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Research Article

The diet of insectivorous cave-dwelling bats from Gombong Karst Area, Central Java, Indonesia

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ABSTRACT. This research aims to determine the prey preference of cave dwelling insectivorous bats in the Gombong Karst Area, Kebumen, Central Java. The research was done from March 2009 to July 2010. Stomach and mouth contents were taken from collected specimens and dissolved in aquadest. The ingested insects were sorted and identified under a microscope, and compared with insects collected by light trap in nearby bat foraging areas. The data were analysed by Principle Component Analysis (PCA), x^2 and niche overlap index. Eleven species of insectivorous bat were identified. The insects in the gut contents of the bats belonged to 10 orders, distributed into 29 families. Based on prey preference, the bats can be classified into four groups as follows, Group 1: *Chaerophon plicata, Hipposideros* sp., *H. sorenseni* and *H. diadema,* which chose hard-bodied and large sized insects as their prey; Group 2: *Miniopterus schreibersii, M. australis, H.* cf. *ater,* and *Rhinolophus borneensis*, which prefer soft bodied and medium sized insects; Group 3: *R. affinis*, which chose hard-bodied and small size insects and Group 4: *H. bicolor* and *H. ater* which chose soft body and small size insects as their prey. The niche overlap index between the species of bats that occupy one cave was less than 30%.

Keywords: Insectivorous bat, cave, prey preference, niche overlap.

INTRODUCTION

Food availability determines the number and the coexistence of bats in a habitat (Feller & Paerson 2002; Russo *et al.* 2004). Therefore, bats tend to choose their roosting areas close to food sources or those having access to food sources. This has been demonstrated by the results of previous research. Law & Chidel (2004) pointed out that *Kerivoula papuensis* (Microchiroptera) have their roost sites 2.1 km away from their foraging area in the rain forest in New South Wales. Hodgkison *et al.* (2003) showed that *Balionyeteris maculata* forage about 1 km away from their roost. Research by Agosta (2002) found that *Eptesicus fuscus* prefer to roost nearby human settlement areas, and an analysis of their gut content indicated that their food was mainly insect species found abundantly around the lights of settlement

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areas. Bats roosting in karst caves also have their special living traits. According to Furman & Ozgul (2007), caves in addition to providing the microclimatic requirements suitable for bats' bodies, should also have food sources.

Other research related to bat roosts in karst caves indicate that one cave can be inhabited by several species of insectivorous bats. Duran & Sentano (2002) found that the insectivorous bats *Pteronotus quadridens* and *Erophylla sezekorni* inhabited the same cave in Bonita Cave, Los Perez, and Furman & Ozgul (2007) discovered that three to five species of bats roosted in one cave in Istanbul, Turkey. In Gua Payu Cave, Sarawak, Hall (1996) found 12 species of bats and Apriandi *et al.* (2008) observed that about three to eight species of insectivorous bats roosted in the karst of Gudawang, Bogor, West Java. Knowing the fact that a cave should have access to food sources, do bats that inhabit the same cave compete for the same food sources? There does not appear to have been any research investigating the sharing of food sources among insectivorous bat species roosting together in caves and how tight the competition is among the species inhabiting the same cave. This kind of basic information is very important for bat conservation especially in relation to cave management as a roost habitat, as well as the management of food sources. In this study, we examined the grouping and niche overlap based on the food preference of insectivorous bats in the Gombong Karst Area, Kebumen, Central Java, Indonesia.

METHODOLOGY

The research was conducted from June 2009 to March 2010 in 12 caves located in the karst area of Gombong, Kebumen Regency, Central Java (Figure 1). The caves and their location were : Celeng cave (07° 42.380SL/109 °23.624 EL); Dempo cave (07° 40.195 SL/109° 25.632 EL); Inten cave (07° 40.211LS/ 109° 25.592 EL); Jatijajar cave (07°39.994 SL/109° 25.562 EL); Kampil cave (07° 42.389SL/ 109° 23.836EL); Kemit cave (07° 42.247SL/109° 23.638EL); Liyah cave (07° 42.392SL/109° 23.838EL); Macan cave (07° 39.745SL/109° 26.163 EL); Petruk cave (07° 42.315SL/109° 24.130EL); Sigong cave (07° 42.487SL/109° 23.389EL); Tiktikan cave(07° 40.166SL/ 109° 25.595EL); and Tratag cave(07° 42.267SL/109° 23.663 EL). Identification of insects from mouth and stomach samples was carried out at the animal laboratory of the Biological and Biodiversity Resource Research Centre at IPB, Bogor, West Java, Indonesia.

