Personal Reflections

My Tryst with the Bats of Madurai

As you set out for Ithaka,
Hope your road is a long one,
Full of adventure, full of discovery

C P Cavafy

I have often been asked by people how I came to work with bats. The story may be well worth recounting, weaving into my account, for the benefit of younger readers, the minor hurdles, the adventure, excitement and thrill of working out in the open at night and inside caves with bats. My affair with the bats of Madurai had lasted two decades and five of my students wrote their PhD theses on the biology, ecology, behaviour and biological clocks of bats. Today the Department of Animal Behaviour & Physiology, Madurai Kamaraj University, has the biggest data base on the biology and behaviour of bats anywhere. In this article I wish to show that first-rate work on animal behaviour can be done in our backyards in India. J B S Haldane felt that the study of animal behaviour was the area in which we are likely to do entirely original research and R.Gadagkar has belaboured this point and, of course, set an example himself with his own researches on the paper wasp.

My enterprising first student R Subbaraj had begun field work on bats a year before I had even returned to India from Germany and joined the School of Biological Sciences at the Madurai Kamaraj University in the summer of 1975. Bats were far from my mind, having until then worked for a whole decade on rather abstract concepts such as phase response curves, kinetics of phase shifts of circadian clocks, transient and limit cycles, singularities and light and energy relations of the circadian rhythms in *Drosophila*. I told Subbaraj that if he wanted to work for a PhD it would have to be based on laboratory work on the biological clock of bats. Subbaraj was intelligent, bright eyed, quick in grasping problems, eager to learn and was a natural talent. He was thrilled that I was opening up a new world, the world of chronobiology, for him. I was glad he was introducing me reciprocally to the exotic world of bats. I told him "The farmer does not eat what the farmer does not know. So let me get to know your bats properly".

MKU Campus

Madurai, the Athens of the East, was also great bat country. The 900-acre MKU campus nestles on the southern slope of the Nagamalai Ridge rock formation (9°58' N lat; 78°10' E long). The vegetation was scrub jungle with close to a thousand planted neem trees, and was surrounded by rock complexes virtually on all sides, many of them harbouring bats in crevices and caves. The campus and the small villages around and about were a fascinating biotope to get to know during the cool and breezy nights and the villages had melodious names like Chekkanoorani, Usilampatti, Keelakuyilkudi and Pannianmalai. The campus became an enchanted place after sunset. Myriad insects, mostly Lepidotera, Diptera, Coleptera and Orthoptera, swarmed the atmosphere. The air bore the fragrance of the flowers that open only at night, such as *Millingtonia* and jasmine, which are pollinated by the insects, the crickets stridulated shrill calls which rang through the night and there was the alluring smell of ripening fruits. This nightly world of a virtual sea of insects is the arena of bats, metaphorically called the 'swallows of the night'. Bats came to feed on insects attracted by street lights in the university campus, hunting in open air near the foliage and between branches of trees. In the outer stretches of the scrub jungle we set up petromax lamps 2 m. above the ground. Within minutes flying insects began to converge forming a concentrated 'cone' of small flying insects. The bat flight circles and pathways around obstacles remained stereotyped indicating a stable foraging ground; most probably the same individuals foraging in the same tracks. The most common bats at our observation sites were *Pipistrellus* spp., *Hipposideros speoris*. *H. bicolor* and *Rhinopoma hardwickei*. These species are typical 'within the canopy' foragers. To document the activity of bats we counted 'bat passes' in 30-min intervals from 7 p.m. to 6.30 a.m. We have often made these all night foraging studies and it always struck me on such occasions how bountiful nature was in the tropics in terms of teeming insect life. We carried out these observations for a decade on sympatrically occurring nine species of echolocating bats in Madurai. This unique project, the 'Indo-German Project on Animal Behaviour' with me and G Neuweiler of the University of Munich as PIs, has yielded results which illustrate the diversity of preferred foraging areas for bats not only found in Madurai but also in other tropical and temperate biotopes studied. The only problem I had to put up with was the heat for the best part of the year, which was at midday close to 40° C and I used to quip that it was always 39°C in Madurai .

