Asian Journal of Conservation Biology, December 2020. Vol. 9 No. 2, pp. 315-321 AJCB: SC0045
ISSN 2278-7666 ©TCRP Foundation 2020

Short Communication

Urban Diversity of Butterflies as a Biological Indicator of an Air Quality in Manila, Philippines

Alma E Nacua[1*], Ken Joseph Clemente[2], Ernest P. Macalalad[3], Custer C. Deocaris[4,5], Maria Cecilia Galvez[6]

[1]*Biodiversity Laboratory, Universidad de Manila, One Mehan Gardens, Ermita Manila 1000, Philippines*
[2]*Senior High School, University of Santo Tomas, España Blvd, Sampaloc, Manila 1015, Philippines*
[3]*Physics Department, Mapua Institute of Technology 658 Muralla St, Intramuros, Manila 1002, Philippines*
[4]*Technological Institute of the Philippines, 938 Aurora Boulevard, Cubao, Quezon City, Philippines*
[5]*Atomic Research Division, Philippine Nuclear Research Institution, Department of Science & Technology, Diliman, Quezon City, Philippines*
[6]*Environment and Remote Sensing Research Laboratory, Physics Department, College of Science, De La Salle University, 2401 Taft Avenue, Malate, Manila, Philippines*

(Received: September 20, 2020; Revised: November 13, 2020; Accepted: November 20, 2020)

ABSTRACT

The aim of this study is to observe the urban diversity of butterflies as an indicator of air quality. Opportunistic Field Sampling. The butterfly sampling and AQMS were done once a month from May 2018 to April 2019 for a period of one year. All butterflies within Line transect of 500 meter and 100 meter away from the transect line were collected for identification. Only 2-3 butterfly per species were collected for proper identification, the rest were set free. Air Quality Monitoring. Simultaneous to butterfly sampling, the concentrations of particulate matter ($PM_{2.5}$), Nitrogen Dioxide (NO_2) and Ozone (O_3) was measured. For $PM_{2.5}$ measurements a DustTrak™DRX aerosol monitor (Model 8533, TSI incorporated) that used light scattering technique to infer mass concentration of particles was used. NO_2 and O_3 concentrations were measured by a real- time gas sensor monitor (AEROQUAL Series 500 sensors; O_3 sensor: 0–10 ppm, NO_2 sensor: 0–1 ppm) with 1-min time resolution. QGIS: are used to plot the butterflies along the transect line of 500 m by 100 m away from the transect line in all the four sampling in Mehan garden, Arroceros park, Manila zoo and Botanical Garden, Japanese garden and Martyrdom, Luneta park. Conclusion. There was a higher concertation NOx, O_3, and PM 25 pollutants affecting the urban diversity of butterflies the Urban diversity of butterflies, the decreased number of butterfly families.

Key words: Host plants, Air quality, particulate matters ($PM_{2.5}$)

INTRODUCTION

Major changes in climate worldwide have been identified as the cause of recent shifts observed in species' geographical distributions (Hickling *et al.,* 2006; Lenoir *et al.,* 2008; Root *et al*., 2003). Many such shifts follow a poleward range expansion pattern (Parmesan *et al.,* 1999; Permesan, 2003; Warren *et al.,* 2001) Climate warming results in locations becoming generally more favorable for species near the ''cool'', high-latitude limits of their distributions, but it may be less favorable for species near their ''warm'', low-latitude limits (Opdam, 2004). with consequent changes in relative species' abundance and community composition (Beaugrand *et al*., 2002). Butterflies are known to be highly sensitive to climate change Parmesan *et al.* (1999). It is because they have very short life span. The average life span of butterfly range between 2 to 3 weeks. However, there are species of Nymphalidae such as Idea leuconoe, life span may last up to 2 to 3 months. Air quality is strongly dependent on weather and is therefore sensitive to climate change (Jacob, 2009). Air quality refers to the condition of the air within the environment. Air pollution is a mixture of solid particles and gases in the air. Car emissions, chemicals from factories, dust, pollen and mold spores may be suspended as particles. Ozone, a gas, is a major part of air pollution in Metro Manila.

