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Diet of cave-dwelling bats in Bukidnon and Davao Oriental, Philippines

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Abstract. The Philippine archipelago has high species richness of bats, many of which are cave-dwellers. Information on the feeding behavior of these species is important toward their conservation. This study was conducted to determine the diet of 8 species of cave-dwelling bats from 13 cave sites in Mindanao, Philippines based on percentage occurrence of the diet items in the gut contents. Among the frugivorous species, *Rousettus amplexicaudatus* had the highest percentage occurrence of fruit bits (73.68 %) and fruit fibers (36.84 %) suggesting high fruit consumption. Some individuals of *Cynopterus brachyotis* were found to consume *Ficus* sp. seeds while a *Ptenochirus jagori* individual had an unidentified seed in the gut. Insect limbs were present in the diet of *R. amplexicaudatus* and *P. jagori*. Presence of insects in these fruit-eating bats implies that these bats might have consumed fruits along with the insects associated with the fruits. Among the insect-eating bats, digested insect parts, wings, limbs, and exoskeletons of Hymenoptera, Formicidae, Orthoptera, and *Scotinophara* sp. were observed in their gut. Fruit bits and fruit fibers observed in *Hipposideros diadema*, *Miniopterus schreibersii* and *Taphozous melanopogon* suggest that these bats consumed insects as well as fruits or fruits associated with certain insects. Unidentified dietary items among insect-eating bats included digested flesh, cartilaginous materials, and hair fibers. Bird feathers were found in some individuals of *Rhinolophus virgo* and *H. diadema*. Larvae and parasitic helminths were observed in the gut of some individuals identified to have consumed hair fibers, digested flesh and arthropod parts. Samples from other caves in Mindanao need to be examined to fully establish the diet of a given species.
Key Words: *Cynopterus brachyotis*, fruit-eating bats, insect-eating bats, *Ptenochirus jagori, Rousettus amplexicaudatus.*

Introduction. Caves support the greatest diversity and abundance of bats, making these areas critical for bat fauna (Hutson et al 2001). The Philippines is a country with numerous caves. In fact one of the caves in Mindanao, the Monfort cave, is known to have the largest population of Geoffroy's Rousette fruit bat in the world (Locke et al 2006; Tupas 2010).

Caves are preferred roost sites of many species of bats due to their permanency and stable microclimate (Mann et al 2002). As critical sites for bat faunal assemblage, caves are very vulnerable to threats compared to any land resource. Globally, cave-dwelling species of bats are in an alarming population decline due to destruction of roosts and other anthropogenic disturbances (Locke et al 2006). Human utilization of caves includes limestone extraction and tourism. Tourism in caves has been globally popular. Worldwide, there are about 650 tourist caves annually visited by around 20 million people (Watson et al 1997).

Colonies of bats in caves are highly vulnerable to anthropogenic disturbances. Their roosts in caves are restricted to certain locations for several months after they raise their young (Mann et al 2002). Many studies focused on the diversity of bats in caves providing significant findings regarding their decreasing population trends. However, Arita (1993) suggested that a conservation plan based solely on diversity of cave dwelling bats is not adequate for their protection. Southeast Asia, where bats comprised nearly one third of the region's total mammalian species (Kingston 2010), is among those large areas in the world which have too little information on the status and distribution of bats (Hutson et al

2001) and even have very limited data on their feeding ecology. In the Philippines, Chiroptera is one of the poorly known orders of mammals (Ingle & Heaney 1992) despite the fact that it comprised about 20 % of the astonishing high terrestrial mammal endemism rate (Ong et al 2002).

Examining the dietary items of any species especially bat fauna in caves is essential for species management. Knowledge on diet can provide important insights into the ecology and behavior of any species. Population decline especially for endangered species may be related to diet issues (Kurta & Whitaker 1998).

Similarities in the diet of bats could indicate important insights into the autecology and interspecific competition for food (Stier & Mildenstein 2005). Many bat species consume a wide variety of insect prey. In Russia, diet composition of *Plecotus auritus* was analyzed to contain fragments of lepidopterans belonging to 11 families (Rostovskaya et al 2000). In Israel, three insectivorous bats were found to consume arthropods belonging to 13 different insect taxa (Whitaker & Tov 2002). In the Philippines, a study on the food and roosting habits of *Megaderma spasma* roosting in a tree hollow and a small cave showed that the diet of this species contained 10 insect orders comprising more than 99 % of the prey cullings indicating a predominantly insectivorous feeding habit (Balete 2010).

