Logic Model

Inputs	Outputs		Objectives		
- Sites to do research (Boulder County shrub-steppe ecosystems) - Partnership with Boulder County Parks and Open Spaces (BCPOS). - Clearance to treat new sites and continuously collect soil samples - PCR & data extraction analysis materials -Ways to measure N, SOC, and PH -Access to LC-MS for indaziflam residual measurements	Activities	Participation	Short	Medium	Long
	- Collaborate with land management agencies (BCPOS) to manage invasive species - Mitigate harm to native species (particular focus on soil microbes) -Reduce risk of widlfire	- This research will be particularly helpful for ranchers as shrublands are often used as rangeland - Decreased risk of wildfire from cheatgrass management benefits locals. -Better understanding the effects of indaziflam on soil microbes allows land managers to make more informed indaziflam application decisions	- Data about temporal impacts of indaziflam on soil microbial species in shrub-steppe ecosystems - Clarity on the effects of indaziflam on soil microbes (isolate herbicide impacts from changing plant community impacts)	- Better land management outcomes. - Balanced cheatgrass management with preservation of healthy soil & microbial communities.	- Optimally restored open spaces - Increased plant biodiversity and increased or stable microbial diversity -Data contributes to a new broader framework for rangeland/shrub-steppe pest management and herbicide use.

Assumptions:	External Factors:
- Maintaining and protecting soil microbial diversity is necessary for efficient restoration - BCPOS is interested in this sort of research - Temporal analysis will produce new and useful information	- Land is managed by agency external to research institution (might not be able to spray new sites depending on BCPOS objectives) - Difficult to control conditions in a field study

Personal, Background, and Future Goals Statement

Personal Background

Being raised in Colorado, I was fortunate to grow up with the great outdoors right in my backyard. I spent my summers as a kid camping in national forests, building terrariums, and learning about the environment through direct exposure. These experiences were the beginning of an exciting curiosity - to understand the inner workings of the environment and its constituents - that has followed me throughout my life.

Yet, as I have grown older and more observant of the world around me, I have been forced to confront difficult truths about the great outdoors that have raised me, and that have become synonymous with home, familiarity, and comfort. During the pandemic, feeling as if the world was ending and being disgruntled by the fact that I had to spend my entire summer isolated from friends, I spent lots of time in nature. I remember one early evening in late summer I drove up to Horsetooth Reservoir in the foothills of Fort Collins. I parked in a lot that I visited often and hiked down to a familiar pair of trees that I often set up my hammock in. As I laid in my hammock overlooking the water that reflected the setting sun, my peaceful outdoor abode quickly shifted to what would become a real-life nightmare. Just beyond Horsetooth Rock, I saw plumes of smoke stretching into the sky. Those plumes of smoke were coming from the Cameron Peak Fire, the largest fire in our state's history[1]. In the following months, the sky rained ash, wildlife flooded the city seeking refuge from the flames, and our local river turned black from burnt debris. To this day, scars from the fire remain etched in our lands.

This event was pivotal. Beforehand, climate change and environmental degradation were threats that I knew of and that I thought were important, but they seemed distant and intangible. After experiencing the Cameron Peak Fire, I realized just how present and urgent these issues were. I realized that the outdoors that had become my home were in grave danger.

My childhood experiences that fostered a gentle curiosity for the environment combined with the harsh realizations elicited by the Cameron Peak Fire are largely what led me to study Ecosystem Science and Sustainability at Colorado State University.

Intellectual Merit

My path into the world of academia has been a bit non-traditional. I finished high school early, graduating when I was 16, with hopes that fast-tracking my education would allow me to escape a difficult home life. Yet, being so young and burnt-out from rushing through high school, I realized that because I had been so laser-focused on finishing school, I hadn't thought much about what I wanted to do with my life, and I didn't feel ready to jump into college. Because of this, I chose to spend time working and saving money while thinking about my next steps.

After a semester off from school, I decided to enroll at my local community college. My first semester, I only took one class while continuing to work outside of school. That one class was an introductory programming class, which I really enjoyed. I ended up spending three semesters in community college, taking several general requirement classes as well as a handful of computer science courses. I intended on transferring to Colorado State University to pursue a degree in computer science, because I really enjoyed data science and programming. However, during the summer before transferring to CSU, I noticed that the thought of pursuing a career in computer science made me feel anxious and uneasy. I realized that while I enjoyed computer science, I didn't have a passion for it.

I spent many weeks thinking about what I truly wanted to do. I had to land on something that I enjoyed doing, that I felt passionate about, and that would allow me to do something good in this world. Still having that persistent curiosity and love for the environment and recognizing that a real need existed

for environmental protection, I decided to pursue my Bachelor's in Ecosystem Science and Sustainability at CSU.

During my time at CSU, I have taken several courses that have helped me explore this passion and prepare me for future academic endeavors. Of note, the classes that I found most fulfilling were those that focused on environmental sciences. In these courses, I gained fundamental understanding of several key topics, including nutrient cycling, dynamic systems, soil taxonomy, atmospheric composition, plant ecology, and ecosystem production.

Outside of the classroom, I had the opportunity to apply my knowledge in a lab setting, working as an undergraduate research assistant in Dr. Cynthia Brown's lab at Colorado State University. As a research assistant, I worked alongside graduate student Lauren Myers, whose research evaluated non target impacts to the plant community of indaziflam, a pre-emergence herbicide used to manage Bromus tectorum (cheatgrass), an invasive annual grass widespread in the western United States. Indaziflam inhibits cellulose production, preventing radicle formation and seedling emergence. While indaziflam effectively reduces cheatgrass cover, land managers were unsure of the herbicide's impact on the native seedbank. This helped to inform the research question of our study: Does indaziflam inhibit seed emergence for native species in Colorado? For this study, we used several species of different functional groups, including invasive and native grasses and native forbs. We conducted a greenhouse dose-rate response study to investigate our research question. After helping with data collection and analysis for the original project, I took on my own sub-project and used our data to investigate the relationship between functional group & rate and seed weight & rate as predictors for emergence. I used R to create generalized linear models and to create plots that demonstrated trends across groups.

I had the opportunity to present my project at Colorado State University's Celebrate Undergraduate Research & Creativity event in 2025. My experiences as an undergraduate research assistant allowed me to see the research process go from theory to practice; I participated in several stages, from planning to data collection to analysis. Creating my own sub-project allowed me to navigate these stages a bit more independently, and to practice using tools like R to analyze data and interpret summary statistics. Presenting my project helped me practice communicating to the broader public and conveying the significance of the research we had done.

Another project that I got to help with was the Two Frontiers Project, a research initiative that aims to discover and investigate extremophilic microbial species. I participated in this project as part of my capstone course and learned much about microbes and their importance to the environment. During my time on this project, I produced forum content for the CitSci project page which helped generate interest among citizen scientists, I produced GIS products that mapped hot springs across Colorado, I created an ArcGIS story map to be used for outreach, and I practiced DIC microscopy to obtain pictures of cyanobacteria and other microbes found in samples from field sites.

I believe all these experiences have allowed me to practice and develop the skills necessary to spearhead my own research.

