POPULATION ECOLOGY, DIET AND MOVEMENT OF STRAW-COLOURED FRUIT BATS (*Eidolon helvum*), WESTERN KENYA

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POPULATION ECOLOGY, DIET AND MOVEMENT OF STRAW-COLOURED FRUIT BATS (*Eidolon helvum*), WESTERN KENYA

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Abstract
The population status, movement, roost-site selection and diet of straw-coloured fruit bats (*Eidolon helvum*) were studied over a seven-month period in western Kenya. Overall, the bat population fluctuated markedly from as low as 7,000 to as high as >25,000 bats, and the bats shifted from one roosting camp to the other within the same general area, perhaps reflecting the seasonal variation in the availability of preferred foods. Preliminary results suggested that tree density was an important factor in roosting-camp selection for *E. helvum* in western Kenya, and the removal of roost trees could have serious ramifications on their conservation in the region. Germination experiments and direct observations indicated that *E. helvum* helped to disperse seeds of >32 plant species belonging to 18 families. Further monitoring is needed to provide a complete picture of the status and migration patterns of *E. helvum* in Kenya. Additionally, because the bats were viewed negatively with attendant persecution through roost-tree clearance and eradication programmes, a robust education and community outreach programme in local schools and local communities should be continued for the long-term conservation of viable populations of *E. helvum* in western Kenya.

Introduction
Fruit bats or flying foxes are keystone species in the maintenance and re-establishment of natural vegetation in the Old World (Fujita & Tuttle, 1991). The role in seed dispersal and pollination is particularly important in tropical rainforest succession and community composition (Fleming 1982; Medellin & Gaona, 1999; Henryi & Jouard, 2007). One of the most important fruit bat species that forms large colonies, and certainly plays a key role in seed dispersal and plant pollination, is the straw-coloured fruit bat (*Eidolon helvum* Kerr 1792). In West Africa, *E. helvum* is a critically important seed dispersal agent for the economically important and threatened timber tree, the African Iroko (*Milicia excelsa*) (Omaston, 1965; Thomas, 1983; BCI, 1989, 1994-95 & 1995-96). Colony members' ability to venture 59 km or more on nightly foraging flights enhances seed dispersal far and wide, and through their long annual migrations, single colonies can have enormous impact (Richter & Cumming, 2008).

Colonies of *E. helvum* are rarely found in protected areas or deep in dense forests, but within human habitation especially roosting on trees in gardens, institutional houses (government offices) or in big towns (Racey, 2004; Mutere, 1967; Fayenwvo & Halstead, 1974; Baranga & Kiregyera, 1982). In Kenya, only a single colony of *E. helvum* is known and this occurs in the west of the country, a few miles away from Kenya's only true rainforest at Kakamega. The role of *E. helvum* in the dispersal of seeds and pollination of flowers of many plants in western Kenya has hitherto been un-investigated. Yet the species is threatened by a combination of factors including habitat loss (cutting down of roost trees to evict the bats or for timber or construction), and chemical spraying which causes direct mortality. Additionally, negative perceptions and traditional beliefs exert pressure on household owners to be intolerant to the bats and their roosting camps leading to roost destruction via deforestation. The loss of roost trees in the area may be crowding too many bats into too few trees for roosting. These threats are not dissimilar to those facing the species elsewhere over much of its range across sub-Saharan Africa. Consequently, *E. helvum* is listed as Near Threatened (NT) on the IUCN Red List because of dramatic population declines and habitat losses (Mickleburgh *et al*., 2008; IUCN, 2011). The survival of the species may, thus, in large part depend on saving many smaller groups over a very large area. The single Kenyan colony certainly ranks among the largest dozen groups known in Africa making it a relatively high priority for protection. The main goal of this project was to maintain a viable population of *Eidolon helvum* in Kenya, with the only known colony in the country at Kakamega as the focal point. The vital element of the project was the identification, mapping and protection of *E. helvum* roosting camps in western Kenya. Consequently, the project sought to monitor population trajectories in order to better understand seasonal (intra-annual) as well as long-term (inter-annual) fluctuations of *E. helvum* bats through regular monthly counts in relation to climate and their annual migrations. In addition, seed sampling studies were also undertaken alongside an educational and community outreach programme.

Specific objectives

1. Generate critical data on population status, trends and migration patterns of the bats for monitoring.
2. Identify and protect roosts of *Eidolon helvum* in Kenya
3. Identify plant species consumed by *E. helvum* and to verify which species could be or are being dispersed by these animals
4. Document threats that the bats and their habitats face
5. Create local awareness of the value of fruit bats as pollinators and seed dispersers
6. Build the capacity of local communities to protect fruit bat colonies

Methods

Study area

This study was conducted near Mbale Town, Vihiga District, Kakamega County in western Kenya (Fig. 1). Vihiga District lies between longitudes 34^{o} 30’ and 35^{o} 0’ east of the prime meridian and 01^{o} 5’ north. With the highest human population density in rural Kenya at >1000 persons per square km and a population growth rate of 3.3% (above the national average of 2.4%), the District has seen average farm sizes steadily decline to a current 0.5 ha (GOK, 2005). Vihiga has a tropical climate with annual average rainfall of between 1,800 mm and 2,000 mm and average temperature of 24^{o}C. The land around it is used mainly for subsistence agriculture although tea plantations are common in a few areas. Common subsistent crops include maize, cassava, and millet for local consumption and an occasional dairy cow for milk production.

