# Restoration of Native Upland Prairies: Habitat for Fender's Blue Butterfly (*Icaricia icarioides fenderi)*

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**Order No. 10181M660**

**November 2005**

**SUMMARY**

Our project goal is to promote the abundance of the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*) by recreating upland prairie habitat in former agricultural land at Finley National Wildlife Refuge, Corvallis, Oregon. To achieve this goal we initiated the following three studies.

Study One: Experimental Investigation on the Effectiveness of Restoration Treatments
Our approach was to set up experimental field plots in a former agricultural field into which we sowed seeds of native grasses and dicots in the fall for two years, 2003 and 2004.

*Objective one*: Investigate the effect of carbon banding on abundance of sowed native species and non-native species. Carbon banding is a treatment used by Willamette Valley grass seed farmers to promote seedling establishment of agricultural grasses and inhibit seedling establishment of weeds.

*Objective two:* Investigate the effect of the sowing sequence of native dicot and grass species on the abundance and species richness of the sowed species. Our experiments were designed to test the hypothesis that our native grasses are more aggressive than the target native dicots in the initial stages of restoration.

*Objective three*: Investigate the effect of the sowing sequence of the native dicot and grass species on the abundance of non-native species.

Study Two: Monoculture Sowing of Native Species Compare the cover of non-native species and the cover of native species one and two years after sowing native species in monocultures.

Study Three: Buffer Sowing of Native Grasses Monitor the abundance of the native grasses sowed in the buffer areas outside the experimental plots.

Carbon banding had no significant effect on cover of non-native species or on cover and species richness of sowed native dicots or grasses after both the first and second growing seasons. However, carbon banding tended to reduce the cover of the annual *Clarkia rhomboidea* after the first growing season.

Our results supported the hypothesis that our native grasses are more aggressive than the target native dicots in the initial stages of restoration. The sowing sequences tested did not affect cover and species richness of grasses but did affect cover and species richness of dicot species. Both dicot cover and dicot species richness were greater when sowed a year ahead of the grasses. *Eriophyllum lanatum* had significantly greater cover when sowed a year before the grasses. Average cover of sowed dicots was significantly greater when dicots were sowed with grasses compared to when dicots were sowed into a year-old stand of grasses. In particular, *Madia gracilis* and *Prunella vulgaris* var. *lanceolata* had less cover when sowed into the existing stand of grass.

Species richness of all native species (grasses + dicots) was significantly less when dicots were sowed into a year-old stand of grasses. However, total cover and species richness of sowed native species (grasses + dicots) were not significantly different whether dicots were sowed a year ahead of the grasses or whether dicots and grasses were sowed together. Average cover of sowed native dicots after two years was always greater than the cover of sowed native grasses except when dicots were sowed a year after the grasses.

After two growing seasons, non-native cover did not significantly vary among the three sowing sequences of sowing grasses and dicots at the same time, sowing grasses into existing dicot vegetation, and sowing grasses into existing dicot vegetation.

The first year after sowing the monocultures (Study two), *Collinsia grandiflora* had the highest cover, greatly surpassing the next top performers, *Sanguisorba occidentalis* and *Madia gracilis*, all of which are annual species. In general, the cover of individual species sowed in monocultures decreased the second year after sowing. Only seven species, all of which were perennials, out of the 26 sowed species increased in cover. Two of these species *Eriophyllum lanatum* and *Prunella vulgaris* var. *lanceolata* were the top performers for 2005, but their cover did not reach the levels of the top performers in 2004.

**Management Recommendations**

We make the following recommendations based on the results of the species tested in this short-term study. Note that most of these perennial native species take more than two seasons to reach maturity. Thus, longer-term data collected from these experiments will produce even more valuable recommendations.

- Carbon banding is not recommended as a restoration tool as it did not enhance abundance of native species and did not inhibit non-native species.
- To maximize species richness and cover of dicots:
  a) if the choice is to sow dicots before or with grasses, sow dicots before grasses.
  b) if the choice is to sow dicots with grasses or after grasses, sow dicots with grasses.
- The sequence of sowing grasses did not affect cover or species richness of grasses. Therefore we recommend that other considerations be given greater weight when determining when to sow grasses.
- To maximize cover and species richness of total native cover (grasses +dicots), either sow dicots before or with grasses and avoid sowing dicots a year after sowing grasses.
- Of the grass species, we recommend *Festuca roemeri* and *Bromus carinatus* to get initial high cover and for persistence.
- Dicot species that produced initial high cover included the annuals *Collinsia grandiflora*, *Collomia grandiflora, Clarkia amoena, C. rhomboidea*, and *Madia gracilis*. However, only *Madia gracilis* maintained its high cover into the second year in mixed sowings. *Prunella vulgaris* var. *lanceolata* and *Eriophyllum lanatum* are good perennial dicot species to sow for increased cover over time.
- To minimize non-native cover, increase the sowing rate that was used in this study of 50 seeds/ft$^2$. Include a large number of annual dicot species in the first year sowing mix to provide initial high cover.

## INTRODUCTION

The Willamette Valley was once an immense landscape of prairies and oak savannahs that were maintained by burning by the Kalapuya native people. However, due to agricultural activities, urbanization, and introduction of weedy non-native plant species, less than 1% of these native prairie lands remain.

The remnant prairies that do remain contain a diversity of plants and animals species found in no other place, including many rare and endangered species (USFWS 2000). Two of these rare species are the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*) and its host plant, the threatened Kincaid's lupine (*Lupinus sulphureus* spp. *kincaidii*). These species require a prairie ecosystem to survive: a mixture of native plant species, including nectar plants; a prairie structure of low vegetation with bunchgrasses; and a diversity of native insects and soil biota that result from native prairie vegetation (Hammond and Wilson 1992, Wilson et al. 1997, Schultz et al. 2003, Wilson et al. 2003).

Managers of public agencies such as the U. S. Fish and Wildlife Service have two approaches for preserving this diversity. One is to restore and conserve existing native prairie remnants (e.g., Clark and Wilson 2001). They also are attempting to recreate native prairies from former agricultural fields. A crucial step in recreating native prairies is establishing native plants. Challenges to successful establishment include the selection of proper species and the control of non-native cover. Former agricultural fields, especially fields that have been allowed to go fallow, can present formidable weed problems. Our study aims to provide key information on the type and sequence of species to sow in the face of competition from non-native plant species.

## GOAL

Promote the abundance of the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*) by recreating upland prairie habitat in former agricultural land at Finley National Wildlife Refuge, Corvallis, Oregon.

## STUDIES AND APPROACHES

The approach used for study one was to set up experimental field plots in a former agricultural field into which we sowed seeds of native grasses and dicots in the fall for two years. For studies two and three we established monitoring plots into which seed of native species were sowed once. All plots were monitored for two years.

### **<u>Study One</u>:**

### Experimental Investigation on the Effectiveness of Restoration Treatments

**Objective one:** Investigate the effect of carbon banding on abundance of sowed native species and non-native species. Carbon banding is a treatment used by Willamette Valley grass seed farmers to promote seedling establishment of agricultural grasses and inhibit, with the use of the pre-emergent herbicide, seedling establishment of weeds.

**Objective two**: Investigate the effect of the sowing sequence of native dicot and grass seed on the abundance and species richness of the sowed species. The following three predictions are based on the hypothesis that our native grasses are more aggressive that our target native dicots in the initial stages of restoration.

a) We predicted that the native dicots would gain an advantage by being sowed a year before the native grasses and that the native dicots would be inhibited when sowed into a year-old stand of native grasses.
b) We predicted that the native grasses would be robust enough to be sowed with dicots and would also not be harmed by being sowed the year after the establishment of the dicots.
c) We predicted that total sowed native cover and species richness (dicots + grasses) would be maximized with the sowing sequence in which the dicots were sowed a year before the grasses. We also predicted that total sowed native cover and species richness would be the least with the sowing sequence in which the dicots were sowed into a year old stand of grasses.

