Using Traditional Indigenous Knowledge of Prescribed Burning as a Tool to Shift a Reclaimed Tailings Storage Facility in Southern British Columbia Dominated by Agronomic Grass to a Native Plant Community

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Introduction

With a growing global population and increasing consumption, urbanization and industrial expansion, maintaining healthy ecosystems that support access to tangible and intangible assets is a major challenge. As the use of land to yield materials for processing and creating goods and services represents some of the most substantial changes to Earth's ecosystems, we must properly manage both our impacted and natural landscapes to ensure a positive net balance is maintained with respect to ecosystem function (Vitousek et al., 1997). Additionally, a growing public demand for both socially responsible and ecologically viable industrial practices has forced industries to respond with advancing sustainable practices in their operations (Fonseca et al., 2014). Historically, Canadian mining operations often resulted in some combination of environmental degradation, Indigenous community disruption, and displacement of Indigenous peoples from traditional lands (Melosi, 2017). This was due to a lack of industry policy, regulation, and checks and balances with respect to restorative or reclamation practices, combined with little forethought given to the impact occurring to ecosystem services, human livelihoods and health (Virgone et al., 2018).

Because of this legacy, there currently exists a vast heritage of degraded lands and displaced communities from historical mining efforts that require restoration, reclamation and reconciliation (Bradshaw, 1997). Restoration and reclamation research has emerged within the last two decades as a relatively new scientific discipline to address and counteract the issues of worldwide loss of biodiversity and ecosystem services (Hölzel et al., 2012). Additionally, as mining industries faced significant amounts of scrutiny with respect to land use management, sustainability issues and other adverse socio-environmental issues, this stimulated a response from industry to place components like sustainability reporting, and social and environmental assessments at the forefront of operations, to prove due diligence is being met in order to secure a social licence to operate (Azapagic, 2004; Melosi, 2017; Virgone et al., 2018). Today, beyond addressing environmental impacts, reclamation and restoration efforts within the industry have begun to encapsulate building and maintaining strong, resilient and beneficial relationships with Indigenous peoples and local communities to reconcile past inequities. The gold standard moving forward for industries should be to move beyond a 'social licence to operate' and into dynamic, trusted and mutual management of the landscape with communities and rightful landowners.

The research presented in this paper is based on examination of a unique project partnership between management at Teck Resources Limited's (Teck) Highland Valley Copper (HVC) mine in the Thompson Okanagan Region of the southern interior of British Columbia (BC) and the Nlaka'pamux peoples, where part of the building of this relationship rests on the intent to collaborate on the goal of reclaiming and restoring ecosystem function and traditional land uses to a pre-mined landscape to the extent possible given the impacts the HVC mine has created. This work becomes especially important in reclaiming mined lands to more desirable native grasslands in a province where grass-

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lands represent less than 1% of the total land base (Lee et al., 2014). This collaboration integrates and examines contemporary ecological theory with the traditional Indigenous knowledge of prescribed burning as a reclamation tool to enhance biodiversity and ecosystem reclamation, with the goal of reclaiming native grasslands on a tailings storage facility dominated by 25-year-old reclaimed, low diversity, agronomic species (Figure 1).

Figure 1. Landscape of the former site of Teck Resources Limited's Highmont tailings, Highland Valley Copper mine, in the Thompson Okanagan Region of the southern interior of British Columbia, is dominated by 25-year-old reclaimed vegetative cover crop represented by a monoculture of agronomic grass species.

Background and Theory

Traditional Ecological Knowledge, History of Indigenous Use of Fire and Changing Landscapes

The Thompson Okanagan Region comprises the traditional territory of numerous Indigenous peoples. The nations of particular interest with respect to the location of the HVC mine are the Nlaka'pamux (Thompson region) and Secwepemc (Shuswap region). The traditional territory of the Nlaka'pamux is centred around the Nicola valley, while farther north, encompassing the city of Kamloops and extending even farther north, is traditional Secwepemc territory (British Columbia Assembly of First Nations, 2021). For several thousand years the southern interior Indigenous peoples developed sustainable management practices that utilized what we understand today as fundamental ecological principles. For the Secwepemc and other Indigenous peoples, these practices are based on an intimate knowledge of their lived lands that facilitated a belief system that imposed social and spiritual sanctions on people who did not treat all living things sustainably and with respect. All interaction with the environment is grounded in respect for changing ecologies, and fine-tuning ways to sustainably harvest fish, plants and animals to ensure sustainable yield for the future (Turner et al., 2000; Ignace and Ignace, 2017). This type of natural resource management style and philosophy are becoming a focus of attention of many industries, professionals and researchers who seek ways to advocate for biodiversity and provide models for sustainable practices. Traditional ecological knowledge and wisdom has also received major recognition recently for being regarded as equivalent and complementary to western scientific knowledge, which has spurred western researchers into applying traditional ecological knowledge in various ways (Turner et al., 2000). Combining traditional ecological knowledge and western scientific knowledge to manage our landscapes can be used as a tool to help reconcile relationships and restore ecosystems.

The history of wildfire within BC presents a complicated and ever-changing path forward as we continue to modify our ecosystems and the way we manage our land. As the semi-arid grasslands of the interior receive typically less than 400 mm of rainfall on average, the low precipitation patterns paired with warm summer temperatures and moderate to high winds create a landscape that is naturally conducive to wildfire (Climatedata.ca, 2021). The most recent fire-regime study within the province places the southern interior of BC at a mixed-severity regime, with low-severity fires being most extensive and common (Heyerdahl et al., 2012). However, it is important to note that the semi-arid grasslands of BC present a prehistoric history of anthropogenic burning (called 'prescribed burning' from here on) by Indigenous peoples that ranges from roughly 7000 years before present (Blackstock and McAllister, 2004; Lewis et al., 2018) to shortly after European settlement in BC in the early 1900s, when prescribed burning by Indigenous communities was halted as European interest in the forest complex no longer permitted burning of any kind (Lewis et al., 2018).

