Ecosystem benefits of invasive annual grass removal

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Abstract. Invasive winter annual grasses (IAGs) are altering rangeland ecosystems across millions of hectares in the western US. These winter annuals outcompete native plants for soil moisture and nutrients, leading to devastating impacts on ecosystem functions. The IAG seedbank is short-lived and often does not persist beyond 3 years. Past tools for IAG control have only provided short-term control or caused injury to the native plant community, making it difficult for researchers to assess the ecosystem benefits of IAG removal. A newer herbicide option, indaziflam, provides IAG control for three or more years. Indaziflam's extended soil residual control and tolerance of perennial species creates the opportunity to deplete the IAG seedbank, allowing time for remnant plant communities to recover. Research has been conducted on sites across the western US where IAGs were managed using indaziflam. Long-term IAG management has led to increases in native plant cover and biomass as well as greater biodiversity within the native plant community. The shift from an IAG dominated community to a healthy native plant community has resulted in improved pollinator and wildlife habitat in these sites. By changing the management paradigm to target the IAG seedbank, land managers can achieve long-term restoration.

Introduction

Invasive annual grasses (IAGs), such as cheatgrass (*Bromus tectorum*), Japanese brome (*Bromus japonicus*), ventenata (*Ventenata dubia*), and medusahead (*Taeniatherum caput-medusea*), have transformed western US rangelands on a landscape scale. Cheatgrass is the most widespread IAG, invading over 22 million hectares of western lands (Duncan et al. 2004). Invasions have impacted millions of hectares of the fragile sagebrush-steppe ecosystem, which provides important habitat for over 170 species of birds and mammals (Shinneman et al. 2018). IAGs produce large amounts of dry litter which act as a fuel source. This added fuel source has increased fire frequency and severity throughout the arid climate of the western US. Wildfire is the biggest threat to wildlife and native ecosystems in IAG invaded ranges, as it converts native plant communities to annual grass dominated communities, which provide little to no forage value or cover for wildlife and domestic livestock (Shinneman et al. 2018). These shallow-rooted annual grasses steal critical moisture and nutrients from native plants, which struggle to persist in conditions analogous to a constant state of drought. The IAG seedbank is short-lived, persisting for <5 years (Sebastian et al. 2016, Wallace et al. 2015, Young 1992). Managing the soil seedbank is key to successful restoration of areas invaded by IAG.

Methods

There are several options for IAG control including chemical and manual methods, although most options provide short-term control, requiring yearly or intra-season retreatment, or can cause injury to the native plant community. A more recent herbicide option, indaziflam, has been shown to provide multi-year IAG control with safety in perennial rangelands (Clark et al. 2019, Koby et al. 2019). Indaziflam is a cellulose biosynthesis inhibitor, controlling weed seeds at germination. The soil residual of indaziflam provides multi-season activity, working to deplete the IAG seedbank. Past research has shown benefit to the native plant community when IAGs are removed (Davies and Sheley 2011) but it has been difficult to demonstrate additional ecosystem benefits beyond the plant community, such as to pollinators and wildlife, as long-term IAG control has been hard to achieve with past tools. The long-term control provided by indaziflam has allowed researchers to evaluate additional ecosystem benefits that occur with IAG removal.

Results and Discussion

Native Plant Community Benefits

Research trials in the western US have shown increased perennial plant cover and biomass as well as greater biodiversity when long-term IAG control is achieved. On the Colorado front range, indaziflam treatments provided 97-99% control of cheatgrass, feral rye (*Secale cereale*), and Japanese brome at 2 years after treatment, with a 28- to 42-fold increase in perennial grass biomass and a 3- to 5-fold increase in forb biomass (Sebastian et al. 2017). In the inland Pacific Northwest, perennial grass cover increased 1.7- to 6-fold while perennial grass biomass increased 2- to 3-fold at 16 months after successful ventenata treatments, compared to plots that received no treatment (Koby et al. 2019). Treatments that provided poor or short-term ventenata

control did not show any increases in perennial grass cover or biomass by the year after treatment. Across several rangeland sites in Utah treated for ventenata and medusahead, only indaziflam treatments reduced IAG cover (<6%) for multiple years. Sites with remnant perennials saw significant increases in perennial grass cover with successful IAG removal. Species richness was only increased with treatments that provided over one year of control (Beckley et al. 2021).