Broader Impacts

Participating in undergraduate research sparked a passion for me, and while I learned many skills from the opportunity, I also recognize that there is lots left for me to learn. Graduate school will give me the opportunity to practice the research process further and continue to develop skills that I began to practice during my time in Dr. Cynthia Brown's lab. While I've learned so much as an undergraduate student, it can be difficult to take theoretical knowledge and translate that to a research project and applicable information for informing policy, management decisions, and other broader implications.

Graduate school will allow me to practice this skill, learn new skills, and become more confident as a scientist. I hope that the skills that I gain will allow me to produce work that can be used by local, state, and national agencies for land management, restoration, combatting the effects of climate change, and progressing our collective understanding of biogeochemistry.

I also hope that my experiences will allow me to participate in scientific education as my career progresses. During my time as an undergraduate student, I had the opportunity to work as a lab teaching assistant for an introductory biology course. Helping my peers learn foundational scientific knowledge and practice new skills in a lab setting was so exciting for me, because I got to see the beginning of future scientific careers, and use my knowledge to help people that may one day be my colleagues. Just as important as producing novel research is the passing of the torch to future generations of scientists who will lead the way in combatting the same issues that I hope to address throughout my career.

Although I've always had an interest in science, I never thought that research was something that someone like me could pursue. I thought that I didn't come from the right background, and because no one in my family has gone to graduate school, I always thought I wouldn't either. My perspective changed because of the people that I've worked with as an undergraduate student, and the teachers that have inspired me and showed me that science is for everyone. I hope that one day I can be that person for someone too.

The last way that I hope to reach others through research is by contributing information that will help local ranchers and land managers make well-informed decisions. I believe that in our fight against the most pressing environmental issues, scientists must not forget about the people that are suffering from the consequences of the issues we study.

Future Goals

After graduate school, I hope that I can continue to work in research. My hope is that I can produce novel studies that provide information that can be used both by local stakeholders as well as policymakers.

References

1 Department of Public Safety, Colorado Division of Fire Prevention and Control

Research Plan Statement

Non-target effects of indaziflam on soil microbial communities in semi-arid shrublands

Background

Cheatgrass is an invasive annual grass that has increased in both abundance and extent across the Intermountain West in recent decades[1]. One concern associated with cheatgrass is wildfire. Cheatgrass generates fine fuel that increases fire frequency and severity, and risk of fire mortality for native plants[2]. The Intermountain West is a region dominated by semi-arid shrublands, which provide rangeland resources among other ecosystem services[3]. The effects of cheatgrass on semi-arid shrubland fire regimes can disrupt the system, resulting in a shift to an invasive annual grass alternative state[3] and creating a feedback loop that makes shrubland recovery difficult[4].

Indaziflam, a pre-emergence herbicide that prevents cellulose biosynthesis, has been used to effectively reduce cheatgrass cover and fine fuel, positively impacting native species richness[5]. Yet, indaziflam may also cause non-target effects that could negatively impact native species. While some studies have investigated the non-target effects of indaziflam on native plant species in semi-arid shrublands[6], research on the non-target effects on soil microbial species is extremely limited.

The one study that has been conducted to investigate the effects of indaziflam on soil microbial species in semi-arid shrublands found significant differences between indaziflam treated and non-treated plots. In their study, Bradbury et al. collected soil samples from field sites in Boulder County and measured physical soil characteristics including concentration of soil organic matter, concentration of soil nitrate, and pH of soil samples. Bradbury found significant differences across these soil characteristics between treated and non-treated plots. Additionally, Bradbury et al. collected soil samples for microbial analysis, extracting DNA and using PCR and gene amplicon sequencing. They found that microbial community composition significantly differed between treated and non-treated plots, for bacteria, archaea, and fungi. For bacteria and archaea, they found that differences in soil characteristics were correlated with community composition. Fungi composition differences were only correlated with soil organic matter changes[7].

While the findings of this study suggest that indaziflam could impact microbial community composition, samples were only collected at one time point for each site rather than at multiple time points. Thus, temporal analysis of the effects of indaziflam on soil microbial communities is lacking, and it is unclear whether the changes that Bradbury documented were due to indaziflam itself or due to reduced cheatgrass cover.

Understanding the effects of indaziflam on soil microbial communities is imperative, as altering soil microbial communities can impact restoration efficiency. Consequences of herbicide application can be vast, from microbial diversity changes, altered microbial functions, and even introduction of evolutionary pressure on microbial communities[8].

Question

How does indaziflam affect soil microbial communities in semi-arid shrubland ecosystems over time?

Objectives

To better understand how microbial communities change over time after indaziflam treatment and to differentiate the effects of indaziflam itself on microbial composition changes versus the effects of changing plant communities because of reduced cheatgrass cover.

Methods

For this study, I will collaborate with Boulder County Parks and Open Spaces (BCPOS) to conduct a field study on land managed by BCPOS. I will include paired treated and non-treated 5m x 5m sites in Boulder County, and either 1) treat sites at the beginning of the study so that changes can be documented from initial treatment or 2) identify sites treated most recently, depending on BCPOS objectives.

I will take initial soil samples from both treated and non-treated sites as a control, as I expect to see non-treated site samples remain comparable to initial samples, and treated samples to change over time. I will take soil samples at the beginning of the growing season (April), in the middle (July), and at the end (October) to compare seasonal variations. I will also take plant cover data, using quadrats to measure plant cover of a randomly selected 1m x 1m section of each plot. I will take samples and measurements for two growing seasons.

For soil samples, I will measure soil organic matter, pH, soil nitrate, and microbial community species composition. In addition, I will measure indaziflam residue and metabolites of soil samples using LC-MS, to better understand the relationship between indaziflam residuals and soil characteristics.

Intellectual Merit

While indaziflam is effective at controlling cheatgrass, its non-target effects, especially regarding soil microbial communities, remain nebulous. There is no question that cheatgrass must be controlled to preserve the health and stability of semi-arid shrublands, but restoration may be ineffective if negative impacts to soil exist. By including a temporal aspect, this research will provide novel information on the direct impacts of indaziflam on soil microbes and characteristics over time. Additionally, indaziflam residual measurements can be coupled with soil measurements to investigate whether concentration of herbicide and soil characteristics are related.

Broader Impacts

Semi-arid rangelands characterize much of the continental U.S., extending across more than a third of the land[9]. Semi-arid shrublands provide rangeland and thus are an integral resource for ranching and agricultural practices. This research will provide information that addresses current knowledge gaps regarding the non-target effects of indaziflam on soil microbial communities and soil health. Non-target effects identified by this research will provide land managers and ranchers with information that will better equip well-informed decision-making when applying indaziflam. Data generated by this study will also help land managers develop prevention strategies to mitigate negative non-target effects if needed, reducing harm to soil health while accessing benefits such as reduced wildfire risk and increased native plant species richness.

I plan to publish my research in relevant journals such as Restoration Ecology. Additionally, I hope to collaborate with Boulder County Parks and Open Spaces and/or other local agencies to create resources (infographics, guides) for local ranchers and other land managers to ensure that the information generated by my study goes to those most impacted by the results. I will present my findings at relevant conferences, including the Society for Range Management annual conferences in 2027 and 2028.