**Objective three**: Investigate the effect of the sowing sequence of the native dicot and grass species on the abundance of non-native species. Based on the hypothesis that the greater the initial sowing density of the native species, the greater the inhibition of non-native species, we predicted that cover of non-native species would be the least with the treatment in which the dicots and monocots were sowed at the same time.

**Study Two: Monoculture Sowing of Native Species** Compare the cover of non-native species and the cover of native species one and two years after sowing native species in monocultures.

**Study Three: Buffer Sowing of Native Grasses** Monitor the abundance of the native grasses sowed in the buffer areas outside the experimental plots.

## STUDY SITE

The field study was conducted at William Finley National Wildlife Refuge approximately 16 km south of Corvallis, Oregon. The site, about 25 acres, is located near the western entrance to the Refuge at approximately 330 feet above sea level. The mapped soil type is Hazelair complex, which is a composite of moderate to well-drained silt loams and silty clay loams (Knezevich 1975). The soils at this site are moist throughout the winter, but the site is on a topographically high area that drains to an adjacent pond.

Until recently this site (Field 29) was managed to grow various cultivated crops. US Fish and Wildlife personnel, in actions separate from this study, took steps in 2002 to restore the site to a native upland prairie:

- August 29, 2002: prescribed burn
- September 17 and 19, 2002: drilled seed native grasses
- November 5, 2002: spot herbicide sprayed post-burn green-up of new vegetation
- November 14, 2002: sprayed entire field with herbicide due to poor vegetative response, i.e., heavy annual rye grass growth

## STUDY SPECIES

The study species, five native grasses, and 22 native dicot species are listed in Table 1. Species selection was based on importance in native upland prairies and seed availability. Seed of the dicots and *Poa scabrella* was purchased from Heritage Seedlings, Inc. (4194 71$^{st}$ Avenue, S.E., Salem, OR 97301). USFWS provided seed for the other four grass species.

The average weight of three replicates of 100 seeds was used to weigh out lots of seeds for the sowing treatments. For the grasses the average weight of 103 seeds was used. Any chaff was included in the weights as we were unable to entirely separate the chaff from the seeds.

Viability of seed was estimated by seed germination tests, the results of which are presented in Appendix A.

**Table 1**. Target species for restoration study at Finley National Wildlife Refuge, 2003-2005.

| | |
|---|---|
| **<u>Grasses</u>** | |
| *Bromus carinatus* | perennial |
| *Danthonia californica* | perennial |
| *Elymus glaucus* | perennial |
| *Festuca roemeri* | perennial |
| *Poa scabrella* | perennial |
| **<u>Dicots</u>** | |
| *Clarkia amoena* | annual |
| *Clarkia rhomboidea* | annual |
| *Collinsia grandiflora* | annual |
| *Collomia grandiflora* | annual |
| *Gilia capitata* | annual |
| *Lotus micranthus* | annual |
| *Lotus purshianus* | annual |
| *Lupinus micranthus* | annual |
| *Madia gracilis* | annual |
| *Sanguisorba occidentalis* | annual |
| *Trifolium tridentatum* | annual |
| *Achillea millefolium* | perennial |
| *Agoseris grandiflora* | perennial |
| *Aquilegia formosa* | perennial |
| *Eriophyllum lanatum* | perennial |
| *Erythronium oreganum* | perennial |
| *Lomatium utriculatum* | perennial |
| *Ligusticum apifolium* | perennial |
| *Potentilla glandulosa* | perennial |
| *Potentilla gracilis* | perennial |
| *Prunella vulgaris var. lanceolata* | perennial |
| *Sidalcea campestris* | perennial |

## STUDY ONE
## Experimental Investigation on the Effectiveness of Restoration Treatments

### METHODS FOR STUDY ONE: Experimental Investigation on the Effectiveness of Restoration Treatments

#### *Experimental Design*

The study design consisted of a randomized block design with five replicated blocks (Appendix B, Plot layout). Each block contained 5 treatments with buffers (30 ft × 30 ft) between the treatments. The treatments were 21ft × 21ft, with 21 one-foot wide planting rows running north-south and another 21 one-foot wide planting rows running east-west. Three permanent sampling quadrats (0.5m × 1.0m) were randomly placed within each treatment.

Treatments one and two were designed to test the effects of carbon banding on abundance and species richness of native species and abundance of non-native species (Table 2). Treatments two, three, four and five were designed to test the effect of sowing sequence of dicots and grass species on abundance and species richness of native species and abundance of non-native species (Table 2). All measurements for these tests were taken in 2004, two years after initiation of management treatments.

a) To determine whether to sow dicots with grasses or sow dicots a year before grasses, dicot cover and dicot species richness were compared between Treatments 2 and 4.
b) To determine whether to sow dicots with grasses or sow dicots a year after grasses, dicot cover and dicot species richness were compared between Treatment 5 and 3.
c) To determine whether to sow grasses with dicots or to sow grasses a year before dicots, grass cover and grass species richness were compared between Treatments 2 and 3.
d) To determine whether to sow grasses with dicots or sow grasses a year after dicots, grass cover and grass species richness were compared between Treatments 5 and 4.
e) To determine the effect of sowing sequence on total native cover and species richness and on non-native cover, Treatments 2, 3 and 4 were compared.

Seeds were sowed at a density of 25 seeds/$ft^2$ for the grass seed mixture and at a density of 25 seeds/$ft^2$ for the dicot seed mixture, either in the fall of 2003 or 2004, depending on the treatment.

The response variables, cover of each sowed native species and cover of non-native species as a group, were measured in late spring of 2004 and 2005 (Table 3). Species richness of native species was calculated from cover data.

#### *Data Analysis*

Effects of treatments were analyzed using analysis of variance (STATGRAPHICS Plus Version 5.0 November, 2000), using rank transformed data when necessary to meet statistical assumptions. All treatments were compared and when appropriate, separation of means tests (LSD, Least Significant Difference), were used ($\alpha = 0.05$).

**Table 2.** Description of treatments for Study one, Investigating the effectiveness of restoration treatments on seedling establishment of sowed native species.

| Treatment | Sowing sequence | | Carbon treatment |
|---|---|---|---|
| | **Fall 2003** | **Fall 2004** | |
| 1 | Grass seed mixture + Dicot seed mixture | | application of carbon/fertilizer slurry; no application of Diuron |
| 2 | Grass seed mixture + Dicot seed mixture. | | application of carbon/fertilizer slurry; application of Diuron |
| 3 | Grass seed mixture | Dicot seed mixture | application of carbon/fertilizer slurry; application of Diuron |
| 4 | Dicot seed mixture | Grass seed mixture | application of carbon/fertilizer slurry; application of Diuron |
| 5 | | Grass seed mixture + Dicot seed mixture | no application of carbon/fertilizer slurry; no application of Diuron |

**Table 3**. Dates for collection of vegetation cover data.

| Study | Year | Dates |
|---|---|---|
| Experimental investigation of the effectiveness of restoration treatments | 2004 | May 12-25 |
| | 2005 | May 18-26, June 1 |
| Monitoring study on monoculture sowing | 2004 | May 12, 26, June 10 |
| | 2005 | June 15, 22 |
| Monitoring study on buffer sowing | 2004 | June 2 |
| | 2005 | July 6 |

***Field Procedures***

Year one

Before seed was sowed in fall 2003, the study site was tilled October 6, 7, and 8 by the USFWS with a John Deere 9100 and heavy disc with cult-packer repeatedly run at shallow depth, similar to a roto-tiller. Seeding in Treatments 1-4 was done on October 14, 2003 with a cone planter mounted on a carbon planter. Grass seed mixtures were planted in rows that ran at right angles to the rows in which dicot seed mixtures were planted.

