PATTERNS OF ANNUAL BROME ABUNDANCE IN RECLAIMED AND NATIVE RANGELANDS IN THE NORTHERN GREAT PLAINS: A CASE STUDY FROM THE BIG SKY MINE, SOUTHEASTERN MT[1]

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Abstract: Annual bromes, primarily cheatgrass (*Bromus tectorum*) and Japanese brome (*Bromus japonicus*) are Eurasian winter annual plants that have come to be considered "invasive". As such they are not included purposely in seed mixes used for mine reclamation. Examination of long-term vegetation monitoring data from reclaimed and reference areas at the Big Sky Mine in Rosebud County, MT offer insight into the dynamics of the presence of these weeds in a Northern Great Plains setting. Over the past 22 years, annual brome cover as a percent of total vegetation cover in the native open ponderosa pine (*Pinus ponderosa*) woodland vegetation at the Big Sky Mine has varied from as low as 0.3% in 2002 to as high as 50.7% in 1991. In reclaimed areas over the same period, annual bromes ranged from as little as 1.5 % to as much as 25.1 % of total vegetation cover. As of 2008 Native Reference Area vegetation was 37.0% annual bromes while reclaimed areas had declined to 6.5% annual bromes. Biomass production in reclaimed areas has exceeded reference area levels by 50 to 75% on most years. Precipitation in these adjacent areas can be presumed to have been very similar and grazing of both areas has been light to non-existent over the period. These data suggest that strong perennial herbaceous growth suppresses annual brome abundance especially during periods favorable precipitation. Native area vegetation periodically experiences outbreaks of annual bromes as drought stresses increase and then annual bromes decline as the competitive strength of the native perennials returns. High abundance of annual bromes is a symptom of reduced or lagging competitive strength of perennial plants: it is suggested that at least in the Northern Great Plains, annual bromes constitute a litmus test for community competitive strength, and are not of themselves a conquering invasion.

Additional Keywords: Invasibility, reclamation biomass production, cheatgrass, downy brome, Japanese brome, invasive plants, cycles of invasions.

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Introduction

Cheatgrass (*Bromus tectorum*, also known as downy brome) and Japanese brome (*Bromus japonicus*) are species originating in Eurasia that have become prominent components of North American grassland and shrub-steppe ecosystems. Both are winter annual plants meaning that they generally germinate during late summer or fall and over-winter as rosettes very close to the ground surface. In the relative warmth of the environment immediately above the ground surface, they may be active at various points during fall and winter before resuming vertical growth in spring at which time they bolt and rapidly produce flowers and mature seed by late spring or early summer. The winter annual life cycle is the same as that of winter wheat and it is thought that both of these annual bromes have evolved in and around the cultivation of wheat or other small grains and in fact probably made entry to North America in lots of grain seed brought to the New World from the Old. It may be important to note that certain races of these annual grasses have the facultative capability of behaving as "normal" (spring) annuals, that is germinating in spring and proceeding to flower and fruit without cold treatment (Stewart and Hull 1949).

The extent of the spread of annual bromes in North America has been immense and cheatgrass especially has been successful in near total replacement of native herbaceous species in vast areas of the Great Basin of North America (D'Antonio and Vitousek 1992, Chambers et al. 2007). In the Northern Great Plains, both plants are common and may be joined by *B. commutatus* (bald brome) and/or *B. squarrosus* (corn brome). In the Northern Great Plains, the behavior of the annual bromes is less dramatic than in the Great Basin. It is true that they were apparently not present in the Northern Great Plains in pre-Columbian times and have invaded (with human assistance) in the past 120 years (D'Antonio and Vitousek 1992). Like many annual weeds they invade recently disturbed sites, but stand-replacing invasion with apparent permanent displacement of native or other established perennial vegetation is <u>not</u> common.

Nonetheless, the increased abundance of these species over that past 20 years in the Northern Great Plains has elicited widespread concern that their presence represents a threat to both rangelands and to reclamation efforts (Mosley et al. 1999). This study presents results of evaluation of the dynamics of annual bromes in long-term monitoring data from areas of native rangeland and coal mine reclamation in southeastern Montana in order to assess this threat.

