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- ASTRACTS -

CHANGES IN LHRH NEURONS ASSOCIATED WITH OVULATION IN THE LITTLE BROWN BAT

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Changes in the LHRH system associated with ovulation were studied in the seasonally breeding North American bat *Myotis lucifugus*. LHRH neurons of pre- and post-ovulatory females were examined by light and electron microscopic immunocytochemistry (ICC), and LHRH tissue contents were determined by radioimmunoassay. Hypothalamic content, as well as the mean number of LHRH neurons detected by ICC, was reduced in post-ovulatory bats, although the distribution of neurons was similar in both groups. LHRH fibers that extend into the pituitary neural lobe also exhibited changes during the periovulatory period. Neural lobe LHRH content was reduced in post-ovulatory bats, as were morphometric indices of fiber density in this terminal region. Fine structural studies revealed networks of LHRH-LHRH neuronal interaction that were most complex in post-ovulatory animals. These results suggest that in this bat, LHRH secretion from the lower infundibular stem and neural lobe partially depletes hypothalamic stores during the preovulatory period. In addition, increased complexity of contacts between neurons may contribute to seasonal activation of the LHRH system.

OBSERVATIONS ON THE OVARIES OF SOME INDIAN MONOTOCOUS BATS

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In monotocous bats the structure of the non-functional ovary during gestation varies in different species. In those species, where ovulation occurs invariably from the same ovary in all cycles, the non-functional ovary undergoes partial atrophy. In the bats, where the two ovaries are potentially functional, the development of the follicles is arrested at the beginning of oestrus in the non-ovulating ovary, and the ovary presents a typical anoestrous picture during pregnancy. In *Miniopterus schreibersii fuliginosus* large masses of luteal tissue are formed in the non-ovulating ovary after ovulation in the contralateral ovary. In all bats the functional ovary develops a large corpus luteum in the ovulating ovary, and the corpus luteum is included in some species and extrovert or pedunculated in other species. After ovulation and the development of the corpus luteum in the functional ovary, all other follicles undergo atresia.

BEHAVIOUR OF *MEGADERMA LYRA* IN A NURSERY COLONY

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A colony of about 350 Indian false vampire bats inhabits a temple in Southern India. The bats breed between January and May. An attempt has been made to study the behavioural interactions between the mother and the infant during the breeding season. It was observed that adult males were roosting separately. Each female bore a single baby. When mothers left the diurnal roost for foraging, they carried the babies and left them at the secondary roosting sites such as cow sheds, unused houses, store rooms, etc. Mothers returned after about four hours to rejoin the babies. After one or two hours they flew out again for a second foraging. They came back during pre-dawn hours and after retrieving the babies flew back to the temple roost. But the young volants were left in the diurnal roost itself when the mothers flew out for foraging and were attended to periodically.

FIELD STUDIES OF ECHOLOCATION BEHAVIOUR: FORAGING AND ECHOLOCATION FLEXIBILITY - THE CASE OF

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Species which take prey from surfaces (= gleaners) present a complex array of foraging and echolocation strategies. Some species take prey from water surfaces and from the air. Echolocation calls are similar for both strategies, reflecting the uncluttered acoustic environment in both situations. Species which take prey from other surfaces have very different characteristics. Some use long constant frequency calls to detect fluttering prey. In others, cues other than those provided by echolocation (e.g. prey sounds) are required for prey detection. The calls of these bats are short, broadband, high frequency, low intensity signals which may be used solely to monitor the substrate. Non-moving, silent prey seem to be undetectable by echolocation alone. Some of these bats also capture aerial insects. Are the calls used in aerial feeding different from those used by the same individual while gleaning? Is echolocation as flexible as foraging behaviour?

PLASMA PROGESTERONE, OVARIAN STEROIDOGENESIS, AND DELAYED IMPLANTATION IN THE LONG-FINGERED BAT *(MINIOPTERUS SCHREIBERSII)*

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Pregnancy in the long-fingered bat is divided into four months of delayed implantation (DI) when plasma progesterone (P) concentrations are at non-pregnant levels, and four months of active embryonic and foetal development during which plasma P levels climb to a peak of 67 ng/ml prior to parturition. Both the luteal cells and the ovarian interstitial cells contain all the organelles associated with steroidogenesis. The interstitial cells show no marked changes in ultrastructure during pregnancy. However, ultrastructural changes in the luteal cells suggest that steroidogenesis may be depressed during DI and elevated for a short

period after implantation, and that luteolysis occurs in the last two months of the gestation.

THE CHIROPTERAN PINEAL: REMARKABLE IN COMPARATIVE MORPHOLOGY AND ULTRASTRUCTURE

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Despite the available data on pineal morphology of about 110 chiropteran species, our knowledge of bat pineal organs still remains meager. Of the 950 bat species, only about 12 have been examined ultrastructurally. Bats are unique for pineal studies because they are behaviorally divergent and roost under numerous natural photoperiodic conditions. Bat pineals show extreme variations in their location with respect to brain components, sizes (indices, 18 to 4393; volumes, 0.01 to 16.34 mm^3), shapes and types (eg., AB, ABC, μC, μßC), compactness, intimate relation and open communication with the third ventricle, CSF, and circumventricular organs, association with habenular and posterior commissures, and the intrapineal neurons. Unique ultrastructural features of the pineal organs of *Pteropus poliocephalus, P. lylei, Rousettus leschenaulti, Rhinopoma microphyllum, Megaderma lyra, Rhinolophus ferrumequinum, Desmodus rotundus,* and *Eptesicus fuscus* are discussed. A plea is presented here for interdisciplinary studies on chiropteran pineal which are long overdue and urgently needed to help resolve the enigma which continues to shroud pineal function.

ANATOMICAL SPECIALIZATIONS OF BATS FOR FRUIT-NECTAR-POLLEN FEEDING

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Bats intimately associate with plants for shelter, roost, food, thermoregulation, and protection from predators. Specializations for such 'commensalism' are seen in the limbs, long claws, and laterally rotated femur for roosting, flying, ambulating, and hanging posture. Tooth modifications include reduced dentition, small canines, distinctive labial molar rim, smaller stylar shelf (buccal crown) on the molariform row, wider palates, and a larger angle of the palatal arc (bite curvature). Some bats cut leaves for tent making. Labial and chin warts assist bats in firmly holding food and as a strainer while feeding. The bamboo bat's flattened skull allows entrance through the slit into the bamboo; it has thumb and sole pads. Disc-winged bats roost in rolled leaves. Other specializations include elongate tongues with modified papillae, long snouts, intricate palates, short intestines, scaly hair, large body size, large eyes, "acute" main and accessory olfactory systems, high encephalization index, and a large amount of neocortex. The fruit-nectar-pollen feeding bats are morphologically adapted for their modes of subsistence.

VAMPIRE BATS DO HAVE FULLY DEVELOPED ENAMEL*

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Conflicting reports on vampire enamel ranging from its absence, lacking it on the lingual side, to poor degree of enamel prism development in *Desmodus* have

appeared in the literature. Furthermore, it has been speculated that amelogenesis would be found absent in advanced embryos and that a normal tooth crown could develop in the absence of oral ectoderm. Such startling observations necessitated a study of tooth development in fetuses and adults of *Desmodus, Diaemus* and *Diphylla*. Microradiographs of ground sections of mandibular and maxillary incisors and canines of *Desmodus* confirmed the presence of enamel. Sections through decalcified teeth of adult vampires showed enamel spaces. Radiographs of vampire skulls, and pteropodid skulls for comparison, indicated the presence of enamel. Active amelogenesis was observed in the developing tooth buds in fetal *Desmodus* and *Diphylla*. Our studies confirm the presence of enamel in vampires. The relative thickness of enamel compared with that of the dentin appears to be proportionate to the tooth size and shape, and perhaps it may even be species specific and related to dietary specialization. *Anat. Rec., 223:14A (1989) † Deceased.

HISTOCHEMICAL AND BIOCHEMICAL ANALYSIS OF PLACENTA IN THE INDIAN FRUIT BAT, *ROUSETTUS LESCHENAULTI* (DESMAREST)

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The present study describes histoenzymological and biochemical observations in the placenta of Indian fruit bat, *Rousettus leschenaulti*. Histochemistry : Lactate dehydrogenase activity was moderate in the syncytiotrophoblast and stromal tissues. While the succinic dehydrogenase activity within the cytoplasm was much weaker and diffused. Alkaline phosphatase activity in the labyrinthine placenta was restricted to the wall of the maternal blood spaces while the inner segment (interstitial membrane) of the wall displayed an exceedingly intense reaction. Moderate acid phosphatase activity was observed in the junctional zone and in the trophoblastic cells. A weak Glucose-6-phosphatase activity was observed in the trophoblastic cells. Placental tubules presented an intense activity of 5-Nucleotidase and moderate activity of carbonic anhydrase enzymes. Minute particles of sudanophilic material were seen in the trophoblastic cells. Biochemistry : The activity of ß-Glucuronidase in the placenta was significantly decreased with increasing age of the embryo. The Hyaluronidase enzyme indicated an unchanged activity during the early and mid pregnancy with a slight decrease in activity during the full term. The phosphatases gradually decreased in the placenta as the gestation advanced, with a significant decrease during full term pregnancy. A steady increase in placental DNA and RNA contents observed with an increase in maturity of the placenta. However, the glycogen and cholesterol contents remained unchanged. The probable role of these enzymes in the placenta is discussed.

IMMUNOLOCALIZATION AND ULTRASTRUCTURAL CHANGES OF LH GONADOTROPES IN RELATION TO THE REPRODUCTIVE CYCLE OF *MINIOPTERUS SCHREIBERSII*

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LH gonadotropes (identified using a monoclonal LH antibody and a gold labelled secondary antibody) occur throughout the anterior pituitary of male and female *M. schreibersii*. These cells contain numerous small (100-250 nm) secretory granules, which vary in electron-density and which contain LH throughout the year. Changes in gonadotrope activity are indicated by changes in abundance of

secretory granules and the amount of gold label per granule. In the males, secretory granules are most abundant and label greatest between January and April (spermatogenesis) after which the number of granules and amount of label decreases. In the females, changes in secretory granules indicate periods of LH release between February and May (follicular development and ovulation), and after implantation in August.

FORAGING BEHAVIOR AND ECHOLOCATION IN THE DIADEM HORSESHOE BAT *(HIPPOSIDEROS DIADEMA)*

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The foraging behavior and echolocation in the Diadem horseshoe bat *(Hipposideros diadema)* was investigated during the 1980 National Science Foundation-sponsored expedition to Chillagoe, Queensland. Using radio-telemetry, the bats were tracked throughout the night to determine activity periods, home range and foraging behavior. All bats roosted in the limestone caves in the tower karst formation, but at dusk would fly several kilometres to specific foraging areas where they would remain until just before dawn. Using "flycatcher" behavior, they would dart out from a tree limb to capture passing beetles. These bats employed a 55 KHz CF echolocation pulse while resting, but while hunting would lower the frequency to compensate for the Doppler-shifted echo resulting from their flight or the moving prey.

HISTOLOGICAL APPEARANCE OF THE TERMINAL PHALANGES IN THE WING OF *MYOTIS LUCIFUGUS* AS AN INDICATOR OF AGE

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While there is evidence that female *M. lucifugus* in boreal regions do not mature until they are yearlings, age cannot be determined with certainty after uncalcified epiphyseal plates disappear at ~60 days. To determine whether skeletal composition would provide identification after 60 days, we stained wing whole-mounts with alcian blue and alizarin red to reveal cartilage matrix and calcium salts, respectively. Most structures stained strongly with alizarin red, but the terminal (cartilaginous) phalanges of digits III-V were unstained save at their proximal heads (designated by III-3p, IV-3p, V-3p). In bats judged to be <1 yr old, III-3p was hemispherical and well stained with alizarin red, while no staining was seen in IV-3p or V-3p. In putative yearlings, III-3p stained moderately in alizarin red and most also stained faintly with alcian blue. Moreover, transverse bands of alcian blue + alizarin red, or alcian blue alone, were seen in IV-3p and V-3p. In older The striking correlation between reproductive condition and osteogenic activity in the terminal phalanges indicates that alizarin red/alcian blue staining can serve to distinguish hibernating *M. lucifugus* that are <1 yr old from yearlings.

