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Distribution and underground habitats of cave-dwelling bats in China

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Abstract

To understand the distribution and relative abundance of cave-dwelling bats and to identify those sites that would be important for conservation of bat species, 25 underground sites that had not been previously surveyed were investigated in this 3-year study (from December 2003 to April 2006) in Funiu Mountain of Henan province, China. Approximately 80 000 bats were recorded, representing 12 species. The most abundant species were *Rhinolophus affini*s, *Miniopterus schreibersi* and *Hipposideros pratti*. The roosts were evaluated for their conservation importance. The most important sites in the area are Yunhua and Nanzhao caves, which serve as hibernaculums and nursery roosts to *c.* 13 740 and 11 803 bats, respectively, representing seven species. By means of cluster and correspondence analysis, the distribution of bat species was different between the two sides of the mountain and was highly dependent on the size of the cave. The underground sites in the south region hosted *c.* 80% of the total bats, representing 11 species. The sites in the north region hosted 20% of the total bats, representing seven species. Presently, none of the caves in the region has adequate protection and some bat populations are under serious threat. Many large caves that contained large bat populations and several species of concern had been developed as tourist sites, and so some advice on protecting the most important local habitats was sought based on the assessment of the conservation status of underground sites. This paper presents basic data concerning the distribution of cave-dwelling bats and the patterns of cave use on Funiu Mountain. The data will help local governments and policy-makers develop suitable strategies to promote local tourisms while protecting important habitats of animal species.

Introduction

There is a growing agreement that more effort is needed to ensure the survival of bat species all over the world, and that success or failure will depend on our basic knowledge of these populations (Furman & Özgül, 2004). The nocturnal nature and mobility of bats mean that they are relatively less studied and our knowledge of them lags behind that of more conspicuous mammals (Furman & Özgül, 2004). The presence of bats might be a necessary condition for the subsistence of some cave environments. For instance, bat guano is an important source of nutrients for diverse arthropods in caves. By transporting tons of organic matter to the caves, bats act as mobile links connecting cave environments with the outside world (Arita, 1996).

The protection of roosting sites is an essential component of any strategy for the conservation of bats. Underground sites, both natural (e.g. caves) and artificially created (e.g. mines and fortifications), are crucial to the survival of many bat species worldwide (Dalquest & Walton, 1970; Hutson, Mickleburgh & Racey, 2001; Kunz & Lumsden, 2003), although some bat species use caves only as alternate refuge. For example in the United States, all five species listed as endangered by the IUCN use caves as roost sites at least part of the year (McCracken, 1989). The endangered Kitti's hog-nosed bat *Craseonycteris thonglongyai* (IUCN, 2006), restricted to two small areas of south-east Asia, relies completely on caves for day roosting (Humphrey & Bain, 1990; Bates *et al.*, 2001; Hutson *et al.*, 2001). Therefore, the preservation of underground site should be of foremost interest for the conservation of chiropteran species.

Owing to destruction and degradation of their foraging habitats and roosts, 62 species of 125 bat species in China have been listed as 'Near Threatened' (NT) (22 species), 'Vulnerable' (VU) (30 species) and 'Endangered' (EN) (10 species). The status assessment of these bats species was made by the Biodiversity Working Group of China Council for International Cooperation on Environment and Development (BWG/CCICED) and has been listed on China Species Red List (Wang & Xie, 2004), which is based on IUCN Red List of Threatened Animals (2001). Environmental factors (including landscapes, climates, human

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activities, vegetation and water systems) have important impacts on bat distributions (Ji & Chen, 1990; Li *et al.*, 2005); therefore, any plan aimed at the conservation of these bats should first identify and protect their foraging habitats and roosts.

Funiu Mountain is of typical karst landscape and it is situated at a transitional zone between the Warm Temperate Zone and the Northern Subtropical Zone in China (Chen, 2004). The geological and climatic characteristics of the Funiu Mountain result in numerous caves. These caves and other man-made underground structures such as mines and tunnels provide ideal roosts for bat populations. However, little research has been carried out on cave-dwelling bats in this area.

