting plant	1987	3.8	5.7
	1988	14.0	6.3
# fruits per inflorescence	1987	2.3	2.3
	1988	5.2	4.3
% plants with more than one rosette	1987	11%	22%
	1988	7%	29%
% one-rosette plants with fruit	1987	25%	37%
	1988	13%	24%
% multi-rosette plants with fruit	1987	83%	67%
	1988	0%	13%

Table 2. Summary of size and fecundity data for individual *Arabis fecunda* plants in permanent monitoring transects, 1987-1988.

	Birch Creek	Charleys Gulch
Plants first observed in 1988	9	5
1987 plants not observed in 1988	25	7
Number of plants with a greater number of rosettes in 1988	3	3
Number of plants with a smaller number of rosettes in 1988	2	0
Plants with the same number of rosettes in 1987 and 1988	33	30
Plants with increased fecundity in 1988	3	6
Plants with decreased fecundity in 1988	10	12
Seedling survival	--	64%

Table 3. Percent canopy cover of knapweed (Centaurea maculosa) in removal transects in 1987 and 1988 (before knapwed removal). An asterisk (*) indicates plots from which knapweed was removed; remaining plots are controls.

Charleys Gulch #2

Year	1*	2	3	4*	5*	6	7	8*	9*	10	Control Mean	Removal Mean
1987	20	25	20	25	28	23	20	23	30	25	23	25
1988	5	20	28	15	18	30	25	23	18	35	28	16

Birch Creek #2

Year	1	2*	3	4*	5*	6	7	8*	9*	10	Control Mean	Removal Mean
1987	30	35	35	30	33	38	28	23	23	28	32	29
1988	30	20	30	30	20	30	15	30	30	20	25	26

Density and fecundity data for plants of A. fecunda in removal and control plots are presented in Table 4. In general, these data show the same trends as found in the long-term monitoring study: a drastic reduction in number and percent of plants fruiting and an increase in the average number of fruits per inflorescence and per fruiting plant in 1988 (see above for discussion). Density of A. fecunda plants at Charleys Gulch showed no increase in 1988 in either the control plots or the removal plots. At Birch Creek, while control plots showed no appreciable increase in density of A. fecunda plants in 1988, there was a more than three-fold increase in the removal plots. The density of A. fecunda in individual removal and control plots in 1987 and 1988 at Birch Creek are presented in Table 5. Between 1987 and 1988, density decreased slightly in all but one of the control plots, while density increased in all but one of the knapweed removal plots. Our notes from 1987 indicate that there were large numbers of seedlings in plots 8, 9, and 10. Many of these survived in the removal plots (plots 8 and 9), but few survived in the control plot (plot 10). These results suggests that A. fecunda recruitment may be curtailed by the presence of knapweed.

Soil Crust Ecology Study

In this study, the null hypothesis is that within the three belt transects Arabis fecunda plants are distributed at random, i.e., without respect to the presence of soil crusts. The results of a chi-square analysis of the data are presented in Table 6. The null hypothesis was strongly rejected in all three cases, indicating that the distribution of A. fecunda is not random. The data show that A. fecunda is associated more often with soil crusts than bare soil within the transects. There are two possible explanations for these results: (1) A. fecunda is able to establish and survive better in soil crusts, and/or (2) A. fecunda is able to establish and survive with equal success in bare soil and soil crusts; however, perturbations caused by livestock destroy not only the A. fecunda plants growing in bare soil and soil crust, but also the soil crust itself. This would result in an increase in the amount of bare soil without A. fecunda. These two explanations are not mutually exclusive.

If the first explanation is correct, A. fecunda may be dependent on the presence of soil crusts to maintain viable population levels within these transects. Grazing by livestock has been shown to reduce the cover of soil crusts (St. Clair et al. 1984), thus reducing the availability of microsites which are important for seedling establishment and survival. If the second explanation is correct, livestock grazing is destroying A. fecunda plants in these transects regardless of whether they are rooted in bare soil or soil crusts. Under either interpretation, our results indicate that livestock grazing is detrimental to populations of A. fecunda on the steep, highly erodible slopes in these transects.

Table 4. Density and fecundity data for *Arabis fecunda* in knapweed removal transects.

		Birch Creek		Charley's Gulch	
		Removal	Control	Removal	Control
Density (plants/m^2)	1987	16.0	21.4	12.8	14.2
	1988	54.6	24.0	14.2	14.6
# plants fruiting	1987	44	41	29	24
	1988	6	7	2	2
% plants fruiting	1987	55%	38%	45%	34%
	1988	2%	6%	3%	3%
# fruits per fruiting plant	1987	6.3	4.8	4.7	4.1
	1988	15.2	5.7	11.5	8.5
# fruits per inflorescence	1987	2.5	2.4	2.2	2.2
	1988	5.1	3.6	4.6	3.4
% plants with more than one rosette	1987	19%	36%	14%	25%
	1988	7%	17%	13%	29%
% one-rosette plants with fruit	1987	51%	55%	47%	28%
	1988	2%	8%	4%	2%
% multi-rosette plants with fruit	1987	73%	66%	33%	50%
	1988	10%	0%	0%	5%

Table 5. Density of *Arabis fecunda* plants in individual knapweed removal and control plots at the Birch Creek site in 1987 and 1988.