CYTOARCHITECTURE AND NEURONAL COMPOSITION OF FLYING FOX HIPPOCAMPUS

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Volumetric analysis of pteropid brains reveals that, in comparison to microchiropteran bats, megachiropterans possess a considerably larger hippocampal formation. Also the cytoarchitecture of the flying fox has a number of unusual features. Amongst them are an unusually large subfield CAI and an apparent dispersion of the pyramidal layer in the CA3 subfield. In addition the hilar neurones formed two distinct groups, a polymorphic layer and a prominent CA4

Neuronal morphology was determined by intracellular injection with Lucifer Yellow in fixed brain slices. Subsequently the fluorescent dye was photoconverted to a light microscopically visible and stable reaction product. A variety of different neuronal types was analysed in all hippocampal regions. The presence of pyramidal neurones in the presumed CA4 region provides further evidence for two

In conclusion, the flying fox hippocampus exhibits several anatomical features predominantly found in primates, suggesting a closer phylogenetic relationship than previously assumed.

LISTENING AND FORAGING BY GLEANING IN ECHOLOCATING BATS

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Several species of echolocating bats are characterized by large ears and readily attracted by low frequency "noisy" sounds such as those produced by potential prey moving on a substrate. Such gleaning bats have the ability to capture prey without the conventional use of echolocation and apparently rely on passive acoustical cues for prey detection and localization. Amongst the megadermatid bats, *Megaderma lyra* and *Macroderma gigas* have been shown behaviourally and neurally to possess audiograms with unusually high sensitivity to sound in the low frequency range between 9-20 kHz. Sound pressure thresholds in this hypersensitive band reach -20 to -25 dB (re. 20 µPa), sufficient for prey capture by listening, but echolocation and vision may be required for spatial orientation during flight. Remarkably, a vespertilionid gleaning bat, *Plecotus auritus* has now been shown to have a neural audiogram with very similar hypersensitivity to low frequencies as seen in the megadermatids and *P. auritus* has relatively enormous ears. A key element in the adaptation of the auditory system of these gleaning bats to listening for prey is the presence of a relatively large external ear or pinna. The pinna functions as an acoustical horn, producing high amplification and directionality at low frequencies, well below the ultrasonic sonar band.

ECHOLOCATION AND DOPPLER-SHIFT COMPENSATION IN *RHINONYCTERIS AURANTIUS* AND *HIPPOSIDEROS ATER*

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The Orange Horseshoe bat, *Rhinonycteris aurantius* and the Dusky Horseshoe bat, *Hipposideros ater* were studied in colonies located in the Napier Range, Oscar Range and Geikie Gorge of the Kimberley, Western Australia, during the 1988 Kimberley Research Project. *R. aurantius* belongs to a monotypic genus endemic to Australia and may show affinities to both rhinolophid and hipposiderid bats. *R. aurantius* and *H. ater* use CF-FM calls; CF (resting frequency) is 113 kHz and 152 kHz respectively (individual ranges 112-115 kHz; 144-158 kHz); FM sweep about 20 kHz maximum for both species. In captive individuals, pulse durations range between 6-13 msec for both species, but tend to be longer in *R. aurantius.* Individuals from both species were tested for the ability to compensate for a Doppler

shift in returning echoes by changing the CF frequency of emissions. Experimental Doppler-shifted echoes were produced by swinging bats on a pendulum towards a large stationary target (the Morown Cliffs) and recording their echolocation pulses. In forward swings (positive Doppler shift) for both species, the frequency of the CF component was observed to decrease by up to 5 kHz, confirming behavioral sensitivity to Doppler-shifted echoes.

(Supported by the Royal Geographical Society and Linnean Society of London.)

IDENTIFICATION OF AUSTRALIAN BATS BY ECHOLOCATION CALLS

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The echolocation calls of 40 species of bats have been recorded from captive and free-flying individuals throughout Australia (except for South Australia and Tasmania). Analog methods were used to capture sonar signals either by direct high-speed tape recording or via frequency dividing devices. Sonar signals were analysed by conventional sonargraph and computer based digital signal processing techniques such as FFT and zero crossings analysis. Sonar calls are compared by several parameters such as frequencies of maximum energy, high and low frequency limits, harmonic content, duration etc. In many cases, the sonar call characteristics are species-specific and can be used to identify species. This approach is particularly useful for the identification of bat species flying in the field and to assist in survey work. (Supported in part by 1988 Kimberley Research Project.)

COMPUTER-BASED CALL ANALYSIS FOR MICROBAT IDENTIFICATION

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Field identification and rapid censusing of microbats is greatly facilitated by the use of a laptop computer to analyse ultrasonic calls. I developed a system to display frequency-time graphs on the monitor of an IBM compatible computer interfaced to the countdown output of a bat detector. Calls can be analysed in real time or from audio tape-recordings and the graphs can be dumped to disk or printer. A sixteen second call sequence can be displayed in less than a second and then manipulated for readability or to filter out echoes and other noise. Accuracy is

In southeast Queensland, most species can be identified by their calls and others may be with further study. Search phase calls must be used as other calls are too variable or too rare. Calls given in captivity or just after release are often unrepresentative of search-phase calls from free-flying bats.

ALPHA AND BETA TYPE GANGLION CELLS IN THE RETINA OF THE FLYING FOX - *PTEROPUS SCAPULATUS*

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The fluorescent dye, Lucifer Yellow, was intracellularly injected into retinal neurones of adult male flying foxes. The ganglion cell layer contained displaced

amacrine cells, and the three main classes of ganglion cell identified in the cat retina, namely: the respective homogeneous populations of alpha and beta cells and the heterogeneous population of gamma cells. Detailed analysis was confined to the alpha and beta cells. The alpha cells had larger somata and dendritic field areas than the small bushy beta cells. In the central retina, both cell types were smaller than in the far periphery, and their dendrites were always unistratified within the inner plexiform layer (IPL). Regular pairs of cells were present in both cell classes, and each cell of a pair unistratified in a separate sublamina of the IPL. These are presumed on/off pairs of cells, whereby one cell responds to the onset of light and the other cell responds to light being extinguished. The morphology of these cells in the flying fox retina closely resembles that of cats and primates.

NIGHTLY AND SEASONAL MOVEMENTS OF *PTEROPUS POLIOCEPHALUS* (CHIROPTERA:PTEROPODIDAE) FROM RAINFOREST REMNANTS IN NORTHERN NEW SOUTH WALES

Peggy Eby and Carol Palmer
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Nightly foraging movements of *P. poliocephalus* were monitored using radio-telemetry during February 1989. Six individuals were followed over 5 nights from a communal maternity roost (40,000 animals) in a 13 ha rainforest remnant. Continuous direct-line distances flown to nightly feeding territories were measured, and ranged from 15 km to 41.5 km (median 21.3 km). Return distances from last nightly feeding location to roost were similar.

Seasonal movements of nineteen *P. poliocephalus* from two maternity roosts were monitored using aerial radio-tracking from February to June 1989. Animals moved among communal roosts, changing locations regularly. The majority of individuals (n = 14) dispersed south during February and March over direct-line distances ranging from 85 km to 610 km (median 342.5 km). Implications for *P. poliocephalus* management are discussed.

JOHN GOULD AND JOHN GILBERT'S AUSTRALIAN BATS

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John Gould - the London-based bird artist and author - and his assistant, John Gilbert, arrived in Australia in 1838 with the express purpose of collecting and describing new species. They worked primarily on the bird fauna but also discovered many new mammals. Gould's subsequent three-volume folio work *The Mammals of Australia* includes the first depictions of many of these species. Some of the original watercolours for the plates were later purchased from Gould by the 13th Earl of Derby and are still in his library at Knowsley Hall, just outside Liverpool. Three of these originals are of different species of fruit bat. Gould and Gilbert's bat types from their Australian expeditions are now in the British Museum (Natural History). They have recently been re-examined and photographed as part of a PhD project to discover the relative importance of the period 1835-1850 in the discovery and interpretation of the Australian fauna.

REVISION OF THE GENUS *MELONYCTERIS*

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The genus *Melonycteris* consists of three species: *M. melanops* Dobson, 1877; *M. woodfordi* Thomas, 1887; and *M. fardoulis* n. sp. *Melonycteris woodfordi* consists of three subspecies that are distinguished primarily on the basis of size, while *M. fardoulis* n. sp. includes three very distinct subspecies that differ in size, color and the degree of sexual dimorphism. *M. melanops* is the sister taxon to the remaining species. Some subspecies of *M. fardoulis* n. sp. are highly sexually dimorphic, more so than any other Australo-Papuan bats. The close geographic proximity of the highly sexually dimorphic *M. fardoulis* n. sp. and the non-dimorphic *M. woodfordi* provides an ideal opportunity for study into the function of cranial and dental dimorphism in bats.

FEEDING MECHANISMS IN MICROCHIROPTERAN BATS: A REVIEW

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Insectivorous bats that take hard-shelled prey items have thicker jaws, well-developed cranial crests, fewer but larger teeth, longer canines, and abbreviated M3's than species that take soft items. Several, particularly the larger insectivorous species also have wide skulls. Carnivorous bats have more elongate skulls, larger brain volumes and larger pinnae, lengthened metastylar ridges on the upper molars, and larger protoconids compared to insectivores. The crania of wide-faced insectivores (all oral emitters) are positively tilted relative to the basicranial axis while crania of carnivorous species (all nasal emitters) have negatively tilted heads. The most derived fruit-eating bats have small canines, wide palates, and close-fitting postcanine teeth with a distinctive labial rim. The labial rim of the lower teeth nests inside the labial rim of the upper teeth like opposing cookie-cutters. Frugivores have a greater allocation of tooth area at the anterior end of the toothrow, while animalivorous species have more at the posterior end of the toothrow. Frugivores have wider palates than long while many carnivores have

MOTH DEFENCES AGAINST INSECTIVOROUS BATS: AN UPDATE

James Fullard
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Three recent studies of the defences of moths will be described. A noctuid moth interneurone (501) with monosynaptic connections to the most sensitive auditory receptor, A1 responds with unusually short EPSP's. This cell may assist the moth in discriminating between background, high frequency sounds and the echolocation

Studies conducted in western Canada indicate that tympanate moths cannot detect the short, faint echolocation calls of the big-eared bat, *Myotis evotis*, when in a gleaning foraging mode. Gleaning may present a category of bat predatory behaviour for which moths have no immediate defence.

Not all moths possess ears and the defensive repertoires of inauditive moths (e.g., silkworm moths) are unknown. Studies in Ontario suggest that these moths isolate themselves from bats temporally (flying during times when bats are not present), spatially (flying in areas where bats do not) or physically (possessing large bodies or rapid flight).

BAN ON DDT IN THE UNITED STATES: ITS EFFECT ON BATS FROM CARLSBAD CAVERN

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Pesticide body burdens of young, flying Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) from the migratory colony at Carlsbad Cavern were monitored from 0.6-10.6 years (1973-83) following the ban on DDT in the United States. Similar to a number of migratory birds living in other areas of North America, a gradual decline of DDE in carcasses of these bats has occurred in conjunction with decreased use of DDT in the United States and Mexico during the

BREEDING HABITS OF *MEGADERMA LYRA LYRA* (GEOFFROY) AT DIFFERENT PLACES IN INDIA

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The breeding habits of *Megaderma lyra lyra* have been studied from different localities in India at different latitudes with markedly different climatic conditions such as temperature, rainfall, relative humidity and duration of day. This species breeds once a year in a sharply defined season and has an 'autumn' breeding pattern. The breeding occurs almost synchronously in all the localities, the date of conception advancing only by a few days towards lower latitudes. The gestation period is same in all the localities. Evidently, the breeding pattern in this species is genetically determined and external factors do not play a significant role.