Air pollution is a serious threat to the urban diversity of butterflies. This cause acidification and nitrogen fallout. The specific pollutants such NO_2, O_3, SO_3 and other volatile organic substances and particulate matter. The larval stage of butterflies like Papilionidae and Nymphalidae are very sensitive to corrosive pollutants in the atmosphere. Corrosive pollutants react with moist Oxygen and water to form inorganic acids and organic acid. The oxides of Carbon, oxides of nitrogen, oxides of Sulphur, oxides of haloes and hydride of Sulphur form carbonic acid, nitric acid, nitrous acid, sulphuric acid, sulphrous acid and halo acids. Organic acids are formic acid, acetic acid and benzoic acid. Butterflies come in contact of these corrosive acids to develop microbio electrochemical corrosion cell. Oxidation and reduction reactions start on the body butterfly. It disturbs catabolic and anabolic process of butterflies. Such type of corrosion cell reaction destroys the life of butterflies. These corrosive pollutants reduce their population growth. The greenhouse gases, acid rain, oxygen depletion and global warming are also producing bad effect to species of butterflies.

These acids previously mentioned were mixed in the clouds eventually developed precipitation. The acid rain accelerates corrosion reaction with butterflies. The concentration of carbon dioxide and methane are increased in atmosphere everyday due heavy

*Corresponding Author's E-mail: almanacua@yahoo.com

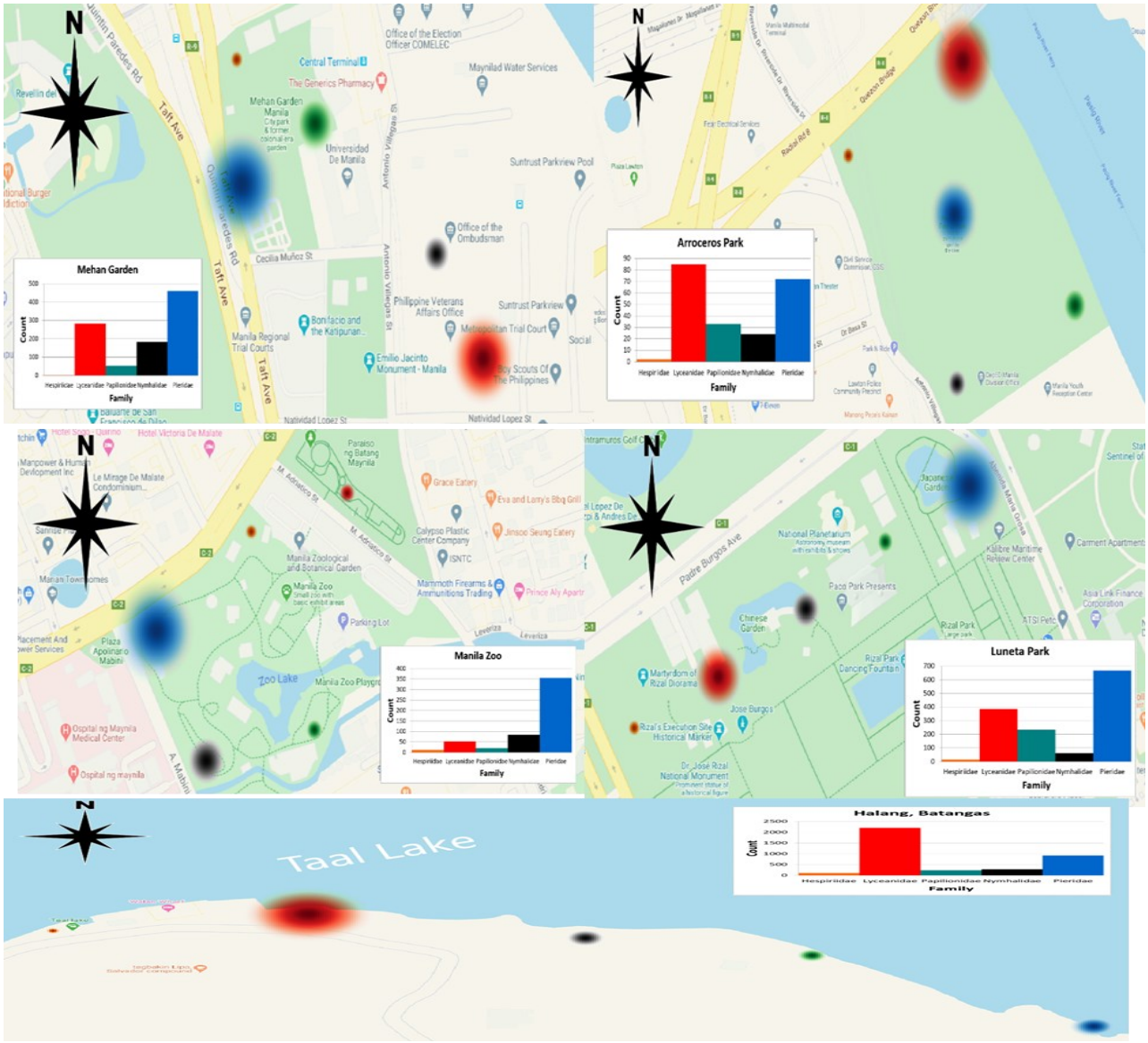

Figure 1. QGIS heat map of the sampling area of the butterflies at dipterocarp forest