The grasslands of BC, which now represent less than 1% of the provincial land base, provide habitat to over 30% of BC's threatened and endangered species, and is home to 42% of all vascular plant species that occur within the province (Wikeem and Wikeem, 2004). As the landscape of BC changes due to environmental and social factors, like the implementation of fire exclusion in the early 1900s, significant changes in the ecological and cultural conditions across the province have occurred and are readily visible upon inspection of our vulnerable grasslands ecosystems. Indigenous Elders from the Nlaka'pamux, Silx (Okanagan), Secwepemc, Stl'atl'imx (Lillooet) and Ts'ilquot'in (Chilcotin) nations from the interior of southern BC, have recalled and reminisced when "grasses were belly-high to a horse" and the grasslands were thriving (Blackstock and McAllister, 2004). Many bunchgrass biogeoclimatic zones that once naturally presented a high plant diversity to support ungulate species and foodstuffs for Indigenous communities have now been replaced with woody encroachment of sagebrush (*Artemisia tridentata*) and ponderosa pine (*Pinus ponderosa*) and these zones are at risk of shrinking in size and diversity (Fuhlendorf et al., 2008; Lewis et al., 2018). Cumulative effects of overgrazing by cattle and fire exclusion have strongly interacted to cause shifts in the plant community composition to be less productive and comprised of more ephemeral species. These changes also affect the habitat of grassland specialists and keystone species as these areas are slowly converted into shrublands and forests (Fuhlendorf et al., 2008; Symstad and Leis, 2017). Fire exclusion has also led to a shift in Indigenous community dynamics and the loss of important cultural use. Traditional prescribed burning, which was used to manage grasslands with ecological-based goals of selecting for desirable herbs and vegetation and maintaining important grazing habitat through managing woody encroachment, has now transitioned to understanding prescribed fire as a tool for fire safety only, within strict guidelines and only to be used when given government consent (Lewis et al., 2018). As the grasslands of BC have evolved naturally and anthropogenically in a fire-driven ecosystem, we must continue to push the boundaries of exploring how to move forward using traditional ecological knowledge to reclaim these shrinking landscapes.

Challenges in Reclaiming Mine Ecosystems and Disturbance Ecological Theory

In the pursuit to reclaim ecosystems within a mine setting there are many external factors that place limits on the reconstruction of a plant community. Restoration and reclamation following the mining process is both complex and challenging due to various biotic and abiotic factors (Turner et al., 2006; Gasch et al., 2014). One of the first steps in restoration or reclamation of these lands is typically revegetation. In addition to the semi-arid environment and climate conditions that exert the primary control on plant productivity and composition, many characteristics of mine wastes produce conditions unfavourable to successful vegetation establishment, notably the levels of residual heavy metals, low nutrient status, poor physical structure of soils, and extreme pH values (Tordoff et al., 2000; Sample and Barlow, 2013). The combination and interactive effects of unfavourable substrate paired with low annual precipitation can compound the challenges to restoration in semi-arid mine lands and poses a unique challenge. In the case of the HVC mine, as demonstrated by Figure 1, historical revegetation practices have used hearty, fast-growing, non-native species to achieve their goal of revegetating former mine and tailings sites. The problem ahead is the recovery of native grass communities into fields dominated by these fast-growing, exotic species, which is often impeded by the competitive advantages of the established plant community (Yahdjian et al., 2017). A mechanism to transition these exotic species to native species on mine lands may be prescribed burning and was brought to the attention of the HVC mine employees through consultation with the Nlaka'pamux community.

The contemporary ecological theory being used within this study to aid in biodiversity and successional advancement pertains to disturbance theory, and connects with the traditional Indigenous use of prescribed burning. It is important for both land managers and ecologists to understand various ecological theories that explore how ecosystems respond to limiting factors and disturbances that structure ecosystems and plant community assemblages. Grime's *C-S-R* triangle theory (Grime, 1977) has been discussed in plant ecology with respect to examining the role of competition, disturbance and stress tolerance, also known as environmental stressors to plant community dynamics. Generally, this theory states that species density or richness will increase as environmental stress increases along a bell curve, whereby disturbance acts to reduce competitive exclusion for species that can tolerate environmental stressors found on each side of the curve that limit the plant community (Grime, 1973; Fraser et al., 2015). Similarly, the intermediate disturbance hypothesis (IDH), which was initially proposed by Connell (1978), states that the greatest species diversity occurs in the middle range of disturbance severity. Both ecological theories have evidence to support predicting plant species diversity in response to disturbance and provide the ecological background for the basis of this study.

In natural ecosystems, disturbances, notably fire, have major positive and negative impacts as they can influence the abundance and diversity of species, nutrient cycling, biomass accumulation, primary production and other processes (Pulsford et al., 2016). In semi-arid grasslands, the relationship between prescribed burning and post-fire plant community response is not uniform. This is likely due to the highly variable nature of fire, as well as the lack of quantification of fire severity on the plant community and inherent environmental variance within each community.

Generally, fire can modify relationships among species on the landscape and change dominance in a community due to species-specific responses to changes in soil moisture, nitrogen cycling, and direct effects on meristem mortality (Ghermandi et al., 2004; Augustine et al., 2014). Fire in semi-arid and arid ecosystems has been shown to increase the availability of inorganic nitrogen in the first year post-burn, as well as for extended periods beyond the burn. This increase in plant-available nitrogen can influence regrowth, native species seedling establishment, invasion of annual plants and, ultimately, site recovery (Rau et al., 2007; Augustine et al., 2014), therefore making fire beneficial in reclamation of former mine sites where nitrogen is limited. Grasslands also benefit from fire in arid and semi-arid environments where microbes cannot readily break down accumulated plant litter (Brockway et al., 2002). Post-fire conditions often favour establishment of new species due to decreased soil moisture, removal of accumulated litter and subsequent release of nutrients immobilized within the dead plant tissue, increased solar radiation to the ground, and allowing a period of reduced competition (Brockway et al., 2002; Scheintaub et al., 2009). Additionally, in highly productive sites, litter accumulation that is left in a state without disturbance or some form of reduction may ultimately restrict above-ground net primary productivity (ANPP) and species richness, and favour tall species, reducing functional diversity in life form (Peco et al., 2012).

