THE NATURAL HISTORY OF BATS ON MT. MAKILING, LUZON ISLAND, PHILIPPINES

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ABSTRACT. Over 1500 bats representing 20 species were captured in lowland forest on Mt. Makiling, Luzon Island, from January to August 1989. The two most commonly captured species, the fruit bats *Ptenochirus jagori* and *Cynopterus brachyotis*, were found to reproduce seasonally with two birth periods per year. Although microchiropterans comprised only 8% of all captures, they represented 14 species. Species accounts presented here include information on reproduction, habitat use, and other aspects of natural history.

INTRODUCTION

The Philippine bat fauna is very diverse, with 70 species recorded, of which at least 20 are endemic (Heaney *et al.*, 1987; Ingle and Heaney, 1992; Koopman, 1989). However, the ecology and distribution of most species are very poorly known. This is particularly true for microchiropterans, which are much more rarely caught in mist nets than megachiropterans, or fruit bats.

Heaney *et al.* (1987) reviewed information on the occurrence, distribution, and conservation status of bats of the Philippines. They noted large gaps in our knowledge of the taxonomy and distribution of Philippine bats, dramatically illustrated by identification of five new species since 1969. Studies on the population biology (Heideman and Heaney, 1989), reproductive ecology (Heideman, 1987, 1988, 1989), and foraging ecology (Utzurrum, 1984; Utzurrum and Heideman, 1991) of fruit bats on Negros Island comprise the bulk of the work conducted on the ecology of Philippine bats. The taxonomy and biogeography of Philippine fruit bats were reviewed by Heaney (1991). Reports of recent mammal surveys (Heaney *et al.*, 1981, 1989; Mudar and Allen, 1986) included information on the ecology of the bats captured, particularly on their habitat and reproduction.

This paper provides information on the natural history of bats captured in lowland forest on Mt. Makiling during a seven-month field study. Along with the work conducted on Negros Island, this is one of the few studies on Philippine bats involving intensive netting and collection of seasonal reproductive data. Species accounts for the 20 species captured include information on their habitat, reproduction, and other aspects of their natural history.

Mt. Makiling is a dormant volcano in central Luzon about 60 km south southeast of Manila. Its protected status as a forest reserve and its proximity to the capital and to the University of the Philippines at Los Baños (UPLB), situated at the base of Mt. Makiling, make it attractive for long-term research. Previous reports on the bats on Mt. Makiling include notes on eight species of bats netted on the UPLB campus and in forest on Mt. Makiling (Catibog-Sinha, 1982, 1987), and studies on the foraging ecology of *Megaderma spasma* within the Makiling forest (Balete, 1988) and of *Scotophilus kuhlii* on the UPLB campus (Rubio, 1977). The latter study included a list of bat species netted at sites along the access road up Mt. Makiling.

STUDY AREA

The study was conducted within a 330-ha area of second growth forest (14°09'N longitude, 121°13'E latitude) within Makiling Forest Reserve, Luzon Island, Philippines. The study area is located on the northeastern face of Mt. Makiling, a dormant volcano with an elevation of 1143 m at the peak. Elevation within the study area ranges from 200 to 500 m. The topography is characterized by ridges and valleys, with few flat areas. Four major creeks drain the study area. Despite variation in the annual pattern of rainfall on Mt. Makiling, in most years a wet season and a dry season can be identified. In 1989 the annual rainfall on the UPLB campus (elevation ca. 50 m) was 2055 mm. The wettest months were from May to October, when the monthly rainfall always exceeded 200 mm (mean monthly rainfall = 284 mm; Fig. 1). The six other months of the year received less than 120 mm of rain (mean monthly rainfall = 59 mm). Mean monthly temperature ranged from 25°C to 29°C.

The forest canopy is about 25 m high in valleys and on slopes and is slightly lower on the tops of ridges. Dominant tree species include *Nephilium mutabile* Blume (Sapindaceae), *Celtis luzonica* Warburg (Ulmaceae), *Parashorea malaanonan* (Blanco) Merrill (Dipterocarpaceae), *Diplodiscus paniculatus* Turczaninow (Diliaceae), *Ficus variegata* Blume (Moraceae), *Palaquium foxworthyi* Merrill (Sapotaceae), *Chisocheton pentandrus* (Blanco) Merrill (Meliaceae), *Bischofia javanica* Blume (Euphorbiaceae), *Alstonia macrophylla* Wallich *ex* De Candolle (Apocynaceae), and *Shorea contorta* Vidal (Dipterocarpaceae) (Quimbo *et al.* 1980). Palms and rattans are common in the understory.

METHODS

Between 11 January and 10 August 1989, bats were netted with 35 mm mesh monofilament mist nets 6- or 12-m long at 20 sites within the study area. Each site was sampled once for a period of one to four consecutive nights. In the first seven sites only ground-level nets were set. At subsequent sites, nets were set 3-16 m above the ground using a pulley system (for details see Ingle, 1990).

Nets were usually open from 1800-0530 h but were closed during periods of rain. Nets were checked at 30-min to 2-h intervals throughout the night. Each bat captured was identified to species, sexed and weighed to the nearest 0.1 or 0.5 g with a 50- or 300-g Pesola spring balance and its forearm was measured to the nearest 0.1 mm with dial calipers. Bats were classified into age classes based on the presence or absence of cartilaginous metacarpal and phalangeal epiphyseal plates, determined by transilluminating the metacarpal-phalangeal joints with a flashlight (Anthony, 1988). Juveniles were defined as those bats with both phalangeal and metacarpal plates visible, subadults as bats with only one plate visible, and adults as bats with no plates visible. Reproductive condition was not a criterion for classifying individuals into age classes. In females, pregnancy was determined by palpation and the lengths of embryos were estimated and recorded (see Heideman, 1988, for an estimate of the accuracy and precision that can be obtained using this technique). For female *Ptenochirus jagori* and *Cynopterus brachyotis*, only embryos at least 20 mm long were recorded before 24 May. After this date, females with embryos estimated by palpation to measure 3 mm or more were scored as pregnant. The criteria for determining pregnancy changed because of increased ability to detect embryos by palpation. Lactation was determined by squeezing the nipples to express milk.

Most bats captured were released immediately after processing at the site of capture. Before release, bats with adult weights of at least 20 g were marked with a numbered aluminum band (Gey Band and Tag Co., Norristown, PA) on a stainless steel ball-chain necklace (Ball Chain Manufacturing Co., Mt Vernon, NY).

Some bats were collected as voucher specimens. These were fixed in 10% formalin solution for three days and then transferred to 70% ethanol. Standard specimen measurements were taken (Handley, 1988). Specimens are deposited in the American Museum of Natural History, Cornell University Vertebrate Collection, Field Museum of Natural History and the Philippine National Museum.

For the analysis of pregnancy and lactation in *Ptenochirus jagori* and *Cynopterus brachyotis*, adult females were grouped by trapping period. Sites with $n < 5$ were excluded. Condition of pregnancy was divided into four categories: not palpably pregnant; embryo < 2 cm long; embryo ≥ 20 mm long; and either not palpably pregnant or with an embryo < 20 mm long.