Data on diet of bats can be taken from stomach contents, feces, culled parts, and direct observations of feeding bats. Major limitation of fecal analysis is the taxonomic level to which insect prey fragments are to be assigned. Dietary studies of bats could be based on varying methods, if possible, to provide a more comprehensive picture of what prey items were consumed (Lacki et al 2007). A study on the social organization and foraging of the five species of Emballonurid bats through examination of stomach contents suggested a directly proportional relationship on the bat body size versus the prey size consumed. Within species, there was a considerable overlap of prey items and the habitat where they foraged (Bradbury & Vehrencamp 1977). In Indonesia, ingested pollen grains were assessed from the alimentary tracts of 10 Old World fruit bats which included *Cynopterus brachyotis* and *Rousettus amplexicaudatus.* Twenty-eight pollen types were found to be consumed by these bats (Kitchener et al 1990). In central Appalachians, a combined fecal and stomach examination on the food habits of four-species of cave dwelling bats: *Eptesicus fuscus, Myotis keenii, Myotis lucifugus,* and *Pipistrellus subflavus* showed that these bats consume Neuropterans, Hemipterans, Coleopterans and Lepidopterans (Griffith & Gates 1985).

Notable bat species roosting in caves included some frugivorous species such as *C. brachyotis* (Nowak 1999), *R. amplexicaudatus* and *P. jagori* (IUCN 2010). *C. brachyotis* feeds on fruits such as palms, figs, guavas, plantains, mangoes, chinaberries, and on pollen and flowers of some plants and seems to subsist mainly on fruit juices rather than the pulp. *R. amplexicaudatus* was found to have a diet consisting of fruit juice and flower nectar (Nowak 1999). *P. jagori* was shown to be able to locate and discriminate accurately between an empty dish and a dish containing fruits of several species as well as determine between ripe and unripe fruits of the same species by olfaction (Luft et al 2003). Prominent cave residents also include insectivorous species of bats such as *Miniopterus schreibersii*, *Rhinolophus virgo, Hipposideros diadema*, *Taphozous melanopogon* (IUCN 2010) and *Pipistrellus javanicus* (Chan et al 2009). Prey prediction hypothesis links the predator selectivity on the body sizes of the diet of these insectivores. The hypothesis proposed that small bats tend to have a broad diet by using a full echolocation range while the large ones are restricted to predating large prey (Insell & Sitters 2007).

In the Philippines where diet of cave-dwelling bats is poorly known, it is important to allot attention to this field. In this study, the diet of cave-dwelling bats in Mindanao was examined to identify the diet composition, the percentage occurrence of the dietary items, and determine if there is significant dietary overlap that occurs between species. Common dietary items consumed would signify interspecific relationship (Stier & Mildenstein 2005) or competition for food resources between species.

Material and Method. Voucher specimens of 8 species of bats from 13 caves in Mindanao were examined for their diet. Table 1 shows the sampling sites and the geographical coordinates.

Table 1

Location of the sampling sites

Site	*Location*	*Coordinates*	*Elevation (masl)*
1	Quezon, Bukidnon	07° 42’ 017” N 125° 03’ 322” E	282
2	Quezon, Bukidnon	07° 42’ 014” N 125° 03’ 219” E	356
3	Quezon, Bukidnon	07° 42’ 006” N 125° 03’ 209” E	341
4	Quezon, Bukidnon	07° 42’ 062” N 125° 03’ 249” E	278
5	Quezon, Bukidnon	07° 42’ 062” N 125° 03’ 249” E	241
6	Kitaotao, Bukidnon	07° 38’ 685” N 125° 01’ 932” E	316
7	Kitaotao, Bukidnon	07° 38’ 685” N 125° 01’ 932” E	353
8	Kitaotao, Bukidnon	07° 38’ 633” N 125° 01’ 969” E	315
9	Kitaotao, Bukidnon	07° 38’ 628” N 125° 01’ 929” E	334
10	Valencia City, Bukidnon	07° 42’ 062” N 125° 03’ 249” E	720
11	Valencia City, Bukidnon	07° 42’ 062” N 125° 03’ 249” E	437
12	Tarragona, Davao Oriental	07° 01’ 719” N 126° 16’ 984” E	370
13	Tarragona, Davao Oriental	07° 01’ 719” N 126° 16’ 984” E	470

masl – meters above see level.

