The Distribution and Ecology of Bats in the Polillo Islands, Philippines

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ABSTRACT

The bats of Polillo Island group are described. A total of 25 species of bats were recorded. These include eight fruit bats, one megadermatid, nine rhinolophid and seven vespertilionid. Of the 25 species recorded, 11 are listed as new records for the island. The study employed disturbance gradient surveys in Sibulan watershed, Polillo Island to determine diversity patterns. Trends show that many species are generalist, particularly fruit bats, owing to the small size of the forest and its proximity to disturbed habitats. In addition, new netting techniques were employed: ground netting, sub canopy netting and tunnel trapping. Tunnel trapping proved to be more efficient in capturing bats having an efficiency of 41 and 28-fold than ground and sub-canopy netting respectively. Preliminary assessment shows that foraging behavior plays a great role in discrepancies in capture efficiencies.

INTRODUCTION

The Philippine bat fauna is very diverse, with 71 species recorded, of which 24 species are endemic to the country (Heaney et al, 1997). Studies even at the level of alpha taxonomy and its associated distribution records are lacking, and seven new species have been identified since 1969 and additional four new records (*Murina cycloti*s in 1991, *Pteropus dassymalus* and *Harpiocephalus harpia* in 1992 and *Hipposideros lekaguli* in 1995) in the country during the start of the 1990's (Ingle, 1992 and Heaney et al 1997).

Mistnets have been used in the Philippines for bat surveys since the 1960s, but the method does not work well for microchiropterans. A seven-month study conducted in the Mount Makiling Forest Reserve in 1993 utilized nets that were raised above the ground from three meters to 16 meters and captures were compared with nets set-up at standard heights (0-3 meters). This study enabled inferences on community structure in the subcanopy. Likewise, species composition significantly differed along the different strata in which nets set-up at the subcanopy yielded more species. A study done in the same locality in 1998 also made inferences on the foraging behavior and space-time movement of microchiropterans and made use of a netting technique (tunnel trap) that can capture microchiropterans with relative ease compared with ground nets (Sedlock, unpublished data). Incorporating these new netting techniques into standard field methodologies or protocol will enable a researcher to ensure adequate sampling of bats in a relatively short period of time. In addition, inferences can be made on bat community structure (from subcanopy and below) and their use of natural corridors or flyways.

Primary forest cover in the Philippines as a whole has been reduced from more than 80% of the total land area near the turn of the century to ca. 8% in 1988 (Myers, 1988). Furthermore, impacts of deforestation on wildlife may be particularly severe on small islands, where population and community structure may be less robust (Rickart et al, 1993). This is particularly true on several small islands such as Lubang, Batamnes, Marinduque, Siquijor and Polillo among others, where most of the original forest have been extirpated over the past century. In Polillo, at the turn of the century, McGregor had a first glimpse of what was then a pristine and primeval thick forest, where grasslands and clearings were non-existent (Gonzalez,1997). Today, pressures from industrialization and small-scale farming systems have marginalized the original forest of Polillo at a critical minimum (Gonzalez, 1997).

This paper presents the first synoptic list of mammals from Polillo Island. Previous records from the islands came mostly from collecting trips and inventory of other faunal groups where specimens of bats were taken as "sidetrip", e.g. Crombie in 1994, Taylor in 1922, and McGregor from 1910.

The present study documents diversity of bats based on disturbance gradients and assesses the efficiency of new netting techniques.

METHODOLOGY

Field work were conducted at five site in Polillo island. Most of the field work was conducted along a disturbance gradient in Sibulan forest

Site P1 - Agriculture site, Sitio Sta. Maria, Bo. Pinaglubayan, Polillo Munic. Polillo Is. Seven net-lines were placed on this site, four ground nets, two subcanopy nets and a tunnel trap (net G). Two groundnets (A and E) were set-up traversing a river while rest of the groundnets were placed along a ricefield paddy (net F) and within a coconut grove (net E). Subcanopy nets were hoisted 10 meters above the ground and were placed facing a rice field (net c) and along coconut groves adjacent a sizeable meadow (net B). The tunnel trap (net G) was placed traversing a river with its opening facing the widest junction of the river. This site is about a kilometer east of the watershed boundary and is proximal to a nearest barangay. Much of the vegetation consists of coconut groves and ricefields in between. Fruit trees are uncommon which made up mostly of *Ficus nota*, *F.variegata* and *Antidesma pentandra*. Pioneer plant species are also present in this area like *Tremma orientalis* and *Premna odorata.* Netting effort for ground nets and subcanopy nets are 71 and 32 net-nights respectively while tunnel trapping effort was 12 net-hours.

Site P2- Secondary forest; Sitio Sta. Maria and Mahabang Kahoy, Bo. Pinaglubayan and Sibulan, Polillo Munic. Polillo Is. This site is located within the boundaries of the western part of the watershed. Six net stations were placed in this site. Three ground nets, A ,C and D were set-up along a small trail, ridge tops , and across a creek respectively. Two subcanopy nets (nets B and E) were placed seven meters above the ground and were set up along gaps in the vegetation while tunnel trapping (net F) was conducted adjacent a fishpond that flows through an underground spring. Emergent trees (mostly non-dipterocarp) had small to medium sized buttresses, diameters at breast height of about 0.8 to 1.2 m and reaching heights of 15-25m. Canopy cover is not continuous and is replaced by *Musa* vegetation and occasional bamboo thickets and small-sized meadows. Canopy vegetation mainly consists of *Ficus* spp particularly *minahasse* and *variegata*. An occasional cluster of dipterocarp trees are present although it is restricted along steep slopes of hills of about 25-40 m. These dipterocarps have a rather small dbh (0.2-0.8 m) although saplings are numerous. Epiphytic ferns like *Asplenium*, *Drynaria* and *Freycinettia* were rare to moderate, with their frequency increasing with proximity to the watershed. An open understorey consisted of saplings, small palms (*Calamus*) low ferns, tree ferns (*Cyathea*) and erect terrestrial pandans (*Pandanus*), though the last one is quite rare. Fallen logs are quite common and most of them have medium sized dbh. Exposed rocks or rock formations having crevices are almost non-existent. An occasional clearing can be seen near the southern portion of the watershed and most of them are titled lands. A trail coming from the nearby barrio bisects this site and extends across the watershed to the town. This trail not frequented by the inhabitants of the nearby barrio. A temporary camp was set-up near net C. Netting efforts for ground and subcanopy nets were 64 and 32 net-nights respectively. Tunnel trapping effort accounts for 8 net-hours.