The distributions of weight and of forearm length of juvenile *Ptenochirus jagori* and *Cynopterus brachyotis* netted in each trapping period were examined with histograms. Means of weight and forearm length were calculated for each site. Mean weight and mean forearm length were regressed separately against trapping date (the middle of the trapping period when it comprised more than one night of netting). For juvenile *P. jagori* recaptured at least 10 days after they were necklaced, mean daily changes in forearm length and in weight were calculated.

Numbers of adult and juvenile *Ptenochirus jagori* and *Cynopterus brachyotis* netted at each site were summed; for each species, the hypothesis that proportions of juveniles and adults were homogeneous among trapping periods was tested using contingency tables. Subadults were excluded from this analysis because they represented only 64 of 1059 *P. jagori* captures and four out of 217 *C. brachyotis* captures. For both juveniles and adults of each species, the sex composition was tested for homogeneity with a contingency table. In contingency tables for *P. jagori* the x^2 statistic was calculated using the statistical computer package Minitab (Ryan *et al.*, 1985). In contingency tables for *C. brachyotis* sample sizes were small so Monte-Carlo approximations of the *P*-value were computed using StatXact (CYTEL Software Corp., 1989). If no significant difference in sex composition was detected between trapping periods then all trapping periods were pooled. A binomial test was performed to test if the overall sex ratio was significantly different from 1:1.

The population size of the *Ptenochirus jagori* colony was estimated by the Lincoln-Petersen method using a 95% confidence interval of the Chapman estimate (Pollock *et al.*, 1990). For *P. jagori*, differences in both weight and forearm length between various pairs of groups defined by sex and whether they were netted in the forest or at the roost were tested for statistical significance with t-tests.

For all statistical analyses $p < 0.05$ was deemed statistically significant. All statistical analyses other than contingency tables were performed using SAS (SAS Institute, Inc., 1985).

RESULTS AND DISCUSSION

A total of 1548 bats representing 20 species were captured (Table 1). Many of the species captured in the study had not been reported from Mt. Makiling. Standard external measurements of adults are given in Table 2. Species names follow Heaney *et al.* (1987).

***Cynopterus brachyotis* (Muller)**

Cynopterus brachyotis is found throughout Southeast Asia (Hill, 1983; Koopman, 1989); it occurs throughout the Philippines (Heaney *et al.*, 1987). (Kitchener and Maharadatunkamsi (1990) split *C. brachyotis* into several species assigning Philippine records to *C. luzoniensis.* However, as this proposed revision has not yet been evaluated by other workers, the previously accepted taxonomy is followed here.) The species had been previously reported from Mt. Makiling by Catibog-Sinha (1982, 1987) and Rubio (1977).

Cynopterus brachyotis was the second most commonly captured bat in this study, accounting for 15% (231 individuals) of all captures (Table 1). The age class composition of *C. brachyotis* varied significantly between trapping periods (Fig. 2; contingency table with Monte-Carlo approximation of *p*-value computed using statistical package StatXact due to low sample size, p 0.05; subadults were excluded from this analysis as they represented less than 2% of all captures). The sex ratio of adults also varied significantly between trapping periods (Fig. 3; StatXact contingency table, $p < 0.01$). Sex ratios of juveniles, however, were homogeneous (StatXact contingency table, $p > 0.20$) and not significantly different from 1:1 (binomial test, $p = 0.19$)

Temporal variation in age class composition and sex composition of adults were also detected in the most commonly captured species, the fruit bat *Ptenochirus jagori*. For this species these patterns appeared to be linked to seasonal reproductive patterns. It is likely that this was also the case for *Cynopterus brachyotis*, but sample sizes were too small to infer such a relationship.

In *Cynopterus brachyotis*, patterns of lactation indicate a birth period sometime between mid-March and mid-May. A more precise estimate of the timing of the birth period from either this or the pregnancy data is not possible because of the lack of samples. Four out of five adult females captured in early June carrying embryos <20 mm were lactating, suggesting post-partum estrus. Three *C. brachyotis* females were captured carrying young on April 16 and 17, and on July 23. The first and last such females netted were captured more than three months apart. The umbillicus was still attached to the neonate captured on 17 April, indicating that it was born utmost a few days previously.

The distributions of both forearm length and weight of juvenile *Cynopterus brachyotis* netted in each trapping period were unimodal when sample sizes were $\geq$ 15, as would be expected if the juveniles belonged to a cohort that had been born at roughly the same time. Mean forearm length of juveniles netted within a trapping period increased from 59 mm to 64 mm from late May to mid-June, and was strongly correlated with trapping date (r^2 = 0.97, slope = 0.0565 mm/day). Mean weight showed a similar strong correlation (Fig. 4; r^2 = 0.93, slope = 0.111 g/day, *S.E.* = 0.01). The cohort sampled was represented in juvenile captures from late May to early August.

In the 30-g African pteropodid *Micropteropus pusillus*, weight increases of a cohort of free-flying juveniles about 2-6 months old were 0.116 g/day and those for the 120-150 g *Epomops beutikkoferi* were 0.276 g/day (Thomas and Marshall, 1984). Rates of increase in mean weight of a cohort will represent growth rates if catchability and mortality of equal-aged individuals do not differ with weight. The increases in mean weight of cohorts of *C. brachyotis*, *M. pusillus*, and *E. beutikkoferi* are low compared to the growth rates of other similarly sized mammals. Thomas and Marshall (1984) attributed the apparently slow growth rates of pteropodids to the low-protein quality of their fruit diets.

Eonycteris spelaea **Miller**

Eonycteris spelaea is widely distributed in South and Southeast Asia, occurring from India to Timor, and is found throughout the Philippines (Heaney *et al.*, 1987; Koopman, 1989). The species is strongly associated with agricultural areas (Heideman and Heaney, 1989; Heaney *et al.*, 1989) feeding on pollen and nectar (Start, 1974). *E. spelaea* was previously reported from Mt. Makiling (Catibog-Sinha, 1987; Rubio, 1977).

Of the six individuals netted (Table 1), a female with unfused epiphyses that was captured on 10 May was pregnant. Populations of *Eonycteris spelaea* in central India (Bhat *et al.*, 1980) and in Selangor, Malaysia (Start, 1974), appear to breed aseasonally (with births occurring throughout the year) and with a post-partum estrus. On Negros Island the reproductive status of ten adult females captured over one year was consistent with births occurring throughout the year (Heideman, 1987).

Haplonycteris fischeri **Lawrence**

Haplonycteris fischeri is endemic to the Philippines. It occurs throughout the country, possibly excluding Palawan and associated islands (Heaney *et al.*, 1987) and was previously reported from Mt. Makiling (Rubio, 1977). Fourteen individuals were netted in this study (Table 1). Although *H. fischeri* was not common in the study area on Mt. Makiling, it was the most commonly netted bat species in submontane dipterocarp rainforest on Negros Island (830-1000 m elevation); it accounted for a third of all captures and was estimated to occur at a density of 3.7 individuals/ha (Heideman and Heaney, 1989).

Two adult females caught on 28 May and 4 June carried embryos that were judged to be near-term based on palpation, and two adult females caught on 2 and 3 July were lactating. Heideman (1988, 1989) described the reproductive ecology of *Haplonycteris fischeri* on Negros Island. Parturition occurred in June, after an 11.5-month gestation period including an 8-month delay in embryonic development following implantation.