In all the caves under study, the bat roost sites were located and mapped. Five to 10 bats from each roost site were collected using a hand net, a mist net, or a harp trap in the early morning directly after the bats had come back from foraging (from 05.00 to 07.00 am). The insect food samples were collected from the mouth and stomach of bats and observed under a 4.5 x 10 magnifying microscope. Insects were identified by using the key of insect food items by Whitaker (1987) and the identification key of insects by Borror *et al.* 1996. Species of insects from the stomach and mouth samples were then compared with insects collected from nearby foraging areas of bats.

The comparison insects in the identification process were collected using a light trap set up in three locations used by foraging insectivorous bats, namely a rice field at Candi Renggo village, a conservation forest a karst area in South Gombong, and around the settlement area of Jatijajar village. To identify each bat's preference for particular insects as a food source, PCA was used. The analysis on the similarity of food types among the species of bats was done using niche overlap index and chi square testing (Ludwig & Reynold 1988).

RESULTS

The results of roost location and mapping indicated that eight out of the 12 caves observed were inhabited by insectivorous bats. These bats were of 11 species: *Chaerophon plicata* (Dobson), 1874; *Hipposideros ater* Templeton, 1848; *Hipposideros* cf. *ater*; *Hipposideros* sp.; *Hipposideros bicolor* Temminck,1834; *Hipposideros sorenseni*

