The Ecology of Bat Reproduction

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Did you know there are numerous species of bat, 963 in all, making them second behind the rodents as the mammalian Order with the most number of species. The question addressed in this study was to focus on the ecology of bat reproduction and the many reproductive strategies that bats have evolved throughout time, such as: delayed ovulation, delayed implantation and sperm storage. Every bat species is different to the next in these respects so the aim was to try and gather a general picture of the various reproductive strategies. This would be a help to improve the knowledge and awareness of bat population ecology.

Bats are in the order of Chiroptera, which means hand-winged. This has two sub-orders, Megachiroptera (megabats) and Microchiroptera (microbats). There are approximately 175 species of megabats and ~790 species of microbats. Megabats belong to one family, the pteropodidae, which are known as the old world fruit bats or flying foxes (Figure 1). Microbats are distributed across four superfamillies, with a total of seventeen families within this (Figure 2). The megabats are confined to the Old world tropics and feed mainly on fruit, flowers, nectar and pollen. These bats are generally larger than the microbats. Megabats do not echolocate, with the exception of only a few species of the genus *Rousettus*. Microbat species are a numerous and diverse group. All species have the ability to echolocate. Due to the excellent combination of flight and echolocation, the microchiroptera have become very skilful nocturnal hunters of insects. It is common for Microbats to have small eyes but their visual capacity is is good and none are known to be blind, contrary to the saying “as blind as a bat”.

Bats have evolved mechanisms to ensure that the birth of their young is timed to give the greatest chance of survival, for both the female and its young. For example, in the case of the bats living at the highest latitudes, the summer is short, and the young must be born early on in the year to ensure full development before winter. The females need a good food supply through gestation and lactation, the young also need to be weaned. However, there must still be time for both mothers and young to fatten themselves up for hibernation in the winter months. The summer is not long enough for mating, gestation, lactation, weaning and feeding before hibernation. The bats overcome this problem by a number of strategies.

The first of these strategies is delayed ovulation. After copulation, which occurs before hibernation, the sperm is stored in the bat uterus and oviduct. Ovulation and fertilisation is then delayed for weeks or months and does not commence for about 1-3 days after waking from hibernation. Then the egg is then fertilised and the young are born for the summer. This can be seen in many temperate species such as, *Plecotus townsendii.*

The second strategy is delayed implantation. Fertilisation always occurs immediately after copulation, which takes place usually in autumn. The fertilised egg then goes through several cell divisions and then enters an inactive state, preventing implantation. After waking from hibernation the fertilised egg can then implant. This can be seen in the Flying Fox species.

The third strategy is sperm storage. This is where sperm is stored in either the caudal part of the epididymis or the vas deferens of the male or after copulation in the uterus and oviduct of the female. Whether in the epididymis or uterus, sperm can stay alive and healthy for months.

The final strategy is reproductive synchrony with the environment. This is where birth is often synchronized so that the offspring are born in time for the periods of maximum food availability. This is beneficial as it provides abundant food for the the mother during lactation, as lactation is an energy demanding process. The births are often synchronized with the rainy seasons in the tropics, as this is a strategy mainly observed in tropical bats.

A useful way to explain the strategies was to create several case studies. Each study gave an example of each of the reproductive strategies in question.

Case study 1-*Pipistrellus Kuhlii* (chiroptera, Vespertilionidae)

Location: Widely distributed through Europe, North Africa and Arabia, mainly in temperate latitudes.

Physical attributes: Wing membrane has a white posterior margin. They are small in size, as shown in Figure 1, with forearms of 30-37 mm in length.

Monoestrous or Polyoestrous: Monoestrous

Hibernating or non-hibernating: Period of hibernation intervenes the reproductive cycle

Figure 1 *Pipistrellus Kuhli*   http://www.mammology.org

Reproductive strategy: Sperm Storage. Normally in mammals that don't store sperm large numbers of white blood cells gather and phagocytize the sperm cells. Therefore this is a remarkable process because 'foreign' cells, which are normally destroyed by the immune system, are not only tolerated, but perhaps even nourished for several months in the female (Sharifi et al, 2004).

Due to a short summer in temperate regions, the breeding cycle should typically be synchronised with abundance of insects and birth should occur over a short period of time. Sperm storage enables the bat to synchronise the above factors and is common in the genus pipistrellus. These bats have been shown to give birth in late June, therefore it is assumed that ovulation and fertilization occurred during the second half of May. Since bats collected in mid-December had uterus packed with spermatozoa it is therefore evident that spermatozoa can be stored for up to five months in the female reproductive tract.