In recent years, with the development of the economy and ecotourism, some caves have been targeted for development as tourist sites, giving rise to the conflict between the economic development and biological conservation. These caves will provide a case study to determine whether economic development and biological conservation are indeed compatible.

Materials and methods

Study area

This research was carried out in nine counties of three districts in Funiu Mountain (Fig. 1). Five counties (Songxian, Luanchuan, Shanxian, Lingbao and Lushi) covering 13 944 km^2 are located on the north side of the mountain. Four counties (Nanzhao, Xixia, Neixiang and Xichuan) covering 11 662 km^2 are located on the south side.

Funiu Mountain (E110°30′–113°05′, N32°45′–34°47′) is situated in the west of Henan Province. It is *c*. 400 km long and 40–70 km wide in north-west–south-east orientation. The mountain is an eastern extension of Qinling Mountains and an important dividing line between the Warm Temperate Zone and the Northern Subtropic Zone in China. The south region falls within the Northern Subtropic Zone, with a mean annual temperature range of 14.1–15.1 °C, while the north region is part of the Warm Temperate Zone, with a mean annual temperature range of 12.1–12.7 °C. Annual rainfall is 800–900 mm on the south side and 650–800 mm on the north side. Evergreen broadleaf and deciduous broadleaf mixed forest is the predominant vegetation in the southern slope of the mountain, while deciduous broadleaf forest is the predominant vegetation in the northern slope (Shang, Wang & Feng, 1998).

Methods

All fieldwork abided by the Law of the People's Republic of China on Protection of Wildlife. The methods used for capturing and counting bats are in accordance with the Guidelines on the recommended methodologies to be used for the monitoring of bat species in Europe (Eurobats, 1998). Data were collected in 25 underground sites (labeled as 'a' to 'y') located in nine counties mentioned above. The fieldwork was conducted during four periods: December 2003–March 2004, June–September 2004, July 2005–September 2005 and November 2005–April 2006. Each cave was visited at least twice (once in the bat's active summer period excluding their breeding period, and once in their hibernation period). The data were collected on many variables of the caves such as location, the maximal height (*H*) and width (*W*) of the passage, the total length of passages (*L*), the number of entrances (*EN*) and the number of chambers (*CH*). To minimize disturbance to bats, the

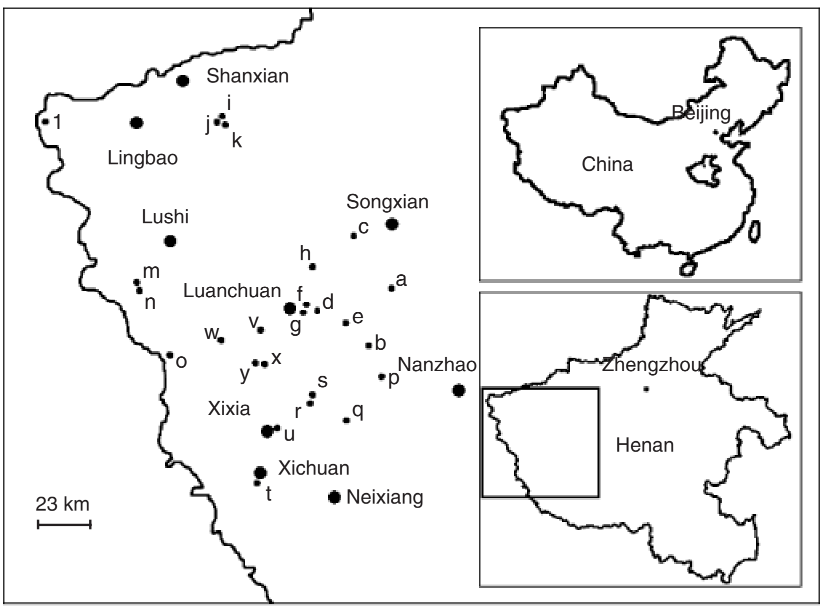

Figure 1 Map of the research area and locations of surveyed sites.

interval between the two visits to each cave was more than 2 weeks.