BATS VS. BIRDS: COMPARISONS AMONG PERUVIAN VOLANT VERTEBRATE FAUNAS ALONG AN ELEVATIONAL GRADIENT

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Both taxa of volant vertebrates, bats and birds (diurnal and nocturnal), have had approximately equal time to evolve along the eastern slopes of the Peruvian Andes. Bats, however, have been relatively less successful than birds at colonizing and radiating in the higher elevations. Relative species richness (the number of species recorded for each elevational interval expressed as a proportion of the total number of species in each group) decreases more rapidly with increasing elevation in bat faunas than in bird faunas, and fewer bat species are restricted to the highlands relative to birds. The breadths of elevational distributions of bats are greater than those of birds and increase markedly with elevation, unlike the bird distributions. The number of large species, relative to the total number of species, decreases with elevation more rapidly in bat faunas than in diurnal bird faunas. Differences in energetic requirements, acting independently or perhaps collectively with resource differences, have probably made colonization and radiation in the highlands more difficult for bats than for birds.

BAT CONSERVATION IN AUSTRALIA

Leslie S. Hall
University of Queensland, Brisbane

In the 200 years since European occupation, Australia has suffered large scale landscape modifications. Extensive areas of forested country have been cleared for urban and agricultural use. Changes in the distribution of a number of bat species have occurred as a result of both natural and man-caused reasons. It appears that no species have become extinct during this period. Three species are listed by the IUCN, *Macroderma gigas* as vulnerable, and *Phoniscus papuensis* and *Murina florium* as rare. Conflicts arise between the use of natural resources and roosting requirements of bats. These issues are diverse and range from limestone mining and forestry operations to crop management, pesticide use and recreation. Legislation protects all Australian bats, except flying foxes *(Pteropus)* in Queensland. There has been a slow but positive community acceptance of bats which has resulted in the formation of groups who promote bats.

CHEIROMELES TORQUATUS, A SPECTACULAR MOLOSSID IN TROUBLE

Leslie S. Hall and J. D. Pettigrew
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Cheiromeles torquatus is one of the largest microchiropterans. It is found in southeast Asia, Java, Sumatra, Borneo and southern Philippines where it forms colonies in large caves often occupied by edible nest swiftlets (*Collocalia* spp.). The bat lacks body fur, has deep wing pockets in the axillary region, and has a throat pouch. Earwigs have been recorded as ectoparasites and the bat has an opposable toe. The majority of specimens in collections originate from a colony in Niah Cave, Sarawak. This colony was estimated by Medway to contain 20,000 in 1958. Visits to the colony in June 1988 and January 1989 located around 100 bats. Possible reasons for the decline include human harvesting. The scarcity of records of other colonies and the dramatic decline at Niah Cave, suggest that this bat is in urgent need of special protection.

THE STATUS OF TWO VULNERABLE AUSTRALIAN BATS: VIEW FROM THE 4TH DIMENSION

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Accumulating data gathered from bat-rich fossil deposits on Riversleigh station in northwestern Queensland may provide important information for the conservation of the Ghost Bat *(Macroderma gigas)* and Orange Horseshoe Bat *(Rhinonicteris aurantius).* These cave-dwelling microchiropterans are sparsely distributed within their broad northern Australian ranges, the Ghost Bat being listed as a vulnerable species by the IUCN. Southern Australian Pleistocene and Holocene fossils and subfossils indicate that the past distribution of the Ghost Bat was much wider. Riversleigh Tertiary fossils indicate that both groups were once far more diverse. In the Oligo-Miocene (25-15 million years ago), their ancestors dominated local cave-dwelling bat faunas, outnumbering all other contemporary Riversleigh bat taxa (13 of 23 taxa). In at least one cave deposit, 5 *Rhinonicteris*-like species appear to

have coexisted and in other Riversleigh deposits 2 species of *Macroderma* are commonly present. By the early Pliocene (5-3 million years ago), diversity had dropped slightly to 4 *Rhinonicteris*-like taxa and 2 *Macrodermatid* species of , including what appears to be an early population of *M. gigas.* Possible reasons for the Quarternary decline of these groups are discussed.

AUSTRALIAN FOSSIL HIPPOSIDERIDS: NEW EVIDENCE ABOUT THE EVOLUTIONARY HISTORY AND RADIATION OF OLD WORLD LEAF-NOSED BATS

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Hipposiderid species far outnumber all other fossil taxa identified from bat-rich, 15-25 million-year-old limestone deposits on Riversleigh Station, northwestern Queensland. The ancient Riversleigh hipposiderid fauna bears little resemblance to the modern Australian hipposiderid fauna which is comprised of the endemic *Rhinonicteris aurantius* and 5 species of the genus *Hipposideros.* The Riversleigh fossils indicate that *Rhinonicteris* -like hipposiderids once dominated the Australian hipposiderid fauna and species of H. *(Hipposideros)* were rare. Hipposiderid diversity approached that found today in some rainforested limestone areas of South-East Asia where up to 8 species may co-exist. There is evidence that the large, rainforested Australian landmass of the early Tertiary was an important centre of radiation for primitive hipposiderids and probably an equally important exporter. Living descendants of this radiation appear to include species scattered throughout the Old World tropics and subtropics.

THE BATS OF MALAWI

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The location of Malawi, midway between warm temperate South Africa and the equator, makes Malawian bats (55 species, 8 families) particularly interesting. Comparison of the bats of Malawi and other African countries revealed patterns and trends in community composition, species-latitude relationships, trophic diversity and domiciles. Comparison also showed how reproductive strategies vary interspecifically, intraspecifically, and in different African environments, and indicated that reproductive flexibility is sometimes likely to influence distribution. Two sympatric species of *Tadarida* exemplify different reproductive chronologies in Malawi, and each modifies its chronology in different ways in other parts of Africa. Comparison of renal form in Malawian bats enabled relationships between renal function and ecology to be investigated. Comparison of the biology of the banana-bat, *Pipistrellus nanus*, in Malawi, South Africa, Kenya and Zaire, revealed differences related to climate and the use of permanent or ephemeral domiciles.

TORPOR - AN ADAPTIVE RESPONSE BY *CHALINOLOBUS MORIO* TO FOOD SCARCITY

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In winter *C. morio* roosted by day in caves on the Nullarbor Plain of Western Australia. Bats left the caves at sunset, presumably to forage, despite the evenings being cool (often <10°C) and flying insect prey scarce. To test the response of these bats to food scarcity, I monitored the activity and body temperature (Tb) of five captive bats before, and during restriction of food. With food available the bats were non-torpid (i.e. resting, active or flying) during 48% of 120 observations made over two days, with activity commencing in the afternoon and continuing into the night. The bats were torpid during 52% of observations. After 24 hours without food, the same bats were very much less active and were usually torpid (87% of 45 observations). Tb of torpid bats ranged from 14.5°C to 22°C and was usually at or within 2°C of ambient, indicating that they were not expending energy on thermoregulation. The starved bats did arouse periodically but their bouts of activity were short, not sustained as when they were fed. In July, the testes of males (N = 36) were abdominal and females (N = 30) had no palpable pregnancies. Moths and Diptera were being eaten.

OBSERVATIONS ON THE PLACENTA OF THE FLYING-FOXES *PTEROPUS SCAPULATUS* AND *PTEROPUS POLIOCEPHALUS*

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The biology of Australian megachiropterans has been suggested in some quarters to have primate affinities. Aborted terminal placenta of *Pteropus poliocephalus* and *Pteropus scapulatus* have been shown to conform to the structure of non-Australian megachiropterans in the possession of a discoidal labyrinthine endotheliochorial type main placental disc derived from the fused chorio-allantois. An accessory yolk-sac placenta was also present in both species. This was a separate vascularized glandular structure not closely abutting against the fetal surface of the main placental disc and is not represented in primate species. The present data when viewed against the literature contraindicates close affinity between extant megachiropterans and primates. However, when considering the whole placental profile of development including implantation by a highly invasive syncytiotrophoblast, both megachiropterans and primates might well be judged to have distant affinities.

WATER TURNOVER IN 3 SPECIES OF FREE-LIVING INSECTIVOROUS BATS

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Tritiated water turnover (WTO) was measured in free-living animals at various times of the year for three species of insectivorous bats, as part of a broader investigation into their reproductive energetics. Insect abundance was very low in winter, with a rapid increase in September or October (depending on the year) which was maintained until May. WTO was highest for both males and females in early to mid-summer when insect abundance peaked and females were lactating. WTO varied from 136-391 ml/kg/day in *Mormopterus planiceps* , 151-880 ml/kg/day in *Nyctophilus geoffroyi* and 350-1008 ml/kg/day in *Chalinolobus morio* . All 63 measurements in *M. planiceps* were less than 400 ml/kg/day whereas 17/28 values for *N. geoffroyi* and 24/34 values for *C. morio* were in the range 400-This higher WTO in the latter two species may explain their earlier breeding and higher reproductive output.

AN EVOLUTIONARY SCENARIO FOR THE MALE REPRODUCTIVE CYCLE IN THE COMMON SHEATH-TAIL BAT

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The male common sheath-tail bat (*Taphozous georgianus*) of tropical Australia has a curious reproductive cycle with peaks in spermatogenesis and accessory gland activity six months apart, the collapse of spermatogenesis in the face of peak testosterone levels and the storage of sperm in the cauda epididymidis over winter. Assuming that bats originated in the tropics and colonized Australia from the north, a scenario is proposed for the evolution of the reproductive cycle in the sheath-tail bat. In the archetypal sheath-tail bat reproduction was probably year round. As the bat moved south, cooler and/or drier winters would have favoured mating in spring. Spermatogenesis is not energetically demanding and may have remained relatively aseasonal. When faced with harsher winters necessitating the use of torpor the profound drop in body temperature probably depressed spermatogenesis prior to the spring mating and this would have favoured the capacity for sperm storage.

FORAGING BEHAVIOUR, DIET AND ECHOLOCATION IN THE GREATER HORSESHOE BAT *RHINOLOPHUS FERRUMEQUINUM*

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Can insectivorous microbats select prey, or are they opportunistic foragers? The degree of selectivity shown by the bat probably depends on the quality of information received from the processing of its echolocation calls. Perceptual constraints may be important in determining the degree of selectivity shown by foraging bats. The diet of the greater horseshoe bat was studied (by using faecal analysis and study of dismembered prey) in relation to measurements of prey abundance (measured by light trapping). The bat is known to use long FM/CF/FM echolocation calls in the field (Jones & Rayner, in press), such calls probably having the capacity to encode insect wingbeats in their echoes. The diet of the bat was analysed to determine whether the bats foraged opportunistically, or whether they were able to select certain taxa from those available. Conclusions were drawn on the perceptual ability of *R. ferrumequinum* under natural conditions.

FACTORS AFFECTING THE DISTRIBUTION PATTERN OF BATS (CHIROPTERA:VESPERTILIONIDAE) IN UPPLAND, CENTRAL SWEDEN

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Bats were surveyed and insects were trapped in several different habitats in order to test the hypothesis that insect abundance and types are the most important factors affecting the distribution pattern of bats in a region. A bat community of ten species dominated by *Eptesicus nilssoni* and *Pipistrellus pipistrellus* was analysed. The results show that the general pattern of the distribution of bats in different habitats, and the seasonal changes in habitat utilization, were possible to explain in terms of the abundance of swarming insects, mainly chironomids.

Deciduous forest near water was found to be a key habitat in early summer for all the bat species. In the autumn street-lamps were found to be an important factor affecting bat distribution.

THE ACTUAL SITUATION OF BAT RABIES IN NORTHERN GERMANY WITH GENERAL REMARKS ON THE PROBLEM

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Although a rabies virus in a European bat was first discovered in 1954, bat rabies has become a significant phenomenon only in this decade. Until now, infected specimens of 9 European bat species have been found, but a single species (*Eptesicus serotinus*) is the main carrier of bat rabies virus. Available data show the centre of virus distribution to be in Denmark, North Germany and the Netherlands.