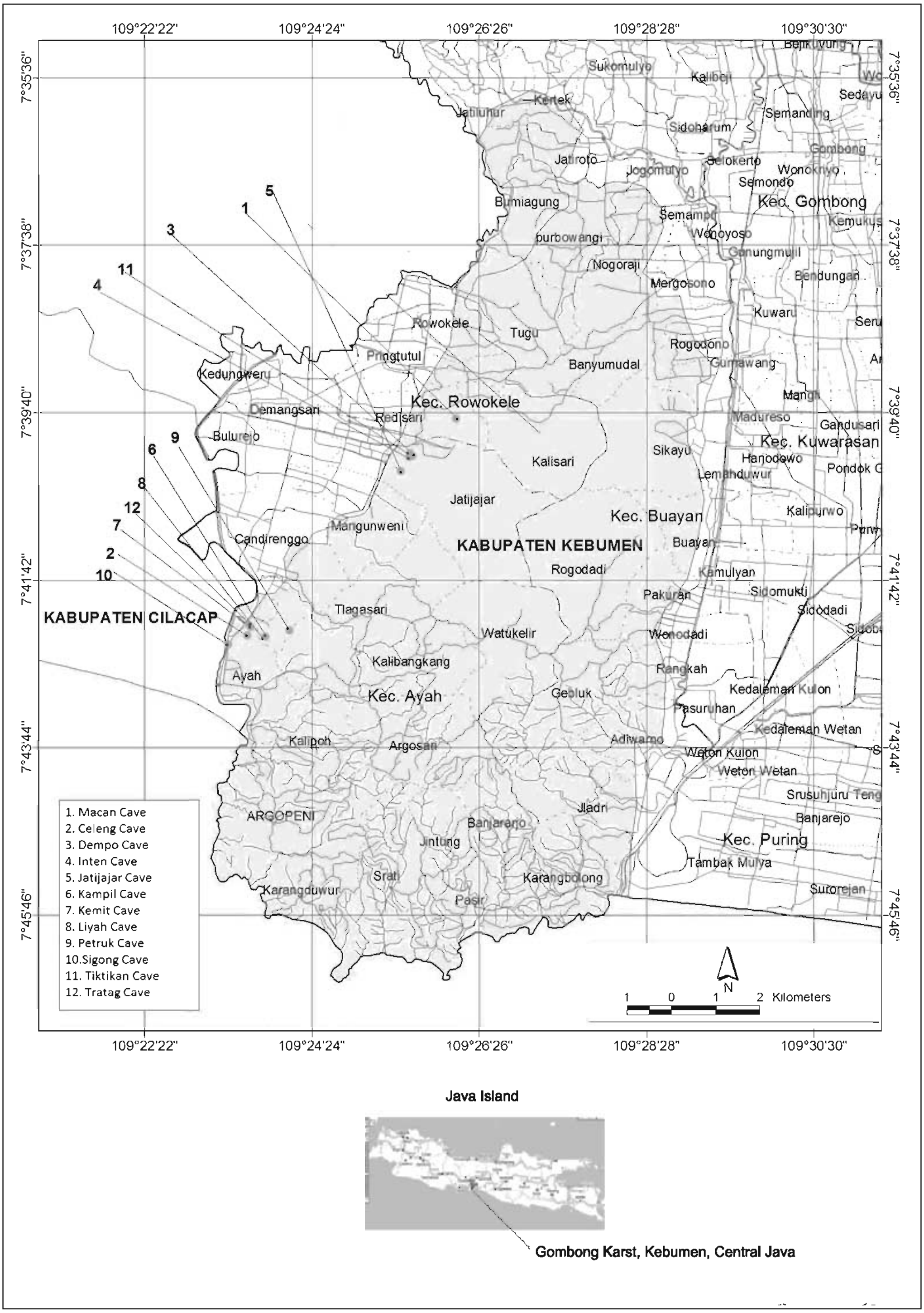

Figure 1. The location of the study area and the position of caves in the Gombong Karst Area, Java, Indonesia.

Kitchener & Maryanto,1993; *Rhinolophus borneensis* Peters,1861; *Rhinolophus affinis* Horsfield, 1823; *Miniopterus australis* Tomes, 1858; *Miniopterus schreibersii* Kuhl, 1819; *Hipposideros diadema* (E.Geoffroy,1813). Dempo cave and Macan cave were only inhabited by one species of insectivorous bat. The caves of Celeng, Inten, Jatijajar, Kemit and Liyah were inhabited by two species and Petruk Cave was inhabited by seven species of bats. The occurrence of bat roosts in the 12 caves is shown in Figure 2.

The results of the analysis of food preference of the insectivorous bats indicated that there were 29 species of insects from eight orders. *Hipposideros sorenseni* preyed on the most species (from 17 families), followed by *Hipposideros* sp. (8 families), *M. schreibersii* (6 families), *C. plicata* (8 families), *H. bicolor* (5 families), *M. australis* (6 families), *R. affinis* (5 families), *H.diadema* (5 families), *H. ater* (4 families), *H.*cf.*ater* (4 families) and *R. borneensis* (1 family). The insects found and the proportion in each species is presented in Table 1. Based on the identification of insects that were collected in the nearby foraging areas of insectivorous bats, as well as the results presented in a study by Aguirre *et al.* (2002), the characteristics of insects could be identified and are presented in Table 2.

The results of PCA with three principal components illustrating 85% of the total variance is described. Component 1,2,3 respectively, explained 47.5 %, 23.5 % and 14.0 % of the variation. Scores of each component after reduction to three principal components can be seen in Table 3. PCA results are presented in Figure 3. Based on Figure 3 and Tables 2 and 3, bats are put into four groups based on their diet preference:

1. Group 1 is that of *C. plicata, Hipposideros* sp., *H. sorenseni* and *H. diadema* preying on Coleoptera_Scarabidae, Coleoptera_Clambidae, Coleoptera_unknown 8a, Coleoptera_unknown 7a, Orthoptera_Acredidae, Orthoptera_ Gryllothalpidae, Neuroptera_unknown 12a, and Neuroptera_Myrmeteonidae. Based on the insect characteristics (Table 2), this group