Bat species were identified based on their morphological characteristics. Specimens were captured either by hand or with a hand-held net mounted on an extendable rod. When the ceilings were very high, we captured flying individuals using mist nets set in multiple locations of the cave. All captured bats were released as soon as possible after being measured. Calipers were used to take measurements of the length of the forearm, and for some species groups, additional measurements (like the length of some fingers and the length of the hind foot) were also taken.

Population sizes were estimated for each species. When the number of bats in a group was <30, all individuals were directly counted. For larger colonies of bats, the density of individuals per meter square was first estimated by directly counting the total individuals within a small but measurable area, with the total population calculated based on the total occupied area of the cave. The total area covered by bats was determined using data from cave surveys. For mixed species groups that occupied certain sections of a cave, a photographic method of counting bats inside the roost was used (Eurobats, 1998). For species that occupied wide sections of a cave but formed discrete groups, the number of individuals in each group and the number of such groups were estimated by direct counting. Additionally, the rate of captures in mist nets was used as an indirect estimator of relative abundance, and was used only as a complementary count when determining the number of certain species was very difficult.

Cluster analysis was used to group the counties using data on the presence of bat species in a given county during survey. An ordination method based on canonical correspondence analysis (ter Braak, 1986) was used to illustrate the relationships between the cave's morphometric variables and the bat species. Cluster analysis was conducted using SPSS11.0 for windows (SPSS Inc., 2001); Canonical Correspondence Analysis was conducted using MVSP 3.13i for Microsoft Windows (Covach Computing Services, 2004). The data collected in 3 years supported the following assumptions: bat populations do not fluctuate dramatically during a 1 year period, and bats continue their yearly roosting cycles in the same set of sites (Furman & Özgül, 2002). Therefore, we referred to data collected in April–September as summer data, and to data collected in November–March as winter data. Three caves (Daizhang, Chongdugou and Gujiazhuang bat cave) and two species (*Plecotus auritus* and *Myotis formosus*) were excluded from the statistical analysis, as these caves did not host bats during the surveys, and we encountered only one individual of *P. auritus* and two individuals of *My. formosus* in only one site, respectively. We encountered only a single *Rhinolophus macrotis* individual in Luanchuan County, and so this species was also excluded from this region during cluster analysis.

A preliminary evaluation of the sites' conservation status was based on the species abundance and the scores attributed to them, as proposed during the third session of the meeting of Eurobats Agreement Parties (Mitchell-Jones *et al.*, 2000). The highest number of individuals encountered during our visits was used to represent the species abundance of the site. Species that are considered to be vulnerable by the China Species Red List (Wang & Xie, 2004) were given four points. Species that are considered to be near threatened were given two points. Each site was assigned a score that is the sum of contributions from all species found there (Furman & Özgül, 2004). Four priority levels were used to grade the sites based on their scores: level 1 refers to the most important underground roosts, which support the largest populations of most bat species and hold the scores of 10 000 or more; level 2 refers to very important underground habitats, in which there are large populations and more bat species ($1000 \leq$ Score $< 10\,000$); level 3 includes sites having a lower priority, which are used by small populations of bats ($100 \leq$ score < 1000); and Level 4 is assigned to the sites having the lowest priority, which are used by only a few bats (Score < 100).

Result

We recorded four species of *Rhinolophus* (Lacepéde, 1799), three *Myotis* (Kaup, 1829), two *Hipposideros* (Gray, 1831), one *Plecotus* (Geoffory, 1818), one *Murina* (Gray, 1842) and one *Miniopterus* (Bonaparte, 1837) (Tables 1 and 2), specifically: *Rhinolophus affinis* (Horsfield 1832), *Rhinolophus cornutus* (Temminck 1835), *Rhinolophus ferrumequinum* (Schreber, 1774), *Rhinolophus macrotis* (Blyth, 1844), *Hipposideros armiger* (Hodgson, 1835), *Hipposideros pratti* (Thomas 1891), *Murina leucogaster* (Milne-Edwards 1872), *P. auritus* (Linnaeus, 1758), *Myotis fimbriatus* (Peters, 1871), *My. formosus* (Hodgson, 1835), *Myotis ricketti* (Thomas, 1894) and *Miniopterus schreibersi* (Kuhl, 1819). Based on the China Species Red List, 2004, the conservation status of these species in China is as follows: *My. formosus* is (VU); *Plecotus pratti*, *P. auritus*, *R. affinis*, *R. cornutus* and *My. fimbriatus* are NT; and *R. ferrumequinum*, *H. armiger*, *R. macrotis*, *Mu leucogaster*, *My. ricketti* and *Mi. schreibersi* are Least Concern (LC).

