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Air pollution and light exposure: lichen species richness, abundance, and diversity in San Luis, Costa Rica

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ABSTRACT

Lichens are a unique and diverse group of organisms that can be bioindicators of atmospheric pollution. In this study, the effects of atmospheric pollution on lichen abundance, richness, and diversity were determined for lichens growing on rocks and fence posts in San Luis, Costa Rica. Lichens growing on rocks from a secondary forest were subjected to large amounts of ATV exhaust, and the effects of the exhaust on the lichens were observed over 22 days. Lichen species richness and abundance were quantified on fence posts along two sections of dirt road: one with high vehicle traffic and one low. Additionally, canopy cover was determined for these fence posts in order to observe the effects of light exposure on lichen species richness, diversity, and abundance. Atmospheric pollution from vehicle exhaust and/or dust negatively impacted lichen species richness, diversity, and abundance. The mean Simpson Diversity Index was 0.33 +/- 0.28 for posts along the main road with more traffic and 0.48 +/- 0.21 for the side road. Mean percent total lichen cover and species richness were also higher for the side road than the main road. In addition, Lichen species richness, diversity, and abundance decreased as sun exposure increased. Four lichen species were correctly identified on the fence posts, and *Heterodermia* species 1 and *Coccocarpia* species 1 had the biggest percent area difference between main and side road fence posts (both 160% higher on the side road), and are therefore better bioindicators of atmospheric pollution than the other two species. These results suggest important implications for determining the sensitivity of specific lichen species to air pollution so that they can one day be used to determine the air quality of a specific region and current air quality monitoring techniques can be improved.

RESUMEN

Los líquenes son únicos y un grupo diverso de organismos que pueden ser bioindicadores de contaminación atmosférica. En este estudio, los efectos de la contaminación atmosférica en la abundancia, riqueza de especies y diversidad de líquenes se determino, para líquenes que crecen en rocas y postes de cercas en San Luis, Costa Rica. Líquenes que crecen en rocas de un bosque secundario fueron sometidas a grandes cantidades de humo producido por un cuadracíclo, y los efectos del humo en los líquenes se observaron por 22 días. La riqueza y abundancia de líquenes en postes de cercas fueron cuantificados a lo largo de dos secciones de un camino de lastre: uno con un alto tránsito vehicular y el otro con bajo. Adicionalmente, la cobertura de dosel se determinó para estos postes para observar el efecto de la exposición a la luz en la abundancia, diversidad y riqueza de especies. La contaminación atmosférica producida por vehículos o polvo impacta negativamente la abundancia, diversidad y riqueza de especies de los líquenes. El promedio del índice de diversidad de Simpson fue 0.33 +/- 0.28 para parches en el camino con mayor tránsito y de 0.48 +/- 0.21para el lado del camino. El porcentaje promedio de la cobertura total de líquenes y la riqueza de especies fue también significativamente mayor en el camino lateral que en el principal. Además, tanto la riqueza de especies como la diversidad y abundancia disminuye con la exposición al sol. Cuatro especies fueron correctamente identificados en los postes de cercas, y *Heterodermia* y *Coccocarpia* tienen el mayor porcentaje de diferencia en el área entre el camino principal y el lateral (ambos 160% mayor en el camino lateral), y son por lo tanto mejores bioindicadores de la contaminación atmosférica que las otras dos especies. Estos resultados sugieren implicaciones importantes para determinar la sensibilidad específica de ciertas especies de líquenes hacia la contaminación atmosférica de manera que estas puedan ser utilizadas algún día para determinar la calidad del aire de una región específica así como para mejorar las técnicas utilizadas hoy en día.

INTRODUCTION

Atmospheric pollution continues to be a major health threat around the world, especially in developing countries where air standards are less rigorous and the burning of fossil fuels is on the rise (Loomis 1999). Though negative impacts from pollution in urban areas are substantial, air pollution from farm machinery and cars can be significant in rural areas as well (McCarthy 2009). In addition, rural areas lack sophisticated air quality monitoring equipment (McCarthy 2009), therefore, in these areas bioindicators may be the best way of monitoring air quality (Conti and Checchetti 2000). Sulfur dioxide, a common gas found in most engine exhaust, is particularly harmful to lichens (Conti and Checchetti 2000). As lichens are exposed to more sulfur dioxide, the structures of chloroplasts are damaged within the plant cells, and photosynthesis rates decrease substantially (Tarhanen 2000). Air pollution can also cause a decrease in ATP production, respiration level change, as well as membrane damage within lichens (Conti and Checchetti 2000). Therefore, lichens may be useful tools in assessing air quality in rural landscapes of developing countries.

More than 20,000 species of lichens have been identified, and they are divided into three different forms: foliose, fruticose, and crustose (Umana 2002 and Graziano 2010). Lichens do not have roots, and since they often inhabit nutrient-poor areas, they must obtain nutrients, minerals, and water from the atmosphere. As a result, water and air pollution negatively affects lichens (Conti and Checchetti 2000). While all three forms of lichens (foliose, fruticose, and crustose) are negatively affected by sulfur dioxide, crustose forms are most resistant due to the fact that they have lower rates of photosynthesis (Purvis 2000).

Due to the limited knowledge of tropical lichen species and their ecology and community structure, lichen use as bioindicators in tropical countries has been hampered (Worseley 1991). In San Luis, Costa Rica, a rural area of coffee and dairy, the richness and abundance of lichens was found to be greater on the back sides of trees that were facing away from roads (Toy 2005). Also, trees that were further away from the road had greater richness and abundance than those that were closer (Toy 2005). In addition to pollution studies, Esseen and Renhorn (1998) found that there was a lower abundance of lichens along the forest edge than in the forest, signifying that lichens prefer a specific amount of sunlight. These studies, however, did not determine the relative sensitivities of specific lichen species to air pollution or light abundance.