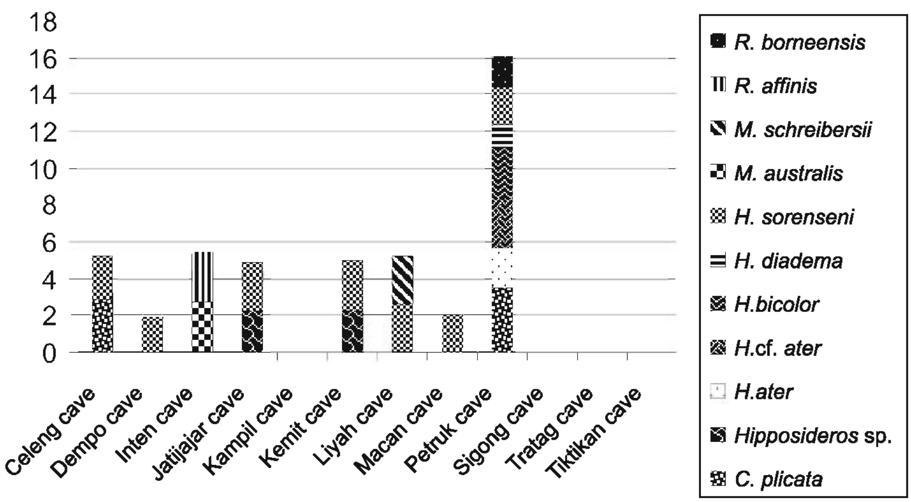

Figure 2. The occupation of caves by 11 species of insectivorous bats in the study area, Gombong Karst Area, Java, Indonesia. For cave locations see Figure 1.

Table 1. An analysis of the proportion of insects in the diet of 11 species of bats from Gombong Karst Area, Java, Indonesia. (Proportion = amount of insects "x" found in each species of bat / amount of all insects found on each species of bat).

	Insect		Proportion										
No	Order	Family	A	B	C	D	E	F	G	H	I	J	K
1	Coleoptera	Scarabidae	0,12	0,16	0,14	0,00	0,00	0,00	0,00	0,11	0,00	0,00	0,00
2	Coleoptera	Clambidae	0,00	0,00	0,22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	Coleoptera	Unknown 8a	0,05	0,00	0,00	0,00	0,00	0,10	0,00	0,00	0,00	0,00	0,00
4	Coleoptera	Unknown2a	0,00	0,00	0,00	0,00	0,00	0,39	0,00	0,00	0,00	0,00	0,00
5	Coleoptera	Rhisodidae	0,23	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6	Coleoptera	Unknown 7a	0,09	0,03	0,06	0,00	0,00	0,00	0,00	0,21	0,00	0,00	0,00
7	Coleoptra	Staphilinidae	0,00	0,02	0,00	0,00	0,05	0,00	0,00	0,00	0,00	0,00	0,00
8	Diptera	Tipulidae	0,00	0,12	0,00	0,00	0,17	0,00	0,00	0,00	0,33	0,00	0,00
9	Diptera	Cullicidae	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,00	0,00
10	Diptera	Unknown 9a	0,00	0,03	0,00	0,12	0,00	0,00	0,00	0,00	0,00	0,16	0,00
11	Hemiptera	Unknown 11a	0,00	0,00	0,00	0,00	0,15	0,07	0,00	0,16	0,25	0,23	0,00
12	Hemiptera	Miridae	0,00	0,00	0,00	0,32	0,00	0,00	0,00	0,00	0,00	0,00	1,00
13	Homoptera	Flugoriidae	0,00	0,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	Homoptera	Delphaciidae	0,00	0,09	0,00	0,18	0,00	0,00	0,00	0,00	0,00	0,00	0,00
15	Homoptera	Unknown 10a	0,00	0,00	0,00	0,06	0,12	0,00	0,00	0,00	0,00	0,00	0,00
16	Hymenoptera	Agaonidae	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00
17	Hymenoptera	Unknown 4a	0,07	0,04	0,00	0,15	0,00	0,00	0,28	0,00	0,00	0,00	0,00
18	Hymenoptera	Formycidae	0,26	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,23	0,00
19	Isoptera	Unknown 1a	0,00	0,00	0,00	0,18	0,15	0,00	0,00	0,00	0,00	0,00	0,00
20	Isoptera	Unknown 1b	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
21	Lepidoptera	Unknown 5a	0,11	0,03	0,00	0,00	0,00	0,00	0,48	0,00	0,39	0,00	0,00
22	Lepidoptera	Unknown 6	0,00	0,06	0,00	0,00	0,37	0,00	0,00	0,00	0,00	0,39	0,00
23	Orthoptera	Acredidae	0,07	0,15	0,18	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
24	Orthoptera	Grillidae	0,00	0,13	0,00	0,00	0,00	0,27	0,00	0,00	0,00	0,00	0,00
25	Orthoptera	Grylothalpidae	0,00	0,05	0,10	0,00	0,00	0,00	0,00	0,37	0,00	0,00	0,00
26	Neuroptera	Myrmeteonidae	0,00	0,09	0,06	0,00	0,00	0,00	0,08	0,16	0,00	0,00	0,00
27	Neuroptera	Unknown 8a	0,00	0,00	0,13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
28	Neuroptera	Mantisipidae	0,00	0,00	0,10	0,00	0,00	0,17	0,00	0,00	0,00	0,00	0,00
29	Trichoptera	Unknown 3a	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00
		Sample (n)	8	3	3	3	3	9	16	5	4	5	1

Table 2. The characteristics of insects (body weight, body length and hardness of body) recorded as prey from 11 species of Indonesian bats.