Site P3 - Primary forest; Sitio Maganit, Mahabang Kahoy, and San Francisco, Bo. Sibulan, Polillo Munic. Polillo Is. This site is confined inside the watershed boundary and most of the netting stations are located on a ridge system bounded by steep valleys in intact original lowland forest. Emergents reach heights of about 25-35m with buttress' dbh of about 0.8 to 1.6m. The canopy was 15-25m high and broken by occasional tree falls. Woody vines clinging around large trees are common particularly the large wrist-sized *Entada*. Epiphytes, particularly ferns, were common. Moss was limited to trunks of large trees and fallen logs. Understorey was similar to P3 although medium sized trees and erect pandans are common. Many rivers that serve as potable water source are scattered over the watershed. These rivers, that form numerous tributaries and veins, are Mahabang Kahoy, Sabian, Maganit and Sta. Maria rivers. Eight netting stations are scattered over this site. Three ground nets, C,D, and E were placed along ridge tops, stream, and at edge of forest gaps respectively. Subcanopy nets A and E were likewise placed above a stream and forest respectively. Three tunnel trapping stations (B,G,and H) were placed separately from each other and all them set-up across rivers. Ground and Subcanopy netting efforts were at 64 and 32 net-nights respectively while tunnel trapping accounts for 12 net-hours.

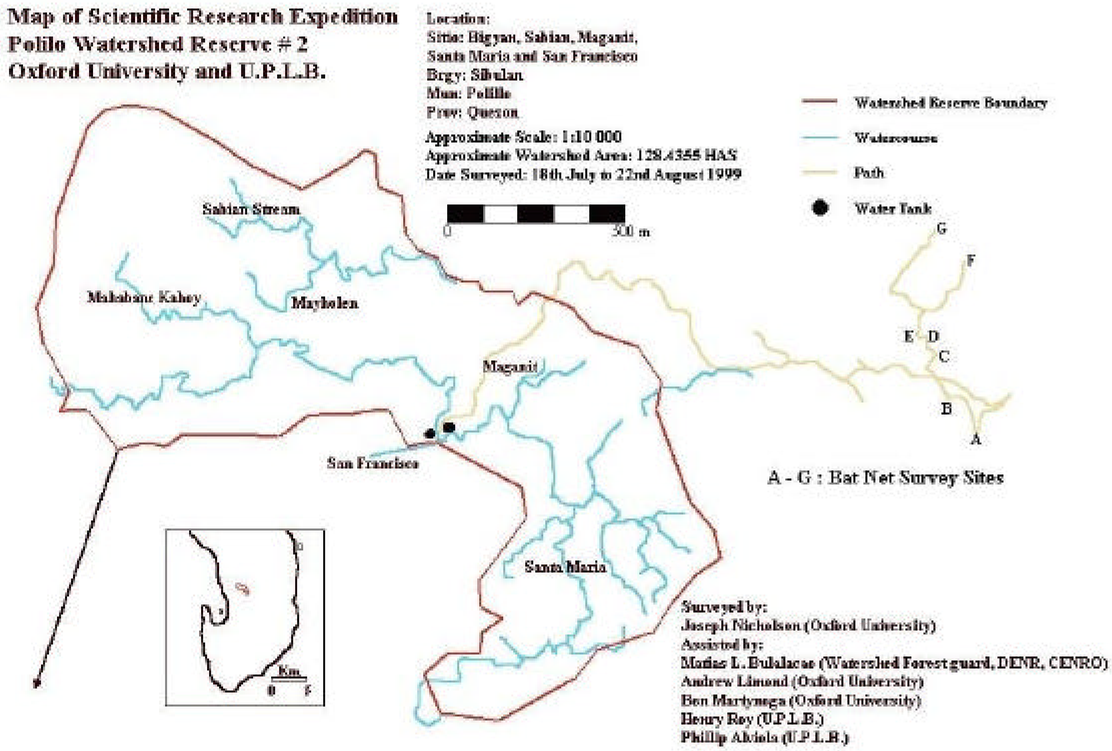
Site P4 - Sitio Kitiwan, Bo. Bato, Panukulan Munic.Polillo is. The site, along its adjacent forest constitutes the main Panukulan Watershed Reserve. The forest is a secondary patch with mixed agricultural crops such as coconut groves, rice paddies and herbaceous shrubs. The secondary patch is confined to the steep hills of about 50 m that surround and form a wall facing the sea. There are few emergents, with heights reaching 20-25 m. Canopy cover is, more often than not, broken except along steep slopes of hills. Much of the original vegetation has been cleared for agriculture. An open understorey consists of an occasional palms (*Calamus*), low and tree ferns, and erectile pandans. *Ficus* density is high although some dipterocarp species were observed although with small dbh. Water source, in the form of creeks, are rare while rivers are absent. The expedition stayed only for five days and netting effort was only confined to ground netting with four stations. Total net-nights was 56.

Site P5 - Bulalon and Mapanghi Caves, Bo. Bulalon, Burdeos, Polillo Is. the Bulalon cave was surveyed last 1974 by UPLB led by Prof. P. Alfonso and Prof. P.L. Alviola III. They stayed for three days and netted four species of insect bats, *Miniopterus australis*, *M.schreibersi*, *Rhinolophus arcuatus*, and *Hipposideros "coronatus"*.The author went back during the span of the expedition surveyed the Bulalon cave and eventually found another cave, apparently missed by earlier researchers, the Mapanghi Cave. These caves are about five kilometers south of the town proper. The Mapanghi cave is nearer with respect to the baranggay, with walking distance of about 300m. The trek to Bulalon cave is much longer, about 30 minutes of negotiating steep hills and valleys. Vegetation uphill from the Bulalon cave was heavily disturbed secondary forest although patches of high woodstands can be seen high portion a hill leading to Bulalon cave. Areas downslope were predominantly agricultural land. Farther west about 500 meters, small limestone formations were observed having jagged edges although for alcoves and can be possible roost site for bats. Roost site of *Acerodon jubatus* was discovered within this vicinity and they were observed to be roosting on a tree of about 15 high.

The largest cave at this locality, locally known as Mapanghi cave, had two main entrance (northwestern and southern). The northwest opening is at the center of a large concavity in the limestone cliff. The height of this opening is about 13 m (outer) and the inner portion is about 10 meters. This entrance leads to a cathedral, with a height and width of 20 m and 50m respectively. Several shallow solution pits were located along the path. The southern opening is about 10 meters and a shallow stream flows through the opening. Along the path coming from the south opening, a long, uphill shaft was seen that leads to the eastern opening about 50 m. The eastern opening is small, about 3 meters in diameter. Sampling of bats were done using hoopnets.

