The Relationship of Bulbous Bluegrass and Big Sagebrush in Utah

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THE RELATIONSHIP OF BULBOUS BLUEGRASS AND BIG SAGEBRUSH IN UTAH

By

Jason D. Cox
27 May 2013
A capstone monograph submitted in partial fulfillment of the requirements for the degree of MASTER OF NATURAL RESOURCES

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ABSTRACT

The increase in abundance and distribution of bulbous bluegrass (*Poa bulbosa*) has been a concern of the Utah Division of Wildlife Resources. Very little research has been conducted to analyze the invasiveness of bulbous bluegrass in the Intermountain West. This study used data from 1982 to 2012 at range trend study sites across the state of Utah to investigate trends in bulbous bluegrass abundance, range expansion, and co-occurrence with big sagebrush (*Artemisia tridentata*) and cheatgrass (*Bromus tectorum*). This study addressed the question of whether the increase of bulbous bluegrass correlates with changes in sagebrush and/or cheatgrass in Utah using a log-response ratio analysis. The log-response ratio identified the correlation of dominance of each species to one another over time. Results of this analysis illustrated an increased abundance of bulbous bluegrass in relation to cheatgrass and sagebrush. In addition to the log-response analysis, a series of maps were created that clearly show the increase abundance and range expansion of bulbous bluegrass during the study period. The results illustrate the need for more research to identify if bulbous bluegrass is detrimental to sagebrush populations. The increased abundance of bulbous bluegrass within sagebrush rangelands could threaten desirable flora and fauna and have negative effects on human dimensions and economics. Further research is recommended to identify the effects of bulbous bluegrass on sagebrush rangelands, and whether bulbous bluegrass is detrimental to sagebrush plant communities and how this will affect social and economic aspects of human dimensions. In addition, research is needed to examine whether climatic, landscape, or anthropogenic variables are attributing to the increase of bulbous bluegrass within sagebrush rangelands.
Table of Contents
List of Figures ........................................................................................................................................... 3
List of Tables ............................................................................................................................................... 3
PART A ......................................................................................................................................................... 4
THE POTENTIAL IMPACTS OF BULBOUS BLUEGRASS IN UTAH ..................................................... 4
INTRODUCTION ........................................................................................................................................ 4
LIFE HISTORY OF BULBOUS BLUEGRASS .................................................................................. 6
  Plant Description ................................................................................................................................. 6
  Origins ............................................................................................................................................. 6
  History of Introduction in Western United States .......................................................................... 7
  Reproduction, Growth, and Dispersal ............................................................................................... 8
MANAGEMENT ISSUES ..................................................................................................................... 9
  Ecological .......................................................................................................................................... 9
  Humans and Bulbous Bluegrass ....................................................................................................... 10
  Law and Policy ................................................................................................................................. 13
  Economics ....................................................................................................................................... 13
PART B ......................................................................................................................................................... 17
THE RELATIONSHIP OF BULBOUS BLUEGRASS TO BIG SAGEBRUSH AND CHEATGRASS IN UTAH ............................................................................................................................... 17
  Introduction ...................................................................................................................................... 17
  Study Area ......................................................................................................................................... 17
  Methods ............................................................................................................................................. 20
  Results .............................................................................................................................................. 22
  Discussion ......................................................................................................................................... 35
  Conclusion ........................................................................................................................................ 36
  Acknowledgement ............................................................................................................................ 37
LITERATURE CITED ............................................................................................................................ 38
List of Figures:

Figure 1. Photo of bulbous bluegrass ................................................................. 5
Figure 2. The distribution of bulbous bluegrass in North America ................. 7
Figure 3. Distribution map based on mule deer winter range trend study sites 18
Figure 4. Range trend sites that have sampled bulbous bluegrass ................. 19
Figure 5. Plot of the Least Square Means of the Log (POBU/ARTR) over four time periods ... 24
Figure 6. Plot of the Least Square Means of the Log (POBU/BRTE) over four time periods ... 25
Figure 7. Plot of the Least Square Means of the Log (BRTE/ARTR) over four time periods .... 26
Figure 8. Mean total percent cover for bulbous bluegrass (POBU), cheatgrass (BRTE), and sagebrush (ARTR) over four time periods ................................................................. 27
Figure 9. Map of Bulbous Bluegrass frequency (1982-1987) ......................... 29
Figure 10. Map of Bulbous Bluegrass frequency (1988-1992) ........................ 30
Figure 11. Map of Bulbous Bluegrass frequency (1993-1998) ...................... 31
Figure 12. Map of Bulbous Bluegrass frequency (1999-2003) ...................... 32
Figure 13. Map of Bulbous Bluegrass frequency (2004-2008) ..................... 33
Figure 14. Map of Bulbous Bluegrass frequency (2009-2012) ...................... 34

List of Tables:

Table 1. Table of Herbicides .................................................................................. 16
Table 2. The summary of fit for log-response ratio for bulbous bluegrass (POBU), sagebrush (ARTR), and cheatgrass (BRTE) models ................................................................. 23
Table 3. Least Square Means Differences Tukey HSD of Bulbous Bluegrass and Sagebrush... 24
Table 4. Least Square Means Differences Tukey HSD of Bulbous Bluegrass and Cheatgrass... 25
Table 5. Least Square Means Differences Tukey HSD of Cheatgrass and Sagebrush .......... 26
Table 6. Explanatory table for Range Trend Study Sites that sampled bulbous bluegrass from 1982-2012 .................................................................................. 28
PART A

THE POTENTIAL IMPACTS OF BULBOUS BLUEGRASS IN UTAH

INTRODUCTION
The introduction of non-native species into ecosystems can have negative effects and lasting consequences. Bulbous bluegrass (*Poa bulbosa*) is a non-native species that has grown in abundance across western North America (Scheinost et al. 2008). Despite the fact that many aspects of its life history are documented, not much is known about the effects of bulbous bluegrass on sagebrush ecosystems. In Utah it is usually found in areas where cheatgrass (*Bromus tectorum*) has also become well established (Gunnell et al. 2012). Data collected by the Utah Division of Wildlife Resources (UDWR) Range Trend Project (1982-Present) appears to indicate a correlation between decreases of sagebrush (*Artemisia tridentata*) with increases of bulbous bluegrass. The primary concern is the alarming increase and spread of bulbous bluegrass throughout Utah with an apparent corresponding decrease in sagebrush cover. The range trend data also indicates bulbous bluegrass is spreading and increasing in distribution and abundance throughout the state of Utah (Gunnell et al. 2012). The decrease in sagebrush cover is a concern for wintering mule deer (*Odocoileus hemionus*) as sagebrush provides crucial forage habitat during winter months (Anderson et al. 2012). Loss of sagebrush is also a concern for shrubsteppe obligate bird species in Utah (Braun et al. 1976, Sutter, et al. 2005) such as the Greater sage-grouse (*Centrocercus urophasianus*) which is currently being considered for federal listing (USFWS 2010).

The first section of this paper presents the findings of a literature review conducted to answer the following questions:

- What are the life history traits of bulbous bluegrass?
- How was bulbous bluegrass introduced to the western United States?
- How does it interact within native and introduced ecosystems?
- What are the potential social and economic impacts of bulbous bluegrass?
- What are the current policies for control of bulbous bluegrass?
- What can be done to control bulbous bluegrass?