Box 1.

Bats owe their conspicuous success, with close to 1000 species with wide zoogeographical distribution, to three unique features : 1) true flight 2) powers of echolocation and 3) their nocturnality, freeing them from pressure of predation. Echolocation is a method of self-information in which one organ is used to emit the sound (the *sonar* apparatus) and another organ is used for receiving the sound (the *radar* mechanism) by the same animal. Echolocating bats emit brief sounds of high frequencies (15 to 200 kHz) through the mouth or nostrils and listen to echoes reflected from prey and objects around them. (See G Marimuthu's article on p.20 for details).

Space Memory in Bats: Most animals have space memory in that they return to the same place after the day or night activity. But in certain bats, as in *H. speoris* there is something called 'personal space' where a bat returns to the same spot. Such personal space may also be associated with dominance hierarchy behaviour. The flying fox *Pteropus giganteus* shows such dominance hierarchy behaviour with the alpha male literally roosting in the highest sustainable branch of the tree. In the case of *H. speoris* the personal space is demarcated by urine marking by the males. *H. speoris* females do not have personal space and seem to roost close to the male to which they may be pair-bonded. The common dog bat *Rousettus leschenaulti* noisily crowding the interiors of temples in south India and ruins do not have any personal space. The other species of insectivorous bats of Madurai, nine in all, do have roost memory but not space memory.

The Role of Eyes in Bats: Surprisingly little is known about the precise use of eyes of bats in vision and prey capture. Hearing is the main channel through which an echolocating bat perceives its external world during its nightly foraging excursions and in locating its 'personal' space, as in *H. speoris*. Morphologically, the auditory region of the brain of insectivorous bats are disproportionately large compared to the optic regions. A book on the biology of bats makes only one reference to the role of eyes in prey capture. It is now believed that eyes of echolocating bats such as *Hipposideros speoris* and *H. bicolor* may not be efficient in prey capture but may act much like photoreceptors for 'sampling light' during twilight, thus entraining their circadian clocks. In contrast the fruit bats depend entirely on their eyes and sense of smell to locate ripening fruits and possess no powers of echolocation.

Can Bats see Colour?: We have done the action spectra of the circadian rhythm in the activity/rest cycles of the crevice-living bat *Taphozous kachhensis* and conclude they do indeed see colour. In a paper we have postulated that there might exist two classes of photoreceptors in the retina of *H. speoris*. The 'S' photoreceptors (short wavelength sensitive) having a maximum sensitivity at 430 nm and 'M' photoreceptors (middle wavelength sensitive) having a maximum sensitivity at 520 nm, on the evidence of their creating delay and advance phase shifts in the circadian rhythm in flight/rest activity, respectively. These light spectra do indeed occur in nature during dusk and dawn twilight. (See Suggested Reading). Ours is the only work known to me to impute colour vision in bats.

The Jain Hills

One hot, fine afternoon in 1975 Subbaraj and I set out for my first encounter with the granitic Jain Hills complex and the bats that abounded in their caves and crevices. The Jain Hills were 8 km east of the university campus with 9th and 10th century Jain carvings on the rocks. We headed towards the Palkalainagar railway station just across the well-known Madurai Theni highway to catch the 5 pm. Madurai – Bodinayakkanur passenger train , which had the endearing quality of arriving in each station 5 min earlier than scheduled. A one-man ticket vending office gave tickets 10 min prior to the arrival of the passenger train. Our journey was for a stretch of 9 km to the Nagamalai–Pudukkottai unmanned rail stop. This train, with as many as 18 bogies, reminded me of old wild west Hollywood movies. We were in the hill slopes by about 5.30 pm climbing on stairs cut into the rock-face by the Jain ascetis leading to the sites of rock-cut beds and engraved statues of reclining and sitting Jain Thirthankaras, over the hills on the north side. But Subbaraj's observation site was on the southern slope. The hill was 100 m at its highest and sturdy blades of fragrant lemon grass grew in the upper reaches.