The most abundant species were *R. affini*s, *Mi. schreibersi* and *Plecotus pratti*. *P. auritus* was represented by only one individual, and *My. formosus* was represented by only two individuals. In total, we recorded more than 47 000 bats of nine species in summer and *c.* 33 000 bats of eleven species in winter. There was a considerable difference in species-specific abundances between seasons. *Rhinolophus affinis*, *R. ferrumequinum*, *R. cornutus* and *R. macrotis* had many more individuals in summer than in winter (24 000 vs. 14 000, 2500 vs. 1500, 3900 vs. 1400 and 1600 vs. 900, respectively). *Myotis ricketti* with 180 individuals was present only in summer. *Miniopterus schreibersi*, on the other hand, was more abundant in winter than in summer (11 000 vs. 9000). *Myotis formosus*, *P. auritus* and *Mu. leucogaster,* with only a few individuals each, were encountered only in winter. The number of *H. armiger*, *H. pratti* and *My. fimbriatus* was approximately the same during both seasons.

Table 1 Bat censuses in the north region in Funiu Mountain

Key[a]	Cave name	Date	*R. aff.*[b]	*R. fer.*	*R. cor.*	*R. mac.*	*M. sch.*	*H. pra.*	*H. arm.*	Others
a	Chantang	23.12.03	–	3	–	–	–	–	–	–
		15.06.04	230	–	140	–	–	–	–	–
		06.07.05	140	–	120	–	–	–	–	–
		26.11.05	–	3	–	–	–	–	–	–
b	Baihe	24.12.03	230	58	–	–	250	–	–	–
		15.06.04	360	–	120	–	1400	–	–	–
		05.07.05	530	–	150	–	1300	–	–	–
		26.11.05	310	60	–	–	240	–	–	–
d	Miaozi	24.12.03	–	4	3	–	–	–	–	–
		16.06.04	10	–	–	–	–	–	–	–
e	Taoyuan	25.12.03	300	86	–	–	300	–	–	*M. leu.* 2
		17.06.04	1200	–	–	–	700	–	–	–
		30.03.04	200	60	–	–	600	–	–	–
		06.07.05	1000		–	–	600	–	–	–
		26.11.05	700	–	–	–	500	–	–	*M. leu.* 4
f	Gujiazhuang mine	25.12.03	–	–	2	1	–	–	–	–
		18.06.04	130	–	118	–	–	–	–	–
i	Zhangcun-1	25.02.04	–	17	–	–	–	–	–	*M. leu.* 2; *P. aur.* 1
		19.06.04	–	–	–	–	–	–	–	–
j	Zhangcun-2	25.02.04	–	13	–	–	–	–	–	*M. leu.* 4
		19.06.04	9	–	–	–	–	–	–	
k	Zhangcun-3	25.02.04	–	9	–	–	–	–	–	*M. leu.* 2
		19.06.04	–	–	–	–	–	–	–	
	Yuling	28.12.03	700	–	–	–	–	–	–	–
		05.07.04	1360	–	60	–	–	–	–	–
		11.09.05	1200	–	60	–	–	–	–	–
m	Jiulong cave	28.12.03	100	–	150	–	–	–	–	–
		25.07.04	340	–	–	–	–	–	–	–
		12.09.05	210	–	120	–	–	–	–	–
		23.04.06	300	–	140	–	–	–	–	–
n	Xianren cave	28.12.03	400	–	–	–	–	–	–	–
		28.07.04	1400	–	–	–	–	–	–	–
		25.08.05	1300	–	–	–	–	–	–	–
		23.04.06	280	–	–	–	–	–	–	–
o	Long-quanping	29.12.03	600	–	–	–	1000	–	–	–
		01.08.04	1620	–	–	–	1700	–	–	–
		14.09.05	1600	–	–	–	1800	–	–	–
		24.04.06	500	–	–	–	1000	–	–	