Mining reclamation at the Big Sky Mine has been for the most part directed to concurrently support rangeland and wildlife habitat land uses. In accordance with State requirements, topsoils and subsoils were salvaged prior to mining and replaced with minimal length of storage. Fertilizers are not used. Seeding utilizes native species of perennial grasses and forbs, as well as shrubs. Annual bromes are NOT part of the seed mix. However, because of the ubiquity of annual bromes in the native vegetation, their seeds are likely included in virtually every cubic yard of native topsoil salvaged and replaced, however.

Methods

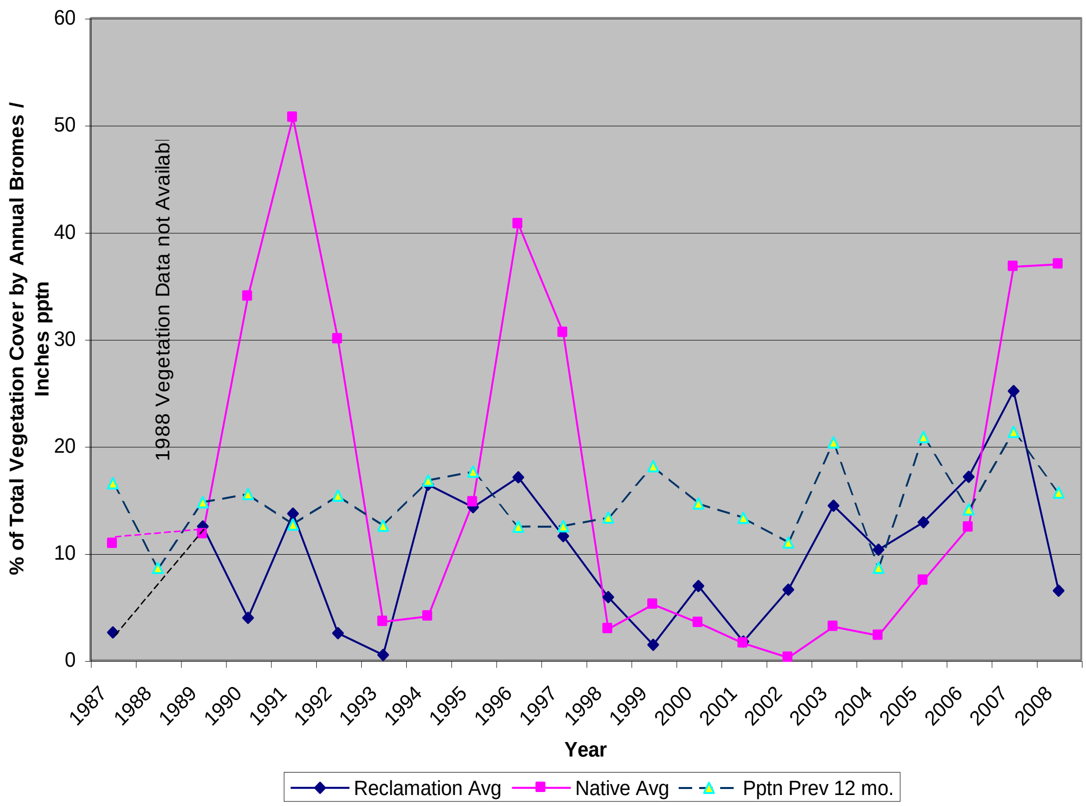
Quantitative data from field sampling of plant cover and biomass production have been collected annually at the Big Sky Mine in Rosebud County from mined and reclaimed areas as well as native reference areas since 1987 and submitted to the Montana Department of Environmental Quality in association with required annual reports of mining and reclamation activity. Cover data were collected using the point intercept method (100 points along a 50 m transect) each year from 1993 to 2008. Prior to that (1987 to 1992), data were collected using ocular estimates in 20cm x 50 cm microplots. Production data were acquired using clip samples of standing crop biomass from 0.5 sq.m.plots in July of each year. Harvested material was separated by species/life form and oven-dried at 105^{o} C for 24 hours. To avoid the confusion of weed abundance typical of juvenile vegetation, only data from reclaimed areas at least five years old were included in this study. 1988 vegetation data were unavailable. Precipitation data were obtained from the Big Sky Mine meteorological station for the period of 1982 through 2006. Precipitation data from 2007-2008 were obtained from a NOAA meteorological station in Colstrip, Montana located about 9.7 km northeast of the sample site (WRCC, 2009). .