 

Abandoned E. helvum *roosting camp at Mbihi Village after 90% of the roost trees were cut between 2006 and 2009 (left) and an aging Alfred Abunzwa's (holding white hat), the farm owner.*

We mapped five roosting camps, three that were actively used by *E*. *helvum* and two probably abandoned for good (Fig. 1; Table 1). The camp at Mbihi Village recorded the largest colony of *E*. *helvum* in 2005 but reports indicate that it has been abandoned since 2006 after almost all roost trees were cleared. Similarly, anecdotal reports indicated that the roosting camp at Vihiga District headquarters hosted a large colony of *E*. *helvum* but the bats abandoned it after most trees were cleared to "get rid of the bat menace".

The agroforestry farm at Ilwanda Eidolon *roosting camp*

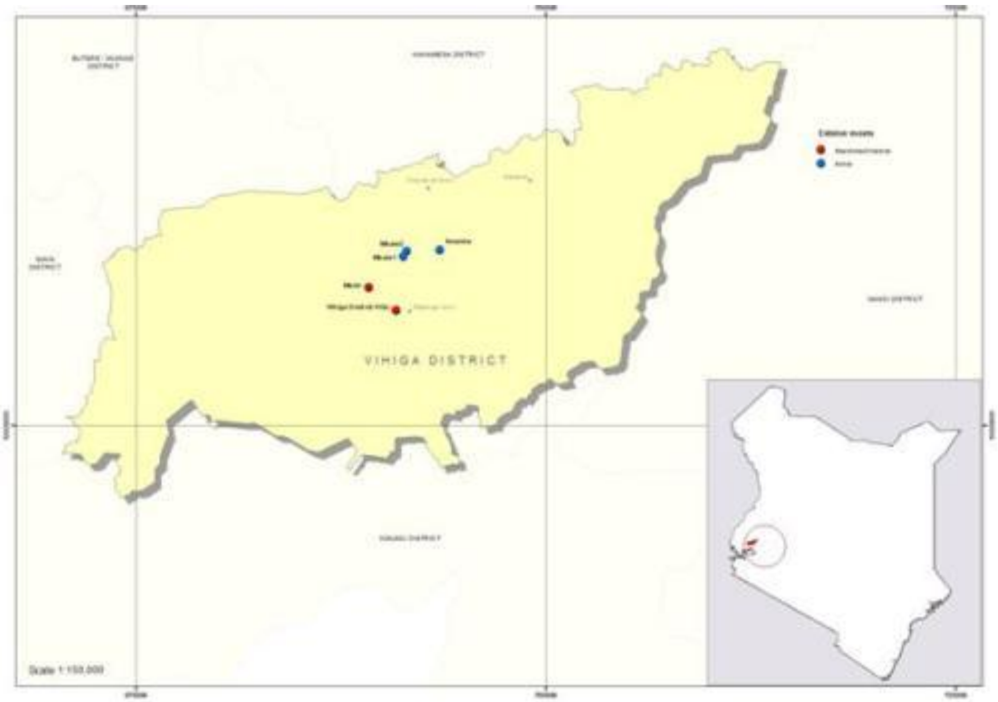

Figure 1. Map showing roosting camps of *E. helvum* in Vihiga District, western Kenya. Inset shows the location of Vihiga District in Kenya.

Field methods

Mapping of roosting camps and population estimates

The larger area of Vihiga District and adjoining areas in Kakamega County were surveyed via interviews of local people and administrators, and through visits to, and interviews with, local wildlife, forestry and environmental agencies, to map active and abandoned *E. helvum* roosting camps. Additionally, databases and NGO records were examined for information on location of *E. helvum* roost camps in western Kenya. After approximate locations of roost camps were identified and mapped, the bats were counted cluster by cluster, branch after branch and tree after tree. Counts were conducted on a regular monthly basis between October 2011 and July 2012. For each cluster, we estimated the number of bats contained in each cluster as 50 individuals. Total bat numbers per roost tree were obtained by counting the number of 50-bat clusters multiplied by 50. Summations of bat numbers per tree were then made to obtain total numbers of bats per roosting camp. This process was repeated twice per roost site per month to estimate population size of roost camps.

Roost characteristics

To help understand roost choice in *E. helvum*, we measured a number of tree and site parameters at active roosting camps for comparison with those at abandoned roosting camps or randomly selected sites. First, we counted trees used as roosts and those with potential for use (only trees with diameter at breast height over bark – DBHOB- ≥ 20 cm) in 2 or 3 50x50 m randomly placed plots at each site depending on its size. Tree density was then estimated on the basis of measured acreage. We measured DBHOB of all trees with DBHOB ≥ 20 in each plot at each site using a measuring tape at 1.3 m over bark and estimated tree height and the heights of both the lowest and highest branch using a Tree Vertex. The number of branches per tree was placed in four ordinal categories as 1 < 10; 2 = 10 – 20; 3 = 20-30 and; 4 > 30. Similarly, tree bark was assessed as 1= smooth; 2 = moderate; and 3 = rough. In addition, tree species were identified to species but specimens were collected for later identification at the Herbarium of the National Museums of Kenya (NMK) for those trees that could not be readily be identified in the field. The tree and site characteristics were similarly measured at camps deemed to have been abandoned as roost trees.