San Luis, Costa Rica provides an excellent opportunity to determine the relative resistance of different lichen species to air pollution, since there may be more than 20 species in one area of forest (Hosford 2005). I propose to study the relative resistance to atmospheric pollution of different species of lichens that commonly inhabit rocks found in a secondary forest in San Luis. Since the source of air pollutants (like sulfur dioxide) in San Luis is from vehicular exhaust, I will subject the rocks to a large amount of ATV exhaust and observe how the lichens growing on the rocks change in a short amount of time (22 days). In addition, I will study the species richness and abundance of lichens on fence posts along dirt roads in San Luis. Fence posts are often closer to the road than trees and they have a different surface texture than tree bark, so the influence of vehicle exhaust and/or dust may have a pronounced impact on the lichens there.

I will also determine the effect that overhead cover has on lichen species richness, abundance, and diversity in order to determine whether lichens grow better on fence posts when they are exposed to more or less sunlight. In order for lichens to be successfully used as bioindicators, their preference for abiotic factors such as sunlight must be considered and studied as well. The effects that abiotic factors have on specific lichen species can have just as great of an impact as atmospheric pollution, so factors such as sunlight abundance must be studied in more detail in addition to pollution effects.

MATERIALS AND METHODS

Study Site

San Luis, Costa Rica is a fragmented Premontane Wet Forest at 1200 meters. Although most of the forest was replaced by coffee and dairy 60 years ago, some windbreaks and secondary forests remain. The area consists of many family farms of approximately 4-10 hectares. The ownership of vehicles in San Luis has increased due to the affluence from tourism in nearby Monteverde, and vehicular traffic on the area's main road has increased. The roads in San Luis are unpaved and can be dusty, and even a few cars can send dust into the air that lingers for several minutes. While this effect is less pronounced on side roads, dust generated from vehicles is deposited on plants and fence posts lining the road. This dust is harmful to plants and can also negatively impact human health. Fence posts were sampled from two locations along dirt roads in San Luis. The first section was along the main road, before La Trocha and up to the Pulperia. The second section was between the Pulperia and the University of Georgia station on a side road. The first section had more vehicle traffic than the second section. Vehicles travel along the main road at the rate of approximately one vehicle every 5 minutes, and along the side road at one vehicle every 45 minutes.

Experiment 1: Effects of ATV exhaust on lichens growing on rocks

Thirty rocks were chosen from a secondary forest in San Luis that were between 15 and 30 cm in diameter. They were collected from an area that had about 80% canopy cover and was approximately 17°C. The rocks chosen all had similar lichen species growing on them since they were all collected from the same location within the forest. Photographs and initial observations (lichen diameter, appearance, surface texture, and species composition) were taken of the 30 rocks. Ten rocks were placed in ten large plastic bags (one rock per bag) and tied air-tight. When the bags were tied, the air that was in the bag while it was open remained inside so that each bag was about half-filled with outside air when it was tied. These bags were placed on the ground in the same secondary forest as they were originally found, and placed in a location that had 80% overhead cover and was about 17°C. Ten more rocks were not placed in plastic bags, but rather set next to the other ten rocks in bags and left out in the open (the control). The remaining ten rocks were placed in ten bags (one rock per bag) and used for the pollution trials.

An ATV was used as the pollution source. The opening of one bag (with one rock inside) was placed over the exhaust pipe of the ATV, and the ATV was revved so that exhaust entered the bag. After 10 seconds, the bag was quickly tied air tight (the bag was about half-filled with the exhaust), and the ATV was shut off. This process was repeated for the remaining nine bags. These 10 bags containing exhaust were set next to the other 20 rocks in the secondary forest.

The 20 bags were refilled with either exhaust or fresh air (the latter was accomplished by opening the bag, shaking it out, letting outside air enter, and re-tying the bag) every two days, and this process was continued for 22 days total. Once a week new observations (lichen appearance, diameter, and surface texture) were noted and photographs were taken of the lichens.

Experiment 2: Effects of vehicle traffic and overhead cover on lichens growing on fence posts

Fence posts sampled were within one to three meters from the edge of the road. Straight wooden posts were sampled, and all posts that were sampled had no paint, were at least one meter tall and eight centimeters wide, and had a flat section that was facing the road. All posts were old, showing definite signs of exposure. A 16 x 21 cm transparent grid was placed over the flat section (the side facing the road) and the grid was placed in the middle of each post. The post width and area occupied by each lichen species within the grid was recorded. Lichens were categorized into species based on physical appearance, and lichen species were later identified by a lichen expert based on photographs taken of each species on the fence posts.

Percent overhead cover was recorded for each post based on the vegetation cover above the post (ex. tree cover) and estimating the amount of sun that the flat side receives throughout the day. This was determined based on the sunrise and sunset location and estimating how overhead vegetation cover influences the amount of sunlight hitting the flat side of the fence posts. Along the main road (most vehicle traffic), 58 posts were sampled, and along the side road, 67 posts were sampled.

RESULTS

Experiment 1: Effects of ATV exhaust on lichens growing on rocks

Air pollution from ATV exhaust had a significant effect on lichens growing on rocks (One Way ANOVA, F =11.895, df =30 , $p < 0.0002$). The edges of the lichens that were effected turned white (Figure 1), and after 22 days, seven out of the ten rocks that were exposed to exhaust had visible changes. All of the 20 rocks that weren't exposed to pollution showed no visible changes. The mean edge change for the rocks subjected to pollution was 7.8 mm (+/- 7.1), while for the rocks kept in a bag and subjected to normal air it was just 0.1 mm (+/- 0.3) and for the rocks left out in the open it was zero (Figure 2). There was a significant difference between the mean lichen edge change for the rocks that were exposed to pollution and those that were not (Tukey's HSD, $p < 0.05$). Two lichen species were observed on all 30 rocks, *Crptothecia* species 1 and species 2 (see Appendix 1), and only *Crptothecia* species 1 showed visible effects from pollution.