Seeds are dispensed from the cone planter immediately after the carbon slurry is sprayed on the ground in a 1inch band. The carbon slurry is a mixture of activated charcoal, water (0.5 lb charcoal/gallon of water) and fertilizer (N-P-K-S: 7-7-0-5). About 25 pounds of charcoal are used per acre.

After sowing on the same day, a pre-emergent herbicide, Diuron, was applied to Treatments 2, 3, and 4 at a rate of 1qt/acre. A total of 20 gallons of chemical solution was applied (20 gallons of water/1qt chemical). No herbicide was used with Treatment one. The carbon absorbs the pre-emergent herbicide, preventing mortality of the sowed seeds (personal communication, Mark Melbye, Linn County Extension Service). The pre-emergent lasts about 2-3 months, supposedly long enough for a competitive advantage for the sowed seeds (personal communication, Mark Melbye, Linn County Extension Service). The technique has been used for at least 25 years in the Willamette Valley by commercial grass seed farmers.

On October 30, 2003, after the seeds were sowed and before any of the sowed seeds had germinated, experimental plots and buffer areas were sprayed with an herbicide (2% glyphosate).

Year two

In preparation for the second year sowing, the experimental plots were mowed September 24, 2004 at a height of about 3 inches with a John Deere 6400 with a 15-foot batwing mower, run at PTO speed.

Treatment 5 was tilled on October 5, 2004 by the USFWS with a John Deere 6400 and roto-tilled, run at PTO speed. The tilled depth was approximately 4-6 inches. Seed was sowed in Treatments 3, 4 and 5 on October 14, 2004. Sowing depth was about ½ inch (range ¼ to ½) in Treatment 5, which was just tilled, and about ¼ inch or less in the untilled Treatments 3 and 4. Seeds were sowed at a density of 25 seeds/ft$^2$ for dicots and at a density of 25 seeds/ft$^2$ for grasses (the same density as for the 2003 sowing). The seeds were sowed in rows at right angles to the previous year's sowing for Treatments 3 and 4.

## RESULTS AND DISCUSSION FOR STUDY ONE:
## Experimental Investigation on the Effectiveness of Restoration Treatments

**Objective One** *Investigate the effect of carbon banding on abundance of sowed native species and non-native species. Carbon banding is a treatment used by Willamette Valley grass seed farmers to promote seedling establishment of agricultural grasses and inhibit seedling establishment of weeds*.

Non-native species cover averaged 24%-29% across treatments in year one (Table 4) and 32%-38% in year two (Table 5). Carbon planting did not significantly decrease non-native cover (Treatment 1 vs. Treatment 2) (P>0.05).

Average cover of sowed native grasses did not increase significantly (P >0.05) when they were sowed with the carbon banding treatment (Treatments 1 vs. 2), in year one (Table 4) or year two (Table 5). The same was true of the sowed native dicots (Tables 4 and 5), although the cover of the annual, *Clarkia rhomboidea*, was actually reduced with the application of the carbon banding treatment in year one (P<0.05) (Table 6).

Species richness of native sowed dicots and native sowed grasses in year two did not significantly increase with the carbon banding treatment (P>0.05) (Table 5).

**Table 4:** Effect of experimental management treatments on average cover (%) of non-native species and average cover of sowed native species at Finley National Wildlife Refuge May 2004 following sowing in October 2003 (Year one). Subscripts indicate the year of sowing. d = dicots; g = grasses. Values in parentheses are standard deviations.

| | **Cover (%) (sd)** | | | |
|---|---|---|---|---|
| | **Treatment 1** $d_{03} + g_{03}$ **(no carbon banding)** | **Treatment 2** $d_{03} + g_{03}$ | **Treatment 3** $d_{04} + g_{03}$ | **Treatment 4** $d_{03} + g_{04}$ |
| non-native species | 28.17 (7.60) | 28.77 (10.94) | 26.93 (10.62) | 24.30 (11.85) |
| sowed native dicots | 12.18 (7.20) | 9.60 (6.46) | | 11.93 (9.83) |
| sowed native grasses | 7.40 (5.06) | 10.07 (5.51) | 10.70 (5.87) | |
| sowed native dicots + grasses | 19.58 (10.82) | 19.67 (9.95) | | |

**Table 5**. Comparison of experimental restoration management treatments (carbon banding and sowing sequence of grasses and dicots) on average cover (%) of non-native species, cover of sowed native grasses and dicots, and species richness at Finley National Wildlife Refuge in May 2005, following sowing in October 2004 (Year two). Subscript indicates the year of sowing; d = dicots; g = grasses. Values in parentheses are standard deviations.

| | **Treatment 1** $d_{03} + g_{03}$ **(no carbon banding)** | **Treatment 2** $d_{03} + g_{03}$ | **Treatment 3** $d_{04} + g_{03}$ | **Treatment 4** $d_{03} + g_{04}$ | **Treatment 5** $d_{04} + g_{04}$ |
|---|---|---|---|---|---|
| non-native cover (%) | 33.9 (13.1) | 35.9 (12.0) | 35.7 (10.9) | 38.1 (14.1) | 32.3 (9.2) |
| sowed native cover (%) | 15.7 (8.6) | 14.5 (10.8) | 8.0 (4.8) | 15.2 (12.4) | 2.7 (2.7) |
| sowed grass cover (%) | 4.5 (4.0) | 5.6 (4.1) | 7.8 (4.6) | 0.1 (0.3) | 0.3 (0.4) |
| sowed dicot cover (%) | 11.3 (7.5) | 8.9 (8.0) | 0.2 (0.4) | 15.1 (12.3) | 2.5 (2.6) |
| sowed native species richness | 10.3 (2.5) | 10.9 (3.4) | 6.6 (2.1) | 9.8 (3.2) | 5.9 (2.8) |
| sowed grass species richness | 3.2 (0.9) | 3.8 (1.14) | 3.7 (0.7) | 0.7 (0.5) | 1.1 (0.3) |
| sowed dicot sp. richness | 7.1 (1.9) | 7.1 (3.1) | 2.9 (2.1) | 9.1 (3.0) | 4.8 (3.1) |

**Table 6:** Effect of experimental management treatments on mean cover (%) of individually sowed native species at Finley National Wildlife Refuge in May 2004 following sowing in October 2003 (Year one). Values in parentheses are standard deviations. A pair of treatment means with different letters denotes a statistically significant difference for that comparison. Subscript indicates the year of sowing. d = dicots; g = grasses.

