The Impact of Railway Pollution on Grassland Plant Species Diversity in Jasper National Park, Alberta, Canada

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Abstract

Research was conducted in Jasper National Park, Alberta to study the impacts of the railway on species diversity of meadow plants adjacent to the railway tracks. Five transects with similar vegetation characteristics were chosen to represent the local population. These study sites were located in grassy meadows, and were within 15 km of each other at approximately 1100 m of elevation. We hypothesize that species diversity increases with distance away from the railway, and that the presence of the railway increases soil acidity. Each individual meadow was selected as a representative of the range of microhabitats within the valley bottom meadows. We believe that they are representative of all meadows adjacent to the railway on a larger scale. At each study site a 75 m transect was laid down perpendicular to the train tracks and ten different 1 x 1 m quadrats were systematically applied to each transect. Measurements of pH were taken at each quadrat to determine soil acidity and all plants within the quadrat were identified and counted. It was found that soil pH dropped when sampled closer to the rail bed; however this differed for each site. Additionally, the species diversity and evenness decreased in the quadrats closer to the rail bed. The sites varied in pH and diversity, resulting in a trend, but not a statistically significant one.

Introduction

Jasper National Park has been subject to railway traffic for nearly 100 years, since the construction of the Grand Trunk Pacific Railway in 1911 (Parks Canada, 2009) As such, the landscape has been chronically exposed to train pollution for a substantial amount of time. Most of the world's haulage trains run on diesel, which is deemed to be one of the most dangerous pollutants because of its carcinogenic compounds and the toxicity of its fine particles (Professional Engineers Ontario, 2010) There is a high volume of rail traffic in Jasper with over 4000 transport railcars passing through the town each day (CN Public Enquiries, 2010).

The construction and subsequent use of the railway has altered the surrounding soil and vegetation. Wheat and other agricultural crops are shipped from the Canadian Prairies through the Park and can take root in nearby soil when released from the base of the rail cars. Wheat is only one example of the many invasive species that have taken hold in the Jasper soil, altering vegetation. Invasive species are of such great concern that park wardens take explicit measures to protect the valued native vegetation (Parks Canada, 2009). Hansen & Clevenger (2005) found that grasslands along railways and highways are highly susceptible to invasive species, suggesting that Jasper's high traffic railway may both increase the susceptibility of and be the source of numerous invasive species found within the park.

Pollution causes dramatic changes to community structure and ecosystem functioning, as found in a study by Medina et al. (2007). The consequences of pollution include plant adaptation, and in turn, environmental modification. It was found that depending on the level and duration of pollution events, a series of modifications can occur in the environment: 1) the elimination of sensitive species due to direct toxic events, 2) the replacement of these species by less sensitive ones due to release from competition, 3) shifts in food-web interactions as a result of decreased predation and/or grazing of toxicant susceptible species, 4) acclimation (physiological adaption), and 5) the selection of favourable genetic adaptations (p. 2106). Extended pollution therefore has the potential to completely alter the vegetation of a meadow-grassland environment (Hansen & Clevenger, 2005). Bernhardt-Römermann et al. (2006), and Bignal et al. (2007) both studied transects along highways, noticing that the vegetation was altered due to pollution, resulting in a lower species diversity closer to the highway. This was attributed largely to nitrogen emissions. The studies above suggest that the train pollution in Jasper substantially impacts the vegetation surrounding the railway.

The purpose of this study is to quantify the effects of the railway on plant species diversity and soil acidity within Jasper National Park. Our aim is to increase the understanding of the ramifications of the railway on the nearby environment, focusing specifically on native vegetation. No published research on this subject has been conducted specifically in Jasper, AB, making our research primary to the topic. Based on both initial observations and the literary review of highway and railway vegetation studies conducted elsewhere, it was hypothesized that species diversity would increase perpendicularly from the railway, and that soil acidity would be altered by railway activity.

Study Area

For the purpose of the study, five meadow areas within Jasper National Park where chosen to best represent the local grassland environment and to control for environmental conditions. All sites were within 15 km of each other at approximately 1100 m of elevation. The locations of each site can be seen in Figure 1 and detailed sites descriptions are in Appendix B (Table 4-8).

Figure 1 – Study sites 1 through 5 within the context of Jasper National Park.

Choosing sites at a constant elevation and within a small range minimized microclimatic effects. Potential pollution from the highway was taken into account by choosing sites on the opposite side of the railway from the highway when possible, or by ensuring a large natural barrier between highway and railway (such as dense tree cover). The far side of the tracks was unsuitable for sampling at site 5, but as the highway was several hundred meters from the railway, highway effects were deemed negligible. The study focused on grasses and flowering plants, so sites with intermittent tree cover were avoided. Locations with known human disturbance (other than the railway) were also avoided. In general, the topography of the sites (extending perpendicularly from the tracks) was a raised rail bed followed by a downward slope to a drainage ditch, with an upward slope of a few metres leading to a flat meadow area (Figures 2 and 3).

Figure 2 – First study site, an example of the sloping drainage ditch trend observed at the study sites.