I plan to work with undergraduate students for my study and will include the students at every step of the research process, from planning to data collection to analysis. I wouldn't be filling out this application or pursuing research if it weren't for the graduate student that I got to work with as an undergraduate, so nothing would make me happier than to help someone else develop the skills and passion for research that may lead them to pursue their own research one day.

References

1 Bradley et al. Biological Invasions, 20, 1493-1506 (2018). **2** Davies et al. International Journal of Wildland Fire, 22, 353–358 (2013). **3** Barker et al. Ecosphere, 10(11):e02929 (2019). **4** Rodhouse et al. Global Ecology and Conservation, 28:e01689 (2021). **5** Sebastion et al. Pest Management Science, 73(10), 2149-2162 (2017). **6** Sebastion et al. Restoration Ecology, 33(8): e70163 (2025). **7** Bradbury et al. Frontiers in Microbiology, 15:1450633 (2024). **8** Michael et al. Asian Soil Research Journal, 8, 34-41 (2024). **9** DeLoss, Colorado State University Source (2025).

Supplemental Material (Previous Assignments)

Assignment 1 Materials

Short Summary

The Goals and Objectives of the GRFP are primarily to support the expansion of the scientific workforce in the United States, and to promote the inclusion of more people in STEM. The GRFP evaluates applicants using a range of criteria, but especially considered are Intellectual Merit, meaning the applicant's seeming potential to fulfill their research plans and goals, and Broader Impacts, meaning the societal benefits that the applicant's research will bring (GRFP, pg. 17-18). The GRFP aims to support awardees who demonstrate strong potential and competency in research, in hopes that the awardee will go on to make significant discoveries, innovations, and production of information that will bolster the well-being of society (GRFP, page 18).

Reverse Outline

Important Information And Revision Notes
This section provides details about basic submission requirements including where to submit your proposal, when to submit it by, when reference letters are due by, where to find information regarding highest priority research initiatives for the U.S. government, and how to request accommodations.

Summary of Program Requirements

1) Outline of the purpose of the GRFP, which is to bolster the STEM workforce by providing 3 years of support to "outstanding graduate students who are pursuing full-time research-based master's and doctoral degrees in [STEM] or STEM education," (GRFP, page 3).
2) Describes the reason the GRFP was created, which was to support students who show promise to "make significant contributions in STEM," (GRFP, page 3).

Broadening Participation in STEM

1) NSF is legally mandated to encourage participation of historically underrepresented groups in STEM.
2) Information on how to contact the cognizant program officer(s) and a list of the Catalog of Federal Domestic Assistance Number(s) for different fields of STEM.
3) Award Information: Specifications about the award, including that it is a fellowship award, the number of awards likely to be granted, the average funding likely to be granted per awardee (stipend and education allowance), and how funding will be allocated to the awardee.
4) Organization Limit: Students awarded this Fellowship must be accepted into a graduate program in STEM at an accredited university in the United States or Puerto Rico and be enrolled in that program by the fall.
5) Applicant Eligibility: List of several conditions that must be met by the applicant when the application is due in order for their application to even be considered (most requirements are straightforward, complexity arises if the applicant is already a graduate student).

6) Number of Times an Individual May Apply: Describes the differing limits for seniors/bachelor's degree holders, current graduate students, and bachelor's-master's concurrent degrees, where seniors/bachelor's degree holders have the least restrictions and may apply an unlimited number of times.
7) Limit on Number of Applications: "An eligible applicant may submit only one application per annual competition," (GRFP, page 5).
8) Application Preparation and Submission Instructions: Informs the reader that application instructions deviate from standard guidelines and to continue reading for more information about applying and budgetary limitations, and also provides due dates for different fields of study.
9) Application Review Information Criteria: Fellowship money will be sent to and managed by the institution (but the institution must follow NSF GRFP administrative guidelines), and the student must submit yearly financial activity records.

Introduction

1) The GRFP exists to support (for 3 years) students pursuing graduate educations who show great potential to contribute to advancing research in STEM**.**
2) The GRFP has two main goals, which are to financially support early career scientists and to increase participation in science.
3) GRFP is integral to the NSF's mission to be a leader in STEM research and innovation, as evidenced by NSF Fellows who have gone on to do breakthrough work.

Program Description

1) The applicant must prepare a comprehensive plan that highlights their academic and research experience as well as their graduate plan to show why they have potential in research advancement.
2) Applicants must be enrolled in a STEM research graduate program at an accredited university by the time the Fellowship begins and must stay enrolled through the duration of the Fellowship.
3) There are many STEM fields that NSF supports and that are eligible to apply for the GRFP.

Award Information

1) The GRFP will be awarded to a maximum of 2,300 Fellows and funding will be granted for a maximum of three years (available to use for 5 years), and will be allocated each fall.
2) The GRFP awards a maximum of $53,000 per year to the awardee, $37,000 of which in the form of a stipend and $16,000 of which in the form of a Cost of Education allowance.
3) The institution the Fellow attends must exempt Fellows from tuition in excess of the Cost of Education (if the awardee institution accepts the fellowship funds).
4) Supplemental funding is permitted.
5) Describes how Fellows with disabilities can apply for special assistance funding.
6) Fellows can apply for NSF non-academic INTERN opportunities as well.
7) The NSF may award Honorable Mentions to applicants that show potential but who are not chosen for the Fellowship.

Eligibility Information

1) Applicants must submit their own application, must use the specified submission module to submit, must have evidence of acceptance into a graduate degree program within the United States or Puerto Rico, and must stay enrolled in a graduate degree program throughout the duration of the fellowship.
2) Repeat of previously stated application requirements.
3) Applicants must understand and certify their understanding and fulfillment of all criteria.
4) Citizenship: Applicants must be US citizens, nationals, or permanent residents, visa holders are not eligible.
5) Degree Requirements: Undergraduates or bachelor's degree holders who have not been enrolled in graduate programs and who will begin graduate school when the award period begins, graduate students who have completed a year or less than one academic year, or students who seek to return to graduate school who are two plus years past their most recent enrollment in graduate school.
6) Undergraduate students and bachelor's degree holders who have never enrolled in grad school can apply an unlimited number of times as long as they are prepared to begin graduate school in fall of the year the award begins.
7) Joint Bachelor's-Master's degree students may only apply once.
8) Specifications for current graduate students of what counts as one academic year of graduate study.
9) Previous graduate students returning to school are eligible as long as it has been two or more consecutive years since they were enrolled in a graduate program.
10) Various fields of study are eligible (geosciences and life sciences are likely most relevant to ESS).
11) Applicants must enroll in a program that matches the stated Major Field of Study proposed in their application.
12) Only research based graduate degrees qualify for GRFP support.
13) Ineligible degree programs: Students enrolled in practice-oriented graduate degree programs are not eligible for GRFP funding.
14) Ineligible areas of study: Health/patient based research is not eligible for GRFP support.
15) Ineligible proposed research: Health and disease related research is ineligible, with limited exceptions if the research advances fundamental knowledge within the field of study.
16) Plant pathology research is eligible unless it is primarily for the purpose of increasing agricultural production or food safety.
17) Research may have policy implications but may not demonstrate expressed support for certain policy outcomes.
18) Applicants are encouraged to consult an advisor or faculty when preparing research plans.