***Macroglossus minimus* (E. Geoffroy)**

Macroglossus minimus is found from Thailand to Australia and throughout the Philippines (Heaney *et al.*, 1987; Koopman, 1989). This species was previously netted on Mt. Makiling (Catibog-Sinha, 1982, 1987; Rubio, 1977). In the present study, 32 individuals were netted, of which two were kept as voucher specimens (Table 1). The species is strongly associated with agricultural areas and is uncommon in forest, but when found in forest it is most common in clearings (Heideman and Heaney, 1987). *M. minimus* feeds on nectar and pollen (Start, 1974).

Pregnant females were caught on 16 July ($n = 1$) and 25 July ($n = 2$). Four lactating females were caught on 5, 11, and 26 May. *Macroglossus minimus* breeds aseasonally on Negros Island (Heideman, 1987) and in Selangor, Malaysia (Start, 1974). This species has been demonstrated to undergo post-partum estrus (Start, 1974).

***Ptenochirus jagori* (Peters)**

Ptenochirus jagori is found throughout the Philippines, except the Palawan region (Heaney *et al.*, 1987). This endemic species was known to occur on Mt. Makiling (Catibog-Sinha, 1982, 1987; Rubio, 1977). In this study 1143 individuals were netted, accounting for 74% of all bats captured (Table 1).

The proportion that juveniles comprised of all *Ptenochirus jagori* captures varied significantly between trapping periods (Fig. 5; $x^2 = 222$, $d.f. = 11$, $p << 0.005$; subadults were excluded from this analysis as they represented only 6% of all captures). From April through mid-June, adults outnumbered juveniles. In late June juveniles and adults were captured in roughly equal numbers, and in July through mid-August juveniles constituted about 80% of the netted population. The increase in the proportion of juveniles was due partly to the addition of free-flying juveniles from a seasonal birth period, which was also indicated by the patterns of pregnancy and lactation (discussed below). It was due also to greater catchability of juveniles relative to adults, which is evident if one considers that in July and August juveniles greatly outnumbered adult females, even though each adult female gives birth to only one young at a time.

The sex ratio of juveniles did not differ significantly between trapping periods ($x^2 = 13.5, d.f. = 11, p > 0.25$). When all trapping periods were combined, the overall sex ratio did not differ significantly from 1:1 (binomial test, $p = 0.76$).

Among adults, however, the sex ratio was not consistent between trapping periods (Fig. 6; $x^2 = 24.8, d.f. = 11, p < 0.01$). Females constituted about 75% of adults captured at all sites trapped in May and June (Fig. 6). At the sites trapped before and after this period, however, the females constituted about 50% of all captures. It should be noted, however, that for some of these sites samples sizes were small.

Temporal variation in the age class and adult sex composition of captured *Ptenochirus jagori* was probably caused by seasonal reproductive patterns. The patterns of lactation and pregnancy (Fig. 7) in adult female *P. jagori* indicate that a birth period occurred sometime from the second half of April to the first week of May. Sixty per cent of adult females captured in 25-29 May in early stages of pregnancy (embryo cm; $n = 30$) were lactating, suggesting that post-partum estrus occurred after parturition during the April-May birth period. After the April-May birth period most females were palpably pregnant by late May. From monthly samples of *P. jagori* on Negros Island, Heideman (1987) estimated gestation to last about four months. With this estimate of gestation length, a second birth period for the Mt. Makiling population is predicted to occur around September.

Of 240 lactating females captured in May and June only four were carrying young. This suggests that females are leaving their young at a roost while they forage. In May and June, sex ratios for adult *Ptenochirus jagori* were strongly female-biased (Fig. 6). Females may have an increased likelihood of capture during lactation if they spend more time flying to forage to meet their increased energetic demands, and possibly to return periodically throughout the night to feed their young. Females with young were also caught on 16 April ($n = 1$) and 3 July ($n = 1$).

Captured juveniles fell into two size classes by body weight and forearm length. These size classes were inferred to represent cohorts of approximately equal-aged individuals. Members of cohort A were netted from March, when the first sites were trapped, to mid-June, after which they became subadults or adults because their epiphyseal plates had closed. Members of cohort B overlapped with members of cohort A and were first trapped in late May. For sites at which > 25 juvenile *Ptenochirus jagori* were netted, the distributions of weight and forearm length were distinctly unimodal except for the sites trapped from late May to mid-June when both cohorts were netted. At the three sites netted during this period the distributions of weight were sharply bimodal. As the ranges in weight for the two peaks did not overlap there was no ambiguity is separating juveniles caught in each of the three sites into the two cohorts. However, in the period in which both cohorts were netted, their ranges of forearm length overlapped.

For both cohorts, mean weight of juveniles netted at a site was positively correlated with trapping date (cohort A, $r^2 = 0.95$; cohort B, $r^2 = 0.96$; Fig. 8). For cohort A, mean weight ranged from 60 to 71 g, and increased by an average of 0.12 g/day (*S.E.* = 0.01). For cohort B, mean weight ranged from 45 to 62 g and increased by 0.26 g/day (*S.E.* = 0.02). Rates of weight gain differed significantly between the two cohorts ($p = 0.0001$). This difference is probably because at the time that they were captured, members of the two cohorts differed in weight, and therefore presumably in age; rates of weight gain tend to decline with increasing age.

Mean forearm length of members of a cohort trapped at a site and trapping date was also positively correlated with trapping date (cohort A, $r^2 = 0.53$; cohort B, $r^2 = 0.99$), but this relationship was not as consistent as the relationship between mean weight and trapping date. For cohort A, mean forearm length ranged from 76 to 78 mm and increased by 0.02 mm/day. For cohort B, mean forearm length ranged from 74 to 76 mm and increased by 0.03 mm/day. Unlike rates of increase in mean weight, rates of increase in mean forearm length did not differ significantly between cohorts ($p = 0.37$). The weaker relationship of netting date with mean forearm length compared to the relationship with mean weight is probably due to greater measurement error. The range in mean forearm length was 2-3 mm, whereas the range in mean weight was 20 g; thus measurement errors would have a stronger effect on forearm measurements. In further such studies, careful measurement of forearm length with calipers is important.

Rates of increase in body weight were obtained from 19 marked juveniles recaptured 10-59 days after initial capture. Recaptures came from both cohorts. Mean increase in weight was 0.12 g/day (*S.E.* = 0.03). Rates of increase in forearm length were similarly obtained. Mean increase in forearm length was 0.03 mm/day (*S.E.* = 0.005). These rates of increase of recaptured juveniles are comparable to those obtained for the two cohorts netted during the study. As noted in the section on *Cynopterus brachyotis,* pteropodids appear to have slow growth rates compared to other similarly-sized mammals.

A colony of *Ptenochirus jagori* roosted in a cave located just beyond the northeast edge of the Makiling forest. The cave was about 15 m from a road, between the Jamboree Swimming Pool and the Jamboree Center. The area near the cave was called "Grotto" because two religious statues had been placed nearby. The cave was about 6 m off the ground in a 15-m high vertical rock face. It measured about 2 m wide, 1 m high, and 2 m deep. People came within 10 m of the cave almost daily to visit the statues, and flourescent lights illuminated the area in the early part of the night. However, as the cave itself was not easily accessible, it probably was not subjected to frequent direct human disturbance.

