RESTORING ENERGY FIELDS FOR WILDLIFE
2009 ANNUAL REPORT

APPENDIX 2:
CHEATGRASS SEED DISPERSAL IN RECLAMATION AREAS

Danielle Bilyeu Johnston

Colorado Division of Wildlife
711 Independent Ave.
Grand Junction, CO 81505
970-420-8375
danielle.bilyeu@state.co.us

ABSTRACT

Cheatgrass (*Bromus tectorum* L.) seed disperal has been quantified for sagebrush ecosystems, but little is known about cheatgrass dispersal over the bare soils common in newly reclaimed areas. Recently, fluorescent seed marking has emerged as a useful tool to study seed dispersal. We used fluorescently marked seeds to quantify cheatgrass dispersal distances on simulated well pads in northwestern Colorado. A total of 1300 sterilized, marked seeds were released in groups of ~100 from 20-cm high platforms in three types of environments: a mesa top, a gulley, and a ridge top. Seeds were recovered at night using blacklights 4 times over 14 days, and the distance between each seed and its release platform was measured. At all sites, the majority of movement occurred within 2 days of release. Dispersal distance averaged 2.4 m and was highly variable, with 5% of seeds traveling further than 10.6 m. Differences in dispersal distance between sites occurred but did not coincide with measured differences in wind speed. Seed recovery was > 94% at the first time step, and fell to 60-70% after 14d. The average distance reported here is seven-fold higher than the maximum distance recorded for an intact sagebrush ecosystem, and implies that in the absence of impediments, cheatgrass seeds may penetrate the interior of reclamation areas. Fluorescent seed marking is a promising method to explore cheatgrass dispersal dynamics.

INTRODUCTION

The expansion of cheatgrass (*Bromus tectorum* L.) in the intermountain west has caused dramatic declines in the productivity, diversity, and habitat quality of invaded lands (Leopold 1949, Knapp 1992, DiTomaso 2000, Schaffer et al. 2003). Reducing the dominance of cheatgrass and preventing its further expansion are goals common to land managers, wildlife managers, ranchers, and farmers (DiTomaso 2000).

Disturbances can allow cheatgrass to expand into new areas (Bradford and Lauenroth 2006), but may also afford opportunities to replace cheatgrass stands with more desirable vegetation. In restoring disturbed areas, the presence or absence of cheatgrass has a large impact on reclamation success (Pilkington and Redente 2006), and good choices of reclamation materials and methods depend on whether or not cheatgrass competition will be present. Predicting the likelihood of cheatgrass competition is not always simple because our understanding of how cheatgrass seeds disperse is incomplete.

While long-distance dispersal of cheatgrass seeds by animal vectors has long been discussed (Leopold 1949, Mack 1981), very little attention has been given to how cheatgrass disperses over shorter distances. In a unique study, Kelrick (1991) used seed traps to quantify wind deposition of cheatgrass seeds in a Wyoming big sagebrush (*Artemesia tridentata* ssp. *wyomingensis* L.) environment. He found that secondary dispersal was common, with only 45% of seeds landing in a particular location remaining in that location (Kelrick 1991). He also found that litter and shrub cover were important in retaining cheatgrass seeds (Kelrick 1991). In a study of seeds similar to those of cheatgrass in that they contained awns (long, thin appendages which increase the seed's surface area) Chambers (2000) found that final seed distribution is greatly affected by the type of substrate over which the seed travels (Chambers 2000). How cheatgrass seeds travel over the bare substrates common in early reclamation has not yet been studied.

Recently, the use of fluorescent powder has emerged as a promising method for tracking seed movements (Lemke et al. 2009). In this study, we examine the usefulness of fluorescently marked seeds for studying cheatgrass dispersal, and use the method to quantify cheatgrass dispersal distances over bare soils for three locations in northwestern Colorado.

