
Wings of the Night: The Natural History of Bats

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For most of us, bats are one of the most enigmatic creatures that normally evoke a sense of mystery, fear and even revulsion. The main reasons for this pitiable attitude towards these animals are rampant myths and misconceptions about them that prevail in our society. The following article is an attempt to present these animals in scientific light and to dispel any misconception about these misunderstood creatures.

In zoological parlance, bats belong to a group called Chiroptera, which literally means, 'hand winged'. The very name is derived from the fact that in these mammals, the forelimbs are modified to accommodate a fold of skin stretched between the limbs. This thin but highly tensile skin, known as patagium, is the flying apparatus of bats which is capable of producing enough thrust to counteract drag and gravity for flying (*Figure 1*). Such development of functional wings is the unique characteristic of bats and thus makes them the only mammalian group with the capacity of highly maneuverable flight. Evolution of flight in bats is accompanied with extensive morphological and anatomical specializations like development of pectoral area for attachment of strong flight muscle, concentration of body mass towards the centre of gravity to increase aerodynamic stability, development of uropatagium (tail membrane) and calcar (cartilaginous projections from the ankle) to support it (*Figure 2*). However, what promoted these animals to resort to flying is still a matter of speculation.

Flapping flight as exhibited by bats is the single most evolutionarily successful mode of animal locomotion. But the fundamental mechanics of this highly maneuverable, three dimensional and complex movement is little understood. The flying mechanism of a bat differs markedly from that of birds and insects largely owing to the unique structural design of bat wings. Scientists have found



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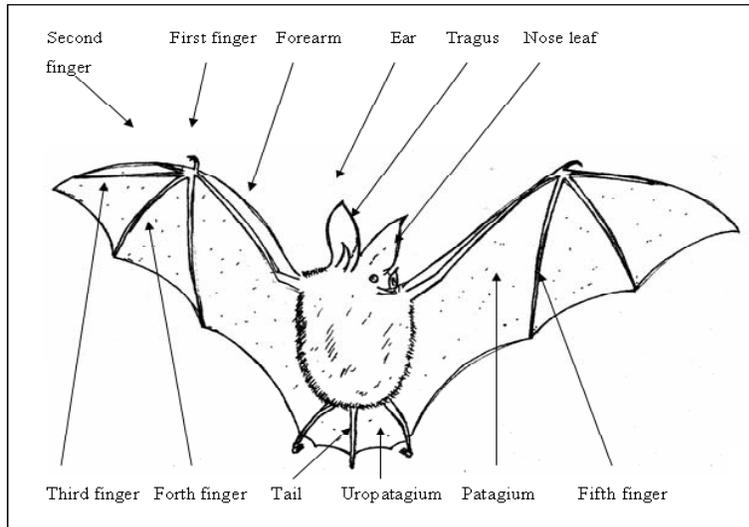
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Figure 1. External Morphology of a bat.

Illustration by Uttam Saikia



that bat wings have certain special features like multiple joints which can be controlled independently, flexible bones that deform adaptively during wing-beat, tensile wing membrane skin with adjustable stiffness across the wing and a distributed network of skin sensory organs believed to provide continuous information regarding flows over the wing surfaces. High-speed camera studies on bat flight have suggested that a wing-beat cycle has two components, an upstroke and a downstroke. During downstroke, initially the whole body and wing is stretched to get maximum lift and is aligned in a straight line, followed by the wings bending downwards. At the end of a downstroke (beginning of upstroke), the wing is still bent downward and then retracted towards the body. During upstroke, substantial bending

of elbow, wrist and finger joints is observed with bone length maxima and minima occurring at regular interval in a wing-beat cycle. However, how this bending influences flight maneuverability is yet to be explained.

Origin and Evolution: Leaps in the Dark

There has been a lot of speculation among the scientific community regarding origin and consequent evolution of these flying mammals. It is

Figure 2. Colourful Painted bat *Kerivoula picta*.