transportation in Manila, urbanization, infrastructure development. The corrosive gases, acid rain, oxygen depletion and greenhouse gases become threat to the life cycle of the butterfly. Particulate matter adheres to the sensitive parts of butterfly larva and they react with moisture to produce alkaline and acidic. Thus, a major cause of corrosion in the butterfly larval skin and may cause death. Thus, this will affect the urban diversity of butterflies in Manila. In this research, criteria pollutants like O_3, NO_2, and $PM_{2.5}$ were measured environmental and weather monitoring sensors was placed on the same site where butterfly diversity. The butterfly diversity was monitored in different parks namely (1) Arroceros Park, (2) Mehan Garden, (3) Rizal Park, and (4) Manila Zoological and Botanical Garden. The aim of this study is to the measure the concentration observeof NO_2, O_3, PM 2.5, affecting the urban diversity of butterflies as an indicator of air quality.

MATERIAL AND METHODS

Mehan garden Ermita Manila is with the coordinate 14.5923° N, 120.9808° E, with a lot area of 2,800 square meters, a dipterocarp forest in the city of Manila (Figure 1). There are many host plants and nectarine plants for the butterflies are found. Arroceros park with the coordinate 14°35'39"N 120°58'55"E, with 21428 square meter forest park. The only last lung dipterocarp forest in Manila. This is haven for butterflies and bird species, such as the long-tailed shrike, pied fantail, zebra dove, Pacific swallow, yellow-vented bulbul and brown shrike. Manila Zoo and Botanical garden is with the coordinate 14.5651° N, 120.9885° E, lot area is 5,500 SQ. this is manage by the city of Manila. A dipterocarp forest, tall trees are haven for birds, they are visitors coming from Manila bay that feed on fishes and goes back to tall trees of Manila Zoo and Botanical garden. Japanese garden and Martyrdom at Luneta Park coordinate is 1.3353° N, 103.7311° E, with a lot area of 138 m, it is a dipterocarp forest with a fish pond, an array of nectarine plants and a long list of host plants in the area, considering it is near the Manila bay. The air and soil is saline which attracted to butterflies. Halang Lipa, Batangas (Control sampling area) Has the coordinates of 13°57'44" N 121°4'38" E, Halang is a 95 meter above sea level (MASL) and a mixed dipterocarp forest, there were different host plant found in the sampling area which are similar to Urban city of Manila.

Opportunistic Field Sampling: The butterfly sampling and AQMS were done once a month from May 2018 to April 2019 for a period of one year. All butterflies with in Line transect of 500 meter and 100 meter away from the transect line were collected for identification. Only 2-3 butterfly per species were collected for proper identification, the rest were set free.

Materials: DSLR Camera were used for documentation of butterfly behavior. Microscopes (for identification), 95% ethanol was used to immobilized the natural enemies caught in the garden, Weather station Earth AQMS. Lux meter use to determine the luminosity of light.

Air Quality Monitoring : Simultaneous to butterfly sampling, the concentrations of particulate matter ($PM_{2.5}$), Nitrogen Dioxide (NO_2) and Ozone (O3) was measured. For $PM_{2.5}$ measurements a DustTrak™DRX aerosol monitor (Model 8533, TSI incorporated) that used light scattering technique to infer mass concentration of particles was used. NO_2 and O_3 concentrations were measured by a real- time gas sensor monitor (AEROQUAL Series 500 sensors; O_3 sensor: 0–10 ppm, NO_2 sensor: 0–1 ppm) with 1-min time resolution

***QGIS*:** are used to plot the butterflies along the transect line of 500 m by 100 m away from the transect line in all the four sampling in Mehan garden, Arroceros park, Manila zoo and Botanical Garden, Japanese garden and Martyrdom, Luneta park.

Identification of butterflies*:* The Field Guide of Butterflies of the Philippines by Hardy, Peter B. *et al* (2017), Butterflies of Thailand, Amnuay, Pisuth Ek (2012) Revised Checklist of the Butterflies of the Philippines. Threadaway, Colin G Heinz G. Schroeder (2012)

RESULTS AND DISCUSSION

Urban Diversity of Butterflies and Air Quality

This research started from May 2018 to April 2019, there were five (5) sampling site found in Figure 1.

