

A preliminary investigation of corticolous lichen diversity in urban and suburban sites in New Amsterdam, Berbice, Guyana

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Abstract: The aim of this study was to document and compare the corticolous lichen species diversity present on barks of trees at four study sites in urban and suburban environments in New Amsterdam, Guyana. A 50m by 20m plot was demarcated within each of the four sites. Healthy mature trees within the each were sampled to determine species richness, evenness and diversity of corticolous lichens communities. Forty-one healthy individual trees from five species were sampled using (10cm by 50cm) ladder quadrats on the tree trunk (N, S, E, W) at 150cm height. A total of 14978 individual lichens were identified from 10 families, 13 genera and 18 species. Shannon Diversity Index and Simpson's Diversity Index, Pielou's Index, Menhinick's Index and Whittaker's diversity index were calculated and used to compare the lichen diversity. The results showed that species richness, species evenness and diversity was higher at the urban study sites than at the suburban sites.

Index terms: Corticolous lichens, diversity, urban, suburban, Guyana.

1. Introduction

Lichens are symbiotic partnerships between fungi and algae and/or cyanobacteria [19] and in this association the mycobiont acts as structural support and protection for the photobiotic partner, which provides nutrition via photosynthesis, [22] while there is a reciprocal transport of water and other liquids from the mycobiont to the photobiont [23]. These partnerships vary in color and structural form depending on the species of fungi and algae/cyanobacteria working together. Characterizations by thallus structure include crustose (crust-like), fruticose (branch-like), foliose (leaf-like) and other various growth forms [14].

Different kinds of lichens can colonize various terrestrial environments and may range in their tolerance to desiccation [14]. Therefore, lichens can also be characterized by their substrates: saxicolous lichens grow on rocks, lignicolous lichens grow on wood stripped of bark, terricolous lichens grow on soil, muscicolous lichens grow on mosses, foliicolous lichens grow on leaves of vascular plants and corticolous lichens grow on the barks of vascular plants [22]. Corticolous microlichens are the biggest known group of lichens, however they are the least known [6]. Due to their restriction to the barks of trees, epiphytic lichens are useful bio-indicators of their environment's health [9], particularly with atmospheric quality [15].

This study focused on assessing the diversity of corticolous lichens in New Amsterdam, Guyana. It examined and compared the corticolous lichen diversity (alpha diversity, beta diversity, species richness and species evenness) between two urban and two suburban environments in New Amsterdam.

Guyana, situated between 1 and 9 north latitude and between 56 and 62 west longitude, is in the Neotropical bio-geographical territory of north eastern South America and is a part of the Guiana Shield region which forms part of the Amazon Biome [5]. There are seasonal variations in temperature along the coast due to the northeast trade winds and temperatures are mostly constant with an average high of 32°C and an average low of 24°C in July, the hottest month. There is an average range of 29°C to 23°C in February, the coldest month. Humidity averages around 70% year-round. Rainfall is heaviest in the northwest and lightest in the southeast and interior [12].

New Amsterdam is one of Guyana's largest urban locations and is found within the low coastal plain which occupies about five percent of Guyana's total land area. In recent years, the degree of urbanization has increased in New Amsterdam with the introduction of better infrastructures: roads, shopping complexes, residential buildings.

Urbanization dramatically alters the environmental conditions of rural and natural environments resulting in atmospheric and acoustic pollution, loss of biodiversity and climatic changes [15]. Ascertaining the diversity of lichen species in any ecosystem helps in tracking ecological variables, such as pollution concentration, which can give a basis for ecosystem health [2]. In turn, deduction of disturbed sites and species status is needed to make policies and decisions to protect threatened species [13]. Unfortunately, floristic inventory data necessary for environmental impact and conservation assessments are lacking for urban and suburban areas in Guyana.

2. Justification for study

There is a lack of data concerning lichen diversity in urban areas in Guyana. This makes it difficult for the government to make accurate species status assessments and environmental management policies concerning lichens and urban ecosystem health.

The main objective of this study, therefore, was to investigate the diversity of corticolous lichens in suburban and urban New Amsterdam. The following research questions were addressed in this study.

1. What is the diversity of corticolous lichens in suburban and urban New Amsterdam?
2. What is the species richness of corticolous lichens in suburban and urban New Amsterdam?
3. What is the species evenness of corticolous lichens in suburban and urban New Amsterdam?
4. Do suburban areas in New Amsterdam have a more diverse corticolous lichen community than urban areas?