Photo: Abhijit Das



Box 1. Earliest Flying Mammal

A team led by scientists from American Museum of Natural History (AMNH) discovered the first flying mammal. According to a recent report in *Nature*, scientists have found fossil of a small mammal in China that they believe is 130-165 million years old. This animal with a fur covered skin stretched between limbs was probably a deft glider, indicating that mammals romanced with flight along with birds or even before the Jurassic period. *Volaticotherium antiquus*, as scientists named the new animal, belong to an entirely different extinct mammalian order. According to Dr. Jin Meng, a paleontologist at the AMNH and an author of the article, the squirrel size animal was probably nocturnal and insectivorous.

believed that ancestors of bats were either arboreal, diurnal frugivores or arboreal and nocturnal insectivores, and probably gliders. They later developed powered flight presumably driven by the energetic and anti-predatory advantages associated with flight. Some scientists even hypothesized that bats are descendants of primates, although recent molecular studies do not support the idea. Interestingly enough, bats are not the first group of mammals that courted with flight (*Box 1*). The earliest known fossil of a true bat is 53 million years old (early Eocene) found in marlstone from the Great River formation in south-west Wyoming, USA. A well preserved skeleton of a bat (*Icaronycteris index*) was excavated from there and the exceptional clarity of wing membrane and enlarged cochlea left no doubt about it's capability of echolocation and sustained flight. No reliable fossil record has ever been found predating this and indicating the intermediate stage of chiropteran evolution. However, scientists speculate that in order to evolve completely by early Eocene, they must have originated in the Paleocene or mid/late Cretaceous (70-100 million years ago). Having said that, it is important to emphasize that in the absence of any fossil evidence, all interpretations of origin and evolution of these animals are only conjectures and merely intellectual leaps in the dark.

Bat Diversity

Bats are a very diverse and complex group of mammals found throughout the world except the Arctic, Antarctic and certain oceanic islands. Among mammals, they are the second most

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Box 2. Taxonomy

Ever since the time of Dobson (1875), the order Chiroptera is classically subdivided into two suborders, Megachiroptera (megabats) and Microchiroptera (microbats). The basis for this classification was apparently body size although afterwards, the two suborders were shown to exhibit profound differences in anatomy, behaviour and ecology. Megachiroptera include comparatively large and fruit eating bats that rely on visual perception for orientation and foraging. On the other hand, Microchiroptera, comprises smaller and largely insectivorous species that have very reduced reliance on visual mode of perception, instead, evolved a signature acoustic mode of perception called echolocation. All Megachiroptera belong to a single family Pteropodidae comprising 167 species distributed in the old world tropics. Microchiroptera comprises 834 species distributed over seventeen families. Based on premaxillary morphology, Microchiroptera is further subdivided into two infraorders, 1) Yinochiroptera comprising seven families – Rhinopomatidae, Craseonycteridae, Emballonuridae, Nycteridae, Megadermatidae, Hipposideridae, Rhinolophidae and 2) Yangochiroptera comprising ten families – Noctilionidae, Marmoopidae, Phyllostomidae, Natalidae, Furipteridae, Thyropteridae, Myzopodidae, Vespertilionidae, Mystacinidae and Molossidae. Of the Microchiropterans, the most diverse family is probably the Phyllostomidae (the New World Leaf-nosed Bats), with 49 genera, and the largest family is Vespertilionidae (Vesper or 'Evening' Bats), with over 300 species.

speciose group after rodents. Conservative estimates put their number at 1,001 species globally that constitutes up to 20% of mammalian diversity. But applications of recent molecular techniques have resulted in the splitting of several species complexes and elevation of some subspecies to species status. As a result, the current number of recognized species has increased substantially to 1,105. These studies also call into question the classical subordinal divisions of the order Chiroptera as Mega- and Microchiroptera (*Box 2*). There has been an increasing body of evidence to suggest that all megabats along with certain families of microbats form a sister group to the rest of microbats (*Box 3*).

Echolocation: Inbuilt Sonar in Bats

Contrary to the popular perception of bats being blind, they possess functional eyes with good vision and some species like *Taphozous kachhensis* probably see colour. All megabats have large eyes which are sensitive to low light situations enabling foraging and movements in the night. In microbats, eyes are somewhat less developed and thus have reduced dependency on this mode of perception for navigation and foraging. Instead, they



