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Effect of Microclimate to Bat Diversity in Mangrove Forest of Brgy. Tubajon, Laguindingan, Misamis Oriental, Philippines (Mammalia Chiroptera)

Richel E. Relox, Christine Mae M. Eugenio, Flonica F. Imperial & Aira Jayne L. Raut

Department of Environmental Science and Technology, College of Science and Mathematics, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines

ABSTRACT Bat diversity is declining in the country because of habitat loss. Hence, an assessment study of the environmental factors affecting bat diversity was conducted in mangrove forest of Tubajon, Misamis Oriental. Quadrat sampling and mist-netting were used to assess mangroves and bats respectively, and mapped using the Geographic Information System (GIS). Shannon Diversity Index was used for both mangroves and bats while the Pearson Correlation Coefficient and Canonical Correspondence Coefficient were used to correlate bats with rainfall, temperature and humidity. Results showed that there are two species of mangroves, namely *Rhizophora mucronata* and *Rhizophora apiculata*, and three species of bats, namely *Cynopterus brachyotis, Macroglossus minimus*, and *Ptenochirus minor*, in the site. Mangroves and bats obtained the diversity index of 0.6428 and 1.018 respectively. Among the three species of bats, only *C. brachyotis* has relationship with humidity with a result of 0.04065. Thus, bats in the area highly depend on the quality of the habitat with low diversity of mangroves and varied climatic factors.

KEY WORDS Bats; humidity; mangroves; rainfall; temperature

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INTRODUCTION

Mangrove ecosystems are wetland or tidal habitats which can be found in intertidal zones of tropical and subtropical areas (Soares et al., 2016). There are different types of species that inhabit this ecosystem which include both aquatic and terrestrial species (Makori, 2017) including bats. Mangrove provides food, and serves as nursery and breeding sites for different species in terrestrial and aquatic ecosystems (Carugati et al., 2018). Hence, mangroves are significant to the life cycle of various species that are considerably important economically and ecologically (Soares et al., 2016). Among the species in the mangrove forest are bats of which *Sonneratia* mangrove trees are dependent on these mammals for pollination (Lim et al., 2001). These bat species include the lesser Musky Fruit Bat *Ptenochirus minor* Yoshiyuki, 1979, the Common Long-tailed Bat, *Macroglossus minimus* (E. Geoffroy, 1810) and the Lesser Short-Nosed Fruit Bat, *Cynopterus brachyotis* (Müller, 1838) (Bat Conservation International, 2021).

Regardless of the importance of mangroves, their population is declining at a global rate of about 1 to 2% annually (Carugati et al., 2018). Mangrove areas experienced degradation and habitat fragmentation due to development-related projects including growing population, industrialization and urbanization (Makori, 2017) which are also caused by climate changes like the rise of sea level and altered precipitation (Carugati et al., 2018). Habitat loss could result in a loss of biodiversity (Carugati et al., 2018) and thus bat species are also affected by these threats.

The population of bat species seriously declines due mainly to habitat fragmentation and overexploitation, with 37% of them classified as threatened (Aziz et al., 2021). Some species are sensitive to human disturbances while others are urban tolerant which is used to determine if the environmental quality is high or low (Benvindo-Souza et al., 2019). There are different factors affecting the diversity of bats but their biology is not yet fully understood and therefore better conservation of these species is needed, including the habitats in which they live, such as mangroves.

One of the areas in Misamis Oriental with large cover of mangroves is in Brgy. Tubajon, Laguindingan, Misamis Oriental. The bat diversity in mangrove forests is not well studied especially in Mindanao. Considering that bat species contributes to ecological balance, the researchers aimed to have an assessment of this species to determine their composition, richness, abundance, diversity, status and geographic distribution as affected by factors such as the mangrove species composition, diversity, density, frequency, dominance and importance value and the microclimate such as rainfall, temperature and humidity.

