The Effects of Road Salt on Forest and Lotic Ecosystems

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Table of Contents

Abstract

Due to the ever-growing number of cars on the road, the amount of road salt utilized has simultaneously increased. This is a major issue as the negative effects road salt has on ecosystems are vast;thus, the study was narrowed down to lotic and forest ecosystems. The study was conducted by completing a plant survey along transects whilst collecting samples for chlorophyll levels. Further, the influx of salt was measured through a series of transects perpendicular to a major roadway. To retrieve plant data during winter, plant tanks were created to replicate varying amounts of salt. The overwhelming data proved that road salt definitively harmed the ecosystems by reducing main-producer's health, as shown through lower levels of chlorophyll, biomass, and plant height, in addition to lower biodiversity levels.

Introduction

The use of road salt effects both aquatic and land ecosystems; for example, salt drastically effects embryophytes, by a) increasing water stress, as the water molecules are held tightly by the salt ions, thus making it difficult for plants to absorb water, b) creating a toxic level of chloride ions, which results in leaf burn, and c) causing a deficiency of potassium and phosphorus, because the plants will absorb the road salt instead. Besides land plants, salt drastically affects aquatic ecosystems, and this can be seen as a study in 2016 found that zooplankton are becoming tolerant to road salt. This can/will be devastating, as the fish who have been eating the same zooplankton for the past couple of centuries, will not be suited to eat this new type of plankton.

Going into specifics, plants become injured when roots and foliage are exposed to salt-laden water. The foliage on roadside vegetation is damaged when salted water sprays up from the pavement by passing vehicles. Salt-laden water can also percolate down through the soil profile, coming into contact with soil particles, soil microbes, and plant roots. This road salt causes increasing water stress, which means that in the roots the water is being held together with these salt ions making it difficult for roots to absorb sufficient quantities of water. This then causes a drought like scenario making the plants have a depressed growth and yield. This is just one of the things that can affect the vegetation in a negative way causing plants and ecosystems to dwindle. We can minimize these salt injuries to the plants by first shovelling and plowing the snow and then use as little salt as possible to melt the ice. The reason for minimizing salt usage is because once the salt is in the soil it is incredibly hard to get rid of it, but you can leach the soil with fresh water as soon as it happens. However, the best choice is to avoid this by using less salt, or to use an alternative to salt, in order to save vegetation and sea life in the water.

By increasing the amount of concern over road salt via research, nearby communities will be more aware of the harmful effects, thus resulting in stronger ecosystems and improved health for the community. The garnering of specific, strong data, will enable communities to prevent cyanobacteria in lentic waters, reduce the amount of car crashes from deer and moose(salt licking hotspots), and to allow ecosystems to thrive. Furthermore, the data would entice the Highway Department to reduce the amount of road salt that’s put down, and to find/use alternatives.

Research Objectives

The goal of the experiment was to determine the effect(s) of road salt on forest and lotic ecosystems, by gathering information such as salinity/conductivity, soil PH, soil moisture, and the chlorophyll levels and biodiversity. The data collected would then help us see how these independent variables change based on their vicinities to roads; thus, a definitive line would be put down on how road salt affects ecosystems, specifically under those data points.

Research Hypotheses

The main hypothesis for the study was that an increase in road salt on forest and lotic ecosystems would reduce the overall health of the ecosystems. This was further delved into, with the independent variables of the study(biodiversity, plant height, biomass, ect.) each being hypothesized that there would be a reduction in their quantities.

Methodology

Data was collected from two different sites within the Tioga River watershed. The first site was located downstream from all major roadways representing habitat affected by road salt and the second site was located upstream from all major roadways where a large natural buffer exists from potential road salt sources. It should also be noted that the roadway dividing the two sites represents a busy highway where surrounding land is used primarily for commercial and industrial purposes.

A survey of plant species at both sites was completed along a transect to calculate species biodiversity and collect leaf samples. Biodiversity was measured in relation to species richness, or the number of species in a given area. The samples collected were then further analyzed for chlorophyll concentration using a Vernier SpectroVis to help determine the overall health of plants. Additionally, the plant survey showed prevalent species throughout each distance on the transect. This allowed for plants to be grown in a lab, allowing for the collection of plant data throughout the winter.