METHODS

Study area

Study locations were within the geological Piceance Basin, which is currently under intensive development for the extraction of natural gas. Cheatgrass cover in the Piceance Basin reaches 70% in lower elevation gullies, is more moderate on slopes and mesas, and is constrained to roadsides and disturbed areas at higher elevations. The Grand Valley Mesa site (GVM; 1662m) lies atop a small mesa near Parachute, CO, on Potts-Idlefonso soils. The Ryan Gulch site (RYG; 2084m) lies within one of the many gullies which drain to Piceance Creek, is bordered by steep slopes, and is on Glendive fine sandy loam soils. The Wagon Road Ridge site (WRR; 2216m) lies on a ridge on Piceance fine sandy loam soils. Slopes of all study sites were less than 5%.

A simulated well pad disturbance was created in all study locations by clearing all vegetation, stripping the top 20 cm of soil, and then cutting and filling the subsoil to create a level surface. This work was completed in August of 2008. The simulated well pad surface was kept weed-free through the 2009 growing season by repeated hand-spraying of emerging plants with 2% (v/v) glyphosate. The seed dispersal study was conducted on the bare soil of the simulated well pad surface in late July and August of 2009.

Cheatgrass seed preparation

We collected cheatgrass seed from our study sites in June of 2009 using hand clippers. Fully formed seeds with a hard seed coat and without any sign of fungal infection were selected. Spikes were air dried until the seeds fell apart from the spike at the touch. Seeds were killed by allowing the seeds to imbibe water from moist paper towels for 5 hours, microwaving the seeds for 55 seconds on high power, and then oven-drying for at least 12 hours. To verify that this method achieved complete seed kill, we compared germination percentages of treated and untreated after-ripened seeds collected the prior year. This method killed seeds completely and did not alter seed dispersal appendages. Seed was counted into bundles of 100. In precise terms, the counted units were not seeds, but propagules, as sometimes two seeds or one seed plus the awned glumes did not easily shatter apart at the touch. These were left together to better approximate natural dispersal units. 2.5% of propagules contained two seeds, and the remainder contained one seed. For simplicity, we will hereafter refer to these simply as seeds. Seeds were coated in green fluorescent powder (DayGlo® Color Corporation, Cleveland OH) by gently shaking them in a plastic bag containing powder, and then gently shaking propagules in a 1mm sieve to remove excess powder. The weight addition due to the powder was quantified by weighing 3 large batches of seeds before and after coating. Coating with fluorescent powder added 10% to the weight of the seed.

Seed release and tracking

Four groups of seeds were released at each site. Seeds were released from 8cm-diameter posterboard platforms tacked to the top of wooden stakes. Release platforms were 20-25 cm from the ground surface, a height similar to that of cheatgrass in the study area in the 2009 season. Release platforms were separated by at least 14m from each other and at least 7m from the edge of the simulated well pad. Well pads were bare or nearly bare of vegetation during the course of the study.

Average wind speed and wind gust data were collected at each site beginning at the time of release using a WindSmart sensor and MicroStation (Onset® Computer Corporation, Bourne, MA) mounted 30 cm from the ground surface. Rain data were collected at GVM and at a monitoring location approximately 27 km from the WRR and RYG sites using an RG3 datalogging rain gauge (Onset® Computer Corporation, Bourne, MA).

Upon release, wind almost immediately blew all seeds from release platforms, and seeds were informally noted to have landed within 1.5 m of the release platform upon initial contact with the ground. Seeds were located at night using blacklights, and polar coordinates from the release platform were taken using a tape measure and compass for all located seeds. In a few cases, seeds traveled so far that it was difficult to determine which platform was the release platform. In those cases, polar coordinates were taken from the nearest platform. Seeds were located four times at each site: 1-2 days, 3-4 days, 7-8 days, and 13-14 days following release.

Analysis

The effect of time since release on dispersal distance was analyzed separately for each site using analysis of variance (ANOVA) in SAS PROC GLM with the number of days since release as a categorical variable. Differences between dispersal distance for consecutive measurement intervals were calculated using ESTIMATE statements. Differences between sites in dispersal distance for the final time step was determined using ANOVA in SAS PROC GLM. Means are reported with standard errors.