Application Preparation and Submission Instructions

1) Applications must be submitted by the field specific deadline by 5:00pm of the applicant's local time on the deadline.
2) Applicants need three reference contacts and two reference letters must be submitted by reference writers and received by the NSF by 5:00pm ET on the deadline.
3) List of all of the required information and statements required for the application.

4) Additional information that is not required by the GRFP Application Module will not be reviewed.
5) List of stylistic guidelines.
6) The GRFP Application Module will not accept documents that do not meet listed criteria, thus applicants should be very careful and proofread application materials to prevent delays.
7) Specifications for statements, with an emphasis on producing original work.
8) Both statements must include individual and separate "Intellectual Merit" and "Broader Impacts" sections, or they will not be reviewed.
9) Transcripts are required and at least one transcript is needed for the GRFP Application Module to accept the application.
10) Transcripts should be submitted as PDFs, with personal information redacted, and must not be encrypted.
11) Specifications for applicants who earned their master's degree through joint Bachelor's-Master's program.
12) Applications must be submitted by the deadline with required materials and must display "received" status in the Application Module in order to be reviewed.
13) Applicants must provide contact information for 3 reference writers, may have up to 5 potential reference writers, must have two reference letters by the deadline, and reference writers must not be the student's family members.
14) The list of reference writers may not be changed after the application is submitted, and students are responsible for checking accuracy of reference emails and reference willingness to participate.
15) Applicants may list 5 reference writers, but if more than three reference letters are received, only the top three will be considered as ranked by the applicant.
16) Reference writers must submit to the GRFP Module and will receive email confirmation after they upload their letter on behalf of the applicant.
17) Applicants should give reference letter writers plenty of time and should provide writers with copies of their application materials.
18) Specifications for reference letters and what reference letters should include.
19) The GRFP Application Module has an "Application Completion Status" feature that allows the applicant to see their progress and make sure they have submitted all required materials before deadlines.
20) NSF applicants hoping to pursue interdisciplinary research are eligible to apply.
21) Applications must be submitted by the deadline for the field of study stated in the application.
22) Applications may be withdrawn on or before November 15th of the application year and will not count towards the application limit for students with a limit.
23) Repeat of budget information already provided.
24) List of due dates by field.
25) Repeat that application materials must be submitted through the GRFP Application Module.

Application Review Information

1) Applications will be reviewed by reviewers from a broad spectrum of related fields, thus it is important that the applicant pick the Major Field of Study most closely related to their proposed graduate program.

2) Intellectual Merit and Broader Impacts especially will be reviewed, and should have their own headings, where intellectual merit is "the potential to advance knowledge" and broader impacts is "the potential to benefit society and contribute to the achievement of specific, desired societal outcomes."
3) Broader impacts with socially relevant outcomes, such as advancing education, public engagement, well-being of individuals, facilitation of partnerships across fields, national security, and economic benefits.
4) Reviewers will look at a range of criteria including educational and research experience, leadership, service, etc.
5) Reviewers will complete a comprehensive review of applications, recommend applicants for the GRFP, and the NSF will then select applicants from recommendations using the NSF's mission and goals to guide decisions.

Award Administration Information

1) Awardees will be notified by early April of the competition year.
2) Funds are given to the awardee's institution of higher education and are subject to terms and conditions.
3) Applicants must accept or decline the offer and terms and conditions by the specified deadline if awarded the Fellowship.
4) Fellows must accept terms and conditions and make a diligent effort and academic progress towards receiving their graduate degree while receiving the Fellowship, and the Fellowship may be revoked if terms are breached.
5) Applicants may not accept the GRFP award if they accept a different federal graduate fellowship.
6) Research must follow legal and ethical guidelines, and Fellows must be trained in the Responsible and Ethical Conduct of Research.
7) Research involving human subjects must get IRB approval or be exempt from IRB review.
8) Research involving vertebrate animals must be in compliance with the Animal Welfare Act and regulations under the Secretary of Agriculture, and must be approved by the Institutional Animal Care and Use Committee (IACUC).
9) Vertebrate animal research involving international research must still be approved by the US grantee's IACUC and must follow the International Guiding Principles for Biomedical Research Involving Animals.
10) The NSF does not claim rights over Intellectual Property produced by fellows, however fellows should include an Acknowledgement and Disclaimer in publications using the following statement:

    > "This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. (NSF grant number). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."

11) Fellows must update their Annual Activities Report and Fellowship Status Declaration each year to show progress (broader impacts, presentations, publications, teaching and research assistantships, awards and recognitions, etc.) and to verify that they will be utilizing the Fellowship for that year.

12) If a Fellow does not declare intent to utilize the Fellowship for the year, they will be in violation of the terms and conditions and the Fellowship will be terminated.
13) The Division of Graduate Education (DGE) gathers information about Fellows to understand the efficacy of the Fellowship, thus Fellows may be contacted for information about their educational and career pursuits and may be subject to evaluation.
14) GRFP institutions must submit a GRFP completion report to update student status each year.

Agency Contacts

1) Provides a list of emails and phone numbers to contact for different issues and inquiries.

Other Information

1) Guides applicants to the NSF website for information of NSF initiatives and changes to procedures.
2) Provides website for other federal government-wide grant opportunities, including NSF funding opportunities.
3) Provides information about pursuing research internationally through opportunities offered by the NSF.

About The National Science Foundation

1) Describes the history of the NSF as an independent Federal agency which got its mandate from the National Science Foundation Act of 1950.
2) The NSF funds a broad range of STEM fields in schools across the country, both primary, secondary, and post-secondary, and other organizations.
3) While the NSF does not operate any laboratories, it supports labs and research projects across the country and across fields.
4) The NSF has awards for scientists with disabilities to provide support for them to acquire equipment that can help them conduct their research.
5) Describes accessibility options for people with hearing impairments.
6) The NSF means to advance scientific progress within the United States through grants.

Privacy Act And Public Burden Statements

1) Information requested on the GRFP application may be used by other government agencies or involved parties.
2) Information Collection is only required by an issuance from the Office of Management and Budget with the appropriate control number (3145-0023).

Appendix

1) The applicant must select a Major Field of Study and the program that they pursue must match a subfield of the Major Field selected in their application.
2) The applicant's selection of a Major Field will impact the deadline of their application, which experts will review the application, and which graduate programs apply.
3) Most ESS related fields fall under Geosciences (biogeochemistry, earth system science, environmental science) or Life Sciences (ecology, environmental biology, evolutionary biology).