Box 3. New Tools in Bat Systematics

The classical approach describing a bat species is based on morphological characteristics like external appearance, colour, fur texture, dentition, cranial structure etc. Although this old fashioned approach is still largely useful, new emerging techniques have revolutionized bat taxonomy and provided new insights to our understanding of the speciation process. Scientific advances in the last few decades have created some staggering tools that can tell the similarities and differences among bat populations that look identical otherwise. Protein electrophoresis and Polymerase Chain Reaction (PCR) are two techniques that are now widely used in bat taxonomy. Protein electrophoresis is used to determine the size and electric charge of protein. Protein from different organisms are placed in a gel and subjected to field. Depending upon size and net charge, individual proteins will move towards one or the other pole at different speed. Differences in the electrophoretic patterns of proteins serve as distinct markers for distinguishing species or populations. One good example of its application in bat taxonomy is in solving the taxonomic complexity of fruit bat *Cynopterus brachyotis* that occur in South and Southeast Asia. Protein electrophoretic studies by scientists from Western Australian Museum demonstrated that *C. brachyotis* is indeed a species complex with many distinct species clubbed together. Some species within this complex are confined exclusively to certain islands of Indonesian and Phillipine archipelago. Polymerase Chain Reaction is another potent biological tool by which countless copies of individual DNA segments can be made with ease. DNA sequences derived from PCR can be used to answer a host of questions like origin, evolution, phylogeny etc. Bat biologists are increasingly resorting to this technology to define species and to understand their phylogenetic relationship. For example, recent PCR based molecular studies have demonstrated that the classical subordinal division of bats as Megachiroptera and Microchiroptera is erroneous with many families under Microchiroptera sharing a closer relationship with Megachiroptera rather than Microchiroptera. This has led to the proposition of a new scheme of subordinal divisions – Yinpterochiroptera which included microchiropteran families Rhinolophidae, Megadermatidae, Rhinopomatidae along with megabats and Yangochiroptera including rest of the microbat families. [2]

have developed a distinct sensory specialization called echolocation which enables them to orient in space, search their food, and to roost in places where light intensity is low. Two megachiropteran genus *Rousettus* and *Eonycteris* display some primitive capability of echolocation although the sound producing mechanism is markedly different from that of Microchiroptera. However, it remains an open question whether Megachiroptera evolved echolocation and subsequently lost it or did not evolve the skill at all.

Echolocation, is an acoustic sensory mechanism wherein sound waves of high frequency is used to extract information about the immediate environment. Echolocation works on the same principle as sonar used in sea vessels. Bats produce sound wave from laryngeal vibrations whose frequency ranges from 20-200 kHz ¹.

¹ The upper limit of human auditory range is 20 kHz, hence bat sounds are largely inaudible to us.



Box 4. The Ducking Moths

In the endless struggle for existence, organisms sometimes acquire some novel survival skills. In order to counteract a hunting bat, certain insects groups like moths, crickets have evolved functional ‘ears’ that are sensitive to ultrasonic sound. Upon detecting a bat call, these insects may display evasive maneuvers like dropping to the ground or produce a warning call. The Polka dot wasp moths *Syntomeida epilais* respond to a bat call with it’s own ultrasonic call that sometimes thwart a bat attack. Although how these moths deter bat attacks is not entirely clear, the acoustic aposematism (warning) hypothesis suggests that these warning calls convey the message that they are distasteful and thus deterring a marauding bat.

Upon hitting any target in space, the sound waves are reflected back and the echo is detected by the bat and analyzed. Insectivorous bats use a variety of signals to obtain information about the environment and prey while hunting. In fact they are able to decipher information like presence, position, speed and even identity of potential prey. Intensity and frequency of echolocation calls varies among species and even among individuals. Certain groups of insects can hear an echolocating bat and have developed novel bat avoidance strategy to counteract it (*Box 4*).

Roosting Habits

Evolution of flight has permitted bats to exploit a variety of resting places that are inaccessible to most of the other vertebrates. Some bats roost in protected shelters like rock crevices, caves, dilapidated buildings, abandoned mines, tunnels, tree trunks and fallen logs while others use temporary external shelters like foliage (*Figure 3*). Some species even manipulate leaves and

Figure 3. Fulvous fruit bat roosting in a cave.

Photo: Uttam Saikia



branches of trees to use them as roosts known as tents (*Figure 4*). More than twenty species of bats are known to roost in such tents. Megabats have successfully adapted to a variety of external roost while microbats with the help of echolocation have succeeded in utilizing a variety of protected shelters. Sheltered roosts offer the advantages like permanency, microclimate stability, lesser predation risk and protection from environmental rigors while external shelters are temporary, and prone to envi-





Figure 4. Flying foxes roosting in a Eucalyptus tree.