FIGURE 1. Visible edge change of *Crptothecia* species 1 on one rock subjected to ATV pollution in rural San Luis, Costa Rica. The photo on the left shows the rock at the beginning of the experiment (no pollution exposure) and the photo on the right is the same rock 22 days later after it had been exposed to repeated pollution. The visible edge change can be observed on the two large lichens on the right. Eight millimeters of the radius of one lichen turned white, while ten mm of the other lichen turned white. The moss on the other parts of the rock was also influenced by pollution exposure, but was not studied in this experiment.

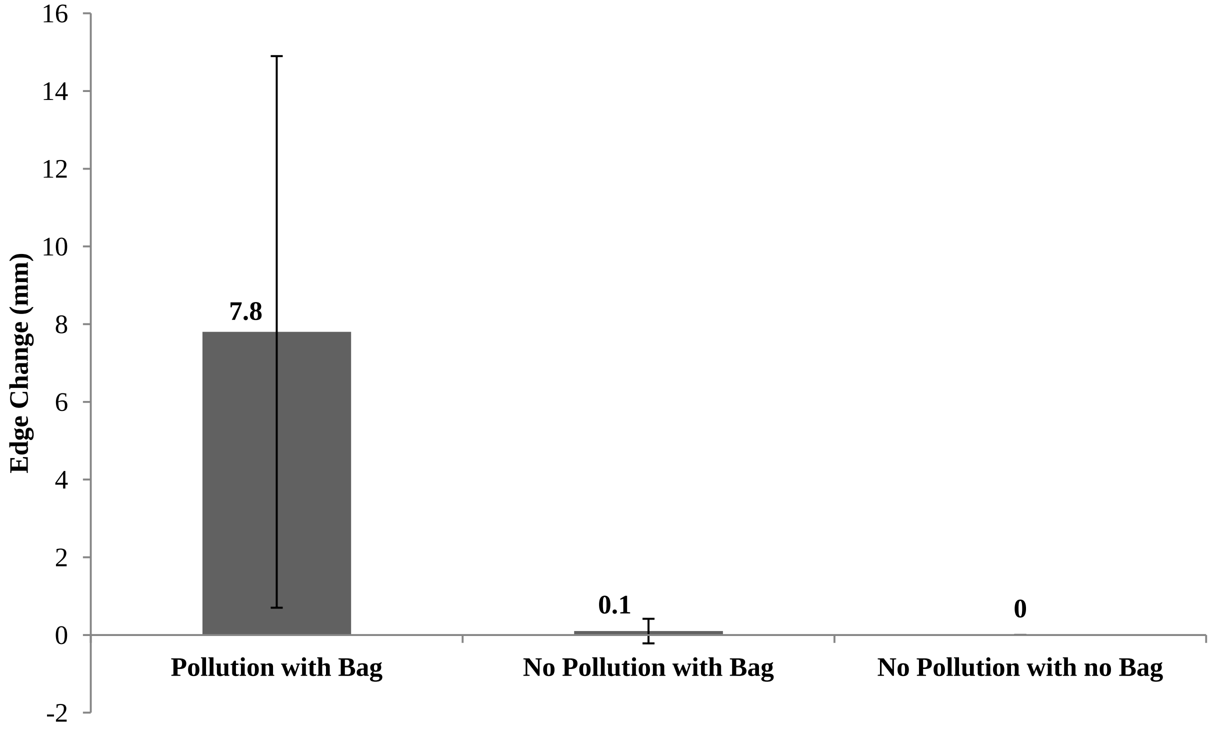

FIGURE 2. Mean lichen edge change observed on rocks in rural San Luis, Costa Rica. Ten rocks were exposed to ATV exhaust while the other 20 rocks were not exposed to pollution. Ten of these 20 rocks were kept in a plastic bag that was re-filled with fresh air at the same time as the other 10 bags were filled with exhaust. The remaining ten rocks were not kept in bags, but left out in the open. All rocks were placed in the understory of a secondary forest similar to where they were found. The number over the bars indicate the mean change observed. The lichens on the rocks that were exposed to pollution were significantly affected by the pollution and had the highest edge change observed (mean +/- SD = 7.8 mm +/- 7.1) (One Way ANOVA, F =11.895, df =30 , $p < 0.0002$).

Experiment 2: Effects of vehicle traffic and overhead cover on lichens growing on fence posts

The abundance of individual lichen species varied depending on whether the posts were along the main or side road, however, only four out of 13 lichen species were able to be correctly identified by a lichen expert. The remaining nine species were either unidentifiable or may have been incorrectly grouped as a species. All four species occupied more percent area on the fence posts that were along the side road than the main road (Table 1). However, three of the lichen species that were correctly identified (*Heterodermia* sp. 1, *Coccocarpia* sp. 1, and *Thelotrema* sp. 1) occupied significantly more area on the fence posts that were along the side road rather than the main road, while Lecanoraceae family species 1 showed very little difference (Table 1).

All four lichen species identified were present along the main and side road fence posts, however, *Heterodermia* sp. 1 and *Coccocarpia* sp. 1 had the highest percent difference of 160% between the main and side roads, while the other two species had the lowest percent difference (Figure 3). Overhead cover did not have significant impact on the average area occupied by these four species.

TABLE 1. Average area of lichen species on fence posts in San Luis. Lichen species abundance was determined using a 16 x 21 cm transparent grid that was placed over the flat sections of sampled fence posts. Area occupied by individual species was averaged for the posts along the road that receives more vehicle traffic (main road) and less traffic (side road). Along the main road, 58 posts were sampled, and along the side road, 67 posts were sampled.