As described within the literature, plant community responses to prescribed burning with respect to community composition, amount and type of cover, and diversity of species, have been presented as net neutral, positive, or negative, depending on the study. Scheintaub et al. (2009) found that spring burning within a semi-arid shortgrass steppe community resulted in an overall decrease in ANPP by 20% in burned versus unburned control areas. However, as ANPP decreased, perennial grass and annual grass productivity decreased whereas perennial forb production and total vegetative cover increased with response to fire. Forb response to fire is most consistent with regard to increasing in total cover after fire, which is backed up by results presented within other literature, as compiled by Ruthven et al. (2000). This increase in cover is likely due to an interaction between death of the apical meristem during spring burning in select species, which removes growth inhibition and spurs formation of new shoots (Brown and Smith, 2000). In contrast to this, Augustine et al. (2014) found that annual burning significantly reduced cool-season (C_3) plant production and forb cover but did not affect warm-season (C_4) plant production. Positive plant community responses including increases in plant species richness and plant cover have been historically noted in semi-arid grasslands by Kirsch and Kruse (1973) with a steep increase in plant richness post-fire, from 38 to 69 species. More notably, McDonald and McPherson (2011) found that prescribed burning reduced the abundance of dominant non-native grasses and increased the abundance and diversity of native grasses and herbaceous dicotyledons.

Objectives

The aim of this study is to address three research questions that blend traditional Indigenous knowledge of prescribed burning with contemporary ecological theory pertaining to plant community dynamics and response to fire disturbance as a tool for enhancing ecosystem reclamation. Each research question is paired with an experimental procedure and associated methodology aimed at answering the specific question.

1) Can prescribed burning successfully act as a disturbance to transition low-diversity agronomic-driven vegetative communities to native grasslands?
2) What role does fire intensity play in the vegetative community when trying to establish native species under controlled conditions?
3) What level of involvement have the Nlaka'pamux peoples had in the prescribed burning project and what practices have industry professionals employed to connect with these communities?

Methodology

Field Study

In May of 2019, a total of 12 prescribed burns were conducted for this study at the Highland Valley Copper mine (UTM Zone 10, 638846E, 5594478N, NAD 83; Figure 2), located approximately 35 km from Logan Lake, BC. The prescribed burns were conducted at the Highmont tailings facility (UTM Zone 10, 647608E, 5588930N, NAD 83), a historic tailings storage facility that has been reclaimed to agronomic grasslands for approximately 24 years. The study site is located at an approximate elevation of 1500 m, within the Montane Spruce Msxk2 biogeoclimatic zone (Meidinger and Pojar, 1991). The Montane Spruce zone is characterized by cold winters and moderately short, warm summers. The mean annual temperature is 3–4.5°C, and mean annual precipitation ranges from 380 to 900 mm (Mahoney and Lee, 2021).

A total of 12 plots (each 20 by 20 m) were arranged in a completely randomized block design spaced a metre apart on each side and subjected to one of the following four treatments:

- burn (no amendments)
- burn (no woody debris added, seeded post-burn and trees planted)
- burn (woody debris added, seeded post-burn and trees planted)
- control (no amendments or burning)

This design involves three blocks of twelve plots each, resulting in each treatment being replicated three times. Treatments that indicate 'woody debris added' had lodgepole pine slash placed on the experimental site prior to burning, to assist in fire spread and provide a source of conifer seed. After burning, treatments that indicate 'seeded' were hand-broadcast with a native seed mix (Table 1) at a density of 20 kg/ha, or 0.8 kg per plot. Tree planting was completed with two species: aspen (*Populus tremuloides*) and lodgepole pine (*Pinus contorta*) at a density of 5000 stems per hectare, or 200 stems per plot.

Omegalaq™ temperature-sensitive paints ranging from 107 to 510°C were applied at gradations of approximately 30°C to each plot to quantify fire intensity and estimate the measure of fire severity (Figure 3).

Vegetation measurements were collected in each experimental plot prior to burning. Measurements included estimating absolute cover amounts in 1 by 1 m quadrants and the collection of biomass from subquadrants 0.5 by 0.5 m in