The cave was visited on 11 occasions from 7 February to 23 May 1989. On four nights a net was set outside the roost; captured individuals were marked and processed in the same way as those caught in the forest. Twenty *Ptenochirus jagori* were netted at least once; some were captured on more than one night. Nineteen were adults; one female was not aged. The sex ratio among adults was 2.8 males per female (n = 19). Lincoln-Petersen point estimates of the population size (Pollock *et al.*, 1990) ranged from 20 to 54. This author estimated that 20-30 bats flew out of the cave when she first visited the roost on 7 February. Two adult females captured on 6 April were pregnant with embryos at least 2 cm long. Two juvenile female and one juvenile male *Macroglossus minimus* were caught outside the cave in the same net in which *P. jagori* were caught.

Although in the large sample of bats netted in the forest no sexual dimorphism in forearm lengths of adults was detected (males: $\bar{x}$ = 78.2 mm, n = 128; females: $\bar{x}$ = 78.2 mm, n = 339; t-test, p = 0.89), among adults captured at the cave roost, males had significantly longer forearms than females (males: $\bar{x}$ = 80.1 mm, n = 14; females: $\bar{x}$ = 76.6 mm, n = 5; t-test, p = 0.002). This and the longer forearm length of males netted at the roost over those netted in the forest (t-test, p = 0.001) suggest that males netted at the roost are on average larger than males from the general population. This pattern might be expected from a species with a harem roosting system, but the male-biased sex ratio of individuals netted at the roost would not be consistent with this social system if all individuals that were netted were roost inhabitants.

Fecal material, and pellets of fruit fiber and seeds that bats had spat out after squeezing out the fruit juices, were found on the cave floor below the roost.

Few bats were observed at the roost on 16 May, and no bats were seen there on 18 and 23 May. The reason why the roost was abandoned was not clear, but could have been due to human disturbance.

***Rousettus amplexicaudatus* (E. Geoffroy)**

Rousettus amplexicaudatus is widely distributed in Southeast Asia, occurring from Thailand to the Solomon Islands; the species is found throughout the Philippines (Heaney *et al.*, 1987). *R. amplexicaudatus* was previously reported from Mt. Makiling (Catibog-Sinha, 1987; Rubio, 1977). Four individuals were netted (Table 1); both adult females captured were netted on 14 May and were lactating. The species is found primarily in or adjacent to agricultural areas (Heaney *et al.*, 1989;

Heideman and Heaney, 1989); both sites in which it was captured, although in secondary forest, were within 300 - 400 m of agricultural areas. On Negros Island, *R. amplexicaudatus* has two annual birth periods, the first in March through April and the second in July through early September (Heideman, 1987).

Emballonura alecto **(Eydoux and Gervais)**

Emballonura alecto is found throughout the Philippines, and in Borneo and Sulawesi (Heaney *et al*., 1987).

Of the eighteen individuals netted at the entrances of three roosts (Table 1) three individuals were collected. Roost 1 consisted of a rock shelter about 8 m long and 3-5 m wide was formed by two large boulders leaning against each other. Smaller boulders contributed to the sides of the shelter. Several openings were formed by gaps between the boulders; bats were netted in front of the largest opening (ca. 2 m by 1.5 m). The roost was at 180 m elevation, 5 m from a 3-5 m wide creek lined with boulders. Five adult males and six adult females were netted outside Roost 1 on 14 April. This author estimated that the total roosting group consisted of 15-20 individuals.

Roost 2 was formed by a large boulder, supported at a 45^{o} angle by smaller rocks. Like Roost 1, Roost 2 was dimly lit. It was located at 260 m elevation, on a slope leading down to a creek. Three adult males, one juvenile male, and two adult females were netted outside Roost 2 on 13 June. The total number of individuals inhabiting the roost was not estimated.

Roost 3 was a shelter under a boulder located about 20 m from Roost 2, and contained about five roosting bats, of which an adult female was captured. The roosting group was discovered 3 hours after roost 2 had been netted, and therefore possibly consisted of bats disturbed from Roost 2. Shelters formed by other boulders in the area around Roosts 2 and 3 were inspected but no other bats were found.

All six females caught on 14 April were pregnant. One of the three adult females caught on 13 June carried a fetus that was judged to be near-term. The female and fetus together weighed 9.4 g (non-pregnant female weight = 7.2-7.7 g). Of the two other females captured on 13 June, one was lactating and the other was neither pregnant nor lactating.

***Megaderma spasma* (Linnaeus)**

Megaderma spasma is found from India through Indonesia and throughout the Philippines (Heaney *et al.*, 1987). The species was previously netted on Mt. Makiling (Catibog-Sinha, 1987; Rubio, 1977). Eight individuals were captured in this study (Table 1). Seven were captured in mist nets set 0-3 m above the ground. One female was netted at a roost.

Megaderma spasma is known to roost in caves and hollow trees (Payne *et al.*, 1985) and under the eaves of houses (Phillips, 1922). In this study, six *M. spasma* roosts were located and one of two roosts within the study area that had been discovered by Balete (1988) was visited. All seven roosts were cavities in large (diameter = 1.2-1.6 m) living trees, with one to four openings (usually one) either on the ground (n = 5) or within 1.5 m above it (n = 2). Except in Roost 7, the openings measured about 1 m at the widest part and 0.5 m at the tallest part, and the cavities extended 2.5-7.0 m above the ground and were 0.6-1.2 m in diameter. In two of these roosts the cavity also had an opening at the top (diameter $\geq$ 0.7 m). In Roost 7 the opening was a high arch extending from the base of the tree, where it was 1 m wide to 5 m above the ground. The top of the cavity in this roost could not be seen in the weak light of a flashlight. Balete (1988) described a small cave in which *M. spasma* roosted. The cave was located on the bank of a creek and was about 7.5 m wide, 1 m high, and 4.5 m deep.

Roosting groups consisted of one to seven individuals. As roosting *Megaderma spasma* are easily identified by their large joined ears, pale underparts, and relatively large size, nets were only set at Roost 2. Two roosts were visited twice. Seven bats were seen in Roost 4 on visits four days apart. On the first visit to Roost 3, four or five bats were seen, but only one bat was seen two days later. The number of roosting bats in the roosts Balete (1988) visited fluctuated from three to seven in the tree hollow and from none to six in the cave during regular visits over a one-year period.

Parts of exoskeletons of large insects were found on the floor of most roosts. Balete (1988) collected culled insect parts below two roosts on Mt. Makiling over a one-year period. Most of the insects represented were relatively large and were sound-producing, and spend most of their time on the substrate. These characteristics of the insect prey suggest that the insects were gleaned from the ground and from low foliage (Balete, 1988). The fact that in the present study *Megaderma spasma* was only captured in low nets is consistent with the hypothesis that the species gleans its prey from low-level foliage and the ground. In India, *M. spasma* were observed flying very low, almost touching the ground (Brosset, 1962; Phillips, 1922). In the laboratory, *M. spasma* was shown to have two foraging strategies: surface gleaning, and flycatcher-style foraging, in which prey are captured in short sallies from a perch (Tyrell, 1987, 1988).