Minasawa

The island of Minasawa, still contains relatively good beach forest in its small five hectare area, due to its protection as a game refuge and bird sanctuary. Large hardwood trees are found in the interior, smaller trees in the periphery with the low canopy dominated by Marang and Dapdap. Colonies of *P. hypomelanus* and possibly *P. vampyrus* roost within these canopy numbering to about 100



B. Netting techniques

Our field studies were conducted using procedures that evolved over time. The primary purpose of surveys of 1996 was to ascertain species richness and diversity of birds as M.Sc dissertation of Gonzalez. Mistnetting of bats became only secondary to that purpose. Standardized field methodologies were not employed so no records of how many nets were set-up, only species richness per island. The present survey had the additional aim of documenting habitat disturbance gradient and employing new mist-netting techniques that were not conceived during the 1996 surveys. Great care was involved in placing nets, number of nights run and the total effort given at each disturbance gradient. Moreover, documentation of ecological parameters such as roost sites was added.

Bats were caught in mistnets set on ridge top, across established trails and streams, or at the edge of clearings in forest, and among fruit trees in agriculture areas. The number of net-nights were standardized more or less so as to permit valid comparison between sites particularly in the disturbance gradient study. For convention, one netnight is equivalent to one 6-meter net left open for 12 hours.

Four types of collecting techniques were employed:

a. Ground mistnetting - 35 mm mesh monofilament mistnets (6 or 12 m long) were set up. These nets were placed 0-3 m above the ground. Total netting effort for the gradient study was 200 net-nights.

b. Sub-canopy netting - this methodology was adopted from Ingle's work in Mt. Makiling during her study about chiropteran vertical stratification. Sub-canopy nets, each consisting of two 12 m nets, one placed above the other, were hoisted by a pulley system or by long bamboo poles. The height of the placement of these nets ranged from 5-10 m depending on the terrain. These nets were placed on natural gaps in the forest or in between two coconut stands in agriculture land. Comparison of this method, in terms of its catching success and type of species captured, with other netting technique was done. A total of 96 net-nights was conducted in this technique with each disturbance gradient having 32 net-nights.

c. Tunnel trap- this methodology was adopted from Sedlock's unpublished work on foraging behavior of microchiropterans. The tunnel trap consists of a series of nets (eight) that are connected with each other, forming a rectangular box configuration. The longer sides and the ceiling consisted two 12 nets (each) placed above the other. One of the shorter sides was left open since no nets were attached, and this serve as the opening. All four corners are supported by poles of about 5-7 meters long, with two of these poles being stationary. Three people manthe contraption, two holding the stationary poles (opening) while the other stays inside the "tunnel". Once a bat goes inside the tunnel the poles are dropped, sealing the tunnel and the bat is caught in a hoopnet. The tunnel trap was placed strategically on sites such as across creek where insect swarms are plenty. Total netting effort for this method was 32 net-hours, 12 each for primary and agriculture sites and 8 for secondary forest.

d. Roost site survey - this procedure was supplementary for the abovementioned techniques so as to document bats that are very hard to observe or capture. Roost site observed by this study included hollow trees, crevices in rock formation, culverts, leaf fronds especially Anahaw (*Livistona*) and caves especially those that formed cathedrals.

RESULTS

Species Accounts

Family Pteropodidae - Fruit bats

Acerodon jubatus (Eschscholtz, 1831)

The globally-threatened golden-capped flying fox is a Philippine endemic and is found through out the country with the exception of the Palawan region. This species is the first record for the islands. It was observed in a roosting site with colonies of about 50 in Bulalon, Burdeos. We did not obtain any specimens nor tried to capture this species since the rocky and loose terrain could not permit it. Our field guide reported numbers close to 1000 and some roost in other places . These bats, while in roost, were observed to display aggressive behavior like "boxing" and squeals when they come into contact with each other.

Individuals observed/captured: Close to fifty individuals were observed, all in Burdeos (P5)

Cynopterus brachyotis (Peters, 1862)

The short-nosed fruit bat is common through out the Philippines and is widely distributed in Southeast Asia. This bat was captured in all sites except in Minasawa Island. This bat

was also the commonest species captured in the disturbance gradient study with 73 individuals of which 31 was in agroforest (P1). It was also common in secondary forest (P2) with 24 although it was uncommon in primary forest (P3). Netting in P4 also proved this bat to the commonest. Four individuals were taken in P4 underneath an Anahaw leaf and likewise was also observed in the Watershed near P2. This bat was caught mostly in groundnets (38) although subcanopy nets proved to be successful also with 25 individuals. Only two individuals were caught inside a tunnel trap.
Individuals caught/observed: Total 73. Site P1 (31); site P2 (24); site P3 (10); site P4 (8).

Eonycteris spelaea (Lawrence, 1939)
The cave nectar bat occurs from India to Timor and is common throughout the Philippines. In our disturbance gradient study it was only captured once, in agriculture site (P1) using the subcanopy nets. It is possible that this species occurs in the caves we visited, so a more thorough examination is required. The lone individual captured was an adult female (measurements are given in table).
Individuals caught/observed: site P1 (1).

Macroglossus minimus (Matschie, 1899)
The dagger-toothed flower bat occurs from Thailand to Australia and is found throughout the Philippines. This is the third most common bat caught in the disturbance gradient sites and is common in agriculture site (P1) with 26 individuals captured. It is quite uncommon in forested areas especially in primary forest (P3) due to paucity of banana stands. Ground nets proved to be the most successful in capturing this species (26) although it was also captured in subcanopy (7) and tunnel trap (1). In Panukulan (P4) a lone individual was captured.
Individuals caught/observed: Total 38. Site P1 (26 indv); site P2 (7); site P3 (4); P4 (1).

Ptenochirus jagori (Peters, 1861)
This species is a Philippine endemic, occurring throughout the archipelago with the exception of the Palawan region. It is the second most abundant bat captured in gradients with 72 individuals. It was most common in agriculture (P1) and primary forest sites (P3) with 29 and 33 individuals each and uncommon in secondary forest (P2) with only 5 individuals. Subcanopy netting was the most successful method in capturing this species with 42 individuals. It was also captured in Panukulan (P4 with 5 individuals) and it may be present in Burdeos. This species was observed to fly very high inside forested areas and this could account for few individuals captured in secondary forest (P2) since subcanopy nets set-up in that site were not high enough (5 meters). Heaney (1989) reported this species to be common in forested areas but ventures out in agriculture lands if there is forest areas present nearby. This conclusion was observed in this study.
Individuals caught/observed: Total 72. site P1 (29); site P2 (5); site P3 (33); site P4 (8).