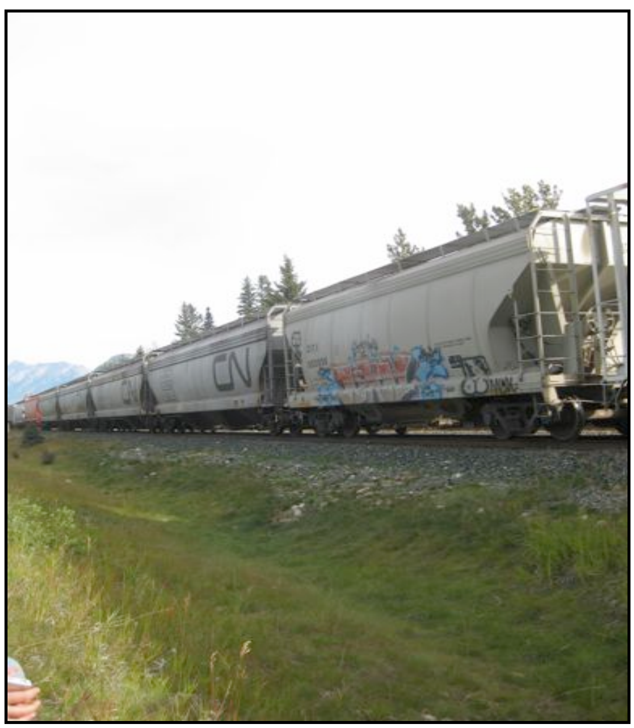

Figure 3 – Drainage ditch at one study site

Site One –

This site was a grassy slope with wood fragments measuring over 10 cm in length (covered in creosote) in the area, flattening out at around 10 m from the railway. The fragments appeared to be railway debris. The drainage ditch occurred about 5 m from the tracks. Beyond the ditch, grasses and flowering plants dominated the vegetation, with any bare ground often covered by species of lichen and moss. Power lines were present near this site. Figure 3 shows this study site, one of the quadrats is also visible within this photograph.

Figure 4 - Meadow area study site

Site Two –

At this site, the soil was sandier in quality compared to other study sites. Wood fragments were once again present near the railway, along with scraps of metal. In the area further from the railway, there was significantly less vegetation cover than near to the railway, and lichen and moss dominated bare ground. Figure 4 depicts the transect line in site two.

Site Three –

Here the drainage ditch was larger than found at other sites; the ditch was located at the beginning of the 5 m quadrat. Upon tactile observation, the soil was found to be more organic in nature than sandy, especially when compared to that of site two. Pieces of wooden railway fragments extended as far as 25 m from the railway. Vegetation was once again composed primarily of low grass cover with moss and lichen dominating any bare ground.

Site Four –

In this study area, the drainage ditch extended to about 4 m from the tracks. Invasive wheat species that came from passing rail cars were present in this area. Further afield, bare ground became very mossy, at times almost completely filling the quadrat. Soil appeared to be more organic here than at other sites.

Site Five –

Unlike previous transects; our final site did not have a ditch area, but consistently sloped downhill. Charred wood fragments were found up to 5 m away from the tracks, and railway gravel was found up to 10 m away from the tracks. This site was located near an elk fence and bike path. Once again, grasses dominated quadrats; however there appeared to be more bare ground with lichen and moss at this area, especially farther from the tracks.

Methods

Quadrat samples were taken along a 75 m transect. Each transect was measured using a tape measure extended perpendicularly from the railway (Figure 6). The quadrats, which measured 1 x 1 m, were placed and analyzed at 1 m, 2 m, 3 m, 4 m, 5 m, 10 m, 15 m, 25 m, 50 m, and 75 m from the railway. These intervals were chosen to provide insight into the variation in vegetation near and far from the railway. Each quadrat was divided into four and each group member identified and counted the plant species in their 50 x 50 cm quarter of the quadrat (Figure 5). Plant species were enumerated and photographs were taken of unknown plants for identification at a later time. Identification was done using local field guides (Plants of the Western Boreal Forest & Aspen Parkland: ref, Edible & Medicinal Plant of the Rockies: ref, and Plants of the Rocky Mountains: ref), with help from botanists on the Mount Allison Campus, the USDA plant database, and with local knowledge of the flora. The soil pH was taken using a Kelway Soil Tester in each quadrat (when possible) as an indication of acidity. Site description and notable features were accounted for at each quadrat, and GPS coordinates were recorded using a handheld Garmin-60 GPS.

Figure 5 – Plant identification in a 1 x 1 m quadrat

Figure 6 – Analysing plant species along a 75 m transect at Site 5

Data analysis of our findings was done using standard diversity analysis techniques, including diversity indices and regression analyses.

The Shannon-Weiner Index uses species richness as a determinant of biodiversity based solely on the number of species within a site (MacDonald, 2003). It is commonly used in pollution studies to indicate the health of an ecosystem (Connell, 1999). This was used in our study to determine the species richness of our sampled quadrats.

Species richness focuses solely on quantifying biodiversity; by determining this we would be able to determine if there was a significant trend in increasing biodiversity with distance from the railway. The Shannon-Weiner index is a measurement that includes both species richness and evenness and takes the form:

$$H' = -\sum pi \ln pi$$

The H' value has been found to range from 1.5 for systems with low species richness and evenness, to 3.5 for species with high species richness and evenness (MacDonald, 2003). Species evenness and species richness are important within potentially pollution-affected sites. Monitoring species richness or individual species abundance has been a key method in detecting environmental impacts in many conservation and management studies (USDA Forest Service, 2002).

Pearson's correlation is denoted by r, and is a measure of the linear relationship between two values. This was used in this study to determine if there was a correlation between plant species diversity and distance from the railway, as well as pH versus distance.

Regression analysis was implemented to the study in order to analyze the relationships between distance and soil acidity, and between distance and species diversity.

Results

All species sampled are compiled in Appendix A (Table 3). The data collected from the five sample transect sites was used to analyze vegetation diversity and pH variance. The Shannon-Weiner Index was used to assess any changes in diversity between quadrats at individual sites (Table 1).

Table 1 – Shannon-Weiner Index value for each quadrat. Values for this index are the least diverse near 1.5 and highest near 3.5 (MacDonald, 2003). Sites with a value of zero did not contain any vegetation.