The female caught on 30 March at Roost 2 was pregnant. Balete (1988) observed a female with young in the cave roost on 8 June 1986. On 31 May 1987 he observed a female with young at both the cave roost and the tree roost. The above observations are consistent with a seasonal birth period in April-May, but further work is necessary for confirmation. *Megaderma spasma* has been reported to breed seasonally in west India (Brosset, 1962) and in Thailand (Phillips, 1922).

Hipposideros diadema **(E. Geoffroy)**

Hipposideros diadema occurs from Burma to the Solomon Islands and is found throughout the Philippines (Heaney *et al.*, 1987). The species was previously recorded from Mt. Makiling (Catibog-Sinha, 1987; Rubio, 1977). Of the 14 individuals netted (Table 1), one escaped before its sex was determined. The other 13 captured were all males (10 adults, three juveniles). Four individuals were collected. *H. diadema* showed a strong association with creeks. Twelve *H. diadema* were netted either over a creek (n = 7) or on creek banks 10-15 m from the creek (n = 6). The other two *H. diadema* were caught more than 20 m from a creek.

Two adult males captured on 31 May did not fly immediately after they were released onto a twig of a small sapling, but hung from the twig turning their heads from side to side, noseleaves and ears twitching. Similar scanning behavior has been described for *Hipposideros commersoni*, a 120-g congener that hunts by making repeated sallies from a perch (Vaughan, 1977). Observations of *H. diadema* by Brown and Berry (1983) and Goodwin (1979) indicate that this species has the same "flycatcher" hunting behavior.

Hipposideros obscurus **(Peters)**

Hipposideros obscurus is endemic to the Philippines; specimens have been collected from Dinagat, Luzon, and Mindanao (Heaney *et al.*, 1987). Two juveniles were netted on 25 and 29 July and kept as voucher specimens (Table 1).

Rhinolophus arcuatus **Peters**

Rhinolophus arcuatus is found in Indonesia, Borneo, the Philippines, and Papua New Guinea. It occurs throughout the Philippines, possibly excluding Palawan and associated islands (Heaney *et al.*, 1987).

Twelve individuals were caught; seven were retained as voucher specimens (Table 1). A female collected on 11 May carried a 23-mm long embryo. All three adult females caught on 4 and 6 July were lactating. Of six *Rhinolophus arcuatus* captured on 4-6 July, all were adults, except one male with incompletely fused epiphyses. The fur of the three males was much darker than that of the females, which was more orange. The brighter fur of females may have been caused by bleaching from ammonia in roosts. One possible explanation for the color difference between the sexes is that females do not molt at the same time as do males. Alternatively, males and females may roost separately and be bleached to different degrees because of different roosting environments. It is also possible that the fur of males is naturally lighter than that of females.

Rhinolophus macrotis Blyth

Bats assigned to *Rhinolophus macrotis* have been captured from southern China, Nepal, Indochina, Thailand, Sumatra, and the Philippines (Lekagul and McNeely, 1977). Specimens from the Philippines, however, appear to differ in noseleaf structure and overall size from those captured elsewhere in Asia, and may represent a distinct species (Ingle and Heaney, 1992); further work will be necessary to document this. Two adult males were caught on 21 May; both were retained as voucher specimens.

Rhinolophus rufus Eydoux and Gervais

Rhinolophus rufus is endemic to the Philippines; specimens have been taken from Luzon, Mindanao, Bohol, and Mindoro (Heaney *et al.*, 1987). One nonpregnant adult female was caught on 25 June and retained as a voucher specimen.

Rhinolophus subrufus Andersen

Rhinolophus subrufus is endemic to the Philippines (Heaney *et al.*, 1987). Twenty-seven individuals were captured (Table 1). Eight were retained as vouchers. Of 13 adult females captured on 3-5 July, nine were definitely lactating and three showed signs of either lactation or recent lactation (i.e. hairless ring around nipples, swollen mammary tissue). As with *R. arcuatus*, two distinct pelage colors were observed in *R. subrufus*. Subadults of both sexes were considerably darker than adults, which were all female. Observed color differences were perhaps due to a difference in the initial pelage color of subadults and adults, to differences in the duration since molt, or to different roosting environments.

Rhinolophus virgo **Andersen**

Rhinolophus virgo is endemic to the Philippines, where it is widespread and common (Heaney *et al.*, 1987). One adult male was captured on 14 June and kept as a voucher specimen.

Myotis horsfieldii **(Temminck)**

Myotis horsfieldii occurs from southeast China to the Malay Peninsula, Bali, and Sulawesi. In the Philippines it has been recorded from Luzon, Mindanao, Negros, and Palawan (Heaney *et al.*, 1987). A juvenile male netted on 25 June was kept as a voucher.

Myotis muricola **(Gray)**

Myotis muricola is found throughout Southeast Asia (Koopman, 1989). It is widespread in the Philippines, common in both agricultural and forested areas (Heaney *et al.*, 1987). Eleven individuals were caught (Table 1) of which three were kept as voucher specimens. *M. muricola* appeared to be associated with riparian habitat because, out of the 11 individuals captured, seven were netted over creeks. Two adult females caught on 25 May were lactating. The only other adult female caught, netted on 26 July, was neither pregnant nor lactating.

Philetor brachypterus **(Temminck)**

Philetor brachypterus occurs in Indonesia, Borneo, Papua New Guinea, and the Philippines, where it has been recorded from Mindanao and Negros (Heaney *et al.*, 1987). A male and female with incompletely fused epiphyses were caught on 4 and 6 July and were kept as voucher specimens.

Pipistrellus javanicus **(Gray)**

Pipistrellus javanicus is found from Korea to Java and the Philippines. It is found throughout the Philippines where it is common in forest (Heaney *et al.*, 1987). Fourteen individuals were caught (Table 1); 12 were kept as vouchers. Six individuals were caught either over a creek (n = 1) or within 15 m of one (n = 5), two were caught within the UPLB campus, and the remaining six were caught in forest sites at least 20 m from creeks. Two females caught on 18 April within the UPLB campus were pregnant. One, which at 10.8 g weighed twice non-pregnant body weight (see Table 2), was dissected and found to have two embryos. The other adult weighed 10.2

g, and was released. A female caught on 3 June weighed 11.2 g and had a single embryo 19 mm long.

***Scotophilus kuhlii* Leach**

Scotophilus kuhlii is found from Pakistan to Taiwan and Bali; it occurs throughout the Philippines, where it is abundant in urban and agricultural areas (Heaney *et al.*, 1987). The species was previously reported for Mt. Makiling (Catibog-Sinha, 1987; Rubio, 1977). Five adults were caught on 18 April outside a house within the UPLB campus (Table 1). They were roosting under the eaves. *S. kuhlii* has been reported to roost under modified fan palm fronds which drooped down to form "tents" because of cuts near the base of the leaf blades (Rickart *et al.*, 1989).

All three females that were captured were pregnant. Working also on the UPLB campus, Rubio (1977) collected pregnant females in April and June, and lactating females in June through August. Thus, in the UPLB population, parturition appears to occur in June. *Scotophilus kuhlii* is also known to reproduce seasonally in Vietnam (Topal, 1974).