The second part of this paper specifically addresses the relationship of bulbous bluegrass to big sagebrush and cheatgrass in Utah, and the expansion of bulbous bluegrass on UDWR big game range trend study sites from 1982 to 2012.
Figure 1. (Sheri Hagwood @ USDA-NRCS PLANTS Database). Photo of bulbous bluegrass. The photo shows the inflorescence of bulbous bluegrass. The inflorescence is proliferated consisting of asexual reproductive bulblets.
LIFE HISTORY OF BULBOUS BLUEGRASS

Plant Description
Bulbous bluegrass is a fairly small perennial bunchgrass species. It can vary in height depending on moisture availability, but most plants are less than 6 decimeters in height. It has a shallow root system arising from a bulbous base. It reproduces asexually with the formation of bulbils and bulblets. Harris and Harris (2009) defined bulbils as “A small bulb arising from the base of a larger bulb” and bulblet as “A small bulb; a bulblike structure borne above ground, usually in a leaf axil.” The terminology of bulbil and bulblet seem to be synonymously used in the literature, mainly referring to the plant’s inflorescence production (seedhead or flower). Bulblets act similar to seed which are grown from the panicle and are deposited similarly. Bulbs are formed from the bulbous base of the plant. The inflorescence consists of bulblets and rarely seed. The leaves of the plant are mostly flat, but may be rolled. The foliar vegetation starts growing in late fall to early spring and dries out in May to early June (Cronquist 1977, Gucker 2007).

The mode of bulblet formation (asexual reproduction) and normal seed production (sexual reproduction) of bulbous bluegrass is distinct. The floret of a normal seed consists of a lemma, palea, anther, stamen, and stigma. The asexual reproduction of bulbous bluegrass is known as vivipary. Vivipary of bulbous bluegrass consists of a bulblet that is formed from the lemma within the floret. The stimuli which signal production of the palea and sexual organs are inhibited in the bulblet formation. The bulblets are formed from the modified lemma (Younger 1960).

The following is a technical physical description of bulbous bluegrass by Cronquist et al. (1977):

Densely tufted perennials from somewhat bulbous bases, purplish below, the rhizomes absent; culms wiry, (2) 3-5 (6) dm tall; innovations numerous; sheaths open nearly to the base, smooth; ligules 1.5-4 (6.5) mm long, obtusish to acuminate, entire or somewhat erose; blades flat to usually folded or loosely involute on drying, 1.5-4 mm broad, somewhat scabrous; panicles (3) 4-7 (12) cm long, usually compact and crowded, sometimes ovoid, the branches ascending and scabrous; spikelets nearly always proliferous with the 4 to 6 florets produced into bulbetts with broad, shiny, dark purple bases and protruding foliaceous linear tips, the bulbils as long as 2 mm; glumes narrow, the first 2-3 (3.5) mm long, the second 2.2-3.5 (4) mm long; lemmas (2.5) 3-5 (6.5) mm long; normal lemmas rarely present, but if present 4-6 per spikelet, pubescent on the nerves and cobwebby at the base, the modified spikelets usually producing a single bulbil that is capable of rooting immediately and asexually producing a new plant; 2n = 14, 21, 18, 39, 40-58.
Origins
Bulbous bluegrass is a short lived perennial grass species that is native to southern Asia, Europe, and northern Africa (Gucker 2007). According to Scheinost (2008) bulbous bluegrass can be found throughout the world in temperate and subtropical regions, and is found throughout North America along roadsides and fields. Bulbous bluegrass has spread to nearly every state in the United States, but is more common in the western United States (Figure 1, Soreng 2007). Accounts differ to where, when, and how bulbous bluegrass was first introduced to North America, although most accounts suggest it was likely a contaminant of alfalfa and clover seed (Gucker 2007).

Poa bulbosa

Figure 2. The distribution of bulbous bluegrass in North America by (Soreng, 2007). The map represents known locations of bulbous bluegrass from reported records. UTC - is specimens at the Intermountain Herbarium of Utah State University. MEB – is specimens the author(s) saw in another herbarium (M. Barkworth, Intermountain Herbarium, personal communication).

History of Introduction in Western United States
The first collection of bulbous bluegrass in North America was in Oregon in 1901 (Morris et al. 2009). In 1906 the United States Department of Agriculture (USDA) acquired bulblets of bulbous bluegrass from Russia, which were subsequently planted at experimental farms in Arlington Virginia in 1907, 1908, and 1909; and Pullman Washington in 1907 (Locke and
Burrill 1994, Scheinost et al. 2008). The USDA abandoned the experimental seeding of bulbous bluegrass a short time later. In 1915 a groundskeeper discovered an unidentified grass species growing at the state capitol in Richmond, Virginia. The USDA identified the grass species as bulbous bluegrass and advised not to get rid of it, but to manage it as a winter grass species in conjunction with Bermuda grass (*Cynodon dactylon*). The following year in 1916, the USDA distributed bulblets of bulbous bluegrass to several experiment stations. Commercial production of bulbous bluegrass commenced shortly after and in 1928 the center of seed production was located in Medford, Oregon (Scheinost et al. 2008). The commercial production of bulbous bluegrass was intended to promote its use in conjunction with Bermuda grass in pastures and as turf for golf courses (USGA Green Section 1931). However, the overall effectiveness of bulbous bluegrass as a turf grass was not successful and commercial production ceased sometime later (Scheinost et al. 2008).

In the mid-1900s bulbous bluegrass was experimentally seeded in parts of Utah, Nevada, Idaho, and Wyoming (Bleak et al. 1965, Scheinost et al. 2008, Schwendiman 1956, Hull Jr. 1974, Plummer et al. 1955). The experimental plots contained many other non-native species of grass such as crested wheatgrass (*Agropyron cristatum*) and intermediate wheatgrass (*Thinopyrum intermedium*), and several native grass species such as bluebunch wheatgrass (*Pseudoroegneria spicata*) and various varieties of Sandberg bluegrass (*Poa secunda*). Most of the seeded areas were experimental plots designed to identify traits favorable for palatability and forage production. Bulbous bluegrass was chosen as an experimental grass species due to its short season and early growth characteristics (Plummer et al. 1955).

Bulbous bluegrass was also used in the early to mid-1900s to help with soil erosion and improve depleted rangelands in the western United States (Marsh 1952, Marcella et al. 1953). The limited literature available on these efforts does not specify how intensive bulbous bluegrass was used for either of these purposes.

In 1956 the Pullman Plant Materials Center developed P-4784, a cultivar of bulbous bluegrass. The cultivar was not distributed to seed growers because of the poor long-term germination of the bulblets, and in 1976, after several years of evaluation, the seed stock of P-4784 was destroyed (Scheinost et al. 2008).

The idea of using bulbous bluegrass as a cultivated crop is still being explored today. In a U.S. patent application filed in July of 2011, bulbous bluegrass hybrids were being patented for use as a turf grass. The patent application claims that bulbous bluegrass hybrid cultivars can be used in “sports fields, golf greens or fairway, playing field, park, and lawns” (Miebach and Witten 2012). The use of bulbous bluegrass as a grass alternative may further accelerate the spread and increase bulbous bluegrass range.
Reproduction, Growth, and Dispersal

In its range in North America, most of bulbous bluegrass reproduction is from bulblets and basal bulb production, and is rarely from seed (Scheinost et al. 2008, Gucker 2007, DiTomaso and Kyser 2013). However a genetic test on populations in Idaho and Washington found a high degree of genetic variation, suggesting that there is some sexual reproduction within the population (Novak and Welfley 1997). In contrast to North American populations, seed reproduction is common in its native habitats (Scheinost et al. 2008, Gucker 2007, DiTomaso and Kyser 2013).