	Main Road (cm^2)	Side Road (cm^2)
Lecanoraceae familiy sp. 1	14.37	15
Heterodermia sp. 1	2.67	6.92
Coccocarpia sp. 1	4.32	11.25
Thelotrema sp. 1	8.56	12.2

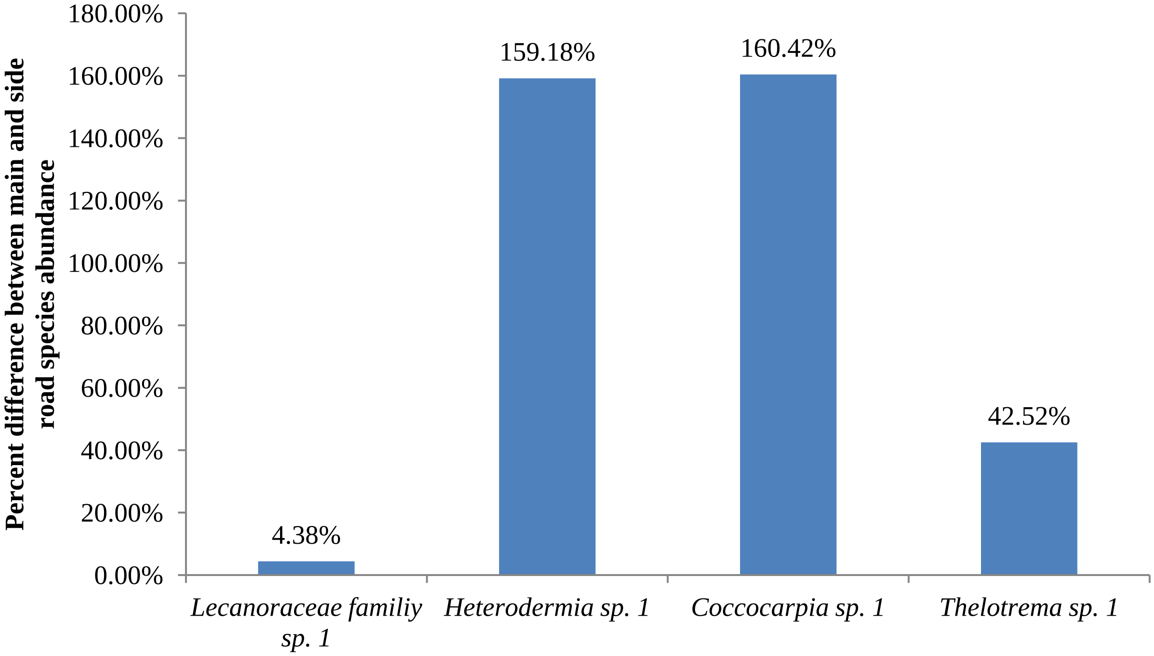

FIGURE 3. Percent difference between lichen species abundance along main and side road fence posts in rural San Luis, Costa Rica. The flat sections of fence posts facing the road were sampled, and species abundance was determined using a 16 x 21 cm transparent grid. The fence posts were sampled along the main road in San Luis from La Trocha to the Pulperia and along a side road from the Pulperia to the Georgia Station. 58 posts were sampled along the main road, and 67 posts were sampled along the side road. The abundance of the four identified lichen species was averaged for the main and side road fence posts, and the percent difference between main and side road abundance was determined. *Heterodermia* sp. 1 and *Coccocarpia* sp. 1 had the highest percent difference out of the four species.

Being on the main road had a significant impact on fence post lichen cover compared to posts on the secondary road (*t*-test, df = 123, *t* = -2.80, *P* = 0.003. The mean percent total lichen cover was highest for fence posts that were along the side road in San Luis that recieves less vehicle traffic (from the Pulperia to the Georgia Station) (Figure 4). The mean percent fence post cover was 15.4% (+/- 14.2%) for the busier road (La Trocha to the Pulperia) and 23.1 (+/- 16.2%) for the side road (Figure 4). In addition, percent lichen cover on fence posts was significantly affected by canopy cover (Regression, $R^2 = 0.12$, p = 7.93E-05, n = 125). As the percent overhead cover increased and the lichens on fence posts were exposed to less light throughout the day, the percent total lichen cover decreased (Figure 5).

