The impact of proximity to roads and road type on bark pH in grand fir (*Abies grandis*)

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Summary

1. Roads affect the ecosystems they traverse through processes such as habitat fragmentation and increased erosion.
2. Dust pollution from vehicle traffic may alter the bark pH of roadside trees, which may negatively impact sensitive plant and lichen species.
3. The objective of this study was to investigate how distance from roads and road type (gravel or asphalt) impact bark pH in grand fir (*Abies grandis*) in Ponderosa State Park, McCall, Idaho. I hypothesized that I hypothesize that bark from individuals near roads will have a more basic pH than bark from trees further from roads. I also hypothesized that grand fir bark will have a higher (more basic) pH near gravel roads than near asphalt roads.
4. Bark pH samples were taken from grand fir individuals at three sites (gravel road, asphalt road, and control site) and at three distances from the edge of the road (0-10m, 10-20m, and 20-30m).
5. Analysis of the data collected indicate that the interaction term incorporating distance and road type had a statistically significant effect (α=0.05) on bark pH, although the distance and road type terms did not have statistically significant effects on bark pH individually. Overall, results from this study were not consistent with the hypothesis that road type and distance impacted conifer bark pH through dust pollution.
6. *Synthesis.* Dust pollution from vehicle traffic can interact with nearby plants and substrates, often resulting in negative ecological consequences for roadside areas. An analysis of grand fir bark pH at different road types and different distances from roads was largely inconclusive; however, this study recommends continued monitoring of roadside dust pollution and other ecosystem-level impacts of roads, particularly in ecologically sensitive areas.

Key Words

Disturbance, dust pollution, conifers, basic, acidic, vehicle traffic.

Introduction

Roads in scenic areas allow widespread and efficient access by tourists. However, roads can affect the ecology of the areas they transverse in ways ranging from habitat fragmentation to increased light penetration in the sub-canopy (Forman 2000). Because many impacts of road use can extend beyond the roads themselves, Forman (2000) calculated that 19% of the land in the U.S. is directly impacted by the network of roads crossing the country. The ecological effects of roads are often so pronounced that they are considered to be definitive variables in determining landscape-level patterns and processes (Hawbaker *et al.* 2006). One ecologically relevant process which occurs along many roads is the production of dust pollution (Walker and Everett 1987).

Dust pollution is driven by the substrate disturbance caused by road construction as well as by vehicular traffic, and its intensity can vary greatly depending on road type, vehicle traffic, and other factors (Walker and Everett 1987). High levels of roadside dust pollution can contribute to earlier snowmelt in high-use areas because when dust particles settle over snow they lower the albedo, which causes the snow to absorb greater heat from solar radiation (Walker and Everet 1987). Additionally, dust pollution can have physiological impacts on roadside plants (Sharifi *et al.* 1997). Windblown dust from roads may form a layer over the leaves of nearby plants, reducing their gas-exchange efficiency and water-use efficiency (Sharifi *et al.* 1997). Photosynthetic rates of dusted leaves of desert shrubs decreased 21-58% compared to the leaves of their non-dusted counterparts (Sharifi *et al* 1997). Dust also increased the leaves' absorbance of infrared radiation, raising their surface temperatures by 2-3 degrees Celsius compared to control plants (Sharifi *et al.* 1997). Marmor and Randlane (2007) found evidence that dust pollution from roads may raise the pH of tree bark in some conifer species in Tallinn, Estonia. This change in substrate pH can negatively impact sensitive plant and lichen species (Walker and Everett 1987). Bark pH may be used as an indicator of dust pollution and air quality overall, providing researchers with a means to quantify some of the airborne impacts of road use (Lötschert and Köhm 1977).

The primary objective of this study is to determine how proximity to roads and road type (asphalt or gravel) affect bark pH in grand fir (*Abies grandis*). Specifically, I hope to determine if there is a statistically significant difference in mean bark pH for grand firs at different distances from roads and at different road types. Since Marmor and Randlane (2007) found that dust pollution tends to raise bark pH, I hypothesize that bark from grand firs sampled near roads will have a more basic pH than bark from trees of the same species sampled at a greater distance from roads. Additionally, I hypothesize that grand fir bark will be more basic near gravel roads than near asphalt roads, because gravel roads have greater potential for dust pollution.