During a two-year study, 159 bats of 7 species were tested for rabies virus in Schleswig-Holstein (North Germany). 9% were rabid: besides 26% of *E. serotinus,* 2 *Pipistrellus pipistrellus* were proven to be virus carriers. Some serotines could be observed during their last days until death. In the case of two human beings, who had been infected and not received their first vaccination till a period of two months, no signs of illness occurred.

OVARIAN CHANGES IN *RHINOPOMA HARDWICKEI HARDWICKEI* (GRAY)

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In the ovary of new born young of *Rhinopoma h. hardwickei* medulla is well differentiated from the cortex and contains numerous primordial follicles. In a suckling, it is difficult to distinguish the medullary region from the cortex. Ovary of a weaned young shows a thicker cortex with a large population of primordial follicles. The structure of the ovary undergoes marked changes correlated with the reproductive periodicity of the animal. The development of Graafian follicle follows the pattern as in most other bats. Pre-ovulatory follicle measures 556 μ. Insemination occurs during latter half of February until about the middle April. Ovulation, however, was not recorded until 11 March. Ruptured follicle develops into a pedunculated C.L. Contralateral ovary shows some developing follicles and some in atresia. During lactation both the ovaries show marked atresia. Sexually quiescent ovary shows developing follicles which never reach beyond multilaminar stage.

ANNUAL TESTICULAR CYCLE IN *RHINOPOMA HARDWICKEI HARDWICKEI* (GRAY)AND EPIDIDYMIS AS A STORAGE ORGAN

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In newborn males (born between June-July) of *Rhinopoma h. hardwickei,* although they attain adult body weight in August, gonads show immature condition until animal is at least a year old. The immature testis acquires weight from July of the second year and reaches adult testis weight during October-November, showing spermatogenesis for the first time. Meiotic stages are noticed from September onwards. In adult males, testis gains weight from August (about 4 mg) and reaches

maximum value (about 140 mg) in December. During mid-September some of the tubules show commencement of spermatogenesis. Vigorous spermiogenesis begins from November onwards and continues until February. From the beginning of March testis shows progressive regression and remains in a regressed condition until July. Although there is complete regression of spermatogenesis in the testis by end of March, the cauda epididymis remains filled with sperm and is considerably distended beyond the testis.

REFLEX OVULATION IN GREY-HEADED FLYING FOXES (*PTEROPUS POLIOCEPHALUS*)

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The Australian grey-headed flying fox *Pteropus poliocephalus* is a seasonal breeder bearing a single young annually. *P. giganteus*, a similar flying fox from India, has been described as a reflex ovulator based on the presence of a corpus luteum (CL) in pregnant animals only. We thought this an oversimplified explanation in our species as judged by the frequency of mating and the presence

Five female *P. poliocephalus* were housed in natural photoperiod without males throughout the breeding season and then, two months after the end of the breeding season, were exposed to sexually active males whose season had been delayed by photoperiod manipulation. All females showed sperm in vaginal smears within three days. One female was castrated after two days and a fresh CL was found in the right ovary. The remaining four all conceived and three successfully delivered. Parturition dates indicated that conceptions occurred soon after exposure to males. This suggests that this species is capable of reflex ovulation.

ASPECTS OF THE FEEDING BIOLOGY OF FRUIT BATS (PTEROPODIDAE) ON LOMBOK ISLAND, NUSA TENGGARA, INDONESIA

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Ingested pollen was assessed from the alimentary tract of 11 pteropodid bat species from 4 areas on Lombok Island during September and October 1987. A total of 28 pollen types was recorded. The common small and medium sized bats visited, on average, from 2.5 to 5.2 plant species per night, with a maximum of 10

The overall pollen diet generally differed between *Eonycteris spelaea, Rousettus amplexicaudatus* and *Macroglossus minimus* irrespective of area. These species also differed from *Cynopterus brachyotis, C. horsfieldi* and *C. tittaecheilus*. However, *C. brachyotis, C. horsfieldi* and *C. tittaecheilus* were similar to each other and with *M. minimus*. Of the less frequently collected species, *Aethalops alecto* appeared to have a pollen diet closest to *Cynopterus brachyotis*. The larger fruit bats: *Pteropus spp, Acerodon mackloti* and *Dobsonia peroni* have a pollen diet which appeared distinct from the smaller species. The extent of pollen dietary niche overlap reflected the above pollen dietary groupings.

For the six common pteropodid species there was a trend for increased pollen dietary niche overlap to occur with increasing body size (forearm length) between species pairs, but not with morphological characters related to the feeding

The extent of nectarivory of the six common species was highly positively correlated with total tongue length and not to sub-familial systematic position.

E. spelaea, M. minimus and R. amplexicaudatus were primarily nectarivorous. *Cynopterus spp* had a pollen dietary niche breadth approaching these nectarivorous species at near-coastal sites, but this decreased at the inland, higher altitude sites. Conversely, the pollen dietary niche breadth of *E. spelaea, M. minimus* and *R. amplexicaudatus* increased at these inland sites. These changes

Only *C. tittaecheilus* and *C. brachyotis* had substantial numbers of individuals that ingested plant epidermis. Insects were ingested incidentally. Plant seeds were present only in *Cynopterus spp* and then uncommonly.

BATS OF THE MALAY ARCHIPELAGO: WALLACE'S LINE REVISITED

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Cluster analysis of 320 species in the Malay Archipelago indicates that there are two regional bat faunas in this Archipelago. The first region includes those islands associated with the Sahul Shelf to the east of Weber's line as modified by Mayr (1944). The second region lies to the west of this line and comprises two subregions: (i) continental Asia, large Sundaic island and Bali; Sulawesi, Philippines and Palawan; and (ii) some small islands on the edge of the Sunda Shelf and Nusa Tenggara. Seven provinces are recognised in these regions.

The number of bat species on islands in the Malay Archipelago is significantly correlated with island area. Isolated oceanic islands have similar bat species to islands on the Sahul Shelf when scaled to remove effects of island area. The trend for species impoverishment from Java eastwards along Nusa Tenggara, supposed by earlier workers, is not apparent until travelling from Lombok to Sumbawa. The drop in species richness between Lombok and Sumbawa is reflected in a significant negative correlation between species diversity and increasing longitude.

Attenuation of faunal richness in Nusa Tenggara between Lombok and Timor appears little affected by the marine straits between these islands.

REPRODUCTIVE STRATEGIES OF TEMPERATE BATS: DO MIGRATORS AND HIBERNATORS HAVE DIFFERENT

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Temperate bats deal with a seasonal food resource and climate in various ways. Most hibernate near their summering grounds, some migrate south and hibernate in warmer regions, and a few migrate great distances and remain active throughout the winter. Hibernating bats are restricted to a short growing season while migration provides a longer season. Whereas young hibernators must attain a large size by autumn in order to survive the winter, this is not necessary for young migrators. Slower growth, smaller fledgling mass and continued growth during the

winter may be possible. Overall, reproduction may thus be less costly for migrators than hibernators for the same litter size and migrators may have the option of raising larger litters. The energetic requirements of migration may shorten lifespans compared to hibernators and select for larger litters.

ADAPTATIONAL TRANSFORMATIONS IN THE BAT POSTCRANIAL SKELETON IN CONNECTION WITH THE CHARACTER OF LOCOMOTION

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A comparative-anatomical study of the thorax of members of eleven bats families showed the thorax to be differentiated in the degree of mobility of the elements. This mobility could be characterized as high, medium and low.

Due to the fragmentary nature of paleontological evidence, we made our judgement about the ancestoral type of bat thorax based on comparative anatomy and embryology as well as data on the ecology of recent bats. We propose that high mobility of the thorax is the ancestoral state. The lowering of the mobility of the elements of the thorax and associated structural transformations are more recent acquisitions under the influence of alteration in both habitat and mode of locomotion.

HISTOMORPHOLOGY OF THE OVARY IN THE VESPERTILIONID BAT, *SCOTOPHILUS HEATHI*

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Present study describes the presence of rete ovarii and unusually large amount of interstitial tissue in the ovary of the Indian Vespertilionid bat, *Scotophilus heathi*. The rete ovarii are located in the ovarian medulla close to the hilus. These consist of tubules lined with cuboidal or cylindrical epithelial cells. These epithelial cells are either ciliated type or secretory type. They are arranged both as a single layer or appear pseudostratified. The cells possess round or oval nuclei with prominent chromatin, mitochondria with tubular cristae, rough endoplasmic reticulum (ER) and

The cells of the interstitial tissue are large and highly vacuolated. They are separated by elongated fibroblast-like cells and elements of the vascular system. They are mostly associated with remnants of the atretic follicles indicating that they develop by transformation of theca or granulosa cells of atretic follicles. The interstitial cells are characterized by the presence of smooth ER, mitochondria with tubular cristae and abundant large lipid droplets. Studies are in progress to evaluate the functional significance of rete ovarii and interstitial tissue cells in this bat species.

BEHAVIORAL ECOLOGY OF TENT-MAKING BATS

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This report summarizes our observations on tent-making bats in Trinidad, West Indies. Four species of bats (*Uroderma bilobatum, Artibeus jamaicensis, Artibeus*

cinereus, and *Mesophylla macconnelli*) were observed and captured in tents. Thirteen species of plants were used by bats for tent construction, including six species of palms (family Palmaceae), four species of Philodendron, one herbaceous epiphyte, and wild tannia (family Araceae), one species of Heliconia (family Musceae), and a deciduous, understorey tree (family Polygonaceae). Typically, one to three leaves (or fronds) of a given plant were modified into tents. Tents were most commonly found at heights of two to three metres above the ground. Roosting groups ranged from two to five individuals, consisting either of one adult male and up to four pregnant females, lactating females and their young, bachelor males, or bachelor females (immature and non-reproductive). Solitary bats were usually males.

REPRODUCTIVE BEHAVIOUR OF CAPTIVE MALE GREY-HEADED FLYING-FOXES

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Observations were made of groups of grey-headed flying-foxes *(P. poliocephalus)* breeding successfully in captivity. In December, males prepare for the mating season by spreading out around the cages and selecting and marking territories. While defending their territories, males engage in 'boxing matches' which can lead to more vicious combat. Males start attempting to collect females in January by loudly vocalizing and grabbing at them as they pass. By late February most females are collected into harems of one to six per male. Copulation, which involves prolonged grooming of the female genitalia and repeated intromissions, takes place from March to May, with peak activity in April. As mating activity decreases in June males abandon their territories and will 'play wrestle' together, although they occasionally groom and copulate with the pregnant females. This pattern of behaviour then continues unchanged until December.

TECHNIQUES AND LOGISTICS OF REARING ORPHAN *PTEROPUS* IN NUMBERS FOR RELEASE TO THE WILD

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Since 1982, more than 350 orphan flying-foxes (*Pteropus poliocephalus, P. alecto*) have been reared from a very early age and released to the wild. The greatest number in any one year was about 150. Over this period a dependable regimen for hand raising both species was developed. The method is labour intensive, therefore the programme has involved the development of a network of foster parents for the feeding and rearing. The stages whereby individually reared humanized animals are grouped and reintegrated into the wild flying-fox population are: (1) closely monitored grouping of juveniles, (2) integration with captive adult females at the release cage complex 4 km from the main local camp, and (3) transfer to an "open" section of the complex containing resident and wild flying-foxes who visit the release site.

ECHOLOCATION BY *MYOTIS ADVERSUS* FORAGING OVER WATER

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The foraging behaviour of *Myotis adversus* was observed at two study sites in Victoria. Sound recordings of sonar signals were made whilst *M. adversus* was foraging over water, including the normal patrol or search phase and feeding sequences. *M. adversus* has a characteristic flight pattern over water, flying parallel to the surface within a height of about 30 cm. Sonar calls consist of descending FM sweeps with a fundamental frequency range of about 62 kHz to 28 kHz and maximum energy at 35-40 kHz. Pulse durations range from 2-6 msec depending on the recording situation. An unusual feature of the sonar calls of *M. adversus* is the presence of periodic amplitude minima or notches in the waveform envelope. Notches in the sonar pulse waveform have also been observed in the European species *M. daubentoni* whilst foraging over water. This phenomenon appears to be a recording artefact generated by a time delay between the primary pulse and its reflection from the water surface, and can be reproduced under laboratory conditions (Rayner, Coles & Guppy, in preparation).