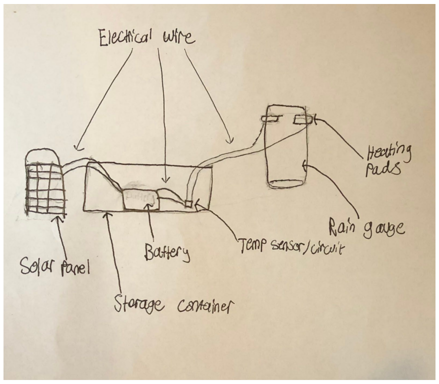
To assess the influx of salt into the ecosystem, data for snow depth, snow density, and snow salinity content was collected from a series of transects running perpendicular to the major roadway (route 140) into the downstream habitat. This allowed for estimated salt amounts to be put in the lab grown plant. Salinity concentrations within the Tioga river itself was continuously monitored at both sites through the winter using HOBO Fresh Water Conductivity Data Loggers. Finally, air temperature, relative humidity, solar radiation, precipitation, and soil moisture was also continuously monitored during the same time period using two Onset USB Micro Station Data Loggers.

Downstream	**Upstream**

The blue circles represent the location for the fresh water conductivity probes, the red square represents the location of the microstation data logger for weather data, and the green lines represent transects for collecting snow data.

The lab grown plants were grown in three varying amounts of road salt concentrations, with each tank having two of the most prevalent species in the forest: Perennial Ryegrass, and Crabgrass. Road salt concentrations were determined based off of the salinity data. This resulted in the estimated road salt tank to bear 1000 microsieverts(μs), and the high to hold 5000μs. The salt concentrations were made into a salt-water mixture, with a salinity probe allowing for accurate concentrations. After both species had perceivably reached peak height, biomass, chlorophyll, plant height, and root health were all measured.

Engineering



In order to utilize the HOBO Ware Rain Gauge to measure snowfall, a heating system was created. The first step in making this system was to make a diagram(see picture on the right). As seen from the picture, the brainstormed system is fairly simple: you have a temperature controller that determines when to turn on and off a 7 W heating pad that is directly on the rain gauge. A battery powers this flow, which is recharged through a solar panel. This makes a looped system, ideal for remote and hard to reach areas.

Next, the temperature controller was programmed to turn on the heat pads when it was 32 °F or less. The heating pads were then attached to the inside of the rain gauge which was subsequently connected to the sensor through electrical wires. We tested both the pads and controller by sticking the controller into a cup of ice. Sure enough, the controller sensed the low temperature and turned on the heating pads, which maintained a high temperature. It was tested again with luke-warm and warm-water, and both times the controller didn't turn on. Next, the wires were connected through both ports on the battery from the controller. We left the controller running in cold water for a period of time past the normal controller's battery life, proving that the battery properly worked. The final step of the process was to connect a solar panel to the system. It was determined that the best and easiest way to angle the solar panel(to maximize efficiency) would be to attach it to a step stool. This was completed by drilling holes into a slab of wood and then attaching it to the top of the step stool with U-bolts. Z-clamps were attached to the solar panel to have it stay on the wooden slab. Finally, connected wires from the solar panel to the battery were put into place.

