19

The role of captive breeding in the conservation of Old World fruit bats

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19.1 INTRODUCTION

Bats belong to the order Chiroptera. There are about 950 species worldwide, making up almost a quarter of all known mammal species. The order Chiroptera is divided into two major sub-orders; the Microchiroptera and the Megachiroptera (Old World fruit bats). The Megachiroptera are distinguished from the Microchiroptera by having a simple external ear forming an unbroken ring and by having a second finger that is relatively independent of the third finger and which usually bears a small claw. They do not possess a nose-leaf (often well-developed in the Microchiroptera) or tragus (a small structure inside the ear). They generally have large eyes, and sight and smell appear to be the major locational senses, in contrast to the Microchiroptera, which have small eyes. Echolocation, a method of orientation using ultrasonic sounds emitted through the mouth or nose, is universal among the Microchiroptera but is, with a few exceptions, unknown in the Megachiroptera.

Creative Conservation: Interactive management of wild and captive animals.
Edited by P.J.S. Olney, G.M. Mace and A.T.C. Feistner.
Published in 1994 by Chapman & Hall, London.
ISBN 0 412 49570 8

There are 41 genera of Megachiroptera containing a total of 161 species. They occur throughout the Old World tropics and subtropics from Africa through southern and South-East Asia to Australia and islands in the western Pacific. Many species occur on small islands or island groups.

19.2 THREATS

The main threats to fruit bats are deforestation, disturbance, hunting, conflict with commercial fruit growers, and tropical storms.

19.2.1 Deforestation

Many fruit bat species are dependent on primary forest for roosting and feeding, and are thus threatened by the large-scale destruction of rain forest in many tropical areas. Habitat loss has been cited as a major factor contributing to the declines in fruit bat populations (e.g. Wodzicki and Felten, 1975; Cheke and Dahl, 1981; Fujita and Tuttle, 1991). Many species, particularly those in mangrove swamps or lowland forest, have lost critical habitat, while others have lost vital food resources. The loss of tamarind trees (*Tamarindus indica*) has been identified as one factor responsible for the decline of the Rodrigues fruit bat (*Pteropus rodricensis*).

19.2.2 Disturbance

Fruit bats frequently roost in large, highly visible colonies. This makes them prone to disturbance by humans. Cave-roosting species are especially vulnerable, particularly where they are taken for food or share the roost sites with insect-eating species whose guano is collected by humans for use as fertilizer.

19.2.3 Hunting

In many areas of the world, fruit bats provide an important food source for local peoples, for example in Guam (Wiles, 1987a, b), Vanuatu (Chambers and Esrom, 1991), Samoa (Cox, 1983) and the Seychelles (Racey, 1979; Cheke and Dahl, 1981). In the past harvesting has been on a sustainable basis but more recently the use of firearms has led to serious declines in numbers (Wodzicki and Felten, 1975; Engbring, 1985; Wiles, 1987b). In the Pacific, a commercial trade in dead fruit bats has developed, centred on the island of Guam. In the period 1975–89 over 220 000 bats were imported into Guam from nearby islands to satisfy local and tourist demand (Wiles, 1992). The 1989 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulations were amended to curb much of this trade. However, bats are still imported, legally and illegally, into Guam, threatening a number of populations on surrounding Pacific islands.

19.2.4 Conflict with fruit growers

In areas of the world where commercial fruit-growing is a major industry (e.g. Israel, South Africa and Australia) there have been conflicts between bats and fruit growers. This has arisen because many cultivars are developed from wild species that are dependent upon bats for pollination and seed dispersal (van der Pijl, 1957; Marshall, 1983). Destructive control measures such as shooting are often still favoured. The conflict is particularly acute where fruit orchards have replaced primary or secondary forest habitat (Fleming and Robinson, 1987; Tidemann and Nelson, 1987).

19.2.5 Tropical storms

Species that occur on small islands are particularly vulnerable to the effects of tropical storms, which destroy habitat and food resources. Serious declines in populations after tropical storms have been recorded for a number of species (e.g. *Pteropus rodricensis* on Rodrigues [Jones, 1980; Carroll, 1984]; *P. samoensis* and *P. tonganus* on Samoa [E.D. Pierson, pers. comm.]; *P. rayneri* and *P. tonganus* in the Solomons [Flannery, 1989]).