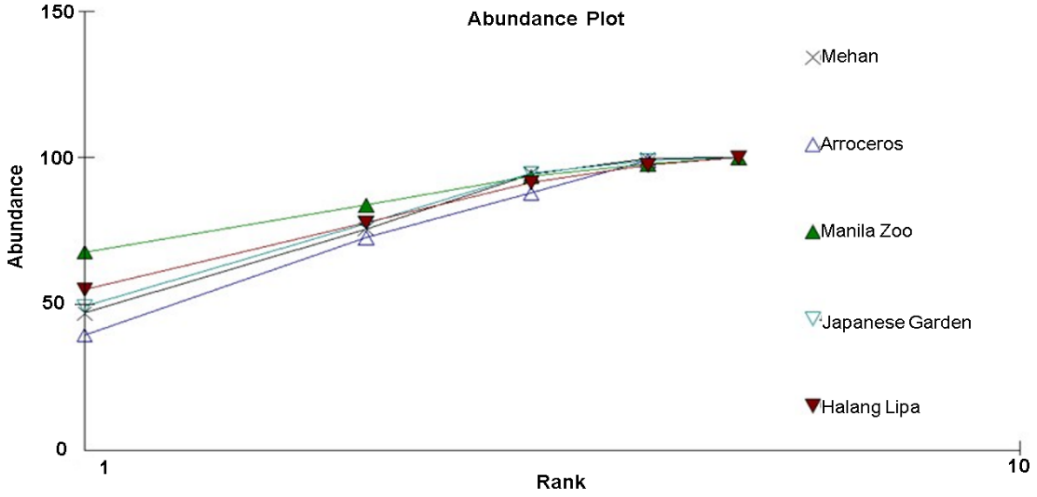

Figure 2. Abundance plot of butterflies in five (5) sampling site

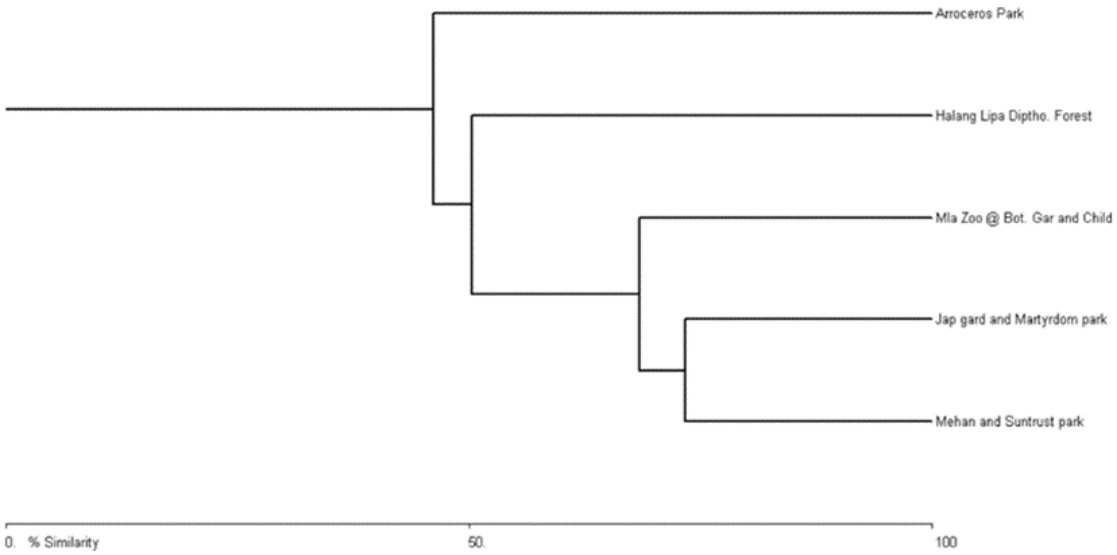

Figure 3. Cluster Analysis by Bray Curtis; Japanese garden and Martyrdom and Mehan garden has 85% similarities of butterfly's families, Manila Zoo @ Botanical garden and Children's Park is 75% compared to Japanese garden and Mehan garden, Halang Lipa Batangas is 50% similarity with the three sampling site, however Arroceros is the list having only 40% similarities compare to the four sampling site.