| **Species** | **Cover (%) (sd)** | | | |
|---|---|---|---|---|
| | **Treatment 1** $d_{03} + g_{03}$ **(no carbon banding)** | **Treatment 2** $d_{03} + g_{03}$ | **Treatment 3** $d_{04} + g_{03}$ | **Treatment 4** $d_{03} + g_{04}$ |
| Grasses | | | | |
| *Bromus carinatus* | 3.43 (2.29) | 5.90 (3.63) | 5.63 (3.80) | |
| *Danthonia californica* | 0.07 (0.18) | 0.47 (0.83) | 0.52 (0.73) | |
| *Elymus glaucus* | 1.52 (1.40) | 1.08 (1.19) | 1.43 (1.30) | |
| *Festuca roemeri/ Poa scabrella* | 2.75 (3.02) | 3.15 (2.99) | 3.72 (2.68) | |
| Dicots | | | | |
| *Achillea millefolium* | 0.07 (0.26) | 0.20 (0.56) | | 0.07 (0.26) |
| *Agoseris grandiflora* | 0.77 (1.43) | 0.30 (1.03) | | 0.17 (0.45) |
| *Aquilegia formosa* | 0.0 (0.0) | 0.0 (0.0) | | 0.0 (0.0) |
| *Clarkia amoena* | 2.27 (3.54) | 0.75 (1.40) | | 0.37 (0.67) |
| ***Clarkia rhomboidea*** | **1.77a (2.13)** | **0.37b (0.77)** | | 0.10 (0.28) |
| *Collinsia grandiflora* | 4.40 (3.43) | 3.20 (3.15) | | 5.00 (7.63) |
| *Collomia grandiflora* | 1.30 (1.45) | 2.13 (2.54) | | 1.63 (2.09) |
| *Eriophyllum lanatum* | 0.17 (0.65) | 0.07 (0.18) | | 0.07 (0.18) |
| *Erythronium oreganum* | 0.0 (0.0) | 0.0 (0.0) | | 0.0 (0.0) |
| *Gilia capitata* | 0.17 (0.52) | 0.13 (0.35) | | 0.23 (0.62) |
| *Ligusticum apifolium* | 0.0 (0.0) | 0.0 (0.0) | | 0.0 (0.0) |
| *Lotus micranthus* | 0.47 (0.55) | 0.43 (0.65) | | 0.77 (1.08) |
| *Lotus purshianus* | 0.30 (0.68) | 0.28 (0.57) | | 0.10 (0.28) |
| *Lomatium utriculatum* | 0.22 (0.43) | 0.57 (0.8) | | 0.37 (0.48) |

| | | | | |
|---|---|---|---|---|
| *Lupinus micranthus* | 0.30 (0.80) | 0.67 (1.68) | | 0.42 (0.97) |
| *Madia gracilis* | 0.97 (1.32) | 0.80 (1.25) | | 1.87 (2.38) |
| *Potentilla gracilis* | 0.0 (0.0) | 0.0 (0.0) | | 0.0 (0.0) |
| *Potentilla glandulosa* | 0.0 (0.0) | 0.0 (0.0) | | 0.0 (0.0) |
| *Prunella vulgaris var. lanceolata* | 0.30 (0.37) | 0.60 (0.97) | | 0.73 (0.92) |
| *Sanguisorba occidentalis* | 0.20 (0.37) | 0.27 (0.68) | | 0.67 (0.99) |
| *Sidalcea campestris* | 0.00 (0.00) | 0.00 (0.00) | | 0.03 (0.13) |
| *Trifolium tridentatum* | 0.03 (0.13) | 0.07 (0.26) | | 0.33 (0.82) |

**Table 7**. Effect of experimental management treatments on mean cover (%) of each sowed native species at Finley National Wildlife Refuge May 2005 following sowing in October 2004 (Year two). Values in parentheses are standard deviations. Subscripts indicate the year of sowing. d = dicots; g = grasses. A pair of treatment means with different letters denotes a statistically significant difference for that comparison.

| **Species** | **Cover (%) (sd)** | | | | |
|---|---|---|---|---|---|
| | **Treatment 1 $d_{03} + g_{03}$ (no carbon banding)** | **Treatment 2 $d_{03} + g_{03}$** | **Treatment 3 $d_{04} + g_{03}$** | **Treatment 4 $d_{03} + g_{04}$** | **Treatment 5 $d_{04} + g_{04}$** |
| Grasses | | | | | |
| *Bromus carinatus* | 1.17 ( 0.92) | 1.43 (1.04) | 1.88 (1.34) | 0.1 (0.26) | 0.28 (0.35) |
| *Danthonia californica* | 0.12 (0.34) | 1.07 (2.07) | 1.86 (1.99) | 0.00 (0.00) | 0.00 (0.00) |
| *Elymus glaucus* | 0.28 (0.39) | 0.13 (0.21) | 0.26 (0.42) | 0.00 (0.00) | 0.02 (0.06) |
| *Festuca roemeri* | 2.7 (3.30) | 2.5 (3.10) | 3.55 (3.60) | 0.00 (0.00) | 0.00 (0.00) |
| *Poa scabrella* | 0.24 (0.53) | 0.56 (0.87) | 0.30 (0.87) | 0.00 (0.00) | 0.00 (0.00) |
| Dicots | | | | | |
| *Achillea millefolium* | 0.07 (0.26) | 0.08 (0.32) | 0.00 (0.00) | 0.10 (0.32) | 0.00 (0.00) |
| *Agoseris grandiflora* | 0.27 (0.59) | 0.00 (0.00) | 0.00 (0.00) | 0.07 (0.26) | 0.03 (0.13) |
| *Aquilegia formosa* | 0.00 (0.00) | 0.08 (0.22) | 0.00 (0.00) | 0.07 (0.20) | 0.00 (0.00) |
| *Clarkia amoena* | 0.16 (0.29) | 0.12 (0.27) | 0.02 (0.07) | 0.31 (0.89) | 0.44 (0.83) |
| *Clarkia rhomboidea* | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| *Collinsia grandiflora* | 0.12 (0.34) | 1.07 (2.07) | 1.86 (1.99) | 0.00 (0.00) | 0.00 (0.00) |
| *Collomia grandiflora* | 0.00 (0.00) | 0.02 (0.06) | 0.0 (0.00) | 0.11 (0.21) | 0.00 (0.00) |
| ***Eriophyllum lanatum*** | 0.00 (0.00**)** | **0.18a (0.50)** | 0.00 (0.00) | **0.52b (0.92)** | 0.03 (0.09) |
| *Erythronium oreganum* | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |

| | | | | | |
|---|---|---|---|---|---|
| *Gilia capitata* | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| *Ligusticum apifolium* | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| *Lotus micranthus* | 0.02 (0.06) | 0.00 (0.00) | 0.02 (0.06) | 0.01 (0.03) | 0.02 (0.06) |
| *Lotus purshianus* | 0.14 (0.22) | 0.08 (0.12) | 0.00 (0.00) | 0.22 (0.53) | 0.02 (0.06) |
| *Lomatium utriculatum* | 0.05 (0.10) | 0.02 (0.06) | 0.00 (0.00) | 0.1 (0.26) | 0.00 (0.00) |
| *Lupinus micranthus* | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| ***Madia gracilis*** | 9.8 (6.81) | 6.13 (5.41) | **0.03a (0.13)** | 9.6 (7.86) | **1.42b (2.45)** |
| *Potentilla gracilis* | 0.02 (0.06) | 0.03 (0.09) | 0.00 (0.00) | 0.07 (0.26) | 0.00 (0.00) |
| *Potentilla glandulosa* | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.28 (0.84) | 0.00 (0.00) |
| ***Prunella vulgaris var. lanceolata*** | 0.59 (0.87) | 1.89 (3.60) | **0.06a (0.13)** | 2.92 (4.13) | **0.43b (0.82)** |
| *Sanguisorba occidentalis* | 0.07 (0.26) | 0.10 (0.24) | 0.00 (0.00) | 0.25 (0.48) | 0.00 (0.00) |
| *Sidalcea campestris* | 0.03 (0.09) | 0.00 (0.00) | 0.00 (0.00) | 0.15 (0.52) | 0.00 (0.00) |
| *Trifolium tridentatum* | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |

**Objective Two**

Investigate the effect of the sowing sequence of native dicot and grass seed on the abundance and species richness of the sowed species. We made three predictions based on the hypothesis that our native grasses are more aggressive that our target native dicots in the initial stages of restoration.

**Prediction A**

*We predicted that the native dicots would gain an advantage by being sowed a year before the native grasses and that the native dicots would be inhibited when sowed into an one-year old stand of native grasses.*

The cover of the dicots is almost twice as much when sowed a year ahead of the grasses (Treatment 4) compared to the dicot cover when dicots and grasses are sowed together (Treatment 2) (Table 8). Species richness of the dicots is also significantly greater when the dicots are sowed a year before the grasses (Table 8). *Eriophyllum lanatum* was the only individual species to show significant differences between Treatments 2 and 4, with greater cover when sowed a year before the grasses (P = 0.04) (Table 7).

