Mammalia (2006): 48–51 © 2006 by Walter de Gruyter • Berlin • New York. DOI 10.1515/MAMM.2006.014

Estimation of population density of *Eidolon helvum* on the island of Príncipe, Gulf of Guinea

Estimation de densité de population de *Eidolon helvum* sur l'île de Príncipe, Golfe de Guinée

Martin Dallimer[1,*], Tony King[2], David Cope[3] and Manuel Borge Jiana[4]

[1] Biodiversity and Macroecology Group, Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK, e-mail: m.dallimer@sheffield.ac.uk

[2] Projet Protection des Gorilles, John Aspinall Foundation, BP 13977, Brazzaville, Republic of Congo

[3] The Macaulay Institute, Craigiebuckler, Aberdeen, Scotland, UK

[4] ECOFAC Príncipe, Roça Salomão, Príncipe, São Tomé and Príncipe

*Corresponding author

Abstract

Eidolon helvum is a widespread African fruit bat. It is migratory and can form colonies of millions of individuals. On Príncipe, in the Gulf of Guinea, there are seemingly large numbers of *E. helvum*. Here, they have lost their migratory behaviour and rely on the availability of the year-round food resources on the island, which is small (128 km²) but is dominated by both primary rainforest and fruit-tree plantations. We visited the major roost for *E. helvum* on the island. Exit counts carried out on two consecutive nights showed the roost was used by between 10,539 (SE±67) and 14,160 (SE±324) individuals. Compared to mainland Africa, the colony was small, no doubt constrained by the size of the island. Nonetheless, Príncipe still supports a considerable density of *E. helvum* of between 82 and 111 bats/km², which is comparable with densities found on mainland Africa.

Keywords: *Eidolon helvum*; exit count; fruit bat; Gulf of Guinea; population density; Príncipe; roost count.

Résumé

Eidolon helvum est un chiroptère phytophile d'Afrique répandu et abondant. Il est migrateur et peut former des colonies de millions d'individus. Sur Príncipe, dans le Golfe de Guinée, il y a apparemment un grand nombre de *E. helvum*. Ici, ils ont perdu leur comportement migrateur et sont dépendants de la disponibilité des ressources alimentaires au cours de l'année sur l'île, qui est petite (128 km²) mais dominée par la forêt pluviale primaire et des plantations d'arbres fruitiers. Nous avons visité le dortoir principal d'*E. helvum* sur l'île. Les comptages d'envol effectués durant deux nuits consécutives ont montré qu'il était utilisé par 10.539 (SE±67) à 14.160 (SE±324) individus. Selon les standards d'Afrique continentale, la colonie était petite, sans doute une contrainte due à la taille de l'île. Néanmoins, Príncipe supportait une densité considérable de *E. helvum*, entre 82 et 111 chiroptères/km², ce qui est comparable aux densités trouvées en Afrique continentale.

Mots cles: chiroptère phytophile; comptage d'envol; comptage au dortoir; densité de population; *Eidolon helvum*; Golfe de Guinée; Príncipe.

Introduction

The straw-coloured fruit bat, *Eidolon helvum* Kerr 1792, is the most widespread species of fruit bat in Africa, breeding in equatorial regions but ranging across sub-Saharan Africa (Bergmans 1990). It is migratory and forms huge breeding and non-breeding roosts that can be millions of individuals strong (Thomas 1983; Sørenson and Halberg 2001). However, *E. helvum* is not restricted to continental Africa and is found on all four islands in the Gulf of Guinea, where it shows distinct genetic and morphological characteristics (Juste et al. 2000). *E. helvum* has also lost its migratory behaviour and occupies roost and feeding sites year-round, feeding mainly on the maintained and abandoned fruit-tree plantations. Therefore, while huge localised roosts can be present in continental Africa where there is an abundant seasonal food supply, the populations of *E. helvum* on the islands of the Gulf of Guinea are dependent on the year-round food resources available on the islands.