RESULTS

Over the course of the study, wind speed averaged 0.53 ± 0.07 m/sec at GVM, 0.05 ± 0.05 m/sec at RYG, and 0.55 ± 0.05 m/sec at WRR (Figure 1a). Average daily maximum gust speed was 6.3 ± 0.35 m/sec at GVM, 3.8 ± 0.24 m/sec at RYG, and 6.6 ± 0.27 m/sec at WRR (Figure 1b). A rain event of 3.2 mm occurred at GVM on July 29, and no additional rain fell during the course of the study. At the rain monitoring location closest to WRR and GVM, the July 29 rain event was 1.6 mm, and a second rain event of 0.8 mm occurred on August 6.

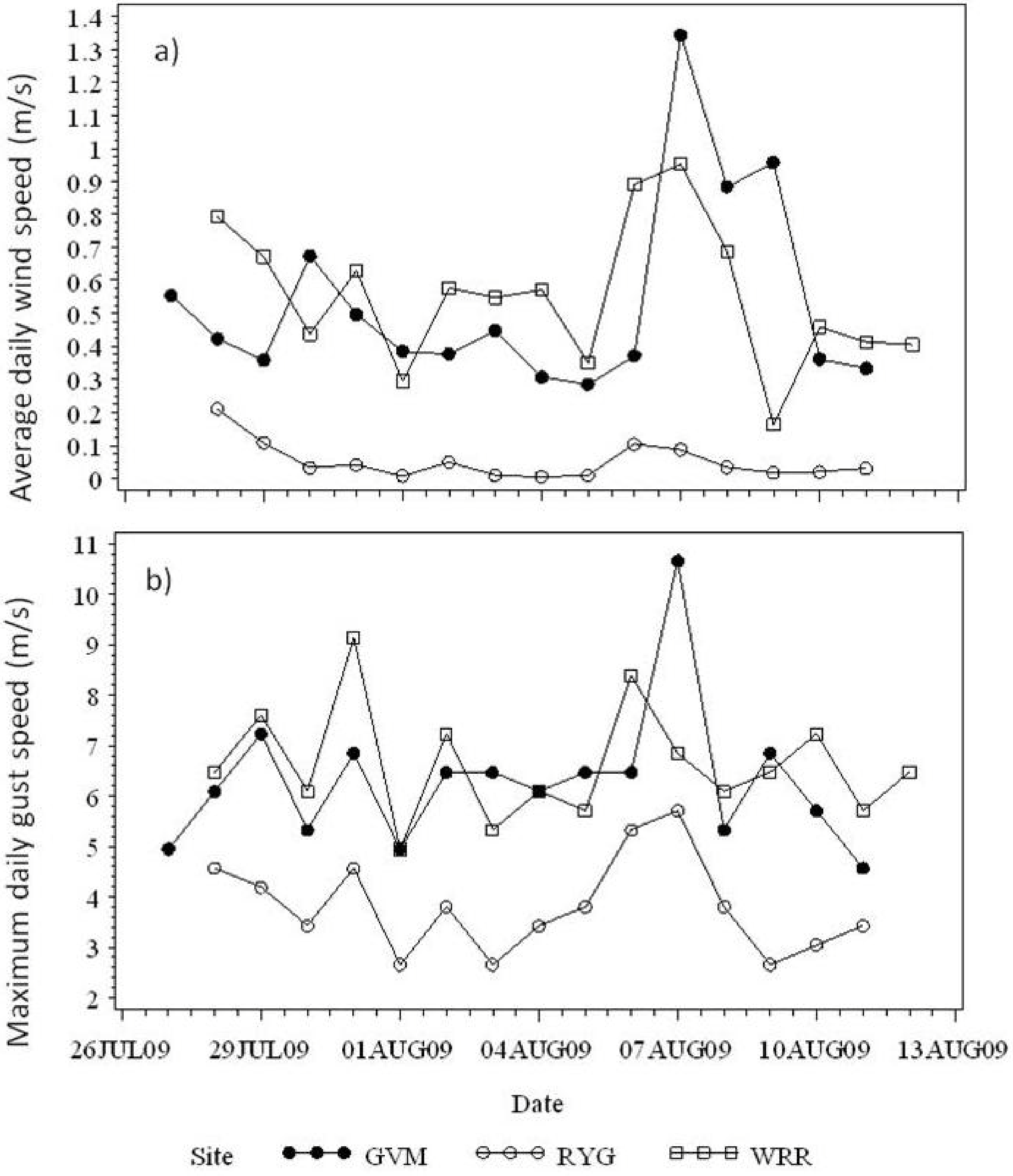

Figure 1. Average daily wind speed (a) and maximum daily gust speed (b) 30 cm from the ground surface at a mesa study site (GVM), a gulch study site (RYG) and a ridge study site (WRR).

Over 94% of seeds were found at all three sites on the first attempt, one to two days following release (Figure 2). On the second attempt, 67% of seeds were found at GVM, and 87 % of seeds were found at RYG and WRR. On the last attempt, recovery had dropped to 60-70% at all three study sites (Figure 2).