Dicot species richness increased, although not significantly, and dicot cover increased significantly when the dicots were sowed with the grasses (Treatment 5) compared to when dicots were sowed after the grasses had grown one-year (Treatment 3) (Table 9). In particular, *Madia gracilis* (P=0.05) and *Prunella vulgaris* var. *lanceolata* (P=0.06) increased in cover when sowed ahead of the grasses (Table 7).

These results are consistent with our predictions that the abundance of the native dicots is promoted by being sowed a year ahead of the grasses and that native dicot abundance is decreased when sowed into an existing stand of grass, thus supporting our hypothesis of the greater aggressiveness of our native grasses compared to our native dicots in the initial stages of restoration.

**Table 8**. Effect of sowing sequence of dicots and grasses on average cover (%) and species richness of sowed dicot native species two years after initiation of management treatments. Subscript indicates the year of sowing. *P* is the probability of differences occurring between treatments just by chance.

| | **Treatment 2** **dicots $_{03}$ + grasses $_{03}$** | **Treatment 4** **dicots $_{03}$ + grasses $_{04}$** | ***P*** |
|---|---|---|---|
| dicot cover (%) | 8.9 | 15.1 | 0.05 |
| dicot species richness | 7.1 | 9.1 | 0.00 |

**Table 9**. Effect of sowing sequence of dicots and grasses on average cover (%) and species richness of sowed grass native species two years after initiation of management treatments. Subscript indicates the year of sowing. *P* is the probability of differences occurring between treatments just by chance.

| | **Treatment 3** **dicots $_{04}$ + grasses $_{03}$** | **Treatment 5** **dicots $_{04}$ + grasses $_{04}$** | ***P*** |
|---|---|---|---|
| dicot cover (%) | 0.2 | 2.5 | 0.00 |
| dicot species richness | 2.9 | 9.1 | 0.08 |

**Objective Two**
**Prediction B**

*We predicted that the native grasses would be robust enough to be sowed with dicots and would not be harmed by being sowed the year after the establishment of the dicots.*

Grass cover and grass species richness were not significantly lower when grasses were sowed with dicots (Treatment 2) vs. dicots sowed a year later (Treatment 3) (Table 10). Nor were grass cover and grass species richness significantly lower when grasses were sowed after the dicots have grown a year (Treatment 4) vs. grasses and dicots sowed together (Treatment 5) (Table 11).

Grass cover was very low in both cases, especially compared with results from the previous year. Treatment 2 (Table 4) produced 10.1% cover of grasses in year one compared with 0.3% cover in the equivalent Treatment 5 in year two (Table 11). The difference is likely caused by the more thorough weed control possible at the start of the experiment: non-native cover averaged 24.3% in Treatment 2 in 2003 (Table 4) but averaged 32.3% in Treatment 5 in 2004 (Table 5).

These results match our predictions that the abundance of grasses would not be significantly affected by the sowing sequence with dicots, thus supporting our hypothesis of the greater aggressiveness of the native grasses compared to the native dicots during the initial establishment stages. This is the same conclusion we reached when using the abundance of dicots as the response variable.

**Table 10**. Effect of sowing sequence of dicots and grasses on average cover (%) and species richness of sowed grass native species two years after initiation of management treatments. Subscript indicates the year of sowing. *P* is the probability of differences occurring between treatments just by chance.

| | **Treatment 2** **dicots $_{03}$ + grasses $_{03}$** | **Treatment 3** **dicots $_{04}$ + grasses $_{03}$** | ***P*** |
|---|---|---|---|
| grass cover (%) | 5.6 | 7.8 | 0.11 |
| grass species richness | 3.8 | 3.7 | 0.34 |

**Table 11**. Effect of sowing sequence of dicots and grasses on average cover (%) and species richness of sowed grass native species two years after initiation of management treatments. Subscript indicates the year of sowing. *P* is the probability of differences occurring between treatments just by chance.

| | **Treatment 4** **dicots $_{03}$ + grasses $_{04}$** | **Treatment 5** **dicots $_{04}$ + grasses $_{04}$** | ***P*** |
|---|---|---|---|
| grass cover (%) | 0.1 | 0.3 | 0.09 |
| grass species richness | 0.7 | 1.1 | 0.09 |

**Objective Two**
**Prediction C**

*We predicted that total sowed native cover and species richness (dicots + grasses) would be maximized with the sowing sequence in which the dicots were sowed a year before the grasses. We also predicted that total sowed native cover and species richness would be the least with the sowing sequence in which the dicots were sowed into a year old stand of grasses.*

As predicted, species richness of all sowed native species (grasses + dicots) is significantly smaller when dicots are sowed into existing stand of grasses, as is the total cover of native species, although not significantly (Table 12). In contrast to our predictions, total cover and species richness of sowed native species was not significantly different whether dicots were sowed a year ahead of the grasses (Treatment 4) or whether dicots and grasses were sowed together (Treatment 2) (Table 12). These results partially support our hypothesis that the native grasses are more aggressive than the study dicot species tested.

For all species except for three, sowing sequence treatment did not significantly affect cover of individual species (Tables 6 and 7). All grasses maintained or increased their cover of the first year (Tables 6 and 7) except *Elymus glaucus*, which decreased its cover to one-fourth of its first year cover. *Bromus carinatus*, *Danthonia californica*, and *Festuca romeri* all had more than 1% cover in year two (Table 7).

For the dicot species, only the annual dicots had at least 1% in year one, *Clarkia amoena, C. rhomboidea*, *Collinsia grandiflora*, *Collomia grandiflora*, and *Madia gracilis* (Table 6). In year two, however, only two of these forbs were able to maintain at least 1% cover, *Madia gracilis*, which increased to almost 10%, and *Collinsia grandiflora* (Table 7). Only one species with less than 1% cover in year one increased to more than 1% cover in year two: *Prunella vulgaris* var. *lanceolata*, a perennial forb (Tables 6 and 7).

Average cover of sowed native dicots at the end of two growing seasons was greater than that of sowed native grasses at the end of the two year study period with the exception of Treatment 3 in which dicots were sowed a year after the grasses (Table 5). Even so, the cover of dicots is probably underestimated compared to grasses because the differences in growth at the time of data collection. Many of the dicots gained much greater cover later in the season, e.g., *Clarkia* spp., *Aquilegia formosa*, *Sidalcea campestris*, and *Eriophyllum lanatum* in contrast to the grasses, which were virtually at maximum size at the time of data collection.

**Table 12**. Effect of sowing sequence of dicots and grasses on average cover (%) of non-native species and on cover and species richness of sowed native species two years after initiation of management treatments. Subscript indicates the year of sowing. *P* is the probability of differences occurring between treatments just by chance. Treatment means with the same letters are statistically indistinguishable. d =dicots; g = grasses.

| | **Treatment 2** $d_{03} + g_{03}$ | **Treatment 3** $d_{04} + g_{03}$ | **Treatment 4** $d_{03} + g_{04}$ | ***P*** |
|---|---|---|---|---|
| non-native species cover (%) | 35.9 | 35.7 | 38.1 | 0.86 |
| sowed native species cover (%) | 14.5 | 8.0 | 15.2 | 0.21 |
| sowed native species richness | 10.9a | 6.6b | 9.8a | 0.01 |

**ObjectiveThree**

Investigate the effect of the sowing sequence of the native dicot and grass species on the abundance of non-native species. Based on the hypothesis that the greater the initial sowing density of the native species, the greater the inhibition of non-native species, we predicted that cover of non-native species would be the least with the treatment in which the dicots and monocots were sowed at the same time.