Control

Plot #	1987	1988
1	23	21
3	27	25
6	11	26
7	19	18
10	27	29

Removal

Plot #	1987	1988
2	16	20
4	22	26
5	15	13
8	16	145
9	11	69

Table 6. Density of bare soil and soil crust and the number of *Arabis fecunda* plants growing in each type of substrate in three belt transects.

Site	# point hits on soil crust	# point hits on bare soil	# of *A. fecunda* in soil crust	# of *A. fecunda* in bare soil	x^2	P
Birch Creek	97	289	81	48	61	<0.0001
Charleys Gulch West	83	117	100	27	44	<0.0001
Charleys Gulch	78	147	52	21	30	<0.0001

CONCLUSIONS

All of the studies reported on are still in progress, and any conclusions must be considered tentative until more data has been collected. Nonetheless, several trends are apparent and are worthy of comment. Results of the long-term monitoring and soil crust ecology studies suggest that livestock grazing on the steep highly erodible slopes, where the transects were located, is destructive, and is probably detrimental to the long-term viability of *Arabis fecunda* populations. Results of the knapweed removal study suggest that, under certain circumstances, spotted knapweed may be inhibiting recruitment of *Arabis fecunda* seedlings. Thus, both livestock grazing and knapweed encroachment may pose a threat to populations of *Arabis fecunda*.

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Appendix A. Performance of individual _Arabis fecunda_ plants in permanent monitoring transects in 1987 and 1988. Seedlings were not recorded at Birch Creek in 1987. An asterisk (*) indicates a plant lost due to slumping soil.

Birch Creek

Plot #	1987	1988
1.	R1	R1
	R1	R1
	R3	R4
	R2-I3-F6	R2
2.	R1	--*
	R1	--*
	R1	--*
	R1	--*
	R1	--*
	R1	R1
	R1-I1-F3	--
	R1	R1
	R1	R1
	R1	R1
	R1-I2-F3	--*
3.	R1-I1-F1	--*
	R1-I2-F4	--*
	R1	--*
4.	R2	--*
	R1	R1
	--	R1
	R1	R1
	--	R1
5.	R1	--
	R1	R1
	R1	R1
	R2-I1-F6	R1
	R1	R1
	R1	R1
	R1	--
6.	R1	R2
	R1	R1
	--	R1
	R1-I2-F6	R1
	R1-I1-F3	R1-I3-F9
	R2-I2-F5	R1
	R1	R1
	--	R1
	R1	R1-I2-F12

7.	R1-I1-F3	R1
	R1	--
	R1-I2-F2	R1
	R1	--
8.	R1-I1-F3	R3
	R1	R1
	R1-I2-F4	R1
	R1	R1
	R1	R1
9.	R2-I2-F5	--*
	R1-I3-F6	--*
	R1-I1-F5	--*
	R1	--*
	R2-I1-F2	--*
10.	--	S
	--	S
11.	R1	R1
	R1	--
	R1	--
	R1	R1
	R1	R1-I1-F3
	--	R1
	--	R1
	--	R1
12.	R1-I3-F7	R1
	R1	R1
	R1	--
	R1	R1
	R1-I1-F1	--
	R1	R1
	R1-I2-F3	R1
	R1	--
	R1	R1
	--	R1
	--	S
	--	S
	--	S
	--	R1
	--	R1
13.	NOT RECORDED	R1
		R1
		R1-I1-F5
		R1
		R1
		R1-I5-F22

14.	NOT RECORDED	R1-I5-F34
		R1
		R1
		R1
		R1-I2-F13

Charleys Gulch

1.	S	R1
	R1-I1-F2	R1-I1-F3
	S	R2
	S	R1
	R1-I4-F15	R1-I5-F23
2.	S	R1-I1-F6
3.	NO PLANTS	
4.	R1-I3-F5	R1
	R2-I4-F11	R2-I1-F5
5.	S	--
	R1-I5-F15	R1-I2-F5
6.	S	--
	R1-I1-F4	R1-I1-F5
	R1-I5-F13	R1-I2-F12
	--	R2
	--	S
	--	S
	--	S
	S	R1
7.	R1-I5-F11	R1-I13-F17
	R1-I1-F2	R2
	R1-I1-F2	--*
	S	S
	S	R2
	R1-I3-F1	R1-I4-F17
8.	NO PLANTS	
9.	NO PLANTS	
10.	R2	R2
	R1-I3-F6	R1
	R1	R1
	R1	R1
	R2-I2-F5	R2
	S	--
	S	--
	R1-I6-F0	--

11.	R3-I4-F8	R3
	R1-I1-F2	R1
	R1-I1-F1	R1
	R3	--
	R1	R1
	R1	R1
	R1	R1
	R2	R2
	R3-I3-F5	R3
12.	R2-I1-F4	--
	R1-I1-F2	R1
	R1-I1-F2	R1
	R2	R2
	--	S