Diet/seed rain sampling

The total area beneath the crown of roosting trees was sampled for seed rain by randomly placing twenty 1-m^2 seed traps (squares of plastic) on the ground under the crown. Trays were emptied every evening before the bats left the roost camps for foraging bouts. Faecal samples were sealed in vegetal paper envelopes and labelled. Seeds were later separated for identification and germination in the laboratory. Any seed that was not identified readily was planted in the Green House at the Botanic Gardens of NMK for subsequent identification of the seedling. We also identified plants growing beneath roosting trees to species and categorized them as dispersed by bats or other means.

Education and community outreach programme

An understanding of the roles that bats play in the various habitats they occur is crucial to their survival as this could be used as leverage for their conservation. It is against this background that an educational and community outreach programme was a crucial component of this project. We conducted socio-economic surveys and interviews with local people in areas around roosting camps and adjoining areas to gauge local people's views and perceptions about bats in general, and *E. helvum* bats in particular. Additionally, a total of three workshops were held for 20 selected teachers and 20 representatives from the local community for interactive sessions on why bats are important to the local economy and the need for their conservation. From the workshops, 30 volunteers (largely drawn from local youths) were identified and trained for two days on aspects of bat ecology, their monitoring (including standard population estimate methods), environmental monitoring in general, and how *Eidolon* colonies could potentially be used to generate revenue for the local community through ecotourism.

As future custodians of natural resources, school-going children were also the focus of educational campaigns. Students were encouraged and facilitated to join Wildlife Clubs of Kenya - WCK (a local non-governmental organisation dedicated in promoting environmental conservation through schools) because the schools in the area had no membership in WCK. PowerPoint presentations were made in three schools in the adjoining areas of *Eidolon* roost camps in Vihiga District. A presentation was made at a single local primary school and attended by 50 pupils. Seminars were also held at two local high schools, with attendance of > 100 students for each school. Topics covered included why bats are mammals, socio-economic and ecological benefits of bats, diseases associated with bats, bat handling precautions, myths and traditional beliefs about bats, threats facing bats and their habitats, bat friendly eviction procedures and installation of bat boxes and bat houses as alternative artificial habitats for bats. Seminars were conducted after classes, and lasted for about 45-60 minutes with an open question-and-answer session at the end. Before the start of each presentation 30 participants (15 boys and 15 girls) were randomly issued with a questionnaire which was filled and returned (Appendix 1). Questions interrogated respondent's knowledge about bats, if and when they have seen bats, where bats live and how they are affected by human activities as well as traditional beliefs about bats and ways in which bats benefit humans.

Aside from the seminars, we also publicly issued a certificate of recognition to two households "hosting" bats on their farms as 'bat guardians' signed by Professor Paul A Racey, Co-Chair, IUCN Bat Specialist Group (Appendix 2).

RESULTS

Roosting camps and population estimates

There were three camps, which were actively used as roost sites by *E. helvum* during the seven months when bat counts were made (Fig. 1). The sites were at Ilwanda, and two near Mbale town, hereafter known as Mbale 1 and Mbale 2. The three camps are unlikely to support bats in the long run because they occurred on private land and were not legally protected. Additionally, two other roost sites were mapped but these were unused (or probably completely abandoned) during the monitoring period (Table 1).

There were marked variations in both numbers of bats roosting at the three camps as well as the conditions of active roosting camps. The colony underwent seasonal fluctuations in size during the monitoring period. Ilwanda camp recorded the highest bat population during the November count of all camps and Mbale 2 was a distant second. However, the same camp recorded the lowest count a month later in December with a turnover of ca. 21000 bats (Table 2). Of all counts, December 2011 and January 2012 recorded the lowest bat numbers. However, March 2012 saw dramatic increase in numbers to within the margin of error of the initial population records in November 2011 (Fig. 1; Table 2).

Table 1. Roosting camps for *Eidolon helvum* at Mbale, Kakamega County, Kenya, July 2012

Roost Site	Coordinates	Roost type	Roost status	Threat to bats and their roost
Mbihi	0.07569°N, 34.70040°E	Homestead	Oldest roost site but now abandoned after 80% of roost and non-roost trees were cleared for timber	***Roost tree clearance***- Farm owner too old with failing health and therefore unable to protect roost trees as before. Farm extensively cleared of trees to create farming land and for sale as timber to generate income. Remaining few trees most likely to be cut down as well.
Ilwanda	0.09666°N, 34.73935°E	Homestead	The farm, owned by a single family, is ca. 3 acres where mixed farming and agroforestry were practiced. Highest density of roost and non-roost trees planted and protected by owner. Bats tolerated despite torrents of negative myths other villagers. Roost site least likely to be abandoned in the near future.	***Limited regeneration*** –there was little evidence of regeneration on the farm given that the farm is regularly cultivated to get rid of weeds but also, inevitably, any regenerating trees. Old and senescent trees were thus not replaced. ***Limited area to plant additional trees***-large family dependent on the farm as only food source and sale of surplus to educate their children. Potentially, economic pressure may lead to tree clearance in the near future.
Mbale 1	0.09308°N, 34.71944°E	Homestead	Farm has few roost trees and these are found only on hedgerows as the small farms (<0.5 acres) are used for crop cultivation. The area has no capacity for planting more trees.	***Tree clearance -*** trees on hedgerows only source of timber or poles for constructing houses
Mbale 2	0.09597°N, 34.72105°E	Homestead	High density of suitable roost trees allowing past roosting by bats.	***Chemical spraying of roosting bats***-Farm owner admitted having driven bats away using an undisclosed chemical but this was ineffective because the bats returned after a while. ***Clearance of roost trees-*** In January 2012, main roosting trees were cleared

				to evict bats because (i) they were reportedly noisy; (ii) they dirtied the compound with large quantities of droppings; and (iii) the farm owner was under pressure from other villagers as the family was perceived to be practicing witchcraft that attracts bats
Vihiga District HQs	0.037667 N, 34.712861 E	Government offices	Compound has several tall trees. Bats evicted after preferred roost trees were cleared. Site now abandoned by bats for years	***Intolerance and tree clearance*** -roost trees cut down to drive bats away