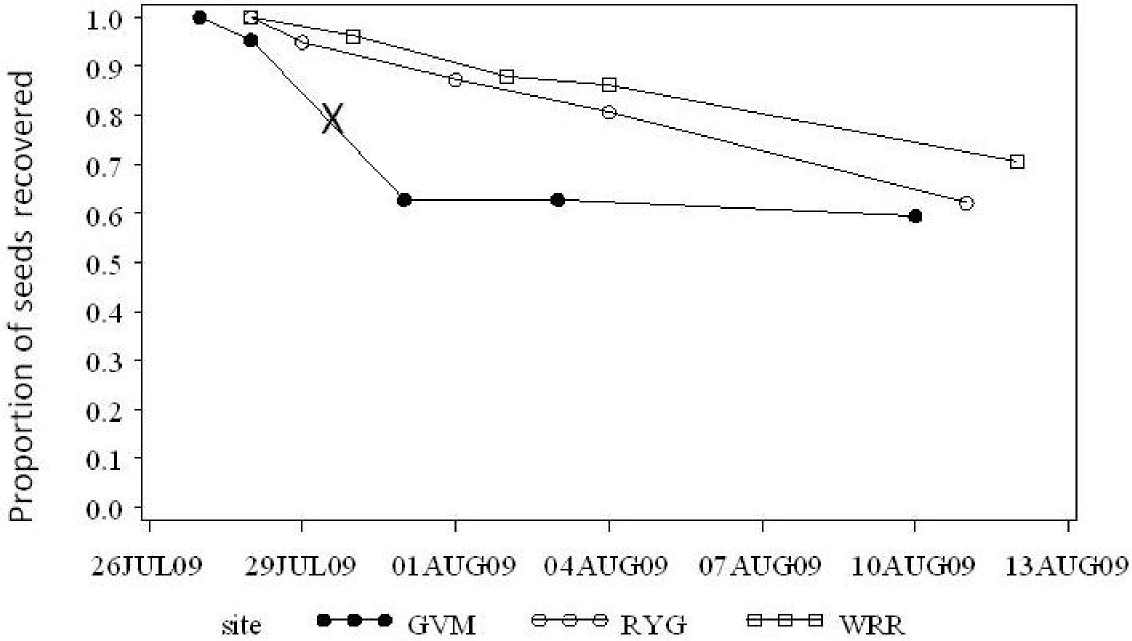

Figure 2. Proportion of released seeds recovered at three study sites. The first time point represents the release date. The X denotes a heavy rain event which occurred at the GVM study site.

At GVM, average measured dispersal distance increased until 3 days following release, when it reached 289 ± 30 cm, and then did not detectably change in the two subsequent measurement intervals (Figure 3a). At RYG, average measured dispersal distance increased until 3 days following release, did not detectably change between the second and third measurement intervals, and then increased between the third and fourth measurement intervals (p= 0.006) when it reached a maximum of 267 ± 17 cm (Figure 3b). At WRR, average measured dispersal distance did not detectably change between the first and third measurement intervals, but increased between the third and fourth measurement intervals (p = 0.0002), when it reached a maximum of 180 ± 15 cm (Figure 3c).

