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Effects of Conversion From Sagebrush to Non-Native Grasslands on Sagebrush-Associated Species

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On the Ground

- There are as many as 170 vertebrate wildlife species throughout the western United States and Canada that are associated with and sometimes dependent on sagebrush habitats and can be negatively affected by conversion of sagebrush ecosystems to non-native perennial or annual grassland.
- We briefly summarize the mechanisms responsible for this conversion and synthesize its effects on wildlife species that are not often in the spotlight, as well as potential effects on management efforts.
- Conversion to non-native annual grasslands is especially difficult for sagebrush obligates because annual grass dominance of former sagebrush sites increases fire frequency, effectively eliminating the ability of functioning sagebrush communities to re-establish following burning.
- Conversion to non-native perennial grasslands also negatively affects sagebrush obligates, because non-native perennial grasses are able to grow in monocultures that compete with native plants and prevent their re-establishment in areas that are dominated by non-native perennials.

Keywords: ecosystem conversion, exotic grasses, fire effects, sagebrush obligate, wildlife habitat.

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Sagebrush (*Artemisia* spp.) is the largest arid/semi-arid vegetation type in North America, dominating more than 600,000 km^2 (118.6 million acres) of the western United States and Canada. Arid and semi-arid climates characterize sagebrush systems with lower annual precipitation, ranging from about 13 cm to 51 cm (5–20 in) per year. The sagebrush biome provides important habitat for a number of wildlife species, including ungulates, small mammals, and a diversity of bird species. Some wildlife species, such as the greater sage-grouse (*Centrocercus urophasianus*), are sagebrush obligates, relying on sagebrush for all life stages, whereas others, such as mule deer (*Odocoileus heminonus*), are associated with sagebrush steppe, but are not necessarily dependent on it for survival.[1,2] It has been estimated that more than 50% of presettlement sagebrush habitat has been lost, and much of what remains is degraded or otherwise threatened.[2] Here, we review the current literature concerning conversion of sagebrush communities to non-native grassland on sagebrush-obligate or sagebrush-associated avian and mammal species that are less widely studied than ungulates or sage-grouse. Our objective was to summarize the effects of conversion to non-native grassland on these species.

A Threatened Ecosystem

Natural and anthropogenic disturbances including energy development, grazing, and fire influence sagebrush systems. Here, we focus on grazing and fire, the most ubiquitous forms of disturbance in sagebrush systems, as mechanisms of conversion to perennial and annual grasslands dominated by non-native grass species. Historically, sagebrush communities were used by bighorn sheep (*Ovis canadensis*), bison (*Bison bison*), elk (*Cervus elaphus*), mule deer, and pronghorn (*Antilocapra americana*).[3] In most areas, domestic livestock have been the primary large herbivores using the sagebrush biome since European settlement.[4] Treatments for reducing sagebrush are sometimes used to increase forage availability for cattle and can result in a conversion to non-native grassland, usually drastically reducing habitat for sagebrush-obligate species.[1] Non-native perennial grasses such as crested wheatgrass (*Agropyron cristatum*), although not as noted for their ability to spread after disturbance like non-native annuals, still often grow in monocultures where they have been seeded.[5] Sites that have become crested wheatgrass monocultures have a much lower diversity of native grasses and forbs than native sagebrush sites with a grass and forb understory.[5] Crested wheatgrass also effectively competes with native shrubs, grasses, and forbs for nutrients, and can prevent these from establishing if measures are not taken to decrease the effects of competition between crested wheatgrass and native plants.[6]

Figure 1. Healthy big sagebrush dominated rangeland (left), sagebrush invaded by cheatgrass (center), and cheatgrass dominated rangeland formerly dominated by sagebrush (right).

Although fire is a natural part of the sagebrush steppe system, invasion of annual grasses has resulted in increased fire frequency in some areas where natural successional processes have not occurred after fire.[7] During natural succession, plants generally resprout from the available seedbank or from seeds that disperse into the disturbed area from nearby unburned patches. Where cheatgrass (*Bromus tectorum*) has invaded, it is likely to become more common in the seedbank as the diversity of native grass, shrub, and forb species decreases (Fig. 1).[7]

Grazing

Herbivory by insects and wild ungulates is a natural part of sagebrush systems, with grazing by domestic livestock playing a larger role in altering sagebrush since European settlement.[4] In our example, we depict paths of conversion to non-native annual or perennial grassland (Fig. 2). In the recent past, the primary human use of sagebrush-dominated rangelands was livestock grazing, and it has therefore been common to apply treatments for reducing sagebrush to increase forage production.[5,8] Treatments for controlling sagebrush include burning, spraying, and mechanical options such as mowing or plowing.[1,9] Crested wheatgrass is also seeded in sagebrush systems because it is believed to provide better forage than native species, as well as to prevent soil erosion.[10] However, this species also has been shown to hinder establishment of Wyoming big sagebrush (*Artemisia tridentata ssp wyomingensis*).[6]