Data

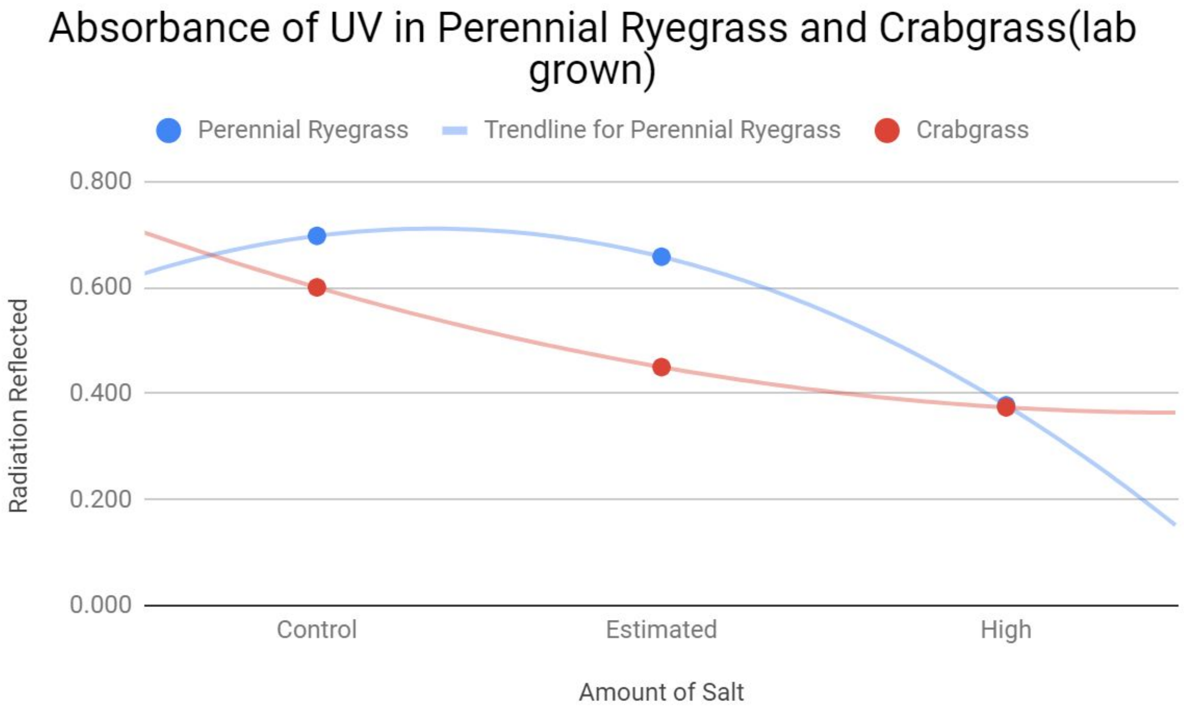


Figure 1

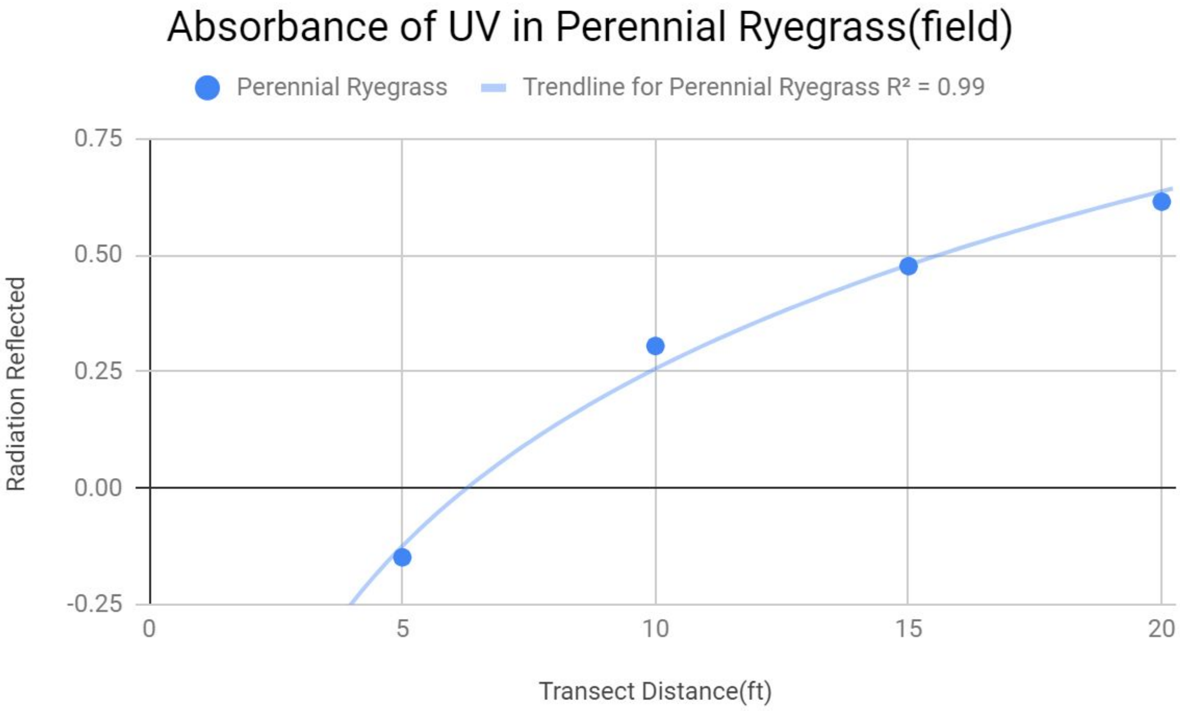