The hypotheses that guided the study were:

Null Hypotheses:

1. H_0 – The diversity of suburban and urban corticolous lichen communities in New Amsterdam is not greater than that shown in current records.
2. H_0 – The species richness of suburban and urban corticolous lichen communities in New Amsterdam is not greater than that shown in current records.
3. H_0 – The species evenness of suburban and urban corticolous lichen communities in New Amsterdam is not greater than shown in current records.
4. H_0 – Suburban corticolous lichen communities are not more diverse than urban corticolous lichen communities in New Amsterdam.

Alternate Hypotheses:

1. H_1 – The diversity of suburban and urban corticolous lichen communities in New Amsterdam is greater than that shown in current records.
2. H_1 – The species richness of suburban and urban corticolous lichen communities in New Amsterdam is greater than that shown in current records.
3. H_1 – The species evenness of suburban and urban corticolous lichen communities in New Amsterdam is greater than that shown in current records.
4. H_1 – Suburban corticolous lichen communities are more diverse than urban corticolous lichen communities in New Amsterdam.

3. Methodology

3.1 Study Area

The study was carried out at four locations (Figure 1) within New Amsterdam in Region 6, East Berbice Corentyne. The four study locations were: New Amsterdam Esplanade (north-west) [GPS: 6.251796W, -57.519136N], Republic Road (central) [6.247062W, -57.515419N], Vryheid (south-east) [6.236738W, -57.516247N] and Smithfield (north-east) [6.248277Q, -57.514583N].

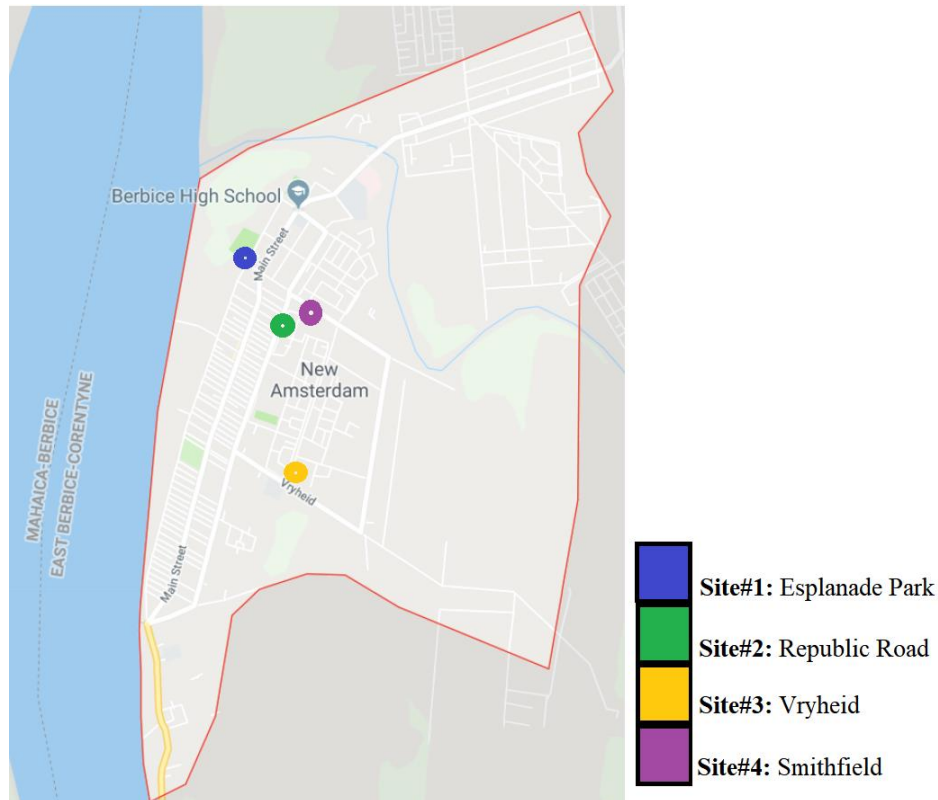


Figure 1 Map of New Amsterdam outlining the study sites

3.2 Sampling and Data Collection

Data collection was done during the period February - May, 2019. Sampling plots of 1000m² at each location were demarcated and for each study site, a plot of 50m x 20m was established.