Photo: Uttam Saikia

ronmental fluctuations. There is a general tendency for bats that roost in internal shelters to be highly gregarious. An estimated 20 million Mexican free-tailed bats roost in the Bracken Cave in Texas, USA which is the largest known mammalian congregation. Bats especially in the temperate regions undergo hibernation during winter. During that period, they congregate in large numbers in suitable cave roosts and maintain a state of inactivity coupled with lowered metabolic rate until favourable temperature returns.

Feeding Habits

During long evolutionary sequence, bats had undergone trophic radiations to a variety of trophic niches. Consequently, modern bats are adapted to a wide variety of feeding habits that include fruit, flower, pollen, insects, the flesh and blood of a variety of animals. All megabats commonly known as fruit bats are predominantly fruit or nectar eaters (frugivores, nectarivore) although some occasionally supplement their diet with insects. However, microbats are most diverse in dietary habits. Even though predominantly insectivorous, some species especially false Vampires (family Megadermatidae), slit faced bats (family Nycteridae) and leaf nosed bats of the family phyllostomidae eat small rodents, lizards, frogs and even other bats. A few species like the Bulldog bat and fish eating bat of Central America

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Box 5. Altruistic Vampires

Among the three species of sanguivorous vampires; white winged vampire *Diaemus youngi*, hairy legged vampire *Diphylla ecaudata* and common vampire *Desmodus rotundus*, the latter show a rare reciprocal altruistic behaviour by way of feeding any hungry individual in the colony. If an individual has not found food for a short period, its condition would deteriorates rapidly. An individual is close to starvation within 2-3 days. Studies have shown that these vampires set up buddy system with pairs of bats (mostly female, may or may not be related) forming tight blood sharing group. Individuals who have fed successfully will feed the hungry one by regurgitating which may be reciprocated by the recipient when need arises. Since starvation can happen to any bat at some time, all bats benefit by this insurance policy of being fed by other at the time of need.

specialize in eating fish (Piscivore). The New Zealand lesser short tailed bat is omnivorous, devouring anything it can overcome. A few species of bats, commonly known as vampires (Box 5) are found in Central and South America and specialize in a diet of blood of vertebrate animals (sanguivore).

Breeding Behaviour

Bats exhibit a great variety of mating systems. Most species including the fruit bats have a polygynous or promiscuous mating system. These bats often congregate in a single place and mate with as many individuals as possible. Some Neotropical micro-bats display the Harem system of mating whereby a few individuals defend small harems of females and secure all mating with them. There are also examples of monogamous bats where male female and offspring roost in a family group. One megabat species *Hypsignathus monstrosus* has a lek mating system where many males will display to females and the female has the liberty of choosing the most desirable mate.

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Breeding season also varies among species. Many temperate bats breed seasonally in order to coordinate reproduction with resource availability to support the newborns. However, most tropical species do not show seasonal breeding as in tropics, resources are less variable seasonally. In contrast to other animals of comparable body size, litter size is small in bats, usually one to



two pups are born. Newborns exhibit complete dependency on mothers till 2-4 weeks of age after which they start flying and are weaned. Females of some species of bats congregate during breeding period and form maternity colony. In these maternity colonies, young pups are collectively looked after by other females when mothers are out on a foraging trip.

Why Bats are Threatened?

Leaving aside habitat destruction and other man-made factors that are posing threats to their survival, bats have certain inherent biological bottlenecks that increase their susceptibility to environmental stochasticity. Typically, small mammals have a high reproductive output in order to balance survival against catastrophic environmental events. Bats are exception to this general rule. Most of the bat species are characterized by small litter size and only one litter per year. Thus, if there is a sudden population decline (whatever the cause may be) they are unable to recover fast. Besides, many of the bat species have specific habitat requirements. For example, cave dwelling bats roost and hibernate inside caves. Since such specific habitats are limited in occurrence, numerous individuals congregate in suitable places where there are less chances of local catastrophic events. Any such event could prove fatal to such local populations and can sometimes jeopardize the species survival. For example, flooding of one hibernating cave of Indiana Myotis in the US caused an estimated loss of 300,000 individuals of an endangered species. Hibernation or winter sleep is another Achilles heel in the life history of bats. Bats are one of the very few mammalian groups that truly hibernate although not all species do so. During the summer season, bats store up fat energy which is crucial to maintain them through hibernation. Arousal from hibernation puts a great energetic strain on them. A single arousal can burn two month's worth of stored fat energy! If hibernating bats are disturbed repeatedly, they would end up spending stored energy which could prove fatal for them. Thus, insulating hibernating caves from anthropogenic disturbances is at a premium for their survival.