The initiation of seed production verses bulblet formation can be a response to environmental factors such as temperature and day length. While it was previously believed the presence of bulblets was solely a genetic component of bulbous bluegrass, other studies suggest day length and temperature may also play a role in producing bulblets (Lee and Harmer 1980, Younger 1960, Marcella et al. 1953, Volaire and Norton 2006). A controlled study by Younger (1960) on the environmental factors that control inflorescence initiation and development found that seed reproduction of bulbous bluegrass was achieved at high temperatures (23°C and 27°C) and long day lengths (16 hours). Normal seed production was only achieved when temperatures were 21°C or higher and long day lengths (16 hours). Long day length and temperature less than 21°C produced mostly inflorescences that contained bulblets. Short days (8 hours) and temperatures less than 27°C resulted in plants producing bulblets or no inflorescence. High temperature (27°C) and short day lengths resulted in inflorescence that had mostly bulblets with some seed produced or inflorescence with all bulblets produced.

The growth of bulbous bluegrass is influenced by temperature and day length. Bulbous bluegrass is considered a cool season and a short day plant (Gucker 2007), which is the optimal condition for asexual reproduction (clonal bulblets) (Younger 1960). The optimal conditions for bulblet growth and seed germination of bulbous bluegrass are short day lengths and cold temperatures. A study by Marcella et al. (1953) examined germination and early growth development of bulbous bluegrass. The study looked at the effects of day length and temperature on germination and early growth development of bulbous bluegrass. Nearly all the bulblets in this experiment sprouted in day lengths of eight hours but germination decreased as the day length increased and temperature increased.

Bulbous bluegrass is considered a desiccation-tolerant plant in that it can lose almost all the moisture content and survive for long periods of time without moisture replenishment (Volaire and Norton 2006) with basal bulbs drying to below 10% moisture content (Gucker 2007). The root system is fairly shallow and following senescence the roots die back to the basal bulb. In wet areas basal bulbs may be lacking entirely (Gucker 2007). In addition the bulblets produced within the inflorescences germinate after a period of dormancy lasting a few months up to 2 years (Scheinost et al. 2008).
MANAGEMENT ISSUES

Ecological
The increased abundance and spread of bulbous bluegrass in conjunction with the decrease of sagebrush in Utah are a concern to rangeland managers. It is speculated that bulbous bluegrass growth patterns may inhibit seedling establishment of sagebrush (Gunnell et al. 2012). In addition, the early growth characteristics may give bulbous bluegrass a competitive advantage, allowing it to use limited water resources prior to other plant species. The life history traits of bulbous bluegrass give it a competitive advantage within sagebrush communities. Like the invasive annual grass species cheatgrass, bulbous bluegrass germinates and exits dormancy early in the spring (Younger 1960, Volaire and Norton 2006). However, variation in spring precipitation and temperature can affect growth, germination, and seed/bulblet production of bulbous bluegrass (Gucker 2007, Younger 1960). Fluctuation of bulbous bluegrass is less noticeable than it is for cheatgrass in part because bulbous bluegrass is a perennial species which re-sprouts from the basal bulbs, whereas cheatgrass is an annual and its abundance fluctuates with variation in spring temperature and precipitation (Zouhar 2003).

This decrease of sagebrush abundance on rangelands can negatively affect mule deer, sage-grouse, and other wildlife populations, whose diet in winter months is primarily sagebrush (Anderson et al. 2012). Sage-grouse also needs the structure of sagebrush (i.e., height/crown and density) for winter habitat and nest success (Sutter et al. 2005). For most of Utah’s deer herds, winter range is the primary limiting factor for increasing deer populations. Because the amount of sagebrush available on the winter range determines its carrying capacity for deer, if sagebrush decreases it is likely that deer population will also decrease (Sutter et al. 2005, Weisberg et al. 2002).

The decrease of mule deer populations as a result of the loss of winter browse forage (sagebrush) could affect hunting opportunity. Smaller deer populations reduce the need for artificial population control, which would result in fewer deer permits being issued and reduced hunting opportunities.

Humans and Bulbous Bluegrass
Effects of bulbous bluegrass on humans are both direct and indirect. Some of the direct effects include: a decrease in suitable livestock grazing areas; a decrease in aesthetics due to a lack of biodiversity; agricultural; and localized weed problems. The indirect effects of bulbous bluegrass on humans include changes to ecosystems in which we live and depend on for our water supply, food sources, and recreation opportunities by reducing watershed quality and possibly increasing the fire return intervals. Literature for the effects bulbous bluegrass has on fire return interval is limited (Gucker 2007).

Grazing
Bulbous bluegrass can have a direct effect on livestock grazing. Bulbous bluegrass has a narrow window of opportunity for grazing. In early to mid-spring both bulbous bluegrass and cheatgrass are palatable to livestock until they dry out. The bulblets of bulbous bluegrass contain starch and fats that are desirable for wildlife species and domestic livestock when available (Gucker 2007); however, the nutritional content of bulbous bluegrass is minimal when the plant dries out (Locke and Burrill 1994). In some instances bulbous bluegrass dominated plant communities lack additional forage for livestock (Gunnell et al. 2012).

The relationship of bulbous bluegrass and sagebrush rangelands in the Intermountain West has not been well researched, although some studies have mentioned the potential threat posed by increased bulbous bluegrass abundance (Bleak et al. 1954, Bleak et al. 1965, Hosten et al. 2007, Hull Jr 1974, Plummer 1955, Schwendiman 1956).

One of those studies was a 30 year review of rangeland conditions by the Bureau of Land Management (BLM) in southwest Oregon (Hosten et al. 2007), which observed that bulbous bluegrass increased in cover abundance in all grassland and non-conifer dominated ecological sites, which is where grazing primarily occurred. While this study suggested livestock grazing promoted the invasion of bulbous bluegrass, it also suggested that cattle grazing in the spring could help reduce bulbous bluegrass abundance. Though the study was not specific on the effects of increased bulbous bluegrass to native plant communities in grazed areas, it concluded “the introduction of bulbous bluegrass appears to have had a greater impact than current livestock use” at changing local vegetation dynamics (Hosten et al. 2007).

A few studies have also examined the effects of grazing on bulbous bluegrass abundance in its native range in the Mediterranean with mixed results (Alados et al. 2004, Farris et al. 2010, Peco et al. 2005, Tukel 1984). Three studies conducted between 2004 and 2010 came to the same conclusion: where grazing occurs bulbous bluegrass is more abundant when compared to similar areas where grazing has been abandoned. Alados et al. (2004) reported their findings from a study done in the Middle Atlas in Morocco in which bulbous bluegrass dominated the grassland under grazing conditions. A study conducted in the dehesa pastoral management systems of Central Spain had similar findings. They examined the effects of grazing abandonment in vegetation communities and found that bulbous bluegrass only provided marginal cover in areas abandoned from grazing for over 20 years. The study also found bulbous bluegrass was the highest cover of any species under grazing conditions (Peco et al. 2005). A similar study in areas of grazing abandonment was conducted in the western Mediterranean island ecosystem. The study examined the short-term effects of grazing abandonment at two and five years post grazing using exclosure to prevent cattle grazing. Throughout the study period bulbous bluegrass was the predominant species outside the exclosure under grazing conditions. The study found bulbous bluegrass decreased in abundance in plots where grazing had been abandoned for both two and five years. The study concluded livestock grazing has a key role in maintaining bulbous bluegrass dominance within the plant community in active grazing areas (Farris et al. 2010).
In contrast, a study comparing grazed to ungrazed rangeland in Ulukisla, Turkey found there was less bulbous bluegrass on grazed than ungrazed rangeland. The study examined an area that was protected from grazing for 30 years and compared it to an adjacent rangeland open to public grazing. In the grazed rangeland bulbous bluegrass consistently decreased (Tukel 1984).