Corticolous lichens were sampled only on undamaged trees with a girth of more than 70cm [1] [21]. To survey the corticolous lichens, four ladders measuring 10cm x 50cm and each having five 10cm x 10cm contiguous quadrats were used. Each ladder was placed securely on the tree trunk on the north, south, east and west directions such that the upper edge of each ladder was 1.5m above the highest point on the ground [7]. Sampling at the bottom of the trunk was avoided because they varied greatly between individual trees [9].

Lichen species and their frequencies within each of the five 10cm x 10cm quadrats of the ladder were recorded. Lichen species cover was estimated to the nearest cm² and expressed as a percentage of the inspected trunk area [9].

3.3 Identification of lichens

Lichen specimen identification was based on morphological characteristics and observations of the thalli and apothecia with the aid of a magnifying glass. Addition information for identification was obtained from [3], [4] [16] [17] 18].

3.4 Data Analysis

All statistical analyses and calculations of diversity indices were done using PAST ver 3.24 Statistical software. To compare species richness between the urban and suburban areas and the different study sites, rarefaction curves were used for this study. Individual rarefaction curves were generated using PAST ver 3.24 statistical software [14].

4. Results

4.1 Species and distribution of lichens

This study focused on assessing the diversity of corticolous lichens in New Amsterdam and comparing the diversity of lichen communities in suburban and urban areas in New Amsterdam.

Overall, five different species of trees were sampled and a total of 14978 corticolous lichen specimen were recorded from the four sites during the study. There were 10 families, 13 genera and 18 species recorded from 41 sampled host trees (Table 1 and Table 2). Two families had more than 1 genus: Parmeliaceae (*Flavoparmelia*, *Hypotrachyna* & *Usnea*) and Graphidaceae (*Graphina* & *Graphis*). Site #1, Esplanade Ground, had the greatest number of corticolous lichen species recorded with 15 different species.

Table 1: Number of species and genera at each site

	Total # of Gen.	Total # of Sp.	Site#1		Site#2		Site#3		Site#4	
			# of gen.	# of sp.	# of gen.	# of sp.	# of gen.	# of sp.	# of gen.	# of sp.
Monoblastiaceae	1	1	1	1	1	1	1	1	1	1
Arthoniaceae	1	3	1	1	1	2	1	2	1	1
Ramalinaceae	1	1	1	1	1	1	1	1	1	1
Cladoniaceae	1	1	1	1	0	0	0	0	0	0
Collemataceae	1	1	1	1	1	1	1	1	0	0
Coenogoniaceae	1	1	1	1	0	0	0	0	0	0
Caliciaceae	1	1	0	0	0	0	1	1	1	1
Parmeliaceae	3	4	3	4	1	2	1	2	1	2
Graphidaceae	2	4	2	2	2	2	2	2	2	2
Lecanoraceae	1	3	1	3	1	2	1	2	1	2
Total	13	20	12	15	8	11	9	12	8	10

Table 2: Species frequency distributed over each site sampled, overall urban site, overall suburban site & overall New Amsterdam

Family	Species	Site #1	Site #2	Site #3	Site #4	Suburban (Site #3&4)	Urban (Site #1&2)	New Amsterdam (Total Sites)
Monoblastiaceae	<i>Anisomeridium biforme</i>	56	206	196	51	247	262	509
Arthoniaceae	<i>Arthonia cinnabarina</i>	0	0	176	0	176	0	176
	<i>Arthonia pruinata</i>	0	182	0	0	0	182	182
	<i>Arthonia radiata</i>	718	351	66	887	953	1069	2022
Ramalinaceae	<i>Bacidia laurocerasi</i>	42	110	176	329	505	152	657
Cladoniaceae	<i>Cladonia parasitica</i>	49	0	0	0	0	49	49
Collemataceae	<i>Collema furfuraceum</i>	1256	205	88	0	88	1461	1549
Coenogoniaceae	<i>Dimerella lutea</i>	291	0	0	0	0	291	291
Caliciaceae	<i>Dirinaria applanata</i>	0	0	191	2816	3007	0	3007
Parmeliaceae	<i>Flavoparmelia caperata</i>	748	462	479	277	756	1210	1966
	<i>Flavoparmelia soredians</i>	405	900	46	41	87	1305	1392
	<i>Hypotrachyna laevigata</i>	24	0	0	0	0	24	24
	<i>Usnea cornuta</i>	3	0	0	0	0	3	3
Graphidaceae	<i>Graphina anguina</i>	250	261	415	143	558	511	1069
	<i>Graphis elegans</i>	31	44	16	43	59	75	134
Lecanoraceae	<i>Lecanora chlarotera</i>	56	48	28	427	455	104	559
	<i>Lecanora confusa</i>	222	0	112	258	370	222	592
	<i>Lecanora conizaeoides</i>	726	71	0	0	0	797	797
		4877	2840	1989	5272	7261	7717	14978