Pteropus hypomelanus (Mearns, 1905)
This common flying fox occurs from the Maldive Islands to the Solomons. It is widespread in the Philippines, where it is commonly encountered in lowland agriculture areas. This species was observed in great numbers in Minasawa Island about 100 indv and

was also seen in mixed colonies with Pteropus vampyrus. It was also observed in Polillo where it can be seen roosting on top of coconut trees usually in group of fours or fives. Individuals caught/observed: Observed in the Sibulan, Panukulan and Burdeos in Polillo Island. Also observed on Minasawa (about a hundred individuals).

Pteropus vampyrus (Mearns, 1905)
The giant flying fox is widespread in Southeast Asia and is locally common in primary forest in the Philippines (Rickart et al, 1993). This species is a new record for the island and was observed in Minasawa island in mixed colonies with P. hypomelanus. Its presence in Polillo needs to be confirmed where it was reported by villagers to be flying at dusk in Sibulan.
Individuals caught/observed: No individuals caught but observed in Minasawa and probably Polillo island (Sibulan).

Rousettus amplexicaudatus (E. Geoffroy, 1810)
The rousette fruit bat occurs from Thailand to Solomon islands and is found throughout the Philippines. Although it was caught at forested sites (P2 and P3 with 11 and 3 individuals respectively), it was most common in agriculture lands (P1) with 14 individuals. Ground netting was the most successful method in capturing this bat accounting for 18 individuals while subcanopy netting captured 11 individuals. It was not capture in the tunnel trap. A lone individual was captured in Panukulan (P4) in nets set up 0.3 meters from the ground near the waterfalls. In Burdeos (P5), it was observed roosting in Mapanghi cave numbering to about several thousands along with other insect bats. It was not caught though in other islands.
Individuals caught/observed: Total 29. Site P1 (14); site P2 (11); site P3 (3); site P4 (1); site P5 (roosting in caves numbering to about several thousands).

Family Magadermatidae- False Vampire Bats
Megaderma spasma (Linnaeus, 1758)
The false vampire bat occurs from India and is found throughout the Philippines. Only two individuals were captured in the study, both in agriculture site (P1) using a groundnet and in the secondary site using the tunnel trap (P2). It was observed while tending nets to fly real low especially in rivers where it was skimming for prey.
Individuals caught/observed: Total 2. Site P1 (1); site P2 (1).

Family Rhinolophidae- Horseshoe Bats
Hipposideros ater (Templeton, 1848)
The dark leaf-nosed bat is found from India to northern Australia and is widespread in the Philippines. This species is a new record for the island. Three individuals were caught in this study, all of them in the gradient sites. Two individuals were caught in agriculture site (P1) while a lone individual was caught in secondary site (P2). This bat was solely caught by tunnel trapping. In agriculture site, it was caught swooping inside the trap on a partially-dried river bank facing an open area where the river flows while its back facing the front of a drooping tree about 1.5 meters from the ground. In secondary forest (P2),

before entering the tunnel, this bat observed to be skimming in narrow creek forming corridors.
Individuals caught/observed: Total 3. Site P1 (2); site P2 (1).

Hipposideros bicolor (Temminck, 1834)
The bicolored round-leaf bat is widely distributed from India to Timor although it is rarely caught in the Philippines. Previous island records in the country includes Luzon (one locality), Mindoro and Palawan so this makes this species a new record for Polillo island and additional record for the country. This bat is one of the rarest bat caught in the study with only a lone individual. It was caught in primary forest (P3) using the tunnel trap. The trap (net B) was placed across a river between two steep hills forming a valley.
Individuals caught/observed: Total 1. Site P3

Hipposideros diadema (Meyen, 1833)
The diadem leaf-nosed bat is widespread from Southern Asia to Northern Australia. It occurs throughout the Philippines in a variety of habitats ranging from agricultural situations to primary forest (Rickart et al, 1993). In Polillo however, it was not caught in primary forest (P3) and most of the captures were from agriculture site (P1) with five individuals and caught in all netting techniques. In secondary forest (P2), two individuals were caught both by ground netting and tunnel trapping. In Burdeos (P4), it was observed roosting in several thousands (Mapanghi cave) hanging in a large cathedral. It was also caught in Patnanungan island.
Individuals caught/observed: Total captured 7. Site P1 (5); site P2 (2); site P5 (several thousands observed). Also recorded in Patnanungan island.

Hipposideros obscurus (Peters, 1861)
This leaf-nosed bat is a Philippine endemic with distribution scattered around the country although there are no previous records from Polillo. This is one of the rarest bat captured in the study - only one individual captured in secondary forest site (P2). Ecological records from other study reported it to be locally common to uncommon in primary and disturbed forest up to 850 m. This species was captured using the tunnel trap that was placed in front of a creek forming a narrow corridor towards the forest. It is speculated that this species inhabits fallen log with hallow interior and may be present in primary forest. None were encountered in other islands.
Individuals caught/observed: Total 1. Site P2

Hipposideros pygmaeus (Waterhouse, 1843)
The pygmy round-leaf bat is also a Philippine endemic with previous records from Bohol, Luzon, Marinduque, Negros and Panay. Also one of the rarest bat caught with 2 individuals, this species is another new record for the island. In the gradient sites, it was netted in primary forest using the tunnel trap. The trap was placed across a river forming a narrow bend 20 meters from the opening of the trap. The river is about five meters wide and is surrounded by a low cliff with dense hard wood vegetation. This species was also caught (by hoopnet) in Mapanghi cave in Burdeos (P5-one individual). It is speculated that the caves are one of the last stronghold for this species in Burdeos.

Individuals caught/observed: Total 2. Site P3 (1); site P5 (1)

Hipposideros sp.
This unknown species was recently discovered being presently housed in Animal Biology Laboratory in UPLB. There were five specimens with their tags placing them caught in Bulalon caves in Burdeos on a collecting trip last 1974 by Pedro L. Alviola. External measurements didn't conform with Ingle and Heaney's Key to the Bat Families of the Philippines. This species may represent new taxa or new record for the country though further analysis of its cranial measurements is still not finished.
Individuals caught/observe: None. Five were caught in 1974 in Bulalon caves, Burdeos.