CONCLUSIONS

Microchiropterans constituted only 8% of all captures, but represented more than two-thirds of all species netted. These species are harder to capture in mist nets than megachiropterans because of their ability to echolocate. The fact that many of the microchiropteran species captured in this study were represented by only a few individuals suggests that the list of microchiropteran species is incomplete. The list of megachiropteran species is also incomplete. Although never netted, large flying foxes (*Pteropus* or *Acerodon* spp.) were observed flying over the canopy and were reported by local hunters. *Otopteropus cartilagonodus*, a fruit bat endemic to Luzon, may be present on Mt. Makiling. This species is apparently confined to high elevations, making its capture unlikely at the low elevation (300-500 m) netting sites. To obtain a complete list of all the bats on Mt. Makiling, intensive field efforts, and methods of capturing bats other than netting, will be required.

Despite the importance of bats in the ecology of Philippine forests, particularly as pollinators and seed dispersers, very little is known about their distribution and ecology. Further studies on this group are greatly needed.

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Table 1. List of species and number of bats netted on Mt. Makiling, Luzon Island, Philippines, from January to August, 1989. Bats were assigned to age classes according to degree of epiphyseal closure as described in text. For some species, totals are greater than the sum of all sex and age classes because some individuals were not aged or sexed.

Species	Adults		Subadults		Juveniles		Total
	M	F	M	F	M	F	
Pteropodidae							
Cynopterus brachyotis	28	69	1	3	52	62	231
Eonycteris spelaea	1	0	0	0	3	2	6
Haplonycteris fischeri	3	7	0	1	1	1	14
Macroglossus minimus	8	6	0	0	6	9	32
Ptenochirus jagori	145	350	29	34	250	245	1143
Rousettus amplexicaudatus	0	2	0	0	1	1	4
Emballonuridae							
Emballonura alecto	8	9	0	0	1	0	18
Megadermatidae							
Megaderma spasma	3	1	0	0	0	0	8
Rhinolophidae							
Hipposideros diadema	10	0	0	0	3	0	14
Hipposideros obscurus	0	0	0	0	1	1	2
Rhinolophus arcuatus	4	5	2	0	0	0	12
Rhinolophus macrotis	2	0	0	0	0	0	2
Rhinolophus rufus	0	1	0	0	0	0	1
Rhinolophus subrufus	0	15	4	7	1	0	27
Rhinolophus virgo	1	0	0	0	0	0	1
Vespertilionidae							
Myotis horsfieldii	0	0	1	0	0	0	1
Myotis muricola	7	3	0	0	1	0	11
Philetor brachypterus	0	0	0	0	1	1	2
Pipistrellus javanicus	5	5	0	0	3	1	14
Scotophilus kuhlii	2	3	0	0	0	0	5

Table 2. Ranges of measurements of adults bats caught on Mt. Makiling, Luzon Island, Philippines, from January through August, 1989. Sample sizes are given in parenthesis. Weights for females are from individuals that were not palpably pregnant.

Species	Sex	Weight (g)	Forearm (mm)	Total length (mm)	Tail (mm)	Hindfoot (mm)	Ear (mm)
Cynopterus brachychiotis	M	(28) 31.6-47.0	(28) 60.3-67.6	-	-	-	-
	F	(21) 32.5-44.5	(70) 60.0-67.3	-	-	-	-
Eonycteris spelaea	M	(1) 92.5	(1) 73.9	-	-	-	-
Haplonycteris fischeri	M	(3) 17.8-19.7	(3) 46.7-48.7	-	-	-	-
	F	(5) 19.9-21.9	(7) 46.5-50.7	-	-	-	-
Macroglossus minimus	M	(8) 15.9-18.1	(8) 39.3-41.7	-	-	-	-
	F	(3) 16.0-16.5	(7) 40.2-41.5	-	-	-	-
Ptenochirus jagori	M	(151) 60.0-88.0	(157) 70.9-84.9	(2) 115-117	(2) 9-10	(2) 20-21	(2) 18-19
	F	(99) 57.5-87.0	(359) 69.5-84.5	(1) 118	(1) 9	(1) 19	(1) 18
Rousettus amplexicaudatus	F	(2) 85.5-88.0	(2) 81.6-85.6	-	-	-	-
Emballonura alecto	M	(8) 4.9-6.5	(8) 45.1-48.5	(2) 63-65	(2) 11	(2) 7	-
	F	(2) 7.2-7.7	(9) 45.4-47.7	(2) 66-68	(2) 12-13	(2) 7-9	-
Megaderma spasma	M	(3) 24.0-24.8	(3) 56.7-59.4	-	-	-	-
Hipposideros diadema	M	(10) 41.5-59.0	(10) 78.2-84.9	(2) 124-132	(2) 42-44	(2) 16-17	-
Rhinolophus arcuatus	M	(3) 7.5-8.9	(4) 43.2-46.3	(3) 67-74	(3) 17-18	(3) 10-11	(2) 19-20
	F	(2) 7.7	(4) 44.0-47.0	(3) 61-69	(3) 16-17	(3) 10-11	(2) 18-23
Rhinolophus macrotis	M	(2) 8.2-8.6	(2) 44.3-45.2	(2) 75-79	(2) 26	(2) 9	-
Rhinolophus rufus	F	(1) 34.3	(1) 65.0	(1) 118	(1) 31	(1) 19	(1) 31
Rhinolophus subrufus	F	(14) 15.2-19.5	(14) 53.9-56.6	(5) 78-91	(2) 22-25	(5) 12-15	(4) 24-25
Rhinolophus virgo	M	(1) 6	(1) 37.8	(1) 68	(1) 21	(1) 8	(1) 15
Myotis muricola	M	(7) 3.4-5.5	(7) 30.3-31.7	(2) 72-73	(2) 34-37	(2) 7	-
	F	(1) 4.2	(3) 30.9-32.0	-	-	-	-
Pipistrellus javanicus	M	(5) 4.5-6.4	(5) 31.5-33.2	(5) 71-80	(5) 30-34	(5) 7	(2) 10-11
	F	(2) 5.6-6.4	(5) 32.9-35.5	(3) 76-84	(3) 27-32	(3) 7-8	(1) 10
Scotophilus kuhlii	M	(2) 18.6-18.8	(2) 47.5-51.5	-	-	-	-
	F	-	(3) 48.7-52.1	-	-	-	-

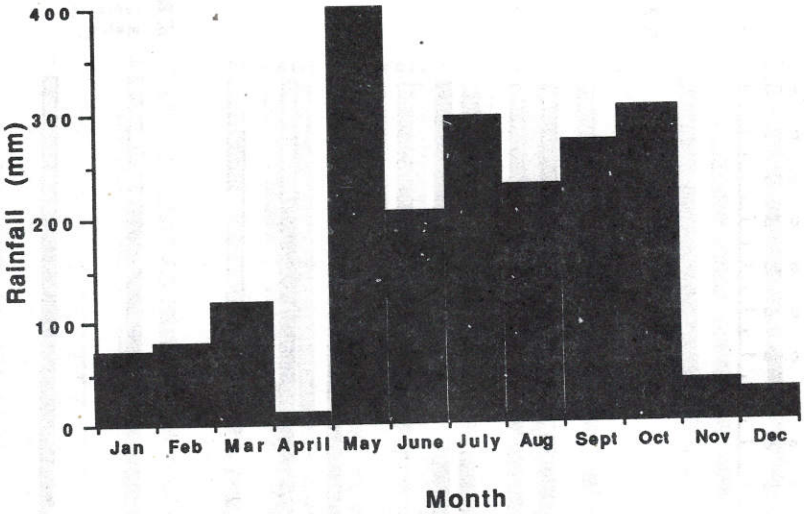

Figure 1. Monthly total rainfall for 1989 on the campus of the University of the Philippines at Los Baños, Luzon Island. Source: University of the Philippines at Los Baños Meterological Station.