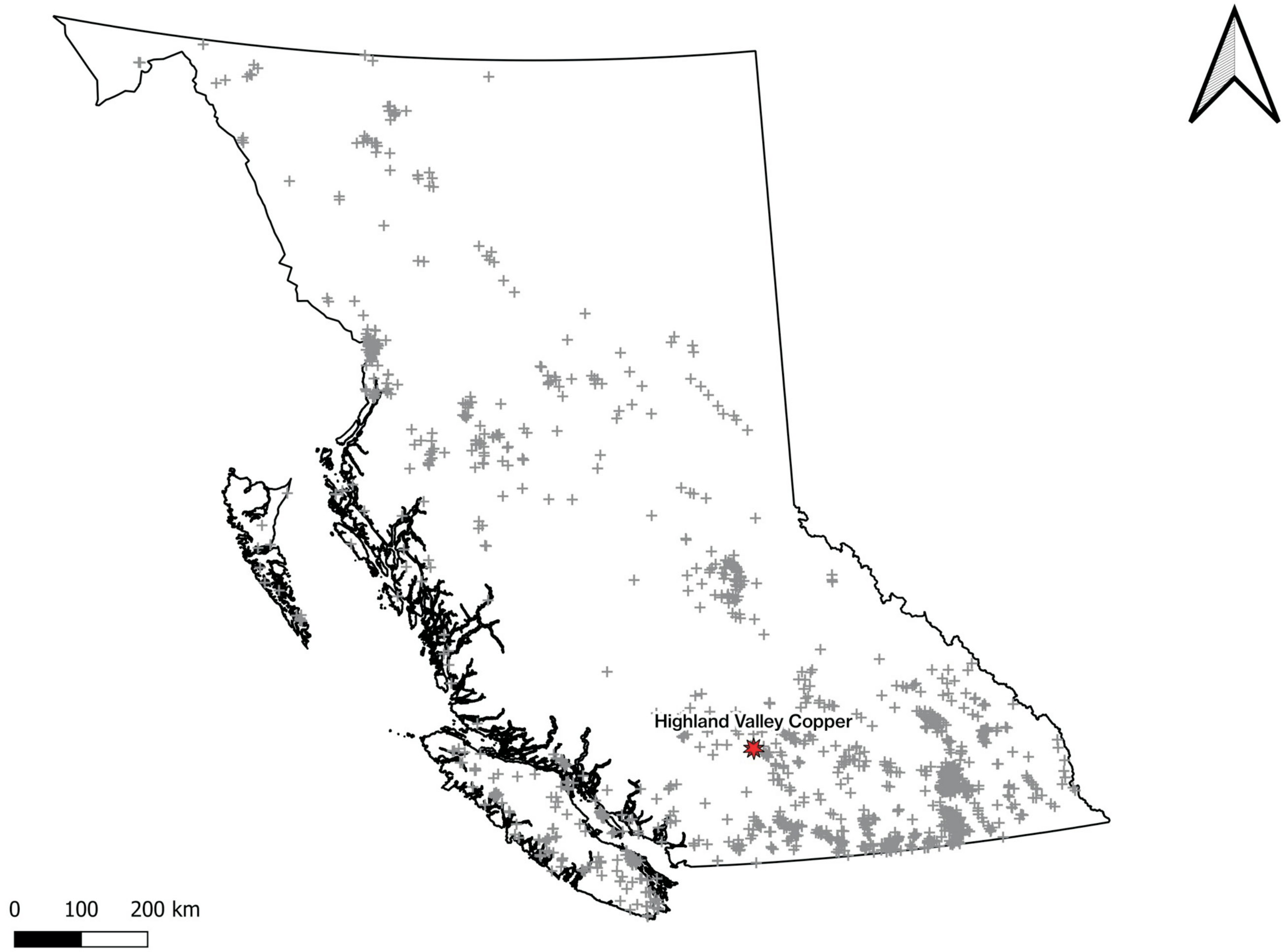

Figure 2. Map of British Columbia showing the location of the Highland Valley Copper mine, where experimental burns were conducted, and historical mines (grey crosses) that are classified as abandoned, closed, or in need of reclamation or restoration. This figure was created using QGIS version 3.18.0 using open-source data collected from the BC Data Catalogue (BC Geological Survey, 2021; BC Ministry of Energy, Mines and Low Carbon Innovation, 2021).

size (Figure 4), with a total of six biomass samples per plot, to quantify ANPP and fuel load. Biomass samples were clipped at ground level and sorted by species into live, litter and fine-fuel material, then dried in a regular oven at 65°C for 48 hours, or until a consistent dry weight was obtained. Sampling of vegetation to examine the post-burn plant community response will be conducted when standing crops are at their peak height, every year up until 2021.

Soil samples were collected at the following time intervals over the course of the research:

1) pre-burn
2) post-burn
3) 3 months post-burn
4) 12 months post-burn
5) 15 months post-burn

Table 1. Native plant species included in the seed mix hand-broadcast on the experimental plots, indicating plant successional status and plant functional group.

Group	Common name	Scientific name	Type	Succession
1	Western yarrow	*Achillea millefolium*	Native forb	Early
2	Arctic lupine	*Lupinus arcticus*	Native legume	Early
3	Rocky Mountain fescue	*Festuca saximontana*	Native grass	Early
4	Idaho fescue	*Festuca idahoensis*	Native grass	Late
5	Junegrass	*Koeleria macrantha*	Native grass	Early–Mid
6	Sandberg bluegrass	*Poa secunda*	Native grass	Early
7	Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Native grass	Late

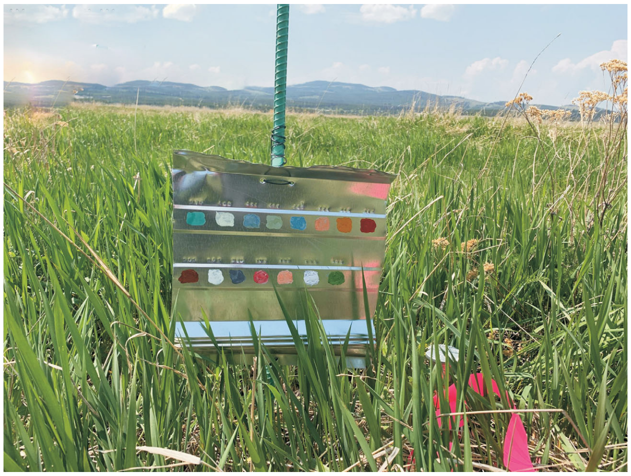

Figure 3. Omegalaq™ temperature-sensitive paints (painted sheet is approximately 30 by 45 cm), applied at gradations of approximately 30°C, used to quantify fire intensity for the prescribed burns conducted at the Highmont tailings facility of the Highland Valley Copper mine in 2019.

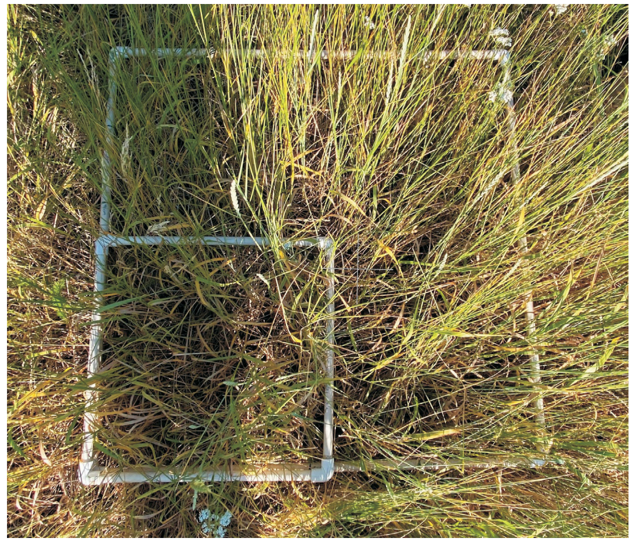

Figure 4. Example of a vegetation sampling quadrant (1 by 1 m) and biomass sampling subquadrant (0.5 by 0.5 m) used to examine the plant community pre- and post-burn, and measure above-ground net primary productivity.

The soil samples were extracted using a stainless-steel soil-sampling probe with a core diameter of 2 cm. A total of three 15 m transects were laid per experimental plot and three 15 cm cores were taken along each transect, resulting in a total of nine samples per experimental plot. Soil samples were then sieved down to 1 mm and will be analyzed for total carbon, nitrogen and hydrogen using a Thermo Scientific Flash*Smart*™ Elemental Analyzer, as well as other routine soils analyses, including soil pH.

Mesocosm Study

In August of 2019, a total of 30 grass turves were extracted from the ground around the Highmont tailings facility of Highland Valley Copper (UTM Zone 10, 647608E, 5588930N, NAD 83; Figure 5).

Each grass turf was extracted as a single unit and placed into a 102 L HDX Tough Storage Bin™ (0.56 m long by 0.46 m wide by 0.38 m high) that was modified by drilling holes for drainage through the bottom. These bins and turf sizes were selected to obtain an approximate area of 0.25 m^2 for vegetation analysis, and to ensure each grass turf contained intact root systems and soil profiles. The grass turves were then transported back to Thompson Rivers University. The mesocosm study was conducted under controlled conditions (natural and artificial light: 18 hours of daylight/6 hours of night; temperature: day and night, 21°C; humidity was between 50 and 60%) within a research greenhouse.