Bat specimens were collected using mist nets placed near cave openings and other probable flyways from April 29, 2010 until May 31, 2010. Nets were set open at 23:00 until 05:00 to trap bats that were returning and had finished foraging. Specimens were identified up to the species level (Ingle & Heaney 1992).

Data on diet analysis of bats can be acquired from stomach or alimentary tract contents. Related studies that examined dietary items from stomach and alimentary tract of bats include the works of Bradbury & Vehrencamp (1977), Whitaker & Black (1976), Griffith & Gates (1985), Kitchener et al (1990), Kunz et al (1995) and Milne (2006). In this present study, dietary items were taken from the gut of each voucher specimen per species. Cut was made from the esophagus up to the last part of the large intestine. The gut was placed in separate vials containing 70 % ethanol for preservation. Dietary items taken from the alimentary walls were stored separately in clean vials containing 70 % ethanol. Dietary items from each bat were examined separately in a clean Petri dish under a stereomicroscope, 40x magnification, with a macron camera attached to its eyepiece and connected to a gateway computer for clear documentation. Baltazar & Salazar (1979), Pancho (1983), Romoser & Stoffolano (1988), and Joshi et al (2007) were used as references for the identification of food items. To calculate the percentage occurrence of diet composition of all the individuals per species, the formula by Flavin et al (2001) which was modified to suit the analysis below was used:

Percentage occurrence = (number of bats positive for a certain dietary item / total number of bats examined in a species) x 100

To determine if there is significant dietary overlap that occurs between species due to the presence of common dietary items, a Cluster Analysis based on Euclidean distance was employed using PAST Software.

Results and Discussion. Cave-dwelling bats were found to have a wide variety of dietary items. Table 2 shows the dietary items of all captured species of cave-dwelling bats and the caves where these bats were captured.

Table 2

Dietary items of cave-dwelling bats

Species	*Cave site*	*Dietary items*																				
		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*O*	*P*	*Q*	*R*	*S*	*T*	*U*
Frugivorous species																						
Cynopterus brachyotis	(6,7,8,9)	+	+	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+
Ptenochirus jagori	(1,2,3,4)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rousettus amplexicaudatus	(1,4,6,11)	+	+	-	-	+	+	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-
Insectivorous species																						
Hipposideros diadema	(9,10)	+	+	-	-	+	+	+	-	-	+	-	+	+	-	-	-	-	-	-	-	-
Miniopterus schreibersii	(11)	+	+	-	-	-	+	-	+	-	-	+	-	+	-	-	-	+	-	+	+	+
Pipistrellus javanicus	(10,11)	-	-	-	-	+	+	-	-	-	-	-	+	+	-	-	+	+	+	-	-	-
Rhinolophus virgo	(12,13)	-	-	-	-	-	+	-	-	-	-	-	+	+	+	-	-	-	+	-	+	-
Taphozous melanopogon	(3,4)	+	+	-	+	+	+	+	+	+	+	-	+	-	-	-	-	+	-	-	-	-

A - fruit bits, B - fruit fibers, C - seeds of A plant species, D - *Ficus* sp. seeds, E - insect limb, F - digested insect parts, G - digested unidentified matter, H - Hymenoptera (geniculate antenna), I - cartilaginous structures, J - Formicidae, K - unidentified blue strand, L - digested unidentified flesh-like matter, M - unidentified hair fiber, N - mammal hair fiber, O - Orthoptera (Filiform antenna), P - unidentified yellow flesh, Q - insect wing part, R - insect exoskeleton, S - *Scotinophara* sp. (Wing part), T - bird feather, U - spider limb. Cave sites 1-5 - Quezon caves, 6-9 - Kitaotao caves, 10-11 - Valencia City caves, 12-13 - Tarragona caves.

Figure 1 shows the respective percentage occurrence of each dietary item in each species of cave-dwelling bats. Fruits and fruit fibers were common in the diet of the three frugivorous species, namely, *R. amplexicaudatus, P. jagori* and *C. brachyotis*. All insectivores mainly consumed insects as their main diet that included the orders Hymenoptera, Orthoptera, and Hemiptera. Arachnida was also documented. There were dietary items which remained unidentified such as cartilaginous structures, blue strand, flesh - like material, hair fiber, and digested matter.