No	Ordo	Family	Weigh (gr)	Body length (mm)	Hardness of body (N)*
1	Coleoptera	Scarabidae	-	30.62±4.13	34.02±11.35
2	Coleoptera	Clambidae	0.54±0.02	1.2±0.5	-
3	Coleoptera	Unknown 8a	-	25±4	-
4	Coleoptera	Unknown2a	-	-	-
5	Coleoptera	Rhisodidae	0.68±0.1	1.5±4	24.96±12
6	Coleoptera	Unknown 7a	1.29±22	22±6	44.68±4.2
7	Coleoptra	Staph ilinidae	1.64±0.3	25±1.8	-
8	Diptera	Tipulidae	0.06	12±6	-
9	Diptera	Cullicidae	0.021	4.1±2.2	0.88±0.02
10	Diptera	Unknown 9a	-	-	-
11	Hemiptera	Unknown 11a	-	-	-
12	Hemiptera	Miridae	-	8±4	2.18±0.21
13	Homoptera	Flugoriidae	-	-	-
14	Homoptera	Delphaciidae	0.08±0.03	15.00±1.00	1.67±0.38
15	Homoptera	Unknown	-	-	-
16	Hymenoptera	Agaonidae	-	2.1±0.8	-
17	Hymenoptera	Unknown 4a	-	8±4.0	-
18	Hymenoptera	Formycidae	0.02±0	2.2±1.0	-
19	Isoptera	Unknown 1a	-	13.00±10	-
20	Isoptera	Unknown 1b	-	-	-
21	Lepidoptera	Unknown 5a	-	-	-
22	Lepidoptera	Unknown 6	-	-	-
23	Orthoptera	Acredidae	0.73±0.16	53.25±17.17	7.45±3.20
24	Orthoptera	Grillidae	0.58±0.08	30±-10	7.30
25	Orthoptera	Grylothalpidae	0.56±0.12	30±5	8.60
26	Neuroptera	Myrmeteonidae	0.13±0.02	35±10	6.88±12
27	Neuroptera	Unknown 8a	-	-	-
28	Neuroptera	Mantisipidae	0.22±0.18	28.3±3.2	-
29	Trichoptera	Unknown 3a	-	6.2±3.0	-

*Note: The hardness of the insect's body was measured by Aguirre *et al.* (2002) using an isometric kistler (= force transducer - Kistler, Switzerland).

Table 3. The score for component coefficients from Principle Component Analysis (PCA) based on the diet content of 11 species of insectivorous Indonesian bats.

Insects Species	PC		
	1	2	3
Col_Sca	-.031	-.230	.792
Col_8a	.918	-.079	-.023
Col_2a	.963	-.028	-.127
Col_7a	-.158	-.195	.843
Col_Sta	-.296	-.344	-.536
Dip_cul	-.463	.042	-.139
Hym_Aga	-.088	.926	-.088
Hym_4a	-.099	.901	-.066
Hym_For	-.052	-.403	.094
Iso_1b	.012	.034	.533
Lep_5a	-.185	.781	-.061
Lep_5b	-.332	-.408	-.592
Ort_Gril	.900	-.058	-.174
Ort_Gry	-.162	-.145	.797
Neu_Myr	-.293	.466	.524
Neu_8a	.048	-.139	.481
Neu_Man	.915	-.093	.114
Tria_3a	-.088	.926	-.088