19.3 IMPORTANCE OF FRUIT BATS

Fruit bats feed almost exclusively on plants, taking floral resources (nectar, pollen, petals and bracts), fruit and often the seeds themselves, and leaves (Marshall, 1985). They are very important pollinators and seed dispersers in tropical forests throughout the world (Marshall, 1983, 1985; Fleming, Breitwisch and Whitesides, 1987; Fleming, 1988; Cox *et al.*, 1991, 1992; Pierson and Rainey, 1992). Megachiroptera visiting flowers for food may effect pollination. This is known to be the case for 31 genera in 14 families (Marshall, 1985). Megachiropteran bats also feed upon at least 145 genera of fruit in 30 families widely distributed throughout the angiosperms (Marshall, 1985). Generally fruits are consumed when ripe. Large fruits must be consumed *in situ*, but smaller fruits may be carried away before being devoured and the seeds ejected through the mouth or anus. The distance a seed is carried will depend on its size and the size of the bat; tiny seeds which pass through the alimentary canal of a large bat will be carried furthest. Some species can travel up to 50 km each night to feed so that long-distance dispersal may sometimes occur. In the Philippines, an increased germination rate has been recorded for fig seeds (*Ficus chrysolepis*) taken from bat faecal masses (Utzurrum and Heideman, 1991). Because long-distance seed dispersal by fruit bats is primarily through faecal deposition, this makes bat dispersal even more effective than previously suggested.

On many oceanic islands, which have limited faunas, fruit bats are the only animals capable of carrying large-seeded fruits. In such ecosystems, fruit bats can be the single most important pollinators and seed-dispersers. In island ecosystems in the south-west Pacific, fruit bats are considered 'keystone species', because significant declines in forest regeneration rates and diversity would accompany their extinction (*Cox et al.*, 1991, 1992).

It has been shown that bats play a vital role in the regeneration of cleared areas. It has been estimated that bats contribute up to 95% of the seeds deposited in cleared, open areas (Thomas *et al.*, 1988).

Many of the plants that benefit from pollination or seed dispersal are economically important to man (Fujita and Tuttle, 1991; Wiles and Fujita, 1992). At least 443 products useful to man are derived from 163 plant species that rely to some degree on bats for pollination or seed dispersal (Fujita and Tuttle, 1991).

19.3.1 Conservation status of fruit bats

Mickleburgh, Hutson and Racey (1992) reviewed the conservation status of all Old World fruit bats. Table 19.1 summarizes the conservation gradings for all species.

19.3.2 Conservation options

There are a number of options available to help conserve threatened fruit bat populations. All of these are not mutually exclusively and ideally a species' survival is best guaranteed through a combination of options.

(a) Survey

For many species there is no information on current population status or trends. Surveys using standardized techniques need to be undertaken, particularly within protected areas.

(b) Habitat protection and management

Most fruit bat species are dependent to a large degree on forest, particularly primary forest. Protection of forest and the control of destruction are of the highest priority to ensure the survival of many

Table 19.1 Conservation gradings for Old World fruit bats (after Mickleburgh, Hutson and Racey, 1992)

Category[a]	*No. of species*
Extinct	3
Extinct (within last 50 years)	4
Endangered	14
Vulnerable	10
Rare	16
Indeterminate	7
No data	35
Not threatened	72
Total	161

[a]These are based on the criteria used by IUCN with the addition of a 'No Data' category for species where there is little or no information available to assess status.

species. In many cases the ultimate survival of endangered bat species rests with the Protected Areas System. The setting up of protected areas should be the goal of national conservation effort.

Forests can be managed with bats in mind through the maintenance of roosting trees (often large canopy trees) and a diverse understorey. Where caves are used as roosting sites, these can be managed to limit disturbance.

(c) Legislation

All *Pteropus* and *Acerodon* species are protected under the CITES regulations, although the level of protection varies. Other species receive varying degrees of protection at a local, national or international level. Legislation at all levels can be improved or implemented to ensure better protection for species, their habitats and roosts.