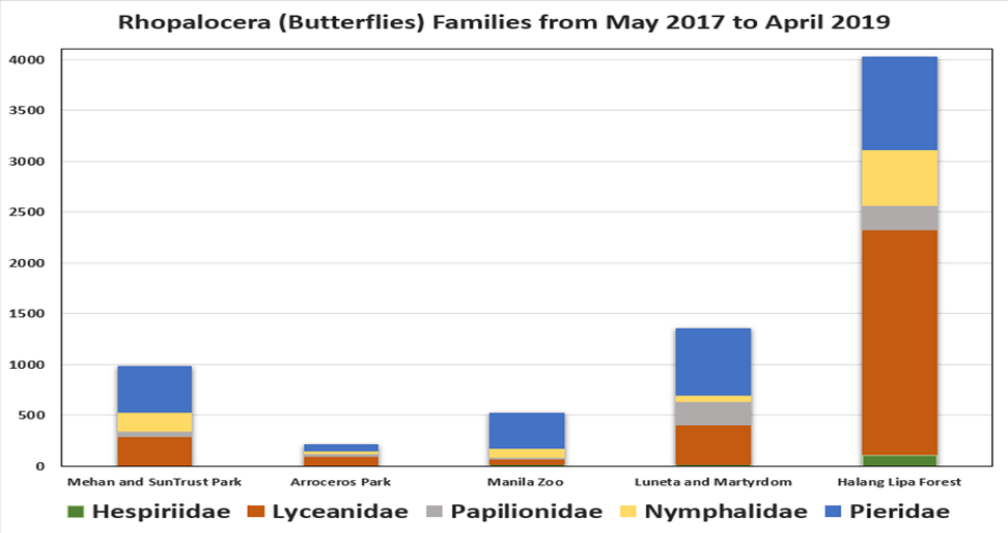

Figure 4. Butterfly families in five sampling site, Pieridae and Lyceanidae are widely distributed

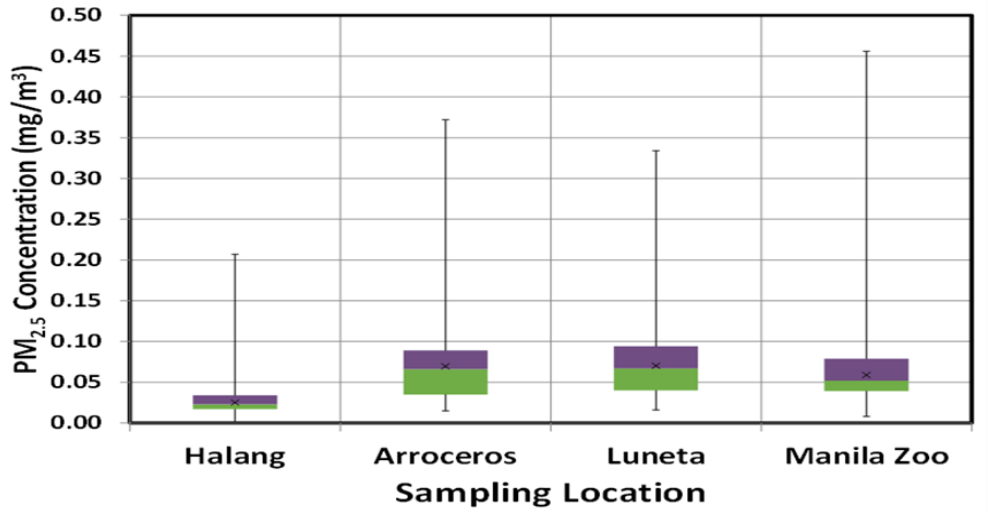

Figure 5. Particulate Matter Concentration. Box plot of $PM_{2.5}$ concentrations at the four sampling sites for a one-year period (May 2018-April 2019).