A cluster analysis shown in figure 2 indicates that based on dietary items cave-dwelling bats were clustered into two main groups robustly supported by a bootstrap value of 100. The first group is composed of insectivorous bats namely *P. javanicus*, *H. diadema,* and *R. virgo*. *H. diadema* and *P. javanicus* were co-roosting in Cave 10 in Valencia City. The second group is composed of both insectivorous and frugivorous bats such as *T. melanopogon, M. schreibersii, C. brachyotis, P. jagori,* and *R. amplexicaudatus.*

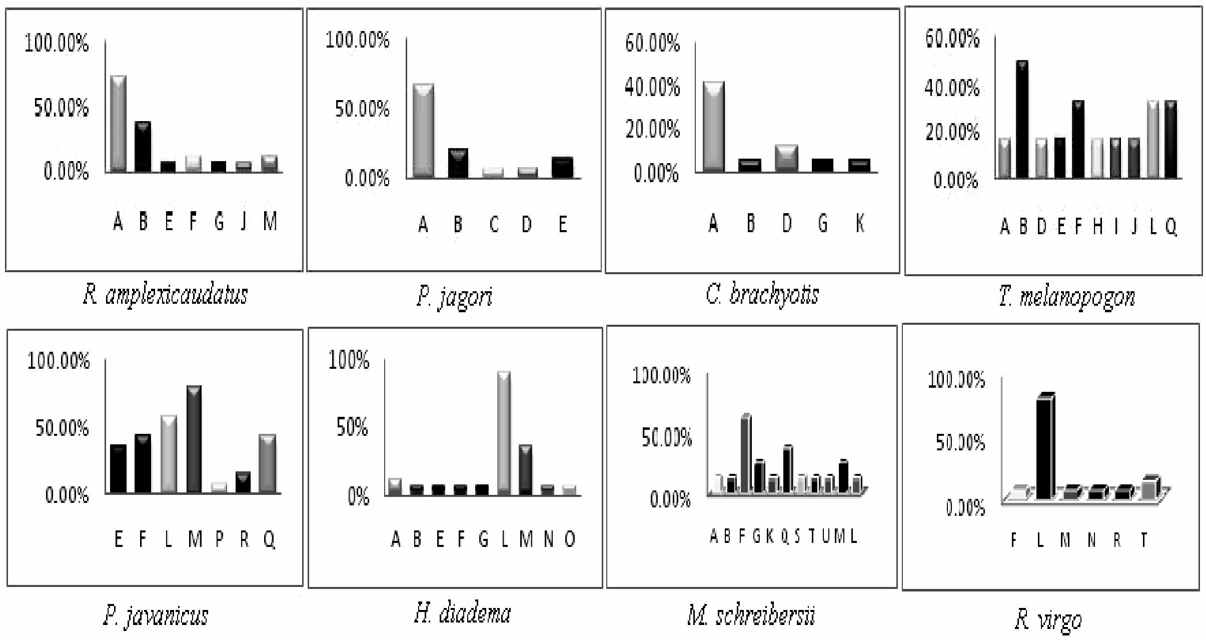

Figure 1. Percentage occurrences of dietary items among cave-dwelling bats (A: fruit bits, B: fruit fibers, C: seeds of A plant species, D: *Ficus* sp. seeds, E: insect limb, F: digested insect parts, G: digested unidentified matter, H: Hymenoptera (geniculate antenna), I: cartilaginous structures, J: Formicidae, K: unidentified blue strand, L: digested unidentified flesh-like matter M: unidentified hair fiber, N: mammal hair fiber, O: Orthoptera (Filiform antenna), P: unidentified yellow flesh, Q: insect wing part, R: insect exoskeleton, S: *Scotinophara* sp. (Wing part), T: bird feather, U: spider limb).