MATERIAL AND METHODS

Study area

The study was conducted in the mangrove forest of Tubajon, Laguindingan, Misamis Oriental

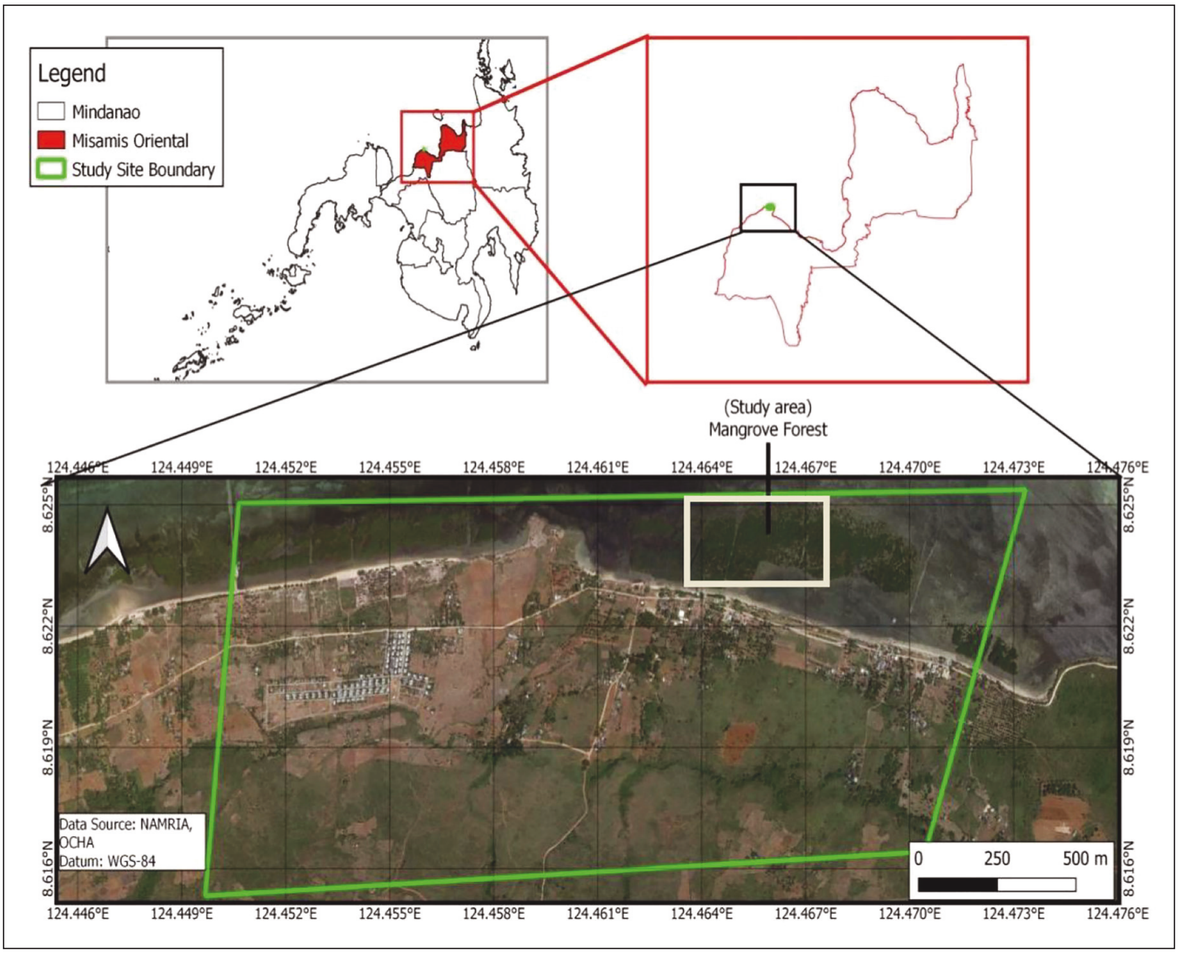

Figure 1. Map showing the location of the sampling site in Brgy. Tubajon, Laguindingan, Misamis Oriental, Philippines.

Figure 2. Map showing the stations and plots in mangrove area of Tubajon, Laguindingan, Misamis Oriental.