Figure 2

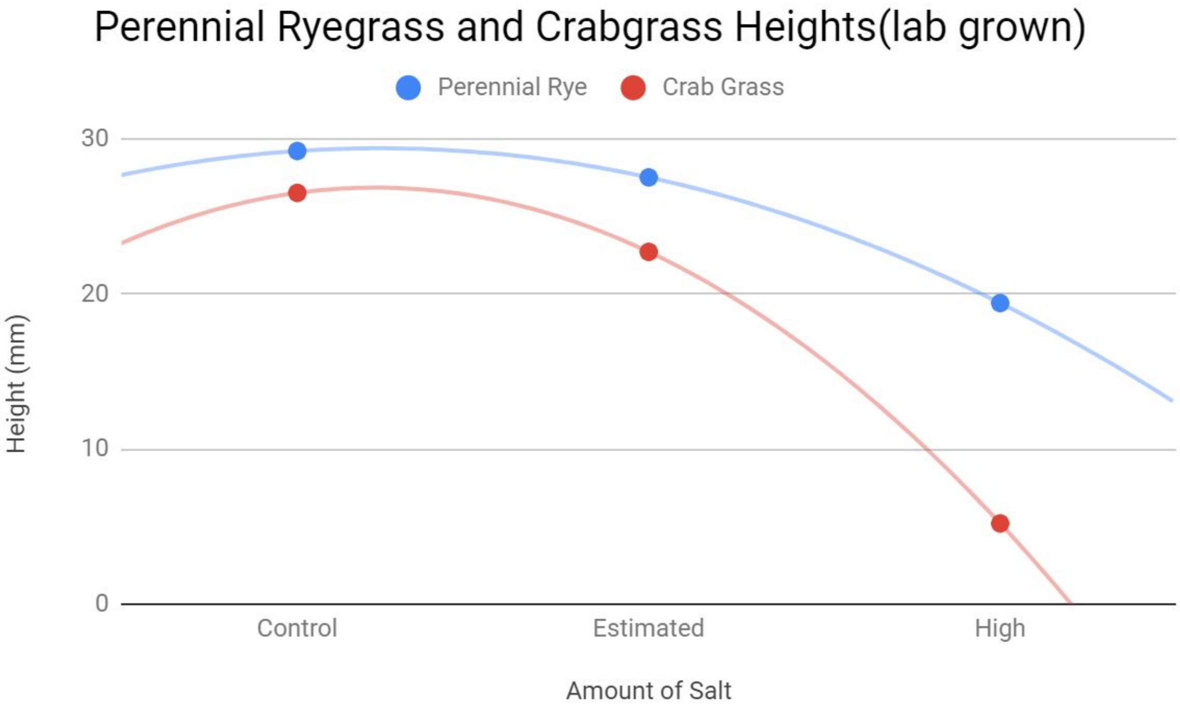


Figure 3