In Boulder County, Colorado a large survey was conducted across thirteen natural areas, including grasslands and shrublands, where operational indaziflam treatments were made to control cheatgrass and Japanese brome (Sebastian et al. 2022). A non-treated check was left at each site to evaluate biodiversity responses to IAG removal. At 1 to 5 seasons after IAG treatments, treated sites had significant increases in biodiversity compared to those sites where IAGs were unmanaged. Native species richness increased by 150% (66 to 104 species) in treated sites (Table 1), while increases in average flower number per plant were observed in 34 species. Rare and concern species diversity increased from an average of 2 species in sites with IAG to 7 species in treated sites (Table 1). At one site, geo-referencing data showed one concern species, pleated gentian (*Gentiana affinis*), going from only 5 plants the year after IAG treatment to 319 plants at four years after treatment. At another site, geo-referencing data revealed 1,071 individual plants considered rare or concern species in Boulder County, five years after IAG removal, compared to 21 individuals in the adjacent check site where IAGs were unmanaged (Sebastian et al. 2022).

Table 1. Species richness and rare and concern species present in sites treated for IAG (treated) and sites with unmanaged IAG (non-treated). Evaluations completed in summer 2021. Sites ranged from 2 to 8 hectares in size. (From Sebastian et al. 2022)

Site	Application Date	Biodiversity Significance Rank*	Species Richness (#)		Rare and Concern Species (#)	
			Non-treated	Treated	Non-treated	Treated
Rabbit East	12/30/2016	B1	77	119	5	9
Colp	12/20/2016	B1	91	146	7	16
Trevarton North	12/20/2016	B1	72	115	3	8
Rabbit Pollinator	1/2/2018	B1	63	114	0	6
Trevarton Hill	1/8/2018	B1	64	96	5	9
Hall Burned	3/8/2018	B1	75	104	1	3
Hall Bitterbrush	3/9/2018	B2	60	103	0	5
Pierce	3/21/2018	B1	62	96	7	9
Heil	3/21/2018	B1	53	86	2	4
Hall Overlook	3/22/2018	B1	51	80	1	6
Trevarton Narrow	1/14/2019	B1	64	99	1	5
Rabbit West	2/4/2019	B1	55	95	0	6
Rabbit North	3/8/2021	B1	37	51	0	1
Mean			66	104	2	7

*B1 ratings are sites that are globally rare and irreplaceable, B2 ratings are nearly irreplaceable; Ranks derived from surveys conducted by the Colorado Natural Heritage Program using the Natural Heritage Ranking Methodology

This research confirms that long-term management of IAG benefits the native plant community and can restore biodiversity on rangelands. Focusing on long-term management through seedbank depletion provides an opportunity for land managers to mitigate effects from IAGs and can aid in restoration of natural habitats. Reducing the competition from IAG and promoting native species can lead to further ecosystem benefits as discussed in the following sections.

Pollinator Benefits

A loss of habitats with diverse flowering forbs is one of the main causes for pollinator population decline. Researchers evaluating impacts on pollinators and floral resources found that long-term control of cheatgrass with indaziflam led to significant increases in flowering forb richness and alpha-diversity measures (Arathi and Hardin 2021). The average number of flowering forb species detected along a transect went from <3 species in the non-treated plots to 4 to 7 species flowering in the indaziflam treatments. These increases were seen across early-, mid-, and late-season evaluations, indicating that cheatgrass removal led to an increase in the flowering period for flowering forbs (Arathi and Hardin 2021). A continuation of the study in 2020 that tracked pollinator visitation to flowering forbs, found significant increases in floral visitor richness and abundance in areas treated for cheatgrass with indaziflam (Nissen et al. 2020). Floral visitor richness was

increased two-fold while floral visitor abundance was increased 2.5-9x in treated plots compared to control plots. Native bees, hemipterans, lepidopterans, and coleopterans were observed more often in the treated sites compared to the control sites, demonstrating increased arthropod usage of the treatment areas including by several pollinator groups. Furthermore, there was a 3.5x increase in number of flowers detected in treated plots, indicating that removing cheatgrass led to increases in floral resources for pollinators.

Although habitat loss from human development and agriculture are main sources of pollinator decline, invasive species play a major role in reducing pollinator habitat quality in remaining habitat areas, especially IAGs which decreases the diversity and abundance of flowering forbs (Rhoades et al. 2016). In the western US, the habitat is dominated by grasslands and shrublands, many of which are impacted by IAGs. This research demonstrates that providing long-term IAG control is necessary to restore and protect the remaining pollinator habitat impacted by IAGs.