**Human Influence on the Spread of Bulbous Bluegrass**

The spread of bulbous bluegrass has been intentional and unintentional. In the early part of the 1900s bulbous bluegrass was experimentally seeded (Bleak et al. 1965, Scheinost et al. 2008, Schwendiman 1956, Hull Jr. 1974, Plummer et al. 1955) and used in restoration projects and erosion control (Marsh 1952, Marcella et al. 1953). In the Intermountain West, bulbous bluegrass was used in restoration projects, experimental seeding projects, and grown experimentally (Hull Jr. 1974, Gucker 2007, Plummer et al. 1955, Locke and Burrill 1994).

In addition, many unintentional anthropogenic activities also assist in the spread and expansion of bulbous bluegrass. Some of these activities include vehicle movement, grazing and ranching, agricultural development, urban development, and other land uses that remove vegetation and disturb soil. Anthropogenic dispersal of bulblets of bulbous bluegrass can be direct or indirect. Bulblets can be transported in clothing, vehicles, equipment, backpacks, and so on. Bulblets can be dispersed many miles to new location. As the population of a bulbous bluegrass increases, the likelihood of bulblets being transported to new locations increases, which will further accelerate its spread and expansion (Nielson et al. 2011, Gucker 2007).

The invasion processes of non-native species into ecosystems beyond its previous geographical range can occur through accidental introduction, escape, or deliberate introduction. Multiple modes of introduction of non-native species also exist. Once a non-native species is introduced to a new location it is likely to naturalize to the new ecosystem as a single or small-localized population for an extended period of time before becoming an invader within the new ecosystem. The triggering point to which invasion occurs is likely caused by a disturbance within the ecosystem, whether it be drought, fire, human caused or animal caused disturbance (Barney 2006).

It is likely grazing livestock or wildlife can spread bulbous bluegrass, though literature is limited on its dispersal. A potential issue with livestock distributing bulblets is the distance that can be covered by means of motor transportation. For example a cow may be ranged on an allotment where bulbous bluegrass is present and then transported to another allotment several hundred miles away and disperse the bulblets. The bulblets may or may not establish but the potential for invasion is present. Potentially, wildlife can have the same effect as transportation of livestock, though the distance traveled with bulblets is likely not very far. Gucker (2007) suggests small mammals may disperse bulblets by caching and depositing them.

The development of agricultural land creates localized areas of potential invasion. When land is disturbed it frees up resources for plant invaders and allows invasive plants to establish. The
invasive plants may not necessarily compete well with the agricultural crops but may slowly invade surrounding plant communities and disturbed sites. This creates reproductive sources for further invasion into adjacent plant communities for expansion.

The impact of urban development on the spread of bulbous bluegrass is similar to the impact of agricultural development. With urban development, land is cleared to build and develop housing communities. The disturbed lands are ideal locations for introduction of weedy species and are excellent sources for seed stock. Over time the surrounding plant communities can become invaded.

Law and Policy
Individual states designate species to their state noxious weed list. In Utah, the Commissioner of Agriculture and Food designates plants species to the state noxious weed list, and the County Weed Control Board designates invasive plant species at a county level. The county legislative body can petition for a review of specific species in order to list them on the noxious species list or delist them if they are on the list. In order for bulbous bluegrass to be listed on the states noxious species list, evidence and reasons for the listing must be reviewed by the county legislative body to petition the Commissioner for listing, or directly to the State Weed Committee for review and approval by the Commissioner (UT Admin Code R68-9 2013, Utah Code 4-17 2013).

Bulbous bluegrass is recognized as an alien species, but is not recognized as an invasive species by the National Invasive Species Council (NISC) under Executive Order 13112 (EO) (National Invasive Species Council 2005). According to Utah Noxious Weed Act, bulbous bluegrass is also currently not recognized as a noxious weed in Utah (UT Admin Code R68-9 2013, Utah Code 4-17, 2013). In accordance to the EO, an invasive species is defined “as a species not native to the region or area whose introduction (by humans) causes or is likely to cause harm to the economy or the environment, or harms animal or human health” (National Invasive Species Council 2005). It can be assumed the reasons for not including bulbous bluegrass as an invasive species as part of the EO is due to the lack of research and evidence validating bulbous bluegrass as an invasive or noxious species adversely affecting ecosystems. Additionally, it has not been considered to cause harm to the economy, environment, animals, or human health.

If bulbous bluegrass was listed as an invasive species it would help place priority on its management and control, which would help agencies find project funding for mitigating the spread of the species. However, to be listed it must first be proven that bulbous bluegrass is directly causing the decline of sagebrush, and has adverse effects to the economy, environment, animals, or human health.

Economics
Economic estimates of damage for invasive species are limited (National Invasive Species Council 2005). Pimentel et al. (1999) estimated that more than $138 billion are lost to damages
caused by non-native species in the United States each year. The cost for an individual species is
hard to estimate due to the complexities of the indirect effects non-native plants have on natural
and human systems. Costs associated with direct effects, such as control and suppression may be
easier to calculate than indirect costs.

The economic costs of bulbous bluegrass in Utah are not known. Most of the economic costs
associated with bulbous bluegrass are likely associated with agriculture and rangeland.
However, currently bulbous bluegrass is not recognized as a serious threat to Utah’s economy,
environment, animals, or human health, so no studies on what bulbous bluegrass costs Utahans
have been done. It is likely costs associated with agricultural practices are from crop loss due to
competition from bulbous bluegrass and costs associated with control and prevention.
Rangeland costs are harder to define, but probably include loss of forage due to competition of
bulbous bluegrass with higher value forage species. Changes in plant communities occupied by
bulbous bluegrass may also affect wildlife.

Control
The control of bulbous bluegrass can be expensive and labor intensive. Potential methods of
control include prevention, biological control, cultural, herbicide application, and
mechanical/physical removal (Parent 2005). Currently, there is no known biological control for
bulbous bluegrass (Bulbous Bluegrass 2013, DiTomaso and Kyser 2013). As with the control of
nearly all weeds, prevention is one of the best ways to guard against invasion (Parent 2005).

Cultural control is an indirect method used to manage land for sustained use and to insure the
land remains in good condition. Good land management practices include control of bulbous
bluegrass and other invasive weeds. Managing cultural practices such as agricultural and
livestock uses can help reduce the spread of bulbous bluegrass (Parent 2005). Control measures
may include seeding or maintaining competitive species which will resist invasion of bulbous
bluegrass (Bulbous Bluegrass 2013).

The use of herbicides can be effective at controlling bulbous bluegrass (Bussan and Dyer 1999).
Several herbicides are available for the control of bulbous bluegrass (Table 1, DiTomaso and
Kyser 2013). One of the advantages of herbicide application as compared to mechanical
methods is the ability to treat large areas of land where access may be limited by terrain or other
obstacles. Another advantage is it is conducive to multiple ways of application. Herbicide can
be applied by hand, machinery, horseback, and airplane. The major disadvantage of using
herbicide is it can affect other desirable plants, and effectiveness varies based on timing,
environmental conditions, and geographical factors. The herbicide may remain active in the soil
for several years depending on the herbicide (Parent 2005). Table 1 lists herbicides DiTomaso
and Kyser (2013) have suggested for use in controlling bulbous bluegrass.

Mechanical methods of control are expensive and labor intensive. Furthermore, they may not be
very effective due to the multiple modes of reproduction of bulbous bluegrass. Ground
disturbing activities have been shown to increase the production of bulbous bluegrass. It is speculated that the reason for the increase in abundance from ground disturbance is due to the bulbs and bulbils being deposited across the landscape from ground disturbing mechanical control methods (Brooks 2005). Disking, plowing, mowing, and drill seeding are some of the mechanical methods which have been used to control bulbous bluegrass (Welch 2005, Brooks 2005). Nine years after control treatments (fall burning and fall plowing, summer disking, drill seeding) on the Curlew National Grasslands in southern Idaho, bulbous blue grass remained the dominant species on the site at 22% cover, leading Welch (2005) to state “controlling bulbous bluegrass appears to be questionable at best”.