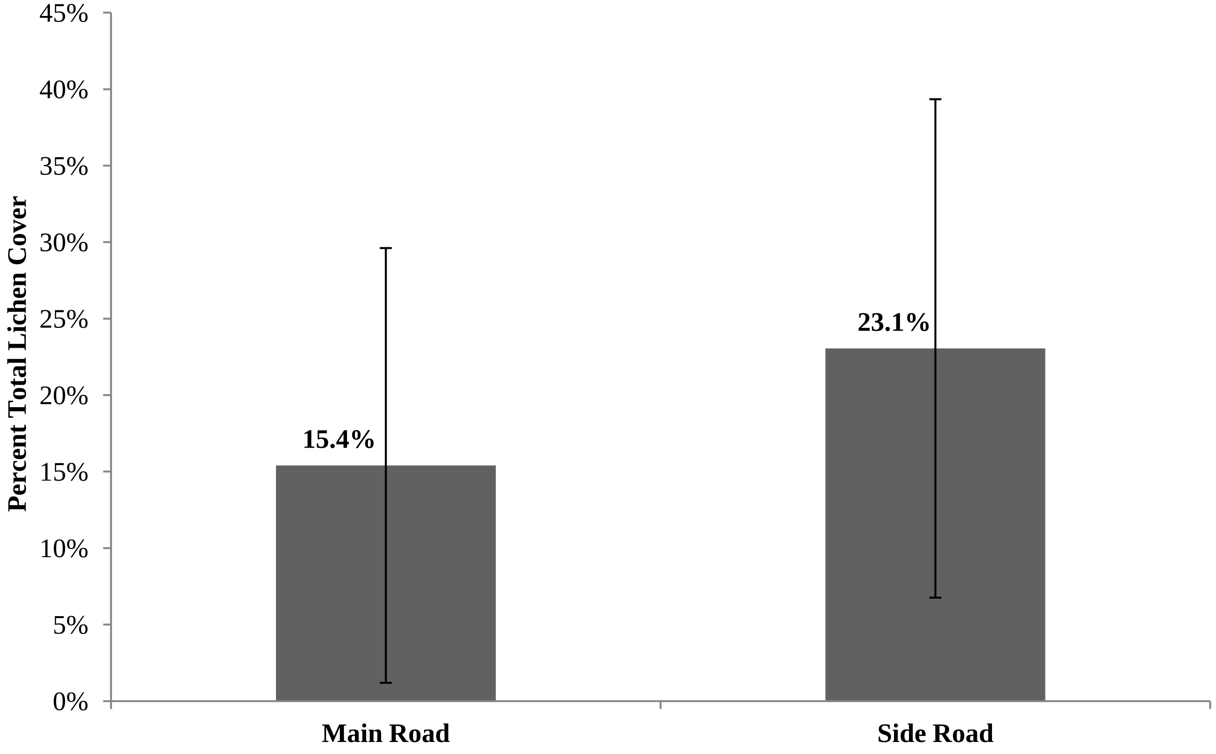

FIGURE 4. Mean percent total lichen cover for fence posts along the main and side road in rural San Luis, Costa Rica. The flat sections of fence posts facing the road were sampled, and percent area was determined using a 16 x 21 cm transparent grid. The fence posts were sampled along the main road in San Luis from La Trocha to the Pulperia and along a side road from the Pulperia to the Georgia Station. Along the main road, 58 posts were sampled, and along the side road, 67 posts were sampled. The mean percent total lichen cover on fence posts was highest along the side road (mean +/- SD = 23.1% +/- 16.2%) (*t*-test, df = 123, *t* = -2.80, *P* = 0.003).

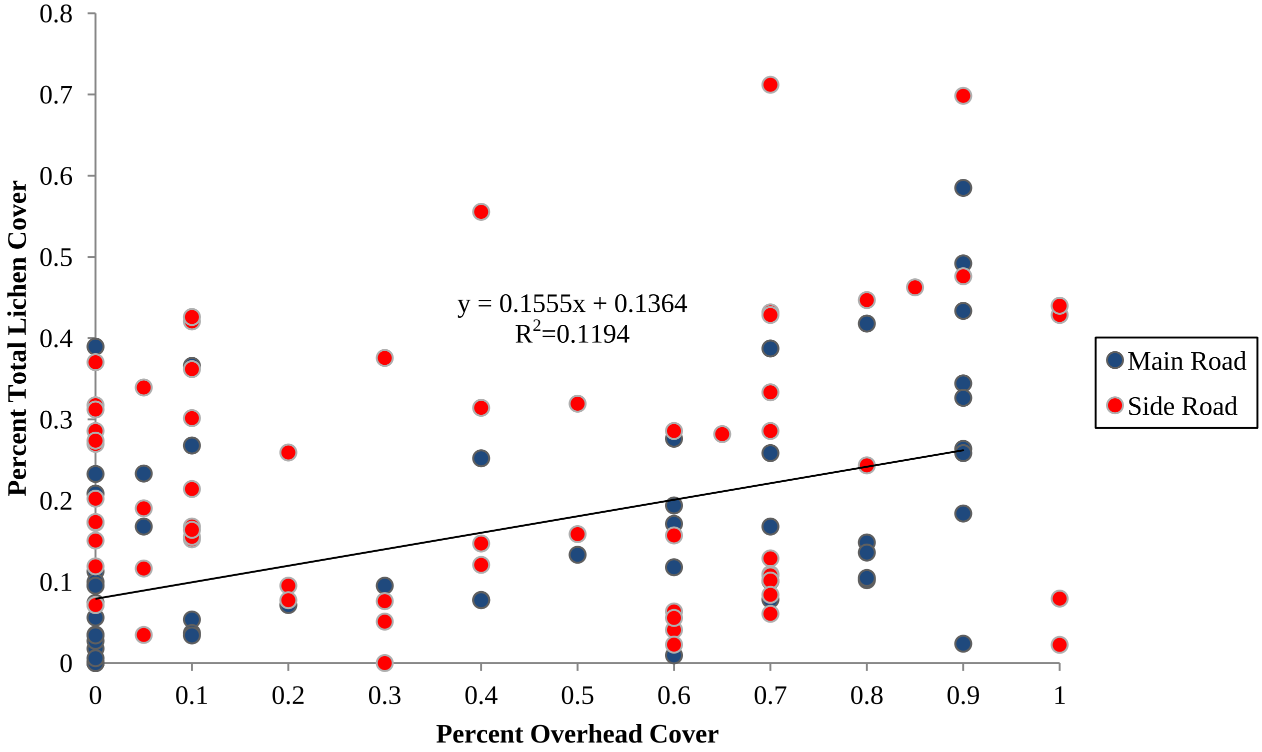

FIGURE 5. Change in percent total lichen cover on fence posts with varying canopy cover. Percent total lichen cover was determined for each fence post using a 16 x 21 cm transparent grid. The Along the main road, 58 posts were sampled, and along the side road, 67 posts were sampled. Percent overhead cover was determined using the sunrise/sunset location, overhead vegetation, and estimating the amount of sunlight the flat side of the fence post recieves throughout the day. As percent overhead cover increased, percent total lichen cover on the fence posts increased as well (Regression, $R^2 = 0.12$, p = 7.93E-05, n = 125).

Road location had a significant impact on the lichen species richness of the fence posts along the road (*t*-test, $R^2 = 0.051$, p = 0.01, n = 125). Percent overhead cover also had a significant impact on lichen species richness (Regression, $R^2 = 0.062$, p = 0.005, n = 125). As percent overhead cover increased and the lichens were exposed to more sun throughout the day, lichen species richness on the fence posts increased as well (Figure 6). Lichen species richness was higher along the side road (the Pulperia to the Georgia Station) that receives less vehicle traffic than the main road (La Trocha to the Pulperia) (Figure 7). There was an average of 0.63 more lichen species within the 16 x 21 cm transparent grid on the side road fence posts than the main road fence posts (Figure 7).