The 30 grass turves (each ~0.25 m^2) were arranged in a completely randomized block design, to examine four different disturbance treatments:

- high-severity burn (200 g litter applied, 20 s burn, seeded post-burn)

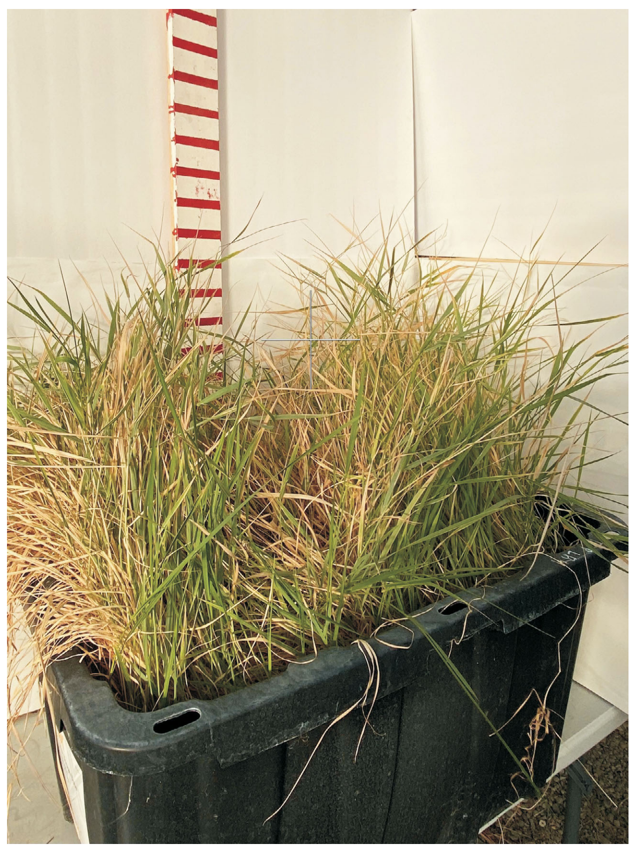

Figure 5. Example of grass turf extracted from the vicinity of Highland Valley Copper's Highmont tailings facility for this study. For reference, the scale in the back is 4 feet (~1.2 m) in height, with gradations every 1.5 inches (~3.8 cm).

- moderate-severity burn (150 g litter applied, 15 s burn, seeded post-burn)
- low-severity burn (50 g litter applied, 10 s burn, seeded post-burn)
- clip (litter and fines removed, clipped at ground height, not burned)
- control (seeded only)

This design involves three blocks, resulting in each treatment being replicated six times. Fire severity was determined by amending the weight of dried litter applied to each experimental unit, along with the length of time each grass turf was torched. After burning, all experimental units were seeded at a rate of 200 seeds/species/turf (~2400 seeds per m^2), with a total of six unique species applied (Table 2).

The composition of the native seed mix was guided by plant characteristic data that selected for species best fit to soil conditions at the site, pH tolerance and moisture regime for the ecosystem.

As for the field study, vegetation measurements that were collected in each experimental unit prior to burning included estimating the absolute cover on the entire grass turf as approximated by a 0.5 by 0.5 m quadrant. Biomass was collected from each unit, except the control units, to quantify ANPP. Biomass samples were clipped at ground level and sorted by species into live, litter and fine-fuel material, then dried in a regular oven at 65°C for 48 hours, or until a consistent dry weight was obtained.

Soil samples were extracted using a stainless-steel soil-sampling probe with a core diameter of 2 cm. A soil core was extracted from the complete depth of the grass turf and separated into the top 10 cm of soil and bottom 10 cm of soil (Figure 6), to be analyzed for total nitrogen, total carbon and total hydrogen, using a Thermo Scientific Flash-*Smart*™ Elemental Analyzer.

Sampling of vegetation and soil in the mesocosm study units will be conducted at the following time intervals over the course of the research:

1) pre-burn
2) post-burn
3) three months post-burn
4) six months post-burn
5) seven months post-burn

Semi-Structured Interviews

In August of 2020, a total of four, hour-long, semi-structured interviews were completed with non-Indigenous but

Table 2. Plant species selected for the mesocosm experiment, indicating plant successional status and plant functional group.

Group	Common name	Scientific name	Type	Succession
1	Common paintbrush	*Castilleja miniata*	Native forb	Late
2	Brown-eyed Susan	*Gaillardia aristata*	Native forb	Early-Mid
3	Rough fescue	*Festuca campestris*	Native grass	Mid-Late
4	Rocky Mountain fescue	*Festuca saximontana*	Native grass	Early
5	Field locoweed	*Oxytropis campestris*	Native legume	Early-Mid
6	Arctic lupine	*Lupinus arcticus*	Native legume	Early

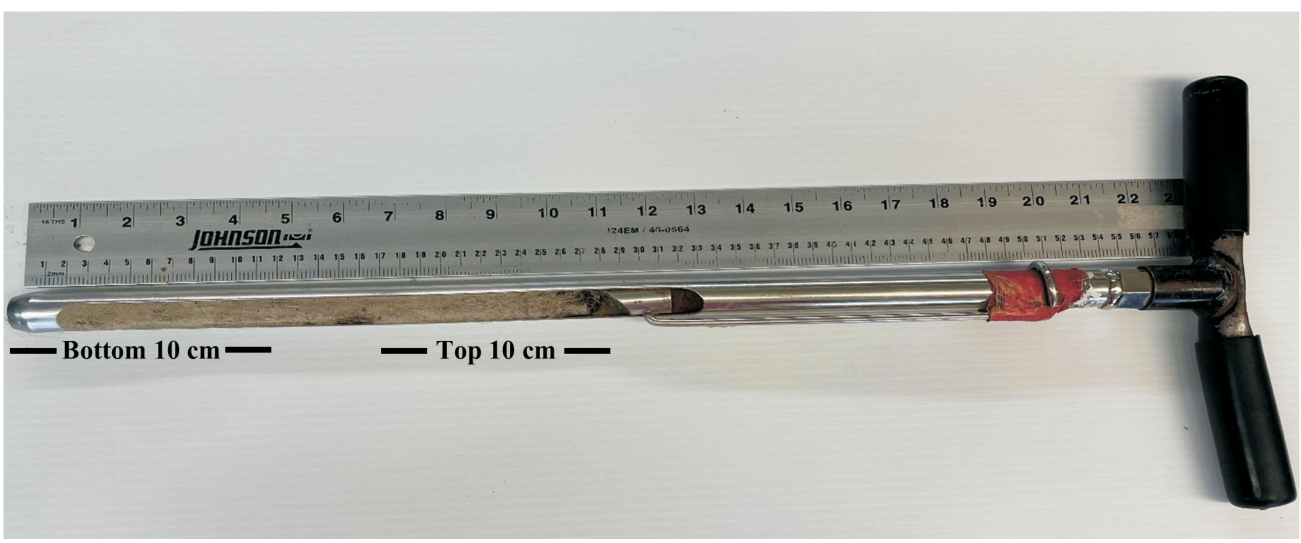

Figure 6. Intact soil core extracted from an experimental grass turf. The top 10 cm and bottom 10 cm of soil were separated and used for analysis.