The control of bulbous bluegrass may require a combination of control methods and persistence to be effective. In addition, management of one area may be very different from another area and being adaptive to the condition and the needs of an area may achieve the optimal outcomes.
<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Rate:</th>
<th>Timing:</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clethodim Select, Envoy</td>
<td>Broadcast foliar Treatment: 6 to 8 oz product (Select)/acre (1.5 to 2 oz a.i./acre) for seedlings.  Spot treatment: 0.25% to 0.5% v/v solution</td>
<td>Postemergence. Best when applications are made before plants are 6 inches tall. It is less effective if applied after a mowing.</td>
<td>Clethodim is grass-selective and safe on broadleaf species. To select for perennial grasses, apply before perennials emerge. It has no soil activity. Use crop oil surfactant. Registered for fallow and non-crop areas, not generally for rangeland /natural areas, but has specific-use supplemental labels. Note that Envoy formulation is 1 lb a.i./gallon, Select is 2 lb a.i./gallon.</td>
</tr>
<tr>
<td>Glyphosate Roundup, Accord XRT II, and others</td>
<td>Rate: 0.33 to 1 qt. product (Roundup ProMax)/acre (0.37 to 1.1 lb a.e./acre)</td>
<td>Postemergence in early spring, to rapidly growing, non-stressed plants after most seedlings have emerged. If possible, apply before desirable perennials emerge</td>
<td>Glyphosate is a nonselective herbicide. It has no soil activity.</td>
</tr>
<tr>
<td>Imazapic Plateau</td>
<td>Rate: 4 to 12 oz product/acre (1 to 3 oz a.e./acre)</td>
<td>Preemergence to early postemergence from fall to early spring.</td>
<td>Long soil residual activity, mixed selectivity. Tends to favor members of the Asteraceae and some grasses. Use a spray adjutant for postemergence applications. Effects vary depending on soil texture and organic matter. Heavy soils and high organic matter may require higher rates. Can tie up in litter; efficacy is reduced in situations where there is thick thatch on the soil surface. Not registered for use in California.</td>
</tr>
<tr>
<td>Imazapyr Aresenal, Habitat, Chopper, Stalker, Polaris</td>
<td>Rate: 2 to 3 pt product/acre (8 to 12 oz a.e./acre)</td>
<td>Preemergence or postemergence.</td>
<td>Imazapyr has long soil residual activity. It is a nonselective herbicide.</td>
</tr>
<tr>
<td>Rimulsulfuron Matrix</td>
<td>Rate: 2 to 4 oz product/acre (0.5 to 1 oz a.i./acre)</td>
<td>Preemergence in fall to early postemergence in early spring.</td>
<td>Controls several annual grasses and broadleaves. Perennial grasses are tolerant to fall applications when established and grown under dryland conditions. Application to rapidly growing or irrigated perennial grasses may result in their injury or death. It provides soil residual control in cool climates but degrades rapidly under warm conditions. Will not control summer annual weeds when applied in fall or spring. Add a surfactant when applying post emergence.</td>
</tr>
<tr>
<td>Sulfometuron Oust and others</td>
<td>Rate: 1 oz product/acre (0.75 oz a.i./acre)</td>
<td>Preemergence of early postemergence from fall to early spring. Most effective control is with early postemergence treatment after bluegrass seedlings have emerged.</td>
<td>Mixed selectivity, fairly safe on native perennial grasses. Good for revegetation use. Use lower rates in arid environments and higher rates in wetter areas (&gt;20” rainfall) and on high organic matter soils. Fairly long soil residual activity. At higher rates, this treatment will generally result in bare ground.</td>
</tr>
<tr>
<td>Sulfometuron + Chlorsulfuron Landmark xp</td>
<td>Rate: 0.75 oz product/acre</td>
<td>Preemergence in fall or after soil thaws in spring.</td>
<td>See sulfometuron.</td>
</tr>
<tr>
<td>Sulfosulfuron Outrider</td>
<td>Rate: 0.75 to 2 oz product/acre (0.56 to 1.5 oz a.i./acre)</td>
<td>Early postemergence, fall to early spring, when desirable perennials are dormant and target plants are growing rapidly.</td>
<td>Mixed selectivity; fairly safe on perennial grasses, especially wheatgrasses. Fairly long soil residual. Treatments should include non-ionic surfactant. Sequential applications can be made (minimum of 21 days between applications) as long as the total rate does not exceed 2.66 oz product/acre per year.</td>
</tr>
</tbody>
</table>

Table 1. Table of Herbicides from (DiTomaso & Kyser, 2013). List of herbicides that may be effective at controlling bulbous bluegrass, based on reports by researchers and land managers. Herbicides are listed by mode of effect and are not reflective by efficacy or preference.
PART B

THE RELATIONSHIP OF BULBOUS BLUEGRASS TO BIG SAGEBRUSH AND CHEATGRASS IN UTAH

Introduction
The UDWR, in collaboration with the US Forest Service (USFS) and Bureau of Land Management (BLM), has been collecting range inventory data since the 1950s. UDWR started an intensive range trend inventory of Utah rangelands in 1982 to monitor the condition of mule deer winter habitat. Over this time there appears to be a correlation between the deterioration of sagebrush rangelands and the increase of bulbous bluegrass (Gunnell et al. 2012). This is a concern for wildlife managers since sagebrush rangelands are a crucial part of mule deer winter habitat. Other important wildlife species such as sage-grouse (*Centrocercus urophasianus*), Brewer’s sparrow (*Spizella breweri*), pygmy rabbit (*Brachylagus idahoensis*), and sage thrasher (*Oreoscoptes montanus*) are also dependent on sagebrush rangelands (Anderson et al. 2012, Sutter et al. 2005). I conducted an analysis of UDWR long-term range trend data to determine if there is a relationship between changes in the abundance of bulbous bluegrass, sagebrush, and cheatgrass on study sites throughout the state of Utah.

As discussed in Part A of this report, there is little research on the relationship of bulbous bluegrass and sagebrush. Although a pattern appears to exist between deteriorated sagebrush rangelands and bulbous bluegrass, the relationship is not well understood.

This part of this paper explores the relationship between bulbous bluegrass, sagebrush, and cheatgrass using a log response ratio statistical analysis. The analysis incorporates the UDWR range trend data which was collected from 1992-2012. In addition to this analysis, I have also graphically depicted the expansion of bulbous bluegrass on UDWR big game range trend sites from 1982 to 2012 to show the increase and range expansion of bulbous bluegrass in Utah.

Study Area
The UDWR big game range trend study sites are located in Utah on mule deer winter range within big sagebrush habitat. The majority of the studies that have sampled bulbous bluegrass in mule deer winter range are located in central and northern Utah, though it has been sampled on several sites in southern Utah as well (Figure 3 and Figure 4).
Figure 3. Distribution map based on mule deer winter range trend study sites (1982 – 2012). Range trend sites in Utah that have sampled bulbous bluegrass on the study site.
Figure 4. Range trend sites that have sampled bulbous bluegrass (1982 – 2012). The map shows the location of the UDWR range trend sites used in the analysis.
**Methods**

**Sampling techniques**

In collaboration with the US Forest Service and BLM, intensive monitoring methods were established by the UDWR to gather vegetation information for areas across the state of Utah. The following is a general description of the sampling techniques used by the UDWR range trend project for collection of data for bulbous bluegrass, sagebrush, and cheatgrass.