Case Study 2-North American Big-Eared Bat, *Plecotus Townsendii* *(*Vespertilionidae)
Location: Western Canada, The western united states to southern Mexico and a few isolated populations in eastern United States.
Physical attributes: Weight: 8-14 grams, Wingspan**:** 30-32 centimetres, feeds entirely on moths. Large ears that are well adapted for echolocation (Figure 2)

Monoestrous or polyoestrous: Monoestrous

Figure 2 *Plecotus townsendii.* http://www.mammology.org

Hibernating or non-hibernating: Hibernating

Reproductive strategy: Delayed ovulation, After copulation, sperm are stored in the uterus and oviduct. Ovulation is delayed for weeks or months and does not re-establish until 1-3 days after initial arousal from hibernation (Neuweiler, 2000).

In this bat, copulation takes place in late autumn and continues throughout the winter hibernation though the temporary periods of arousal. Oestrous begins in August in the female bat and although a fully developed follicle is present at the time of copulation, the sperm are unable to fertilize it. The egg remains enclosed in the follicle, surrounded by a structure called a discus proligerus. This stores large amounts of glycogen that the egg uses for energy during hibernation (Neuweiler, 2000). During hibernation the ovaries are under the influence of FSH until around late February when LH secretion resumes and brings about ovulation. Now, the sperm that have been stored in the uterus for many months can fertilize the egg.

On the basis of the enzymes present in the follicle during hibernation, it can be concluded that the reproductive cycle is simple interrupted and does not end. Even though the oestrogen levels sink to a minimum during the hibernation period, the full sets of enzymes necessary for oestrogen and progesterone synthesis are still retained. These only disappear in the summer after the birth of the young.

Figure 3 *Miniopterus schreibersii* http://www.mammology.org

Case Study 3-Miniopterus Schreibersii*, (Vespertilionidae),* Bent-winged bat

Comparative locations: Southern Europe and Australia, temperate regions

Physical attributes: It has a short snout and a high 'domed' head with short round ears (Figure 3). Its colouration is black to red-brown on top with a paler colour underneath. They are capable of fast and level flying that is interrupted by quick, shallow dives to gather prey.

Monoestrous or Polyoestrous: In Europe *Miniopterus Schreibersii* has a typical mammalian Monoestrous cycle. However, in Australia the shorter period of hibernation means that the summer is long enough to accommodate two consecutive ovulatory cycles, whereas in Europe the longer period of hibernation appears to prohibit this occurrence.

Hibernating or non-hibernating: Hibernating, European species hibernate for 5 months and Australian species hibernate for 3 months

Reproductive strategy: Delayed Implantation.
Copulation is carried out in autumn and is followed immediately by ovulation, fertilization and initial embryogenesis. The females then enter hibernation in late autumn in a pregnant condition with unimplanted blastocysts in their uteri. Permanent arousal in spring from hibernation follows with the blastocyst implanting and embryonic development is resumed. Parturition occurs in late spring, followed by a lactational anoestrous period.

Since *Miniopterus schreibersii* has a wide geographical distribution, it displays a wide variety of reproductive patterns dependent upon location (Altringham, 2001). Figure 4 shows the adaptive reproductive cycles of this bat in four locations.

Physiological Explanations for Adopted Strategies

Firstly, Bernard and Bojarski (1994) investigated the possible effects of prolactin and human chorionic gonadotrophin (hCG), to see if it could be a possible cause or explanation for the physiological control of delayed implantation in *Miniopterus schreibersii*. They concluded that prolactin seems to be the most important pituitary hormone in the control of delayed implantation, although the route via which it induces implantation is unknown.

Secondly, Krishna and Abhilasha (2000) carried out a study to evaluate the effects of luteinizing hormone (LH), follicle-stimulating hormone (FSH), insulin, and insulin-like growth factor-1 (IGF-1) to try and understand the mechanism responsible for delayed ovulation in *Scotophilus heathi*. They concluded that, increased LH release, if coincident with the period of enhanced ovarian responsiveness to LH, may result in the excessive androstenedione production responsible for delayed ovulation in *S.heathi.*

Thirdly, Beasley et al (1984) investigated whether melatonin could be the controlling mechanism for initialising sperm storage in male pallid bats. They concluded that subcutaneously implanted melatonin plays an important role in the onset of storing sperm leading up to the hibernation period when the days shorten.