Results and Discussion

The Big Sky Mine in Rosebud County, MT is located in a landscape characterized by ponderosa pine (*Pinus ponderosa*) woodlands and skunkbrush (*Rhus trilobata*) shrublands on convex sites and sagebrush steppe or grassland on toe slope and concave sites. The sagebrush communities are dominated by *Artemisia tridentata* and *A. cana* and the grasslands are composed of western wheatgrass (*Pascopyrum smithii*)/needlegrasses (*Hesperostipa comata, Achnatherum nelsonii, Nasella viridula*). From1994 to 2008, precipitation for the 12 months preceding sampling (i.e. July to June) varied from approximately six inches (40%) above to six inches below the average of 15 inches per annum (Fig. 1). Figures 1 and 2 show that the abundance of annual bromes also fluctuated considerably. During the 22-year record extending from 1987 to 2008, there have been three peaks of annual brome abundance in the native reference areas at the Big Sky Mine, 1990-1992, 1995 –1997 and 2006 to 2008. Biomass data presented in Fig. 2 offer much the same pattern of annual brome abundance as the cover data in Fig. 1. Limited data available prior to 1987 suggest that there were also annual brome peaks in years from 1976 to 1986.

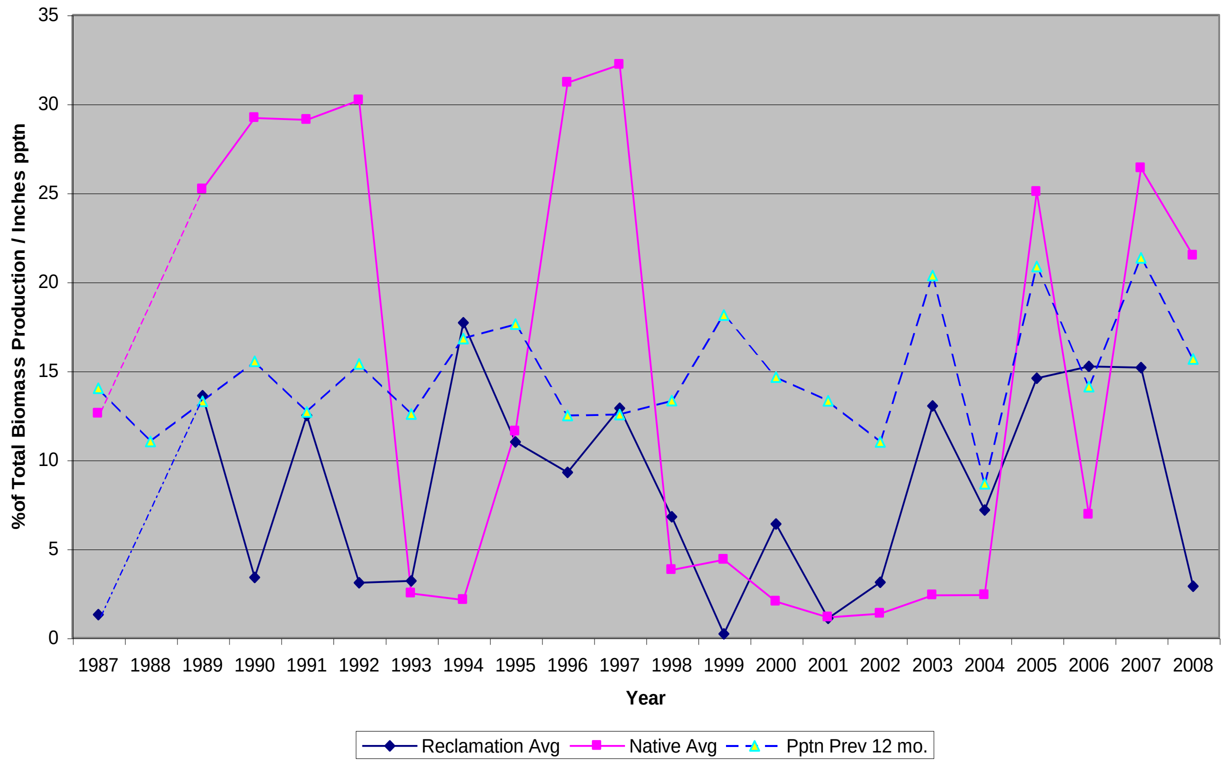
Cover by annual bromes expressed as a percentage of total vegetation cover (i.e. relative cover) in the native areas has varied from as low as 0.3% in 2002 to as high as 50.7% in 1991.