Estimated percent cover and nested frequency data for herbaceous species (e.g., bulbous bluegrass and cheatgrass) and browse species (e.g., sagebrush) were sampled using a quarter meter quadrat with a modified Daubenmire Cover-class method (Gunnell et al. 2012). A detailed explanation of the UDWR sampling techniques can be found at: [http://wildlife.utah.gov/range/methods.html](http://wildlife.utah.gov/range/methods.html).

A total of 125 UDWR range trend site have sampled bulbous bluegrass during one of the sample periods from 1982-2012 (Figure 3. Distribution map based on mule deer winter range trend study sites (1982 – 2012). Range trend sites in Utah that have sampled bulbous bluegrass on the study site.). Following the criteria for site selection, 46 range trend sites were selected for the analysis (Figure 4. Range trend sites that have sampled bulbous bluegrass (1982 – 2012). The map shows the location of the UDWR range trend sites used in the analysis.). Four of the studies occurred in basin big sagebrush communities, three of the studies occurred in Wyoming big sagebrush communities, and 39 of the studies occurred in mountain big sagebrush communities. The analysis only included data collected from 1992-2012 because Daubenmire cover data was not collected from 1982 to 1992.

**Log-Response Ratio Analysis**

Only sites that occurred in mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), or Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) community types were used in the analysis. Sites that had major perturbation such as fire or treatment were also excluded from the analysis to alleviate confounding effects from disturbance. Of these big sagebrush sites, it was determined that sites would not be included in the analysis unless there was at least one sample year in which bulbous bluegrass was sampled at 1% cover or higher.

The analysis of the UDWR range trend data was calculated using a log-response ratio because the relationship between bulbous bluegrass and sagebrush abundance is washed-out or ambiguous using linear regression. When bulbous bluegrass is plotted against sagebrush using linear regression it does not account for variations of population abundance, stages of invasion, and other factors. The response ratio is a good work-around because it standardizes this relationship across sample site and sample years. This helps identify what is responsible for the variation between study sites and whether it varies by sample year. The ratio has interpretive value too, with a low value indicating low relative abundance of bulbous bluegrass and a high

The log-response ratio was calculated using percent cover data for bulbous bluegrass, sagebrush, and cheatgrass since cover was a similar variable between each plant species. Cover data was used from 1992-2012 for each of the selected range trend study sites. Most of the study sites had four sampling points over this 20 year period.

The log-response ratio for bulbous bluegrass (POBU), sagebrush (ARTR), and cheatgrass (BRTE) were calculated as follows:

\[
\log \left( \frac{POBU \% \text{ cover}}{ARTR \% \text{ cover}} \right)
\]

\[
\log \left( \frac{POBU \% \text{ cover}}{BRTE \% \text{ cover}} \right)
\]

\[
\log \left( \frac{BRTE \% \text{ cover}}{ARTR \% \text{ cover}} \right)
\]

To account for zeros within the data, each zero was replaced with 0.0001. The log-response ratio for bulbous bluegrass, cheatgrass, and sagebrush were then fitted in a model run in JMP (JMP Version 7, 1989-2007). The analysis used the log-response ratio, individual study sites, and time period. Since individual study sites were read on a five year rotation based on regions of Utah, the study sites were combined into five year periods of time (time period). This gave the analysis four time periods to compare; time period 1 (1992-1997), time period 2 (1998-2002), time period 3 (2003-2007), and time period 4 (2008-2012). Within the model, an analysis of variance (ANOVA) and Tukey HSD test was run to measure for significant differences of the log-response ratio over time (time period).

I tested for three relationships among the species: the correlation in changes in abundance of bulbous bluegrass and sagebrush; bulbous bluegrass and cheatgrass; and sagebrush and cheatgrass. The addition of cheatgrass in the analysis was to determine if cheatgrass was reacting similarly to bulbous bluegrass.

Since the log-response ratio measures the proportion of the percent cover that each species provides in relation to each other and does not readily explain if one species is decreasing or increasing on a study site, the mean cover percentage values were also calculated and plotted. Each of the mean cover percentage values for bulbous bluegrass, cheatgrass, and sagebrush were plotted over the four time periods.

Expansion of Bulbous Bluegrass

In addition to the above analysis, the UDWR range trend data from 1982-2012 was used to show how bulbous bluegrass has expanded and increased in abundance. The expansion of bulbous bluegrass was graphically depicted using ArcGIS software (ESRI, 2012). Since cover
measurements were not measured prior to 1992, nested frequency values of bulbous bluegrass were used to depict changes of bulbous bluegrass abundance and range expansion since 1982. The 125 study sites were combined into sample periods, because most study sites have been only sampled six times since 1982. The six sampled period were; (1982-1987), (1988-1992), (1993-1998), (1999-2003), 2004-2008, and (2009-2012). Some of the studies sites were not sampled in the last sample period (2009-2012) because the studies are to be read in summer of 2013 (studies located in southwest Utah), and other study sites have been suspended for various reasons and were not sampled in every sample period. The range of nested frequency values was used to show how frequently bulbous bluegrass was sampled on each study site for a given sample period. Prior to 1992 the highest nested frequency score an individual study site could record was 400, and following 1992 the highest nested frequency value was 500. The change in nested frequency scores was due to the changes in individual quadrat measurement scores from 1-4 prior to 1992 and changed to a score 1-5 from 1992 to 2012. The lower the overall nested frequency value the less frequent bulbous bluegrass occurred on the study site. The nested frequency values were categorized in ranges of nested frequency values to depict different ranges of frequency for a given study site.

**Results**

**Response ratio of bulbous bluegrass and sagebrush**

There was a significant effect of the log-response ratio for bulbous bluegrass to sagebrush over time (time period). Table 3’s summary comparisons using the Tukey HSD test indicate that the least square mean score for the log-response ratio for bulbous bluegrass to sagebrush at time period 1 was significantly different than at time period 2, time period 3, and time period 4. Also, the least square mean score at time period 2 was significantly different than at time period 4. However, the log-response ratio for bulbous bluegrass to sagebrush at time period 3 was not significantly different from time period 2 and time period 4 (Figure 5, Table 2 and Table 3).

Because the log-response ratio is negative for time periods 1-3, sagebrush cover was more abundant in proportion to bulbous bluegrass on the study sites as a whole, though the abundance of sagebrush cover decreased with each consecutive time period. In time period 4, bulbous bluegrass cover was slightly more abundant in proportion to sagebrush on the study sites as a whole (Figure 5 and Table 3).

The proportion of cover provided by bulbous bluegrass has increased in comparison to the proportion of cover provided by sagebrush over the time periods. The results indicate that where bulbous bluegrass occurs, it has become more abundant and sagebrush has become less abundant in relation to one another on the study sites as a whole (Figure 5 and Table 3).

**Response ratio of bulbous bluegrass and cheatgrass**

There was a significant effect of the log-response ratio for bulbous bluegrass to cheatgrass over time (time period). Table 4’s summary comparisons using the Tukey HSD test indicate that the
least square mean score for the log-response ratio for bulbous bluegrass to cheatgrass at time period 1 was significantly different than at time period 2, time period 3, and time period 4. However, the log-response ratio for bulbous bluegrass to cheatgrass at time period 3 was not significantly different from time period 2 and time period 4 (Figure 6, Table 2 and Table 4).

The proportion of cover provided by bulbous bluegrass has increased in comparison to the proportion of cover provided by cheatgrass over the time periods. The result indicates that bulbous bluegrass has become more abundant and cheatgrass has become less abundant in relation to one another on the study sites as a whole. Time period 1 shows that cheatgrass in proportion to bulbous bluegrass provided more cover on the study sites as a whole. In time periods 2-4 bulbous bluegrass in proportion to cheatgrass provided more cover on the study sites as a whole (Figure 6 and Table 4).