Fire

Fire is also a natural disturbance mechanism in sagebrush communities, although the fire return interval appears to be dependent on the dominant sagebrush species in the area.[11] It is generally acknowledged that fire frequency was historically low in sagebrush systems, with fire rotation estimated to occur every 100 to 240 years for Wyoming big sagebrush and 70 to 200 years for mountain big sagebrush (*A. tridentata ssp vaseyana*), allowing sagebrush relatively long time periods to recover (Table 1).[7,11,12]

Sagebrush ecosystems in areas with an established presence of non-native annual grasses are susceptible to invasion and eventual dominance by these non-natives.[3] Three species of concern are cheatgrass, medusahead wildrye (*Taeniatherum caput-medusae*), and ventenata grass (*Ventenata dubia*). Although most research has been conducted on cheatgrass, these three species function similarly and are problematic because they increase fire frequency.[13] For example, Whisenant estimated the fire return interval of cheatgrass dominated rangelands in southern Idaho at 3 to 5 years, significantly more often than historical estimates.[7] Annual grasses generate fine fuels and their high surface-to-volume ratio allows those fine fuels to dry out quickly, resulting in a situation very conducive to wildfire.[10] These grasses also dry out in early spring as opposed to later in the year, changing the fire season.[10] Balch et al. documented an increase in fire frequency in the Great Basin area and found that cheatgrass-dominated rangelands were about four times more likely to burn than systems dominated by native plant cover.[14] In a sagebrush ecosystem, more frequent fires

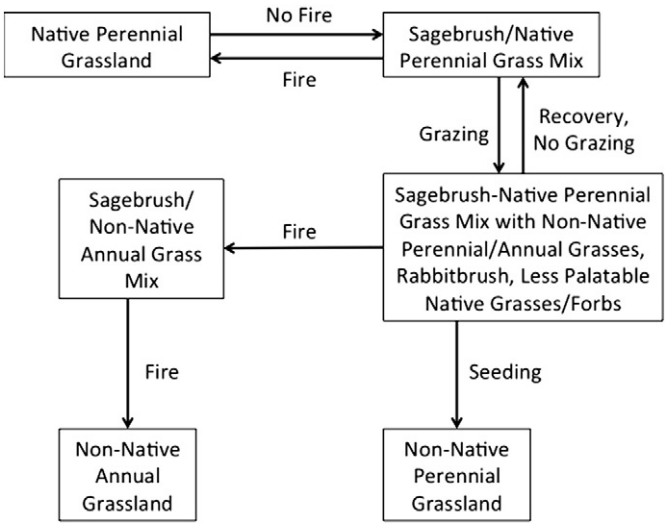

Figure 2. State and transition model showing effects of livestock grazing, seeding, and increased fire frequency in sagebrush (adapted from Knight 1994). Some details were left out from the original model while others were added.

means a reduced number or complete loss of sagebrush.[15] Big sagebrush is not able to resprout after a fire, as it relies on seeds for re-establishment, resulting in a longer recovery time than root-sprouting plants such as rabbitbrush (*Chrysothamnus* spp.).[7] Loss of big sagebrush leads to loss of habitat for sagebrush obligates.[16] Clearly, in cases where the ecosystem proceeds from a native grassland community to a sagebrush community, this may not be permanent. However, in areas where non-native grasslands invade, this loss of habitat is more likely to be permanent.

What Does This Mean for Wildlife?

The conversion of sagebrush steppe to non-native annual or perennial grassland has the potential to directly and indirectly affect wildlife species. Loss of shrubs may translate to losing a food source or structure for concealment from predators or adverse weather. We present a synthesis of effects on sagebrush-obligate bird species, sagebrush-associated bird species, and the overall bird community. Following this synthesis on sagebrush birds, we provide a synthesis of effects on other species often left out of the spotlight, including pygmy rabbit (*Brachylagus idahoensis*), and rodents.

Table 1. Estimates of fire rotation (i.e., time required to burn a specified area, often as a factor of multiple fires) for systems dominated by major sagebrush species in the sagebrush biome.