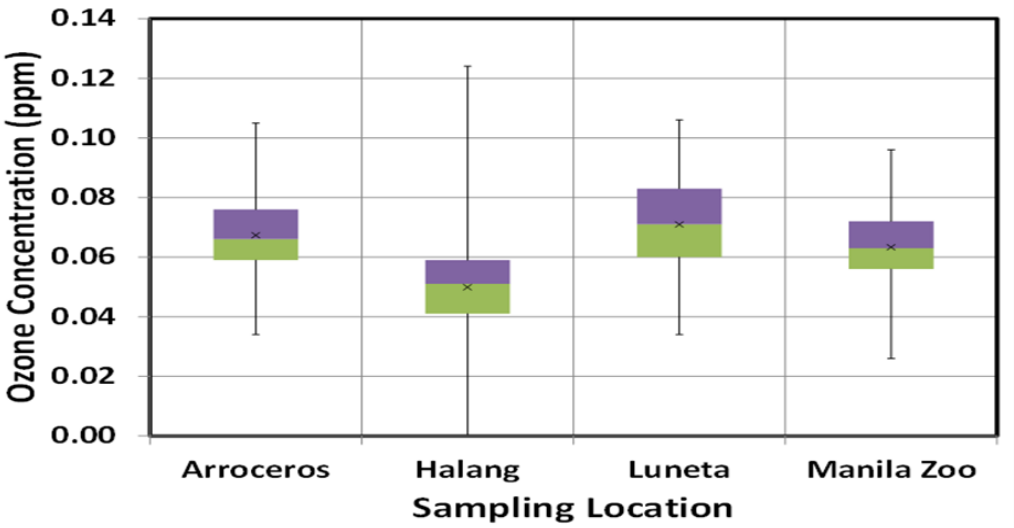

Figure 6. Ozone Concentration. Box plot of Ozone concentration at the four sampling sites for a one-year period (May 2018-April 2019).

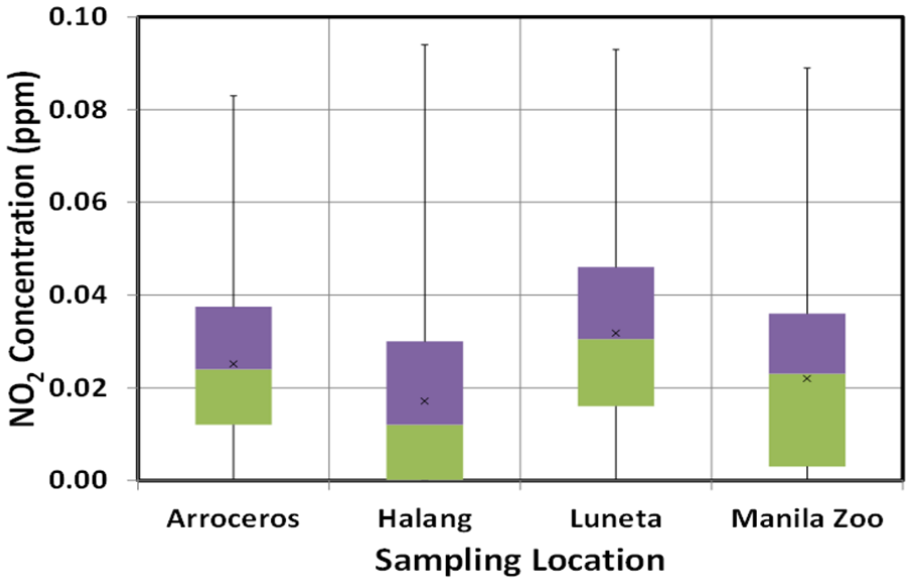

Figure 7. Nitrogen dioxide Concentration. Box plot of NO_2 concentration at the four sampling sites for a one-year period (May 2018-April 2019).

In the urban cities in Mehan Garden and SunTrust Park with the coordinate 14.5651° N, 120.9885° E, Arroceros Park with the coordinates of 14°35'39"N 120°58'55"E, Manila Zoo and Botanical Garden and Children's Park with the coordinate 14.5651° N, 120.9885° E, Japanese garden and Martyrdom at Luneta Park coordinate is 1.3353° N, 103.7311° E. The observation of urban butterfly families in Manila were compared in Halang Lipa, Batangas Has the coordinates of 13°57'44" N 121°4'38" E, there were 55 species and subspecies of butterflies identified a total of 6,918 individual adult butterflies observed for a period of one year. As to note the distance of the sampling site, Mehan garden and Arroceros park is about 2 min. walk (450. m) distance with each other. Luneta park is about 5 min (1.4 km) walk to Arroceros Park. However, Manila Zoo is very to Luneta and Arroceros Park. While Halang Lipa Batangas is much farther than the four sam- pling site, it will take about 1 h 31 min (83.4 km) via R- 3.