key allied professionals who were instrumental in getting the project partnership between staff at Teck's Highland Valley Copper mine and the Nlaka'pamux peoples off the ground. Each interview was standardized in the sense that a predetermined list of 15 questions was prepared for each interviewee. However, questions were formulated to include open-ended and theoretically driven questions that aim to elicit data that is grounded in individuals' experience and guided by the constructs of the research scope. The statement of purpose for these interviews was to gain an understanding of how the project relationships came to fruition and understand the level of involvement the Nlaka'pamux have played in the project.

Each interview was recorded and transcribed verbatim and will be analyzed with coding software for keyword and phrase analysis.

Statistical Analysis

The data from the 2020 Highland Valley Copper mesocosm study was first analyzed descriptively by examining species richness relative to disturbance treatment over the duration of the study. All statistical analyses have not yet been completed, but linear mixed-effect models were used to spot differences between experimental treatments and analyze the variation within the data. Linear mixed modelling was used in this study to model the variation associated with the Shannon-Diversity index against treatments applied to the experimental units. Shannon-Diversity index considers species richness (the number of species present in an area) and evenness (the proportion that each species comprises of the whole) to determine a measure of biodiversity: the higher the number, the higher is the species diversity (Shannon 1948; Nolan and Callan 2006). An analysis of variance was used to examine the models, and Tukey-Kramer (Tukey, 1949) post-hoc analyses were used to determine where treatment effects were significant. In running the linear mixed-effect models, Shannon-Diversity was the dependent variable and disturbance treatment was used as the independent variable, with subject ID used as a random variable. The following models were analyzed:

1) Shannon-Diversity = disturbance treatment (fixed effect) + error (turf ID – within-subject error – random effect)
2) Shannon-Diversity = time span (fixed effect) + error (turf ID – within-subject error – random effect)

All statistical analyses were conducted in RStudio (R Core Team, 2021), a free, open-source integrated development environment for R software, a programming language for statistical computing.

Further statistical analyses will include examination of vegetation data with multivariate methods using the VEGAN package in R, to determine plant community response to fire disturbance, as well as examination of above-ground primary productivity.

Results

Examining species richness as a function of disturbance treatment across a time series reveals a significant and observable difference by simple descriptive statistics only (Figure 7).

The most significant trend shows an increase in overall diversity across all disturbance treatments in comparison to the control group. Additionally, species richness is found to be highest within the first month post-burn in all disturbance treatments except the clip and the moderate-severity treatment. Another significant trend observed is that during the last two months of the experiment (months six and seven) there is a drop in diversity.

The Shannon-Diversity index between disturbance treatments provides more information than species richness data alone (Figure 8). In running the linear mixed-effect model examining the interaction and all pairwise comparisons of the means between Shannon-Diversity and disturbance treatment the results show a significant difference between the control treatment and all other disturbance treatments ($df = 4$, $F = 7.0378$, $p = <0.001$; where df is degrees of freedom, F is a comparison of the variance between two statistical populations, and p is the probability that a result could have occurred by chance).

The comparison examining Shannon-Diversity index between time spans (Figure 9) highlights the distinct grouping examined in Figure 7. In running the linear mixed-effect model examining the interaction and comparison between Shannon-Diversity index and time span the results show three distinct groupings, a significant difference between the control treatment and all other time points, and a significant difference between the first and third time points and sixth and seventh time points ($df = 4$, $F = 34.4417$, $p = <0.001$).

Discussion

Fire Severity and the Plant Community in a Mesocosm

The effects of fire severity on post-mining reclamation within a mesocosm were examined for a semi-arid, historically reclaimed area of grassland in BC. The species richness data as presented in Figure 7 show a promising but slightly skewed vision of how the plant community responds to fire-severity treatments and fire in general, and only represents a small portion of what is occurring within the plant community. However, examining Figures 7 through 9 together, a more accurate depiction of the plant response to fire severity can be pieced together. In Figure 8, it can be