Wildlife Habitat Benefits

Habitat degradation, including IAG invasion, is listed as the number one threat to mule deer (*Odocoileus hemionus*) populations in the sagebrush-steppe (Clements and Young 1997). Having healthy winter range is especially important for deer and elk as their winter diet is naturally lower in nutrients, and annual grasses further deplete the nutrient availability (Clements and Young 1997). Research in critical overwintering habitat for mule deer, elk, and other wildlife found that shrub growth increased in sites where cheatgrass was controlled with indaziflam compared to adjacent non-treated sites (Sebastian et al. 2021). Wildlife browse was increased for seven different shrub species utilized by browsers during winter months, indicating a substantial improvement to critical winter range in the study sites. New leader growth was 1.5x to 2.8x longer on shrubs in areas treated for cheatgrass (Figure 2), while shrub canopy volume increased 120%-400% by just 20 months after cheatgrass treatments. There was a 67%-648% increase in mule deer visitation to treated plots compared to non-treated plots during the critical browse months throughout fall, winter, and spring (Sebastian et al. 2021).

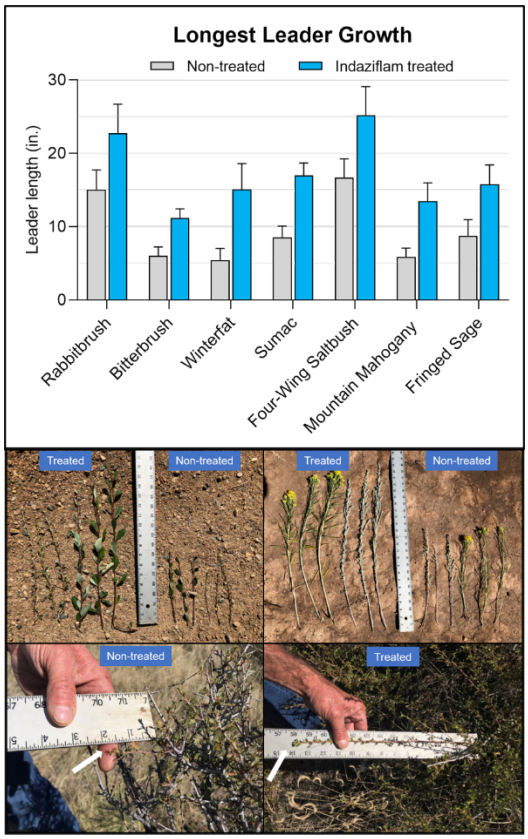

Figure 2. Average longest leader growth on shrubs in treated (indaziflam) vs. non-treated areas across 6 sites at 20 months after treatment. Bottom image showing representative mountain mahogany (top left), rabbitbrush and fringed sage (top right), and antelope bitterbrush (bottom) leader growth comparing treated and non-treated growth. (From Sebastian et al. 2021)

In research trials conducted in Northern Bobwhite (*Colinus virginianus*) habitat on the sand sage prairies of eastern Colorado, indaziflam treatments provided the long-term cheatgrass control necessary to promote higher forb frequency and bareground required for quail nesting and brood-rearing (Marymor 2020). At 2 YAT, there was a 3x increase in forb biomass and a 1.7x increase in bareground within treatments. Bareground increases

were due to reductions in cheatgrass litter biomass, which was near zero in treated areas by 2 YAT. As Northern Bobwhites are in decline due to habitat loss and degradation, results from this trial demonstrate that quail habitat restoration can be achieved in those areas that remain by providing long-term IAG control. Quail need abundant forbs for feeding, as forbs serve as insect habitat, while bareground allows for chick movement and ability to seek cover from predators under the taller, native grasses. Long-term cheatgrass control allowed for restoration of these critical habitat components.

In western US rangelands, shrubs and forbs provide critical habitat for both mammals and birds. Large expanses of these habitats have been degraded through IAG invasion and IAG fueled wildfires. Promoting native forb and shrub growth by reducing the competition from IAGs can help restore critical wildlife habitat in these ecosystems.

Conclusions and/or Implications

IAGs are spreading at alarming rates across the western US and contributing to increased wildfires and ecosystem degradation. Wildlife and pollinator habitat has declined from human expansion, therefore protecting and restoring the remaining habitat is critical. Since IAGs are one of the largest threats to these habitats, removing them from western rangelands has the potential to restore critical ecosystem services. Using tools that provide long-term IAG control, land managers can achieve restoration in vulnerable ecosystems such as the sagebrush-steppe. Priority must be focused in areas with remnant desirable plant communities, as solutions to restore sites with IAG monocultures are costly and difficult, and oftentimes unsuccessful.

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