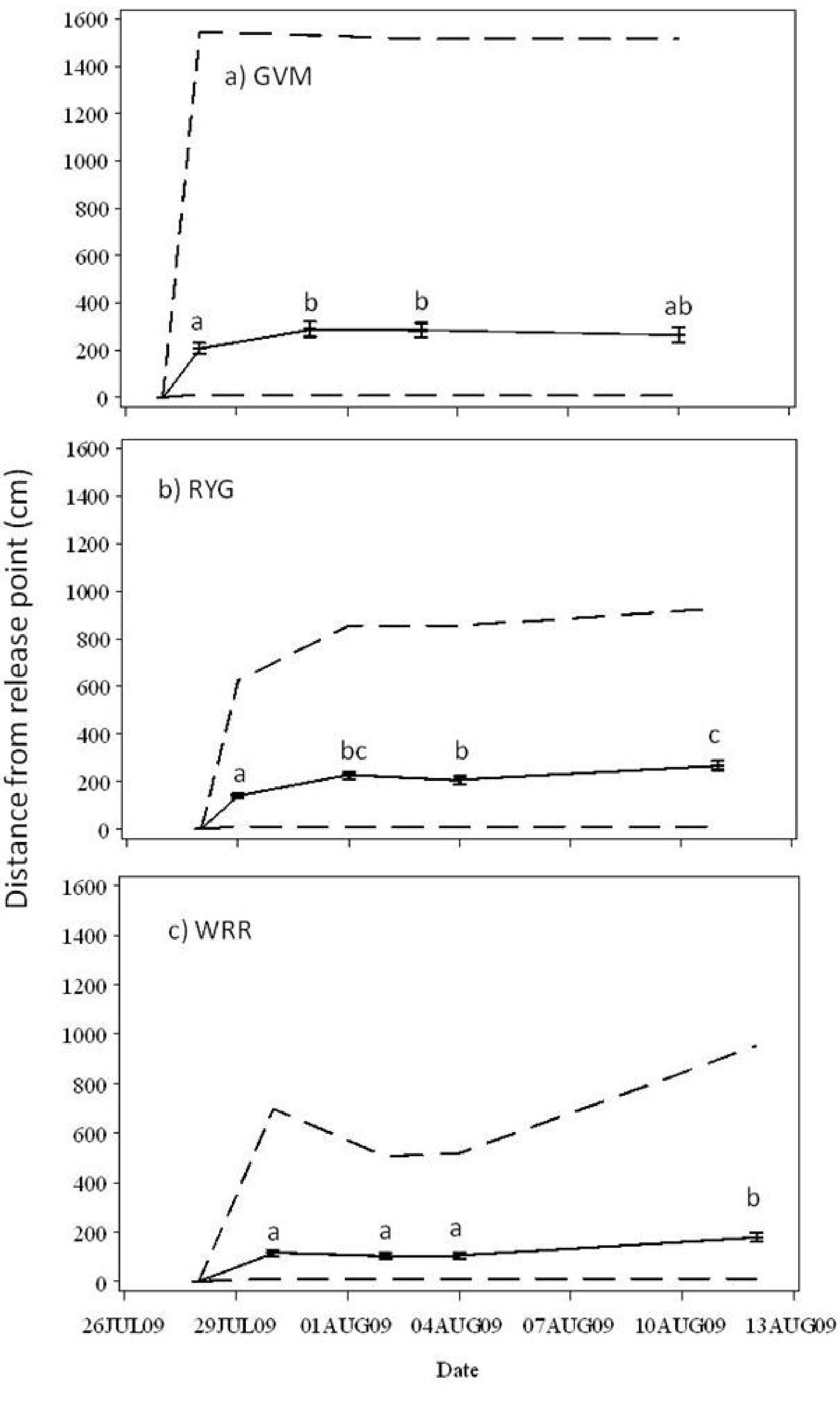

Figure 3. Dispersal of marked cheatgrass seeds at three study sites: a) Grand Valley Mesa, b) Ryan Gulch, and c) Wagon Road Ridge. Solid lines= mean distance from release point, dashed lines= 5% and 95% quantiles, error bars= SE. Time points not sharing letter represent significantly different means at α = 0.05.