Crustose corticolous lichens species were the most recorded (61%) when all sites were considered, while squamulose (5%) and fruticose (6%) were the least recorded (Fig. 2).

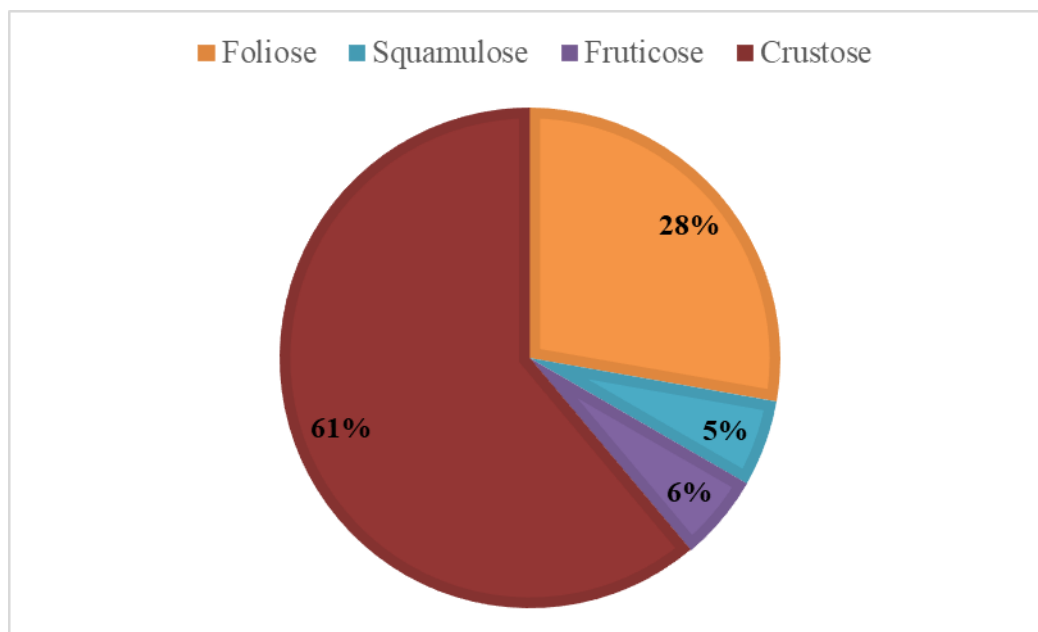


Figure 2: Distribution of corticolous lichen species according to their thallus type.

Site #1 (Urban) – Esplanade Ground [GPS: 6.251796W, -57.519136N] showed heavy anthropogenic influence. Eleven trees from two different species, *Swietenia mahagoni* and *Melicoccus bijugales*, were found within the Esplanade ground plot. Fifteen different species of corticolous lichens were identified at this study site.

At Site #2 (Urban) – Republic Road [GPS: 6.247062W, -57.515419N] there was also evidence of heavy anthropogenic influence with visible signs of land pollution and continuous human and vehicular traffic at this site. Six trees belonging to two species, *Terminalia catappa* and *Swietenia mahagoni*, were present within this plot. Twelve corticolous lichen species were identified from this site.

Site #3 (Suburban) – Vryheid [GPS: 6.236738W, -57.516247N] was a plot on a residential land within suburban Vryheid, indicating anthropogenic influence. Nine eligible trees were found within the Vryheid plot belonging to three different species: *Cocos nucifera*, *Mangifera indica* and *Melicoccus bijugales*. Thirteen different species of corticolous lichens were found on these trees.

At Site #4 (Suburban) – Smithfield [GPS: 6.248277W, -57.514583N] was also within a residential area and fifteen trees were within this plot and all belonged to the same species: *Cocos nucifera*. Ten different corticolous species were identified from this site.