Required Documentation and Information

1) Comprehensive plan that includes "academic achievements, attributes, and experiences that illustrate the applicant's demonstrated potential for significant research achievements…relevant education, research experience, and plans for graduate education…"
2) Confirmation of acceptance to a graduate degree program if awarded
3) Three reference letters, submitted by the reference letter writer through the NSF Reference Letter System

    Requirements:

    - Institutional or professional letterhead, if available
    - SIGNED by the reference writer, including the name, professional title, department, and institution
    - Two (2) page limit (PDF file format)
    - Standard 8.5" x 11" page size
    - 11-point or larger Times New Roman font and 1" margins on all sides
    - Single spaced using normal (100%) single-line spacing

    Specifications:

    "The reference letter should address the NSF Merit Review Criteria of Intellectual Merit and Broader Impacts (described in detail below). It should include details Explaining the nature of the relationship to the applicant (including research Advisor role), comments on the applicant's potential for contributing to a globally-engaged United States science and engineering workforce, statements about the Applicant's academic potential and prior research experiences, statements about The applicant's proposed research, and any other information to aid review Panels in evaluating the application according to the NSF Merit Review Criteria."
4) Personal Information
5) Education and work experience
6) Transcript PDFs
7) Proposed Graduate Study & Graduate School Information
8) Names and emails of a minimum of 3 reference letter writers
9) Personal, Relevant Background, and Future Goals Statement PDF (3 page page limit, including citations, figures, etc).
10) Graduate Research Plan Statement PDF (2 page page limit, including citations, figures, etc).
11) Both statements must include "Intellectual Merit" and "Broader Impacts" sections within individual separate sections under individual separate headings

    Statement Guidelines:

    - 8.5" x 11" page size
    - 11 pt or larger font (excluding image text)
    - Times New Roman for text and Cambria Math for equations, Symbol font for non-alphabetic characters
    - Cited references should include name of journal
    - 1" margins (no header, footer, name, or page number)
    - No less than single-spacing (~6 lines per inch)
    - PDF file format required

CURRICULUM VITAE

NAME Sammy Tetrault **DATE:** 9/25

POSITION Student, Ecosystem Science and Sustainability
Colorado State University
Fort Collins, CO 80523

EDUCATION

Year	Degree	Institution	Area of Study
2023	AGS	Front Range Community College	General Studies
2025 (Anticipated)	BS	Colorado State University	Ecosystem Science & Sustainability

WORK EXPERIENCE

Year	Institution	Position	Department
2024 - 2025	Colorado State University	Undergraduate Research Assistant	Agricultural Biology

Professional Non-Academic

2025 - present	City of Fort Collins	Forestry Field Worker I	

TEACHING EXPERIENCE

Year	Institution	Position	Department
2024	Colorado State University	Undergraduate Lab Teaching Assistant	Biology

PRESENTATIONS

2025 "Effects of Indaziflam on Native Species Seed Emergence" presented at Colorado State University's Celebrate Undergraduate Research & Creativity (CURC) event.

HONORS & AWARDS

2025	CURC 2025 College Honors: Warner College of Natural Resources	Colorado State University
2023-2025	Phi Theta Kappa Scholarship Recipient	Colorado State University

References

Brandeis University. Reverse Outlining. (n.d.).

National Science Foundation. (2025, August). NSF 24-591: NSF Graduate Research Fellowship Program (GRFP).

Assignment 2 Materials

I. Develop drafts of the materials required to be entered into the GRFP Application Module.

The sections that are required include:

Personal Information

Legal Name and Identifier: Samantha Joan Tetrault
Mailing Address: 2001 Kent Ct, Fort Collins, CO 80526
Phone number: 970-215-0685
E-mail address: samanthajoantetrault@gmail.com
Date of Birth: August 23rd, 2004
High School Location: Fort Collins, Colorado

Education

Colorado State University, Fort Collins, CO
Fall 2023 - Anticipated Graduation Fall 2025
Bachelor of Science, Ecosystem Science & Sustainability
GPA: 4.0

Front Range Community College, Fort Collins, CO
Spring 2022 - Spring 2023
Associate of General Studies
GPA: 4.0

Work and Other Experience

Forestry Field Worker I
City of Fort Collins, CO | May 2025 - present

- Responsible for watering over 300 trees every two weeks.
- Communicate in a friendly and informative manner with members of the public who approach with questions about tree health and pests (ie. emerald ash borer)
- Monitor beetle traps to identify which species may be spreading pine wilt nematode.
- Update tree inventory database when new trees are planted or existing trees are removed or exhibit a change in condition.

Research Assistant
CSU Department of Agricultural Biology, Fort Collins, CO | June 2024 - May 2025

- Prepared research materials and planted 2800 seeds for each of the three trials conducted.
- Collected and entered plant emergence, height, herbicide injury, and vigor data daily.
- Harvested the sprout, roots, and soil of individuals with true leaves for biomass measurements.
- Assisted with data sorting and analysis using Microsoft Excel and R.

- Led and presented a sub-project analyzing the relationship between emergence and functional group and emergence and seed weight.

Undergraduate Teaching Assistant

CSU, Fort Collins, CO **|** January 2024 - May 2024

- Supported a graduate teaching assistant for a LIFE102 lab section by retrieving lab materials, answering student questions, and facilitating group discussions.
- Provided demonstrations to students for hands-on activities such as pipetting.
- Taught a lab at the end of the semester to a group of 20 students.

Transcript PDFs

I saved the PDF to my computer, here are screenshots of the PDF:

Unofficial Transcript

Colorado State University Unofficial Transcript for Samantha Joan Tetrault (835302665)

Monday, October 13, 2025 7:11:40 PM

Fall Semester 2025 Curriculum

Program Code: ECSS-BS
Program Description: BS Ecosystem Science and Sustainability
Curriculum Level: Undergraduate

Type	Description	Code	Department	College
MAJOR	Ecosystem Sci & Sustainability	ECSS	Ecosystem Science & Sustainabi	Warner Coll of Natural Resrces

Undergraduate

Overall Credit Hours Earned: 137.000
Colorado State University Credit Hours Earned: 73.000
Colorado State University GPA Credit Hours: 68.000
Colorado State University Grade Points: 272.000
Colorado State University Cumulative GPA: 4.000
Transfer Credit Hours Earned: 64.000

Academic Term Summary

Term	Term Dates	Class	Major	Term GPA	Quality Points	GPA Hours	Hours Earned	End of Term Standing
Spring Semester 2026	01/20/2026 - 05/15/2026	Senior	Ecosystem Sci & Sustainability	0.000	0.000	0.000	0.000	
Fall Semester 2025	08/25/2025 - 12/19/2025	Senior	Ecosystem Sci & Sustainability	0.000	0.000	0.000	0.000	
Summer Session 2025	05/19/2025 - 08/08/2025	Senior	Ecosystem Sci & Sustainability	0.000	0.000	0.000	0.000	

Spring Semester 2025	01/21/2025 - 05/16/2025	Senior	Ecosystem Sci & Sustainability	4.000	72.000	18.000	18.000	Good Standing
Fall Semester 2024	08/19/2024 - 12/13/2024	Senior	Ecosystem Sci & Sustainability	4.000	64.000	16.000	21.000	Good Standing
Summer Session 2024	05/13/2024 - 08/02/2024	Senior	Ecosystem Sci & Sustainability	4.000	20.000	5.000	5.000	Good Standing
Spring Semester 2024	01/16/2024 - 05/10/2024	Senior	Ecosystem Sci & Sustainability	4.000	60.000	15.000	15.000	Good Standing
Fall Semester 2023	08/21/2023 - 12/15/2023	Junior	Ecosystem Sci & Sustainability	4.000	56.000	14.000	14.000	Good Standing