ROOST SELECTION BY THE NORTH QUEENSLAND LONG-EARED BAT *NYCTOPHILUS BIFAX* IN LITTORAL RAINFOREST ON THE NORTH COAST OF NEW SOUTH WALES

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Radiotelemetry conducted in November 1988 and May 1989 was used to examine movements and roost selection by *Nyctophilus bifax.* Lactating females carried their twin young while foraging. Bats were found roosting in tree hollows, amongst foliage, beneath peeling bark, among epiphytes and between strangler fig and host tree. Roosts occurred in a wide range of tree species with no indication of any species preference. Many bats changed roosts nightly, alternating between roosts clustered within a small area. Individuals also showed a marked tendency to roost communally.

AGE GROUPS IN THE FRUIT BAT *ROUSETTUS AEGYPTIACUS*

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During the procedure of "capture-mark-recapture" research conducted in Israel on the local fruit bat *R. aegyptiacus* , from 1982 through 1989, 4725 bats were marked. The age of suckling and of growing bats was determined by the forearm length, the stage of physical development and the bats' weight. These bats constitute the known age groups.

Adults were subjectively sorted into relative age groups according to the extent of abrasion of the canines. The age of recaptured adults which had been marked first as juveniles was evaluated by adding the interval period between the captures. The recapture of adult specimens first caught as adults provided data on the rate of canine abrasion.

On the basis of these recaptures each of the relative age groups was given a range of possible values in terms of absolute age. Among the oldest bats captured most were males, probably indicating that in nature females have a shorter life span. A comparison of the average forearm lengths of the different age groups showed that in both sexes older bats were significantly larger than younger adults indicating that there is a selective pressure favoring large size.

REPRODUCTION IN CAPTIVE AUSTRALIAN FLYING FOXES (GENUS *PTEROPUS*)

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Since 1982 we have maintained substantial numbers of captive *P. poliocephalus, P. alecto* and *P. scapulatus* and from 1985 have successfully bred all three species. Animals are housed in the open in 2 x 2 x 12 m cages with shelter areas at one end and fed a wide variety of fruit *ad lib*, plus powdered milk supplement. Present numbers total >200, with annual fruit consumption >25 tonnes. Males undergo seasonal changes in body weight, testis size, spermatogenesis, plasma testosterone and accessory gland function comparable to those in wild-caught bats and at the equivalent times. Almost all adult females become pregnant each year and most *P. poliocephalus* and *P. alecto* carry to term and rear young to independence. In these species, breeding season and pregnancy hormone levels are similar to those in wild-caught bats and distributions of birth times correspond to those observed in the wild.

STUDIES ON BAT MIGRATION IN ESTONIA

Matti Masing

During five seasons (1984-1988) bat migration was studied at Kabli, SW coast of Estonia. Bats were caught by using a giant bird-trap of Helgoland type into which automatic bat-traps were set up for the night time. During 121 trap-nights, a total of 566 bats belonging to 11 species were caught. The latest modification of our bat-trap consists of two single traps (4 layers of vertical lines, 0.15 mm in diameter) with the distance between the lines in single layers being 7 + 4 cm in the first trap and 3 + 3 cm in the second one. Efficiency of this model reached 58 percent.

POLLINATION OF TWO EUCALYPT SPECIES BY FLYING-FOXES

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Eucalyptus confertiflora and *E. porrecta* are two species of trees on which flying-foxes feed while they are in flower. Most of their flowers open and most of their nectar is produced during the night.

Tests were conducted in order to demonstrate that pollen from the fur of flying-foxes is viable and will fertilize the ovaries of these tree species. Flying-foxes, caught in mist-nets at night and dusted with pollen from their foraging, were rubbed over the stigmas of newly opened flowers. The flowers were covered with netting before and after treatment to prevent pollination from other sources. Flowers treated in this

Flower beds in a control group were covered and not treated with outcrossed pollen (i.e., pollen from a distant tree) when they opened. The only pollen available to the control flowers was pollen of the same genotype from nearby flowers. Flowers in this group eventually withered and no fruit was set. There appears, therefore, to be a floral strategy which attracts flying-foxes for fertilization by pollen with a different genotype in some tree species to them. This study has widespread ramifications for the maintenance of *Eucalyptus* forests in Australia.

SEED DISPERSAL BY FLYING-FOXES AND ITS EFFECT ON THE CASHEW INDUSTRY

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Flying-foxes eat ripe and unripe cashew fruit in the orchard and carry some of the cash crop into the adjacent forest where it is dropped to the ground, obscured by ground cover, and uneconomical to harvest.

Preliminary results of a study on the assessment of damage and management of flying-foxes in cashew demonstrate a considerable economic loss in yield to these animals. For example, the average weight of cashew nuts in a 160 m^2 strip of forest adjacent to the orchard is 183 kg per ha. Approximately 83% of these nuts, however, are dropped beneath the tallest forest trees, which are used as night roosts, and nearest the orchard at the forest edge. These results have important

Non-destructive management of flying-foxes in the orchard is recommended. The provision of 'decoy' night roosts over cleared ground may prove a cheap and effective management strategy. A trial of this strategy has not yet been implemented.

THE EFFECT OF ARCTIID CLICKS ON RANGING BY ECHOLOCATING BATS

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Trained pipistrelle bats performed target ranging perfectly well in the presence of arctiid clicks. However, when the reward was laced with moth poison the bats quickly learned to avoid a clicking target. The clicks did not 'jam' the bats' sonar, but seemed to warn experienced bats of a distasteful prey. The experiments were repeated on two *Eptesicus fuscus* born and raised in captivity. The bats were trained using the 'yes/no' method and 'phantom' echoes. Clicks presented for the very first time startled the naive bats, but they quickly adapted. Clicks coming within or after the phantom echo did not interfere with ranging. However, if the clicks came before the phantom echo the bats' performance deteriorated. With clicks starting at about 0.75 ms before the echo the bats' threshold increased from a Δt of 40 μs (Δ distance of 7 mm) to a Δt of 1400 μs (Δ distance of 240 mm). The bats have a window of about 2 ms in front of the echo during which time clicks will degrade target ranging accuracy. Since the energy of the clicks is -4dB re. that of the phantom echo the clicks appear to interfere with the bat's neural timing mechanism and probably not by forward masking.

FIELD STUDIES ON THE BIOSONAR OF *CRASEONYCTERIS THONGLONGYAI* IN WESTERN THAILAND

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A team of 5 biologists and an engineer from Denmark spent 6 weeks in Thailand studying bat biosonar. With permission and participation of the Royal Forest Department we studied the hog-nosed bat *(Craseonycteris thonglongyai)* in Sai Yok National Park. The 8-min demonstration video shows stop-motion flight maneuvers of this tiny bat in a cave. The bat is able to make 360° turns within 160 to 200 msec. The video continues by showing bats hunting small insects in the field. Hunting "buzzes" recorded via a detector are clearly heard on the audio track of the video tape. These bats use a 4-harmonic sonar signal with little or no frequency sweep during all phases of hunting.

OPTIMAL FLIGHT SPEED OF INSECTIVOROUS AERIAL-HAWKING BIRDS AND BATS

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With the aid of an aerodynamic model the optimal flight speed and the optimal hunting strategy are sought for insectivorous aerial-hawking birds and bats. It is explored in what ways the best flight speed and hunting strategy are dictated by the predator's wing loading, wing shape, wing structure and sensory capabilities as well as by the size of the insect prey and the structure of the hunting habitat.

WING STRUCTURE IN MEGA- AND MICROCHIROPTERAN BATS: CONVERGENCE OR COMMON DESCENT?

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Flight is the most power-consuming way of locomotion and requires sophisticated morphological adaptations. Wing morphology differs among bat species with different foraging behaviours, and there are strict correlations between flight mode (including speed, endurance, manoeuvrability) and wing structure and form. Wing morphology, therefore, may be of very limited use for arguing that megachiropteran and microchiropteran bats are diphyletic.

FLIGHT MORPHOLOGY AND FORAGING STRATEGY IN BATS

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Bats occupy a variety of niches with different requirements for foraging strategies and flight modes, which in turn put different demands on body size and wing form. The optimal morphology is also dictated by habitat selection, size and type of food, and migratory habits; selection pressures for the various demands are often conflicting, necessitating compromises in adaptation. Certain combinations of wing loading (weight/wing area) and aspect ratio (wingspan^2/wing area) permit a bat to express only certain kinds of behaviour and ecology. By knowing a bat's body mass, wingspan and wing area, its predominant flight mode and flight performance

can be roughly predicted. Furthermore, different combinations of wing design and echolocation call structure may represent various solutions to hunting among vegetation of different density and structure.

ENDOCRINE REGULATION OF PLASMA ELECTROLYTES IN THE BAT *ROUSETTUS LESCHENAULTI*

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The role of various endocrine glands in plasma Na and K homeostasis is assessed by extirpation of the glands and replacement therapy. The endocrine glands taken into account are adrenal, thyroid, pituitary, parathyroid and gonads.

It is concluded from the present investigation that major regulation of sodium and potassium in this bat is achieved mainly through the interplay of the hormones of adrenal cortex. Other hormones from pituitary thyroid and gonads play a secondary role but parathyroid hormone is without any significant contribution in the regulation

In addition, ultrastructural changes in the cells of cortical zones during various experimental conditions are also documented to elucidate action at a cellular level.

SEASONAL BREEDING AND PITUITARY HORMONES IN AUSTRALIAN FLYING FOXES

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The grey-headed flying fox (*Pteropus poliocephalus*) is a short-day breeder while the little red (*P. scapulatus*) breeds in spring, i.e., they manifest opposite responses to the same daylength cues. The role of pituitary hormones in mediating these responses is being investigated using immunocytochemistry (ICC). Antibodies against human FSH, LH and prolactin specifically identify gonadotrophs and lactotrophs in formalin fixed, paraffin embedded pituitaries. In this, the first application of ICC to a megachiropteran pituitary, the reaction product is entirely localised in the cytoplasm; gonadotrophs and lactotrophs are usually heterotopically distributed, sometimes being found in reciprocal regions. Preliminary results from male *P. scapulatus* suggest a seasonal pattern, with lactotrophs occupying >20% cell volume of the adenohypophysis during the breeding season and <10% during reproductive regression, in contrast to LH-gonadotrophs which, in preliminary data, do not display marked seasonal variation.

MORPHOLOGICAL CHANGES IN THE GASTROINTESTINAL TRACT OF THE KOREAN GREATER HORSESHOE BAT, *RHINOLOPHUS FERRUMEQUINUM KORAI*

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The LM, TEM and SEM structural characteristics of the tongue, stomach, small intestine and large intestine were observed in the active and hibernating Korean greater horseshoe bat. There were no basic morphologic differences in these structures between other mammals and the horseshoe bat. A number of

morphological modifications were recognized: Tongue - abundant filiform papillae with numerous slender conical processes and deep epithelial pit, extremely rare circumvallate papillae, and no trenches and taste buds even in the fungiform papillae; Stomach - long and lamellated mucosal folds in the fundus, abundant large parietal cells; Small intestine - tall and, doubly branched villi, triply lamellated mucosal folds, abundant Paneth s cells with large spherical secretory droplets; Large intestine - short thick villi, lamellated and branched mucosal folds, and abundant goblet cells.

ADVANCES IN THE NEUROETHOLOGY OF BAT ECHOLOCATION SYSTEMS

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Significant advances have been made in the understanding of the neural basis of echolocation since the previous IBRC (8/86). Much of the research has been performed with the long-CF/FM bats *Pteronotus parnellii* and *Rhinolophus rouxi.* I will outline briefly the results of these studies in order to provide an overview of the present state of the field.