(8°37'22.71''N - 124.46°27'50.09''E), having 74 hectares of mangrove cover (Fig. 1). There is an abundant mangrove plantation and growing tourism in Tubajon. It has numerous mangrove plantations that were planted by the local government and local volunteers (Cailing et al., 2018). Based on the data of Weather Spark (2022), the climate in Laguindingan is hot and overcast and has little seasonal variation throughout the year such as wind, temperature and longevity of the day. Northern Mindanao is subjected to the impacts of climate change and vulnerable to human activities that threaten the species such as recreation and economic activities (Cailing et al., 2018). Based on the 2015 census, the total population rises to 2,738. The site has muddy substrate due to microbial degradation of organic matter (Dacayana et al., 2015).

Mangroves Data Collection and Analysis

To identify the mangrove species present in the area, the researchers used the quadrat sampling and established a transect line (stations) perpendicular to the shoreline (Fig. 2) and Global Positioning System (GPS) was used to take the coordinates of the sampling site (Calimpong & Nuneza, 2015). In each station, there are three (3) 10 x 10 meter plots that were established with a twenty (20) meter interval between plots (Abino et al., 2014). The mangrove was measured with its Diameter at Breast Height (DBH) with the use of a tape meter (Fig. 3). The mangroves were classified according to its fruit, leaves and flowers. The quadrat sampling differs based on the proper zonation of mangroves: landward, middle-ward and seaward. The use of secondary source available online like the Field Guide to the Philippine Mangroves (Primavera et al., 2004) was utilized in order to identify the mangroves and its composition. Shannon Diversity Index was used in this study since it considers the species richness and equitability. The mangrove structures were evaluated using the values of Relative Density, Relative Frequency, and Relative Dominance. The summations of these values were added to obtain the Importance Value in the entire sampling area (Goloran et al., 2020).

Bats Data Collection and Analysis

Ten (10) mist nets were established and used to sample or capture bats, of which four (4) mist nets placed landward, three (3) in mid zone and another

Figure 3. Mangrove sampling in Tubajon, Laguindingan, Misamis Oriental.

three (3) seaward zone. The nets were established in accessible areas for easy retrieval of bats from the nets during the night and high tides (Fig. 4). The nets were checked every one (1) hour from dusk (6 to 10PM) to dawn (4-6AM). The bats were retrieved from nets using gloves and placed in net bags for weighing. The forearm length, tail length, ear length, hind foot length and total length of bats were measured using a vernier caliper. Afterwards, they were marked by applying nail polish to avoid recounting any recaptured bats species. Sugar solution was given to bats. Each species captured was identified according to its morphometric data and released back to the mangrove forests. The taxonomic classification of bats follows the work of Ingle et al. (1999). Species richness, relative abundance, diversity index, endemism and conservation status of each species were determined and calculated. Furthermore, the Geographic Information System (GIS) software ArcGIS version 10.8 (Esri, 1999) was used in plotting the species distribution of bat species in Tubajon, Laguindingan mangrove forest areas to identify their relationship with land cover species.

Microclimate Data Collection and Analysis

Microclimate data such as rainfall, humidity and temperature were obtained during the bat data collection period. Rainfall was measured using a rain gauge (Oregon), while humidity and temperature were measured using an anemometer (Lutron). To interpret the microclimate data collection and its relationship to bats, Pearson Correlation Coefficient and Canonical Correspondence Analysis were used and performed using the Paleontological Statistical Software Package (PAST).

RESULTS AND DISCUSSION

Mangrove Species Composition

There are two mangrove species namely *Rhizophora mucronata* Poir. and *R. apiculata* Blume, under family Rhizophoraceae and Order Rhizophorales found in Tubajon, Laguindingan (Table 1) in three (3) zones: landward zone, mid zone, and seaward zone. *R. mucronata* tree has leaves of yellowish in color with black tiny spots on the underside of the leaves containing fruits and flowers. On the other hand, *R. apiculata* has reddish leaf stalks with dark green, smooth leaves. These species were planted in the year 1991 by the local community with the leadership of the LGU (Local Government Units) in Laguindingan, other private sectors in collaboration with DENR-X (Cailing et al., 2018; Olila & Relox, 2021). *Rhizophora mucronata* and *R. apiculata* are mid zone species (Olila & Relox, 2018), these species are stilt mangroves which thrive at freshwater to full strength seawater (Duke, 2006).