Rhinolophus arcuatus (Peters, 1871)
This species occurs from Sumatra to New Guinea. In the Philippines, there appear to be two morphs, differing in body size (Heaney et al, 1997). Individuals captured here in Polillo represent the smaller morph though one individual taken in Mapanghi cave fits the larger size class. This is surprising since the smaller morphs were also captured in the same cave (Measurements in Table). In the gradient sites, 22 individuals were captured making it the most common microchiropteran caught. It is often captured in agroforest (P1) with 17 individuals and less common in forest sites (P2 and P3). The tunnel trap proved to be the most successful technique in capturing this species (19) and it was not caught in subcanopy nets. One dead individual was seen in Bulalon cave.
Individuals caught/observed: Total 22. Site P1 (17); site P2 (2); site P3 (3); site P5 (observed in caves).

Rhinolophus inops (K. Andersen, 1905)
This horseshoe is a Philippine endemic. It was previously recorded in Polillo but was not captured in the present study. Specimens of this species from the island are currently housed in Field Museum of Natural History in Chicago.
Individuals caught/observed: None.

Rhinolophus rufus (Eydoux and Gervais, 1836)
This large species is a Philippine endemic and its status listed as Indeterminate in the Philippine Red Data Book. This beautiful bat is also one of the rarest species caught in the study (2 individuals) and caught only one in the gradient sites. It was caught in primary forest (P3) using a tunnel trap in the same net station with *H. pygmaeus*. One individual was also caught in Bulalon cave (P5). This species seems to be dependent on primary forest and caves.
Individuals caught/observed: Total 2. Site P3 (1); site P5 (1)

Family Vespertilionidae-Vesper and Evening Bats
Kerivoula whiteheadi (Horsefield, 1824)
The Whitehead's wooly bat is found from Southern Thailand to Borneo and the Philippines. Previous records are from Luzon, Minadanao, Palawan and Panay, making this another new record for Polillo island. All three individuals netted were caught in primary forest (P3) using the tunnel trap. Two individuals were caught in tunnel trap that

placed in a very narrow creek of about 4 meters and also facing a bend of the creek some 5 meters from the opening. Vegetation surrounding the creek is dense with abundant understorey. It was observed that this species frequents flyways that are narrow particularly creeks and small-sized rivers. Another individual was caught in the same net that captured *R.rufus*.
Individuals caught/observed: Total 3. Site P3

Miniopterus australis (Hollister, 1913)
The lesser bent-winged bat occurs from India to Australia and is found throughout the Philippines. Eleven individuals were captured in the gradient sites of which nine came from agriculture lands (P1) while two are from primary forest site (P3). Tunnel trapping was the only successful technique in capturing this bat except in Bulalon cave (P5) where it was caught using a hoopnet (one individual). It was not recorded on other islands. No caves were seen within the gradient sites and it is possible that in the absence of suitable caves, this species may reside on hollow trunks or rock crevices. A group of individuals were observed to roost underneath Anahaw fronds.
Individuals caught/observed: Total 12. Site P1 (9); site P3 (2); site P5 (1 though was observed to number about several hundreds).

Miniopterus schreibersii (Waterhouse, 1845)
This species of bent-winged bat is very widespread, occurring in Europe, Africa, Asia, and Australia. It is found throughout the Philippines. Three individuals were caught, two of them in agriculture lands in net G (P1) and one in primary forest in net B (P3). Two individuals were also captured in Bulalon caves (P5). Only the tunnel trapping method was successful in capturing this species although hoopnets were also successful in Bulalon.
Individuals caught/observed: Total 5. Site P1 (2); site P3 (1); site P5 (2).

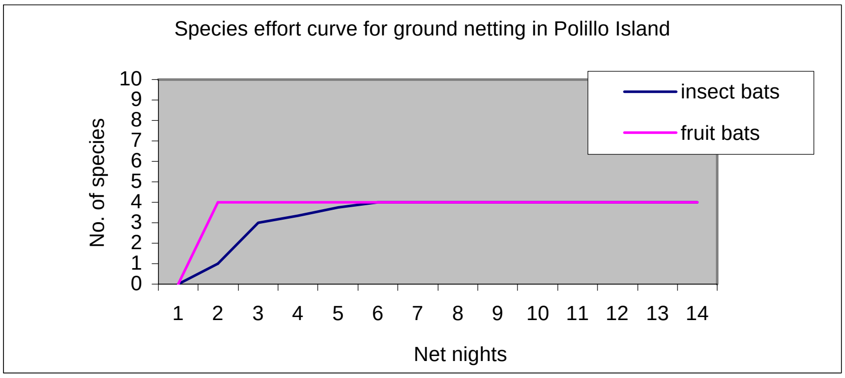
Murina cyclotis (Dobson, 1872)
Recently discovered in the country in 1991, the round-eared tube-nosed bat is distributed from Sri-Lanka, to Hainan and Borneo. Present study in Polillo island group revealed this species to be a new record. Three individuals were netted, all exclusively in primary forest (P3) also suggesting localized habitat requirement. Surveys elsewhere in the country reported this species to be confined to primary and disturbed lowland forest and extends up to lower montane elevations from 250 m to 1500m.
Individuals caught/observed: Total 3. Site P3 (3)

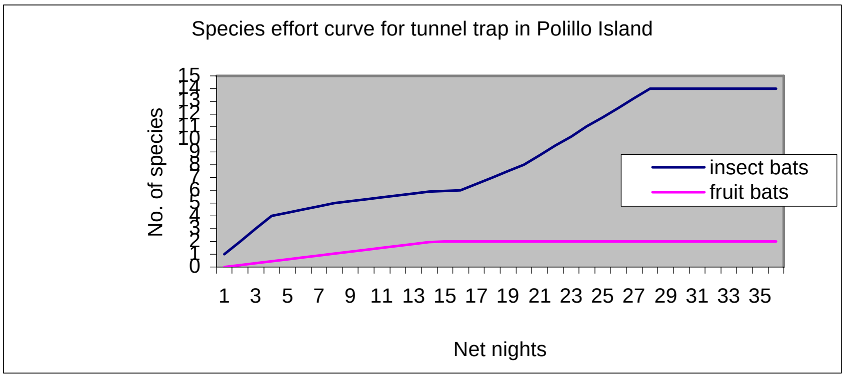
Myotis macrotarsus (Waterhouse, 1845)
The Philippine large-footed myotis occurs from Borneo and the Philippines. This also one of the rarest bat caught- only one individual- in agriculture lands (P1). Ecological studies on other literature suggest it only roosts in caves. Absence of caves in the gradient sites suggests it may reside on hollow trees or crevices. It was only captured in tunnel trap
Individuals caught/observed: Total 1. Site P1 (1)

Myotis muricola (Gray, 1846)

The whiskered myotis occurs from Afghanistan to New Guinea and distribution records in the Philippines is widespread. It is however a new record from Polillo. This bat is the most common microchiropteran caught with 19 individuals and is almost confined in primary forest (P3) with 18 species. One individual was also caught in secondary forest suggesting exclusivity of habitat requirements to forested areas. Of the three netting techniques, tunnel was the most successful in capturing this species with 17 individuals while two were caught in groundnets and none in subcanopy nets implying low-strata behavior. This species was not caught on other islands.
Individuals caught/observed: Total 19. Site P2 (1); site P3 (18).