1. Elucidation of Functional Neural Pathways: in *Pteronotus*, entire pathways from the basilar membrane to the auditory cortex have been defined for the analysis of time-delayed FM signals which encode target range. These pathways include unique adaptations, such as the segregation of neurons encoding first-harmonic signals within the cochlear nucleus, and re-targeting of the projections of the inferior colliculus to non-traditional nuclei in the medial geniculate.
2. Cross-species similarities in cortical organization: *Pteronotus* cortex contains regions devoted to the representation of target range via neurons sensitive to time intervals between pulse and echo FM components. This pattern of cortical processing has also now been demonstrated in *Rhinolophus*, a species phylogeneticaly distant but behaviourally similar.
3. Representation of target location in the auditory midbrain: An elegant representation of target azimuth has been demonstrated in the inferior colliculus of *Pteronotus*. This representation has provided our first real glimpse of how information might be represented within the isofrequency 'slabs' of the tonotopically-organized ascending auditory pathways.
4. Control of biosonar vocalization: in both *Pteronotus* and *Rhinolophus* there has been renewed interest in the control of vocalization, especially Doppler-shift compensation. Anterior cingulate cortex has been shown to be sufficient, but not necessary, for controlling the frequency of the sonar pulse during compensation. In both species, midbrain vocal-control regions have been more precisely defined, and there is evidence at both the cortcal and midbrain level for direct interaction between auditory processing and the vocal motor system.

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HABITAT RESTORATION PROJECT AT KU-RING-GAI BAT COLONY, GORDON, SYDNEY

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The Sydney *Pteropus poliocephalus* breeding colony which occupies tall *Eucalyptus* forest is threatened by tree deaths and suppression of native seedling replacement by dense weed infestation. Without intervention the long term scenario, 25 years, is that the native forest will be replaced with dense exotic shrub and vine vegetation without emergent trees, unsuitable for a flying fox roost.

The project, commenced in 1987 by Ku-ring-gai Bat Colony Committee Inc., is systematically removing the weeds by hand clearing and careful application of herbicide (glyphosphate) and replanting with native tree and shrub seedlings. It is jointly funded by State and Local Government and public donations.

USING STEREO PHOTOGRAPHS TO ESTIMATE THE SIZE OF BAT COLONIES

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Many bat species roost in large clusters which are often too tightly packed to permit the direct count of the individuals. A common approach to estimate the number of bats in such colonies is to take pictures of the clusters, estimate the area covered with bats, and multiply it by a known value of mean number of bats per unit of area. The geometric properties of the photographs used may, however, be a very important source of error in the surface area estimation. (1) The scale of the photographs is often not known with precision because of the usually rough estimates of the camera-colony distance. (2) The walls are often uneven and therefore the projection of the colony on the flat plane of the photographs has a smaller surface than the actual colony. (3) When the film plane is not parallel to that of the colony its projected surface is also smaller than the actual surface. These limitations were successfully overcome using stereo photographs of the colonies. The methodology used, which does not require any special equipment, allowed a correct estimation of the camera-colony distance, and of the surface area of the bat cluster, independently of the irregularities of the wall and the angle from which the picture was taken.

SOCIAL STRUCTURE AND BEHAVIOR OF THE VAMPIRE BAT, *DESMODUS ROTUNDUS*

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The social structure and behavior of the vampire bat (*Desmodus rotundus*) were studied in small groups of a captive colony. The main group of the vampire colony consisted of several adult females, their infants and one harem male. Adolescent males left the main group at 20-27 months of age and formed temporary bachelor groups. The harem males were changed during the course of the study in the period from 1 to 20 months. The harem males exhibited territorial behavior; they vigorously attempted to keep the harem females within the bounds of their roosting area while they also kept intruders out.

NATURAL DIET OF THE GREY-HEADED FLYING-FOX

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Grey-headed Flying-foxes *(Pteropus poliocephalus)* are widely considered to be "fruit" bats because of their occasional attacks on commercial orchards. However, in Eastern Australia attacks on orchards are sporadic and it is clear that native trees supply the bulk of the diet on this species.

In order to determine what native trees are preferred as food sources by *P. poliocephalus* and to establish the pattern of usage of these sources (as part of a wider study to determine factors controlling movements of *P. poliocephalus*), we have examined faeces and spat-out material from 10 colony sites within a 200 km

Results for 1985-1989 show that there are some "preferred" food sources which can generate huge colony sizes in a good year. Examples of these are the nectar and pollen from Spotted Gum *(E. maculata)* and Red Bloodwood *(E. gummifera).* However, the timing of blossom and the quantity of nectar and pollen produced in any one year are highly variable for these and other "preferred" food trees.

In the absence of a "preferred" food, the flying foxes use a number of staple foods which are more commonly available. The most obvious of these are the various varieties of native fig *(Ficus sp.)* which can be found fruiting throughout the year and various blossoming trees such as the Sydney Red Gum *(Angophora costata)* and the Swamp Mahogany *(E. robusta).* While supporting a reasonably sized colony these sources are not associated with very large colonies.

The vast majority of foods identified from the faeces and spat-out material were from native trees, that is fruit and blossom. Only in times when the vagaries of blossom and fruit-set left a food shortage or when weather or insect attack damaged the blossom was commercially cultivated fruit found in the samples.

MORPHOGENESIS OF THE FOETAL MEMBRANES AND PLACENTATION IN THE INDIAN MOLOSSID BAT *CHAEREPHON PLICATA* (BUCHANAN)

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In *Chaerephon plicata* the definitive amnion is formed by the development of folds. The yolk-sac splanchnopleure undergoes progressive collapse and folding until it ultimately remains as a free glandlike structure with hypertrophied endodermal and mesodermal cells. It acts as an active haemophagous organ after the limb-bud stage. An extensive chorio-vitelline placenta which is formed during early gestation is progressively abolished and replaced by the chorio-allantoic placenta. Two kinds of chorio-allantoic placenta are formed - a diffuse endotheliochorial placenta, which persists until about mid pregnancy, and a definitive discoid placenta which is mesometrially located, labyrinthine and haemomonochorial.

DEAF FRUIT BATS, BLIND CAVE BATS AND FLYING PRIMATES: COMPETING SCENARIOS FOR THE EMERGENCE OF MEGACHIROPTERAN FLIGHT

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Megabats share with primates a large number of derived features in the brain, genitalia, skeleton and haemoglobin chains which they do not share with microbats. The number of primate-like brain features found in megabats continues to grow, with hippocampal formation and premotor cortex recently added to the previously-described features in the retino-geniculate, retino-tectal and accessory optic pathways. A number of different scenarios have been proposed to account for these findings. Of the three which follow, the first two maintain a monophyletic origin of megabats and microbats. **1. "Deaf Fruit Bat Scenario"**, where the emerging megabats lose the microchiropteran acoustic specialisations and acquire the primate features: Independent evolution of the primate pattern of brain organisation in primates and megabats is hard to defend because of the absence of any known functional constraint which would lead to this pattern rather than the slightly different but equally serviceable patterns found in other mammalian brains. This scenario has the further difficulty that one would have to explain why the palaeontologically-more-recent megabats should have discarded laryngeal sonar and the associated acoustic specialisations known to be present in the earliest microbats, only for some megabats to re-invent inferior versions later. Finally, this scenario is contradicted by the evidence from the gliding lemur, *Cynocephalus*, which has many of the primate brain and genital features. **2. "Blind Cave Bat Scenario"**. This second scenario has both megabats and microbats sharing a common origin with primates but with the microbat branch subsequently losing all the primate features. Apart from its gross lack of parsimony, this scenario requires that microbats represent the younger lineage. It is therefore incompatible with the relative ages of the microbat divergence and the megabat divergence derived from haemoglobin sequence data and from the fossil record. **3. "Flying Primate Scenario"** derives megabats from an early branch of the primates while microbats are derived separately: This final scenario accounts for all of the brain, genital and haemoglobin data in a parsimonious way and is consistent with the evidence from the fossil record and from the dermopteran, *Cynocephalus*. It requires that mammalian wings evolve twice. Skeletal data from the forelimb support a separate origin of the megabat wing from a primate-like forelimb. Despite similarities to the megabat wing in the patagial arrangement , which may be the result of functional convergence, the microbat wing appears to have had a different origin, from a forelimb with large metacarpals in relation to phalanges.

A VASCULAR COUNTER CURRENT EXCHANGE MAY EXPLAIN ASYMMETRIC ENDOMETRIAL DEVELOPMENT IN *PTEROPUS* spp.

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In *Pteropus*, progestational development of the endometrium occurs at the cranial end of the uterine horn ipsilateral to the single corpus luteum. The reproductive

vasculature was examined using injection media to elucidate mechanisms underlying this reaction. After euthanasia, white latex was injected into the descending aorta and orange microfil into the inferior vena cava. After setting, the reproductive tract and vessels were dissected out, fixed, dehydrated and cleared in benzyl benzoate. All five preparations showed that the ovarian artery is the major blood supply to the cranial tip of the uterus. This artery coils before reaching the ovary, gives branches to ovary and oviduct and continues caudally to anastomose with the uterine artery at the cranial tip of the horn. Serial sections showed that ovarian veins form a sinus completely enclosing the coiled ovarian artery. This would allow counter current transfer of ovarian steroids preferentially to the ipsilateral uterine horn, provide high levels locally, and stimulate the endometrial reaction.

THERMOREGULATORY RESPONSES OF TEMPERATE ZONE MICROCHIROPTERA TO CHANGES IN FOOD SUPPLY DURING REPRODUCTION

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Two fundamentally different strategies are available for coping with the increased energy demands of reproduction. These are firstly increased food consumption, and secondly reduction of expenditure on some other component of the energy budget - called respiratory compensation. There has been some debate recently about the extent to which torpor may be used as a mechanism of respiratory

We aimed to discover the extent to which torpor is used by measuring the temperature of a cluster of approximately 500 pipistrelle bats (*Pipistrellus pipistrellus*) in the field at 15 minute intervals throughout an entire summer and correlating the temperature of the cluster to changes in insect availability and climatic variables. We located 5 thermistors in the cluster and 3 in the roost adjacent to it and logged temperatures using a remote data logger. We also photographed the cluster at 12 hour intervals using a camera linked to a remote

Bats returned to the roost on 14 June. They gave birth between 26 June and 7 July with most births on 4 and 5 July. The logger ran out of file space on 26 August and the bats left on 7 September.

During pregnancy (14 June to 4 July: n = 21 days) the cluster remained at high temperature (c 35°C) throughout the day (0700 to 2000 h) independent of food supply or climatic variables. In contrast, during lactation the bats exhibited varying degrees of torpor on many days. The extent of torpor increased as insect availability and minimum overnight temperature declined. All other variables were not significant. Together these variables explained 31% of the variation in the extent of torpor. Most large deviations from the predicted relationship reflected exceptional events: for example on two days in lactation the mothers did not return

Torpor is clearly used extensively as a compensatory mechanism to low food availability but only in lactation. This pattern contrasts with the suggestion of Kurta *et al* (1987) that bats become torpid infrequently and that of Studier and O'Farrell (1980) that torpor is common in both late pregnancy and lactation. The pattern supports our own suggestion (Speakman and Racey 1987) that torpor is not used during late pregnancy because it results in an increased probability of foetal mortality.

BCI'S WORLDWIDE CRITICAL SITES INITIATIVE

Paul B. Robertson & Gary Graham

During the last few years the profile of bats in the professional conservation sector and general public has appreciably increased. Rapid growth of BCI (a private, non-profit organization devoted solely to the conservation of bats worldwide) attests to this increasing interest and to the critical plight of many species. BCI already has achieved extraordinary success through its own initiatives and through collaboration with other conservation organizations, governmental agencies and

In spite of their critical roles in many ecosystems, bats are often not considered in the design and management of parks and reserves. As the first part of a long range conservation program, BCI is initiating a global register of critical bat sites, to identify and prioritize the most important roosting and foraging habitats around the world. BCI needs the help of biologists and conservationists around the world in this endeavour.