**Response ratio of cheatgrass and sagebrush**
There was a significant effect of the log-response ratio for bulbous bluegrass to cheatgrass over time (time period). Table 5’s summary comparisons using the Tukey HSD test indicate that the least square mean score for the log-response ratio for cheatgrass to sagebrush at time period 1 was significantly different than at time period 2. However, the log-response ratio for cheatgrass to sagebrush at time period 3 was not significantly different from time period 2 and time period 4 (Figure 7, Table 2 and Table 5).

The proportion of cover provided by sagebrush increased in comparison to the proportion of cover provided by cheatgrass from time period 1 to time period 2, but the proportions of cover provided by sagebrush and cheatgrass for time periods 2-4 remained similar. Over all four time periods sagebrush has provided more cover in proportion to cheatgrass on the study sites as a whole (Figure 7 and Table 5).

<table>
<thead>
<tr>
<th>Summary of Fit for the Models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>log (POBU % cover/ARTR % cover)</strong></td>
</tr>
<tr>
<td><strong>log (POBU % cover/BRTE % cover)</strong></td>
</tr>
<tr>
<td><strong>log (BRTE % cover/ARTR % cover)</strong></td>
</tr>
</tbody>
</table>

**Table 2.** The summary of fit for log-response ratio for bulbous bluegrass (POBU), sagebrush (ARTR), and cheatgrass (BRTE) models.
Figure 5. Plot of the Least Square Means of the Log (POBU/ARTR) over four time periods. The vertical bars represent the error bars for the 95% confidence interval. The horizontal axis of the graph represents the log response ratio for bulbous bluegrass (POBU) to sagebrush (ARTR). The more negative the log response ratio the more abundant sagebrush is in relation to bulbous bluegrass and the more positive the log response ratio the more abundant bulbous bluegrass is in relation to sagebrush. A 0 value would represent a neutral relationship between bulbous bluegrass and sagebrush.

Bulbous Bluegrass and Big Sagebrush
LS Means Differences Tukey HSD

<table>
<thead>
<tr>
<th>Time period</th>
<th>LS Mean</th>
<th>Mean</th>
<th>Std Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2012 (4)</td>
<td>0.136140</td>
<td>0.13</td>
<td>0.31</td>
</tr>
<tr>
<td>2003-2007 (3)</td>
<td>-0.582367</td>
<td>-0.58</td>
<td>0.29</td>
</tr>
<tr>
<td>1998-2002 (2)</td>
<td>-1.420144</td>
<td>-1.41</td>
<td>0.30</td>
</tr>
<tr>
<td>1992-1997 (1)</td>
<td>-2.900290</td>
<td>-2.70</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Table 3. Least Square Means Differences Tukey HSD of Bulbous Bluegrass and Sagebrush. Time periods not connected by same letter are significantly different.
Figure 6. Plot of the Least Square Means of the Log (POBU/BRTE) over four time periods. The vertical bars represent the error bars for the 95% confidence interval. The horizontal axis of the graph represents the log response ratio for bulbous bluegrass (POBU) to cheatgrass (BRTE). The more negative the log response ratio the more abundant cheatgrass is in relation to bulbous bluegrass and the more positive the log response ratio the more abundant bulbous bluegrass is in relation to cheatgrass. A 0 value would represent a neutral relationship between bulbous bluegrass and cheatgrass.

<table>
<thead>
<tr>
<th>Time period</th>
<th>LS Mean</th>
<th>Mean</th>
<th>Std Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2012 (4)</td>
<td>A</td>
<td>3.591432</td>
<td>-3.61</td>
</tr>
<tr>
<td>2003-2007 (3)</td>
<td>A</td>
<td>2.569744</td>
<td>-3.08</td>
</tr>
<tr>
<td>1998-2002 (2)</td>
<td>A</td>
<td>2.427069</td>
<td>-3.75</td>
</tr>
<tr>
<td>1992-1997 (1)</td>
<td>B</td>
<td>-0.117533</td>
<td>-2.63</td>
</tr>
</tbody>
</table>

Table 4. Least Square Means Differences Tukey HSD of Bulbous Bluegrass and Cheatgrass. Time periods not connected by same letter are significantly different.
Figure 7. Plot of the Least Square Means of the Log (BRTE/ARTR) over four time periods. The vertical bars represent the error bars for the 95% confidence interval. The horizontal axis of the graph represents the log response ratio for cheatgrass (BRTE) to sagebrush (ARTR). The more negative the log response ratio the more abundant sagebrush is in relation to cheatgrass and the more positive the log response ratio the more abundant cheatgrass is in relation to sagebrush. A 0 value would represent a neutral relationship between cheatgrass and sagebrush.

<table>
<thead>
<tr>
<th>Time period</th>
<th>LS Mean</th>
<th>Mean</th>
<th>Std Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2012 (4) A B</td>
<td>-3.446897</td>
<td>3.76</td>
<td>0.37</td>
</tr>
<tr>
<td>2003-2007 (3) A B</td>
<td>-3.080804</td>
<td>2.57</td>
<td>0.34</td>
</tr>
<tr>
<td>1998-2002 (2) B</td>
<td>-3.791087</td>
<td>2.40</td>
<td>0.35</td>
</tr>
<tr>
<td>1992-1997 (1) A</td>
<td>-2.580578</td>
<td>0.14</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Table 5. Least Square Means Differences Tukey HSD of Cheatgrass and Sagebrush. Time periods not connected by same letter are significantly different.
Actual mean cover percentage values
The mean value across the 46 range trend study sites used for analysis was calculated for bulbous bluegrass, sagebrush, and cheatgrass. Each of these values was plotted over time (by time period). The actual mean cover of bulbous bluegrass, sagebrush, and cheatgrass were calculated to identify whether each species increased or decreased over the time periods. These calculations help identify the relationship of each species in relation to the log-response ratio, whether one species is increasing and another species is decreasing or whether each species is decreasing or increasing at the same time (Figure 8).

Expansion of bulbous bluegrass from 1982-2012
The increase of abundance of bulbous bluegrass and expansion of bulbous bluegrass was captured using UDWR range trend study sites data from 1982 to 2012. Nested frequency data was used to illustrate these changes. From 1982 to 2012, a total of 125 range trend site were established in the state of Utah to monitor big game habitat and sample bulbous bluegrass (Figure 9-14 and Table 6).

Figure 8. Mean total percent cover for bulbous bluegrass (POBU), cheatgrass (BRTE), and sagebrush (ARTR) over four time periods. Time period (1) is represented by studies sampled from 1992-1997, time period (2) is from 1998-2002, time period (3) is from 2003-2007, and time period (4) is from 2008-2012.
## Table 6. Explanatory table for Range Trend Study Sites that sampled bulbous bluegrass from 1982-2012

<table>
<thead>
<tr>
<th>Sample Period</th>
<th>Number of study sites that sampled bulbous bluegrass</th>
<th>Number of study sites that were sampled out of the 125 study sites that sampled bulbous bluegrass from 1982 to 2012</th>
<th>Number of study sites that had moderate to high nested frequency values (&gt;100)</th>
<th>Number of new study sites established</th>
<th>Number of the newly establish study sites that sampled bulbous bluegrass.</th>
<th>Number of study sites suspended and not sampled during and following the sample period</th>
<th>Number of study sites that were not sampled, and were not suspended</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1982-1987)</td>
<td>15</td>
<td>83</td>
<td>5</td>
<td>83</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(1988-1992)</td>
<td>29</td>
<td>95</td>
<td>11</td>
<td>95</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>(1993-1998)</td>
<td>60</td>
<td>107</td>
<td>20</td>
<td>107</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>(1999-2003)</td>
<td>87</td>
<td>118</td>
<td>31</td>
<td>118</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>(2004-2008)</td>
<td>106</td>
<td>122</td>
<td>42</td>
<td>122</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>(2009-2012)</td>
<td>102</td>
<td>112</td>
<td>44</td>
<td>112</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