(d) Education

This is an almost universal need and can cover a variety of subjects. It can be general, emphasizing the role bats play in tropical ecosystems, or be aimed at specific groups such as fruit-growers, hunters or tourists.

(e) Captive breeding

Captive breeding is an invaluable tool to ensure the survival of critically endangered species. Ideally it should be undertaken before populations reach critical levels.

19.4 CAPTIVE BREEDING OF FRUIT BATS

Captive populations of at least 15 species of fruit bat are held at zoological institutions world-wide (Olney and Ellis, 1991). Most are non-threatened species. Some, such as the Egyptian fruit bat (*Rousettus aegyptiacus*) and the Indian fruit bat (*Pteropus giganteus*), have been successfully bred at a large number of institutions. Experience with such non-threatened species may provide invaluable information for current and future breeding programmes for endangered species. Mickleburgh, Hutson and Racey (1992) recommended that captive breeding programmes be considered for 15 species (Table 19.2). Three species were thought to be probably already extinct (two had not been seen for more than 50 years and one within the last 50 years) and for these captive breeding would be essential were they to be relocated in the wild.

In order to facilitate cooperation between zoos and to maximize effective use of cage space available for fruit bat breeding, regional Taxon Advisory Groups (TAGs) for fruit bats have been established in North America and the British Isles. These TAGs have been established under the auspices of the American Association of Zoological Parks and Aquariums and the Federation of Zoological Gardens of Great Britain and Ireland. Through liaison with field workers and the relevant SSC specialist groups, the Taxon Advisory Group seeks to prioritize species programmes for captive breeding and to ensure cooperation among zoos in order to maintain these priority species over the long term.

19.4.1 Recommending species for captive breeding

To date, the only successful endangered species breeding programme has involved the Rodrigues fruit bat, *Pteropus rodricensis*. A number of other schemes are underway or planned (Table 19.2). There are a number of criteria that should be considered when recommending species for captive breeding.

(a) Degree of threat

In general, the more threatened a species, the higher the priority for captive breeding. However, consideration should be given to species whose current status is more secure but whose future prospects are

Table 19.2 Captive-breeding programmes for Old World fruit bats (after Mickleburgh, Hutson and Racey, 1992)

Species	*Distribution*	*Category*[a]	*Captive breeding*
Acerodon jubatus	Philippines	E	Planned
Aproteles bulmerae	Papua New Guinea	E	Suggested
Nyctimene rabori	Philippines (Negros)	E	Planned
Pteralopex acrodonta	Fiji Islands (Taveuni)	E	Suggested
Pteralopex anceps	Bougainville, Solomon Islands (Choiseul)	E	Suggested
Pteralopex atrata	Solomon Islands (Guadalcanal, Santa Isabel)	E	Suggested
Pteropus leucopterus	Philippines	V	Planned
Pteropus livingstonii	Comoros	E	Underway
Pteropus pumilus	Philippines	V	Underway
Pteropus rodricensis	Rodrigues	E	Underway
Pteropus vampyrus lanensis	Philippines	V	Suggested
Pteropus voeltzkowi	Pemba	E	Planned
Acerodon lucifer[b]	Philippines (Panay)	Ex	
Dobsonia chapmani[b]	Philippines (Cebu, Negros)	Ex (?)	
Nyctimene sanctacrucis[b]	Solomon Islands	Ex	

[a]E = endangered; V = vulnerable; Ex = extinct.
[b]These species are thought to be extinct. Should they be relocated in the wild, a captive breeding programme would be an integral part of any management plan.

poor. Removal of individuals for a captive breeding programme from a larger population may be more acceptable than waiting until such action might jeopardize the survival of the wild population. In some instances, species that are thought to be extinct have been recommended for captive breeding. Should a supposedly extinct species be relocated in the wild (as has happened with Bulmer's fruit bat [*Aproteles bulmerae*]) its continued long-term survival may only be secured through captive breeding.