BEHAVIORAL AND ENERGETIC CORRELATES OF HAREM MAINTENANCE IN THE NEOTROPICAL BAT *PHYLLOSTOMUS HASTATUS*

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Field measurements of metabolic rate (using DLW) were combined with radiotelemetry to determine the pattern of roost attendance, nightly foraging activity and daily energy expenditure of harem members of *Phyllostomus hastatus* in Trinidad, W.I. Harem males spend significantly less total time out of the roost than do harem females (96 min. v. 156 min/night) and make frequent departures of shorter duration. Females usually concentrate their foraging into a single longer bout. We consider the greater daily energy expenditure of males, and the greater proportion of both time and energy allocated to roost activities, to reflect the constraints of harem maintenance and defense. Males are able to maintain this significantly higher energy budget (mean = 156.2 kJ/day, versus 124.8 kJ/day for females) despite spending less time out of the roost.

COMPARATIVE PHYSIOLOGICAL ECOLOGY OF BATS ROOSTING IN HOT-CAVES

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A controlled comparison of four species of neotropical bats with overlapping ranges of roosting temperatures may indicate that their thermal performance breaths are not fundamentally different. The four species are *Pteronotus quadridens, Mormoops blainvilli, Erophylla bombifrons* and *Monophyllus redmani*, all are endemic to the West Indian Greater Antilles where they form some of the largest multi-species assemblages known. Physioecological aspects analyzed included metabolic rate, thermopreferendum, evaporative water loss, lethal temperature, thermoregulation and roost selection. *Pteronotus quadridens* and *E. bombifrons*

show small but significant differences in their roosting requirements whereas the other two species show a wide tolerance range.

FEEDING ACTIVITY OF NORTHERN BATS (*EPTESICUS NILSSONI*) DURING PREGNANCY AND LACTATION

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A maternity colony of 17-27 females was observed regularly in a farmland area of southern Sweden from 1983 to 1988. The bats emerged to feed on evenings when the density of flying insects exceeded 0.1 per m^3. A simple model suggests that this is a threshold level above which foraging becomes energetically profitable.

The threshold density was reached in the 6-9°C temperature interval. Variation in parturition date from year to year (25 June-28 July) was correlated with mean temperature prevailing in May and early June, and hence, with the number of feeding opportunities available during pregnancy. This suggests that periods when foraging was not energetically profitable were spent in torpor, resulting in lengthened gestation time.

SOME BIOCHEMICAL ASPECTS OF THE MALE ACCESSORY STRUCTURES OF A MEGACHIROPTERAN BAT

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Ascorbic acid was biochemically estimated in the epididymis and acessory glands of *Rousettus leschenaulti* during the breeding period. This bat breeds twice a year in quick succession, the testis activity being maximum during October/November and February/March. High values were observed in all the accessory structures twice a year corresponding to the breeding periods suggesting that they are under the control of testis activity. Highest concentration was observed in the Cowper's gland, seminal vesicles and prostate showing lower values. The amount of ascorbic acid was fairly high in the epididymis. Although the values were high during the two peaks of breeding activity the values in the second peak were always lower than the first. Similar results were obtained for sialic acid concentrations.

POSTNATAL DEVELOPMENT OF FREQUENCY-PLACE CODE IN THE INFERIOR COLLICULUS OF THE RUFOUS HOURSESHOE BAT, *RHINOLOPHUS ROUXI*

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Young *R. rouxi* are deaf at birth. In the auditory midbrain (inferior colliculus) responses to pure tones could first be monitored in stereotaxic multi-unit recordings at the end of the first postnatal week. At that time all neurons are broadly tuned (25-45 kHz) and exhibit high thresholds (ca. 100 dB SPL). During subsequent development the formation of the tonotopic gradient (low frequencies topmost) starts superficially in dorsolateral parts of the nucleus while ventromedial areas (the prospective auditory filter region) retain their initial broad-band tuning up to the third week. Thereafter (fourth week) units within these parts of the nucleus were found

sharply tuned to frequencies about 10 kHz below the adult level of 72-77 kHz. The latter is finally reached in the fifth postnatal week. This maturational shift of central frequency representation exactly coincides with the frequency shift of the individual echolocation call.

NEURAL CONTROL OF VOCALIZATION IN THE RUFOUS HORSESHOE BAT

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With electrical microstimulation techniques midbrain areas for eliciting species-specific vocalizations in the Doppler-compensating rufous horseshoe bat were defined and injected with tracer (HRP or WGA-HRP) for the determination of their afferent and efferent projections. Sites of optimal eliciting of vocalizations were found in the pretectal area, the deep layers of the superior colliculus, the deep mesencephalic nucleus of the formatio reticularis and in the tegmentum rostro-medially to the dorsal nucleus of the lateral lemniscus.

The physiological properties of the distinct stimulation loci, their indirect connections to the motor nucleus of the laryngeal nerves and neuronal response properties to vocalization and sound are presented. Possible pathways between the auditory system and the vocal control system important for the mutual information exchange are described. (Supported by the DFG, SFB 204 / TP10)

SEASONAL MOVEMENTS OF *MINIOPTERUS SCHREIBERSI* IN N.E. SPAIN AND S.E. FRANCE

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The first reports on the seasonal movements of *M. schreibersi* in the north east of Spain, were published by Balcells at the end of the fifties. After about twenty years we decided to make a more profound study of these movements of *M. schreibersi.* We proceeded to ring 1,600 bats during the winters of 1984-85 and 1986-87. Of these 896 of the total were recaptured: 341 were recaptured once, 99 twice, 52 three times, 28 four times, 8 five times, 7 six times and 1 seven times. From these data we discovered 62 new seasonal movements of *M. schreibersi* in N.E. Spain. Taking into consideration the previously described routes, we have a total of 101 different movements. We have found that part of the population of the Cabrespine cave in France (winter refuge with an estimated population of 70,000 *M. schreibersi)* go to the "Wochenstuben" located on the Costa Brava (Spain). On the other hand, a minor part of the Iberic populations go to the"Wochenstuben" located During this two years' study, we also found that most of the specimens from each winter refuge tended to move around a more or less limited geographic area. Most of the specimens returned to the winter refuge. However, there is some interchange between the members of the winter refuges. The results obtained show that *M. schreibersi* has a high migratory capacity. Other results suggest that during these movements, *M. schreibersi* follow the valley bottoms.

ULTRASTRUCTURAL STUDY OF CHORIO-ALLANTOIC PLACENTAL BARRIER IN THE BAT, *MINIOPTERUS SCHREIBERSII FULIGINOSUS* (HODGSON)

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In *Miniopterus schreibersii fuliginosus* morphologically three main types of placenta develops in chronological sequence during the course of development. These are: (1) primary placenta, (2) secondary placenta and (3) tertiary placenta.

(1) Primary placenta: The placenta at limb bud stage is endotheliochorial but during the advanced stage of pregnancy the placenta becomes haemodichorial by the disappearance of maternal endothelial cells.

(2) Secondary placenta: This placenta which is formed at early limb-bud stage is of endotheliochorial type and the absence of cytotrophoblast at full term pregnancy makes the placenta of endotheliomonochorial type.

(3) Tertiary placenta: This placenta is formed at mid pregnancy stage and it is endotheliochorial but later at full term the definitive tertiary placenta becomes haemodichorial by the loss of maternal endothelial cells.

The above ultrastructural study was undertaken with a view to understand the constitutional heterogenecity of the wall of the maternal capillary, that would help in general interpretation of the structure and function of the placental barrier in most chiropterans.

KARYOTYPIC ANALYSIS, AND G-BANDING PATTERN OF THE CHROMOSOMES OF AN INSECTIVOROUS BAT - *TAPHOZOUS MELANOPOGON MELANOPOGON* TEMMNICK (MICROCHIROPTERA: MAMMALIA)

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Air-dried metaphase preparation from the bone marrow cells of the insectivorous bat, *Taphozous melanopogon melanopogon,* was used to delineate the chromosome morphology and their G-banding patterns. The diploid (2n) number of chromosomes was computed to be 42. While the fundamental (FN) number was estimated as 64. Homologous chromosomes manifested a fairly conservative profile and were easily identifiable. Both macro- and micro-chromosomes were present. The former were either metacentric or sub-metacentric, while the latter were entirely acrocentric. Robertsonian Variation was not demonstrable in this

The males of this species were characterised by Y-chromosome polymorphism which was distinctly acrocentric. In some samples of the population Y-chromosome was as large as the sub-metacentric X-chromosome, while in others it was slightly smaller. Pronounced differences were also observed in the G-banding patterns of autosomes and sex chromosomes. Our data differ not only from the ones reported for this species inhabiting other geographical and ecological habitats but also from that of other emballonurids. The possible causative factors for these karyotypic and G-banding pattern differences shall be discussed.

ENERGETICS OF ECHOLOCATION

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Echolocation has evolved in several diverse animal groups: cetaceans, insectivorous bats, oilbirds and cave swiftlets. Dawkins (1986) has suggested that the paucity of species using echolocation is a consequence of the high energy cost of generating the signals. We measured the costs of signal pulse generation

A positive relationship was established between energy expenditure and pulse rate of echolocation for eight pipstrelle bats (*Pipistrellus pipistrellus*) when hanging at rest in a respirometry chamber at 28°C. The least squares fit equation:

$$\text{Energy expenditure } (J.g.^{-1}h^{-1}) = 110.09 + 40.3 \text{ pulse rate } (n.s^{-1})$$

explained 14% of the minute by minute variation in energy expenditure. For a 6 g bat therefore each pulse costs approximately 0.067 Joules to produce. The net cost of echolocation at 10 pulses per second for a 6 g pipistrelle bat was predicted to be 9.5 x BMR with a range of 7.0-12.2 x BMR. We suggest that since a major portion of the cost of echolocation may result from contraction of the pectoralis and scapularis groups of muscles, the cost of echolocation is reduced for flying animals which contract these muscles anyway during flight. The hypothesis is supported by direct estimates of flight cost in echolocating bats (see Speakman, J.R. and Racey,

These data may explain why echolocation has evolved most often amongst animals which fly and not among terrestrial mammals. However it raises the problem of why echolocation is not even more common amongst the birds and Megachiroptera. Using data from a survey of daylight flying in bats we show echolocation has probably not evolved amongst birds because its directionality, when compared with passive vision, results in an increased susceptibility to predation. In Megachiroptera the absence of echolocation may reflect their different ancestry to the Microchiroptera, and the possibility that evolution has excluded the swapping of specialisations.

ENERGETICS OF FLIGHT IN SMALL MICROCHIROPTERA USING A COMBINATION OF DOUBLY LABELLED WATER AND RESPIROMETRY

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Flight is the most costly activity in which any animal engages and is therefore an important component of bat energy budgets. Unfortunately measuring the energy cost of flight is particularly difficult. There are two alternative techniques: measuring respiratory gas exchange in bats trained to wear masks and fly in wind tunnels or measuring the total energy expenditure using doubly-labelled water (DLW) across a range of bats which vary in the percent time spent in flight. The former technique involves considerable training of bats and has been successfully applied to less than 10 individual bats over the last 15 years. The latter technique however provides only an average cost across several individuals, which may have wide confidence limits dependent on the other activities during the non-flight period. We aimed to combine the techniques by measuring energy expenditure of individuals engaged in free flight and rest using DLW and the costs of their rest by respirometry. Flight costs could then be inferred by subtracting the measured resting costs from the combined rest and flight costs.