The matter (PM2.5), Nitrogen Dioxide (NO_2) and Ozone (O_3) concentrations were measured at the same time opportunistic sampling of butterfly were ob- served. Shown in Figures 5, 6, 7 are the one year concen- trations of PM2.5, O_3 and NO_2. For O_3 and NO_2 meas- urement, Luneta had the highest concentration, then close second was Arroceros and last is Manila Zoo. The measured average concentration for the three sites for O_3 did not exceed the DENR EMB National Ambient Air Quality Guideline Values (NAAQGV) for O_3 which is set at 0.07 ppm (Department of Environment and Natural Resources - Environmental Management Bureau, 2016). NO_2 doesn't have any 1-hour term NAAQGV. (Department of Environment and Natural Resources - Environmental Management Bureau, 2016). For $PM_{2.5}$ concentrations, Arroceros and Manila Zoo were almost the same at 0.07 mg/m3 while Manila Zoo at 0.06 mg/m3. The WHO Air Quality Guideline values for PM2.5 is 0.010 mg/m3 annual mean and 0.025 mg/m3 24-hour mean (WHO, 2018). NAAQGV are 0.025 mg/m3 annual mean and 0.050 mg/m3 24-hour mean (Department of Environment and Natural Resources - Environmental Management Bureau, 2016). The sam- pling was just conducted for one hour and there's no available guideline values for one-hour. For the three criteria pollutants measured in the study, all the urban parks showed higher concentrations as compared to the background site which was at Halang, Batangas.

For the entire sampling period it was very consistent that Halang Lipa Batangas has the lowest record of PM2.5, O_3, and NO_2. Also it is the most di- verse mixed dipterocarp forest. It has an open and closed canopy forest surrounded with lake and diverse nectarine plants and host plants which are conducive to different species of butterfly family of Hespiriidae, Lyceanidae, Papilionidae and Nymphalidae and Pieridae. Using Cluster Analysis on Figure 3. There are 60% similarity of species were found in Halang Lipa, Lyceanidae and Pieridae are widely distributed. Species composition of butterflies in Halang Lipa Batangas consist of 25 species both in wet and dry habitat. The abundance of butterflies in dry weather condition was much greater compared in wet weather condition (Figure 2). They belong to 7 families and 23 genera. Percent distribution per family are Hespiriidae 4.35%, Lyceanidae 18.84%, Nymphalidae 8.70%, Danaidae 11.59%, Papilionidae4.35% and Pieridae 34.78%. Nacua *et al* (2017). It is also to noted that, on January to April 2019 the government of Lipa Batangas were con- structing a road and most of the host plants along the pathways were destroyed and gone. Mehan garden and SunTrust park and Japanese (Luneta) Found in Figure 1, this two sampling area generated of 75%of similarity of species using Cluster Analysis by Bray Curtis found in Figure 3. A diverse mixed dipterocarp forest in the urban city of Manila. Many Host plants and nectarine plants are found in the area Nacua 2016. The Japanese garden and Martyrdom in Luneta is a home for species of Lyceani- dae like *Nacaduba berenice, Catopyrops Ancyra, Zizula hylax* . They found paddling on Bermuda grasses, ovipos- iting on Petunia species and Pithecellobium dulce (Roxb.) Benth. (Mimosaceae), were known to be a host plants for Lyceanidae and Hespiriidae. Also, species of Pieridae such as *Delias henningia*, *Eurema alitha, Eurema hecabe, Leptosia nina, Appias lyncida, Apias olferna, Catopsilia pyranthe, Catopsilia pomona* were attracted to Many host plants of tall trees these are *Cassia Fistula* L. (Caesalpinacea), *Cassia alata* Linn. (Fabaceae), *Pithecellobium dulce* (Roxb.) Benth. (Mimosaceae), *Caesasalpinia pulcehrrima* (L.) Swartz,

Capparis zeylanica (PROSEA) (Capparidaceae). *Troides rhadamantus,* (Lucas 1835), Papilionidae is found on the Red list of IUCN, were also spotted in the martyrdom of Luneta park, Mehan garden and Arroceros Park. Mehan garden has many natural enemies feed on adult butterflies and larvae. These are Aves species such as the long-tailed shrike (Lanius schach), pied fantail (Rhipidura javanica), zebra dove (Geopelia striata), Pacific swallow (Hirundo tahitica), yellow-vented bulbul (Pycnonotus goiavier) and brown shrike (Lanius cristatus). Mehan garden are known to be a home for 22 species of butterflies identi- fied and listed host plants and nectarine plants. Nacua 2016. Arroceros Park, were found to have a higher con- centration of NO_2, O_3, $PM_{2.5}$, it because it is located near the Manuel L. Quezon bridge and Antonio Villegas street (Former Calle Arroceros). About 2.7 Million cars a day uses Quezon bridge . It was observed that the plant leaves in Arroceros park are dried and dusty and no lar- val plants would tribe on the leaves. In Figure 4 shows that it has the least butterfly observed in the rest of the sampling area. Figure 3 Cluster Analysis by Bray Curtis shows that only 40% Similarity of butterfly species. Fewer butterflies' tribe in the area simply because host plants and nectarine plants and higher concertation of pollutants. Fewer butterfly eggs and larvae found on the hostplants due to dust covering the leaves. The insects feeding on these leaves grew poorly, which suggests high levels of air pollution may be having cascading neg- ative effects on communities of herbivorous creatures University of Sheffield (2018) Migrating butterflies visit- ed trees from Arroceros Park were also attacked by Birds a s natural enemies. Similar birds from Mehan garden. Manila Zoo and Botanical Garden and Children's Park. Has a higher concentration of NO_x, O_3, $PM_{2.5}$, However it is a bit lower compared to Mehan, Arroceros, and Luneta. Because, Manila zoo is gated and it is covered with closed canopy trees. It is a mixed dipterocarp forest. Figure 4 shows fewer butterflies recorded. In Manila Zoo and Arroceros park, found to have fewer host plants and nectarine plants for the adult butterflies to sips on nectar, and remaining host plants were covered with dust and other particulate matters which is impossible for larval host plants to survive. Nectarine plants are wilted and dusty which is also impossible for adult butterflies to sip nectar on it.