All around were paddy fields, banana and sugar cane plantations and greenery unlike on the campus. The biotope and vegatation were riverine and the Nagamalai ridge tapered off and ended close by. The scenery was truly captivating. A colony of >300 bats of the species *Taphozous melanopogon* lived in a narrow a vertical crevice on the southern side of the hills and one could hear the shrill shrieks of the bats getting ready for the exodus flight which, regardless of time of year, started between 6.25 and 6.42 pm. Around 6.15 pm we lay on our backs on the still hot rock floor of a ledge which was less than 2 m in width. Then there was a sheer drop of 10 to 15 m. We peered skywards, still a pale blue, to see the bats fly out. Around 6.30 pm a batch of 8 bats shot out and flew swiftly away towards the Nagamalai ridge. More and more batches of bats flew out swiftly and in the next 15 min the last bat had flown out. All this novelty excited me and I was pleased to hear that Subbaraj had already collected data every 10 days on the outflight and return of these bats over the period of a year from this uneasy perch. It was getting dark and we had to begin the descent.

The return to ground level was difficult for it had already become pitch dark. I had also forgotten that twilight lasts barely 12 min in these latitudes. Suddenly I recalled that I

had vertigo and we had to face outwardly with our backs and palms against the rock and move to our left. We had to traverse only a distance of ca 30 m facing the steep drop and darkness. I was also sweating profusely and the crab-like sideways progression on unknown and uneven ground was made with great trepidation.. Subbaraj cheerfully narrated how it was a great place for snakes and scorpions! When we came to a flat place I was grateful that I did not fall face forward. I wanted to rest awhile and look around. The night sky glittered with stars and the glow of street lights of surrounding villages and the famous temples of Meenakshi and Trupparankundram could be seen. Only the screechings of nightjars and owls broke the nightly silence.

The Discovery of a 'True' Cave

I was taken on more such outings and one such memorable adventure was when Subbaraj and G Marimuthu persuaded me to go down some 40 m into a true cave on the sourthern flank of the Jain Hills some 50 m away from the *Taphozous melanopogon* crevice. A 'true' cave is one with just one entrance. The cave mouth was narrow and we had to descend into the cave legs first, Subbaraj leading and Marimuthu following me. The colony of ca 600 *Hipposideros speoris* bats that used the cave as daytime roost had just flown out to forage. The smell of ammonia arising from the deposited bat guano (droppings) was over-powering. The humidity was over 95% and we were drenched in sweat in our trousers, for on expert advice we had removed our shirts and left them outside the cave. I must admit that midway into the labyrinthine and twisting cave I was feeling uneasy. The darkness of course was absolute. Finally we came to the cave bottom where in places one could just stand erect. We flashed torches and planned experiments and framed important questions like 'How did bats living this deep in the cave of constant temperature, humidity and in absolute darkness still know time of sunset?'. Being inside a tropical true cave is a memorable experience. My sense of smell and hearing and awareness were all heightened. I heard the gurgle of an unseen stream somewhere inside the cave, the walls were dripping wet and it was cool (27° +/–0 °C). There was a gentle ventilatory draft, therefore there was absolutely no feeling of suffocation one associates with closed spaces. The remarkable feature of this cave is the utter constancy of temperature, day and night, week after week and through the seasons. Because of this constancy of temperature the relative humidity also remains constant, since temperature and humidity have an inverse mirror imaging relationship. The thermohygrographs we had placed 40 m deep showed two straight lines for several weeks making me suspect that the temperature stylet and relative humidity stylet had

got stuck and we kept placing different thermohygrographs for verification. It is working in this cave that we discovered that there was social synchronization of the circadian rhythms in this bat i.e. the bats were communicating to one another the time of local sunset. G Marimuthu, S Rajan and Dilip Joshi and S Radhamani worked in this cave for varying periods for the next ten years. This cave was teeming with millipedes, insects, soil nematodes and scorpions. Joshi often brought with him moulted and sloughed snake skin which he said he found inside the cave. Dilip Joshi alone, of all my students who worked in caves, had in his possession an anti-snake-bite vaccine and injection syringe, in case it became necessary. I may add with immense relief, that no occasion ever arose for the use of the vaccine.