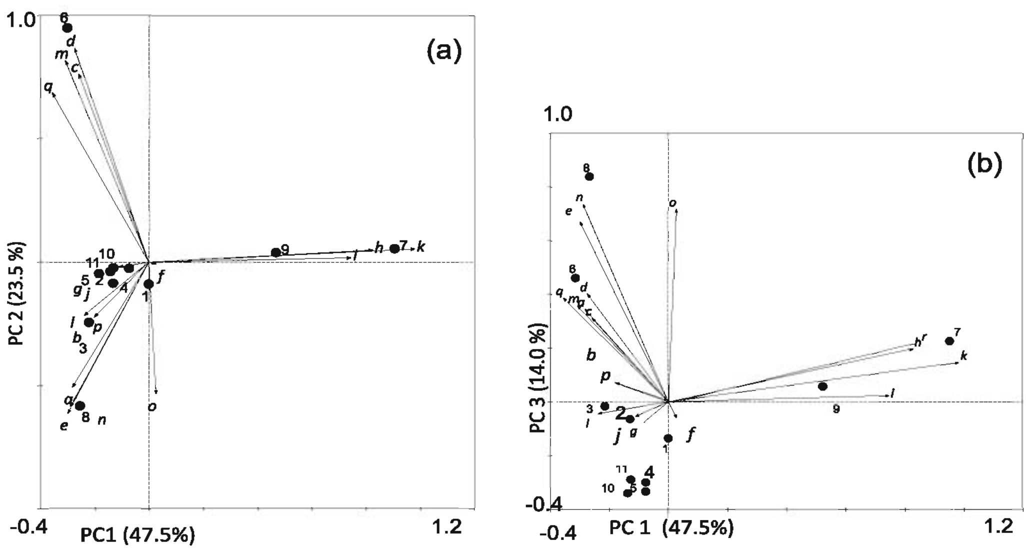

Figure 3. Principle component analysis for 11 bat species based on their insect diet.

Key for Figures:

1. C. plicata	*7. H. bicolor*	*a.* Coleoptera_Scarabidae	*g.* Homoptera_Flugoridae	*m.* Orthoptera_Gryllidae
2. H. sorenseni	*8. H. diadema*	*b.* Coleoptera_Clambidae	*h.* Hymenoptera_Formicidae	*n.* Orthoptera_Gryllothalpidae
3. Hipposideros sp	*9. H. ater*	*c.* Coleoptera_Unknown 8a	*i.* Hymenoptera_Unknown 4a	*o.* Neoroptera_Myrmeteonidae
4. M.schreibersii	*10. H.cf.ater*	*d.* Coleoptera_Unknown 2a	*j.* Isoptera_Unknown 1b	*p.* Neuroptera_Unknown 12a
5. M. australis	*11. R. borneensis*	*e.* Coleoptera_Unknown 7a	*k.* Lepidoptera_Unknown 5a	*q.* Neoroptera_Mantisipidae
6. R. affinis		*f.* Diptera_ Cullicidae	*l.* Orthoptera_Acredidae	*r.* Trichoptera_Unknown 3a

prefers large (> 0.5 gram in weight, > 20 mm in length) and hard (hardness > 7.5 N) sized insects.

2. Group 2 consisted of *M. schreibersii, M. australis, H.*cf. *ater* and *R. borneensis* which preyed on Diptera_unknown 9a, Hemiptera_unknown 11a, and Lepidoptera_unknown 6a and Isoptera_unknown 1a. Based on the insect characteristics (Table 2), this group usually preyed on medium sized and soft bodied insects (5 mm up to 20 mm in length and < 7.5 N in body softness).

3. Group 3 consisted of *R. affinis,* a group that preyed on Coleoptera_unknown 8a, Coleoptera_unknown 2a, Orthoptera_Grillidae and Neuroptera_Mantisipidae. This group usually preyed on small sized and hard insects (0.5 gram in weight, < 20 mm in length and > 7.5 N in hardness).

4. Group 4 consisted of *H. bicolor* and *H. ater*, which preyed on Lepidoptera unknown 5a, Trichoptera_unknown 3a, Hymenoptera_unknown 4a and Hymenoptera _Agaonidae. Based on the insect characteristics (Table 2), this group preyed on small sized and soft insects (5 mm long and < 7.5 N in body hardness).

The niche overlap index of diet among the insectivorous bats found in this study ranged from 0 to 0.683. Table 4 shows that the highest niche overlap index of diet was between *C. plicata* and *H. sorenseni* (0.683). This number implies that 68.3 % of *C. plicata's* diet is the same as that of *H. sorenseni's* diet. Other bats that also had high niche overlap index of diet were *H. sorenseni* and *H. diadema* (0.679), *C. plicata* and *Hipposideros* sp. (0.578), *H. sorenseni* and *Hipposideros* sp. (0. 528), *M. australis* and *H.* cf. *ater* (0.469) and *Hipposideros* sp. and *H. diadema* (0.436).