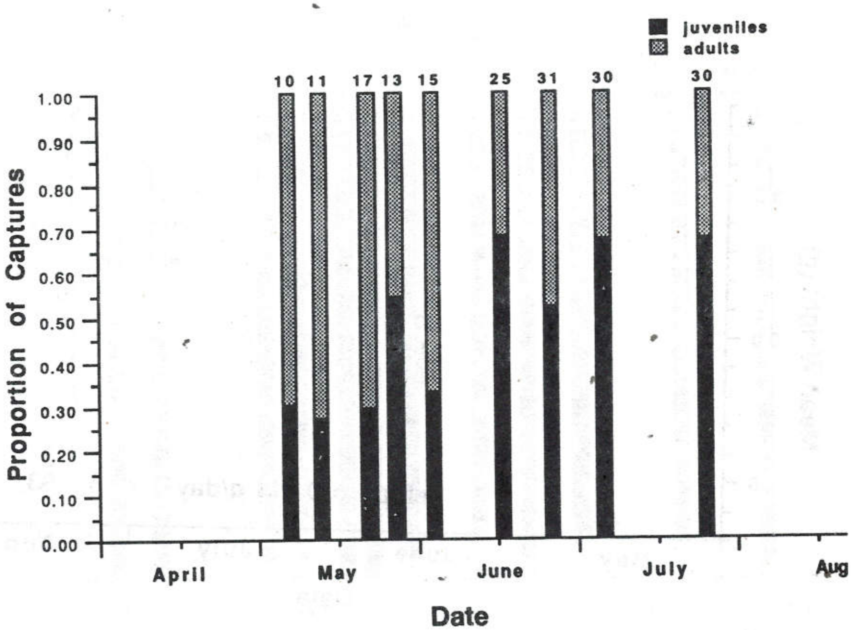

Figure 2. Age class composition of *Cynoptera brachyotis* at each sampling period. Sample sizes are indicated above bars. Only periods where $n \geq 5$ are included.

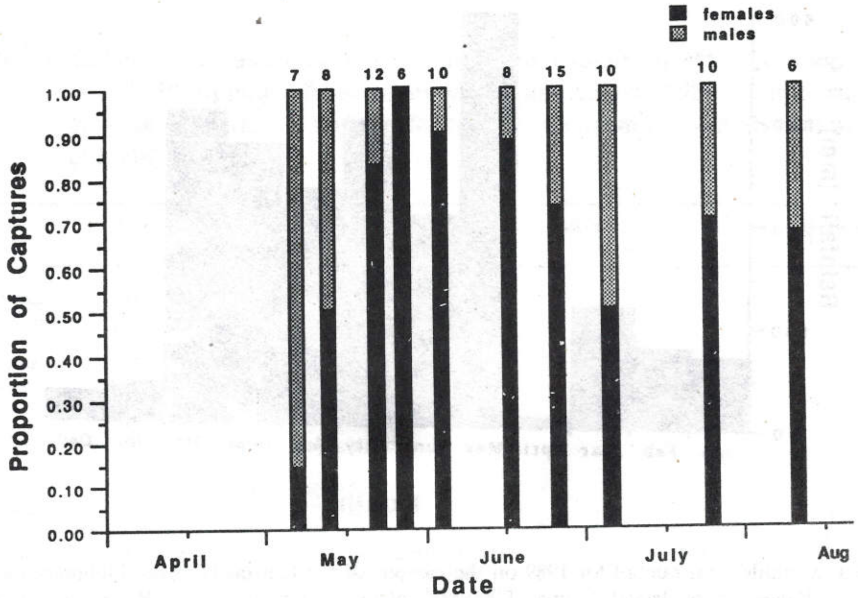

Figure 3. Sex composition of adult *Cynopterus brachyotis* at each sampling period. Sample sizes are indicated bars. Only periods where $n \geq 5$ are included.

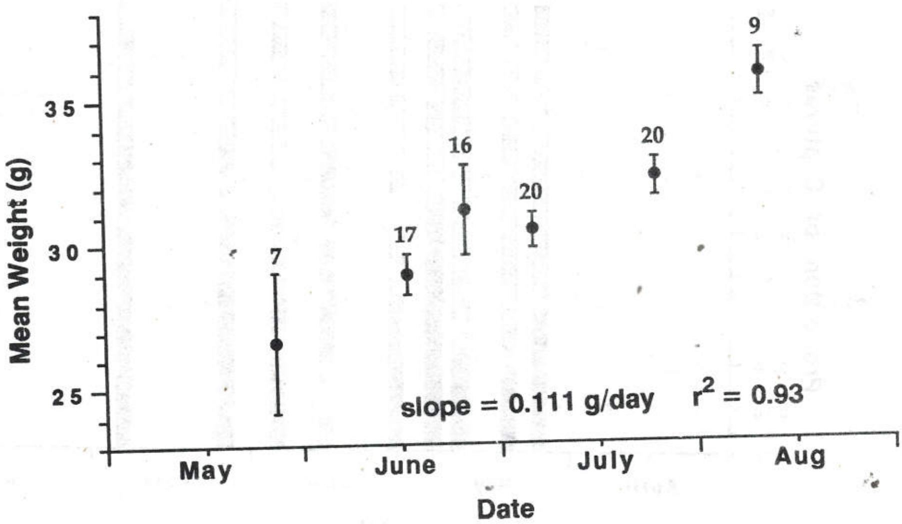

Figure 4. Mean weight of juvenile *Cynoptera brachyotis* at each sampling period. Bars around means represent standard errors. Sample sizes are indicated above points.

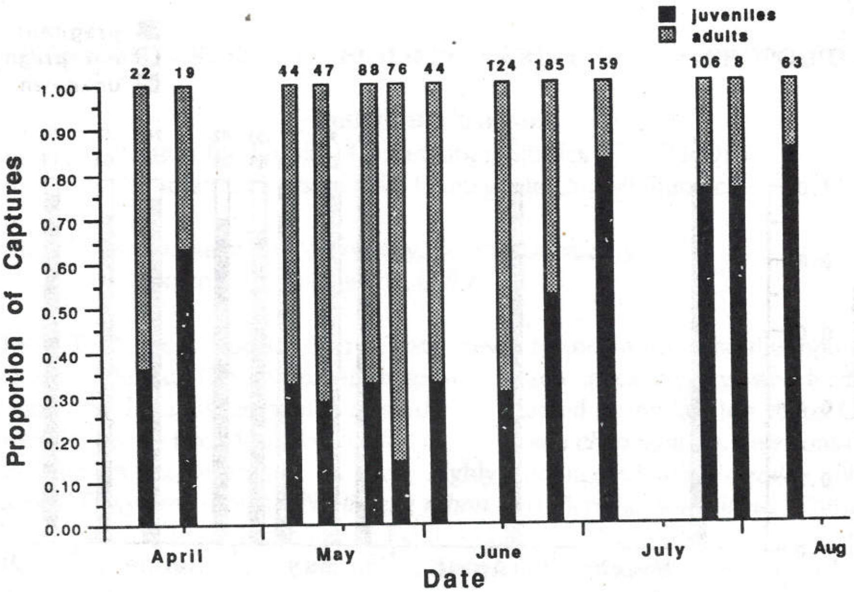

Figure 5. Age class composition of *Ptenochirus jagori* at each sampling period. Sample sizes are indicated above bars. Only periods where $n \geq 5$ are included.