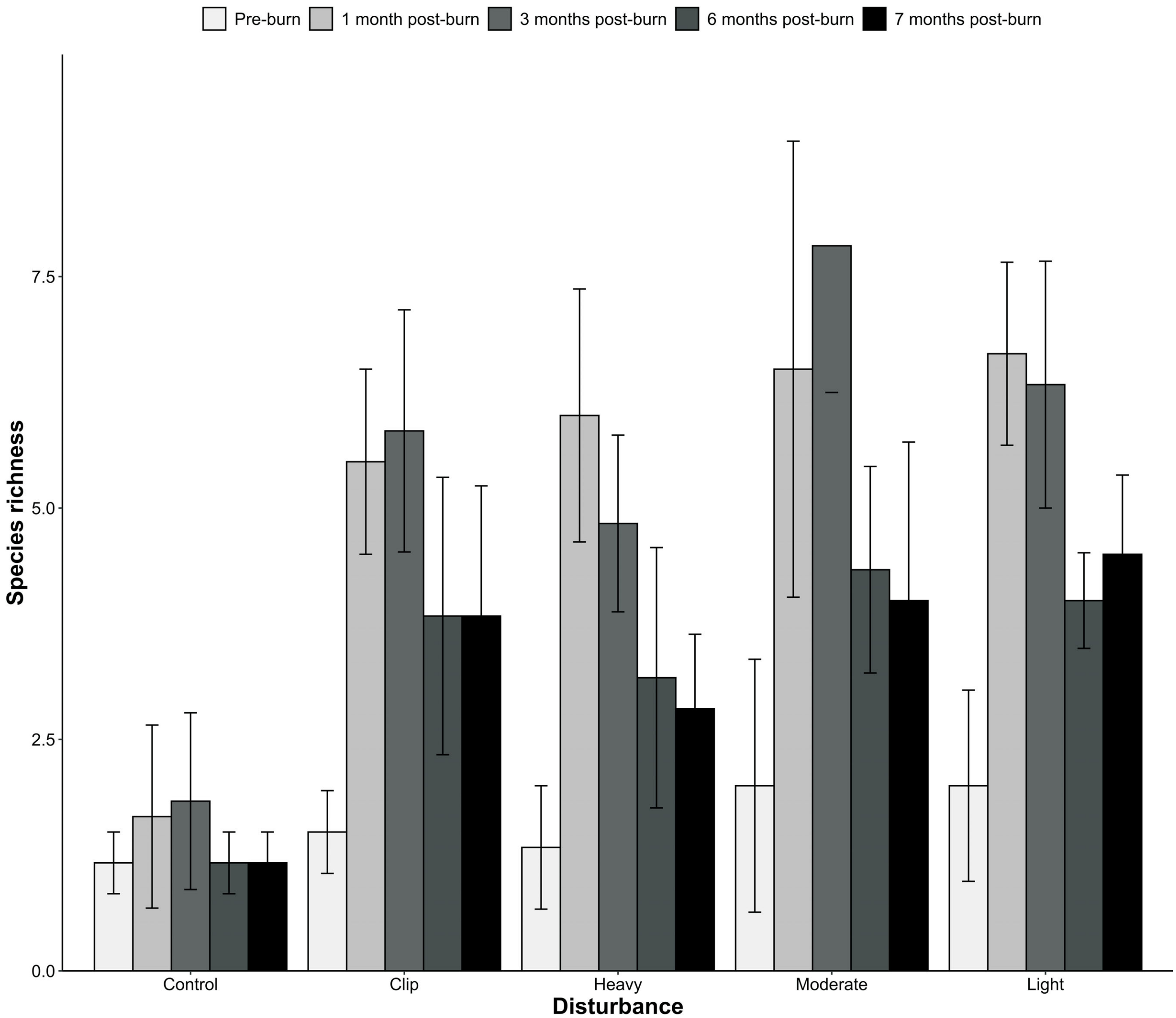

Figure 7. Time series distribution of species richness (number of unique species present in each sample) between disturbance treatments within the controlled mesocosm experiment (number of samples = 6, confidence interval = ±95%).

seen that all the disturbance treatments are causing a significant increase in Shannon-Diversity in comparison to the control unit, which is on par with the initial hypothesis that disturbance will increase diversity. In Figure 9 it can also be seen that timing is playing a significant role in species diversity, whereby the first and third months post-burn result in the highest Shannon-Diversity measurements, and the sixth and seventh months post-burn begin to reach a midpoint between the control unit and the maximum diversity obtained. This, in part, could be explained by competitive exclusion and competition dynamics that are occurring in the grass turves over the course of the seven months. Species richness, as noted in Figure 7, reaches its maximum value in disturbance treatments within the first month post-burn and begins to decrease as the seven-month mark approaches. Within the first month of post-burn conditions it would be expected that these conditions are most favourable for germination of the native seedlings. As the experiment proceeds, the agronomic, rhizomatous-dominant grasses begin to expand above and below ground while also depositing a dense layer of litter on the ground surface. This competition observably prevented many of the native species from germinating while select native species, notably the early successional forbs and grasses, in some cases, won the fight for space and persisted within the environment.

Conclusions and Ongoing Work

The above results and the conclusions reached to date are based upon data that was collected during 2020. Additional and more detailed analyses are underway as the remaining dataset and samples continue to be examined.