4.2 Estimated Species Diversity

Using the frequencies recorded for each species at each site, the alpha diversity indices, index for species richness and index for species evenness (Table 3) were calculated in PAST ver 3.24 statistical software package.

Table 3: Alpha diversity indices, species richness index and species evenness for study sites

	Alpha Diversity Index			
	Simpson's Diversity Index (1-D _{sim})	Shannon's Diversity Index (H')	Menhinick's Index for Species Richness (D)	Pielou's Index for Species Evenness (J')
Site #1	0.8507	2.123	0.2148	0.784
Site #2	0.8322	2.045	0.2064	0.853
Site #3	0.8569	2.151	0.2691	0.866
Site #4	0.6698	1.534	0.1377	0.666

Suburban	0.7811	1.926	0.1408	0.775
Urban	0.8721	2.257	0.1821	0.815
New Amsterdam	0.8902	2.147	0.1471	0.743

Beta diversity was calculated with PAST software and used to compare all four sites, suburban vs urban, site #1 vs. site #2 (urban) and site #3 vs. site #4 (suburban). These results are shown in Table 4 and Table 5.

Table 4: Beta Diversity (Whittaker’s Diversity Index)

Comparison	Whittaker’s Diversity Index (β_w)
All 4 Sites	0.5
Suburban vs Urban	0.28571
Both Urban Sites (#1,#2)	0.23077
Both Suburban Sites(#3,#4)	0.090909

Table 5: Whittaker’s Index pairwise comparison of all four sites

	Site #1	Site #2	Site #3	Site #4
Site #1	0	0.23077	0.25926	0.28
Site #2	0.23077	0	0.21739	0.2381
Site #3	0.25926	0.21739	0	0.090909
Site #4	0.28	0.2381	0.090909	0

4.3 Rarefaction Curves

Rarefaction curves were used to compare species richness among varying sample sizes and different sites. The rarefaction curves indicated highest species richness for Site #1 and lowest for Site #4 (Fig. 3) and higher species richness for Urban compared to Suburban (Fig. 4).

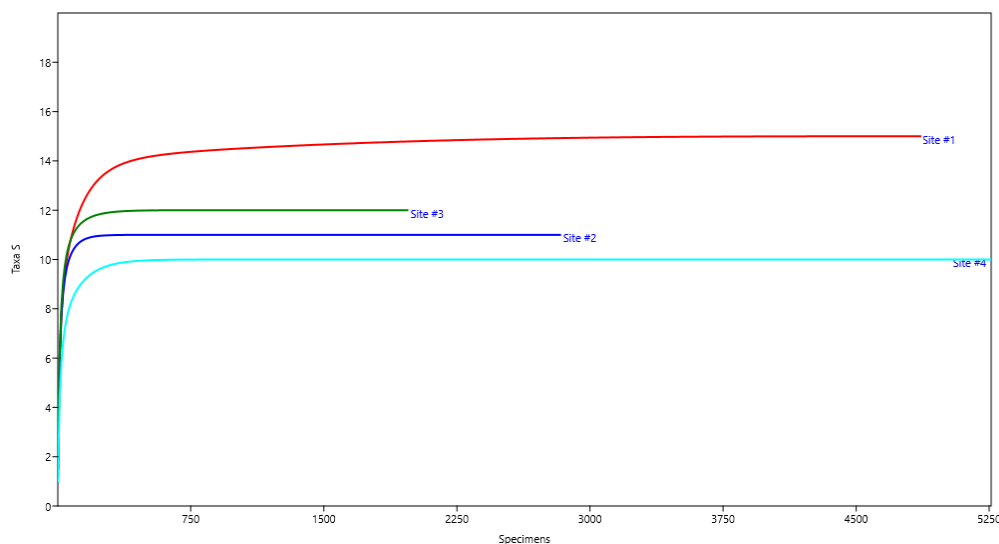


Figure 3: Rarefaction curve showing the species richness of Sites #1, #2, #3 & #4