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An estimated 45% of bats in the world are endangered, threatened or near threatened. Assessment at the Conservation Assessment and Management Plan (CAMP) Workshop 2002, points out that out of the 112 species of bats occurring in India, over 50% are endangered, threatened or near threatened.

Protecting Bats: The Indian Scenario

As human population expands, other species are continuously forced towards the edge of extinction and bats are no exception. Because of wanton damage and destruction of habitats, bat populations are in alarming decline throughout the world and at places have undergone into local extinction, warranting immediate conservation initiatives. To add to this woe, bats are being mercilessly persecuted and destroyed due to misconceived health threats. Besides, in some regions, bats are hunted for food and for purported medicinal purposes, further reducing their numbers. An estimated 45% of bats in the world are endangered, threatened or near threatened. Assessment at the Conservation Assessment and Management Plan (CAMP) Workshop 2002, points out that out of the 112 species of bats occurring in India, over 50% are endangered, threatened or near threatened. Unfortunately, Indian lawmakers are still in slumber and Wildlife (Protection) Act, 1972 continues to categorize fruit bats as vermin that can be killed with impunity. In the backdrop of such a grim scenario, the silver lining is that two critically endangered species namely Salim Ali's fruit bat (*Latidens salimali*) and Wroughton's free tailed bat (*Otomops wroughtonii*) have found a place in Schedule I of the Act in 2002. The former species is known only from the type locality (High Wavy Mountains) in Tamil Nadu and is endemic to India while the latter has been reported from Barapede cave in Karnataka (estimated population size below 100 individuals) and East Khasi Hill district in Meghalaya. There is an urgent need to include at least all endangered species of bats under the purview of the Act and offering them maximum possible legal protection.

Protection of roosting habitat is a major issue in bat conservation. A major hindrance in protecting roosting colonies arises from the fact that in many cases the roosting places are under private ownership and it is difficult to ensure long term protection in private land. In this context, a pragmatic step would be to make the public aware about the tremendous importance of these much maligned creatures and encourage their protection. Conservation



organizations can play a proactive role in this regard but unfortunately we do not have the likes of Bat Conservation International of the US or Bat Conservation Trust of UK championing the cause of bat conservation. Barring certain isolated efforts (like the dedicated bat research group of Madurai Kamraj University), systematic and intensive studies on the chiropteran fauna in India is literally non-existent which is hindering conservation of these animals to some extent. Sound knowledge of the biology and ecology of these little known animals could go a long way in developing an effective strategy for conservation.

Maligned or Malicious ?

Myths and superstitions are artifacts of ill-conceived human imagination. Bats being a poorly known group, misconceptions are rampant, further promoting them as repulsive and dangerous creatures. They are an integral part of folklores throughout the world, but for all the wrong reasons. To add to this are popular media hype where vampire bats are projected as creepy blood sucking creatures that suck blood from humans when asleep. As already mentioned, out of three species of vampires, only *Desmodus rotundus* feed on mammalian blood. They normally make a small slit on an animal body and lick the oozing blood. The small amount of blood it takes does not pose any threat to the animal's health, however, this may sometime serve as a means for transmission of rabies. There are many grossly exaggerated public health concerns regarding bats and disease. One such concern is about human rabies. Rabies, a viral disease, is typically spread by the bite of a rabid animal and is invariably fatal after manifestation. Wild canids (Dogs, Fox, Wolf), Viverrids (Badger, Civet) and Herpestids (Mongoose) etc., are the primary reservoir of the virus and to a much lesser extent bats. According to the World Health Organization, 35-50 thousand people die of rabies worldwide annually. A vast majority (over 95 percent) of these cases result from contact with rabid dogs. According to an estimate, less than 40 people contracted rabies from bats in the United States during the last 40 years. In fact the chances that one will be

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infected with rabies from bat are less than that of being struck by lightning. Despite that, bats are often cited as a high risk animal for rabies transmission. Besides, unlike a rabid dog which becomes aggressive and bites anyone on its way, a rabid bat becomes paralytic and does not attack at all. Another health concern associated with the bat is regarding the pathogenic fungus *Histoplasma capsulatum* which causes human histoplasmosis. This fungus develops in soil enriched with bat or bird droppings especially in hot humid conditions. The fungus is rare in dry and cooler climates. People come in contact with the fungus by inhalation of dust laden with spores. In majority of cases, histoplasmosis is manifested as mild flu like condition which could be serious in some cases. Risk of human histoplasmosis from bat is no more serious than from birds. Excessive and unfounded worry about public health is counterproductive to community health interests and may prejudice people against these beneficial and declining animals.