Figure 1. Cover by Annual Bromes in Reclaimed and Native Reference Areas, Big Sky Mine, Rosebud Co., MT



The peaks of annual brome abundance in the native areas have corresponded to peaks in the reclamation areas except that the peaks in the latter areas tend to begin and end earlier (Fig. 1 and 2).

Figure 2. Biomass Production of Annual Bromes in Reclaimed and Native Reference Areas, Big Sky Mine, Rosebud Co., MT



The repeated rising and falling of annual brome cover in native vegetation is by itself instructive in that it demonstrates that these winter annuals are not, once abundant, eternally successful at establishing themselves year after year. Rather they are prone to falling back to low levels of abundance until again the conditions are conducive to a renewed increase. The peaks of annual brome cover and biomass production in the reclaimed areas tend to be one-third to one-half those of the native reference areas.

What sort of opportunity seems to precede a rise in annual brome abundance? Two factors appear prominently in the rise of annual brome abundance. First a change (inflection) in the yearly precipitation pattern—either drought following a period of near average or greater moisture, or abatement of multi-year drought. For example, the ability of annual brome to grow preemptively with the reappearance of moisture after drought, to the detriment of slower perennial grass recovery, is consistent with previous observations by Stewart and Hull (1949) in southwestern Idaho. Second the pattern of monthly moisture during the inflection year. For winter annuals, late summer/early fall moisture is helpful in germination. High spring moisture is important for enhancing the growth and biomass of seedlings and for producing seed that can fuel a large outburst of growth over subsequent years. This pattern was particularly prominent in 2005, when the peak in biomass was not paralleled in the cover data. Spring precipitation was unusually high that year (Fig. 3), which apparently propelled the relatively few individuals of annual brome to produce a substantial amount of biomass.