Table 2. Population counts of *Eidolon helvum* at Mbale, Kakamega County, Kenya, during October 2011 – July 2012

Count date	Vihiga	Mbihi	Ilwanda	Mbale 1	Mbale 2	Total	Turnover
27/10/2011	0	0	17,000	2,500	0	19,500	0
19/11/2011	0	0	22,320	0	0	22,320	+2,820
19/12/2011	0	0	1,215	0	5,805	7,020	-15,300
19/01/2012	0	0	0	0	9,180	9,180	+2,160
19/02/2012	0	0	15,250	0	0**	15,250	+6,070
18/03/2012	0	0	15,795	4,860	0	20,655	+5,405
19/04/2012	0	0	0	14,450	700	15,150	-5,505
20/05/2012	0	0	0	14,300	650	14,950	-
26/06/2012	0	0	0	25,100	0	0	+10150

** 80% of roost trees cleared after January 2012 counts

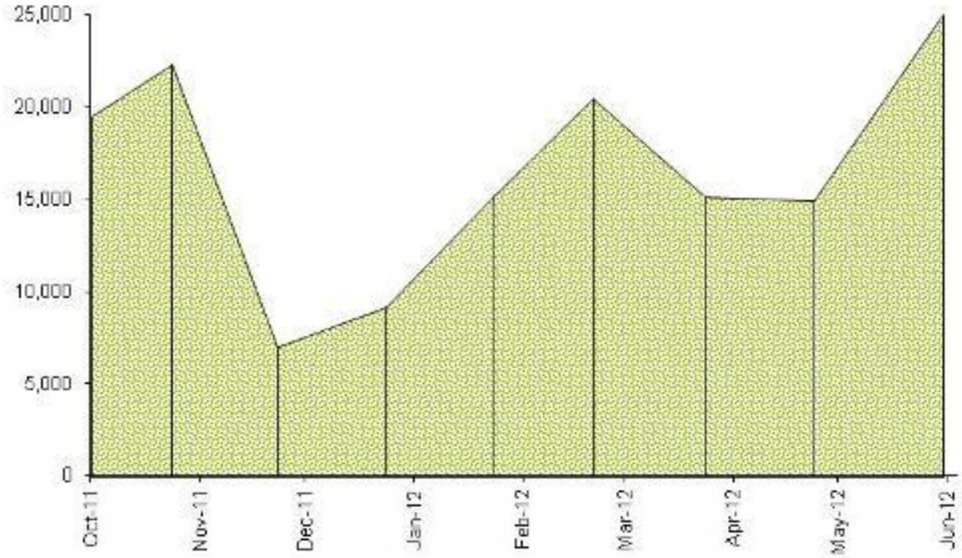

Figure 2. Population trends of *E*. *helvum* at Mbale, Kakamega County, Kenya, during October 2011 – July 2012

Roost characteristics

Eidolon helvum bats preferred Cypress trees (*Cupressus lusitanica*; Family Cupressaceae) for roosting to other tree species available. However, in limited proportions, the bats also roosted on *Croton megalocarpus,* C. *macrostachyus, Ceiba pentandra*, *Markhamia lutea, Mangifera indica*, *Grevillea robusta* and *Persea americana*. However, although eucalypt trees were abundant in the study area, bats generally avoided them as roosting sites.

(a) ***(b)*** ***(c)***

(a) Cupressus lusitanica*, an exotic tree species; (b)* Croton megalocarpus *(indigenous); and (c)* Ceiba pentandra *(exotic) used as* E. helvum *roosting trees in western Kenya*

Tree height and DBHOB were highly correlated at all sites ($r > 0.86$, $P < 0.001$) when compared using Spearman rank correlations. However, both variables were retained for further analysis. The density of trees (DBHOB ≥ 20 cm) differed significantly between sites ($F_{4, 10}$ = 19.647, P < 0.001). Ilwanda roost site had the highest density (42.7 ± 3.5 trees ha^{-1}), followed by Mbale 2 (33.7 ± 2.3 trees ha^{-1}) and there was no significant difference between these two sites, but each had greater densities than Mbale 1(20.0 ± 0.6 trees ha^{-1}), Mbihi (15.0 ± 1.7 trees ha^{-1}) and Vihiga sites (21.7 ± 2.8 trees ha^{-1}) (P < 0.05).

Tests of differences between camps (roosting and non-roosting) in DBHOB using one-way ANOVA (with camp as a predictor variable) showed that DBHOB differed significantly between camps ($F_{4, 462}$ = 18.835, P < 0.001). Vihiga District Headquarters recorded highest DBHOBs (41.5 ± 1.7 cm), which differed significantly from both Mbihi (29.9 ± 1.8 cm) and Ilwanda camps (25.8 ± 0.5 cm) (P < 0.05). Similarly, tests for tree height showed significant differences between camps ($F_{2, 232}$ = 14.358, P < 0.001). Again, Vihiga recorded tallest trees (18.7 ± 0.5 m), which differed significantly from average tree heights at both Mbihi (15.5 ± 0.6 m) and Ilwanda camps (15.6 ± 0.4 m).