Nature Comes to our Aid

Four of my students and a German student of Neuweiler were making 'bat counts' in two different sites on the full moon night of 13th March 1979. The German student and his wife made their observations in MKU campus and my students were counting bats in a scrub jungle area 7 km north-west of the campus. By a fortunate coincidence on that night there was a lunar eclipse that lasted from 1.15 a.m. to 4.30 a.m. At the time of maximal eclipse at 2.55 a.m. about 75% of the moon was covered. Neither group of observers were aware of the occurrence of the lunar eclipse that night. Activity of bat colonies in both sites showed significant differences during the eclipse and in the bright moonlight, preceding the eclipse and after, as shown in *Figure* 1 A and B. During the eclipse bat numbers shot up sharply. The relative absence of bats in bright moonlight was not caused by a paucity of insects during that period. In fact the number of insects caught at the petromax lamp was higher during the moonlight than during the eclipse.

This lovely experiment was actually done for us, as it were, by Nature. From our data independently collected at two different sites we conclude that he suppression of bat activity during moon light is due to the overall brightness of the night sky and not because of endogenous factors coupled to the lunar cycle. In moonlit nights predation by owls might increase therefore these bats restrict their flight to canopy cover and are not easily seen. Our data are clearly against the interpretation of endogenously governed 'lunar phobia'[1] of Morrison. We therefore suggested in our paper that the term lunar phobia be discarded as misleading.

Personally for me, there remain many unexplained puzzles in the behaviour of bats we had investigated so long. Inside the cave in Jain Hills the colony of bats appeared to be