Current Credit Courses

Term	Course	Title	Credits	Level
Fall Semester 2025	CO-301B-014	Writing in the Disciplines: Sciences (GT-CO3)	3	Undergraduate
Fall Semester 2025	ESS-411-001	Earth Systems Ecology	3	Undergraduate
Fall Semester 2025	NR-400-001	Public Communication in Natural Resources	3	Undergraduate
Fall Semester 2025	NR-400-R02	Public Communication in Natural Resources	0	Undergraduate

Completed CSU Courses

Term	Course	Title	Credits	Grade	Level	Comments
Spring Semester 2025	BSPM-495-001	Independent Study	2	A	Undergraduate	
Spring Semester 2025	ESS-312-001	Sustainability Science	3	A	Undergraduate	
Spring Semester 2025	ESS-330-L01	Quantitative Reasoning for Ecosystem Science - Lab	0	NGC	Undergraduate	
Spring Semester 2025	ESS-330-001	Quantitative Reasoning for Ecosystem Science	3	A	Undergraduate	
Spring Semester 2025	ESS-400-001	Global Perspectives on Sustainability	3	A	Undergraduate	

Spring Semester 2025	ESS-440-001	Practicing Sustainability	4	A+	Undergraduate	
Spring Semester 2025	ESS-440-R02	Practicing Sustainability - Recitation	0	NGC	Undergraduate	
Spring Semester 2025	NR-320-001	Natural Resources History and Policy	3	A	Undergraduate	
Fall Semester 2024	ESS-311-001	Ecosystem Ecology	3	A+	Undergraduate	
Fall Semester 2024	ESS-487-001	Internship	5	S	Undergraduate	
Fall Semester 2024	NR-319-L02	Introduction to Geospatial Science	0	NGC	Undergraduate	
Fall Semester 2024	NR-319-001	Introduction to Geospatial Science	4	A	Undergraduate	
Fall Semester 2024	POLS-103-001	State and Local Government and Politics (GT-SS1)	3	A	Undergraduate	
Fall Semester 2024	POLS-364-001	Air, Climate, and Energy Policy Analysis	3	A	Undergraduate	
Fall Semester 2024	STAT-307-002	Introduction to Biostatistics	3	A+	Undergraduate	
Summer Session 2024	PH-121-L02	General Physics I (GT-SC1)-Lab	0	NGC	Undergraduate	
Summer Session 2024	PH-121-001	General Physics I (GT-SC1)	5	A	Undergraduate	
Summer Session 2024	PH-121-R01	General Physics I (GT-SC1)-Recitation	0	NGC	Undergraduate	
Spring Semester 2024	BZ-384-002	Supervised College Teaching	1	A+	Undergraduate	
Spring Semester 2024	ESS-130-001	Intro to Systems Theory for Sustainability	1	A+	Undergraduate	
Spring Semester 2024	LIFE-103-002	Biology of Organisms-Animals and Plants (GT-SC1)	4	A+	Undergraduate	
Spring Semester 2024	LIFE-103-L18	Biology of Organisms-Animals and Plants (GT-SC1) - Lab	0	NGC	Undergraduate	
Spring Semester 2024	LIFE-320-002	Ecology	3	A+	Undergraduate	
Spring Semester 2024	POLS-101-401	American Government and Politics (GT-SS1)	3	A	Undergraduate	

Spring Semester 2024	WR-204-001	Sustainable Watersheds (GT-SC2)	3	A+	Undergraduate	
Fall Semester 2023	ECON-240-001	Issues in Environmental Economics (GT-SS1)	3	A+	Undergraduate	
Fall Semester 2023	ESS-210-001	Physical Geography	3	A+	Undergraduate	
Fall Semester 2023	GES-101-001	Foundations of Environmental Sustainability	3	A	Undergraduate	
Fall Semester 2023	IU-300-102	Becoming A Scientist	1	A+	Undergraduate	
Fall Semester 2023	LIFE-102-L67	Attributes of Living Systems (GT-SC1) -Lab	0	NGC	Undergraduate	
Fall Semester 2023	LIFE-102-001	Attributes of Living Systems (GT-SC1)	4	A+	Undergraduate	

Transfer Courses

Term	Institution	Course	Title	Credits	Grade
Spring Semester 2023	Front Range Comm Coll-Westmin	ACT-2++	Accounting Principles I	1	TA
Spring Semester 2023	Front Range Comm Coll-Westmin	ACT-210	Accounting Principles I	3	TA
Spring Semester 2023	Front Range Comm Coll-Westmin	CS-165	Computer Science II: Java	4	TA
Fall Semester 2022	Front Range Comm Coll-Westmin	BUS-150	Intro PC Application:ms Offic	3	TA
Fall Semester 2022	Front Range Comm Coll-Westmin	CO-1++	English Composition Ii:co2	3	TA
Fall Semester 2022	Front Range Comm Coll-Westmin	CS-1++	Computer Science I: Java	4	TA
Spring Semester 2022	Front Range Comm Coll-Westmin	CS-1++	Intro. To Programming: C++	3	TA
Spring Semester 2021	Front Range Comm Coll-Westmin	FIN-200	Personal Finance	3	TA
Spring Semester 2021	Univ Colo Denver/Hlth Sci Ctr	HIST-150	United States History to 1876	3	TA
Spring Semester 2021	Univ Colo Denver/Hlth Sci Ctr	HIST-151	United States History Sn 1876	3	TA
Spring Semester 2021	Advanced Placement Program	CO-130	Engl Lang Scr 4 & Lit Scr ++	3	TS
Spring Semester 2021	Advanced Placement Program	CO-150	Engl Lang Scr 4 & Lit Scr ++	3	TS
Spring Semester 2021	Advanced Placement Program	E-140	Engl Lang Scr 4 & Lit Scr ++	3	TS
Fall Semester 2020	Front Range Comm Coll-Westmin	LSPA-200	Spanish Language Iii: AH4	3	TA

Fall Semester 2020	Univ Colo Denver/Hlth Sci Ctr	MATH-160	Calculus I	4	TA-
Spring Semester 2020	Advanced Placement Program	CHEM-1++3L	Chemistry Score of 3	4	TS
Spring Semester 2020	Advanced Placement Program	GR-100	Human Geography Score of 5	3	TS
Fall Semester 2019	Univ Colo Denver/Hlth Sci Ctr	CHEM-111	General Chemistry I	3	TA-
Fall Semester 2019	Univ Colo Denver/Hlth Sci Ctr	CHEM-112	General Chemistry Lab I	1	TA-
Fall Semester 2019	Univ Colo Denver/Hlth Sci Ctr	MATH-1++1B	College Trigonometry	1	TA
Fall Semester 2019	Univ Colo Denver/Hlth Sci Ctr	MATH-125	College Trigonometry	1	TA
Fall Semester 2019	Univ Colo Denver/Hlth Sci Ctr	MATH-126	College Trigonometry	1	TA
Spring Semester 2019	Univ Colo Denver/Hlth Sci Ctr	MATH-1++1B	College Algebra	1	TA
Spring Semester 2019	Univ Colo Denver/Hlth Sci Ctr	MATH-117	College Algebra	1	TA
Spring Semester 2019	Univ Colo Denver/Hlth Sci Ctr	MATH-118	College Algebra	1	TA
Spring Semester 2019	Univ Colo Denver/Hlth Sci Ctr	MATH-124	College Algebra	1	TA

Proposed Field(s) of Study

Major Field of Study: Life Sciences
Sub-field: Ecology

Proposed Graduate Study and Graduate School Information

Master's program in Ecology and Evolutionary Biology at University of Colorado Boulder. Advisors in this field of study at CU Boulder study a range of areas related to ecology, including microbial and soil ecology, plant ecophysiology, ecosystem ecology, etc.