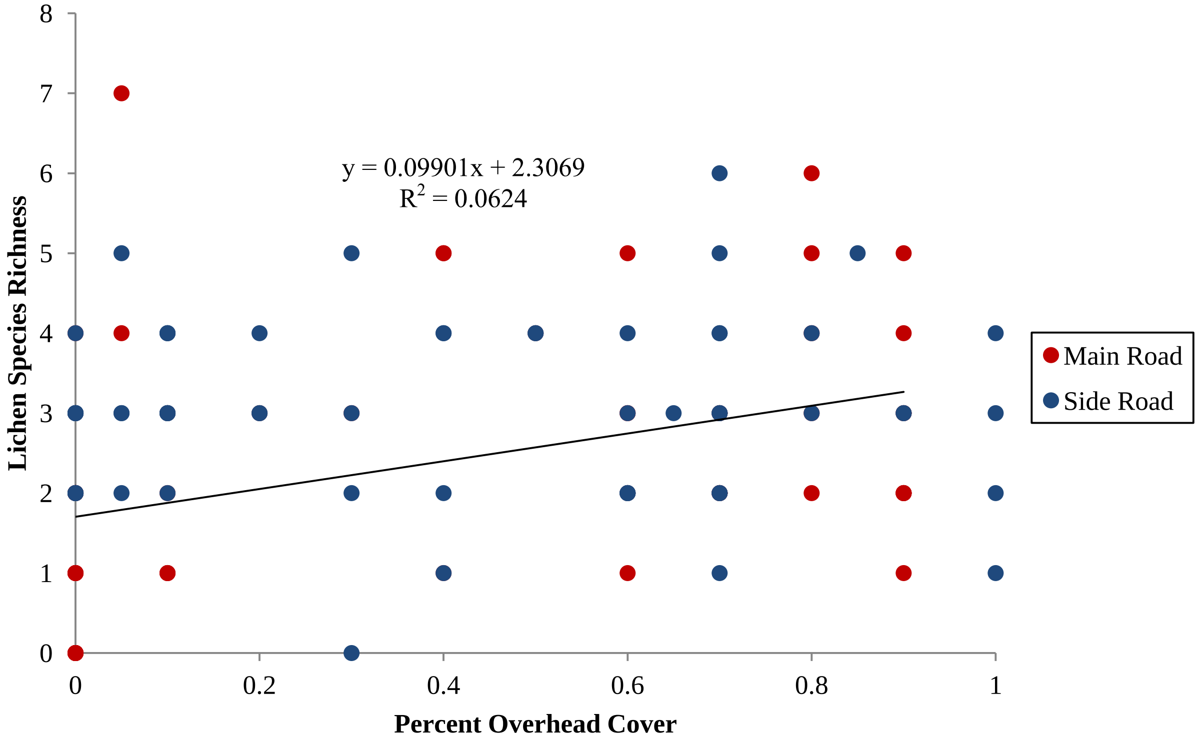

FIGURE 6. Lichen species richness on fence posts with varying percent overhead cover. Lichen species richness was determined for each fence post using a 16 x 21 cm transparent grid. Along the main road, 58 posts were sampled, and along the side road, 67 posts were sampled. Percent overhead cover was determined using the sunrise/sunset location, overhead vegetation, and estimating the amount of light the flat side of the fence post recieves throughout the day. As percent overhead cover increased, lichen species richness increased as well (Regression, $R^2 = 0.062$, $p = 0.005$, $n = 125$).

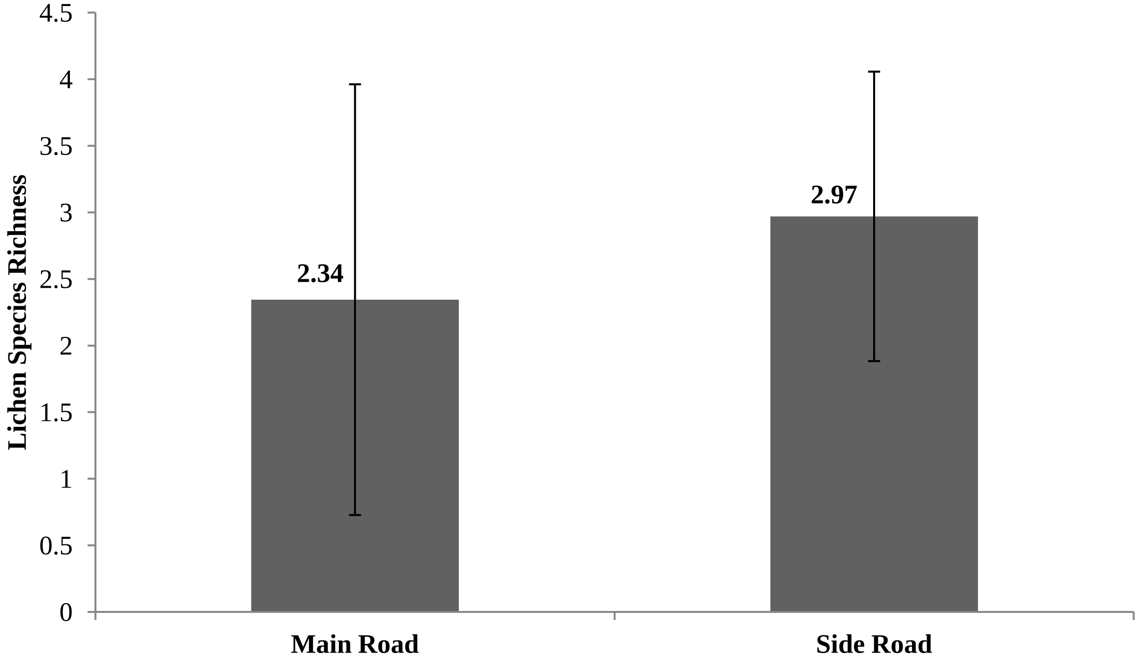

FIGURE 7. Mean lichen species richness on fence posts along the main and side road in San Luis. The flat sections of fence posts facing the road were sampled, and lichen species richness was determined using a 16 x 21 cm transparent grid. The fence posts were sampled along the main road in San Luis from La Trocha to the Pulperia and along a side road from the Pulperia to the Georgia Station. Along the main road, 58 posts were sampled, and along the side road, 67 posts were sampled. The fence posts along the side road had a higher lichen species richness than those along the main road (Regression, $R^2 = 0.051$, $p = 0.01$, $n = 125$).