*These study sites are planned to be sampled in the summer of 2013.
Figure 9. Map of Bulbous Bluegrass frequency (1982-1987). 15 study sites sampled bulbous bluegrass during this sample period. During this period of time 87 of the 125 study sites that sampled bulbous bluegrass were sampled for this study.
Figure 10. Map of Bulbous Bluegrass frequency (1988-1992). 29 study sites sampled bulbous bluegrass during this sample period. During this period of time 95 of the 125 study sites that sampled bulbous bluegrass were sampled for this study.
Figure 11. Map of Bulbous Bluegrass frequency (1993-1998). 60 study sites sampled bulbous bluegrass during this sample period. During this period of time 107 of the 125 study sites that sampled bulbous bluegrass were sampled for this study.
Figure 12. Map of Bulbous Bluegrass frequency (1999-2003). 87 study sites sampled bulbous bluegrass during this sample period. During this period of time 118 of the 125 study sites that sampled bulbous bluegrass were sampled for this study. One study site was suspended and not read during this time period.
Figure 13. Map of Bulbous Bluegrass frequency (2004-2008). 106 study sites sampled bulbous bluegrass during this sample period. During this period of time 122 of the 125 study sites that sampled bulbous bluegrass were sampled for this study.
Figure 14. Map of Bulbous Bluegrass frequency (2009-2012). 102 study sites sampled bulbous bluegrass during this sample period. During this period of time 112 of the 125 study sites that sampled bulbous bluegrass were sampled for this study. Eight study sites were not read during this time period and are planned to be read in 2013 and 2014. Four study sites were suspended and not read during this time period.
Discussion
My results clearly show an increase of bulbous bluegrass abundance and distribution since 1982, as well as an increase in abundance of bulbous bluegrass in relation to sagebrush and cheatgrass since 1992. While this correlation study does not identify the cause of the increase in abundance of bulbous bluegrass, nor prove that bulbous bluegrass is negatively affecting sagebrush or cheatgrass, it does suggest these relationships should be further examined. Specifically, is bulbous bluegrass negatively affecting sagebrush communities or is it simply responding to decrease in sagebrush and cheatgrass populations?

The increase of the log-response ratio of bulbous bluegrass to sagebrush and cheatgrass indicates bulbous bluegrass has increased in abundance in relation to sagebrush and cheatgrass between 1992 and 2012. Although it does not necessarily indicate sagebrush or cheatgrass is decreasing in cover due to the presence of bulbous bluegrass, it does indicate that in relation to bulbous bluegrass, sagebrush and cheatgrass have become less abundant.

The log-response ratio of cheatgrass to sagebrush over the time periods slightly decreased, but was not significant between time period 1 and time period 4. This indicates that cheatgrass in relation to sagebrush abundance stayed fairly constant over the sample years.

The relationship of bulbous bluegrass and sagebrush showed an increasing log-response ratio over the time periods evaluated, with an increase of bulbous bluegrass mean cover from time period 1 to time period 4, and a decrease of sagebrush mean cover between time period 2 and time period 4. There was an increase of sagebrush mean cover from time period 1 to time period 2. This initial increase in the mean cover of sagebrush may be attributed to individual study sites with low abundance of bulbous bluegrass, which was likely in the early stages of invasion. Another factor that likely attributed to the increase of sagebrush was the stage of the sagebrush community.

The relationship of bulbous bluegrass and cheatgrass showed an increasing log-response ratio over the four time periods with an increase of bulbous bluegrass mean cover and a decrease of cheatgrass mean cover. The increased abundance of bulbous bluegrass on these sites is likely affecting cheatgrass populations. The life cycle of cheatgrass is similar to bulbous bluegrass, so there may be some direct competition for resources. Cheatgrass is an annual grass that reproduces from seed (Zouhar, 2003). Since bulbous bluegrass is a perennial and is a sod forming grass, it likely inhibits seed germination and growth of cheatgrass (Gucker, 2007).

Cheatgrass and sagebrush log-response ratio showed no significant change from time period 1 to time period 4. The mean cover for cheatgrass decreased from time period 1 to time period 4. This suggests both species are being negatively impacted on these sites. This analysis suggests a role for bulbous bluegrass, although the mechanism is not known. Further study of this relationship is suggested.
Cheatgrass maybe the initial disturbance allowing for bulbous bluegrass to invade the plant community. In other words, the plant community may be more susceptible to invasion by bulbous bluegrass when cheatgrass is present on the site.

The spread of bulbous bluegrass measured by UDWR range trend study sites illustrates how prevalent bulbous bluegrass has become. Bulbous bluegrass has increased from 15 study sites in the initial sample periods (1982 – 1987) to 125 study sites in 2012. In conjunction with the spread of bulbous bluegrass, it has also increased in abundance on these sites. The spread and increased abundance of bulbous bluegrass over the sampled sites demonstrates the invasiveness of bulbous bluegrass and suggests that bulbous bluegrass will continue to spread and expand within the state of Utah.

The decrease of sagebrush cover across these sites is a concern. With the potential listing of the greater sage-grouse this loss of suitable habitat could be a potential problem for its recovery. Also, other animal species could potentially be negatively affected by the decrease of sagebrush.

Important questions such as whether or not bulbous bluegrass is a driving factor in the decrease of sagebrush or if it is simply a species exploiting a disturbance in sagebrush rangelands remain unanswered and will require more in depth research and experimentation than provided in this treatise. Further research is also needed to understand what effect grazing may have on bulbous bluegrass in sagebrush communities, and if the species’ increased abundance and expansion to new areas will affect the livestock industry. This research could build on the studies done in the Mediterranean countries to determine if grazing promotes increased abundance of bulbous bluegrass (Alados et al. 2004, Farris et al. 2010, Peco et al. 2005), or if it could be used to control the abundance and spread of bulbous bluegrass, as found in the Turkey study (Tukel 1984). In addition, research is needed to identify other effective control methods for bulbous bluegrass. For example, what herbicides work, what mechanical methods are appropriate, and what reduces the spread of bulbous bluegrass? Additional research could examine whether climatic variables, such as precipitation totals, timing, and drought; and what physical features such as soil types, aspect and topography may affect bulbous bluegrass abundance. In addition, competition studies could be conducted to see if bulbous bluegrass does inhibit sagebrush growth or recruitment. These studies could determine if the decreases of sagebrush is a result of direct competition of mature sagebrush plants and/or a problem with sagebrush recruitment. Lastly, studies could examine the effects climate change could have on bulbous bluegrass abundance and expansion, and explore the effects bulbous bluegrass has on fire return intervals.

**Conclusion**

The increase in bulbous bluegrass in abundance and range expansion has been a concern of the UDWR range trend project for some time. Very little research has been conducted to analyze the impacts of bulbous bluegrass in the Intermountain West. This study illustrates the increase of bulbous bluegrass in terms of abundance, range expansion, and dominance compared to sagebrush and cheatgrass. Although it did not directly show a correlation between the increase
of bulbous bluegrass and the decrease of sagebrush, it did show the increased abundance of bulbous bluegrass in relation to sagebrush and cheatgrass. This study also illustrates the need for more research to identify if bulbous bluegrass is detrimental to sagebrush rangelands and to the flora and fauna within those ecosystems.

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