Names and Addresses of at least 3 reference letter writers

1) Cynthia Brown, email: cynthia.s.brown@colostate.edu. I worked with a graduate student (Lauren Myers) advised by Cini as an undergraduate research assistant. I worked closely with Cini not only to support Lauren's research, but also to prepare my own sub-project, which I presented at CURC.
2) Lauren Myers, email: laurenmyers7@gmail.com. I worked directly under Lauren as her undergraduate research assistant for her project regarding indaziflam and Boulder County's native seed bank. Lauren also mentored me for my CURC project and helped me navigate using R to create models and graphs. I think out of all references, Lauren would be able to write the most detailed account of my experience in research and capacity to do my own research project.

3) Ed Hall, email: Ed.Hall@colostate.edu. I took ecosystem ecology with Ed Hall and feel that this class is when I not only started to form a passion for ecology, but also began to understand it. While there is much more for me to learn, I gained so much fundamental knowledge in this class, and feel that Ed is an instructor who got to see me grow a lot throughout the semester. I feel that I participated much more actively than usual in this class compared to other courses I've done at CSU, so I think Ed would be an ideal instructor for me to reach out to.
4) James Henriksen, email: jamesrh@rams.colostate.edu. James was one of the key stakeholders that I worked with for my capstone project. I worked with James frequently during this project, as I was very involved with the microscopy aspect of it. James taught me how to do DIC microscopy, and I was able to take some exciting photos and videos of microbial life from samples.

II. Develop draft paragraphs for your Personal, Relevant Background and Future Goals Statement.

Personal Background

Being raised in Colorado, I was fortunate to grow up with the great outdoors right in my backyard. I spent my summers as a kid camping in national forests, building terrariums, and learning about the environment through direct exposure. These experiences were the beginning of an exciting curiosity - to understand the inner workings of the environment and its constituents - that has followed me throughout my life, and which motivated me to study ecosystem science and sustainability as an undergraduate student at Colorado State University.

Intellectual Merit

During my time at Colorado State University, I have taken several courses that have helped to prepare me for future academic endeavors. Of note, the classes that I found most fulfilling were those that focused on ecology. In these courses, I gained fundamental understanding of several key topics, including nutrient cycling, dynamic systems, soil taxonomy, atmospheric composition, plant ecology, and ecosystem production. Outside of the classroom, I had the opportunity to apply my knowledge in a lab setting, working as an undergraduate research assistant in Dr. Cynthia Brown's lab at Colorado State University As a research assistant, I worked alongside graduate student Lauren Myers, whose research project was inspired by the work of Boulder County Parks and Open Spaces (BCPOS), an agency that uses indaziflam as a restoration tool. Indaziflam is a pre-emergence herbicide used to manage Bromus *tectorum*, commonly known as cheatgrass, an invasive annual grass common across the western United States. Indaziflam halts cellulose production, preventing radicle formation and seed emergence. While indaziflam can effectively reduce cheatgrass cover, BCPOS was unsure of the herbicide's impact on the native seedbank. This helped to inform the research question of our study: Does indaziflam inhibit seed

emergence for native species in Colorado? For this study, we used 14 species, 11 of which were native and 3 of which were invasive. Functional groups used included invasive and native grasses and native forbs. For our study, we planted seeds of each species in planting trays using two types of soil: topsoil and sand mix (50% topsoil and 50% sand by volume). We sprayed trays with indaziflam at varying rates, with a control rate of 0 fluid oz/acre and our highest rate, 7 fluid oz/acre, set at 2 times the base label rate. Our study included 3 repetitions, each with 10 trays of each soil type. We observed each set of trays for 6 weeks in a greenhouse and took daily measurements of emergence, height, injury symptoms, and true leaf emergence. We also collected soil and sprout samples from trays at the end of each repetition. After helping with data collection and entry, I took on my own sub-project and used our data to investigate interactions between functional group & rate and seed weight & rate as predictors for emergence. I used R to create generalized linear models and to create plots that demonstrated trends across groups. I had the opportunity to present my project at Colorado State University's Celebrate Undergraduate Research & Creativity event in 2025. My experiences as an undergraduate research assistant allowed me to see the research process go from theory to practice, and I got to participate in several stages, from planning to data collection to analysis. Creating my own sub-project allowed me to navigate these stages a bit more independently, and to practice using tools like R to analyze data and interpret summary statistics. Presenting my project helped me practice communicating to the broader public, and conveying the significance of the research we had done.

Broader Impacts

Participating in undergraduate research sparked a passion for me, and while I learned many skills from the opportunity, I also recognize that there is lots left for me to learn. Graduate school will give me the opportunity to practice the research process further, and continue to develop skills that I began to practice during my time in Dr. Cynthia Brown's lab. While I've learned so much as an undergraduate student, it can be difficult to take theoretical knowledge and translate that to a research project and applicable information for informing policy, management decisions, and other broader implications. Graduate school will allow me to practice this skill, learn new skills, and become more confident as a scientist. I hope that the skills that I gain will allow me to produce work that can be used by local, state, and national agencies for land management, restoration, combatting the effects of climate change, and progressing our collective understanding of biogeochemistry.

I also hope that my experiences will allow me to participate in scientific education as my career progresses. During my time as an undergraduate student, I had the opportunity to work as a lab teaching assistant for an introductory biology course. Helping my peers

learn foundational scientific knowledge and practice new skills in a lab setting was so exciting for me, because I got to see the beginning of future scientific careers, and use my knowledge to help people that may one day be my colleagues. Just as important as producing novel research is the passing of the torch to future generations of scientists who will lead the way in combatting the same issues that I hope to address throughout my career. Although I've always had an interest in science, I never thought that research was something that someone like me could pursue. I thought that I didn't come from the right background, and because no one in my family has gone to graduate school, I always thought I wouldn't either. My perspective changed because of the people that I've worked with as an undergraduate student, and the teachers that have inspired me and showed me that science is for everyone. I hope that one day I can be that person for someone too.

III. Develop a draft Research/Program Plan Statement that includes the start of a literature review/background section. The literature review will include publications that inspired your choice of research or program plan and will serve as background materials that you are basing your Research/Program Plan on.

a. Identify 1-2 papers to start your literature review.

Sebastian, J., Swanson, J.K., Lauer, D. and Jones, L.C. (2025), Indaziflam for Cheatgrass (*Bromus tectorum*) control increased native species richness for up to 8 years in Colorado Front Range (United States) shrub-steppe. Restor Ecol e70163. https://doi.org/10.1111/rec.70163

b. Develop reverse outlines and summaries of the papers.