Distance from railway (m)	Site 1	Site 2	Site 3	Site 4	Site 5
1	0	0.35	1.01	0.31	0
2	1.39	0.74	0.96	0.26	1.00
3	0.71	0.73	0.40	0.92	1.19
4	0.46	0.41	0.16	0.86	0.41
5	0.69	0.28	0.20	0	0.58
10	0.59	0.64	0.59	0.56	0.30
15	0.13	0.69	0.92	0.33	0.77
25	1.00	0.76	1.20	1.59	0.71
50	0.90	1.57	2.00	0.77	1.05
75	0.61	0.69	1.13	1.56	0.72

The results of the calculated values ranged between 0.0 and 2.5 and illustrate a bimodal trend with peaks at points closest to and farthest from the railway (Figure 7).

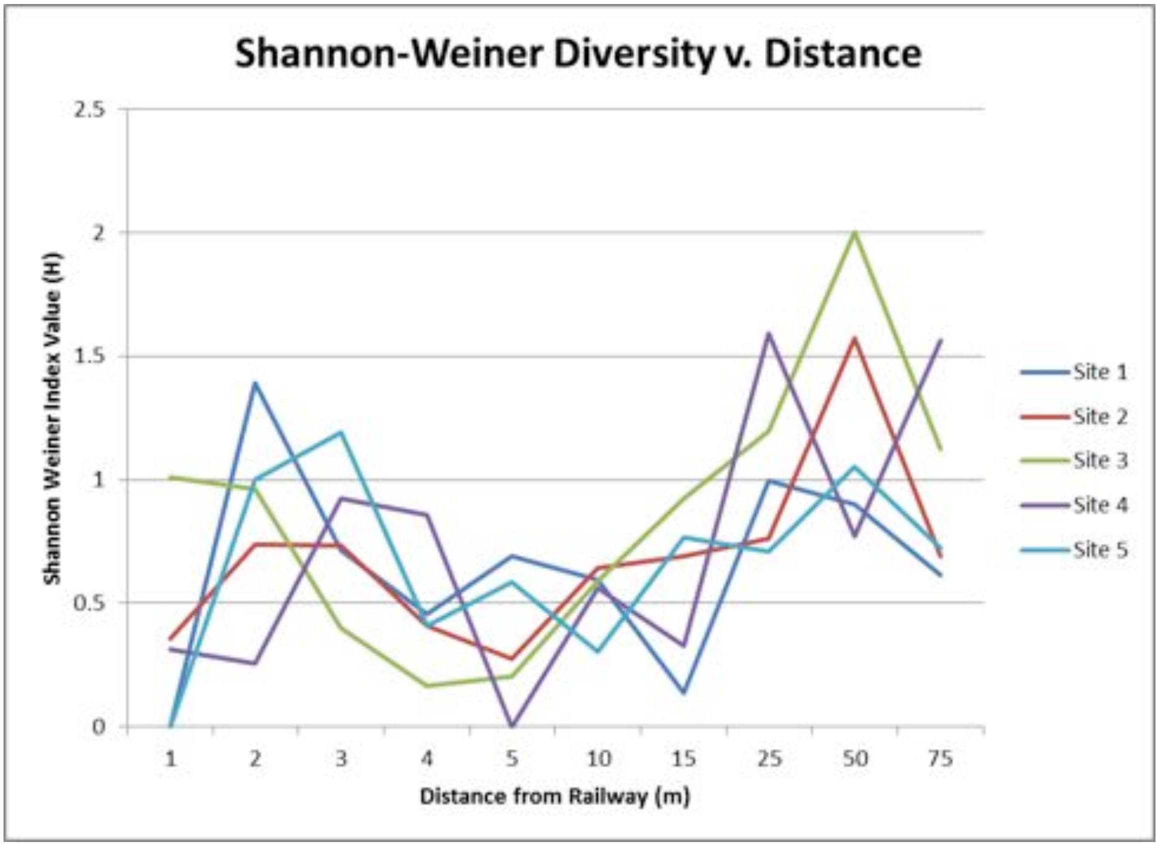

Figure 7 – A graphical representation of the relationship between distance from the railway and diversity as calculated using the Shannon-Weiner Index.

To determine whether the diversity range is significant with increasing distance, a linear bivariate regression analysis was performed (Figure 8).