(b) Availability of suitable breeding institutions

The number of institutions with experience of breeding endangered species successfully is small. This will grow as knowledge is disseminated. The availability of expertise is vital to the success of any programme. Ideally, captive populations should be established within the range of the species with the involvement of local people. To date, this has rarely happened, although this situation will improve as more programmes are instigated.

(c) Control of threats

It is vital that the threats that currently face a species are controllable. A species cannot be released back into the wild if the factors that originally caused its decline are still operating. In some cases control of threats may not be possible and the only other option is to introduce the captive-bred species to another location.

(d) Potential for introduction/reintroduction

It is imperative that the potential for introduction/reintroduction be considered before a programme is started. In many cases the main threat is from habitat destruction. Unless there is a real chance of halting destruction or reclaiming habitat, captive breeding could be a fruitless exercise. While the ultimate aim is to reintroduce the species to its original habitat, introduction to a site outside the species' ecological range may be possible. This however raises ethical and ecological problems. Many fruit bats have very limited ranges, some occurring only on single islands. That single island may be the only possible location for a wild population, thus ruling out opportunities for introduction elsewhere. There is also the problem of the implications for indigenous fauna and flora.

All introduction or reintroduction programmes require strict scientific controls. The IUCN has produced guidelines for undertaking such programmes. These are discussed in detail by Mickleburgh, Hutson and Racey (1992).

19.4.2 *Pteropus rodricensis* – a case history

This species is endemic to the island of Rodrigues in the Indian Ocean, and in 1974 was described as probably the rarest bat in the world, with an estimated wild population of 75–80. In 1976 the Jersey Wildlife Preservation Trust in cooperation with the Mauritian government (which administers Rodrigues) initiated a captive breeding programme (reviewed by Carroll, 1988). Two founder colonies were established, one in Jersey and one in Mauritius. The Jersey colony increased without loss until 1980, although in subsequent years the number of neonatal and juvenile deaths increased. In recent years these have declined in frequency. In 1982 it was thought that density-dependent factors were increasing the incidence of juvenile mortality and the colony was divided (Carroll and Mace, 1988). Further colonies were established so that by 1991 about 250 bats were held in nine colonies in Jersey, Mauritius, England and the USA (Carroll and Barker, 1992).

The experience with *P. rodricensis* highlighted a number of potential problems with captive breeding programmes for fruit bats (Carroll and Mace, 1988). Many fruit bat species are gregarious. In *P. rodricensis* daytime social aggregations may be either harem groups with one male and several females, or mixed-sex subadult groups. At night new feeding groupings are formed. Harem males defend their roost sites with great vigilance while harem and other adult males control access to feeding stations. Thus a female may associate with and be mated by several different males in a 24-hour period. A recent study of *P. rodricensis* at JWPT by Young and Carroll (1989) showed that adult females were indeed promiscuous. They did, however, show marked fidelity to particular roost and feeding sites within the cage. As a result they did not encounter a great number of different males. Of the 11 study females, five mated with one male, four with two males and two with three males during the study period. This behaviour not only makes it impossible to assign paternity to offspring, it also means that considerable manipulation of social groups would be needed to ensure any particular male sired offspring. This would be costly in terms of cage space and would necessitate keeping the bats in unnatural social groups.

Maintaining genetic variability is crucial to any captive breeding programme. In general, the loss of genetic variation from any population depends on the effective population size and the number of generations over which the population is maintained (Carroll and Mace, 1988). It is suggested that for *P. rodricensis* the captive population should be divided into four distinct sub-populations. Within each sub-population there should be regular interchange of animals between each of the captive colonies, whereas movement of animals between sub-populations should be less frequent; only one individual per generation (Carroll and Mace, 1988). The animals moved should be females, as they integrate easily into a breeding situation and it is easier to monitor their breeding performance.

The lack of certainty of paternity is a serious hindrance in genetic management of the population. An attempt to determine paternity in *P. rodricensis* at JWPT was made using DNA fingerprinting techniques. Unfortunately, the fingerprints obtained were almost identical for most of the bats sampled and paternity could not be established (D. Ashworth, pers. comm.). Further attempts to assess paternity in the bats are being made at the Brookfield Zoo, Chicago and the Lubee Foundation, Florida (R. Phillips, pers. comm.; J. Seyjaget, pers. comm.). If data on male reproductive success can be obtained, better genetic modelling of the population and hence better long-term management of the population can be made.