Diet/seed dispersal results

Germination experiments and direct observations at active roosting camps revealed that *E. helvum* helped to disperse seeds of >32 plant species belonging to 17 families (Table 3). Observations of faecal matter showed that guavas *Psidium quajava* (Family Myrtaceae) were the dominant fruits fed on by *E. helvum* probably because of its large-sized seeds. However, observations of germinating seedlings and saplings at roosting camps and germination trials indicated that figs (*Ficus* spp.; Family Moraceae) were the dominant food items in the diet of *E. helvum* (Table 3). Germination experiments also revealed local fruits used by humans such as *Carica papaya* (Family Caricaceae), *Eriobotrya japonica* (Family Rosaceae), and *Syzygium cordatum* and *S. guineense* (Family Myrtaceae) in the diet of *E. helvum*.

Seed rain (droppings) of E. helvum *(left) and a strangling fig (*Ficus *spp.) sapling growing on a Cypress tree (right) at Ilwanda roosting camp, Mbale, western Kenya*

Table 3. Plant species whose fruits are fed on by *E. helvum* in western Kenya as identified from the bats' faecal material and through direct observations

Family	Plant species	Exotic/Native	Identification method
Anacardiaceae	*Mangifera indica*	Exotic	Direct observation
Apocynaceae	*Saba comorensis*	Indigenous	Seed germination
Canellaceae	*Werburgia ugandensis*	Indigenous	Direct observation
Caricaceae	*Carica papaya*	Exotic	Seed germination
Cucurbitaceae	*Momordica foetida*	Indigenous	Direct observation
Flacourtiaceaa	*Flacourtia indica*	Indigenous	Seed germination
Guttiferae	*Garcinia buchananii*	Indigenous	Seed germination
Lauraceae	*Persea americana*	Exotic	Direct observation
Malvaceae	*Ceiba pentandra*	Exotic	Seed germination
Meliaceae	*Melia azedarach*	Exotic	Direct observation
Moraceae	*Ficus amadiensis*	Indigenous	Direct observation
	F. asperifolia	Indigenous	Seed germination
	F. lutea	Indigenous	Seed germination
	F. natalensis	Indigenous	Seed germination
	F. ovalifolia	Indigenous	Seed germination
	F. ovata	Indigenous	Seed germination
	F. sur	Indigenous	Seed germination
	F. sycomorus	Indigenous	Germination/observation
	F. thonningii	Indigenous	Seed germination
	F. vallis-choudae	Indigenous	Seed germination
	Morus alba	Indigenous	Seed germination
Myrtaceae	*Psidium guajava*	Exotic	Germination/observation
	Syzygium cordatum	Indigenous	Seed germination
	Syzygium guineense	Indigenous	Germination/observation
Fabaceae	*Crotolaria lanchnocarpoides*	Indigenous	Seed germination
Rosaceae	*Eriobotrya japonica*	Naturalized	Seed germination
	Rubus apetalus	Indigenous	Direct observation
Rubiaceae	*Vangueria apiculata*	Indigenous	Direct observation
Rutaceae	*Teclea nobilis*	Indigenous	Direct observation
	T. trichocarpa	Indigenous	Direct observation
	Toddalia asiatica	Indigenous	Seed germination
Sapindaceae	*Allophylus ferugineus*	Indigenous	Direct observation

Education and community outreach programme

From workshops with teachers from local schools and representatives of local communities, 30 volunteers were identified and trained as the focal group for monitoring population trajectories of *E. helvum* through monthly counts and reporting of any observable changes such as deforestation in the local environment. Through the workshops and systematic socio-economic surveys and interviews with local people in the vicinity of *E. helvum* roosting camps, we identified a number of perceptions (largely arising from ignorance and lack of information regarding bats' ecological roles) and extreme poverty in the region as the main underlying threats to the maintenance of viable population of straw-coloured fruit bats in western Kenya. For instance, 60% of respondents reported that bats were associated with witchcraft. Farm owners "hosting" bats on their farms or homesteads were accused of using bats to attract or accumulate wealth. These farm owners were thus viewed as witches and in order to eliminate this tag they tried, with varying degrees of success, through means such as tree clearance, tree pruning and direct chemical poisoning to evict bats.

The other threats facing the straw-coloured fruit bats are intrinsic to the bats themselves. For example, 50% of the respondents regarded the bats as a public nuisance because they were reportedly smelly, dirty, noisy, destroy trees by their sheer weight and their faecal matter destroys crops and pasture on farmlands and homesteads. Only a paltry 2% of respondents said that these bats were useful as seed dispersers of economically important local fruit trees, and therefore should be protected.

Although, we anticipated to offer talks to <20 students in each school, especially members of Wildlife Clubs of Kenya, the response was overwhelming with more than 50 pupils from the primary school and >100 students from each of the two high schools participating in the interactive sessions. None of the schools had an operational wildlife or environment club, and we encouraged them to join Wildlife Clubs of Kenya. At the end of the talks a bat poster was donated to the school. From the questionnaires, 85% of the student respondents did not think that bats had any value to humans.