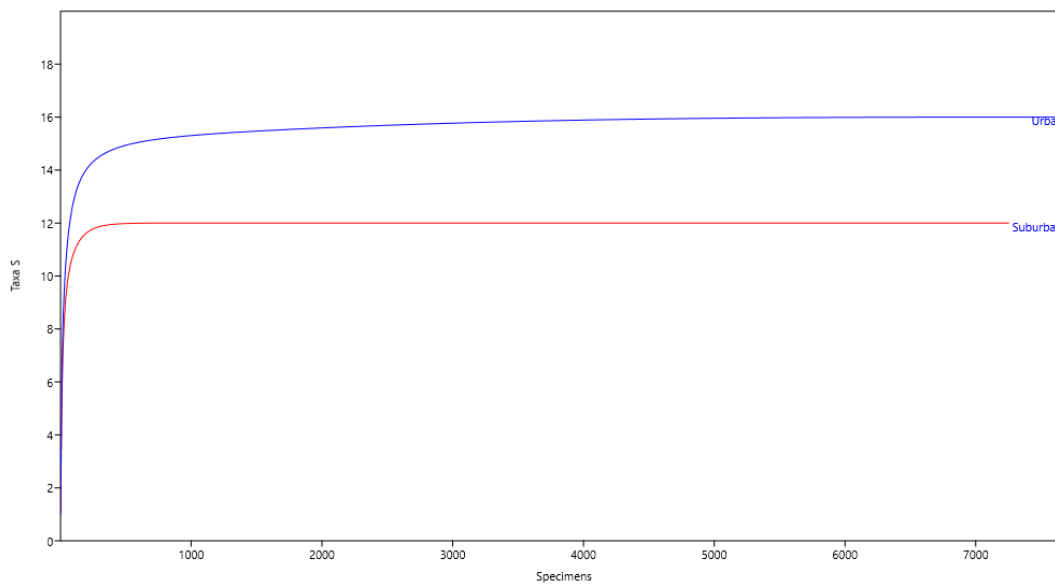


Figure 4: Rarefaction curve showing the species richness of Suburban vs. Urban

5. Discussion

This is one of the first known studies on corticolous lichen diversity in urban and suburban areas in Guyana and, therefore, has added to the pool of knowledge of corticolous lichen flora in Guyana.

A total of 14978 individuals representing 10 families, 13 genera and 18 species of corticolous lichens were identified and recorded. The species richness accounted for in this study may be unable to be directly compared to other results from other similar studies due to differences in sampling methods. Also, unlike other studies where the entire tree may have been sampled, during this study only a part of the tree trunks was sampled.

Crustose lichens were the most prominent corticolous lichens observed (Figure 2) at 61% with the most crustose lichen individuals in Graphidaceae and Arthoniaceae. However, foliose lichens had the species with the most abundance in Parmeliaceae, Caliciaceae and Collemataceae.

Limiting factors, such as site conditions, pollution, light intensity and life expectancy of the species, were not investigated in this study and it is, therefore, difficult to speculate on the possible causes for observed species richness.

Both urban and suburban sites had three species of host trees each. For the urban sites, the species were *Melicoccus bijugales*, *Swietenia mahagoni* and *Terminalia catappa*; for the suburban sites, the host tree species were *Cocos nucifera*, *Mangifera indica* and *Melicoccus bijugales*. The diversity of host tree appeared to possibly influence the vegetation distribution pattern and, in turn, lichen diversity. With a decrease of host tree specificity (Site #4) there was an apparent decrease in corticolous species richness. Although Site #4 had the lowest number of lichen species (10), this site was the one with the greatest number of individuals, possibly due to lack of competition for resources.

Menhinick's Index for richness is based on the ratio of number of species and the square root of the total number of individuals [20]. Overall, the urban community of corticolous lichens has the highest Menhinick's Index. Site #3, Vryheid, has the highest Menhinick's Index followed by Sites #1, Esplanade Ground, and #2, Republic Road, respectively. Site #3 has the lowest individual count and the second highest species count (12). Site #1 has the most recorded species (15), however the individual count was the second highest. Site #4, Smithfield, with the lowest amount of corticolous lichen species and highest individual count, has the lowest Menhinick's Index. The overall species richness index for New Amsterdam was 0.1471.

Individual species rarefaction curves were used to compare species richness. The urban study locations showed higher species richness than the suburban locations, reflective of Menhinick's Index. The urban community has more than one host species at each site and also had the oldest trees, indicative by girth of the tree trunks. A comparison of all sites showed site #1 with the highest species richness followed by #3, #2 and #4 respectively. The rarefaction curve showed a marginal difference with site #1 as richer in

species than #3, unlike Menhinick's Index. This difference may be attributed to the fact that some authors showed that Menhinick's index is not independent of sample size, whereas, rarefaction curves standardize the sample size for comparison [20]. The horizontal asymptotes have converged and infer that the species richness is a good estimate of the value that would be obtained if every individual was observed at least once.