Methods

Study Site

Ponderosa State Park is a 1515 acre park that is located in Valley County, Idaho, USA. Much of the park is situated on a narrow peninsula which juts out into Payette Lake. The park is a popular destination for year-round recreational activities, including camping, hiking, mountain biking, and skiing. Within the park, footpaths and trails provide access to much of the peninsula. Additionally, there are several miles of asphalt and gravel roads in the park which enable vehicles to tour the peninsula in the late spring, summer, and fall (Idaho State Parks and Recreation 2013). Dominant conifer species in Ponderosa State Park include grand fir, Douglas fir (*Pseudotsuga menziesii*) and Ponderosa pine (*Pinus ponderosa*). Mean annual precipitation for the McCall area is over 26 inches (Western Regional Climate Center 2013). The elevation of McCall is just over 5000 feet, and the surficial geology of the park is largely composed of granite from the Idaho batholith along with basalt flows (the Columbia River Basalt Group) (FEMA 2009). Soils are generally well-drained loams overlaying the granite or basalt bedrock (FEMA 2009).

Bark Sampling Protocol

In Ponderosa State Park, three sites were selected in the grand fir-conifer forests: one along an asphalt road, one along a gravel road, and a control site located greater than 100m from the nearest road. This distance for the control site was selected in order to ensure that the control samples were outside the range of dust pollution (Marmor and Randlane 2007). At each site, I collected bark samples from 5 randomly-selected grand fir trees growing less than 10m from the road, 5 that were 10-20m from the road, and 5 that were 20-30m from the road. All samples were taken from grand fir individuals growing on the east side of the road. For each tree, I collected 4 bark samples (from the north, south, east and west sides of the trunk) at approximately 1.5m from the tree base. These 4 samples for each tree were pulverized together using a ceramic mortar and pestle until the approximate particle size of the pulverized bark was <1mm. Pulverized bark was then made into a slurry with distilled water for pH sampling. A Vernier LabQuest and pH probe (Tris-Compatible Flat pH Sensor, Vernier Software and Technology, Beaverton, OR, USA) were used to take pH measurements in the field. All pH readings were taken from slurry samples after less than 2 minutes. At the control site, the protocol was identical except that distances were measured from a haphazardly-selected starting point within the control area, rather than from a road. For this study, the two treatment variables were road type (site) and distance from the road, and each treatment variable had three levels, resulting in a total of 9 treatment groups. There were 5 grand fir individuals in each treatment groups. Distance intervals were selected based on previous findings (Marmor and Randlane 2007) that 75% of the dust load settles out in the first 10m interval from the road and by 30m from the road, 93% has been deposited. Finally, a pH sample was taken from the road surface at each of the two road sites and from the soil at the control site in an attempt to quantify the potential impact of road and soil surface chemistry on bark pH. At the asphalt road site, this was done by scraping the road's surface in order to accumulate a sample of the gravel, tar, and other sediment present. The pH of the distilled water used in the bark slurries was also measured and recorded.

Data Analysis

Data were analyzed in R statistical software version 3.0.2 (R Core Team 2013) using a Two-Way Analysis of Variance (ANOVA), in order to investigate the influence of the two categorical treatment variables (site [asphalt, gravel, and control]) and distance from the road (near [0-10m], mid [10-20m], and far [20-30m]) on the dependent variable (bark pH) The influence of the treatment variables was considered to be statistically significant at probability level of $p<0.05$.

Results

The pH of the gravel road's surface was 6.60, the pH of the asphalt road's surface was 6.70, and the pH of the control soil was 6.64. The pH of the distilled water used in bark slurries was 6.65. The pH readings for bark sampled from individual trees ranged from 4.68 to 7.10. Mean pH values for grand fir individuals from each treatment group are recorded in Table 1 (below).

Distance	Road Type			
		Control	**Gravel**	**Asphalt**
	Near (0-10m)	6.65±0.02	6.54±0.04	5.85±1.11
	Medium (10-20m)	6.62±0.04	6.56±0.01	6.57±0.05
	Far (20-30m)	6.58±0.02	6.49±0.02	6.66±0.05

Table 1. Mean bark pH (± 1 standard deviation) by treatment group of grand firs sampled in Ponderosa State Park.

A Two-Way ANOVA found that the two treatment variables had a moderately weak but statistically significant influence on grand fir bark pH ($p=0.04$, adjusted $r^2 = 0.19$). The distance and road type variables independently were not statistically important in predicting bark pH; however, the interaction term which incorporated both treatment variables did show to have a marginally statistically significant influence on bark pH ($p=0.05$).