We also gave two farm owners certificates of recognition for conserving trees where bat roosted (Appendix 2).

Handing over certificates of recognition to 'bat guardians' in Mbale for helping to protect trees for bat roosting

Bat awareness talks at Bukhulunya and Munzatsi High Schools, respectively and the handing over of bat posters, Mbale, Kakamega County, Kenya, February 2012

DISCUSSION

Roosting camps and population estimates

This is the first study to report on population estimates and roost–site selection of straw-coloured fruit bats (*Eidolon helvum*) in Kenya. The species forms large colonies in widely scattered locations across the central belt of Africa, and on some offshore islands including the Gulf of Guinea islands and Zanzibar, Pemba and Mafia (off Tanzania) (Bergmans, 1990; Simmons, 2005). The Kenyan *Eidolon* colony represents one of the major satellite populations on continental Africa but others are known at Jinja and Kampala in Uganda; Ile-Ife and Lagos in Nigeria; Accra and Wli Falls in Ghana; Abidjan in Ivory Coast; and Dar-es- Salaam in Tanzania. Bat numbers in these large, vulnerable roosts is thought to have declined in recent decades. The primary threats include human hunting for food and the loss of habitat to expanding agriculture (IUCN, 2011). Deforestation, widespread in almost all tropical areas of the world, has had several identifiable consequences for fruit bat populations (US Fish and Wildlife Service and National Environmental Protection Board, 1989).

Although the Kakamega colony of *E. helvum* has been monitored for only seven consecutive months, the population of *E. helvum* fluctuated from as high as 25,000 to as low as < 8,000 (Fig. 2). However, it is unclear whether this represents a decline given the short monitoring period or whether the bats shifted to other unidentified roosting camps due to human persecution and/or habitat loss. Our local surveys did not identify additional roosting camps in Vihiga District. However, it is possible they could be available further afield. According to Mickleburgh *et al*. (1992), population declines and altered population dynamics are a common phenomenon in many fruit bat species, and this could be a response to deforestation and other anthropogenic habitat changes (US Fish and Wildlife Service and National Environmental Protection Board, 1989). From our preliminary results and direct observations, current roost camps were subjected to constant tree clearance. It is therefore possible that habitat destruction via loss of roost trees led to the break-up of the original bigger roosts in western Kenya, causing the bats to find alternative roosting camps. Loss of forest results not only in the loss of critical roost trees but also key food resources for *E. helvum*.

Population size fluctuations in fruit bat colonies have also been attributed to annual migrations of part or most of the colony (Mutere, 1966, 1980; Thomas, 1983; Richter & Cumming, 2006; Parry-Jones & Augee, 2001; Sorensen & Halberg, 2001). We could not conclusively relate population fluctuations of the Kakamega *Eidolon* colony to either local shifts between roosting camps or to annual migration because of the short monitoring period. Clearly, further year-long, and inter-annual, monitoring is needed to provide a complete picture of the migration patterns of this species in Kenya, if any. The straw-coloured fruit bat is a classic example of a species that needs a functional network of roosting and foraging sites (Poiani *et al*., 2000), which probably means that it would require various roosting sites for its survival annually. Fleming & Eby (2003) observed that preserving only one site in the migration route would be inadequate for the long-term conservation of this species and other migratory fruit bats. There is therefore an urgent need to further survey and map a network of possible roosting sites in Vihiga District and adjacent areas in order to assess their conditions and work with local people to protect them for the long-term protection and survival of straw-coloured fruit bats in Kenya.

(a) ***(b)***

(**a**) Felled Cypress trees, and (**b**) pruned Mango (*Mangifera indica*) tree to evict roosting bats at Mbale 2 roosting camp, Mbale, western Kenya

Like colonies in some other African range states (e.g. Mickleburgh *et al*., 1992), *E. helvum* roosted on tall trees in areas near human habitations in western Kenya. *E. helvum* roosting camps were located on private farms within busy villages near Mbale town, Vihiga District, Kakamega County, Western Kenya. However, although these areas are densely populated with >1000 people per km^2 (GOK, 2005), homesteads in some localities had a relatively high density of both indigenous and exotic trees. Our study revealed that tree density was a key factor in the choice of roosting camps. Indeed, active roosting camps were located in areas with relatively high tree density. For instance, the roosting camp at Ilwanda Village was located on 2.0-ha private agroforestry farm with more than 100 indigenous and exotic trees interspersed within crops such as coffee, bananas, and maize. This camp recorded the highest number of roosting bats during the monitoring period (Table 2).

Our study however indicated that tree size and height were not important factors for the choice of roosts for *E. helvum* in Kenya. For instance, although the defunct roosting camp at Vihiga District Headquarters had the tallest and largest diameter trees of all camps, the roosting camp was unused during the seven-month motoring period and has reportedly been abandoned for a couple of years. The *E. helvum* colony in western Kenya was huge (with maximum record counts > 25,000 individuals), conspicuous – and extremely vulnerable to human persecution. Therefore, other than tree density, *E. helvum* could have selected roosting camps in Kenya on the basis of the level of persecution including targeted eradication programs such as chemical poisoning, and regular disturbances such as stones being thrown at them. Indeed, interviews with local people indicated that eradication programs have been attempted in the area. For instance, after failed attempts to kill and completely evict the bats through chemical poisoning at Mbale 2 roosting camp, most roost trees were cleared in February 2012.