The abundance and predictability of food sources can play a pivotal role in determining the density of fruit bats that an environment can support (Hodgkison et al. 2004). The major land-use on the islands is fruit-tree plantations, which provide a reliable and predictable year-round food source for frugivores. Although agricultural fruit may be less nutritionally beneficial than wild fruits for bats (Nelson et al. 2000), the presence of large amounts of fruit could allow a higher density to be supported than by primary forest. Indeed, Juste and Ibañez (1994) suggested that the populations of fruit bats on the islands of the Gulf of Guinea undoubtedly increased when soft fruit trees were introduced after the islands were discovered and colonised from the late 15th century. Here we test the hypothesis that the increased amount and reliability of fruit from plantations on Príncipe have led to high densities of the fruit bat *E. helvum* on the island.

Materials and methods

Príncipe, with an area of 128 km^2, is the second smallest of the islands in the Gulf of Guinea. It is mountainous, rising to 946 m, and lies 220 km from the African coast (Juste and Fa 1994). The predominant land use outside the remaining primary forest is maintained and abandoned fruit-tree plantations. There are no data on the population size of *E. helvum* on the island or any systematic surveys of known roosts. A single roost was visited in the south of the island to assess the population density of *E. helvum* on Príncipe. The *E. helvum* roost, 300 m south of Praia da Nova (1°35′47″ N, 7°20′19″ E; Finland Hayford datum) on the south-west coast of Príncipe, is well known to local fishermen and the largest of three known roosts. The roost is in an area of mature secondary forest (canopy >20 m). Both adult males, identified by their pronounced orange ruffs, and adult females with suckling young were using the roost.

Exit counts were carried out on two consecutive nights to estimate the number of bats using the roost. To ensure that all bats leaving the roost were visible from the observation site, on the evening prior to the exit counts, the direction in which the bats left the roost was noted and a location from which emerging bats could be observed against the sky was chosen. Exit counts were conducted on 26 and 27 January 2002.

The number of bats leaving the roost was estimated by a complete count. Sunset on both nights was at 17:45 h. As *E. helvum* emerge from their roosts within a relatively short period prior to dark (Sørenson and Halberg 2001), counting began at 17:00. The bats could be clearly observed against the sky as they left the roost just before dusk. The number of bats/min leaving after 17:00 was recorded and an emergence rate was plotted. Bats were counted individually when the emergence rate was slow, but in groups of up to 50 at a time when emergence rates peaked. When counting stopped because it was no longer possible to see, bats were still emerging. By extrapolating the emergence rate curve, a better estimate of the total number of bats leaving the roost was obtained. A logistic growth curve was used to model the emergence patterns:

$$y=k/(1+e^{a(t-x)}).$$

The parameters *k*, *a* and *t* were fitted to the cumulative counts/min using iterative procedures that minimised the sums of squares of the residuals in SPLUS 2000 (Mathsoft 1999). The value of the parameter *k* represents the asymptote to the curve (i.e., the predicted maximum number of bats emerging); *a* gives the growth rate parameter and *t* the inflection point. The use of extrapolation to estimate the asymptote assumes that the emergence rate/min follows a peaked distribution across time, with smooth tails at the start and end of the emergence period.

Results

Total counts were 12,540 for the first night and 9,610 for the second (Table 1). The parameter estimates for the logistic regression analysis are shown in Table 2. The model predicts that 14,160 (SE±324) bats emerged on the first night and 10,539 (SE±67) on the second (Figure 1). Bats emerged and flew in a general northeasterly direction (between 010° and 040°).

On both evenings, bats started emerging at 17:16 h. At dark (44 min later), bats were still emerging. Sunset on Príncipe was at 17:45 h on both nights. On the first night the peak emergence time was 17:57 h, while on the second night it was 18:00 h.

Discussion

Eidolon helvum is well known for forming large roosts (DeFrees and Wilson 1988). One non-breeding roost in Zambia reported by Sørenson and Halberg (2001) held an estimated 1.5 million bats. The Príncipe roost surveyed here is therefore small at 10,500–14,200 bats, although the roost did consist of breeding individuals and many of the females were carrying young, so the total number of individuals using the roost is likely to be substantially higher. In addition, exit counts by observers can underestimate the total number of bats present by up to

Table 1 Count of *Eidolon helvum* leaving Praia da Nova roost, Príncipe, January 2002, starting at 17:00 h.