Scotophilus kuhli (Leach, 1822)
This widespread Asian house bat is abundant in most urban and agricultural areas. It occurs from Pakistan to Taiwan and Bali. In the Philippines, this bat is found throughout the Philippines although there is no record from Polillo. It was caught underneath a culvert in Polillo town and it is possible that it is also found in the agriculture site (P1). This bat is not recorded in other islands although extensive netting especially with the tunnel trap may prove otherwise.
Individuals examined: Total 1. Polillo town (1).





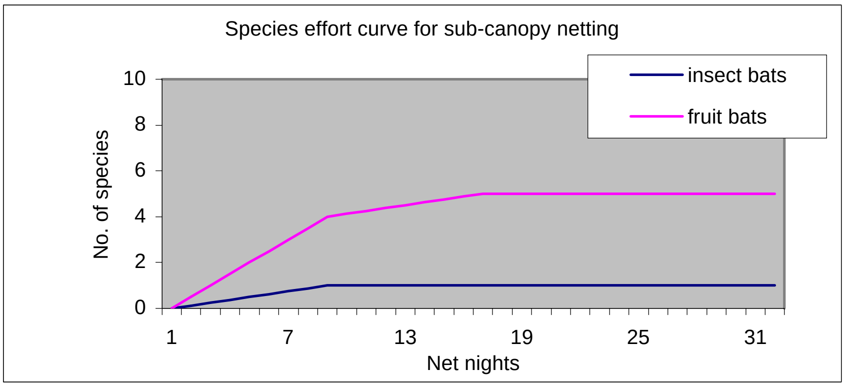

Species effort curve for sub-canopy netting
insect bats
fruit bats
No. of species
10
8
6
4
2
0
1
7
13
19
25
31
Net nights

Table 2 .List of bats recorded from Polillo and Minasawa Islands.

Species	Polillo	Minasawa
Pteropodidae		
Acerodon jubatus	X	
Cynopterus brachyotis	X	
Eonycteris spelaea	X	
Macroglossus minimus	X	
Ptenochirus jagori	X	
Pteropus hypomelanus	X	X
Pteropus vampyrus		X
Rousettus amplexicaudatus	X	
Megadermatidae		
Megaderma spasma	X	
Rhinolophidae		
Hipposideros ater	X	
Hipposideros bicolor	X	
Hipposideros diadema	X	
Hipposideros obscurus	X	
Hipposideros pygmaeus	X	
Hipposideros sp.	X	
Rhinolophus arcuatus	X	
Rhinolophus inops	X	
Rhinolophus rufus		
Vespertilionidae		
Miniopterus australis	X	
Miniopterus schreibersi	X	
Myotis muricola	X	
Myotis macrotarsus	X	
Murina cyclotis	X	
Kerivoula whiteheadi	X	
Scotophilus kuhli	X	
Total	**24**	**3**

Table 3 .Species, numbers of bats caught, and number of captures per net-night/hours by three different methods.

Species	Ground net (0-2m)	Catch/ night	Sub canopy (3-10m)	Catch/ night	Tunnel trap	Catch/ hour
Megachiroptera						
Cynopterus brachyotis	**38**	**0.19**	**25**	**0.2604**	**2**	**0.0625**
	0	**0**	**1**	**0.0104**	**0**	**0**
Eonycteris spelaea	**26**	**0.13**	**10**	**0.1042**	**1**	**0.0313**
	25	**0.125**	**42**	**0.4375**	**0**	**0**
Macroglossus minimus	**17**	**0.085**	**11**	**0.1146**	**0**	**0**
	106	**0.503**	**89**	**0.9271**	**3**	**0.0938**
Ptenochirus jagori	**4**		**5**		**2**	
Rousettus amplexicaudatus						
All megachiroperans						
No. of species	**3**	**0.015**	**0**	**0**	**19**	**0.5938**
	2	**0.01**	**0**	**0**	**17**	**0.5313**
Microchiroptera	**0**	**0**	**0**	**0**	**1**	**0.0313**
Rhinolophus arcuatus	**0**	**0**	**0**	**0**	**11**	**0.3438**
Myotis muricola	**0**	**0**	**0**	**0**	**3**	**0.0938**
Myotis macrotarsus	**0**	**0**	**0**	**0**	**3**	**0.0938**
Miniopterus australis	**0**	**0**	**0**	**0**	**3**	**0.0938**
Miniopterus schreikbersi	**2**	**0.01**	**2**	**0.0208**	**3**	**0.0939**
Kerivoula whiteheadi	**0**	**0**	**0**	**0**	**3**	**0.0938**
Murina cyclotis	**0**	**0**	**0**	**0**	**1**	**0.0313**
Hipposideros diadema	**0**	**0**	**0**	**0**	**1**	**0.0313**
Hipposideros ater	**0**	**0**	**0**	**0**	**1**	**0.0313**
Hipposideros obscurus	**0**	**0**	**0**	**0**	**1**	**0.0313**
Hipposideros pygmaeus	**1**	**0.005**	**0**	**0**	**1**	**0.0313**
Hipposideros bicolor	**8**	**0.04**	**2**	**0.0208**	**68**	**2.125**
Rhinolophus rufus	**4**		**1**		**14**	
Megaderma spasma						
All microchiropterans	**129**	**0.645**	**91**	**0.9479**	**71**	**2.1875**
No. of species	**8**		**6**		**16**	

Table 4.The number of fruit bats (Pteropodidae) netted at principal sites in Sibulan Watershed, Polillo, Polillo Is.