[a]The key corresponds to the one used in Fig. 1 and Table 3.
[b]*R. aff., Rhinolophus affinis; R. cor., Rhinolophus cornutus; R. fer., Rhinolophus ferrumequinum; R. mac., Rhinolophus macrotis; M. sch., Miniopterus schreibersi; H. pra., Hipposideros pratti; H .arm., Hipposideros armiger; M. leu., Murina leucogaster; P. aur., Plecotus auritus.*

The bats were unequally distributed between the two sides of the mountain in terms of both abundance and species. The underground sites in the south region hosted *c.* 80% of the total bats, representing 11 species. *Hipposideros armiger*, *H. pratti*, *My. fimbriatus*, *My. formosus* and *My. ricketti* were encountered only in the south region. The sites in the north region hosted 20% of the total bats, representing seven species. The only *P. auritus* individual was recorded in this region. For all common species in two regions, there were many more individuals in the south region than in the north. The most remarkable discrepancy was the 2800 individuals of *R. ferrumequinum* recorded in the south, with only *c.* 200 individuals recorded in the north.

The distribution of bat species showed considerable differences among sites (Table 3). Three of 25 sites surveyed were not occupied by bats; six sites harbored only one or two species and 11 sites provided roosts for four or more species. In general, natural caves accommodated more than 47 000 individuals representing 10 bat species. Tunnels and mines provided refuges for *c.* 3000 individuals from six species. Correlation analysis showed that the correlation between species abundance and the variable of L, H and W was positive and significant ($r = 0.695$, $P = 0.001$; $r = 0.730$, $P < 0.001$; $r = 0.690$, $P < 0.001$, respectively).

Cluster analysis divided the counties into three groups (Fig. 2). Nanzhao, Xixia, Neixiang and Xichuan clustered in

Table 2 Bat censuses in the south region in Funiu Mountain

Key[a]	Cave name	Date	*R. aff.*[b]	*R. fer.*	*R. cor.*	*R. mac.*	*M. sch.*	*H. pra.*	*H. arm.*	Others
p	Nanzhao	01.01.04	3000	200	–	–	6000	2200	123	*M. fim.* 30
		25.02.04	3000	180	–	–	5800	2000	120	*M. fim.* 30
		18.06.04	1300	300	–	–	2000	1360	80	*M. ric.* 40
		05.08.05	1540	160	–	–	1800	1530	86	*M. ric* 60;
		25.04.06	2500	100	–	–	5200	1800	100	*M. fim* 120 *M. fim.* 40
q	Qiliping	02.01.04	80	23	60	124	–	–	–	–
		07.08.04	620	–	700	560	–	–	–	–
		16.09.05	430	–	800	580	–	–	–	–
		23.04.06	110	33	55	96	–	–	–	–
r	Banchang	02.01.04	–	–	–	–	–	1300	–	–
		08.08.04	–	–	–	–	–	800	–	–
s	Huanglong	03.01.04	500	80	380–	310	–	–	–	–
		13.09.04	1500	–	330–	400	–	–	–	–
		27.04.06	670	–	410–	240	–	–	–	–
t	Shangji	04.01.04	240	150–	400	–	–	70	–	*M. fim.* 56
		14.09.04	700	15	240	–	–	150	–	*M. fim.* 70
		17.09.05	1000	–	600	–	–	130	–	*M. fim.* 50
		14.12.05	200	160–	350	–	–	80	–	*M. fim.* 33
u	Yunhua	04.01.04	3600	400	–	–	2560	1200	160	*M. fim.* 450
	cave	17.09.04	5500	1100	–	–	3400	2600	200	*M. fim.* 400;
		23.08.05	5000	600	–	–	3800	2200	220	*M. ric.*120
		25.11.05	2500	400	–	–	2200	1300	–	*M. ric.* 80
		22.04.06	3000	600	–	–	2000	1300	–	–
v	Miping	04.01.04	1320	145	200	150	–	–	–	–
		18.09.04	3500	120	850	200	–	–	–	–
		18.09.05	4000	100	–	–	–	–	–	–
		22.04.06	300	60	200	100	–	–	–	–
w	Sangping	05.01.04	1400	80	200	70	–	–	–	–
		18.09.04	1000	480	360	180	–	–	–	–
x	Junmahe	05.01.04	–	70	–	–	–	30	–	*M. leu.* 3
		21.09.04	67	32	–	–	–	120	–	–
		05.08.05	100	–	–	–	–	65	–	–
		23.04.06	–	12	–	–	–	20	–	*M. leu.* 7
y	Sunmen	05.01.04	500	–	–	80	–	150	–	*M. for.* 2
		22.09.04	1600	460	300	240	–	60	–	–
		28.04.06	600	280	–	–	–	80	–	–