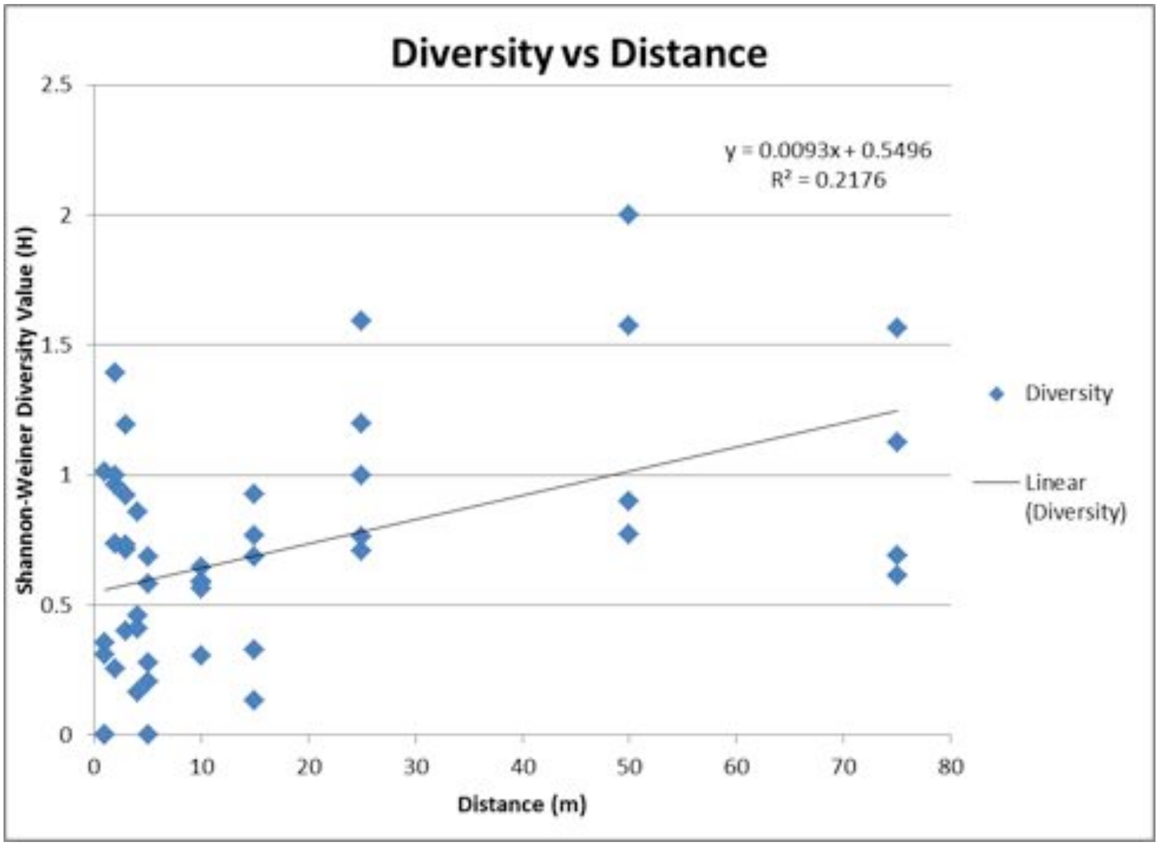

Figure 8 – Regression model depicting the relationship between Shannon-Weiner Index values and distance from the railway.

The regression model displays that Shannon-Weiner Index values vary widely within the first 20 m and shows an increasingly linear trend outside of the 20 m zone. The r^2 value for this regression is 0.218, meaining that 21.76% of variation was explained through the relationship. A two-tailed t-test was performed to determine the signifance of the regression and was calculated to be 0.011 using the b value of 0.008 and standard error value of 0.759. This result is not significant at the 95% confidence interval, as the critical t-value was greater, being 2.9 (Sanders 2005).

As previously mentioned, the pH was measured within each quadrat. Individual quadrat values are tabulated in Table 2. Measurements were unable to be taken at some points nearest the railway tracks due to the rocks cover on the ground and are listed as 'n/a'.

Table 2 – Values of pH by quadrat.

Quadrat	Site 1	Site 2	Site 3	Site 4	Site 5
1	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a
3	n/a	6.8	5.6	n/a	n/a
4	4.6	5.9	5.2	n/a	n/a
5	5.1	6.5	5.8	n/a	n/a
6	6.9	6.8	5.1	7.0	4.3
7	6.4	6.6	5.2	6.9	3.7
8	5.9	6.0	5.4	6.8	6.2
9	6.1	6.5	5.6	6.0	6.9
10	6.2	6.0	5.4	6.4	6.6

A regression model was also performed in analysis of site pH vs. distance. This was done to determine if there was a significant dependence of pH on perpendicular distance from the railway. The results of the regresstion analysis can be seen in in Figure 9.