Species	Agriculture (P1)			2nd forest (P2)			Primary forest (P3)		
	GN	SC	TT	GN	SC	TT	GN	SC	TT
Cynopterus brachyotis	28	3	0	6	16	2	4	6	0
Ptenochirus jagori	15	14	0	1	4	0	9	24	0
Rousettus amplexicaudatus	9	5	0	7	4	0	1	2	0
Macroglossus minimus	22	4	0	3	3	1	1	3	0
Eonycteris spelaea	0	1	0	0	0	0	0	0	0
Total captures	**74**	**27**	**0**	**17**	**27**	**3**	**15**	**35**	**0**
Total net nights/hours	**72**	**32**	**12**	**64**	**32**	**8**	**64**	**32**	**12**
Netting success	**1.028**	**0.844**	**0**	**0.27**	**0.84**	**0.38**	**0.23**	**1.1**	**0**
Species richness	**4**	**5**	**0**	**4**	**4**	**2**	**4**	**4**	**0**
Overall species richness		**5**			**4**			**4**	

Table 5. The number of microchiropterans netted along disturbance gradients in Sibulan Watershed, Polillo, Polillo Is.

Species	Agroforest (P1)			2nd forest(P2)			Primary forest (P3)		
	GN	SC	TT	GN	SC	TT	GN	SC	TT
Megaderma spasma	1	0	0	0	0	1	0	0	0
Hipposideros diadema	1	2	2	1	0	1	0	0	0
Hipposideros ater	0	0	2	0	0	1	0	0	0
Hipposideros obscurus	0	0	0	0	0	1	0	0	0
Hipposideros bicolor	0	0	0	0	0	0	0	0	1
Hipposideros pygmaeus	0	0	0	0	0	0	0	0	1
Rhinolophus rufus	0	0	0	0	0	0	0	0	1
Rhinolophus arcuatus	1	0	16	1	0	1	1	0	2
Myotis muricola	0	0	0	1	0	0	1	0	17
Myotis macrotarsus	0	0	1	0	0	0	0	0	0
Miniopterus australis	0	0	9	0	0	0	0	0	2
Miniopterus schreibersi	0	0	2	0	0	0	0	0	1
Murina cyclotis	0	0	0	0	0	0	0	0	3
Kerivoula whiteheadi	0	0	0	0	0	0	0	0	3
Total captures	**3**	**2**	**32**	**3**	**0**	**5**	**2**	**0**	**31**
Total net nights/hours	**72**	**32**	**12**	**64**	**32**	**8**	**64**	**32**	**12**
Netting success	**0.042**	**0.06**	**2.67**	**0.05**	**0**	**0.63**	**0.03**	**0**	**2.58**
Species richness	**3**	**1**	**6**	**3**	**0**	**5**	**2**	**0**	**9**
Overall species richness		**7**			**6**			**9**	

Table 6 . Summary of parameters listed for three disturbance gradient sites.

Parameters	Agroforest (P1)			2nd forest (P2)			Primary forest (P3)		
	GN	SC	TT	GN	SC	TT	GN	SC	TT
Total captures	77	29	32	20	27	8	17	35	31
Total net nights/hours	72	32	12	64	32	8	64	32	12
Netting success	1.07	0.91	2.67	0.313	0.844	1.0	0.27	1.1	2.58
Species richness	7	6	6	7	4	8	6	4	9
Overall species richness									
	12			**10**			**13**		

DISCUSSION

A. Adequacy of Sampling Effort

Before analyzing the results of this survey, it must be considered how closely current data reflect actual species richness on these islands. Various island surveys done in the past have well considered that the widest possible habitat, elevational range or disturbance gradient must be investigated to ensure adequate sampling of faunas (Heaney et al, 1991 and Rickart et al,1993). In this study, disturbance gradient was considered since elevation in the Polillo island group was not significant enough to merit valid assessment of species richness. Fieldwork done in other locations aside from the aforementioned were side trips in nature and field methodologies employed only managed to ascertain species richness only, thus not included in analysis of data in terms of sampling effort and disturbance gradient. Fieldwork conducted in Sibulan was intensive (though not exhaustive) and comparisons with data from other island surveys of this nature can be tested. Moreover, the present study included surveys in caves and can contribute to cave studies currently being undertaken in other parts of the country (Sedlock, pers com).

The adequacy of sampling may be assessed with species-effort curves that plot the cumulative number of species over sampling time (Rickart et al 1993). This method is usually used to examine the sampling success of a given study and in this case, the comparison of relative success of the different netting methods for two bat groups- fruit bats and microchiropterans. To be a true gauge of sampling success, sampling must be done in the widest possible gradients as possible using field methods that are standardized and diverse, and sampling effort must be long enough (Rickart, 1993) .

On Sibulan watershed, netting in three different disturbance gradients employing three different methods (P1-P3) yielded a total of 19 species of bats, of which five are fruit bats and 14 are microchiropterans. A species-effort curve for ground netting (Figure 1) shows that the total number of fruit bat species was reached well before the midpoint of the survey. Likewise is also evident for microchiropterans. For sub canopy netting (Fig. 2)the total number of fruit bats was also reached midway of the study while species-effort curve for microchiropterans reached within a quarter of the study. The shape of the species effort curve for tunnel trapping (Fig. 3) was different for microchiropterans in which curves reached asymptote late in the study. This suggests that, given the accrual rate for microchiropterans, additional sampling would yield 2-3 additional species. Curves generated for fruit bats reach asymptote very early in the study and this implies that tunnel trapping is not ideal for fruit bats.

It is concluded from these curves that the surveys in Sibulan were adequate (though not exhaustive) and the data presented herein can give a fairly accurate reflection of the species richness. Nonetheless, data generated from other islands (except Minasawa island) are far too incomplete and employment of these three sampling technique is necessary. In the light of these data, certain generalizations can be made about specific bat taxa and their susceptibility to capture or documentation: (1) Large fruit bats (Acerodon and *Pteropus*) are seldom caught using any of the methods employed and acquisition of these species must be done at roost sites; (2) small fruit bats (like *Ptenochirus* and *Cynopterus*) can be caught readily using any of the netting techniques except tunnel trap, and (3) microchiropterans are not easily caught using ground-netting or subcanopy netting but instead additional method should be employed such as tunnel trapping or collected at roost site.

B. Inventory and distribution of bats

Of the 25 species of bats recorded, 11 species are listed as new records. Prior to this study no detailed inventory had been carried out in the islands and all of the records came from collection trips and given to museums as donations. The number of new records and even the number of species recorded as a whole is unprecedented for a short period of inventory and the number of workers involved. This number is comparable with other medium sized island like Leyte, Bohol, Negros, Panay and other small islands such as Catanduanes, all of which have been relatively studied for a much longer period. The high numbers of species recorded as well as the new island records can be attributed to the variety of netting techniques employed. Studies on other islands only employed simple groundnetting.

Twenty-four of the 25 species were recorded from Polillo. The lone exception is *Pteropus vampyrus* of which identification is not certain.