Date	Average flight bearing	Time first bat left roost	Time count stopped	Total no. of bats
26 January 2002	034°	17:16 h	18:08 h	12,540
27 January 2002	010°	17:16 h	18:10 h	9,610

Table 2 Parameter estimates (SE) for the logistic regression analysis.

Date	Parameter		
	k	*a*	*t*
26 January 2002	14,160.2 (323.70)	0.19 (0.01)	41.43 (0.34)
27 January 2002	10,539.1 (66.60)	0.19 (0.00)	42.78 (0.09)

k represents the asymptote to the curve, *a* gives the growth rate parameter and *t* the inflection point.

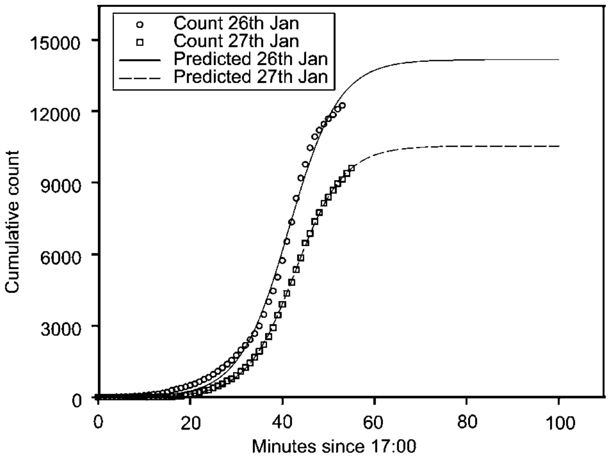

Figure 1 Cumulative number of bats counted leaving an *Eidolon helvum* roost at dusk on 26 and 27 January 2002. Counts started at 17:00 h and stopped at dark. The logistic growth curve modelling the emergence patterns shows predicted asymptotes.

15% (Westcott and McKeown 2004), which may also provide an explanation for the difference between the counts on consecutive nights, although it is equally feasible that different numbers of bats use the roost on different nights.

Although the total number of bats on Príncipe is no doubt limited by the island's size, they do reach a density of between 82 and 111 bats/km^2. No explicit estimates of population density have been made for roosts on continental Africa. Huggel-Wolf and Huggel-Wolf (1965) estimated that a colony of between 20,000 and 50,000 *E. helvum* used a foraging area extending up to 15 km from their roost at Abidjan in Ivory Coast. If bats used all this area equally, their foraging density would be between 28 and 71 bats/km^2. A later estimate of roost size at the Abidjan site was 300,000–500,000 bats, indicating a far higher density of between 424 and 707 bats/km^2 (Thomas 1983). Our estimates for Príncipe are therefore approximately equivalent to previous reports for this species and the island does not support unusually high densities of this species.

The density of *E. helvum* supported by Príncipe could be governed by the extensive areas of abandoned fruit plantations (Juste and Ibañez 1994). The emergence direction of the bats would have taken them directly to the plantations in the north of the island. Food availability can play a major role in determining the numbers and types of frugivores present. For example, the low level of fruit production on Madagascar is thought to be the key reason for the depauperate fruigivore community (Goodman and Ganzhorn 1997) and food availability is important in limiting fruit bat diversity in Malaysian old growth forests (Hodgkison et al. 2004). A similar pattern is evident for frugivorous birds on Borneo (Kimura et al. 2001). In contrast, the urban environments of Australia are able to support a higher density of sedentary grey-headed fruit bats (*Pteropus poliocephalus*) owing to the predictable and reliable nature of the food resource provided by non-native plants (Parry-Jones and Augee 2001; McDonald-Madden et al. 2005).

Although no data on the patterns of food availability are given for Príncipe here, the restricted area of feeding habitat available to the foraging bats could present an ideal opportunity to study the role of resource availability for this species and how this widespread migratory bat has adapted and lost its migratory behaviour in response to a restricted, readily available food resource.