Bats are an integral part of ecosystem providing immense services towards the benefit of the natural world and human economics. Insectivorous bats are an important agent in keeping the level of burgeoning insect population under check. They are super efficient bug eaters, each bat consuming up to 1,000 mosquitoes per hour. A nursing Little Brown bat can consume more than its own weight of insects each night! The 20 million Mexican Free-tailed bats roosting in Bracken Cave in Texas, USA, are estimated to eat a staggering 250 tons of insects each night. Many of these insects are agricultural pests and hence their control is crucial for agricultural productivity. Thus, bats provide a priceless and harm free alternative to pesticides.

Many tropical bats feed on fruit and nectar and in the process pollinate plants and disperse seeds, helping to regenerate the forest. Seeds dispersed by bats can account for up to 95% of forest regeneration in cleared land. There are some 500 species of plant that depend partially or wholly on bat for propagation and many of them are of substantial economic importance. Approximately 70% of fruits sold in the tropical market depend on bats for



Box 6. Some Amazing Bat Facts

- The bumblebee bat *Craseonycteris thonglongyai* of Thailand is the smallest bat weighing just 2-3gm.
- Some flying foxes like *Pteropus vampyrus* have a wingspan over six feet and weighs around 1.5 kg.
- Compared to the body size, bats are amazingly long lived animal, the record being 33 years for little brown bat *Myotis lucifegus*.
- Although look like slow fliers, some species of bat can fly at a speed of 50km/hr.
- The woolly bats of South Africa live in the nest of colonial spiders. Some *Myotis* are known to live in active ant nests.
- Fishing bats have a very sophisticated echolocation mechanism whereby they can detect a minnow's fin protruding slightly over the water surface.
- A potent anticoagulant extracted from saliva of vampire bats may soon be used to treat victims of strokes or heart attack.
- In earlier days, bat guano was an important source of potassium nitrate used for making gun powder.

pollination in the wild. Experiments have shown that seeds of several species of plants have better germination rate if they passed through the gut of a bat than those simply falling on the ground. Some plants have evolved a close mutualistic association with bats, a phenomenon termed as Chiropterophilia. The baobab tree (*Adansonia digitata*) of African savannah is known as the tree of life because it provides food and shelter to numerous animals. Their continued survival is largely dependent on bats. Their flowers open from below and nectarivorous bats are best suited to pollinate them. They are typically visited by fruit bats like *Epomophorus wahlbergi* soon after blooming. In India, pollination of economically important trees like *Ceiba pentandra*, *Ficus* sp. (fig), *Mangifera indica* (mango), *Musa* sp. (banana) *Careya arborea* by Pteropodids like *Pteropus giganteus* and *Cynopterus sphinx* are well documented. Studies on pollination biology of *Ceiba pentandra* and *Careya arborea* in southern India have shown that apart from insects, fruit bats are major pollinators of these trees. Floral characteristics of these plants like nocturnal blooming, strong odour, sturdy flowers with wide mouth, and copious amount of nectar probably evolved to aid nocturnal pollination especially by bats. Bat droppings (guano) are an ideal source of agricultural fertilizer. A variety of microorganisms thrive on guano including bacteria useful in detoxifying

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wastes, producing gasohol, antibiotics, etc. Scientists have discovered that a unique ecosystem develop on bat guano inside caves. A cave dwelling salamander in the USA is reported to use bat droppings as food.

Epilogue

Bats being a provider of crucial ecological and economic service, any drastic decline of their population could result in irreparable ecological and economic loss. In some ecosystems, bats are keystone species and the health of the ecosystem is inextricably linked to them. The existence of many unique ecosystems on earth hinges on the survival of a viable bat population and thus on our ability and willingness to protect them.

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