The loss of roost trees at current roosting camps appears to be a major threat to the survival of straw-coloured fruit bats in western Kenya, making the future of the sole bat colony uncertain in the region. The precarious situation is aggravated by the fact that the colonies occur on private land with no formal protection. Potentially, the roosting camps can be altered through extraction of trees for timber, poles, firewood, or creation of space for human settlement and crop cultivation. With high human densities in Vihiga District, existing roosting camps are likely to be affected as local people are forced to exploit existing resources for survival.

Role of E. helvum in the Seed dispersal of plants in western Kenya

Frugivorous bats are among the most effective seed dispersers over large distances because they are the only mammals capable of active flight (Hall, 1983). They can enhance seed interchange between different forest patches and the re-vegetation of large open areas (Boon & Corlett, 1989; Mickleburgh & Carroll, 1994). In fragmented landscapes they transfer seeds and pollen between isolated sites (Bollen *et al*., 2004). Our study revealed that *E. helvum* helped to disperse seeds for *ca.* 32 plant species of 17 families, including economically important fruit trees in western Kenya that provide their main diet. The common guava (*Psidium guajava*) appeared to be the commonest in the seed traps but this was probably because of the visibility of its large-sized seeds. Conversely, faecal analyses through seed germination experiments and observations of seedlings and saplings at roosting camps indicated that the bats fed on fruits, and helped to disperse seeds, of many plants in the genus *Ficus* (Family Moraceae). Through feeding on fruits, *E. helvum* also apparently aids in the seed dispersal many other plants (Table 3). The species has the ability to forage as far as 59 km or more from the roost in a single evening (Richter & Cumming, 2008), suggesting that the species is a long-distance seed disperser. Furthermore, because *E. helvum* spends at least half of each year on a long distance migration probably to take advantage of seasonal fluctuations in different fruit and flower resources (Fleming, 1982; Racey & Entwistle, 2000; Fleming & Eby, 2003), its impact can be enormous in facilitating tropical forest succession, distribution, and community composition (Fleming, 1982).

According to Hodgkison *et al*. (2004), the abundance and predictability of food sources may determine the density of fruit bats that an environment can support. It is therefore possible that to attribute the existence, and constant shifting, of *E*. *helvum* bats at different roosting camps in western Kenya to the presence of wild and domestic fruiting trees throughout the year, albeit fluctuating seasonally. Although agricultural fruit may be less nutritionally beneficial than wild fruits for bats (Nelson *et al*., 2000), the presence of large amounts of such fruit could allow a higher density to be supported than by primary forest (Dallimer, *et al*., 2006). Indeed, Juste & Ibáflez (1994) suggested that 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 colonized from the late 15th century. Roosting camps of *E*. *helvum* in western Kenya occur in an area with high rainfall, and the existence of indigenous and exotic fruit trees throughout the year could be the reason these bats are not migrating far away to other places in search of fruiting plants. However, loss of roost trees in traditional roosting camps through deforestation and/or clearance could have deleterious effects on the ecology of the entire region given the bats' critical role in forest regeneration and community succession. Therefore, the maintenance and protection of these traditional roosting camps for viable populations of straw-coloured fruit bats should be given high priority going into the future.

Education and community outreach programme

Our effort was a first of its kind of project targeting the need to conserve bats because hitherto there had been no education and community outreach programme about bats in western Kenya. However, the project is far from complete because, even with our little efforts, roost trees were still being cleared and/or pruned to evict the bats at current roosting camps even when our project was ongoing. Additionally, the bats were still viewed negatively despite our outreach programme in the area. In this regard, therefore, much more needs to be done through a robust education and community outreach programme, and other measures to ensure the maintenance and conservation of *E*. *helvum* bats and their roosting camps in western Kenya.

Generally, bats were associated with witchcraft and were regarded as a public nuisance because they roosted in buildings and on trees, defacing compounds, lawns, ceilings and walls with their wastes. The first perception included bats being associated with witches or ghosts. Straw-coloured fruit bats primarily roosted in homesteads and adjoining farms in villages. Our investigations through interviews with farm owners and other villagers indicated that farm owners were under immense pressure to drive the bats away. Fellow villagers viewed households "hosting" bats as harbouring witchcraft or using evil spirits for purposes of attracting or accumulating wealth. The consequence of this enormous pressure led to continued tree clearance to evict the bats at some roosting camps because family members could not bear the negative view from neighbours. This supports observations elsewhere where superstition and ignorance by the general public led to direct killing of the bats or roost-camp destructions (Altringham, 1996; Taylor, 2000). However, in western

Kenya, some households, especially at Mbihi and Ilwanda roosting camps, admirably resisted the pressure to allow the bats to roost on their farms.

Aside from negative perceptions relating to witchcraft and superstition, but to a lesser extent, *E*. *helvum* bats were also viewed negatively because of their faecal droppings, the associated bad smell and their noisy demeanour. Because they roost in large numbers, their noise and faecal droppings were said to cause inconveniences in the small compounds and farmlands (<3 ha) where they roosted. For instance, large quantities of faecal matter on vegetables and other subsistent crops were said to render them unsuitable for consumption. Additionally, the bats were reportedly noisy due to constant jostling for space on few available roosting trees. Therefore, these roosting trees were cleared to create a hygienic environment for crop growing, eliminate the bad smell from the bat faecal matter, and eliminate the noisy bats. However, instead of tree clearance, some farm owners opted for tree pruning via removal of major branches to decrease bat roosting sites on individual trees. Additionally, attempts were also made to evict bats by use of chemicals, especially at Mbale 2 roosting camp.