Acknowledgements

We would like to thank Pedro Nobre, the staff of ECOFAC São Tomé and Príncipe, Angus Gascoigne and Peter Jones for their help in organising the trip to São Tomé and Príncipe. Zoe Davies commented on the manuscript, while two referees, P.J. Taylor and J. Fahr, provided invaluable improvements to the manuscript. The work was funded by the Davis Expedition Fund, the British Ecological Society and the John Ray Trust. Additional support was provided by Garmin (Europe) Ltd. and Berghaus Ltd.

References

Bergmans, W. 1990. Taxonomy and biogeography of African fruit bats (Mammalia, Megachiroptera). 3. The genera *Scotonycteris* Matschie 1894, *Casinycteris* Thomas 1910, *Pteropus* Brisson 1762, and *Eidolon* Rafinesque 1815. Beaufortia 40: 111–176.

DeFrees, S.L. and D.E. Wilson. 1988. *Eidolon helvum*. Mamm. Species 312: 1–5.

Goodman, S.M. and J.U. Ganzhorn. 1997. Rarity of figs (*Ficus*) on Madagascar and its relationship to a depauperate frugivore community. Rev. Ecol. Terre Vie 52: 321–329.

Hodgkison, R., S.T. Balding, A. Zubaid and T.H. Kunz. 2004. Temporal variation in the relative abundance of fruit bats (Megachiroptera: Pteropodidae) in relation to the availability of food in a lowland Malaysian rain forest. Biotropica 36: 522–533.

Huggel-Wolf, H.J. and M.L. Huggel-Wolf. 1965. La biologie d'*Eidolon helvum* (Kerr) (Megachiroptera). Acta Trop. 22: 1–10.

Juste, B.J. and J.E. Fa. 1994. Biodiversity conservation in the Gulf of Guinea islands: taking stock and preparing action. Biodivers. Conserv. 3: 759–771.

Juste, B.J. and C. Ibañez. 1994. Bats of the Gulf of Guinea islands: faunal composition and origins. Biodivers. Conserv. 3: 837–850.

Juste, B.J., C. Ibañez and A. Machordom. 2000. Morphological and allozyme variation of *Eidolon helvum* (Mammalia: Megachiroptera) in the islands of the Gulf of Guinea. Biol. J. Linn. Soc. 71: 359–378.

Kimura, K., T. Yumoto and K. Kikuzawa. 2001. Fruiting phenology of fleshy-fruited plants and seasonal dynamics of frugivorous birds in four vegetation zones on Mt. Kinabalu, Borneo. J. Trop. Ecol. 17: 833–858.

Mathsoft. 1999. S-PLUS 2000. Data Analysis Products Division, Mathsoft, Seattle, WA.

McDonald-Madden, E., E.S.G. Schreiber, D.M. Forsyth, D. Choquenot and T.F. Clancy. 2005. Factors affecting grey-headed flying-fox (*Pteropus poliocephalus*: Pteropodidae) foraging in the Melbourne metropolitan area, Australia. Aust. Ecol. 30: 600–608.

Nelson, S.L., M.A. Miller, E.J. Heske and G.C. Fahey. 2000. Nutritional consequences of a change in diet from native to agricultural fruits for the Samoan fruit bat. Ecography 23: 393–401.

Parry-Jones, K.A. and M.L. Augee. 2001. Factors affecting the occupation of a colony site in Sydney, New South Wales by the grey-headed flying fox *Pteropus poliocephalus* (Pteropodidae). Aust. Ecol. 26: 46–55.

Sørenson, U.G. and K. Halberg. 2001. Mammoth roost of non-breeding straw-coloured fruit bat *Eidolon helvum* (Kerr 1792) in Zambia. Afr. J. Ecol. 39: 213–215.

Thomas, D.W. 1983. The annual migrations of three species of West African fruit bats (Chiroptera: Pteropodidae). Can. J. Zool. 61: 2266–2272.

Westcott, D.A. and A. McKeown. 2004. Observer error in exit counts of flying foxes (*Pteropus* spp.). Wildl. Res. 31: 551–558.