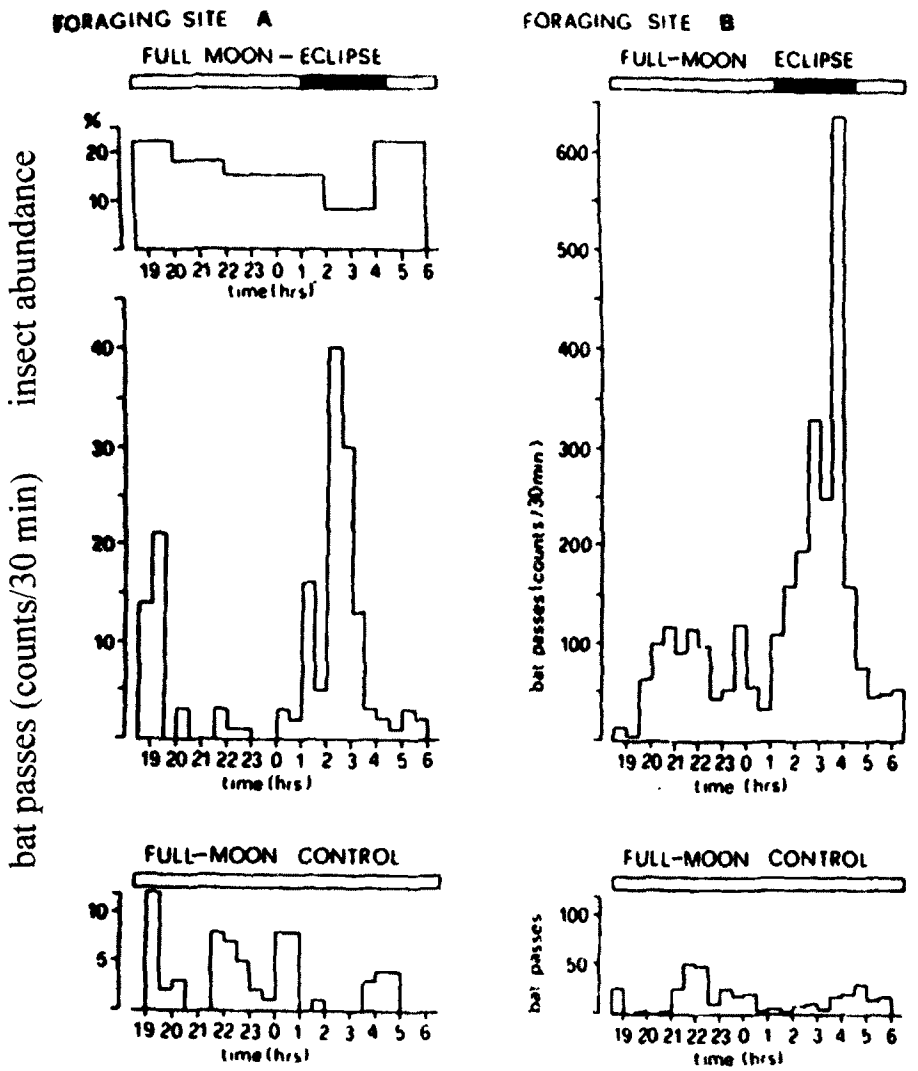

Figure 1 A & B. Activity patterns of bats during a lunar eclipse on 13 March 1979 recorded synchronously at two sites A & B. The bottom shows control measurements at the same sites on a full moon night a month later.

[1]Some nocturnal animals such as bats, kangaroo rats and other rodents restrict their activity on nights of bright moonlight to times when the moon is down. Morrison reported in 1978 that the fruit eating bats *Artibeus jamaicensis* returned to their roosts on full moon nights even when the sky was overcast, breaking foraging activity from 1 a.m. to 7 a.m. On new moon nights they foraged outside throughout the night. Morrison called this phenomenon 'lunar phobia' implying that this specific behaviour is caused by endogenous factors coupled to the lunar cycle. We do not quite agree with this interpretation.

in deep sleep between 2 p.m. and 4 p.m. No *H. speoris* bats flew around and even the restless circular movements of the heads had substantially abated. At such times an accidental displacement of a pebble under my feet and the muffled noise ensuing, made a hundred bats jerk up in alarm. This 'alertness in sleep' is perhaps an adaptation against predators like the smoothly gliding snakes. Interestingly members of this colony of H. speoris bats, ultra-sensitive to gentle noises within the cave, flew about around 9 p.m. in the central bus stop or in the noisy railway station of Madurai. This suggests a heightened threshold sensitivity to audible sound when the bats are on the wing in noisy places. Similarly these shy creatures, which avoid the brightness of the sky on full moon nights (0.3 lux) and fly under canopy cover, forage on swarms of insects drawn to sodium vapour streetlights (>1500 lux). For me, the ecology of roosting sites, site fidelity, and social interactions of some of these bats, were the most fascinating aspects of the biology of bats.

Suggested Reading

[1] M K Chandrashekaran, Chronobiology, ecology and behaviour of some insectivorous bats of southern India, *J. Bombay nat. Hist. Soc.*, Vol 100, pp. 250 - 284, 2003.

[2] G Neuweiler, Satpal Singh and K Sripathi, Audiograms of a South Indian bat community, *J. Comp. Physiol.* A. Vol.154, pp. 133-142, 1984.

[3] G Marimuthu and G Neuweiler, The use of acoustical prey detection by the Indian false vampire bat Megaderma lyra, *J. Comp. Physiol.* A. Vol. 160, pp.509-515, 1987.

[4] D W Morrison, Lunar phobia in a Neotropical bat *Artebius jamaicensis* (: Phyllostomidae), *Anim Behav.*, Vol. 26, pp.852-855, 1978.

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