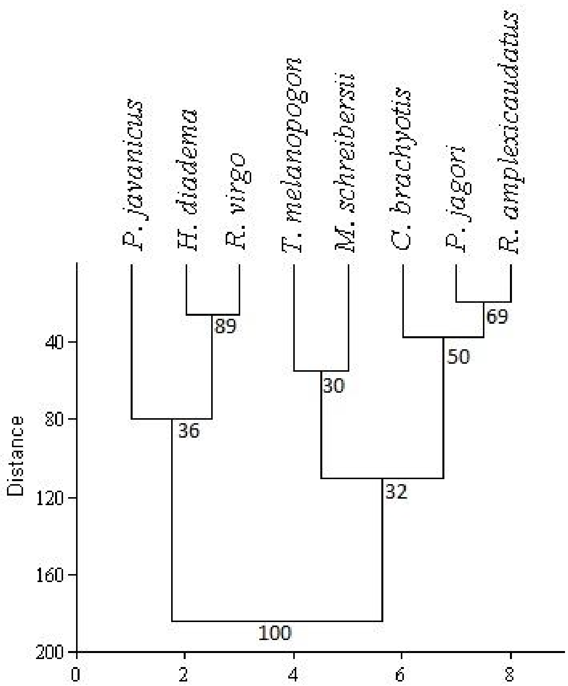

Figure 2. Cluster Analysis of dietary items based on Euclidean distances among the cave-dwelling bats.

Among frugivores, *R. amplexicaudatus* had the highest occurrence of both fruit bits (73.68 %) and fruit fibers (36.84 %). This finding is in contrast with the finding of Nowak (1999) who noted that *R. amplexicaudatus* mainly consumed fruit juices and nectar of flowers. However, Hodgkison et al (2004) reported that in a lowland Malaysian rainforest, *R. amplexicaudatus*, together with other species of bats were found to feed exclusively on fruits of not less than 12 species of fruit bearing plants. Although *R. amplexicaudatus* is a known frugivore, Formicidae (5.26 %), insect limbs (5.26 %) and digested insect parts (10.53 %) were found in the diet of some individuals of this species. Insect occurrence in the diet of *R. amplexicaudatus* suggests the ability of this species to echolocate (Grinnel & Hagiwara 1972). The presence of unidentified hair fibers (10.53 %) suggests that some individuals of this species had consumed a hairy prey. The finding on the presences of insects in the gut of *R. amplexicaudatus* was similar with *P. jagori* having 13.33 % individuals of this species consuming insect limbs. In terms of fruits consumed, more than 66 % of the individuals of *P. jagori* contained fruit bits, while only 6.67 % of them were found to have *Ficus* sp. seeds. The result supported the finding of Nowak (1999) that *P. jagori* feeds heavily on figs, bananas, other fruits and flowers including those of coffee, and coconut palms. These plants were all abundant in cave 4 where some *P. jagori* individuals were captured. Insect parts observed in the gut of these two species are most likely associated with the fruits that these bats consumed such that insects were eaten along with the fruit. Duran & Lewis (1987) reported that in a cave in Puerto Rico, a known nectarivorous bat, *Monophyllus redmani* was found to contain insects in its diet. Unlike the two former frugivorous species, no insect parts were observed in the diet of *C. brachyotis* suggesting its strictly frugivorous diet. Fruits bits (41.18 %) comprised the diet of this species largely although it is known to subsist on pollen from the flowers of some plants (Nowak 1999; Kitchener et al 1990) as well as on fruit juices of some fruits (Nowak 1999). The finding was supported by Mohd-Azlan et al (2010) who reported that *C. brachyotis* in Borneo feeds on fruits of at least 24 species of fruit-bearing plants. However, in this present study, fruit parts were so disintegrated making them unidentifiable except for the seeds that were identified to be the seeds of *Ficus* sp. (11.76 %). Some individuals of *C. brachyotis* had consumed an unidentified blue strand (5.88 %) that looks like a plastic material suggesting that *C. brachyotis* may have consumed a fruit that was wrapped in a plastic at the time it foraged. It can be related to the geographic locale of the cave wherein there were households at the nearby area around 100 m distance. The diet of *T. melanopogon* was found to contain Formicidae, digested insect parts and insect wings, all at 33.33 % occurrence. Hymenoptera and insect limbs were also observed, both having 16.67 % occurrence. In *P. javanicus* individuals, insect limbs (35.71 %) and exoskeleton (14.28 %) were observed as well as insect parts and wings, both having 42.86 % occurrence. Digested insect parts (62.5 %), insect wings (37.50 %), and *Scotinophara* sp. wing part under the order Hemiptera (12.5 %) were prominent in the gut of *M. schreibersii.* Presence of *Scotinophara* sp. is an interesting finding since *Scotinophara* species in the Philippines, until now remained to be a highly invasive insect pest to the country's vast rice field areas (Torres et al 2010). The present finding indicates the important role of *M. schreibersii* and other insectivorous bats as pest control agents. High occurrence of flying insects in the diet of these bats suggests their aerial hawking behavior in catching insect preys. Burles et al (2008) also reported the presence of flying insects in the diet of *M. lucifugus* and *M. keenii* implying that these bats are capable of aerial hawking on preys.