Road location had a significnat impact on the Simpson Diversity Index of the fence posts sampled (Regression, $R^2 = 0.088$, $p = 0.0008$, $n = 125$). The average index value for fence posts along the side road from the Pulperia to the Georgia Station was 0.48 +/- 0.21, which was higher than the average index value for fence posts along the main road (0.33 +/- 0.28) (Figure 8). In addition, the Simpson Diversity Index for lichens on fence posts was significantly affected by the percent overhead cover (Regression, $R^2 = 0.036$, $p = 0.03$, $n = 125$). As percent overhead cover increased and the lichens were exposed to more sunlight throughout the day, the Simpson Diversity Index for the fence posts increased as well (Figure 9).

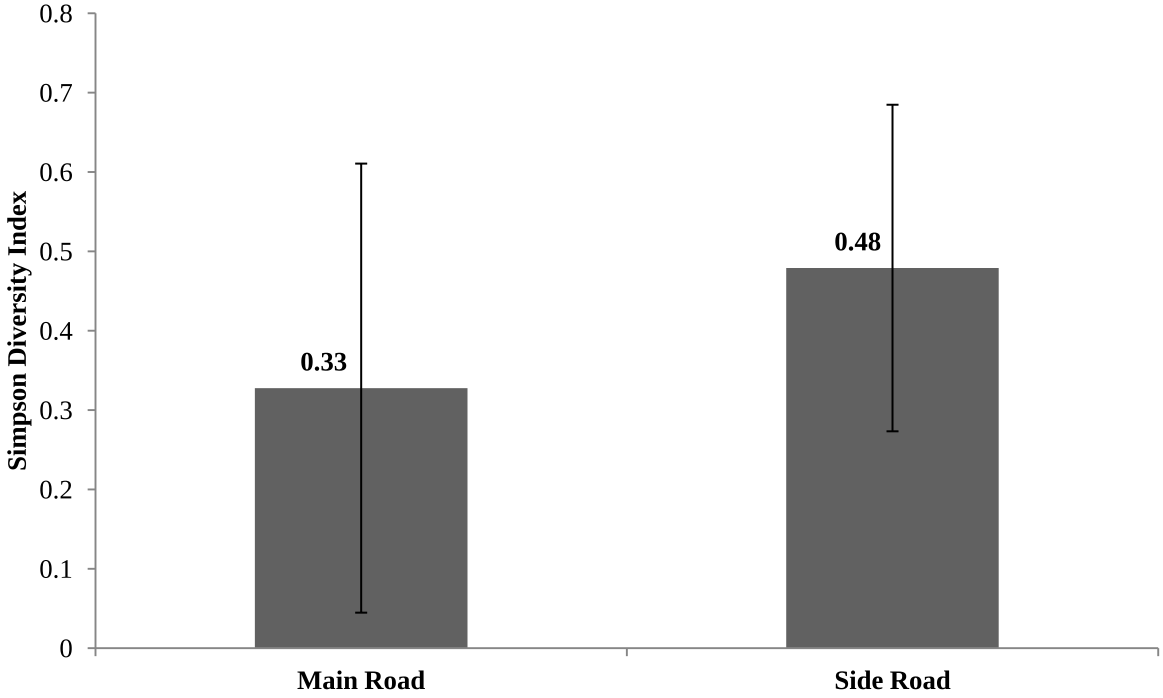

FIGURE 8. Mean Simpson Diversity Index for fence posts along the main road and side road in San Luis. The flat middle sections of fence posts facing the road were sampled, and the percent lichen cover of each species was determined using a 16 x 21 cm transparent grid. The fence posts were sampled along the main road in San Luis from La Trocha to the Pulperia and along a side road from the Pulperia to the Georgia Station. The Along the main road, 58 posts were sampled, and along the side road, 67 posts were sampled. The mean Simpson Diversity Index was higher for fence posts along the side road (Regression, $R^2 = 0.088$, $p = 0.0008$, $n = 125$). The higher the value of the Simpson Diversity Index, the greater the diversity is. The Simpson Diversity Index was calculated using the equation $S=1-(\Sigma n_i(n_i-1)/N(N-1))$, where n_i is the number of individuals of one species, and N is the total number of individuals counted on that fence post.