Non-native cover after two growing seasons is not significantly different whether native grasses and dicots are sowed together (Treatment 2) or whether grasses and dicots are sowed in sequence (Treatments 3 and 4) (Table 12), thus not supporting our hypothesis. Common non-native species found at the study site are listed in Appendix C.

Non-native cover was at least twice as much as the cover of sowed native species for all three treatments (Table 12). Cover of unsowed native species the second season was minimal, (D. Clark, personal observation), thus non-native cover comprised approximately 70% or more of the total cover, suggesting that native cover was not high enough to competitively inhibit the non-native species.

**MANAGEMENT RECOMMENDATIONS FROM STUDY ONE:**
**Experimental Investigation on the Effectiveness of Restoration Treatments**

We make the following recommendations based on the results of the species tested in this short-term study. Note that most of these perennial native species take more than two seasons to reach maturity. Thus, longer-term data collected from these experiments will produce even more valuable recommendations.

- Carbon banding is not recommended as a restoration tool as it did not enhance abundance of native species and did not inhibit non-native species.
- To maximize species richness and cover of dicots,
  a) if the choice is to sow dicots before or with grasses, sow dicots before grasses.
  b) if the choice is to sow dicots with grasses or after grasses, sow dicots with grasses.
- The sequence of sowing grasses does not affect cover or species richness of grasses. Therefore we recommend that other considerations be given higher weight when determining when to sow grasses.
- To maximize cover and species richness of both grasses and dicots, either sow dicots before or with grasses and avoid sowing dicots a year after sowing grasses.
- Of the grass species, we recommend *Festuca roemeri* and *Bromus carinatus* to get initial high cover and maintenance of cover.
- Dicot species that produce initial high cover include the annuals *Collinsia grandiflora*, *Collomia grandiflora, Clarkia amoena, C. rhomboidea,* and *Madia gracilis*. However, only *Madia gracilis* maintained its high cover into the second year in mixed sowings. *Prunella vulgaris* var. *lanceolata* and *Eriophyllum lanatum* are good perennial dicot species to sow for increased cover over time.
- To minimize non-native cover, increase the sowing rate that was used in this study of 50 seeds/ft$^2$. Include a large number of annual dicot species in the first year sowing mix to provide initial high cover.

## STUDY TWO
## Monoculture Sowing of Native Species

### OBJECTIVE
Compare the cover of non-native species and the cover of native species one and two years after sowing native species in monocultures.

### METHODS FOR STUDY TWO: Monoculture Sowing of Native Species
Twenty-six study species were each sowed as monocultures at a density of 50 seeds/ft$^2$ in the fall of 2003 in plots (21ft × 7 ft), each of which contained seven rows (1ft wide). A single quadrat (0.5m × 1.0m) was placed in the center of each sowing plot. The monoculture plots were separated from each other by a 3-foot buffer. This design was replicated three times in 3 blocks (Appendix A). Data were collected from the sample quadrat in spring of 2004 and 2005.

Three species, listed below, were sowed at densities less than 50 seeds/ft$^2$ because of limited seed supply. Due to error, *Elymus glaucus* was not included in the monoculture sowing study.

| Species | Sowing density monoculture |
|---|---|
| *Lupinus micranthus* | 35 seeds/ft$^2$ |
| *Ligusticum apifolium* | 20 seeds/ft$^2$ |
| *Erythronium oreganum* | 26 seeds/ft$^2$ |
| *Danthonia californica* | 37 seeds/ft$^2$ |

These plots were prepared prior to sowing with the same procedures as for the experimental Treatments 2-4 in fall 2003. They received both the carbon and pre-emergent herbicide components of the carbon banding treatment. In fall 2004, no additional seed was sowed and in contrast to the experimental plots, no fall mowing was applied.

### RESULTS AND DISCUSSION FOR STUDY TWO: Monoculture Sowing of Native Species
The first year after sowing, *Collinsia grandiflora* had the highest cover (83.3%) greatly surpassing the next top performers, *Sanguisorba occidentalis* (32%) and *Madia gracilis* (21.3%)(Table 13). All three of these species are annuals.

In general, the cover of individual species sowed in monoculture decreased two years after sowing. The ten top performers in 2004 all had large decreases in cover the following year 2005 (Table 13). Although not statistically significant (P< 0.1), the average cover of native species in 2005 (2.2%) decreased from that in 2004 (9.9%) (Table 13). The reverse was true of non-native cover, which increased from 38.7% in 2004 to 47.8% in 2005 (Table 13).

Only seven native species increased cover in 2005 from 2004 cover (*Aquilegia formosa, Danthonia californica, Sidalcea campestris, Eriophyllum lanatum,* and *Prunella vulgaris* var. *lanceolata*, *Potentilla gracilis* and *P. glandulosa*) all of which were perennials (Table 13). Two of these species were the top performers for 2005: *Eriophyllum lanatum* (15.7%) and *Prunella vulgaris* var. *lanceolata* (11.7%), but their cover did not reach the levels of the top performers in 2004. The cover of the other top performers in 2005, *Festuca roemeri* (6.3%), and *Bromus carinatus* (4.7%), decreased from that in 2004 (Table 13).

This pattern of annual dicots having the highest cover values in the first year and decreasing the second year, with perennials dicots increasing from low cover to higher cover in the second year is consistent with the pattern found in the experimental plots in which species were sowed in mixtures. There, of the five annual dicots with the highest cover in year one, only one, *Madia gracilis*, increased in cover the second year. *Prunella vulgaris* var. *lanceolata* increased in cover from year one to year two in the experimental plots mixture as it did in the monoculture plots.

Although there were significant differences in between cover of individual native species in the monoculture plots between 2004 and 2005 there were no significant differences in non-native cover between monocultures plots (P>0.1) (Table 13).. In other words, there was no strong relationship to indicate that cover of non-native species was correlated with cover of native species ($R^2$= 1.9 for 2004; $R^2$ = 26.8% for 2005).

**MANAGEMENT RECOMMENDATIONS FROM STUDY TWO:**
**Monoculture Sowing of Native Species**

- Sow annual species for initial high cover, particularly *Collinsia grandiflora* and *Madia gracilis*.
- Sow perennial dicot species for increased cover over time, particularly *Prunella vulgaris* and *Eriophyllum lanatum.*
- Increase sowing rate from that used in this study (50seeds/ft$^2$.)

**Table 13**. Comparison of mean cover (%) of native species sowed in monoculture plots and the mean cover of the unsowed non-native species at Finley National Wildlife Refuge in spring 2004 and 2005, following sowing in October 2003. Means of sowed native cover with the same letters within a year were statistically indistinguishable. "a" indicates an annual species; "p" indicates a perennial species.