Prominent among *H. diadema* individuals was an unidentified organism with flesh and hair fibers at 90 % and 35 % occurrence, respectively. This was similar with *R. virgo* which also has digested unidentified flesh (78.57 %) and hair fibers (7.14 %) in the gut. Pavey & Burwell (1997) reported that *H. diadema* was at least occasionally carnivorous as bird feathers were found in its fecal matter. If *H. diadema* and *R. virgo* do not possess occasional carnivory, then these species probably have preyed on scavenger arthropods. Some arthropods are known to visit carcass of vertebrates at various stages of decay. Diptera and Coleoptera are often the largest and most persistent representatives of these arthropods (Perotti et al 2010).

Milne (2006) reported that stomach samples from *H. diadema* in Australia consist mostly of Coleoptera (78 %) and Lepidoptera (20 %). In this study, insect parts and insect limbs, both occurring at 5 %, were also observed in some *H. diadema* individuals. These parts may belong to scavenger insects that may have caused the zoonotic transmission of parasites such as helminths which were found in the gut not only of some *H. diadema* individuals but also in some individuals of *R. virgo* and *M. schreibersii*. Individuals of these bat species which are carriers of helminths could pose a potential risk to the health of the other members of the population. Although known insectivores, *T. melanopogon, M. schreibersii,* and *H. diadema* also had fruits in their gut. This indicates that these bats could also eat fruits or the consumption of these fruits might be accidental. The bats may have preyed on insects that are feeding on these fruits. As shown by the cluster analysis, common in all species of bats in the first group are the digested insect parts, digested unidentified flesh-like matter, and unidentified hair fiber. The bootstrap value of 36 is not significant to conclude that bats in this group exhibited interspecific competition. *R. virgo*, one of the species under this group, was captured only in the caves of Tarragona, Davao Oriental. Between *R. virgo* and *H. diadema,* the bootstrap value of 89, although significant, does not suggest interspecific competition due to their geographical separation distance of hundreds of kilometers.

Fruit bits and fruit fibers were the common dietary items of the five species of bats in the second group. *P. jagori* and *R. amplexicaudatus* were co-roosting in caves 1 and 4 and had a bootstrap value of 69 which shows possible interspecific competition in terms of fruit diet for these two co-roosting species. The high similarity in the diet between these two frugivores is an indication that interspecific competition may exist between them. However, based on their site locations there are caves being roosted by *R. amplexicaudatus* where *P. jagori* was absent. A study in Puerto Rico supported the idea that multispecies assemblage of insectivorous bats in a cave was found to have shown a strong intraspecific component with respect to separate peaks in exit time, and associated differences in their diet. Bats which exit first the cave were found to consume a wide variety of insects compared to those which exit late (Duran & Lewis 1987). Dietary items of cave-dwelling bats were varied. Among frugivorous bats, fruits were prominent in their diet. Presence of insect limbs in the gut of some frugivores does not imply dietary preference due to their non-prominent occurrence. Among insectivorous bats, insects were prominent in their diet. Presence of fruit materials in the gut of some individuals does not imply dietary preference. Instead, this leads to an understanding that those insectivorous bats were having fruit materials in their gut may have preyed on insects which are attracted to certain fruit species as bats could still be able to echolocate a prey even though it is hidden in the fruit surface (Korine & Kalko 2005).

Conclusions. Cave-dwelling bats in Bukidnon and Davao Oriental have varied dietary items. Frugivorous species feed mainly on fruits but some frugivores had insects in their diet. The presence of fruits in the diet of some insectivorous species is something that has to be validated by examining the diet of other insectivorous bat species in Mindanao. Cluster analysis on the dietary items consumed by the cave-dwelling bats showed that these bats are significantly divided into two groups. Interspecific competition seems to occur between *P. jagori* and *R. amplexicaudatus*.

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