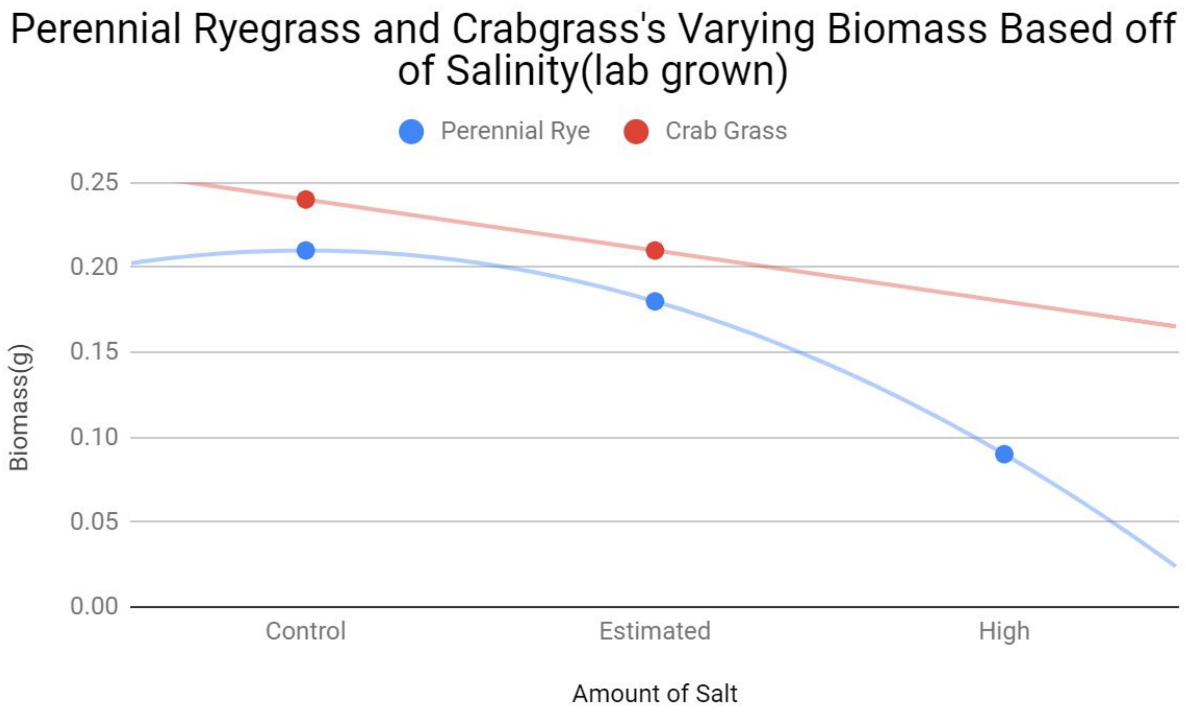
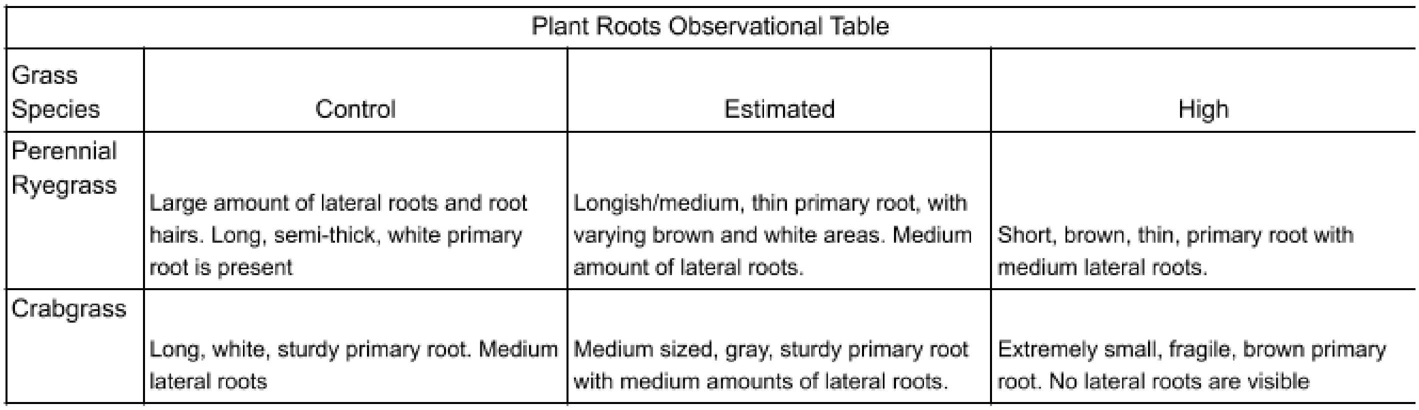