Pollution is a serious threat in biodiversity loss and ecosystem dysfunctional. Major threats of pollution from over enrichment of nutrients, increasing metals and persistent organic pollutants (POPs), and climate change have led to severe ecological degradation in the coastal zone, while few studies have focused on the combined impacts of pollution and climate change on the coastal ecosystems at the global level Yonglong Lu *et al* (2018). Persistent organic pesticide is detrimental to plants and animals like butterflies. Species of butterfly that are vulnerable to the indirect effect of pollution through the concertation of NOx, O3 and $PM_{2.5}$. *Menelaides polytes ledebouria, Graphium sarpedon, Graphium agamemnon* (Papilionidae) are found in Mehan but seldom see in other sampling site. These Papilionidae species sensitive to pollution life span lasted 1-2 weeks only, Larvae are voracious eater but will refuse to eat leaves if it is wilted and with particulate matters, they prefer young leaves, shiny and free from other particulate matters. If many of these butterfly species will not be able to adapt to these change in the environment these species will no longer be observed by the future generation worst become extinct. *Nacaduba beroe, Catochrysops Strabo, Zizina otis, Lam- pides boeticus* (Lyceanidae) and *Eurema hecabe, Lepto- sia nina, Catopsilia pomona* (Pieridae) are example of species that are resistant to pollution. The availability of Many host plant and nectarine plants found in the Manila and in Halang Lipa Batangas made them the life cycle of butterflies sustainable. Pasay City, resilient butterflies found on wet and dry season Lyceanidae butterflies like Nacaduba berenice icena, Spindasis syama negrita, Zizinia Otis oriens (Lyceanidae) species nectarine on species of Fabaceae on the ground. Sipping moisture on the ground. Male butterflies observed puddling on the wet stones followed by mating. Nacua *et al* (2019). But- terflies are important pollinators to most agricultural crops. They are food source to predators like birds, spi- ders, lizards and other animal in addition to their ecologi- cal niche. They are biological indicator for air quality, Butterflies found inside the closed canopy of the forest when there is too much heat (36 degrees Celsius) and humidity (65%) in the environment considering they di- urnal insects, Butterflies perceive strong precipitation of rain and strong wind caused them migration.

It has already been found from the scientific experiments that, by using butterflies as indicators, increase of species richness and species assemblage have been augmented to 47% in a wild state. This wild state has been used as the healthy habitat for all kinds of animals. (Bashar 2010). To date, only a small fraction of the forecasted climate changes and resultant biotic impacts have been observed, but many effects are clear already (Walther *et al*. 2002). Warmer temperatures have ad- vanced the phenologies of plants, birds, and squirrels (Davies *et al*. 2005) and shifted butterfly and bird ranges toward the poles (Peterson *et al* 2004). Climate change has caused extinction of butterfly populations (McLaughlin *et al*. 2002) and loss of habitats (Wilson *et al*. 2005)

CONCLUSION

There was a higher concertation NOx, O_3, and PM 25 pollutants affecting the urban diversity of butterflies the Urban diversity of butterflies, the decreased number of butterfly families in Arroceros park and Manila zoo and Botanical garden is a threat to Biodiversity loss and a sign of poor quality of air (pollution).

ACKNOWLEDGMENTS

We would like to acknowledge the Commission on High- er Education (CHED) for funding this research project. Also, Special thanks for the research assistance who as- sisted in the field sampling and for processing the data. To the members of the research team from DLSU, UST, MAPUA and UDM for making this research possible. To god almighty for giving us the strength and the wisdom to carry on.

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