Maximum recorded distances were: 1863 cm at GVM, 1579 cm at RYG, and 2082 cm at WRR. 95th percentile distances were: 1514 cm at GVM, 927 cm at RYG, and 953 cm at WRR.

DISCUSSION

The average dispersal distance measured in this study was 235 ± 13 cm, while the maximum movement observed in an intact Wyoming big sagebrush stand was only 35 cm (Kelrick 1991). The difference may be due to a lack of impediments to secondary dispersal, as many have reported that shrubs, litter, and other obstructions entrap seeds (Marlette and Anderson 1986, Kelrick 1991, Chambers 2000). At GVM, our field crew noticed a florescent powder print in the shape of a cheatgrass seed. By tracking the trajectory defined by the release stake and this print, the crew found three additional such prints, and then found the seed. At WRR, a significant increase in average dispersal distance was detected between 7 and 15 days after release. In absence of plants or litter, cheatgrass seeds may continue to disperse over several days or weeks.

At GVM, a rain event of 3.2 mm occurred after the measurement date (Figure 2). The proportion of seeds recovered at the next measurement date dropped to 63% from 94%, and no further change in average dispersal distance was detected (Figure 3a). Field crews noted several instances where an awn of a marked seed protruded from the ground surface, and the rest of the seed was buried. Data from the weather station nearest the other two study sites indicates no such heavy rain event. Buried seeds were not found at those sites, and average dispersal distance continued to increase over the following week (Figures 3b and 3c). Rain is likely important for halting dispersal and promoting burial of cheatgrass seeds, as has been shown for seeds of several other species in an agricultural environment (Benvenuti 2007).

The least windy site in this study, RYG, did not coincide with the site with the lowest average dispersal distance, which was WRR. We did not find any evidence of a dispersal mechanism other than wind in this study; there were no caches of seeds found or tracks indicating that rodents had altered the distribution of the recovered seeds. A difference in recovery rate, and therefore error in measuring dispersal distance, is not a likely explanation for the difference in average measured dispersal distance, as recovery rates at WRR and RYG were nearly identical. A possible explanation for the results of this study is that all sites had wind gusts sufficiently energetic to lift cheatgrass seeds off of the ground, and either soil type or some unmeasured spatial variability in gusts determined average distance traveled. Although the difference in average wind speed between RYG and WRR was ten-fold, the difference in maximum gust speed was only two-fold. It is unknown how sufficiently energetic gusts were distributed across the study areas, but the distribution may have been restricted at WRR, which was bordered by pinyon and juniper trees and a large topsoil pile. Potential windbreaks at RYG had only about a quarter as much vertical relief, which may have allowed the anemometer, placed near the middle of the simulated well pad disturbance, to more accurately reflect wind gusts across the study area. It is also possible that WRR received more rain than RYG or had a soil type more favorable for seeds to adhere to the soil surface (Benvenuti 2007).

The average dispersal distance reported here is likely an underestimate of what should be expected in most field conditions. The fact that an increase in dispersal distance was found at the last measurement interval indicates that the measured distance may have been higher if we had been able to continue the study longer. There were several instances where seeds encountered topsoil piles or vegetation at the edge of the study area which may have hindered further movement, and several instances where a seed traveled far enough that it was difficult to determine the stake from which it had been released, and a measurement to the nearest stake was taken. Seeds were 10% heavier than normal due to the fluorescent coating, and the coating was somewhat sticky, which could have hindered movements. Recovery rates dropped off over the course of the study, and seeds traveling further, especially those traveling outside the simulated well pad area, were probably less likely to be detected. Each of these factors would lead to an underestimate of dispersal distance.