Figure 4



Plant Roots Observational Table			
Grass Species	Control	Estimated	High
Perennial Ryegrass	Large amount of lateral roots and root hairs. Long, semi-thick, white primary root is present	Longish/medium, thin primary root, with varying brown and white areas. Medium amount of lateral roots.	Short, brown, thin, primary root with medium lateral roots.
Crabgrass	Long, white, sturdy primary root. Medium lateral roots	Medium sized, gray, sturdy primary root with medium amounts of lateral roots.	Extremely small, fragile, brown primary root. No lateral roots are visible

Figure 5

Distance (m)	**Average Salinity levels on Transect A**				
	Salinity(µs/cm)	**Depth (cm)**	**Mass (kg)**	**Density (kg/cm^3)**	**Salt per kg/cm^3**
0	4478	10.66666667	728	1.839094389	6778.343332
5	1271	7.166666667	615.3333333	3.634454389	667.5530563
10	306.3333333	9.333333333	588	3.179012346	578.0959944

15	141.6666667	6.5	616.6666667	2.671369974	81.95905545
20	35.33333333	8	683	2.004185185	33.98437929

Figure 6

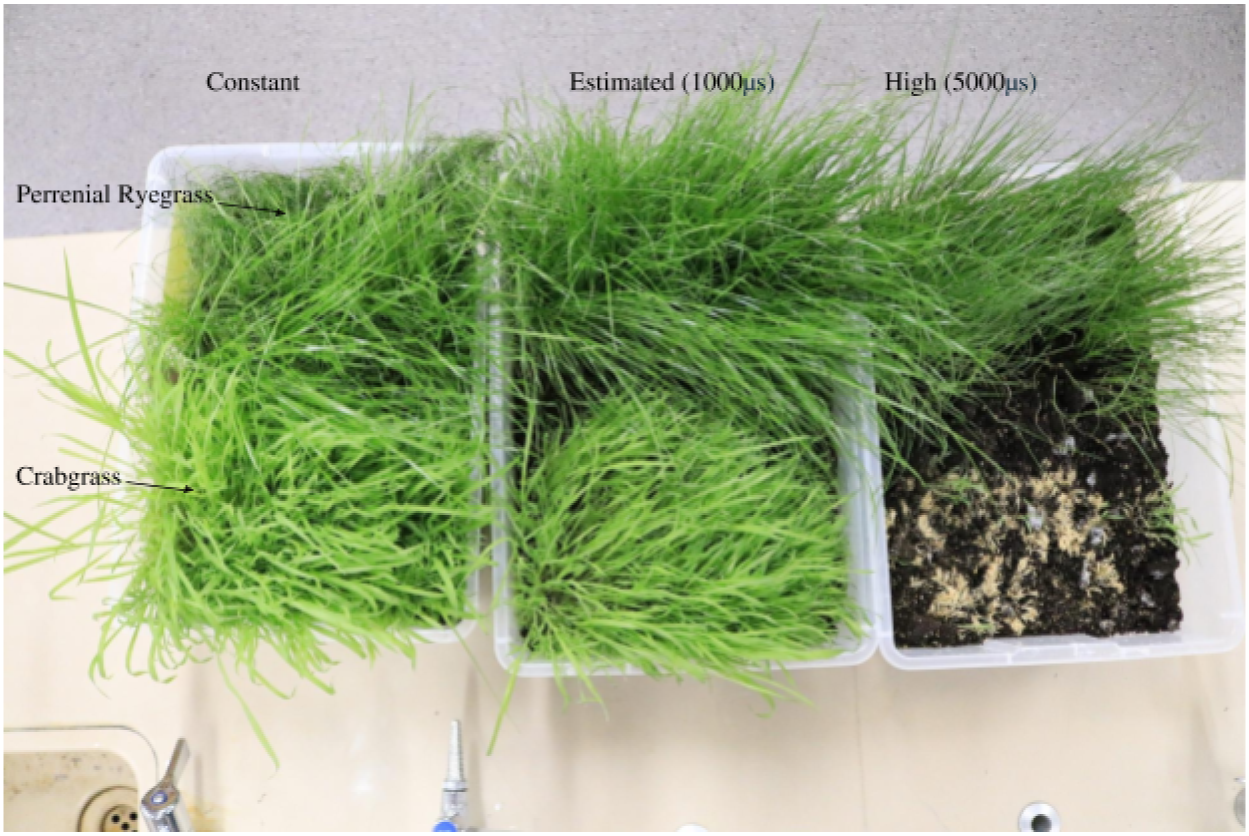


Figure 7

Discussion

Figure 1 and Figure 2 show that there is a clear reduction in chlorophyll levels with an increase of salt. This is in part due to osmosis, as the water from the plant gets ‘sucked’ out. This lack of water results in the stomata to close, severely limiting the Carbon Dioxide (CO2) intake in the plant. The new CO2 concentration directly affects photosynthesis as CO2 is used in the photosynthesis reaction.

As seen on Figure 3, plant height decreases with higher salt concentrations. This is due to what’s called the water-deficit effect of salinity, and the ion-excess effect of salinity. The water-deficit effect refers to a plant’s inability to absorb water, whilst the ion-excess effect is when an excess of salt enters the transpiration stream, damaging transpiring leaves. A plant’s inability to absorb water results in a low absorption of minerals and decreased transpiration, causing the plant cells to not remain firm, and thus wilt. Wilting is then what causes the damaging of transpiring leaves.

Figure 4 reflects the decrease in biomass. The amount of biomass grown in a community reflects the overall productivity of that community, and hence it's a good indicator of overall plant health.

Figure 5 shows physical observations of the lab grown roots. The trend that's seen is that the plants with a lower amount of salt has thick, white, primary roots followed by many lateral roots, compared to plants with more salt which have thin, brownish, primary roots with very little lateral roots(and roots hairs). The strength of these roots is important, as it determines nutrient and water absorption, on top of surviving erosion.