[a]The key corresponds to the one used in Fig. 1 and Table 3.
[b]*R. aff.*, *Rhinolophus affinis; R. fer.*, *R. ferrumequinum; R. cor.*, *Rhinolophus cornutus; R. mac.*, *Rhinolophus macrotis; M. sch.*, *Miniopterus schreibersi; H. pra.*, *Hipposideros pratti; H. arm.*, *Hipposideros armiger; M. fim.*, *Myotis fimbriatus; M. ric.*, *Myotis ricktti; M. for.*, *Myotis formusus; M. leu.*, *Murina leucogaster.*

the same group, showing the most similarity in bat fauna. The bat fauna in these counties were mainly composed of the species of *R. affinis*, *My. fimbriatus*, *R. ferrumequinum* and *H. pratti*. Four counties, Lushi, Lingbao, Songxian and Luanchuan, located in the north flank, made up the second group. This group had the common species of *R. affini*s and *R. cornutus*. Shanxian has the least similarity to other groups, and formed the third group.

Canonical correspondence analysis indicated that the maximal height (*H*), the maximal width of the passage (*W*) and the number of chambers (*CH*) are the most important factors affecting the habitat use by bat species in underground sites (Fig. 3). *Miniopterus schreibersi*, *My. fimbriatus*, *My. ricketti*, *H. pratti* and *H. armiger* tend to use larger sites with more chambers. *Rhinolophus affinis* and *R. ferrumequinum* show no preference to the size of sites. Although *R. cornutus* and *R. macrotis* somewhat show correlations to the number of entrances, we believe that it might be an error because there were not enough gradients of this factor to be used in the analysis.

There are 10 species from this study that are highly dependent on underground sites and two species (*My. formosus* and *P. auritus*) that use underground sites as alternate habitats. Based on our priority grading scheme, three sites are assigned to Level 1, 11 sites to Level 2, four sites to Level 3 and four sites to the Level 4. The sites that are listed at the first and second priority levels accommodated one VN species (*My. formosus*) and four NT species (*P. pratti*, *R. affinis*, *R. cornutus* and *My. fimbriatus*) (China Species Red List status, 2004). Most of these Level 1 and 2