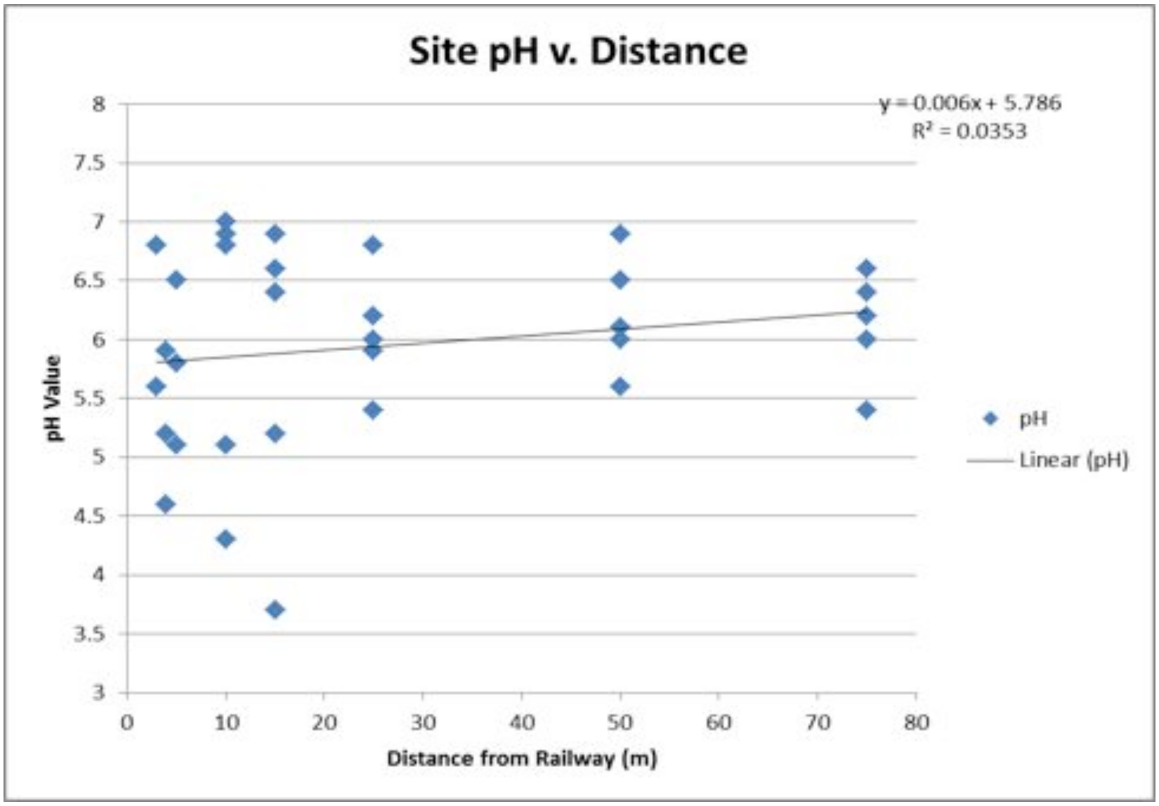

Figure 9 – Regression model depicting the relationship between pH with increasing distance from the railway.

A regression model was run against the data and showed that the correlation was found to be insignificant at the 95% confidence level. The r^2 of 0.035 indicates that only 3.53% of the variation was acounted for in the relationship between distance and pH. To furthur analyze the relationship between pH and distance, a two-tailed t-test was conducted. The calculated t-value was 1.065; a value of 2.9 or greater would show significance at the 95% confidence level using the two-tailed test (Sanders 2005). In order to further quantify the results, A Pearson's Correlation test was used to further compare the relationship between distance and pH, but results of that test were also found to be statistically insignificant. The presence of the 4 invasive species was graphed to determine at what distance from the railway they were most prevalent. Figure 10 shows the number of invasive species present at each sampled quadrat for all 5 sites. It does not show the number of individuals of these species present.

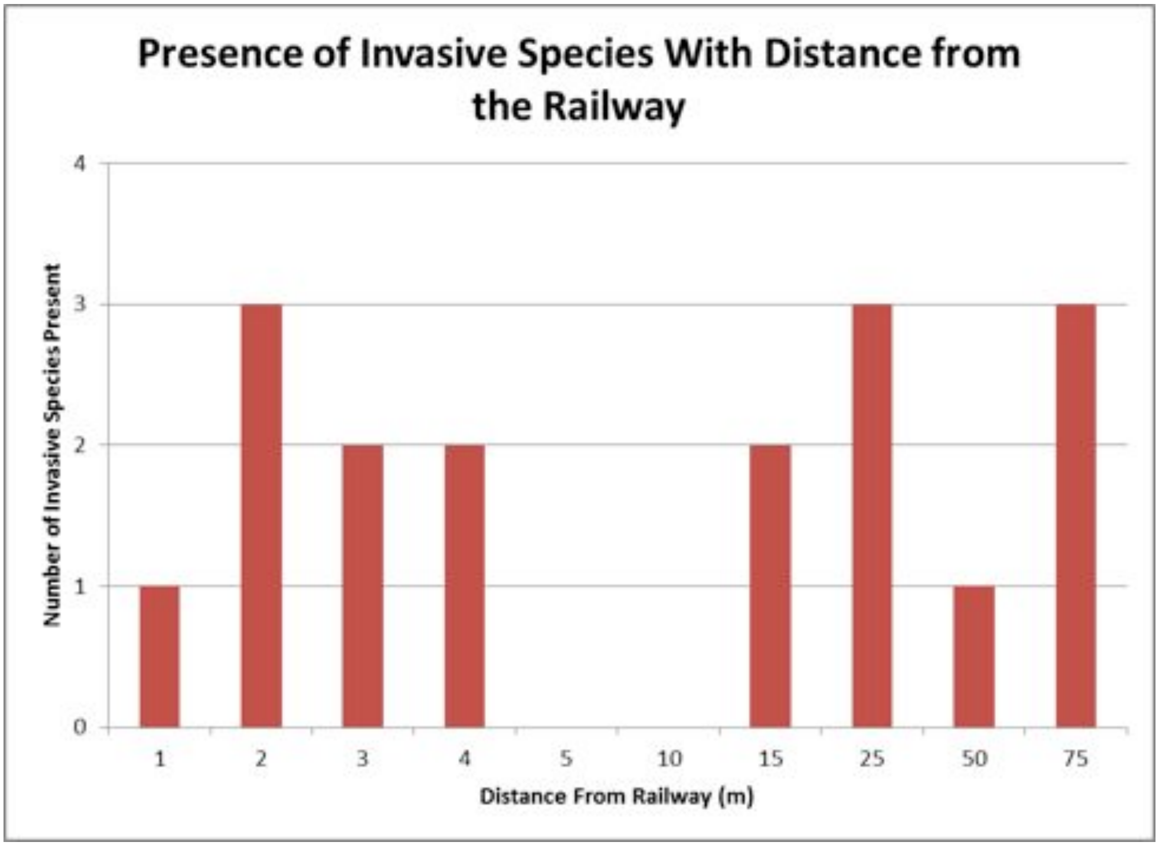

Figure 10– Six invasive species were documented in the quadrats. The number of each invasive species found and their distance from the tracks is shown for all sites.

Canadian thistle (*Cirsium arvense*), Altai Wildrye (*Elymos angustus*), and Western Wheatgrass (*Pascopyrum smithii*) were most commonly found near the track and Leafy Spurge (*Euphorbia esula*) was farthest away, as well as Altai Wildrye once again. The other two species were Oxeye Daisy (*Leucanthemum vulgare*) and Meadow Buttercup (*Ranunculus acris*).