The niche overlap indices of diet indicates forage competition among the species being compared. To identify the niche overlap index of food among bat species that were roosting in the same cave, a X^2 test and the calculation of niche overlap index among the species was conducted. The test and the calculation results are presented in Table 5.

Based on Table 3, it can be seen that the niche overlap indices of diet were less than 30 % among bats roosting in the same cave, except for species roosting in Kemit Cave. This means that there was less foraging competition among these species as they preyed on different forage sources. The niche overlap indices of diet among the bats roosting in the same cave was smaller compared to those roosting in different

Table 4. The niche overlape index of diet amongst 11 species of insectivorous Indonesian bats.

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*
A	1	0.683	0.578	0.156	0	0.155	0.221	0.265	0.191	0.174	0
B		1	0.528	0.246	0.323	0.163	0.301	0.679	0.332	0.189	0
C			1	0	0	0.079	0.04	0.436	0	0	0
D				1	0.181	0	0	0	0.043	0.24	0.26
E					1	0.148	0	0.165	0.246	0.469	0
F						1	0	0.045	0.110	0.178	0
G							1	0.095	0.240	0	0
H								1	0.205	0.128	0
I									1	0.206	0
J										1	0
K											1

Key: *A= C. plicata, B= H. sorenseni, C= Hipposideros* sp., *D= M. schreibersii, E= M. australis, F= R.affinis, G= H. bicolor, H= H. diadema, I= H. ater, J= H.*cf. *ater, K= R. borneensis.*

Table 5. Niche overlape index of the diet and Chi square test among 11 Indonesian bat species that roosting in the same cave.

	Cave	Bat Species	Niche Overlape Index	Chi square
1	Celeng	*C.plicata : H. sorenseni*	0.054	4.97 *
2	Jatijajar	*H.sorenseni* R2 : *H. sorenseni* R4	0.1684	5.98*
		H.sorenseni R2 : *Hipposideros* sp.	0.000	3.86*
		H.sorenseni R4 : *Hipposideros* sp.	0.197	3.81*
3	Inten	*M.australis : R. affinis*	0.048	4.91*
4	Liyah	*M.schreibersii : H. sorenseni*	0.161	3.88*
5	Kemit	*H.sorenseni : Hipposideros* sp.	0.471	1.88 ns
6	Petruk	*H.bicolor : C. plicata*	0.221	5.98*
		H.bicolor : H. sorenseni	0.000	5.96*
		H.bicolor : H. diadema	0.095	3.99*
		H.bicolor : H. ater	0.240	5.92*
		H.bicolor : H. cf. *ater*	0.000	3.84 *
		H.bicolor : R. borneensis	0.000	5.68*
		C.plicata : H. sorenseni	0.196	3.89*
		C.plicata : H. diadema	0.028	4.87*
		C.plicata : H. ater	0.167	3.85*
		C.plicata : H. cf. *ater*	0.000	5.96*
		C.plicata : R. borneensis	0.000	5.98*
		H.sorenseni : H. diadema	0.000	5.92*
		H.sorenseni : H. ater	0.293	3.80*
		H.sorenseni : H. cf. *ater*	0.253	3.81*
		H.sorenseni : R. borneensis	0.05	4.21*
		H.diadema : H. ater	0.205	5.12*
		H.diadema : H .cf. *ater*	0.128	3.96*
		H.diadema : R. borneensis	0.000	5.86*
		H.ater : R. borneensis	0.000	5.99*
		H.ater : H. cf. *ater*	0.206	5.78*

Notes: *- significantly different being at 95 % level (P<0.05), ns - not significantly different being at 95 % level (P>0.05).

caves. For example, the niche overlap indices of *H. sorenseni* and *Hipposideros* sp. which roost in different caves was 0.528. Meanwhile, the niche overlap indices for the same species while roosting in one cave (in Jatijajar cave) was 0.1696. The same situation applies to *C. plicata* and *H. sorenseni.* The niche overlap indices for these two species that roost in different caves was 0.683 while the value for the species roosting together in Celeng cave was 0.054. This indicates that species of bats roosting in the same cave had displaced feeding niches.