System	Fire rotation (years)
Low sagebrush (*Artemisia arbuscula*)	145–290
Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*)	247–495
Mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*)	145–231
Black sagebrush (*Artemisia nova*)	1,389–2,778

Source: Bukowski and Baker 2013[12]

Bird Species

Some passerine species most commonly associated with sagebrush ecosystems include black-throated sparrow (*Amphispiza bilineata*), Brewer's sparrow (*Spizella breweri*), grasshopper sparrow (*Ammodramus savannarum*), gray flycatcher (*Empidonax wrightii*), green-tailed towhee (*Pipilo chlorurus*), horned lark (*Eremophila alpestris*), loggerhead shrike (*Lanius ludovicianus*), sagebrush sparrow (*Artemisiospiza nevadensis*), sage thrasher (*Oreoscoptes montanus*), vesper sparrow (*Pooecetes gramineus*), and western meadowlark (*Sturnela neglecta*). Brewer's sparrow, sagebrush sparrow, and sage thrasher are considered sagebrush obligates. Conversely, horned larks, lark sparrows, vesper sparrows, and western meadowlarks are all grassland-associated species.[17] Generally, sagebrush-associated species decrease with conversion to grassland, and grassland-associated species increase with conversion.[17]

Sagebrush-Obligate Passerines

Research on the effects of sagebrush conversion to grassland have primarily focused on Brewer's sparrows, sage thrashers (Fig. 3), and sagebrush sparrows due to their status as sagebrush obligates. Brewer's sparrows, sage thrashers, and sagebrush sparrows are most common in areas of high sagebrush cover or density.[17–19] Brewer's sparrows and sage thrashers are especially dependent on the structure provided by tall sagebrush plants. As a result, sites that are converted to non-native grasses are unlikely to be suitable for these birds until or unless sagebrush has recovered, which can take up to 20 years if at all.[18] Sagebrush-obligate birds prefer a dense, grassy understory, although Earnst and Holmes[19] found no significant preference of sagebrush sparrows for native bunchgrass versus

Figure 3. The sage thrasher (left) is considered a sagebrush obligate, while the loggerhead shrike (right) is associated with sagebrush and grasslands. Photos © Shutterstock.com.

cheatgrass understory. In areas where smooth brome (*B. inermis*) has invaded, the understory is generally more dense, which may confer a benefit to species nesting in these areas.[20] Compared with areas with an understory comprised mainly of native grasses, Brewer's sparrow nest establishment in areas with a smooth brome understory occurred later and fewer eggs were laid, but overall nest success, as measured by hatched and fledged young, was higher.[20] Earnst and Holmes also reported that predation of nests and fledglings was lower in non-native grass-dominated areas, probably as a result of taller grasses comprising the understory as well as higher overall coverage within the understory.[19]

Non–Sagebrush-Obligate Bird Species

Some species are commonly found in association with sagebrush systems, but are either not sagebrush obligates or are also associated with grasslands. Some of these species, such as the black-throated sparrow, gray flycatcher, and loggerhead shrike, are positively correlated with sagebrush occurrence (Fig. 3).[19] The correlation between other species and sagebrush occurrence is less clear. Green-tailed towhees and lark sparrows both increase and decrease with increased sagebrush occurrence.[17,19] Conversion to grassland has a positive effect for species that are associated with sagebrush communities, but which are more dependent on grasslands across their life histories. Grasshopper sparrows, horned larks, vesper sparrows, and western meadowlarks increase as shrub cover decreases, regardless of the type of grass that replaces the shrub cover.[17,19] Comparisons of bird habitat preference between non-native grasslands and native grasslands are not extensive, but one study found that grasshopper sparrows and horned larks both prefer native bunchgrass systems to cheatgrass stands.[19]

Overall Bird Community

Richness and diversity in the bird community are also affected by conversion of sagebrush to grassland. In addition to the tendency of grasslands to favor a different avian assemblage than sagebrush, the structure and heterogeneity of patches has been shown to affect species assemblages.[17] Researchers in Nevada found that the highest species diversity was found not in undisturbed sagebrush stands, but in crested wheatgrass seedings that had been invaded by sagebrush. Unlike the more

Figure 4. Bird communities adapt to changing landscapes as grass and shrub densities change (Horned lark nest, 29 May 2009, Park Valley UT). Photo courtesy of Beth Fowers.

homogeneous sagebrush-only or grassland-only areas, heterogeneous habitat structure in the sagebrush-invaded seedings was suitable for a wider diversity of species.[17] The ability of areas that are codominated by sagebrush and grasses to support a greater assemblage of bird species is likely due to the heterogeneous plant community structure that provides suitable habitat for both sagebrush-associated and grassland-associated species (Fig. 4).[17] This concept of heterogeneous patch structure positively affecting species assemblages is supported by similar work done in grasslands in the central United States.[21]

Rabbits and Rodents

Most of the focus on shrubland conversion concerns how grasses such as cheatgrass affect plant community structure, composition, and disturbance cycles.[3,7,10,13–15] However, conversion to non-native grassland also affects how and what is available for forage. Many species forage for a variety of foods within a system including insects, vegetative plant components, and seeds.[22] Here, we focus on seeds and aboveground plant parts because of their importance to foraging and cover.