Mangrove Diversity Index

Mangrove diversity is less than 1.99 which indicates that mangrove area has very low diversity. The Shannon Diversity Index is commonly used to determine how diverse species are in the area. Since there are only two species planted in the sampling site, it signifies that the mangrove species in the area has low diversity. According to Alimbon et al. (2021), this is affected by the level of planting of pre-selected species in reforestation.

Importance Value of Mangroves

It can be observed that *R. mucronata* is denser (67.632854), frequent (0.67/67%), dominant (0.64/64%) and has higher Importance Value (199%) as shown in Table 2 compared to *R. apiculata.* Upon observation of the mangrove species in the area, there are a lot of juvenile *R. mucronata* mangroves that are in the stage of development. So, it means that this is a fast growing mangrove species

Figure 4. Map showing the location of the nets established in mangrove area of Tubajon, Laguindingan, Misamis Oriental.

regardless of what zone it was planted. According to Walters (2004), *R. mucronata* generate seeds in the form of viviparous propagules that can be taken off a branch and dropped into mud when ready. If the conditions are favorable and the seedling is not damaged, they will begin to produce roots and leaves. Other tree species are frequently pruned or removed from planted areas while *R. apiculata*, produce fewer propagules (Walters, 2004).

Bat Species Composition

There are three bat species, namely *C. brachyotis*, *M. minimus* and *P. minor* (Chiroptera Pteropodidae), as shown in Table 3. There were only few species recorded in the site because of the low diversity of mangrove as food and shelter of bats.

Bats Species Richness and Abundance

The results in Table 4 shows that *C. brachyotis* is more abundant in the area with a result of nine (9) captured bats than *M. minimus* and *P. minor* with a result of four (4) captured bats, respectively. *C. brachyotis*, *M. minimus* and *P. minor* were observed to be roaming around the mangroves where it indicates that they can adapt on this environment and that mangroves can either be considered as their foraging area or flyway going to the caves because it was found out that there is a cave nearby which could be their roosting place. Based on the study of Thong et al. (2022), *C. brachyotis* and *M. minimus* can be found in *R. apiculata* mangrove. *M. minimus* and *C. brachyotis* were the most common fruit bat in the mangrove forest (Duya et al., 2020). Among the three (3) species, *C. brachyotis* is more abundant because it highly adaptive to different environment and habitat including the mangrove swamps (Del Socorro et al., 2018).

Bat Diversity Index

The diversity index of bat species is

Order	Family	Scientific Name	Common Name	Local Name	IUCN Status	Endemism
Rhizophorales	Rhizophoraceae	*R. mucronata*	Loop-root Mangrove	Bakhaw babae	Least Concern	Non-endemic
Rhizophorales	Rhizophoraceae	*R. apiculata*	Tall-stilt Mangrove	Bakhaw lalaki	Least Concern	Non-endemic

Table 1. Taxonomic classification and composition of mangrove species found in Tubajon, Laguindingan, Misamis Oriental.

Species	Relative Density	Relative Frequency	Relative Dominance	Importance Value
R. mucronata	67%	67%	64%	**198%**
R. apiculata	37%	33%	35%	105%

Table 2. Importance Value of mangrove species in Tubajon, Laguindingan, Misamis Oriental.

Order	Family	Species	Common Name	Local Name
Chiroptera	Pteropodidae	*C. brachyotis*	Lesser Short-Nosed Fruit Bat	Kwaknit
Chiroptera	Pteropodidae	*M. minimus*	Lesser Long-Tongued Fruit Bat	Kwaknit
Chiroptera	Pteropodidae	*P. minor*	Lesser Musky Fruit Bat	Kwaknit

Table 3. Taxonomic classification and composition of bat species found in mangrove forest of Tubajon, Laguindingan, Misamis Oriental.

Species	Number of Individuals	Relative Abundance
C. brachyotis	9	52%
M. minimus	4	24%
P. minor	4	24%
Total	17	100%

Table 4. Relative richness and abundance of bat species in mangrove forest area of Tubajon, Laguindingan, Misamis Oriental.