Looking at Figure 6, it's seen that there is a steady increase of road salt concentrations the closer you get to the road. Then, using this data, figure 7 shows the effects of these concentrations. It's seen that plant abundance and thickness progressively increases from right to left. Additionally, it's observed that Perennial Ryegrass is more tolerant to road salt compared to Crabgrass(Perennial Ryegrass is not completely decimated in the highest concentration)

Conclusion

The trends in the lab, as talked about in the discussion, create a clear connection between road salt and its effects on plants. There were four clear properties that decreased as the amount of salt increased: chlorophyll, plant height, biomass, and root development. Individually, each one of these properties shows if a plant is healthy or not, and with all four properties being inhibited by salt, the cruciality of reducing salt use is of utmost importance.

So, based off of the trends, the hypothesis was proven. The chlorophyll levels of Perennial Ryegrass(a prevalent plant throughout the field), was reduced by .3(nm) from 10m away from the road, to 20m away from the road. Also, plant height was severely reduced in both lab-grown plants, but Crabgrass was especially vulnerable. When it had 5000 microsiemens(µs) of salt(the highest amount of salt seen) diluted into its water, the plant's peak height differed from the control's peak height by 21.3mm. This is compared to Perennial Ryegrass's difference in height, which was 9.8mm, signalling that Perennial Ryegrass is more tolerant to salt than its counterpart. Further, biomass followed the same trend of the plant's heights. Perennial Ryegrass's biomass differed by .3g from the control to the estimated amount of salt(1000µs), and .12g from the control to the high amount of salt(5000µs).Crabgrass differed by .3g as well from the control to the estimated;however, there wasn't enough plant material to record the biomass of the plant in the high amount of salt. Lastly, root development was more accentuated in both grass species with no salt. This is seen through multiple observations, with the trend being that the control had long, white(symbolizes a young/healthy plant), and thick primary roots, with many lateral roots attached, compared to the estimated plants which had thinner and grayish roots, followed by a fewer number of lateral roots. The plants that endured the highest amounts of salt had brown,(signifying old roots)thin, primary roots with very few lateral roots and their subsequent hairs.