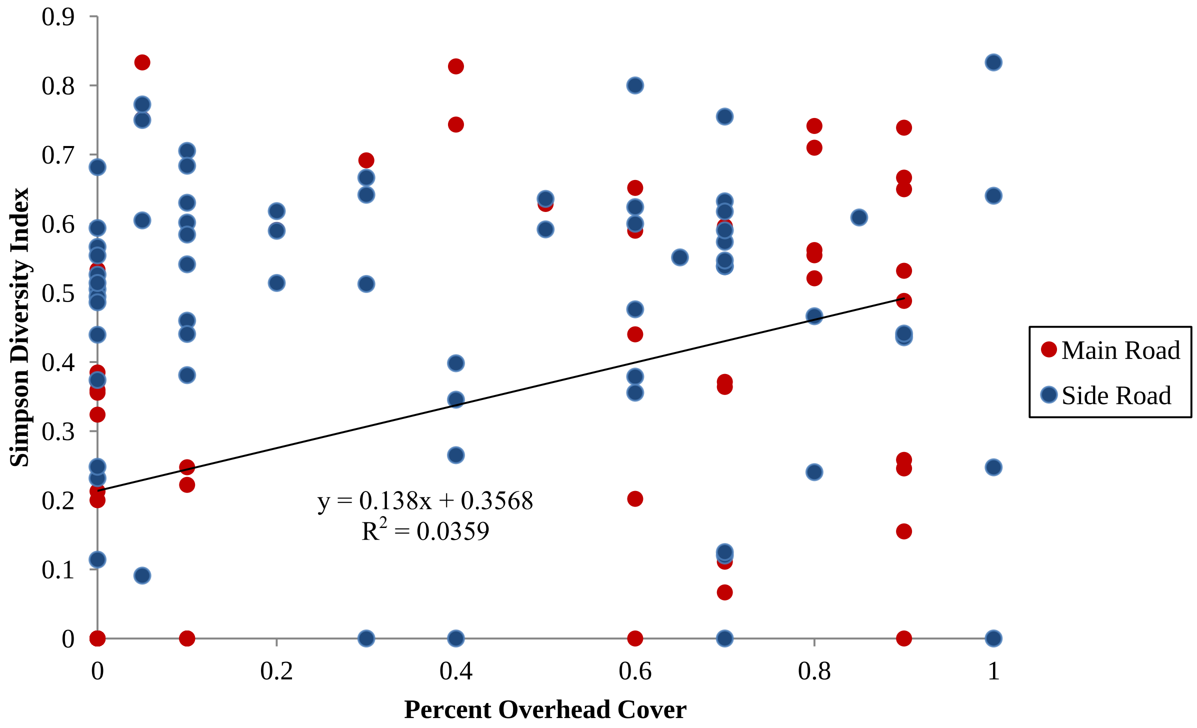

FIGURE 9. Simpson Diversity Index for lichens on fence posts in San Luis with varying percent overhead cover. The flat middle sections of fence posts facing the road were sampled, and the number of lichen species was determined using a 16 x 21 cm transparent grid. Along the main road, 58 posts were sampled, and along the side road, 67 posts were sampled. Percent overhead cover was determined using the sunrise/sunset location, overhead vegetation, and estimating the amount of light the flat side of the fence post recieves throughout the day. The Simpson Diversity Index was calculated using the equation $S=1-(\Sigma n_i(n_i-1)/N(N-1))$, where n_i is the number of individuals of one species, and N is the total number of individuals counted on that fence post. The higher the value of the Simpson Diversity Index, the greater the diversity is. As percent overhead cover increased, the average Simpson Diversity Index increased as well (Regression, $R^2 = 0.036$, $p = 0.03$, $n = 125$).

DISCUSSION

Atmospheric pollution has a negative impact on some lichens (Conti and Checchetti 2000), and in this experiment, it was observed that certain species of lichens growing on rocks and fence posts were negatively affected by ATV exhaust or location, and hence by pollution and/or dust. When lichens growing on rocks were exposed to large amounts of ATV exhaust, significant changes were observed in one lichen species' (*Crptothecia* species 1) appearance. On seven out of the ten rocks, this lichen species showed an increase in white area, most likely due to the damage of photosynthetic material (chloroplasts) caused by the sulfur dioxide in the exhaust (Tarhanen 2000). Since the rocks were not wetted throughout the experiment, it is possible that some of the lichen change observed may have been due to drying out. This, however, is not likely to have made a significant difference since the rocks that were not exposed to pollution showed no visible changes from drying out.

Although crustose forms of lichens are more resistant to atmospheric pollution than foliose or fruticose forms (Purvis, 2000), one *Crptothecia* species (a crustose form) was negatively affected by the exhaust on most of the rocks. The second *Crptothecia* species was unaffected, and this suggests that even certain crustose lichen species can be better bioindicators of pollution than other crustose species. In this case, *Crptothecia* species 1 is a better bioindicator than *Crptothecia* species 2. Unfortunately rocks were not found that had foliose or fruticose lichen species growing on them for comparison.

Even though San Luis, Costa Rica does not have high amounts of atmospheric pollution from vehicular exhaust compared to larger urban areas, lichens were still observed to be negatively affected if they grew along the main road that receives more traffic. Air pollution and/or dust had a negative impact on percent total cover, species richness, and diversity on lichens growing on fence posts. Although only four lichen species could be correctly identified that grew on the fence posts, all species occupied more area on the posts along the side road. *Heterodermia* species 1 and *Coccocarpia* species 1 had the greatest percent difference between average area occupied on the main road and side road fence posts, and this suggests that these two species are more negatively affected by vehicle exhaust and/or dust. Therefore, these two species would be better bioindicators than Lecanoraceae family species 1 and *Thelotrema* species 1. While in the future it would be uesful to determine the relative sensitivities of more lichen species, this experiment suggests that *Heterodermia* species 1 and *Coccocarpia* species 1 have the potential to be good bioindicators of atmospheric pollution.

It is difficult to know whether the lichen species in San Luis were negatively affected by the vehicle exhaust or by the dust created from the vehicles. The exhaust seems to be the likely culprit, since any dust accumulation on the lichens would most likely be washed off by the rain. This may not be the case, however, during periods where it rains a lot, such as during the wet season.

Lichens were also observed to be more negatively impacted by higher amounts of sun exposure. As the percent overhead cover decreased, percent total lichen cover, lichen richness, and diversity decreased as well. This may be due to the increased desiccation potential when the lichens receive more sun. Also, unlike other surfaces (such as tree bark), fence posts most likely do not retain as much moisture since they have smoother surfaces. These factors, combined with sunlight, may create an environment for the lichens where desiccation is a problem.

In this experiment, it was determined that many lichen species are negatively affected by atmospheric pollution. In particular, *Heterodermia* species 1 and *Coccocarpia* species 1 have the potential to be good bioindicators, as well as possibly *Crptothecia* species 1 (even though it is a crustose form). The amount of pollution exposure has a drastic effect on lichens, as does the amount of sunlight they receive. It is clear that lichens prefer environments that have good air quality and little sunlight exposure. This study provides a foundation for further experiments to determine the relative sensitivity of a wide variety of lichen species, possibly including the species identified in this study. These lichen species can then potentially be used in order to accurately determine the air quality of a specific region, including rural areas in developing countries where atmospheric pollution may be a problem. When air pollution is accurately quantified, steps can then be taken in order to improve air quality.

ACKNOWLEDGMENTS

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APPENDIX 1

***Crptothecia* sp. 1**

***Crptothecia* sp. 1 & 2**

***Dictyonema* sp. 1**

***Thelotrema* sp. 1**

***Coccocarpia* sp. 1**

***Thelotrema* sp. 2 (top), Lecanoraceae Family sp 1. (bottom)**

Heterodermia **sp. 1 (foliose)**