| Species | | Sowed native cover (%) | | Non-native cover (%) | |
|---|---|---|---|---|---|
| | | 2004 | 2005 | 2004 | 2005 |
| Total cover | | 9.9 | 2.2 | 38.7 | 47.8 |
| *Collinsia grandiflora* | a | 83.3f | 0.5a | 6.0 | 44.0 |
| *Sanguisorba occidentalis* | a | 32.0e | 0.3a | 28.3 | 49.3 |
| *Madia gracilis* | a | 21.3de | 0.3a | 22.3 | 38.7 |
| *Bromus carinatus* | p | 16.0cd | 4.7ab | 39.7 | 53.7 |
| *Clarkia rhomboidea* | a | 13.3bcd | 0.0a | 25.0 | 50.3 |
| *Achillea millefolium* | p | 12.7abcd | 3.7a | 28.3 | 50.7 |
| *Collomia grandiflora* | a | 11.2abcd | 0.1a | 25.7 | 55.0 |
| *Festuca roemeri* | p | 10.5abcd | 6.3ab | 56.7 | 39.3 |
| *Gilia capitata* | a | 9.2abcd | 2.6a | 19.0 | 48.0 |
| *Agoseris grandiflora* | p | 8.3abc | 0.2a | 28.7 | 59.7 |

| | | | | | |
|---|---|---|---|---|---|
| *Lotus micranthus* | a | 8.3abc | 0.2a | 31.3 | 62.3 |
| *Lotus purshianus* | a | 6.2abc | 1.3a | 35.7 | 51.0 |
| *Eriophyllum lanatum* | p | 5.0abc | 15.7c | 41.7 | 20.3 |
| *Poa scabrella* | p | 4.3abc | 2.3a | 48.3 | 42.7 |
| *Prunella vulgaris var. lanceolata* | p | 3.3abc | 11.7bc | 45.7 | 38.3 |
| *Clarkia amoena* | a | 3.0ab | 0.0a | 51.0 | 47.7 |
| *Lupinus micranthus* | a | 2.7ab | 0.0a | 39.3 | 51.7 |
| *Trifolium tridentatum* | a | 2.2ab | 0.0a | 49.3 | 48.7 |
| *Lomatium utriculatum* | p | 2.2ab | 0.0a | 59.0 | 41.7 |
| *Aquilegia formosa* | p | 0.8ab | 1.5a | 56.7 | 61.3 |
| *Danthonia californica* | p | 0.7ab | 1.1a | 54.0 | 54.0 |
| *Sidalcea campestris* | p | 0.7ab | 3.7a | 49.0 | 43.0 |
| *Ligusticum apifolium* | p | 0.2a | 0.0a | 36.3 | 47.7 |
| *Potentilla glandulosa* | p | 0.2a | 0.3a | 33.3 | 52.7 |
| *Potentilla gracilis* | p | 0.0a | 0.3a | 55.7 | 48.7 |
| *Erythronium oreganum* | p | 0.0a | 0.0a | 35.3 | 43.7 |

## STUDY THREE
## Buffer Sowing of Native Grasses

### OBJECTIVE
Monitor the abundance of the native grasses sowed in the buffer areas outside the experimental plots.

### METHODS
The buffer areas between the experimental plots and the monoculture plots were prepared prior to sowing as described for the experimental study and the monoculture treatment.

Twenty 1-m × 1-m permanent quadrats were randomly located in 4 blocks (Appendix A). They were sowed with the four grass species *Bromus carinatus, Elymus glaucus, Danthonia californica* and *Festuca roemeri* in October 27-29, 2003 without the carbon banding. The bulk of the field (about 85%) was drilled in second gear putting out approximately 7.5 lbs of seed/acre (1 lb *Festuca roemeri*, 2 lbs *Bromus carinatus*, 1 lb *Danthonia californica*, and 3.5 lbs. of *Elymus glaucus* (personal communication, Chris Seale, USFWS). With two exceptions, the remainder of the field (essentially the highest and driest ground immediately east of the largest experimental plots) was drilled in first gear with a rate of 5 lbs seed/acre (1 lb *Festuca roemeri*, 2 lbs *Danthonia californica*, and 2 lbs *Elymus glaucus*. The exceptions are: 1) One small area was retained in the west central portion of the field from the original drilling in 2002, at which time only *Elymus glaucus* and *Bromus carinatus* was sowed and 2) the small area on the west end of the field was drilled at the same time in 2003 but only using *Elymus glaucus*, as seed for the other species was not available (personal communication, Chris Seale, USFWS). Cover the sowed grasses and non-native species as a group were monitored in late spring, early summer 2004 and 2005.

The following management treatments occurred in the buffer areas:

- Herbicide was applied in buffers October 30, 2003 immediately after sowing October 27-29, 2003
- Spot spray broadleaf: June 16, 2004
- Mowed about ¾ of field: June 21, 2004

### RESULTS AND DISCUSSION FOR STUDY THREE: Buffer Sowing of Native Grasses
In 2004 non-native cover (23.5%) was almost four times greater than native cover (6.1%) (Table 16). *Festuca roemeri* (2.5%) and *Danthonia californica* (2.1%) had the most cover, although very small (Table 14). In 2005 non-native cover greatly increased to 60.9%, and was more than 10 times greater than the native cover of grasses, which decreased to 5.9% (Table 14).

**Table 14**. Comparison of mean cover (%) of native species sowed in buffer monitoring plots with the mean cover of the unsowed non-native species at Finley National Wildlife Refuge in late spring 2004 and 2005, following sowing in fall 2003. Values in parentheses are standard deviations.

| | **Cover (%) (sd)** | |
|---|---|---|
| | **2004** | **2005** |
| Non-native cover | 23.5 (6.2) | 60.9 (14.8) |
| *Festuca roemeri* | 2.5 (1.7) | 5.2 (5.5) |
| *Danthonia californica* | 0.2 (0.4) | 0.0 (0.1) |
| *Bromus carinatus* | 2.1 (1.6) | 0.7 (0.7) |
| *Elymus glaucus* | 1.3 (0.7) | 0.0 (0.0) |

**ACKNOWLEDGEMENTS**
We like to acknowledge the commitment of the US Fish and Wildlife Service to this project and their contributions in time and resources: Jock Beall, Chris Seale and Jarrod Jebousek. George Mueller-Warrant (USDA) kindly allowed us to use the cone/carbon planter. We also thank Scott Culver (USDA) for his endless patience and for the numerous hours he contributed helping us with the carbon planter and planting. Several outstanding field assistants made this project happen, but in particular we would like to thank Angela Brandt and Rachael Roberts.

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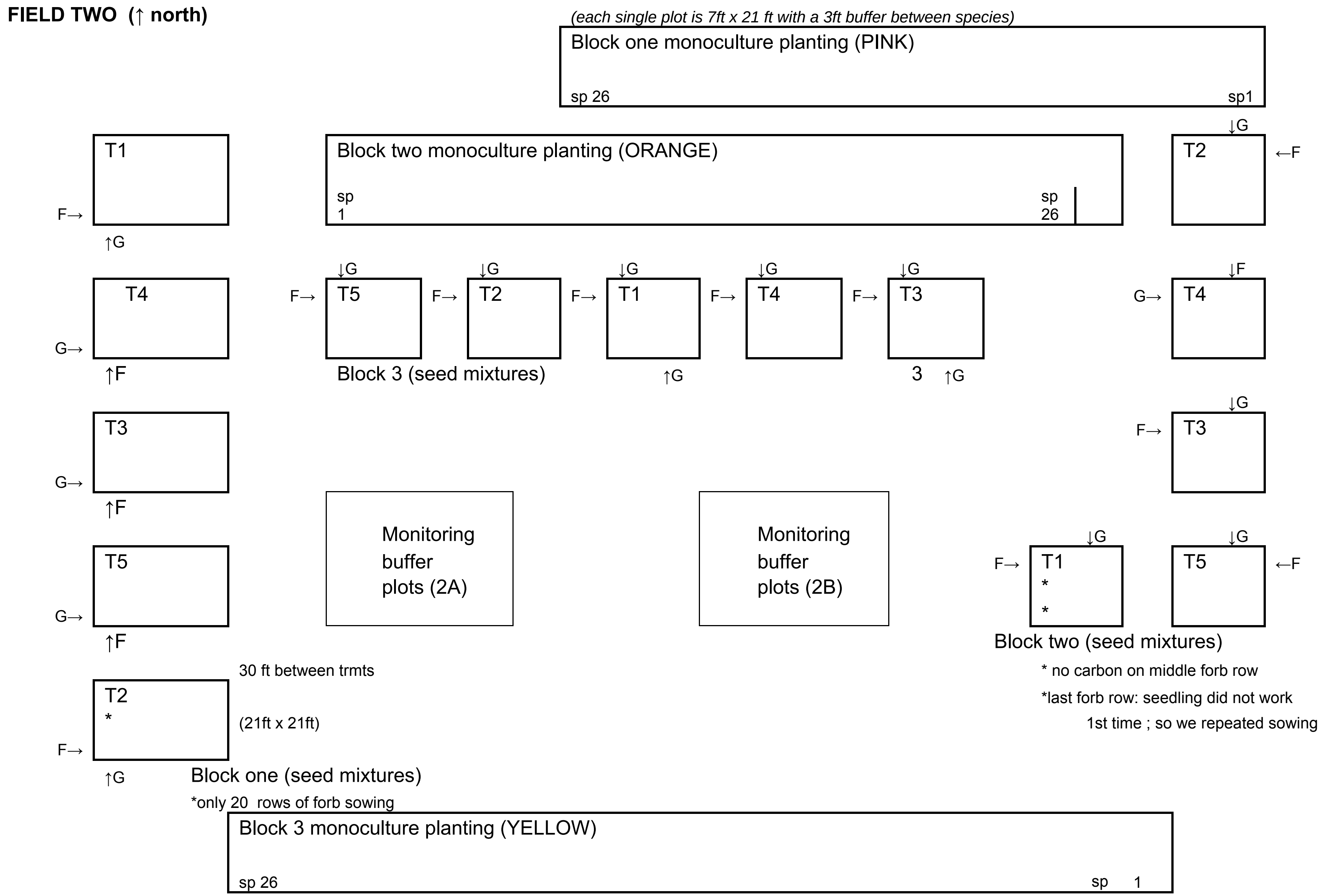
**APPENDIX A** Results of seed germination tests for the study species