During the experiment, a few major things went wrong. The first main issue was overlooking how much water would rise during the winter on the field. During the summer, there was no water, allowing for easy setup of the weather station;however, as water filled the field in the winter, it became difficult to walk to the station. Additionally, insulation was wrapped around the rain gauge to aid in the melting of snow. Unfortunately, this added insulation acted as a mast, causing the station to fall over. This crippled the rain gauge's heating system, as well as making it nigh impossible to set up again. So, the lab is lacking atmospheric data as originally planned. Another mistake in experimentation was putting rope around the conductivity autologger. As the water froze and unfroze, the rope was being destroyed;thus, when trying to retrieve the loggers, we were met with a broken rope in the water.

Further Investigation

Additional research may be completed to better identify the influx of road salt into lotic ecosystems, and then identify indicator species in the river. This will provide stronger data and better pinpoint the effects of road salt on lotic ecosystems, something that was strongly missed in the research.

A secondary study may also be conducted. The study would recognize and test potential substitutes for salt. This would be done by doing something very similar to what was done in this investigation: using lab grown plants to test the effects of various snow melting alternatives.

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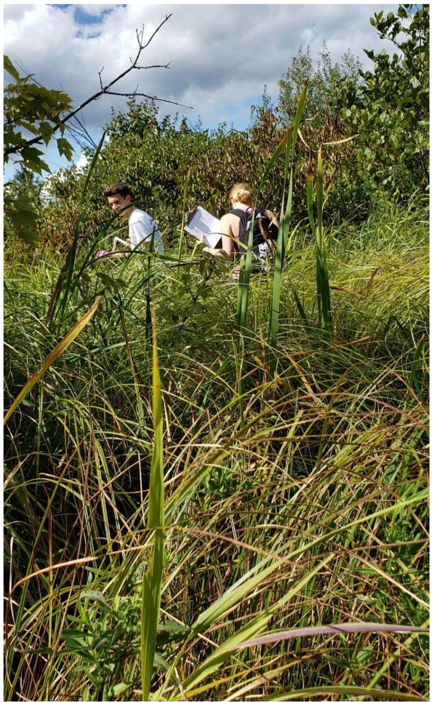
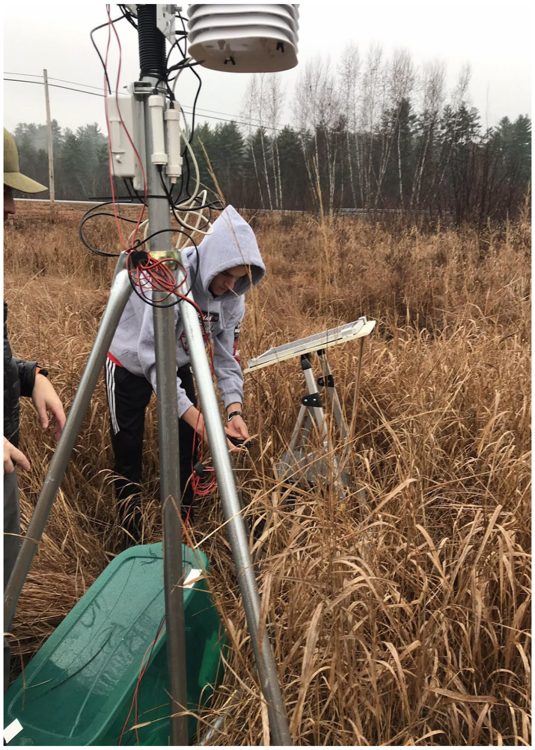
Photos






GRANT STUFF


Ryegrass
control
Crabgass
Ryegrass
estimated
crab grass
Ryegrass
high
Grab grass