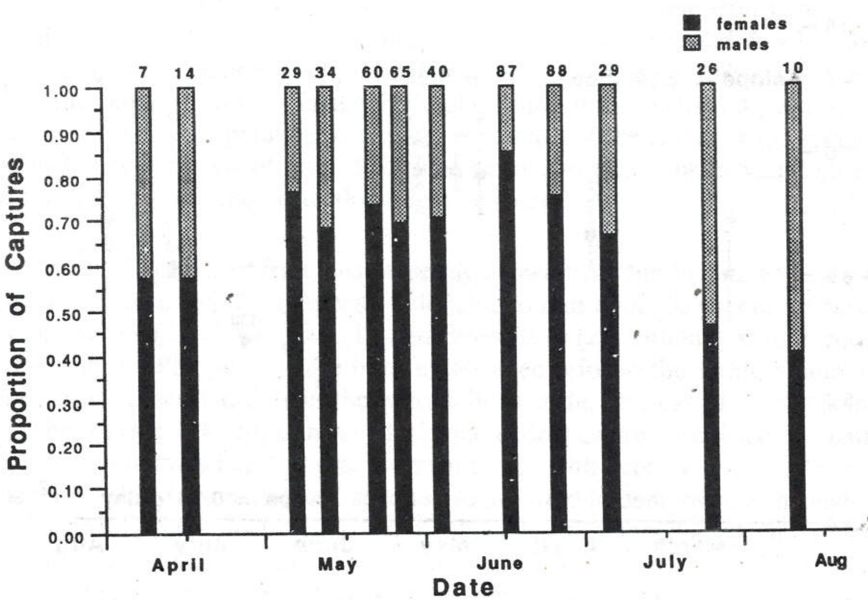

Figure 6. Sex composition of adult *Ptenochirus jagori* at each sampling period. Sample sizes are indicated above bars. Only periods where $n \geq 5$ are included.

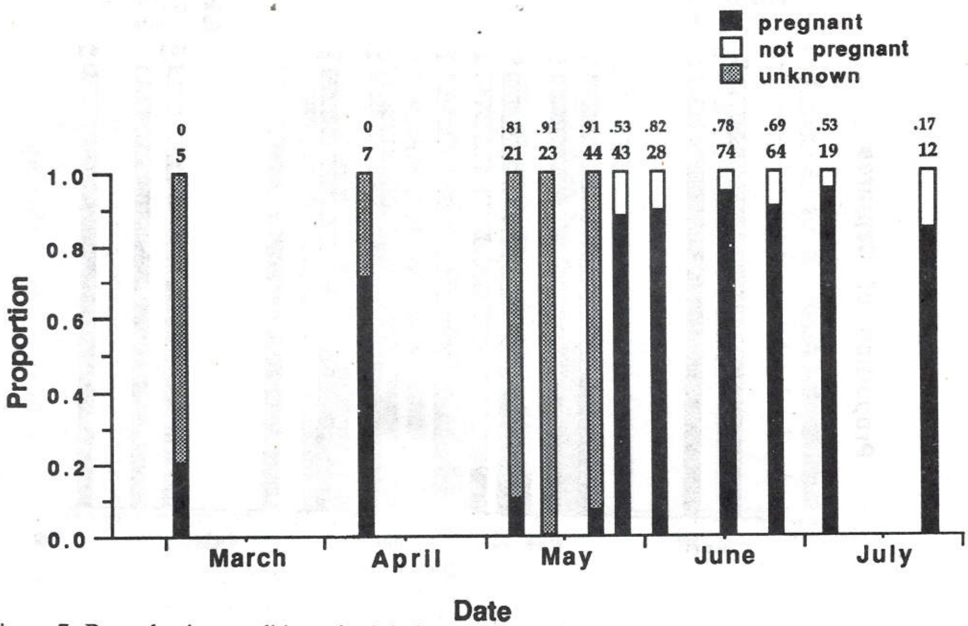

Figure 7. Reproductive condition of adult female *Ptenochirus jagori*. The bars show the status of pregnancy, the numbers directly above the bars are the sample sizes, and the smaller numbers above these represent the proportion of individuals that were lactating. Only periods where $n \geq 5$ are included.

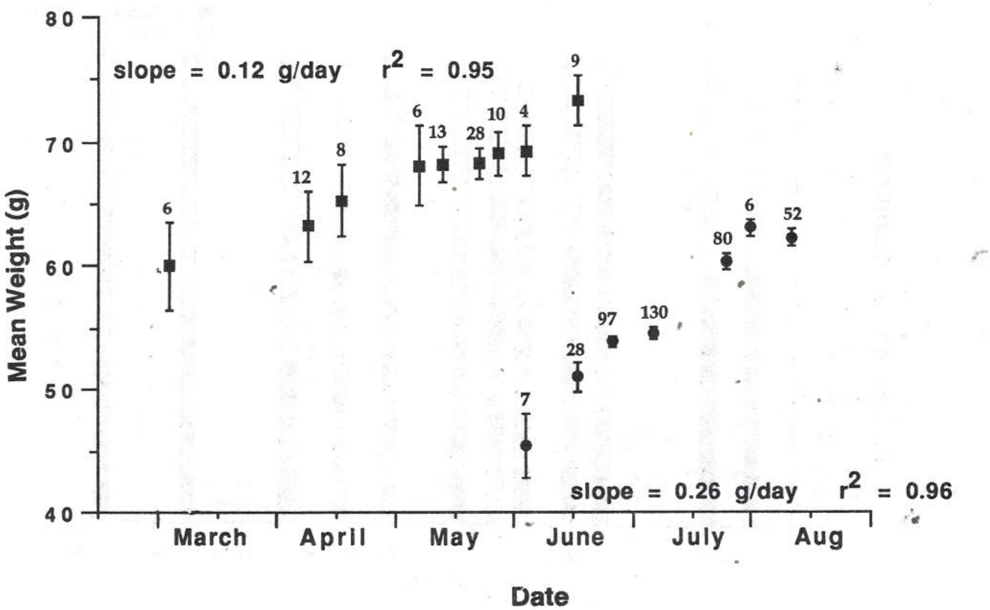

Figure 8. Mean weight of juvenile *Ptenochirus jagori* at each sampling period. Cohort A is represented by squares, cohort B by circles. Bars around means represent standard errors. Sample sizes are indicated above points.