C. Species composition in different disturbance gradients.

To be able to relate species composition and diversity to different disturbance gradients, assessment of netting effort per gradients is mandatory. It is ideal that sampling effort should be more or less uniform and the same for all study sites in order to generate meaningful comparisons and determine species' habitat associations. In this study, A total of 200 net-nights ground-netting were exerted on all gradient sites in which agriculture site has 72 net-nights, secondary and primary forest have 64 net-nights each. Total sampling effort for subcanopy netting was 96 nets of which all gradient sites had 32 net-nights each. As for tunnel trapping, 32 net-hours was exerted where 12 net-hours were allocated for agriculture and primary forest site and eight net-hours for secondary forest. With these sampling efforts, the present study generally meets the uniformity requirement.

Of the 19 species recorded in all gradient sites, 12 (5 fruitbats and 7 insect bats) were recorded in agriculture lands, 10 (four fruit bats and 6 insect bats) in secondary forest, and 14 species (4 fruitbats and 10 insect bats) in primary forest (Table 4 & 5).

FRUIT BATS- All species of fruit bats were found in all disturbance gradients except for *Eonycteris spelaea* which was found in agricultural lands. *Macroglossus minimus* and *Ptenochirus jagori* are common inhabitants of primary forest (Rickart, 1993). That observation applies to *Ptenochirus jagori* in which it was most commonly found in the primary forest. However, fieldwork done on Luzon by Rickart and Heaney, revealed that this species is absent in agriculture lands and ventures into secondary forest. It is contradictory to the present study's findings wherein this endemic fruit bat is more common in agricultural lands than in secondary forest. The high frequency of *P.jagori* in agriculture lands can be attributed to its proximity to the primary forest and the small area of the forest itself. This species is forced to venture out in disturbed habitats to find suitable places to forages and presence of fruit trees outside forested lands can be a substitute. *Macroglossus minimus* like the rest of the fruitbats recorded, is more common in agricultural lands than in forested areas. However, due to proximity of the forest, these species of fruit bats occasionally forage in forested areas. *Eonycteris spelaea* was found only on agriculture areas though it is possible that it can reside in forested habitats as well. In effect generalizations can be made from these observations: (1) Endemic fruit bats like *Ptenochirus jagori* venture out in disturbed habitats if forested areas are relatively small, (2) Endemic fruit bats can be found in disturbed areas if these areas is proximal to the forest, and (3) Non-endemic fruit bats venture into forested habitats especially primary forest if these forest are proximal to disturbed habitats. Paucity of captures in secondary forest can be attributed to low placement of nets since canopy growth was also low.

MICROCHIROPTERANS - Of the 14 species of microchiropterans caught, *Rhinolophus arcuatus* was captured in all disturbance gradients . In previous survey studies done in different islands this species commonly extends its habitat requirements in all types habitat. Habitat specialists were also observed in this study: one species (*Myotis macrotarsus*) in agriculture lands, one also in secondary forest (*Hipposideros obscurus*) and five (*H. bicolor, H. pygmaeus, R. rufus, Murina cyclotis* and *Kerivoula whiteheadi*) in primary forest. Field notes from previous surveys in other islands have reported *M.macrotarsus* to forage exclusively in agriculture areas. *H. obscurus* is known to inhabit exclusively in forested areas and it is possible that this species is also found in primary forest. All species that exclusively resides on primary forest are forest habitat specialist with exception of *K.whiteheadi* which occasionally forage in agriculture areas. Substantial tunnel trapping in secondary forest would reveal these specialists. There are also species that shares two habitats: 2nd forest and agricultural lands with three species (*Megaderma spasma, H. diadema* and *H. ater*), 2nd forest and primary forest with one (*Myotis.muricola*) and primary forest and agricultural lands with two species (*Miniopterus australis* and *M.schreibersii*). All of these species are generalist with habitat requirements ranging from forested habitats to agricultural lands and with wide elevational ranges with the exception of *M.muricola* in which it resides specifically in forested areas. Of the 19 individuals of this species captured, only one was caught in secondary forest. Nevertheless substantial tunnel trapping would yield several individuals of this species. Although *Megaderma spasma, H. diadema* and *H. ater* are generalist, these species were observed to be more common in agriculture areas and degraded forest (Heaney et al, 1997). Unfortunately, it is still premature to make a generalization about microchirpoteran ecology due to lack of knowledge on their foraging ecology.

D. Comparison of netting techniques

Comparison of netting techniques usually employs standard gauges of measures such as catch success and type of species captured. However, when a certain method differs in standard unit of measurement as in the case of ground netting and subcanopy's net-hours as opposed to tunnel trap's net-hours, calibrations should be made in order generate meaningful comparisons. In ground and sub canopy netting, the smallest unit of measure is the net-night which is equivalent to a single six-meter net exposed for 12 hours whereas in the smallest unit of measure is one hour.

One hundred twenty nine individuals representing eight species were captured using ground netting technique (200 net-nights). Subcanopy netting, with a sampling effort of 96 net-nights accounted for 91 individuals of five species while (32 net-hours) accounted for 71 individuals representing 16 species. Catch success for ground nets, sub canopy nets and tunnel trap were 0.504 bats/night, 0.95 bats/night and 2.22 bats/hour. In order to make valid comparisons, calibrations must be done in hours so that rate of capture can be quantified or visualized more easily. Conversions would be for ground net, 0.054 bats/hour and subcanopy nets 0.08 bats/hour. This means that tunnel trapping is more efficient than ground netting and sub canopy netting by 41- and 28-fold! In reality, it is not possible to man the tunnel trap for 32 straight hours while ground and sub canopy nets can be left unattended. Probable reason for this high discrepancies in catching efficiencies can be attributed to the behavior of microchiropterans. In a certain river or creek, there are many insect bats that forage and are very active at night but they are not caught easily by ground or sub canopy nets due to their ability to echolocate. In the tunnel trap, there is wide space inside the net (usually 12m x 6m) hence the name "tunnel". A skimming insectivorous bat foraging for prey transmits sound and is usually one-directional and thus will not enable to detect the walls of the tunnel trap due to the trap's wideness.

Species composition also significantly varies between the three methods. Tunnel trapping is more successful capturing microchiropterans than fruit bats whereas subcanopy nets capture more fruitbats while ground nets have equal number of species captures of fruit bats and microchiropterans. As mentioned earlier, microchiropterans rarely evade capture of tunnel trap due to its usually one-directional sound transmission and the trap's wide tunnel. Fruit bats easily dodge tunnel traps because they can see the walls of the trap and avoid it. Moreover, most of a fruitbat's feeding behavior are high within the canopy of understorey depending on the height of trees (Ingle, 1993).

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