Table 3 The cave surveyed in Funiu Mountain area and the conservation status

Key[a]	Cave name	Type	Threats to site	Location	*L* (m)	*H* (m)	*W* (m)	Entrances	Chambers	Bat species	Max count[b]	Score	Status
a	Chantang	Mine	Disused	Songxian	35	7	0.55	1	1	3	373	743	3
b	Baihe	Cave	Nature	Songxian	80	6	2.3	1	2	4	2140	2820	2
c	Dazhang	Mine	Mining	Songxian	40	4	1.5	3	1	–	–	–	–
d	Miaozi	Cave	Nature	Luanchuan	20	1.8	1.6	1	1	3	17	30	4
e	Taoyuan	Tunnel	Disused	Luanchuan	110	2.5	2.7	1	2	4	1990	3190	2
f	Gujiazhuang mine	Mine	Disused	Luanchuan	60	0.67	2.1	1	1	3	249	497	3
g	Gujiazhuang Bat cave	Cave	Abandoned	Luanchuan	17	5	2	1	2	–	–	–	–
h	Chongdugou	Cave	Tourism	Luanchuan	45	11	12	1	3	–	–	–	–
i	Zhangcun-1	Mine	Disused	Sanxian	10	2	1.0	1	1	3	20	21	4
j	Zhuangcun-2	Mine	Disused	Sanxian	25	6	1.2	1	1	3	26	35	4
k	Zhangcun-3	Mine	Disused	Sanxian	62	5	1.3	1	3	2	11	11	4
l	Yuling	Rock Crevice	Nature	Lingbao	22.6	9	3.0	1	2	2	1420	2840	2
m	Jiulong cave	Cave	Tourism	Lushi	83	9	4.0	1	5	2	490	980	3
n	Xianren cave	Cave	Tourism	Lushi	97	15	10.6	1	2	1	1400	2800	2
o	Long-quanping	Cave	Nature	Lushi	81	12	8.75	1	3	2	3420	5040	2
p	Nanzhao	Cave	Tourism	Nanzhao	184	25	21	1	6	7	11803	17123	1
q	Qiliping	Cave	Tourism	Neixiang	167	16	21.3	2	5	4	2033	3453	2
r	Banchang	Cave	Nature	Neixiang	15	7	3.7	1	1	1	1300	2600	2
s	Huanglong	Cave	Nature	Neixiang	85	9	7.5	1	4	4	2390	4300	2
t	Shangji	Cave	Tourism	Xichuan	144	12	21	1	3	5	1980	3800	2
u	Yunhua cave	Cave	Tourism	Xixia	130	18	15	1	5	7	13740	22240	1
v	Miping	Cave	Nature	Xixia	150	14	2.1	1	1	4	5195	10045	1
w	Sangping	Cave	Tourism	Xixia	100	15	6.5	1	3	4	2420	4180	2
x	Junmahe	Tunnel	Disused	Xixia	91	7	2.1	1	1	4	297	517	3
y	Sunmen	Cave	Nature	Xixia	200	5	10	1	3	6	2752	4804	2

[a]The key corresponds to the one used in Fig. 1 and Tables 1 and 2.
[b]Max count is the total of the highest number of individuals of all species encountered in the cave during our visits.
H, the maximal height of the passage; *L*, the total length of all passages; *W*, the maximal width of the passage.

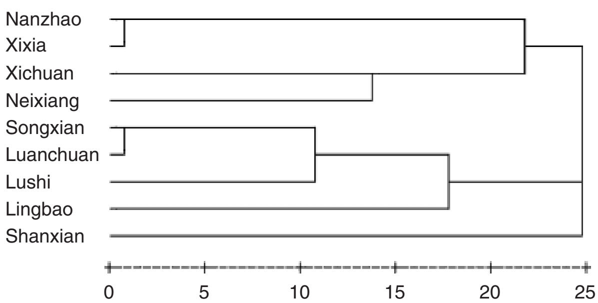

Figure 2 Cluster analysis of counties in the Funiu Mountain area.

sites are large with complex cavern systems. The sites listed in the third and fourth levels are mostly simple mines and tunnels.

Discussion

The species encountered in our survey have also been found in other provinces of China. However, this study was the first to report *H. pratti*, *H. armiger*, *R. cornutus*, *R. macrotis*, *My. ricketti*, *My. formosus* and *My. fimbriatus* in Henan province. There are records of *H. pratti* and *H. armiger* from southern, center and southwestern China (Wang, 2003). The distribution of these two species in Nanzhao and Xixia