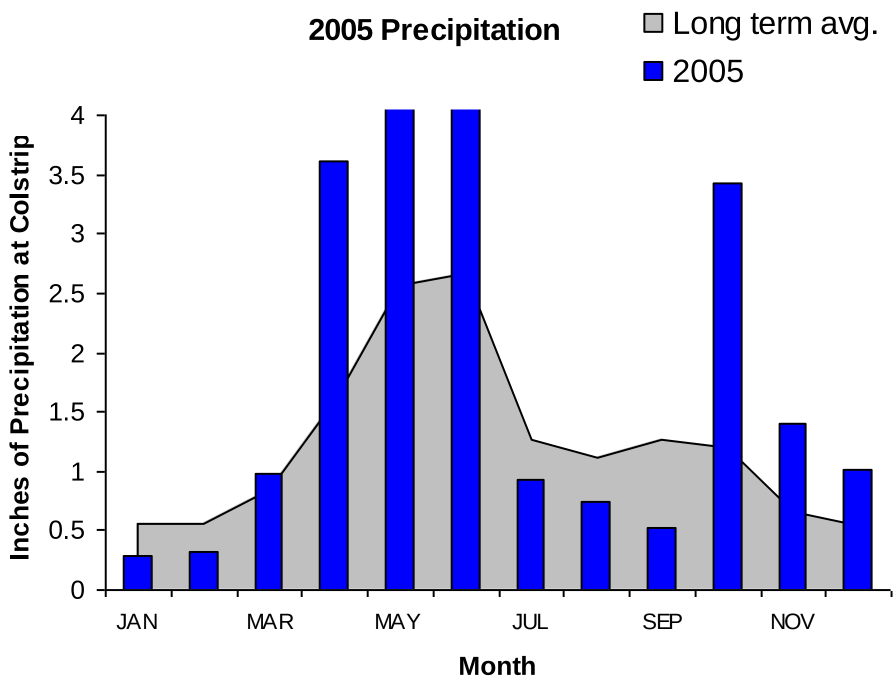


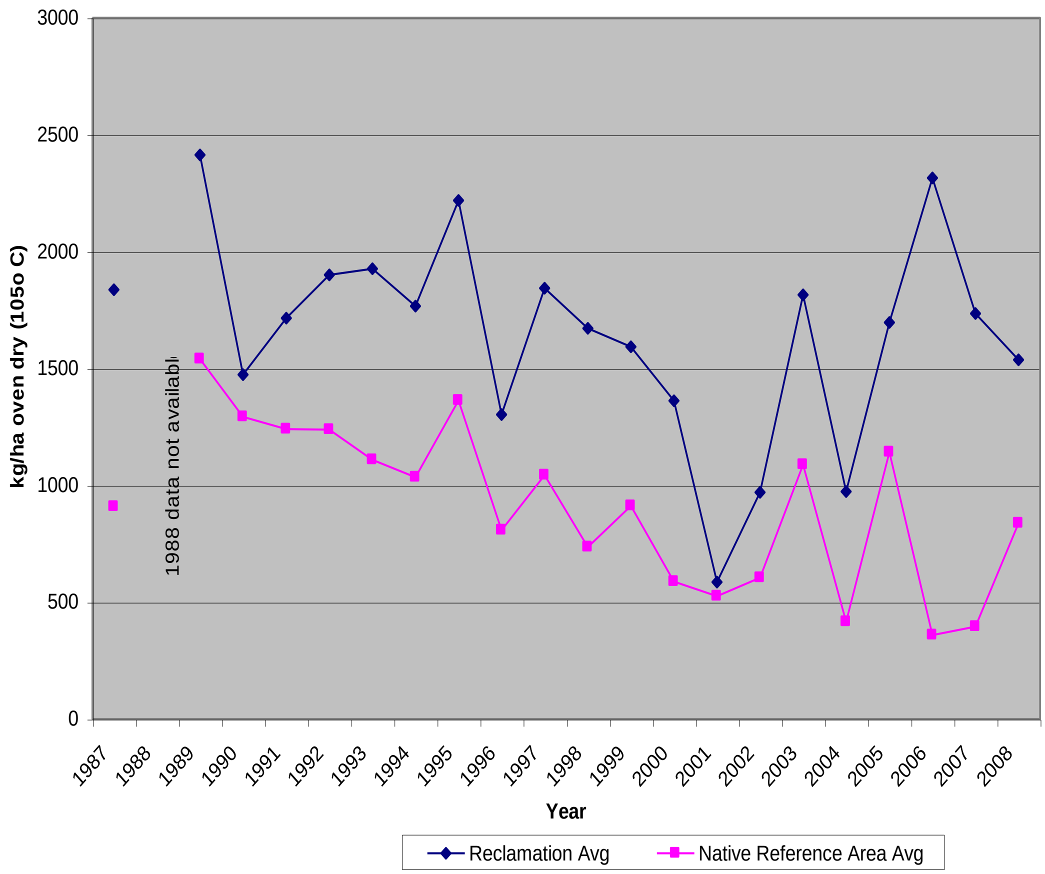
Figure 3. Precipitation at Colstrip, near Big Sky Mine in 2005, showing very wet spring conditions.

With regard to the observed correlation of high spring moisture in the initiation of a spike of annual brome abundance, the capacity of some races of both cheatgrass and Japanese brome to function as spring annuals may be important. An opportunistic exploitation of abundant spring moisture may create a burst of fresh seed that can facilitate near-term rapid expansion. Such a dynamic involving annual brome growth preemptively making use of the reappearance of moisture after drought to the detriment of slower perennial grass recovery would be consistent with previous observations by Stewart and Hull (1949) in southwestern Idaho.