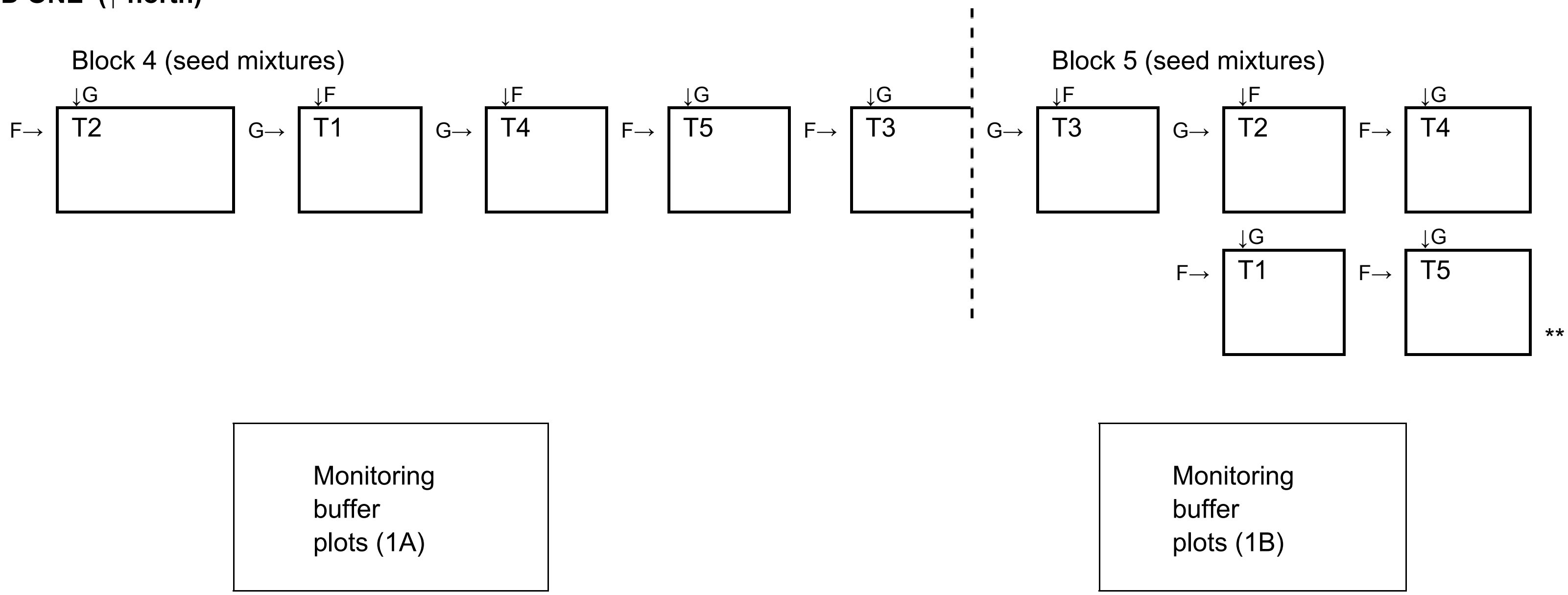
| Species | Germination rate (%) | |
|---|---|---|
| | **Average** | **sd** |
| *Bromus carinatus* | 96.5 | 2.4 |
| *Elymus glaucus* | 95.0 | 3.4 |
| *Clarkia amoena* | 92.3 | 2.9 |
| *Clarkia rhomboidea* | 90.0 | 4.8 |
| *Achillea millefolium* | 83.8 | 10.1 |
| *Festuca roemeri* | 87.5 | 6.4 |
| *Prunella vulgaris var. lanceolata* | 69.3 | 2.9 |
| *Lomatium utriculatum* | 69.7 | 2.1 |
| *Eriophyllum lanatum* | 66.0 | 5.4 |
| *Madia gracilis* | 60.0 | 3.6 |
| *Gilia capitata* | 59.0 | 2.6 |
| *Lotus micranthus* | 44.5 | 5.3 |
| *Poa scabrella* | 43.8 | 8.1 |
| *Sanguisorba occidentalis* | 38.3 | 5.4 |
| *Agoseris grandiflora* | 29.3 | 3.3 |
| *Aquilegia formosa* | 22.3 | 4.3 |
| *Sidalcea campestris* | 20.3 | 1.0 |
| *Trifolium tridentatum* | 17.5 | 3.3 |
| *Lotus purshianus* | 8.3 | 3.2 |
| *Potentilla glandulosa* | 7.5 | 2.6 |
| *Danthonia californica* | 6.3 | 2.6 |
| *Erythronium oreganum* | 0.0 | 0.0 |
| *Ligusticum apifolium* | 0.0 | 0.0 |

**APPENDIX B**

Plot layout of the experimental and monitoring studies at Finley Wildlife Refuge, 2003.



**FIELD ONE (↑ north)**




** *margin note: grass and forbs seeded outside of plots too.*
*last two blocks used wetter seeds outside rows*

**APPENDIX C**
Unsowed species found at the study site.

Most common and abundant species in plots
*Anthoxanthum odoratum* (by far the most abundant non-native species)
*Agrostis stolonifera*
*Aira caryophyllea*
*Briza minor*
*Juncus bufonius*

Frequently found in plots but in small amounts
*Hypericum perforatum*
*Epilobium* spp.
*Myosotis discolor*
*Parentucellia viscosa*

Other species found on site but rarely in sample plots
*Calandrinia ciliata*
*Cerastium* sp.
*Chrysanthemum leucanthemum*
*Cirsium* sp.
*Hypochaeris* sp.
*Leontodon* sp.
*Daucus carota*
*Geranium* sp.
*Gnaphalium* sp.
*Lolium multiflorum*
*Lupinus* sp.
*Montia linearis*
*Montia fontana*
*Rubus discolor*
*Rumex* sp.
*Scandix* sp.
*Sheradia arvensis*
*Sonchus* sp.