To compare species evenness, Pielou's Index for Species Evenness was used. It compares the actual diversity value of Shannon-Wiener's Index to the maximum possible diversity value and is restricted between 0 and 1. More variation in species abundance between different taxa within the sample results in a lower Pielou's index value [10]. The urban community had a higher species evenness than the suburban community. Of the four sites sampled, site #3 had the highest species evenness followed by sites #2, #1 and #4 respectively.

Comparison of the corticolous lichen alpha diversity using Simpson's Diversity Index (1-D) indicated that the urban community was more diverse than the suburban community. Site #4 showed the lowest diversity among all four sites whereas, site #3 was the most diverse followed closely by sites #1 and #2. Simpson's index takes into account evenness and dominance, so as D increases, diversity decreases, therefore the index is usually taken as its complement 1-D and takes on a value between 1 and 0. When 1-D approaches 0 the sample approaches the limit of a monoculture [11]. The overall diversity of New Amsterdam is $1-D = 0.8902$, which is indicative of a very diverse community.

The Shannon-Wiener Diversity Index was also used to compare the alpha diversity among each individual site. Values for this index are usually between 1.5 – 3.5 in most ecological studies with the index rarely exceeding 4 [11]. The index increases as both richness and evenness of the community increases. All values of the Shannon-Wiener Diversity index for each site fell within the normal range. This index followed the same trend as the Simpson's index: the urban community showed higher diversity than the suburban community. For the 4 sites, site #3 showed the highest diversity followed by #1 and #2 respectively with site #4 having the lowest diversity.

[8] stated that beta diversity "measures the change in the diversity of species from one environment to another". It calculates the number of species that are not the same in two different environments. The index follows the normalized scale 0 – 1, where a high beta diversity index indicates a low level of similarity and a low beta diversity indicates a high level of similarity. Based on the pairwise comparison of Whittaker's beta diversity index, the beta diversity for all four sites was 0.5.

Comparing urban vs. suburban diversity revealed the beta diversity as 0.28571 which indicates a somewhat strong level of similarity. Comparing sites #1 vs. #2 (urban sites) revealed a somewhat high level of similarity as well. Comparing sites #3 vs. #4 revealed a very strong level of similarity. 83.3% of species were found in more than one site. *Cladonia parasitica*, *Hypotrachyna laevigata* and *Usnea cornuta* were restricted to *Swietenia mahagoni* trunks in site #1 (Esplanade ground). *Dirinaria applanata*, restricted to *Cocos nucifera*, was found in sites #3 and #4.

6. Conclusions

This study has added to the information currently available on corticolous lichen diversity in urban and suburban New Amsterdam, Guyana. It shows that urban corticolous lichen communities had a higher species richness and species evenness, as well as a higher alpha diversity than the suburban corticolous lichen community, in New Amsterdam.

This study has produced a preliminary checklist of corticolous lichens in New Amsterdam and a preliminary assessment of the species richness and evenness of corticolous lichens in suburban and urban New Amsterdam.

These results rejected the hypotheses proposed for this study that the suburban corticolous lichen community would be more diverse than the urban corticolous lichen community.

Rarefaction curves showed a horizontal asymptote that indicated that the species richness obtained was a good estimate value if each species was recorded at least once. However, due to the sampling method and effort used for this study, substantial taxa may have not been recorded and taken into consideration.

The outputs from this study can provide a useful baseline to investigate the effects of urbanization on local corticolous lichen biodiversity while helping to inform other assessments and management decisions concerning the conservation of Guyana's lichen diversity amid the progression of urbanization.

The findings from this study may further constitute important information for future research into using lichens to detect and monitor environmental changes in Guyana.

7. Recommendations

Future studies should be designed to research other parts of host trees and their lichen diversity in Guyana.

Other urban and suburban areas within Guyana should be sampled and studied to investigate and compare these communities.

With the increase attention being given to conservation efforts, it will be important to also assess other geographical locations in Guyana for lichen diversity. This will inform conservationists and the government on the current conditions of these communities as well as aid in making decisions to protect these communities.

Lichens are good bioindicators of ecological health, therefore, studies pertaining to assessing and monitoring ecosystem and environmental health, especially in urban areas, can focus on using lichens.

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