Bat species	Conservation Status	Endemism
C. brachyotis	Least concern	Non-endemic
M. minimus	Least concern	Non-endemic
P. minor	Least concern	Endemic

Table 5. Conservation status and endemism of bat species in mangrove forest of Tubajon, Laguindingan, Misamis Oriental.

Species	R	p- value	Indication
C. brachyotis vs rainfall	0.530455	0.40183	No significant correlation
C. brachyotis vs temperature	-0.7751	0.22062	No significant correlation
C. brachyotis vs humidity	-0.37897	0.04065	There is a significant correlation

Table 6. Pearson correlation coefficient (r) between *C. brachyotis* and rainfall, temperature, and humidity. *Legend: p>0.05=no statistically significant, p<0.05 = statistically significant

Species	R	p- value	Indication
M. minimus vs rainfall	-0.10607	0.57613	No significant correlation
M. minimus vs temperature	-0.16129	0.82095	No significant correlation
M. minimus vs humidity	-0.2582	0.72973	No significant correlation

Table 7. Pearson correlation coefficient (r) of *M. minimus* and rainfall, temperature, and humidity. *Legend: p>0.05=no statistically significant, p<0.05 = statistically significant.

Species	R	p- value	Indication
P. minor vs rainfall	-0.0804	0.6039	No significant correlation
P. minor vs temperature	-0.1067	0.86395	No significant correlation
P. minor vs humidity	0.240192	0.81989	No significant correlation

Table 8. Pearson correlation coefficient (r) between *P. minor* and rainfall, temperature, and humidity. *Legend: p>0.05=no statistically significant, p<0.05 = statistically significant.

0.017602986 which is less than 1.999, indicating low diversity. There are only three species of bats in the area which means a low number of species. Bats have different preferences in how *C. brachyotis, M. minimus* and *P. minor* found in mangrove forest search for food, favor the climate and the area itself. *C. brachyotis* and *M. minimus* were identified in the study of Duya et al. (2020) and it was found out that the species diversity is lower in mangrove area. Based on the study of Del Socorro et al. (2018), *C. brachyotis* is highly adaptive species into various habitats. *P. minor* is less studied specifically, its association to mangroves, but according to Del Socorro et al. (2018), this species can be found in lowland areas and it is more sensitive to disturbances.

Conservation Status and Endemism of Bat Species

The IUCN classifies bat species as Least Concern if they have a distribution or population status that is neither threatened nor near threatened (Table 5). Non endemic means having a wide native range while endemic species can only be found in a certain area. *P. minor* is endemic in Mindanao region while the others are non-endemic.

Species Distribution

The map illustrates the species distribution of bats in mangrove forest of Tubajon, Laguindingan, Misamis Oriental (Fig. 5). The figure shows that the bats are distributed in the area where they were seen in landward zone, mid zone and seaward zone. Only *C. brachyotis* was seen in all zones.

Correlation of C. brachyotis *and Microclimate*

Table 6 below shows that only humidity has significant correlation with *C. brachyotis* with a result of 0.041. When the result shows a relationship which is affected by some factor, it is considered to have significant correlation. Among the rainfall, temperature and humidity factor, only humidity has significant correlation with *C. brachyotis*, which means that they are inversely proportional. On the other hand, factors such as rainfall and temperature do not affect the activity of the species. This shows that temperature and rainfall have no effect on bat activity. The same result was found out in the study of Basukriadi et al., 2021, wherein there is a weak correlation between *C. brachyotis* abundance and air temperature. Scanlon et al. (2008) also stressed that rainfall (>1 mm/24 h) at midnight did not influence bat activity.

Correlation of M. minimus *and Microclimate*

Table 7 shows that *M. minimus* has no correlation with rainfall, temperature and humidity given that the results are greater than 0.05 which indicates no significant correlation. Rainfall, temperature and humidity indicate no significant correlation with the activity of *M. minimus*. The same result was found in the study of Barros et al. (2014), wherein the relative humidity of the air during the sampling period was never below 60%, which may indicate that variation of humidity has no effect on bat activity.