McGuckin and Blackshaw (1992) carried out a study to look at the effects of photoperiod in the reproductive physiology of male flying foxes, *Pteropus poliocephalus,* to see if it controlled the timing of their reproductive cycle. They concluded that regulation of the timing of reproduction in males of this species is influenced by changes in daylength. However Heideman and Bronson (1994) carried

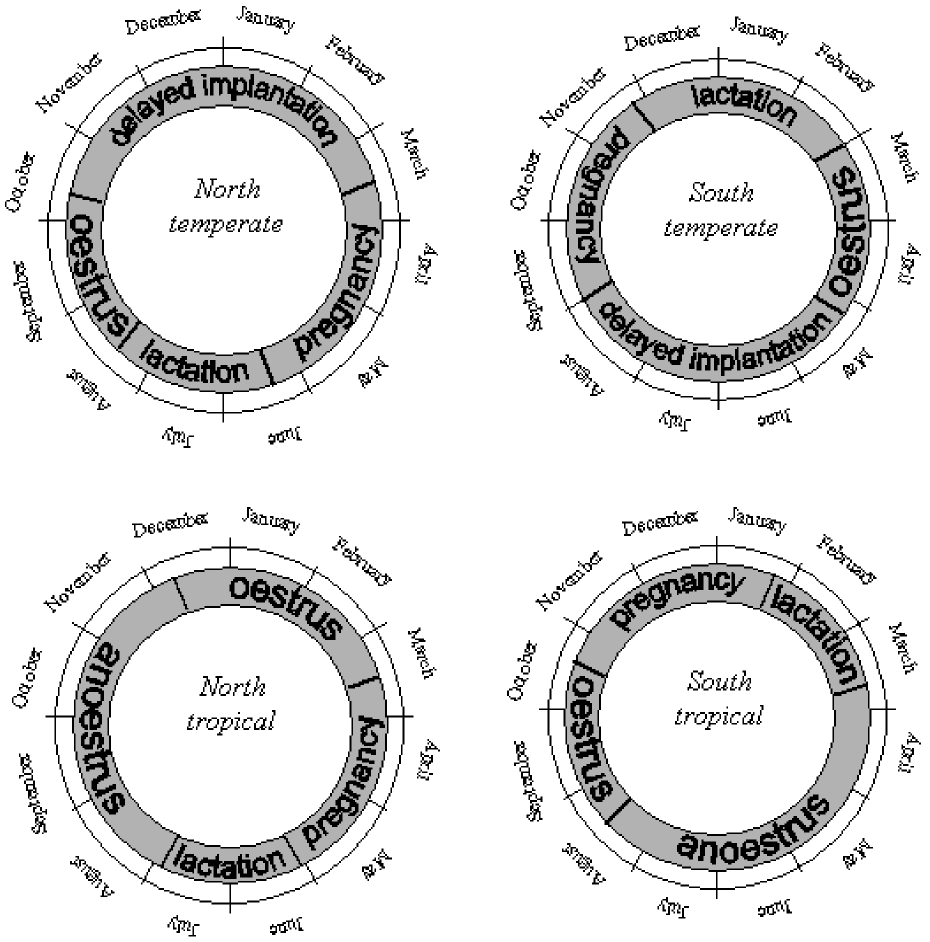

Figure 4 Various reproductive cycles of *Miniopterus schreibersii* in four different locations (Adapted from Altringham, 2001).

out an investigation to look at the effects of photoperiod on the tropical bat, *Anoura geoffroyi.* They found that photoperiod did not have any effect on this bat, so the jury is still out on whether photoperiod has any effect on the reproductive cycle of bats.

Another important question is the role of environmental cues in bat behaviour. One of the main queries is, how do the bats know when to emerge from hibernation?

A possible cue could be temperature, but this will depend upon the depth of the cave. If the cave is deep then the temperature change from the external environment will not be noticeable, but if the cave is shallow and there is some penetration of light then maybe temperature could be a cue.

Another possible cue could be humidity, but again this will depend upon the characteristics of the cave. Photoperiod is not thought to be a cue, as bats favour the dark, damp environment of caves, where there is little light penetration.

It is possible to think that air pressure may be one of the more important environmental cues. External air pressure changes would be able to be sensed within the cave environment more significantly than other seasonal changes, such as photoperiod, temperature or humidity.

There could also be the possibility of 'messenger bats'. This could be one or two bats from a large group that temporarily comes out of hibernation to inspect the external environment.

These bats could then come back and inform the other bats whether the conditions are right for arousal from hibernation.

Finally, biological clocks play a very important role in the timing of hibernation and knowing when to wake from hibernation. All hibernating mammals show an endogenous timer that enables them to anticipate and prepare for the onset of winter (Hastings and Ebling 2006).

This review of bat reproductive ecology has highlighted several possible mechanisms for the physiological processes governing reproduction in bats.Due to the huge diversity of bats it has been hard to find one certain answer as to what is responsible for controlling the various reproductive strategies. Consequently much research remains to be done, before the life cycle of the bat comes out of the dark.

Further Reading

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Author Profile:

Sophie Bradley is 21 years old who went straight to the University of Nottingham on completion of her A-levels. She studied at the School of Biosciences and graduated in July 2006 with an upper second class BSc with honours degree in Animal Science. Sophie was interested in many areas of animal science, especially in the areas of ecology and animal behaviour. She completed a wide range of modules from marine zoology to global environmental processes to animal production science. Sophie aims to work in the field of reproductive biology with a particular interest in captive breeding programmes.

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