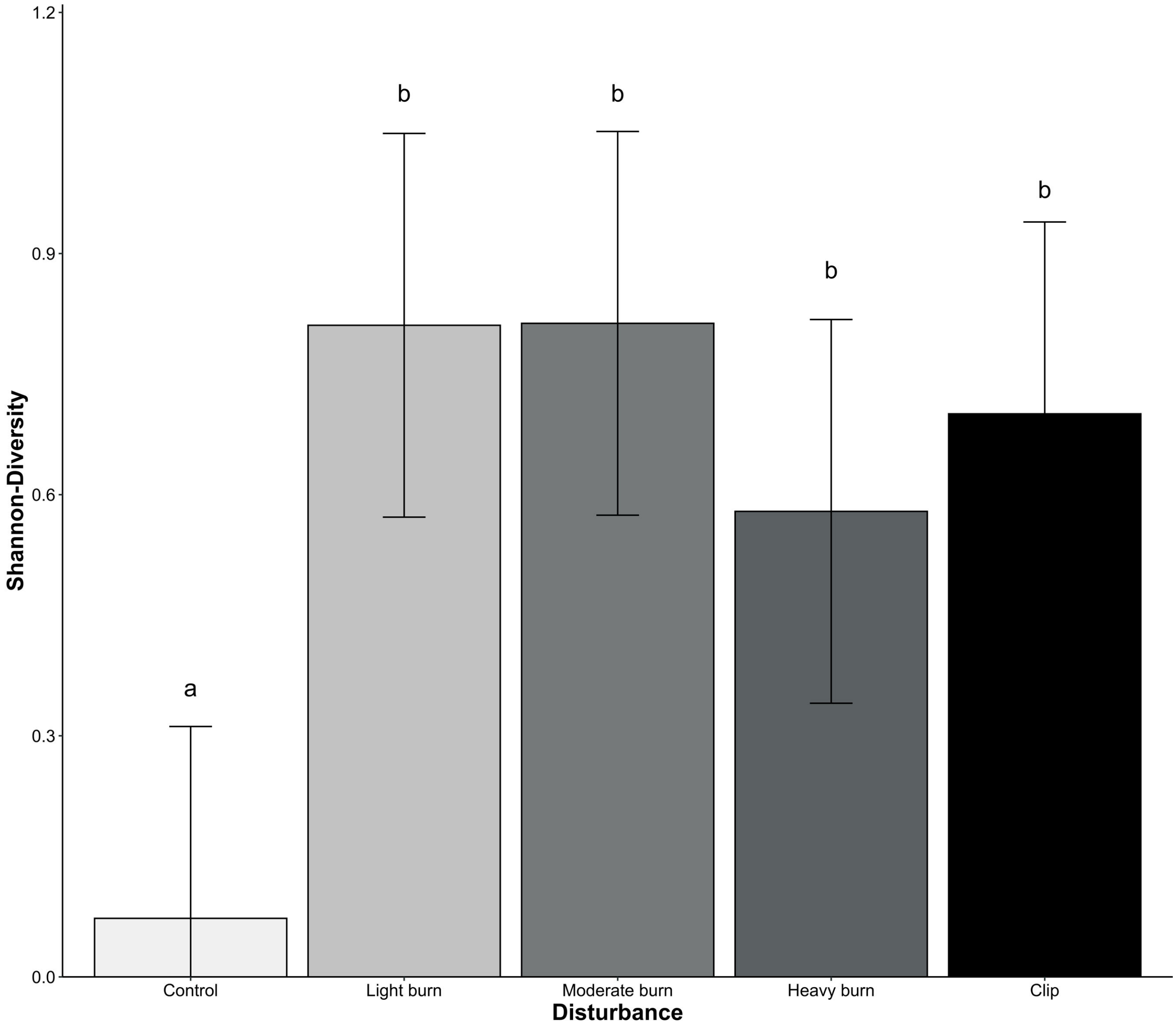

Figure 8. Examining the effect of fire-severity treatment on Shannon-Diversity index plotted as the least-squares mean (number of samples = 6, p = <0.001, confidence interval = ±95%, where p is the probability that a result could have occurred by chance). Bars with different letters indicate significant differences. Pairwise comparisons between the treatment levels were adjusted with false-detection-rate corrections.

This study will aid significantly in enhancing western scientific knowledge surrounding the novel idea of using prescribed burning as a tool for ecosystem reclamation and restoration. This work also bridges western scientific knowledge and traditional Indigenous knowledge to reclaim disturbed landscapes while reconciling past historical inequities between industry and Indigenous communities. This study also pioneers a mesocosm methodology to address the effects that fire severity has on plant community dynamics in a reclamation lens, and will aid others in determining and validating the role fire severity plays on the plant and soil communities. Future studies should continue to examine the role of fire severity in similar experiments but within non-disturbed study areas. Further development should also be taken to incorporate additional Indigenous methodologies and traditional ecological knowledge into restoration and reclamation practices.

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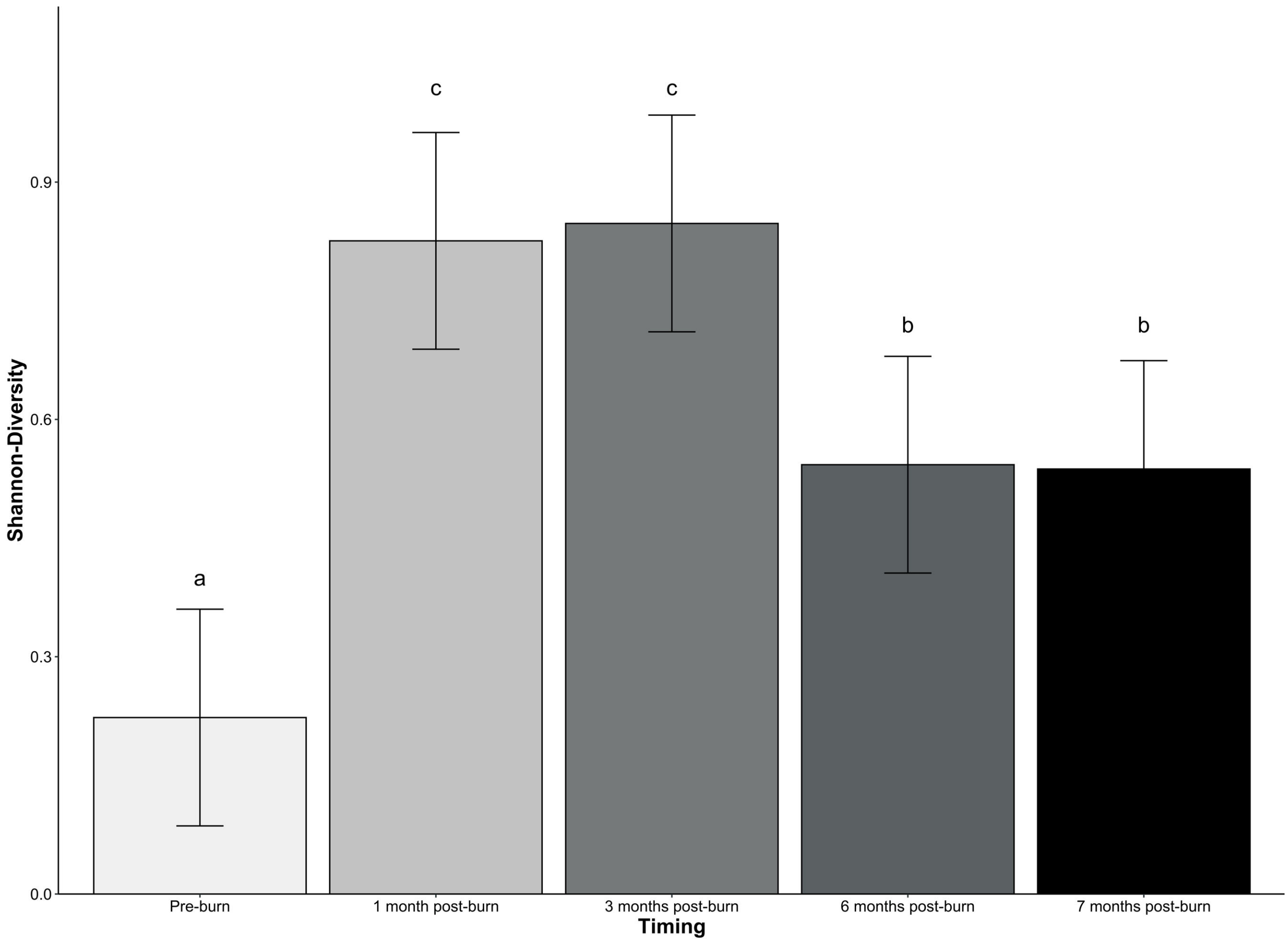

Figure 9. Examining the effect of timing on Shannon-Diversity index plotted as the least-squares mean (number of samples = 30, p = <0.001, confidence interval = ±95%, where p is the probability that a result could have occurred by chance). Bars with different letters indicate significant differences. Pairwise comparisons between the treatment levels were adjusted with false-detection-rate corrections.

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