Correlation of P. minor *and microclimate*

Table 8 shows that *P. minor* has no correlation with rainfall, temperature and humidity given that the results are greater than 0.05 which indicates no significant correlation. The three factors such as rainfall, temperature and humidity do not affect the activity of *P. minor*. The same result was found out in the study of Bacordo et al. (2019) where rain has no significant correlation due to the little amount of rainfall during the sampling period of fruit bats including the *P. minor.*

Bat and Mangrove Correlation using CCA

Figure 6 shows two (2) axes, Axis 1 and 2 measuring two (2) different Eigenvalues and percent values of 0.20 and 0.08 respectively which accounted for 72.3% and 27.7% of the total variance of the total weighted average of species. The left upper and lower quadrant (Axis 1) represents the microclimate parameters while the right upper and

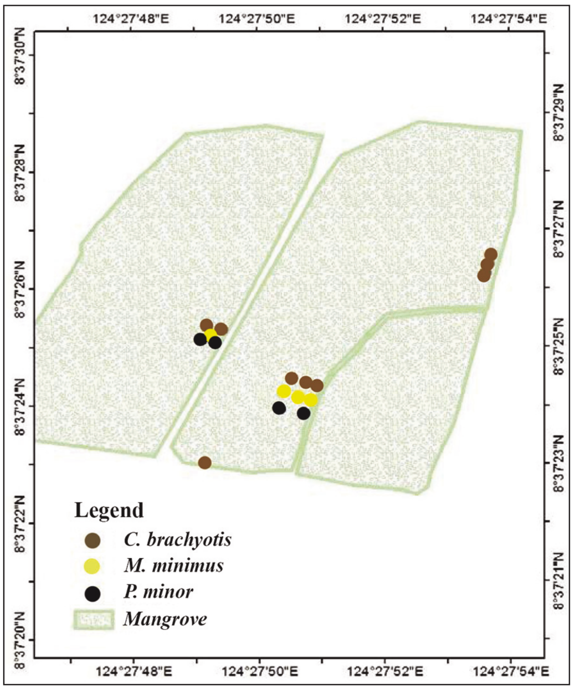

Figure 5. Map showing the species distribution of bats in mangrove forest of Tubajon, Laguindingan, Misamis Oriental.

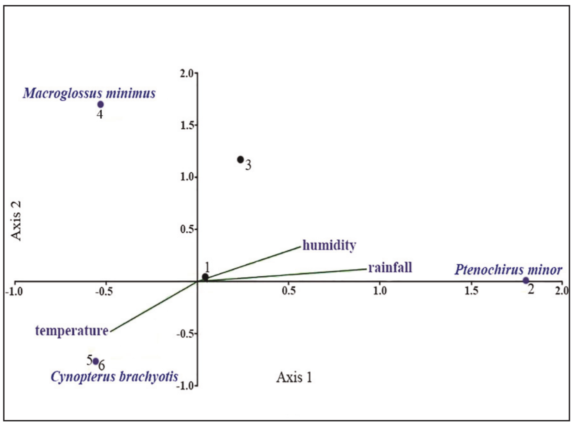

Figure 6. The CCA of Bats (*C. brachyotis*, *M. minimus* and *P. minor*) and microclimate (Temperature, Humidity, Rainfall).

lower quadrant (Axis 2) represents the bat species. It is shown that bat species such as *M. minimus* and *P. minor* observed are not closely related to rainfall, temperature and humidity while *C. brachyotis* is associated with humidity but generally bats and microclimate are not closely correlated in this study. It is also due to the limited data of rainfall, temperature, and humidity in conjunction to bat collection.

CONCLUSIONS

Thus, bats exist in mangrove forest but have low diversity which might be affected by their level of adaptability to various environments. In terms of the microclimate, the bats are indirectly affected by rainfall, temperature, and humidity factors. It is important to continuously study the existence and behaviors of bats in mangroves in the Philippines. LGU's (Local Government Units) can generate policies to avoid exploitation and conduct programs that would enhance the knowledge of the local residents and fisherfolks towards bats and mangroves.

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