Discussion

The first method of analysis was conducting a diversity test using the Shannon-Weiner Index (Table 1). The values calculated are all on the lower end of the scale, which indicates low, overall plot diversity for our study area. There is little variation between values for the plots closest to the rail lines and those farthest away. The Shannon-Weiner DI value was graphed for each quadrat in each transect against distance from the track (Figure 7). While our representation shows a wide variation of values between transects, there is a slight trend of increasing diversity farther from the railway. Diversity fluctuates within the first 10 metres; with little to no diversity at 1 m and 2 m. Diversity is also low, around 0.5, from 4 and 15 m, after which it increases.

Our results generally showed weak a correlation between pH and diversity versus distance. There are several possible explanations for this, the most important being sampling size. We looked at five sites with ten quadrats in each. If there had been more time allotted to continue the study and a greater number of meadow areas close to the railway it would have been possible to produce a study drawing from a larger and more detailed database resulting in higher quality data.

As is evident in Figure 2, topography can account for some of the fluctuation in diversity. As described in the study site description, topography varied widely throughout the study sites, which in turn altered plant diversity. The topography also affected the way in which runoff flowed from the raised rail bed, impacting the pH. Changes in pH have likely had an effect on specie diversity.

For the most part, there was little plant life in the 1 m quadrat because the ground surface was composed of angular rocks laid down during the construction of the railway.

A further explanation for the shape of the graph's curve is related to the characteristics of the plant life documented along the transects. The plotted data shows a bimodal tendency with peaks at about 3 m and 25-50 m; this is largely explained by observing the species present at each peak. Nearest to the railway there was an increase in non-native and disturbance tolerant species, as well as species that prefer more acidic environments. At the farthest peak, the plant life was composed of diverse species native to the area. The transition zone may be an area where there is increased competition, limiting the amount of species found. The presence of non-native species such as Canadian thistle and disturbance tolerant species such as horsetail (*Equisetum scirpoides*) increased the overall diversity of the early quadrats.

Regression analysis (Figure 8) depicts a weak correlation between species diversity and distance, with only 21.76% of variation explained. The effects of the drainage ditches are visible as a cluster in the initial 20 m of the transect. Within this range, diversity varies widely. With a larger pool of data, the linear trend between species diversity and distance may become more obvious.

The pH measurements were generally very low near the tracks, likely due to the drainage ditches located at sites one through 4 (Figure 2). The soil was consistently more acidic at the drainage ditch, which was the lowest elevation of the transects. The level of pH plateaus after the drainage ditches, indicating that the runoff from the tracks impacts the pH of the soil, even though statistical analysis indicates that the relationship is insignificant. It is our thought that the early measurements varied widely due to topographic effects, but further investigation would be needed to prove this. Most of the topographic variation was within the first five metres of the transect line, where the pH varied greatly. This topographic variation may be the reason that only 3.5% of the regression variation was explained by positing a relationship between distance and pH. Another factor may be that the soil composition was inconsistent from site to site. This was most obvious at Site 2, where the soil was found to be much sandier than the other four locations. The pH meter functions poorly in sandy soils and this may have given an inaccurate reading for Site 2.

The regression model in Figure 9 shows the linear trend between the pH and distance. The general trend was that the pH stabilized as we went further from the track. The quadrats located 1-4 m from the railway often did not have pH measurements taken. The rock that was laid down to level the railroad tracks did not allow the measuring of pH and this further decreased the number of samples for the study. The results were not shown to be significant through conducting Pearson’s correlation and regression analysis, but the fact that observed pH levels differed indicates that the area studied next to the railway tracks is environmentally different when anecdotally compared to the surrounding, undisturbed microclimate.

The increase in pH near the railway could be due to pollutants distributed from the passing trains and the chemicals and materials used during railway construction and reparation. The types of materials found within the transects were railway ties, metal scraps, charred wood, and other old materials that were left behind from railway maintenance. The materials were composed of metals or were chemically treated. This could result in the leaching of chemicals to the nearby environment given certain conditions, such as rainy weather. Many invasive and acid-tolerant species are able to grow in these lower pH conditions near the track, causing native vegetation to die out, freeing up space for these more tolerant species to take root. As our quadrats increased in distance from the railway we saw a substantial increase in plant species diversity; we also noticed a change in the types of species. Closest to the tracks, we found species capable of tolerating acidic conditions, such as horsetail (*Equisetum scirpoides*) and farther away we identified species native to undisturbed sites, such as Common Yarrow (*Achilea millefolium*) and Black-eyed Susan (*Rudbeckia hirta*). Many species that could not grow close to the tracks were able to fulfil their habitat requirements in the more optimal conditions found further way.

Another issue of note was the presence of invasive species directly on and along the tracks (Figure 10). The invasive species were found in all quadrats except for 5m and 10 m from the railway. This may be because this is where the drainage ditch is usually found and where the highest concentration of pollutants occurs. The most common were Western Wheatgrass at 1-5 m from the track and Leafy Spurge at distances of 25-75 m from the track. This suggests that invasive species have been able to establish among the native plants and are not confined to the area immediately next to the tracks. Canadian thistle and Western Wheatgrass grew closest to the tracks. These invasive species were generally not dominant in the quadrats, with the exception of Meadow Buttercup. Western Wheatgrass and Altai Wildrye were documented as growing among the rail ties and immediately adjacent to the tracks. Both of these plants are grains that fall out of passing trains and are able to take root where they land. They were rarely found outside of 5 m from the track although rye was found in a quadrat 25 m away. These and other invasive plant varieties have been known to attract animals for grazing. The presence of the invasive plant species, therefore, increases the hazard to local animal populations in terms of the railway.