For households that resisted pressure from neighbours and relatives, roost trees were still cleared as a source of income through timber sales. In Vihiga District, unlike other parts of Kenya, local people are fully committed to tree planting, even on their small farms. In these farms, trees are mostly planted along hedgerows and open spaces around the houses, mainly as a source of firewood, construction poles and timber, both for domestic use and sale for household income. The extreme poverty in the District implies that these trees are cut down as an alternative or only source of income even when colonized by bats. A case in point was at Mbihi Village, where the aging farm owner, Alfred Abunzwa, could not prevent his sons and other relatives from cutting down trees for sale as timber to meet household needs of buying food and school fees for their children. In the absence of livelihood interventions focused on individual households and a robust and comprehensive bat education and community programme, most of the current roosting camps and the *E*. helvum colony might be lost in the near future.

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APPENDICES

Appendix 1. *Questionnaire used to collect information on knowledge and perceptions about bats in schools*

BATS/POPO QUESTIONNAIRE

Read here first: *The purpose of this questionnaire is to collect information about Bats/Popo from local communities purely for scientific research-We request you to fill it and return to undersigned.*

MOTHER TONGUE:______________________GENDER_________AGE________

EDUCATION LEVEL__________________SCHOOL___________________CLASS_______

NEAREST TOWN____________________________VILLAGE:________________________

KNOWLEDGE ABOUT BATS/POPO BY LOCAL COMMUNITIES

1. Name of bat in your local language…………………………………………………...
2. When did you last see a bat…………………………………………………………
3. When did you last hear a bat calling ...……………………………………………….
4. Do you see/hear the same number of bats you used to see/hear in the past………
5. Would you like children of your children to see bats……Give reasons for your answer

……………………………………………………………………………………………..

6. How many types of bats do you know…………………………………..………
7. Where do bats/popo live……………………………………………………………...
8. Give names of places with more than 500 bats living in one place in this area…………..
   ……………………………………………………………………………………………………
   ……………………………………………………………..
9. In which ways do you think bats survival is affected by people activities…………………

………………………………………………………………………………………………

10. How can you help to conserve or protect bats in your village …………..………………

………

………………………………………………………………………..

PERCEPTIONS & BELIEFS ABOUT BATS/POPO

1. What do you do when you see a bat…………………………………………………...

………………………………………………………………………………………………

2. Do people kill bats in your village……………Give reasons for your answer below.……..

………………………………………………………………………………………………

3. What traditional beliefs exists about bats in your village………..……………………...

………………………………………………………………………………………………

4. What benefits do people get from bats in your village…..………………….……………..

……………………………………………………………

5. How do bats affect peoples' live in your village……………………………………………

………

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Appendix 2. *Certificate of recognition to 'bat guardians', Vihiga District, western Kenya*

20th November 2011

CERTIFICATE OF RECOGNITION AS A 'BAT GUARDIAN'

By this letter, the Bat Specialist Group of the IUCN Species Survival Commission recognizes the efforts **Mr. Levi Amadalo Azinwa** and your wife **Beatrice Amadalo** in hosting, and therefore helping in conserving Straw-coloured Fruit Bats *Eidolon helvum* on your farm at Ilwanda Village, Mbale-Western Kenya. Dr. Paul Webala and Mr. Simon Musila from Moi University-Karatina College and National Museums of Kenya, respectively, estimate the colony to consist of about 20,000 bats as at 31st October 2011. This is the largest colony of the species in Kenya. Therefore, this is a letter of recognition as one of the existing '*bats guardians*' in Mbale and the great sacrifice you have made to conserve the bats whilst foregoing your other needs particularly in three ways:

1. ***Bat roost conservation through tree planting***: you have planted more than 100 indigenous and exotic trees in your farm, which are now mature enough for timber extraction but you have retained them as roosts for the bats since they migrated to your homestead in 2006; despite constant pleas from your fellow villagers to cut down the trees in order to evict the bats from their compounds as many have done in the general area of Mbale District.

2. ***High level of tolerance to large colony of bats***: the large number of bats in your 3-acre farm is associated with a lot of inconvenience such as: noise throughout the day, and large quantities of faecal material from trees dropping over crops. The result is that you have given up growing vegetables for consumption or sale.

3. ***Use of alternative source of livelihood compatible to bat conservation***: you have instead resorted to mixed farming (bananas, coffee, cassava, and fruit trees) and dairy farming (with one cow) which are interspersed with grown trees used as roosts by the bats.

There is no question that this exceptionally large colony is of significant ecological importance in the area. As far as the scientists are aware; the colony is by far one the largest remaining in Kenya. The species is exceptionally ecologically important as a primary pollinator and seed disperser of many tropical plants, including many fruit trees and timber trees on which we depend. In short, the bats play critical roles in tropical plant/forest succession, distribution, and community composition and their loss could have very negative ecological consequences locally and regionally. The continued existence of the bats in the area is therefore critical, and your efforts and support in conserving them is greatly appreciated.

Paul A Racey

Professor Paul A Racey

Co-Chair, IUCN Bat Specialist Group

Species Survival Commission

INTERNATIONAL UNION FOR CONSERVATION OF NATURE