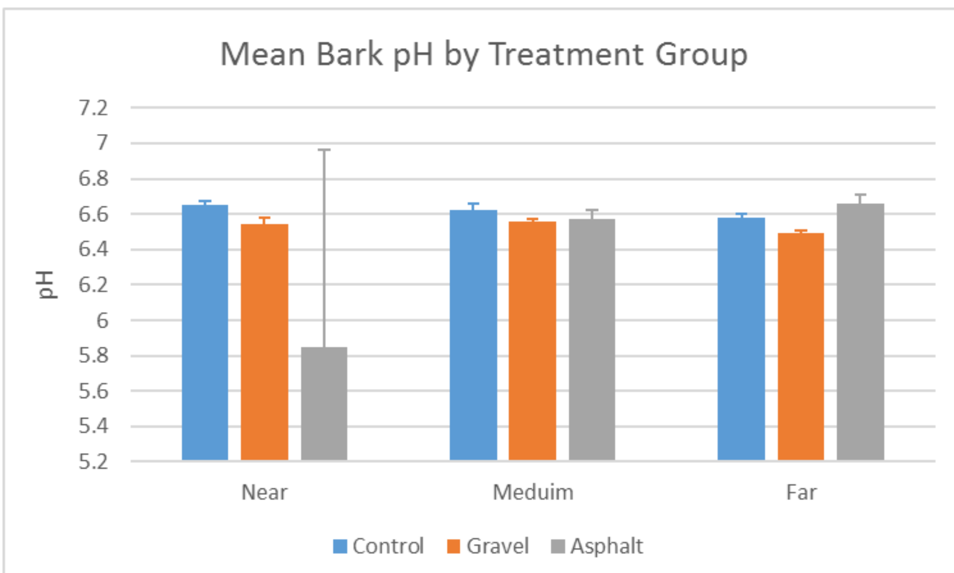

Figure 1. Mean grand fir bark pH by treatment group. Error bars indicate one standard deviation above the mean.

Discussion

Results from this study are not sufficient to support the hypothesis that dust pollution from roads affects bark pH of grand firs in Ponderosa State Park. Indeed, mean bark pH shows no clear directional trends across treatment groups. In a Two-Way ANOVA, neither distance nor road type were shown to be statistically significant predictors of bark pH. The interaction term which tested the combined effects of road type and distance on bark pH was statistically significant ($p=0.05$). The overall model incorporating distance and road type as predictor variables was statistically significant ($p=0.04$), but the low r^2 value of 0.19 suggests that road type and distance are not the primary factors impacting grand fir bark pH in Ponderosa State Park. Limited samples of road and soil material were taken, but their range (6.60 to 6.70) does not appear to differ strongly from the range of mean bark pH across all treatment groups (6.49 to 6.66), nor does their range differ strongly from the pH of the distilled water used to make slurries (6.65). This is a deviation from previous studies (Marmor and Randlane 2007), where dust pollution was shown to be significantly more alkaline than the bark of nearby conifers, raising the bark's pH. Figure 1 demonstrates that the standard deviations for all treatment groups were fairly low (<0.05) except for in the near asphalt treatment, where the standard deviation was 1.11. The range of pH values for this treatment varied much more greatly than the other treatment groups, which may denote a probe calibration error or sampling error. Had the standard deviation for the near asphalt treatment been closer to the standard deviations for the other treatment groups, trends in the data may have been more statistically meaningful.

One flaw in the design of this study was that pH measurements had to be taken in the field. Had the pulverized bark slurries been allowed to hours or even days before pH measurements were taken, the recorded pH values might have been closer to the actual pH of grand fir bark (conifers typically have acidic bark with pH values under 5 , see for example Gough 1975). It is possible that dust pollution from the more pH-neutral roads and soils resulted in higher mean grand fir bark pH, but this seems unlikely given the inconsistency in this study's data. There are also many unmeasured variables, in addition to road dust pollution, that might impact bark pH, such as recent precipitation, tree age and health, and seasonal variations in road use frequency. Vehicle traffic in Ponderosa State Park may not be substantial enough to generate the levels of dust pollution necessary to influence the bark pH of nearby trees. Additionally, recorded values for surface soil from the road site and the control site indicate that the pH of roads in Ponderosa State Park does not differ greatly from the soil pH in the surrounding areas. Therefore, the impact of road dust pollution on bark pH might not be as pronounced as it would be in areas where the surface pH of the road was vastly different from the pH of off-road soils.

Although this study was unable to find sufficient evidence that dust pollution from roads in Ponderosa State Park, a growing body of literature suggests that dust pollution can play a damaging role in roadside plant communities and ecosystems (Walker and Everett 1987, Sharifi *et al.* 1997 and Marmor and Randlane 2007). For this reason, continued monitoring of roadside dust pollution and its effects on roadside plant communities is critical. This is especially true in areas that are ecologically sensitive or that experience high levels of road use. In Ponderosa State Park specifically, a more comprehensive, multi-season study would be valuable in quantifying the potential environmental impacts of road dust pollution on local ecosystems.

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