Species such as Horsetail, Silver Cinquefoil (*Potentilla argentea*), and Tall Fescue (*Schedonorus phoenix*) are able to grow in acidic conditions of a pH of approximately 5.5 to 6.5 (USDA Plants Database, 2010). The conditions favourable for these species are where the land has been disturbed, for example next to a roadside or a railway. Rye and wheat also grow at pH levels of approximately 4.5 to 7.9 but they are also at more basic pH levels of approximately 8.0 and 9.0. A wide range in pH tolerance levels gives the wheat and rye a greater opportunity for growth, as they are able to succeed in diverse conditions. The acidic ditch next to the railway gives the acidic growing plants species a the opportunity to establish and then to move further away from the railway, competing with native plants. Native plant species, such as Black-eyed Susan and Common Yarrow grow at pH levels of approximately 6.5 to 9.0, in a more basic environment. As many non-native plant species are able to grow in similar pH levels, native plants are forced to compete for resources. A further correlation of pH tolerance and preferred pH of the plant found at the location could be determined through further analysis of the data. Plants labelled noxious in Table 3 (Appendix A) are plants that the municipality of Jasper do not want being planted, and if they happen to grow in an area they will be removed either by manual picking of the plant or through pesticides.

If this study were to be continued, a couple of changes should be considered in order to improve it. With only two days to conduct this study, and limited supplies, it can be acknowledged that more time and financial aid would help in finding more adequate results. A major improvement would be to collect soil samples in order to calculate the soil contents within the different quadrates and sites; this could help determine why certain site conditions displayed the results they did. If this were a more extensive study, other sites rather than just meadow sites should be evaluated, as meadows are not the only type of microclimate found along the train tracks. If funds allowed, it would have been very useful to have a botanist on site, as it would have saved a significant amount of time spend trying to identify certain plants. Performing the study in the summer would have been easier for the classification process as well, as most of the leaves and flowers would be present on the plants; whereas this study was performed in September, making it considerably harder to identify some plants that had already gone out of season.

This study was committed to sampling from certain quadrats along a specific transect and selected sites. It was notable that some plant species were observed in the surrounding area, but were not within the quadrats, and therefore could not be recorded. In sampling techniques, it may be better to consider a technique that would encompass more species along the railway. If this study were to be completed further, it would most likely reveal more significant results than what was found in this limited two-day study.

In studying the train tracks in Jasper, certain faults were able to be determined; such as pollution effects and introduction of invasive species and other detrimental pollution effects. There are certain recommendations that can be suggested to improve the health of the environment around the train tracks. Certain things such as the excessive amounts of rail ties found along the tracks could be detrimental to living plants around them and a program that would clean up track ties would be very important to have installed. Communication with the railways should be initiated in order to discuss such programs. Regulations should be enforced to prevent the introduction of invasive species from the rail cars, perhaps by regulating the containment of certain cars passing through the park. As viewed within this study, wheat was found through the study sites, and if not directly within our results, it was observed nearby; this type of plant should not be growing in the Jasper areas. Better containment of cargo loads should be addressed with the rail companies. With further studies more information on the damage that the railroad does to Jasper could be determined, and further terms of action to protect the wildlife could be recommended.

Conclusion

Based on our observations, we were able to identify insignificant correlations between pH and distance as well as diversity and distance. Although the regression analyses showed insignificant correlations between diversity and distance, and also between pH and distance, we were still able to see trends within our data. Our small sample size may be the cause of the insignificant correlations. Pearson's correlation conducted on the relationship between pH and distance further confirmed the weakness of the relationship. We could observe trends while at the study locations, leading us to believe that further research would display a statistically significant relationship. This survey was limited in time and resources and as such functions as a preliminary study. The results indicate that further sampling will be required to determine conclusively the nature of the relationship between all variables.

Acknowledgements

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Appendix A

Table 3 - Identified species. The species marked as noxious indicate species which are invasive.

Common Name	Genus	Species	Noxious/Invasive
Sage	*Artemisia*	*spp.*	
Prairie Golden Bean	*Thermopsis*	*rhombifolia*	
Horsetail (Dwarf Scouring Rush)	*Equiseteum*	*scirpoides*	
#1 Fringed Brome	*Bromus*	*ciliates*	
#2 Rocky Mountain Fescue	*Festuca*	*ovina var. saximontana*	
#3 Black Eyed Susan	*Rudbeckia*	*hirta*	
#4 Tufted Vetch	*Viccia*	*cracca*	
#5 Common Yarrow	*Achilea*	*millefolium*	
#6 Pacific Anemone	*Anemone L.*	*multifida Poir*	
#7 Silver Cinquefoil	*Potentilla*	*argentea L.*	
#8 Unknown	-	-	
#9 Blunt-leaved Sandwort	*Arenaria*	*lateriflora*	
#10 Cushion Buckwheat; Silver Plant	*Eriogonum*	*oralifolium*	
#11 Buttercup (Meadow)	*Ranunculus*	*acris*	Noxious
#12 Unknown	-	-	
#13 Unknown	-	-	
#14 Canada Bluegrass	*Poa*	*compressa L.*	