Reclaimed area biomass production over the 22-year period exceeded to greatly exceed that found in the Native Reference Areas (Fig. 4). Reclaimed area vegetation is comprised primarily of native perennial grasses, though in areas less than ten years old, the proportion attributable to perennial forbs (usually alfalfa, *Medicago sativa*, and cicer milkvetch, *Astragalus cicer)* may also be substantial. As a result, the strength of plant competition in the more mature reclamation sites is intense. This degree of competition is thought to account for the diminished peaks of annual brome development in the reclamation areas compared to the native areas (Fig. 1 and 2).

Similarity or reclaimed area vegetation at the Big Sky mine corresponds to native vegetation at the 65 to 75% level using the Motyka index of similarity at the lifeform level. Total species density of ten year-old reclaimed areas in 2007 and 2008 averaged between 28 and 29 species per 100 sq.m. compared to 32 to 34 species per sq. m. in adjacent native vegetation.

Figure 4. Total Biomass Standing Crop 1987 to 2008, Big Sky Mine, Rosebud Co., MT



Factors that underlie the high productivity of most reclaimed area sites compared to nearby undisturbed native sites is thought likely to relate to two aspects of the replaced soils on the reclaimed sites. First, soil organic matter, upon disturbance (such as during excavation, transport and replacement) is known to experience a rapid mineralization, releasing nutrients, especially nitrogen that is available for plant uptake (Vitousek et al. 1997). This is the basis for the age-old observation of the high productivity of newly plowed native soils. The second factor supporting high reclamation site productivity is placement of a growth medium without zones of restricted permeability. Best management practice in the salvage and replacement of soils, such as practiced at the Big Sky Mine, avoids compaction in replaced soil layers. Native soils often possess restrictive zones such as textural B-horizons or hardpans at shallow depth that may restrict air, water and root penetration. Such features develop through very long periods and reclaimed area soils can likewise be expected to do so over very long periods. In the near term, however, with reduced restrictions to the movement of air and water into and through the soil, every precipitation event has a better chance of placing moisture into a position within the reclaimed area growth media to support plant growth. In short, runoff is typically reduced when soils accept input moisture more readily. The pattern observed at the Big Sky Mine and reported here for reclaimed area plant biomass production to far exceed that of adjacent native areas is thought largely to relate to more effective sequestration of precipitation. Quantitative plant biomass data collected by author Buckner on reclaimed areas and native reference areas at coal surface mines in Wyoming, Colorado, and Arizona have consistently shown the same pattern in annual observations over the past 15 to 20 years.

The observed pattern at Big Sky Mine in which peaks of annual brome abundance begin and end earlier in the reclaimed areas may relate to the favorable soil conditions in the reclamation landscapes. Enhanced moisture levels in reclaimed area soils after small events of precipitation may allow annual bromes to ramp up seed production earlier and move ahead in to the peak more rapidly. It is thought that the earlier termination of annual brome peaks in reclaimed areas is related to the competitive effects of the more vigorous grass and forb growth there.

Summary

In summary, it is apparent that high annual brome presence in southeastern Montana plant communities is not self-perpetuating; it varies dramatically over time. Peak abundance is least in the reclaimed area plant communities where biomass production in highest and presumably plant competition is most intense. Labeling newly arrived opportunistic plants as “invasives” immediately leads to an oversimplification of their interaction with the native flora as “violence against the indigenous occupants.” The presence of life history characteristics that allow for high seed production, highly effective seed dispersal, high seedling vigor and rapid growth to reproductive maturity are usually offset by low competitive strength. Arriving opportunistic plants can prosper only to the extent that undefended niche space is available in a given existing plant community. Details of how and why undefended niche space can appear and disappear in reclamation or native communities of southeast Montana are not completely understood. Based the 22-year record addressed here, it is suggested that such undefended niche space can (doubtless among other ways) appear in the immediate aftermath of sudden changes away from an established moisture status quo. That status quo may be either moisture abundance or scarcity. Facilitation of invasion by either onset of resource abundance or onset of scarcity is consistent with experimental observations of Davis et al. (1999) and theories of invasibility set forth by Davis et al (2000).

Annual brome abundance is a litmus test for plant community competitive strength. Annual bromes are impressive opportunists, but they do not control their own destiny. At least in southeastern Montana, when the competitive effectiveness of the perennial portion of the plant community is sufficiently strong, annual bromes are not capable of sustaining increased levels of cover or biomass that they periodically develop.

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