Pygmy Rabbit

The pygmy rabbit is a sagebrush-obligate species and requires late-successional sagebrush or dense stands for protection from predators. Sagebrush also forms the majority of their diet.[23] The likelihood of pygmy rabbit presence decreases with increased occurrence of cheatgrass.[23] Cheatgrass is only palatable early in the spring when it is still green, so it does not offer a long-term food source and the roots can form dense mats that may make burrowing difficult for pygmy rabbits.[23]

One of the largest concerns for pygmy rabbits is loss of habitat and fragmentation through a variety of factors, including cheatgrass invasion.[24] Tall sagebrush stands provide islands where physical protection is offered in summer and winter. During winter, snow is captured in drifts, allowing pygmy rabbits the opportunity to burrow to food sources and be protected from predation.[23] Increased cheatgrass decreases food availability, and burrowing opportunities for pygmy rabbits. Furthermore, as cheatgrass-dominated areas increase, a potential barrier to dispersal is created as the physical structure providing protection from predation is lost.[24]

Rodents

When cheatgrass invades an area, native wildlife must adapt to the new conditions. Ostoja and Schupp examined at the effects on rodents of cheatgrass invasion in sagebrush systems.[25] They found that regardless of foraging habit (granivorous, herbivorous, or omnivorous), all species were reduced in cheatgrass-dominated areas. Cheatgrass-dominated communities had lower individual abundance and lower species diversity than native sagebrush communities.[25]

For some rodents, mostly within the family Heteromyidae, cheatgrass seed provides a source of food.[26] Rodents cache seeds as a food source throughout the winter; these caches consist of small, shallow scatter hoards, and some of these seeds may not be consumed by rodents, enabling cheatgrass seeds to survive and germinate. However, McMurray et al. found that although a native grass, Indian ricegrass (*Achnatherum hymenoides*), was adapted to germinating and surviving from cached locations with multiple individuals, cheatgrass rarely survived these dense seedling sites to set seed.[26] This indicates that although cheatgrass seed may be used as a food source by rodents, their caching activities may have little effect on its spread.

Three rodent species native to the Great Basin, Great Basin pocket mouse (*Perognathus parvus*), North American deer mouse (*Peromyscus maniculatus*), and Ord's kangaroo rat (*Dipodomys ordii*) show a preference for native plant seed compared with cheatgrass seed.[27] However, Ostoja et al. also found that when native seed occurred in the presence of cheatgrass seed, there was a decrease in native seed collection.[27] These results indicate that management of a cheatgrass-dominated system may be complex when considering variable species responses to cheatgrass seeds as potential food.

Deer mice (*Peromyscus* spp.) are selective opportunists and will consume both vegetation and insects.[28] Although they will remain in areas that have been converted from sagebrush to cheatgrass communities, they are negatively affected by the loss of cover and forage opportunities afforded by sagebrush communities.[29] The open structure of sagebrush systems is important for deer mice because the they allow for foraging of insects, among other activities.[25] In cheatgrass systems, mobility between patches is reduced, resulting in decreased ability to hunt, escape from predators, and find other individuals with which to reproduce.[29] Additionally, although cheatgrass can be used as a food source, the variability in production from year to year and reduced nutritional quality compared with native species can make it difficult for rodent populations to persist.[29]

Cheek pouch contents of Great Basin pocket mice (*P. parvus*) observed in eastern Washington showed that cheatgrass seed was the most common seed collected, despite not being the most common grass by percent cover.[30] This indicates that cheatgrass may become an important and potentially beneficial forage component for some species, even in communities where it does not represent a large contribution to overall coverage. However, it is unclear if the ability of cheatgrass to become a primary forage species can balance the negative consequences of a decrease in protective cover for these rodents, as the study suggesting the potential importance of cheatgrass as a forage species took place in an area where cheatgrass had not yet dominated all available cover.[30]

Food availability is not the sole factor leading to a decrease in rodents in cheatgrass-invaded sagebrush. In addition to providing increased vertical structure for a wider diversity of species, sagebrush communities shade the soil, allowing it to retain more moisture than soil left bare in cheatgrass-dominated grasslands. Rodent olfactory ability is stronger in the moist conditions often found under shrubs, leading to a reduced ability to find seed in cheatgrass-dominated communities.[31]

Conclusion

The sagebrush biome has been reduced by more than 50% and is constantly affected by expanding anthropogenic disturbances and conversion to non-native grassland. In some cases, land managers have purposely converted sagebrush shrubland to perennial grassland to increase forage for livestock. Although grassland can be a functional ecosystem for certain species, the loss of sagebrush ecosystems to conversion to non-native grassland is generally detrimental to sagebrush obligates and many other associated wildlife species. Conversion to annual grasslands is especially difficult for sagebrush obligates, because non-native annual grass dominance increases fire frequency, eliminating the ability of sagebrush communities to re-establish. Although focus often is given to greater sage-grouse and big game species occurring in sagebrush, there are a number of birds, small mammals, and invertebrates that rely on sagebrush. Conserving remaining intact sagebrush communities is thus of critical concern.

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