Common Name	Genus	Species	Noxious/Invasive
#15 Reed Canarygrass	*Phalaris*	*arundinacea*	
#16 Staghorn Cinquefoil	*Potentilla*	*bimundorum Soják*	
#17 Northern Wormwood	*A.*	*campentris*	
#18 Mealy Goosefoot	*Chenopodium*	*incanum*	
#19 Lamb's-Quarters	*Chenopodium*	*album*	
#20 Tall Fescue	*Schedonorus*	*phoenix*	
#21 Leafy Spurge	*Euphorbia*	*eeula*	Noxious
#22 Unknown	-	-	
#23 Smooth Wildrye	Elymus	glaucus	
#24 Unknown	-	-	
#25 Unknown	-	-	
#26 Altai wildrye	*Elymus*	*angustus*	Noxious
#26 Western Wheatgrass	*Pascopyrum*	*smithii*	Noxious
#27 Platte River cinquefoil	*Potentilla*	*plattensis Nutt.*	
#28 Hookedspur violet	*Viola*	*adunca Sm.*	
#29 Nodding microseris	*Microseris*	*mutans*	
#30 Owl Clover	*Orthocarpus*	*luteus*	
#31 Wintercress	*Barbarea*	*spp.*	
Canadian Thistle	*Cirsium*	*arvense*	Noxious
Common Sweetgrass	*Hierchloe*	*odorata*	
False Pixie Cup (Lichen)	*Cladonia*	*chlorophaea*	

Common Name	Genus	Species	Noxious/Invasive
Oxeye Daisy	*Leucanthemum*	*vulgare*	Noxious
Common Dandelion	*Taraxacum*	*officinale*	
Alsike Clover	*Trifolium*	*hybridum*	
Blunt-leaved Bristle Moss	*Orthotrichum*	*obtusifolium*	

Appendix B

Study Sites

Table 4– Site 1 GPS location and physical study site characteristics.

Quadrat	Location	Description
1m	N 52°57.762’ W 118°03.319’	Completely rock covered
2m	N 52°57.762’ W 118°03.320’	Even mix of rail rock and grass
3m	-	-
4m	N 52°57.762’ W 118°03.320’	Mostly grass covered, tall grass
5m	-	Ditch
10m	-	-
15m	N 52°57.759’ W 118°03.329’	Low grass, lichen cover
25m	N 52°57.758’ W 118°03.337’	Low grass, lichen cover
50m	N 52°57.754’ W 118°03.358	Low grass, moss cover, dead grass
75m	-	-

Table 5– Site 2 GPS location and physical study site characteristics.

Quadrat	Location	Description
1m	N 52°59.958’ W 118°04.014’	Rail rocks, railway debris (wood, metal)
2m	N 52°59.959’ W 118°04.015’	Rocks, wheat present, sand/gravel
3m	N 52°59.957’	40% grass cover, rocky,

	W 118°04.016’	wheat present
4m	N 52°59.957’ W 118°04.016’	Grass, some rocks present
5m	N 52°59.957’ W 118°04.016’	Few plants present
10m	N 52°59.956’ W 118°04.023’	Slope, sandy, mostly grass
15m	N 52°59.955’ W 118°04.027	Low grass and flowering plants
25m	N 52°59.954’ W 118°04.035	Low grass and flowering plants, invasive sp.
50m	N 52°59.949’ W 118°04.057	More bare ground, lichen present
75m	N 52°59.944’ W 118°04.076’	Dead tree, taller grass

Table 6 – Site 3 GPS location and physical study site characteristics.

Quadrat	Location	Description
1m	N 52°57.608’ W 118°03.244’	Rail rocks, invasive species present
2m	N 52°57.607’ W 118°03.248’	Partial rock and grass
3m	N 52°57.608’ W 118°03.249’	Down-slope, high grass, charred wood
4m	N 52°57.609’ W 118°03.249	Slope, high grass coverage
5m	N 52°57.610’ W 118°03.249’	Beginning of ditch
10m	N 52°57.607’ W 118°03.251’	Low grass cover, moss and lichen cover
15m	N 52°57.608’ W 118°03.257’	Low grass cover, coarse woody debris
25m	N 52°57.609’ W 118°03.268’	Low grass cover, coarse woody debris
50m	N 52°57.603’ W 118°03.287’	Little plant coverage
75m	N 52°57.599’ W 118°03.308’	Grass medium height, dead grass

Table 7 – Site 4 GPS location and physical study site characteristics.

Quadrat	Location	Description
1m	N 52°58.101’	Slight vegetation, wheat

	W 118°03.468’	present
2m	N 52°58.101’ W 118°03.467’	Rocky, wheat present
3m	N 52°58.101’ W 118°03.465’	Rocky, end of rail bed
4m	N 52°58.102’ W 118°03.466’	Moss cover, wheat present, gravel
5m	N 52°58.101 W 118°03.462’	Moss cover, sparse vegetation
10m	N 52°58.103’ W 118°03.459’	High moss cover (apx. 100%)
15m	N 52°58.103’ W 118°03.452’	Bare ground moss covered, low stunted grass
25m	N 52°58.104’ W 118°03.444’	Some moss cover, low grass
50m	N 52°58.106’ W 118°03.422’	High moss cover, earthy soil
75m	N 52°58.108’ W 118°03.402’	High moss and lichen cover, earthy soil

Table 8 – Site 5 GPS location and physical study site characteristics.

Quadrat	Location	Description
1m	N 52°54.263’ W 118°04.040’	Little vegetation
2m	N 52°54.253’ W 118°04.037’	Rocks and charred wood
3m	N 52°54.254’ W 118°04.034’	Wood debris, some tall grass
4m	N 52°54.256’ W 118°04.038’	Moss cover, rocks present
5m	N 52°54.254’ W 118°04.039’	No moss, wood debris
10m	N 52°54.251’ W 118°04.035’	Very grassy, rocks present, run off from railway
15m	N 52°54.251’ W 118°04.026’	Elk scat, invasive species
25m	N 52°54.246’ W 118°04.021’	Low grass, bare ground
50m	N 52°54.239’ W 118°03.999’	Low grass, bare ground, moss and lichen