Since 1976 the wild population on Rodrigues has increased. In 1990 it was estimated to be greater than 1000 individuals, but following a cyclone in February 1991 it had fallen to around 350 individuals by August of that year (K. Kelly, pers. comm.). The captive-bred population thus still provides an important safeguard against extinction as well as a reservoir of genetic variability.

19.4.3 Other captive breeding schemes

Livingstone's fruit bat (*Pteropus livingstonii*) is endemic to the Comoro Islands in the Indian Ocean. This species was abundant on the island of Anjouan in the nineteenth century but an expedition in 1989 estimated the population to be only around 60 individuals (Thorpe, 1989). In July 1990 a roost containing 60–120 individuals was discovered (Carroll and Thorpe, 1991) and a further roost with some 30 bats was discovered later that year but was abandoned in 1992 (K. Hunter, pers. comm.; S. Wray, pers. comm.). The major threats to the population are deforestation and underplanting of the remaining native forest. *P. livingstonii* appears to be unable to adapt to secondary, disturbed, or deforested habitats, unlike its sympatric cogener the Comoros lesser fruit bat (*P. seychellensis comorensis*). During 1992 an expedition from Bristol University carried out an ecological study of the two *Pteropus* species on Anjouan and, in collaboration with JWPT, attempted to capture some *P. livingstonii* for the initiation of a captive breeding programme. Six individuals were caught, five males and one female, which are now at JWPT. A further capture attempt is planned for 1993 to increase the number of bats in captivity and to equalize the sex ratio. The captive breeding programme is being carried out in collaboration with the Comorian government, which retains ownership of all the bats and of any that may be born in captivity in the future.

The Pemba fruit bat (*Pteropus voeltzkowi*) is endemic to the island of Pemba off the coast of Tanzania. Seehausen (1990) reported on a visit to the island in 1989 during which he managed to locate only three individuals. In late 1989 a single roost containing 150–200 bats was reported (H. Bentjee, pers. comm.). The main threats are from deforestation and possibly hunting. A captive breeding programme based at Phoenix Zoo is planned.

In the Philippines, two endangered fruit bat species, the little golden-mantled fruit bat (*Pteropus pumilus*) amd *P. leucopterus*, are currently held in a captive breeding establishment at CENTROP (Centre for Research in Tropical Ecology) based at the Department of Biology, Silliman University, Dumaguete City, Negros. Permission has been obtained to procure more individuals of six species, including the above two and the endangered golden-capped fruit bat (*Acerodon jubatus*) and Philippine tube-nosed bat (*Nyctimene rabori*), to enlarge this facility. This is being done in collaboration with DENR (Department of the Environment and Natural Resources) and the Lubee Foundation (W.L.R. Oliver, pers. comm.).

19.5 TRANSLOCATION

To date there have been no introductions or reintroductions of endangered fruit bats. It has been suggested that an introduction of *P. rodricensis* to an island outside the cyclone belt might be possible in the western Indian Ocean (Carroll, 1988). So far, no suitable sites have been identified. Controlling threats to populations is vital before captive-bred bats can be reintroduced. This is particularly difficult where the major threat is deforestation. Where threats cannot be controlled, and introduction to an alternative site is considered, there is the problem of availability of suitable areas. This is especially difficult with endemic species on small islands or island groups.

19.6 CONCLUSIONS

It is clear that it is possible to breed endangered fruit bats in captivity, although their survival after introduction or reintroduction has yet to be established. For a number of species, captive breeding may be the last chance to save them from extinction. In some cases, captive breeding of less threatened species may provide an opportunity to highlight their conservation problems in the wild and to prevent the population reaching the position where there is no alternative to a captive breeding programme. Captive breeding should be seen as one a number of tools that can be used to prevent the extinction of endangered species, and where possible it should be combined with education and improved management as a multifaceted approach to species conservation.

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