DISCUSSION

The diets of insectivorous bats found in this study comprised 29 families of insects which are classified into eight orders. All these eight insect orders have been found in the stomachs of Microchiropterans in previous research. Razakarivony *et al.* (2005) found the order of

Orthoptera, Hemiptera, Araneae and Homoptera in the gut contents of five species of Microchiroptera in Madagascar, and Agosta (2002) found Coleoptera, Lepidoptera, Hymenoptera, Hemiptera, Diptera and Lepidoptera in the gut contents of *Eptesicus fuscus* in North America. Aguirre *et al.* (2002, 2003) found Coleoptera, Odonata, Orthoptera, Lepidoptera, Homoptera and Arachnida in the digestive tracts of the 10 species of Microchiroptera in Espiritu National Park in Bolivia. Therefore, it is clear that the insects found in this research are those commonly preyed on by bats.

This indicates that microchiroptera tend to have a particular preference for their prey. According to Razakarivony *et al.* (2005) this preference is determined by prey abundance. Altringham (1996) indicated that based on their foraging strategies, bats can be categorized into specialists and opportunists. Those that are specialists only prey on particular insects that offer high profit. These species spend a considerable amount of time and energy in foraging. The opportunists spend less time and energy, but they get less profit compared to the specialists. In this research, it was suspected that *H. sorenseni* belongs to the opportunist type as they eat various species of insects while *R. affinis, H. diadema, H. ater, H.*cf. *ater* and *R. borneensis* can be categorized as selective types as they only select one to five insect families for their diet. However, further research is needed to investigate the influence of seasonal abundance of different insects because the sampling for this study was not done over a full year.

The result of PCA indicated that there were four groups of Microchiropterans based on their forage preferences. This result can be explained by the findings of Aguirre *et al.* (2003) who showed that the hardness and the size of insect prey chosen by bats is determined by the strength of the bats' jaws and the morphology of their teeth. Zhang *et al.* (2005) also showed that there is a correlation between the body size of Flat-headed Bats and that of their prey where the larger *T. robustula* selects larger bodied insects than the smaller *T. pachypus*.

In addition to hardness and the size of the body, the height that insects fly also influences the preference of foraging bats. Altringham (1996) found that there are two catagories of foraging strategies among bats, namely aerial hawking and flycatching. Aerial hawking is done by detecting the existence of prey, chasing them, and eating them while they fly. Flycatching is done by detecting the existence of prey from an elevated perch, chasing, catching and returning to a perch before consuming the prey. Bats that have an aerial hawking strategy tend to prey on insects that can fly high. Meanwhile, the flycatching strategy is used by bats preying on insects living on the ground, or those that fly low. In this study, the level of insect flying was not observed. However, based on Dr. Hari Sutrisno (pers. comm.), an expert on insects at the Zoological Museum of Indonesian Science Institute, members of the insect Orders Lepidoptera, Orthoptera, Coleoptera and Diptera tend to be at ground surface, while Hemiptera, Homoptera, Trichoptera and Hymenoptera fly high above ground surface.

The niche overlap indices of diet found for insectivorous bats was small. According to Ludwig & Reynolds (1988) the niche overlap indices range from zero to one, resulting in forage overlap among the bats being compared when it was closer to one. The result of this study indicated there was little diet overlap among Microchiropterans roosting in the caves in Gombong, as each species specialized in different types of insects.

The results of this study indicate that associations in roosting in one cave occured among bats having low values in niche overlap indices and that were less than 30 %. Cox (2002) found the use of the same niche results in a competitive interaction, in which each population's competitive interaction produces a bad impact on their competitors. The current research has proven that competition in foraging is very low among species roosting in the same cave. The results of the study has been able to answer why bats roosting in one cave survive from one generation to another and can reach high population numbers whithout having to compete for food resources. Despite foraging in the same location, those bats can share their niche and choose foraging areas with different characteristics except at Kemit Cave, where niche overlap indices were more than 30%. This is presumably because the source of insects for food surrounding the Kemit cave is plentiful.

CONCLUSION

1. Based on their diet, insectivorous bats in the karst area of Gombong can be put into four groups: Group 1 includes *C. plicata, Hipposideros* sp., *H. sorenseni* and *H. diadema* having a preference for large-sized and hard bodied insects, Group 2 includes *M. schreibersii, M. australis, H.*cf. *ater, R. borneensis* having preference for medium sized and soft insects, Group 3 includes *R. affinis* which prefers small sized and hard insects, and Group 4 includes *H. bicolor* and *H. ater* having a preference for small sized and soft insect.

2. The niche overlap indices for food among insectivorous bats which roost in one cave is less than 0.30. This indicates that there is little competition in foraging among the species of bats which share one cave.

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