IMPLICATIONS

From the perspective of promoting re-establishment of desirable vegetation in reclamation areas, the average dispersal distance is less important than the distance over which we can expect a number of cheatgrass seeds sufficient to impede the establishment of desirable plants. Cheatgrass is a prolific seed producer. Cheatgrass seed rain in a year of above average precipitation was 13, 942 seeds/m^2 at a site in western Utah (Smith et al. 2008). Our study found that 5% of cheatgrass seeds travel further than 10.6 m over bare soil. Assuming a productive seed year and that the seed of a 25 cm wide strip of cheatgrass blows into the reclamation area, then we would expect 70 cheatgrass seeds/m^2 10.6 meters from the edge of the reclamation area. Given that cheatgrass seeds germinate earlier in the year than most perennials and rob later-germinating seeds of moisture, 70 cheatgrass seeds/m^2 might hinder reclamation. In areas where cheatgrass is prevalent, reclamation may be more successful if dispersal barriers are used in conjunction with measures to control cheatgrass in the seed bank.

We found the method of marking cheatgrass seeds with fluorescent powder to be useful in the study of cheatgrass dispersal dynamics. At the two study sites where heavy rain events did not occur, we were able to recover over 80% of seeds within the first week following release. However, our crew noticed that the fluorescent coating grew less visible in the second week of the study. The usefulness of this method may be restricted to short-term studies of seed dispersal.

ACKNOWLEDGEMENTS

This work was funded by grants from donations from Encana Oil and Gas, Shell Oil Company, and Williams Production Company (Williams). Land access was provided by Williams. Kim Kaal organized funding efforts, Dirk Baker provided advice on the use of fluorescent powder, and Robert Wayne organized the field crew.

LITERATURE CITED

Benvenuti, S. 2007. Natural weed seed burial: effect of soil texture, rain and seed characteristics. Seed Science Research 17:211-219.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: The importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science 17:693-704.

Chambers, J. C. 2000. Seed movements and seedling fates in disturbed sagebrush steppe ecosystems: Implications for restoration. Ecological Applications 10:1400-1413.

DiTomaso, J. M. 2000. Invasive weeds in rangelands: Species, impacts, and management. Weed Science 48:255-265.

Kelrick, M. 1991. Factors affecting seeds in a sagebrush-steppe ecosystem and implications for the dispersion of an annual plant species, cheatgrass (*Bromus tectorum* L.). Utah State University, Logan, Utah.

Knapp, P. A. 1992. Secondary plant succession and vegetation recovery in two western Great Basin desert ghost towns. Biological Conservation 60:81-89.

Lemke, A., M. von der Lippe, and I. Kowarik. 2009. New opportunities for an old method: using fluorescent colours to measure seed dispersal. Journal of Applied Ecology 46:1122-1128.

Leopold, A. 1949. A Sand County Almanac, and sketches here and there. Oxford University Press, New York, New York.

Mack, R. N. 1981. Invasion of *Bromus tectorum* L. into western North America- an ecological chronicle. Agro-Ecosystems 7:145-165.

Marlette, G. M., and J. E. Anderson. 1986. Seed banks and propagule dispersal in Crested Wheatgrass stands Journal of Applied Ecology 23:161-175.

Pilkington, L., and E. F. Redente. 2006. Evaluation of reclamation success of Williams Production RMT Company natural gas well pad sites near Parachute, Colorado. Colorado State University, Department of Forest, Rangeland, and Watershed Stewardship, Fort Collins, CO.

Schaffer, R. J., D. J. Thayer, and T. S. Burton. 2003. Forty-one years of vegetation change on permanent transects in northeastern California: Implications for wildlife. California Fish and Game 89:55-71.

Smith, D. C., S. E. Meyer, and V. J. Anderson. 2008. Factors affecting Bromus tectorum seed bank carryover in western Utah. Rangeland Ecology & Management 61:430-436.