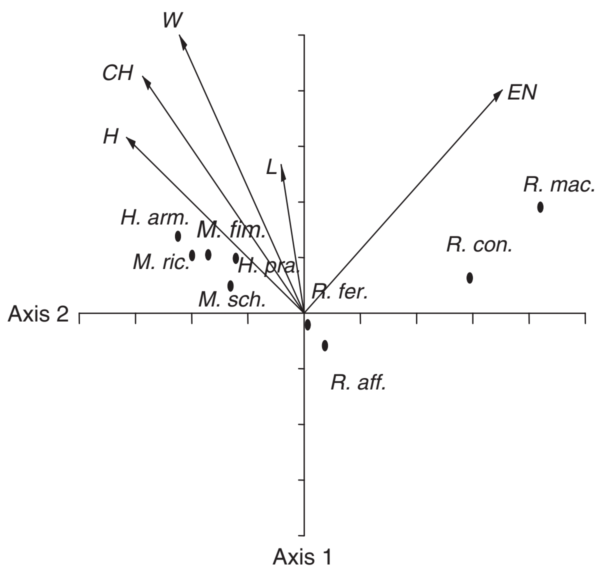

Figure 3 Biplot from a CCA of the underground sites in Funiu Mountain.

counties indicates that the southern flank of Funiu Mountain is their northmost limit in China to date. Only one *P. auritus* was encountered in our census (recorded during hibernation); one possible reason for such a situation is that this species often roosts in roofs of buildings and tree holes in summer, but usually hibernates in cooler regions of caves singly or in very small clusters (Entwistle, Racey & Speakman, 1997). *Myotis formosus* is found sporadically in 30 sites from northeastern and southern China, with typical habitats of forest and houses (Liu *et al.*, 2005; Luo & Gao, 2006); little is known about its hibernation roosts in caves. Two *My. formosus* individuals were observed in our study area only during hibernation, proving new behavioral data for this species. A small group of *My. ricketti* was found only in summer. It has been reported that large areas of water, such as lakes, reservoir and large still rivers, provide important feeding habitats for *My. ricketti* (Ma *et al.*, 2003), and it is highly likely that this species immigrates into the southern region of Funiu Mountains to access greater food resources.

Miniopterus schreibersi is known to have a rather broad migration range (Dwyer, 1969). Some groups from further north in China probably move to the Funiu Mountain caves for hibernation, which would account for the higher abundance in winter than in summer. *Rhinolophus affinis*, *R. ferrumequinum*, *R. cornutus* and *R. macrotis* were much more abundant during the active summer period than in the winter. It is likely that many *Rhinolophus* individuals leave the region in winter, or that there are unknown sites that provide hibernacula for these species in this area. We hope that a future monitoring program will clarify these uncertainties by using frequent field surveys and systematic observations at both summer roosts and hibernation sites.

Geographical distribution of Chiroptera is limited by climate factors and species density distribution is determined by resources abundance of food items (Li *et al.*, 2005). The different climate on either sides of the Funiu Mountains can explain the species composition differences between the south and the north regions. Furthermore, the greater number of large natural caves and the more abundant food resources (usually related to rainfall and annual average temperature) in the south region provide excellent habitats for the bats, which might explain why bats in the south regions are rather more abundant than in the north.

The distribution of bat species is significantly correlated to the type and size of the cave. Large natural caves deserve special consideration for protection because of their unusually high species richness and abundance. Nevertheless, it does not imply that tunnels and mines are dispensable for bat conservation. Some mines provided shelters for hibernating bats of *P. auritus,* which are listed as near-threatened species by China Species Red List, 2004. Also, tunnels will be potential roosts for large colonies of bats because they have broad space and a suitable microclimate.

The site-grading scheme for conservation of the underground sites grouped the caves into four distinct priority levels. These data will help to design a conservation strategy for the caves; however, the implementation of the strategy may be hindered by the boom of tourism in the region. Some caves classified as conservation Level 1 and 2 sites have been threatened by the development of tourism: three caves (Miping, Longquanping and Sunmen) will be developed for tourism. This poses a potential conflict between animal conservation and economic interests. Economic factors were the underlying motivation for the development of these sites, and the only minimal efforts were made to preserve the bat habitat within them. We hope that our findings will draw attention to the status of bats, and we advise that it is urgent to control the frequency of visits to these caves in order to protect the bat species in the region.

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