Summary:

Cheatgrass is an invasive annual grass that dominates swaths of land and thrives in the shrub-steppe ecosystems that characterize the Colorado Front Range. Indaziflam is an herbicide commonly used to control cheatgrass, shown to effectively reduce its cover. While previous studies have only considered the effects of indaziflam over a short-term period (2-4 years), Sebastian et al. present data on the long-term effects of indaziflam over a long-term period (6-8 years) across 12 sites in Boulder County. Their research suggests that indaziflam is effective for long-term cheatgrass control, and that native species richness, including rare and short-lived species, increases as a result. This is likely due to both reduced cheatgrass cover from indaziflam application and existing seedbank diversity. Data and analysis provided by this study can assist land managers in making more informed cheatgrass control and indaziflam application decisions.

Abstract

1) Provides key points, including the location of the study (12 sites across Boulder County), what cheatgrass is and why it threatens native biodiversity, the time scale (6 to 8 growing seasons), and the effects of indaziflam application (70-98% control of cheatgrass and increased species richness).

Implications for Practice

2) Just one application of indaziflam controlled cheatgrass for 6-8 years, allowing native species diversity to increase every year compared to nearby non-treated sites.
3) Cheatgrass control allowed all growth forms and long and short lived species to establish and develop resilient plant communities that were less likely to be reinvaded.
4) Sometimes just one application of indaziflam effectively controlled cheatgrass when the site only exhibited mild degradation.

Introduction

5) Indaziflam, an herbicide that kills cheatgrass seedlings by inhibiting cellulose biosynthesis, has been shown to be effective at controlling cheatgrass long-term, which could allow rare and short-lived plant species to reestablish.
6) Using pesticides can come with non-target effects, including negative effects on plant community composition, which should be considered when weighing the pros and cons of using indaziflam.
7) “Table 1. Published non-target abundance and diversity responses after indaziflam application.”
8) Most existing studies only consider short-term effects of indaziflam (2-4 years), while this study looks at the long-term effects (6-8 years), providing data that can help land managers make more informed indaziflam application decisions.

Methods

9) The study included 12 locations across Boulder County, all exhibiting great biodiversity but also presence of cheatgrass, with a diversity of soil types, aspects, elevations, and land use.
10) “Table 2. Study locations in Boulder County, Colorado. At each location, a non-treated area of the same size and with similar slope and aspect was present adjacent to the treated area.”
11) Herbicide was applied to sites over a 3 year period between 2016-2019 using a tractor, spraying a solution of indaziflam (Rejuvra), glyphosate (Roundup), and non-ionic surfactant, with non-treated plots adjacent to treated plots used as controls.
12) Data on plant coverage was collected 9-12 times annually between March and November in each plot using transects, and species were categorized into

different functional groups using the CNHP Rare Plant Guide, the Flora of Colorado, and the USDA PLANTS database.

Analysis

13) Analysis was done using R, and cheatgrass cover was analyzed using a GLMM using the package “glmmTMB”.
14) Species richness was also analyzed, looking at metrics including gains and losses due to herbicide, with special interest on different effects between functional groups and longevity (short-lived species).
15) Species richness was also analyzed using a GLMM using the packages “glmmTMB” and “DHARMa”.
16) Beta diversity was assessed using the Sørenson dissimilarity index, and the temporal beta-diversity indices function in the R package “adespatial”.
17) Dissimilarity was compared between location-treatment plots 6 summers after treatment (SAT) as this was the longest period of time after treatment for all locations, and R packages “vegan” and “pheatmap” were used to produce metrics.

Results

18) Cheatgrass cover was significantly lower in treated plots than non-treated plots for all locations and across all SAT, with an 89-99% cheatgrass cover control when comparing treated plots to non-treated control plots.
19) “Table 3. Mean comparison tests for Cheatgrass cover (Chk = non-treated, Trt = treated, and SAT = summer after treatment).”
20) Figure 1: Show comparison of non-treated vs treated plot side by side, with the non-treated plot being covered by senesced cheatgrass with very little native plant coverage in between and the treated plot being covered by native plants.
21) Species richness increased significantly as a result of the variables summer after treatment and herbicide application in treated plots, with GLMs showing a 22-116% increase in species richness compared to non-treated plots and significant increases in short-lived and forb richness.
22) Figure 2: Shows increase in species richness for each functional group for each summer after treatment between non-treated and treated plots.
23) Mean total native species richness over 6 SAT was between 47 (low) -76 (high) in non-treated plots and 69 (low) - 165 (high) in treated plots, with 61% greater species richness of short-lived native species in treated plots vs. non-treated plots.
24) Species gain was much greater than species loss in all treated plots, and paired t-tests showed that proportional differences were significant for every SAT and functional group other than shrubs at 2 SAT.

25) Figure 3: Shows dissimilarity (gain + loss) for all species for each summer after treatment.
26) Figure 4: Shows dissimilarity for all functional groups for each summer after treatment.
27) All native functional groups were more often found in treated plots vs non-treated plots, and although rare species data was limited, 1-4 rare species were found in all treated plots whereas only 1 rare species was found in only one non-treated plot.
28) Dissimilarity was greater across non-treated locations than treated locations.
29) Figure 5: “Bray-Curtis treatment-location dissimilarities six summers after treatment for all 247 species across 12 locations.”

Discussion

30) This study suggests that indaziflam treatment is effective long-term (up to 8 years), and this is likely due to depletion of cheatgrass seeds in the seedbank, allowing native species richness to increase and treated plots to remain resistant to future cheatgrass invasion.
31) Richness increases were particularly high for short-lived species, contrasting previous research, therefore this increase was likely due to an existing diverse and resilient seedbank.
32) Non-treated plots exhibited fluctuation over the course of the study in native species richness likely due to precipitation differences, while treated plots exhibited yearly increases in richness likely due to reduced cheatgrass cover that allowed native species greater water resource availability.
33) Non-treated plots were more dissimilar across locations than treated plots, indicating that indaziflam treatment increases richness and decreases dissimilarity across treated sites.
34) Results can be used to exemplify harms of cheatgrass on native species richness, show how invasive species control and biodiversity can prevent cheatgrass reinvasion, demonstrate importance of long-term observation of indaziflam effects, encourage prioritization of land stewardship, and exemplify fast native species recovery in response to reduced cheatgrass cover.

Acknowledgments

This short section just recognizes various people who were not listed as authors but who helped with the study.

c. Identify key aspects of the papers for your literature review.

Invasive annual grasses, cheatgrass, native species richness, shrub-steppe ecosystems, land management

d. Update your reference section from Assignment I to include the papers in your literature review.

References

Brandeis University. Reverse Outlining. (n.d.).

National Science Foundation. (2025, August). NSF 24-591: NSF Graduate Research Fellowship Program (GRFP).

Sebastian, J., Swanson, J.K., Lauer, D. and Jones, L.C. (2025), Indaziflam for Cheatgrass (Bromus tectorum) control increased native species richness for up to 8 years in Colorado Front Range (United States) shrub-steppe. Restor Ecol e70163. https://doi.org/10.1111/rec.70163