Using this technique we measured the flight costs of 17 individual Microchiroptera (n = 14 *Pipistrellus pipistrellus* and n = 3 *Plecotus auritus*) which varied between 5.7 and 8.5 g. Across all individuals the mean flight cost averaged 1.396 Watts (s = 0.506), which was equal to 19.03 x BMR (Kleiber), (s = 7.00, se = 1.7). The flight cost of *Pipistrellus pipistrellus* averaged 19.5 x BMR and for *Plecotus auritus*

These cost estimates were not significantly different from our own previous estimate of flight cost in *P. auritus* using DLW alone (21 x BMR). The very wide variation in individual flight cost estimates is a consequence of error in the DLW technique and a high gearing of this error to error in the final flight cost estimate. The observed coefficient of variation in the flight cost estimate (36.2%) matches closely that predicted using data on the precision of DLW estimates from our own previous validation study (Speakman and Racey 1988) and the times spent in flight and rest (33.5%). Using the techniques together does not overcome the problems of using

Using the data from the validation study on the accuracy of the DLW technique in comparison to indirect calorimetry to correct the flight cost gives a revised average cost of 14.6 BMR (14.9 for *Pipistrellus pipistrellus* and 13.0 for *Plecotus auritus*). This is very similar to previous evaluations using masks and respirometry alone. These data indicate there is no extra cost of echolocation to add to that of flight.

ROOSTING AND FORAGING BEHAVIOUR OF THE QUEENSLAND TUBE-NOSED BAT *NYCTIMENE ROBINSONI* (PTEROPODIDAE), PRELIMINARY RADIOTRACKING OBSERVATIONS

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Roosting and foraging behaviour of *Nyctimene robinsoni* (Chiroptera, Pteropodidae) was studied at Cape Tribulation, North Queensland, in November and December of 1987 using radio-tracking techniques. Bats under and around fruiting soursop (*Annona muricata*) trees in a fruit orchard and under cluster-fig trees (*Ficus nodosa*) in abandoned pastures were captured with mist nets. Females dominated the captures in the orchard, but the sex ratio was 1:1 under cluster-fig trees (their presumed normal food). Bats were fitted with small glue-on transmitters, some of which were fitted with high intensity LED's. Distance between day roost site and place of capture ranged from 63 to 1012 m. During the day bats roosted solitarily in the foliage of canopy or understorey trees, usually in primary forest and most individuals roosted in the same small area for several consecutive days. Except for occasional visits to isolated fruiting trees, individuals foraged at night, within 200 m of their day-roost. The high density of fruiting cluster-fig trees in November and December could account for the observed sedentary behaviour of this bat at this time of year.

MOVEMENT OF *PTEROPUS POLIOCEPHALUS* IN EASTERN AUSTRALIA

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We report the first long-term radio-tracking study of pteropodid fruit bats and the preliminary results from this study. Grey-headed fruit bats *(Pteropus poliocephalus)* from a number of colonies in eastern Australia were captured, fitted with collar-mounted radio transmitters, and their movements monitored over the following year. This study, which relied heavily on volunteer assistance in observing the bats, required the development of low cost radiotracking equipment for distribution to volunteers. Lined leather collars were developed as conventional plastic transmitter collar materials caused severe skin reaction, including ulceration. These leather collars have proved to be completely tolerated by the bats over periods of 6 to 11 months. Bats were observed to move between major colony sites over distances of up to 300 km (Grafton to Brisbane) and movements in both northerly and southerly directions were observed. A Lismore bat had a feeding distance of 22 km, while Sydney bats were observed to fly distances of up to 17 km to feed. There appeared to be a considerable amount of interchange between bats in adjacent colonies. This study was funded through an ARC grant to H. Spencer.

THE ENERGETICS OF HIBERNATION IN *MYOTIS LUCIFUGUS*: FAT RESERVES, WATER LOSS, AND THE COST OF WINTER AROUSALS

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The north temperate species, *Myotis lucifugus*, typically arrives at hibernation sites carrying <20% of body mass in fat. Bats enter torpor to reduce energy expenditures, but steadily lose water through cutaneous and pulmonary evaporation. When losses total ca. 0.3 g, they are forced to arouse to drink. Arousals are energetically costly and result in the majority of winter fat depletion. Here, I present data on evaporative water loss, arousal frequencies, the costs of torpor and arousals, and the size of fat reserves in adults and yearlings. I discuss how these factors interact to determine the energy cost of hibernation and over-winter survival.

OVARIAN FUNCTION IN WILD GREY-HEADED FLYING FOXES (*PTEROPUS POLIOCEPHALUS*)

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The ovaries of *P. poliocephalus* are small, heavily encapsulated and each is attached to the tip of the ipsilateral uterine horn. Both are functional, and ovulations in successive breeding seasons probably alternate from side to side. Before and during the breeding season there is an increase in the number of growing antral follicles and a small concomitant increase in peripheral plasma oestradiol concentrations. After ovulation and formation of the corpus luteum there is no immediate detectable increase in peripheral plasma progesterone levels. These only rise significantly in mid pregnancy as placental secretion increases. A localised unilateral endometrial reaction is observed in the tip of the uterine horn ipsilateral to the developing preovulatory follicle and subsequent corpus luteum, probably in response to localised delivery of ovarian steroids.

ALTERATION IN THE OVARIAN HISTOARCHITECTURE, SUBSTRATE MACROMOLECULES AND ENZYMATIC PARADIGM OF *RHINOPOMA KINNEARI* (RHINOPOMATIDAE : MICROCHIROPTERA) FROM NULLIPAROUS TO PAROUS AND LACTATION STATE

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Ovarian histoarchitecture, substrate molecule profile, enzymology and biochemical estimates of total protein, and lysosomal hydrolases, under various reproductive states, e.g. nulliparous, parous and lactation were evaluated and compared in the insectivorous bat *Rhinopoma kinneari.* This species is characterised by functional equivalence of the contralateral ovary unlike other bat species; and in having an extroverted corpus luteum. The latter retains its functional state to approximately

Classification of follicle types was based on their diameter, number of associated granulosa cells, population, and stage of meiosis. Steps in follicular atresia were also delineated. Significant differences were discerned with respect to this in females under various reproductive states. These morphometric data were matched with the histochemical site and pattern of distribution of substrates such as sudanophilic lipids, glycogen, and protein; and with the profile of lysosomal hydrolases, e.g. acid - and alkaline phosphatases. The intensity of staining of these substrates and enzymes exhibited reproductive - state specific characteristerics. One unique observation was with regard to the corpus leteum, which in early pregnancy was strongly extroverted but later regressed to become introverted. The A further correlation of the above findings (*vide supra*) with biochemical estimates of total protein, acid- and alkaline-phosphatases in the ovaries of bats during various reproductive states was sought. Biochemical differences provided further proof of links between folliculogenesis, follicular atresia, ovulation and corpus luteum function.

EFFECT OF MOONLIGHT ON THE FORAGING ACTIVITY OF THE BAT *RHINOPOMA HARDWICKEI*

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The foraging activity of the bat, *Rhinopoma hardwickei,* in relation to the phases of the moon was studied for one year. The bats occupy a cave environment in Madurai (Lat. 9°58' N, 78°10' E) and the colony consists of 1000-2000 animals of both sexes. Foraging patterns of this species were studied in the riparian forests, grass lands, orchard grove and scrub jungle using mist nets, bat detectors, and a UDT optometer. The studies were carried out during several phases of the moon and also on a full moon night of lunar eclipse. The influence of moon light on the foraging activity of bats was immense. Bright moon light suppressed bat activity and altered the foraging pattern and forced the bats under the canopy and along the 'cover'. This was pronounced on the day of lunar eclipse.

REPRODUCTION IN THE RUSTY BAT, *PIPISTRELLUS RUSTICUS* IN THE NORTHERN TRANSVAAL BUSHVELD, SOUTH AFRICA

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Rusty bats are seasonally monoestrous and give birth to twins between mid November and mid December. Spermatozoa are present in the epididymides from March to August but absent from the testes from April until September. Spermatozoa are therefore stored in the epididymides for five months of the year (April-August). Copulations are initiated during April with females having increasingly more spermatozoa in their uterine horns from then towards the end of July. Ovulations and fertilization occur between mid August and mid September.

PLASMA PROGESTERONE CONCENTRATIONS IN THE FEMALE NATAL CLINGING BAT *(MINIOPTERUS SCHREIBERSII NATALENSIS)*

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Plasma progesterone concentrations measured by radioimmunoassay in the Natal clinging bat remained below 2.01 ng/ml during lactational anoestrus but increased significantly during the period of delayed implantation. Values peaked at implantation but were followed by a significant decrease thereafter. Concentrations remained low (<7.0 ng/ml) during the initial period of foetal development (153-201 days *post coitum*) and attained peak values (85.6-181.3 ng/ml) 216-222 days after fertilization. The sharp postimplantation increase in progesterone levels coincided with a significant increase in placental weight.

PHYLOGENETIC RELATIONSHIPS WITHIN VESPERTILIONIDAE: RESULTS OF CHROMOSOME BANDING STUDIES

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Up to now, the phylogenetic relationships within the family Vespertilionidae remained rather unclear. This is due to the presence of only a few morphological features which are suited for the construction of a phylogenetic tree. By comparison of banded karyotypes, however, a sufficient number of good characters have been

Out of the subfamilies investigated, the Miniopterinae are the first to branch off from the common Vespertilionidae stem. The next branches belong to the Murininae, Kerivoulinae and the tribe Myotini, formerly included in the Vespertilioninae.

The large subfamily of Vespertilioninae is divided into the following tribes: (1) Plecotini (*Plecotus; Barbastella, Idionycteris, Euderma*); (2) "Nycticeini", possibly a polyphyletic group (*Eptesicus, Histiotus, Hesperoptenus, Scotophilus, Rhogeessa, Nycticeius*); (3) Vespertilionini (*Vespertilio, Hypsugo, Vespadelus, .Chalinolobus, Nyctophilus, Tylonycteris, Philetor*); and (4) Pipistrellini *(Nyctalus, Pipistrellus, Scotozous, Glischropus)*. According to the chromosomal characters, the *Pipistrellus* subgenera *Hypsugo* and *Vespadelus* (i.e., Australian "*Eptesicus*" species), have to be placed with the tribe Vespertilionini and, therefore, have to be given a generic rank.

THE EFFECTS OF DISTURBANCE ON THE ENERGY EXPENDITURE OF HIBERNATING BATS

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Disturbance of hibernating bats during survey and research work may result in increased depletion of energy reserves and possibly therefore increased winter mortality. The potential effects of winter survey and research work on energy expenditure in hibernating bats have however been little investigated.

An open flow respirometry system was used to study the effects of torchlight, photographic flash, electronically generated sound, speech, rapid temperature increases, and tactile stimulation on oxygen consumption and hence energy expenditure of torpid vespertilionid bats.

A total of 1400 hours of respirometry was carried out between 20.11.87 and 28.04.88 on a total of 15 individuals of 6 bat species. Ambient temperature was controlled at between 1° and 9°C.

Of 206 non-tactile stimulations only 9 (4.4%) resulted in arousal (ie in a significant increase in oxygen consumption above the prestimulation rate). There was no significant difference between the types of non-tactile stimulations in their likelihood of initiating an arousal of 19 tactile stimulations - all resulted in arousal.

The cost of non-tactile induced arousal varied between 1.85 and 381.37J (mean 49J). This variation did not depend significantly upon body mass, species, ambient temperature, time of day, or time of year. The cost of tactile induced arousal varied between 4.86 and 10242J (mean 2038J). Fifty-nine per cent of this variation was explained by differences in body mass and ambient temperature. Using prestimulation levels of oxygen consumption to evaluate metabolic rate during torpor, estimates of the excess fat utilization and potential reduction in hibernation time consequent on the energy expended on arousal were calculated. These represent maximum impact assessments since no account was taken of natural arousals. On this basis arousals resulting from non-tactile stimuli would on average reduce the maximum potential duration of hibernation by only 5.18 hours whilst arousals resulting from tactile stimulation would on average reduce the maximum potential duration by 104.6 hours.

INSECTIVOROUS BATS OF THE WATAGAN STATE FORESTS - NSW

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The RZS Mammal Section has been researching the effects on mammals of clearing forests for Eucalyptus plantations in Olney State Forest since 1977. Because of improved trapping techniques bats have been included in this study

Nine trap sites were chosen on tracks through the study area. Bats caught are weighed, measured, sexual condition observed and then banded with numbered aluminium bands. In recent years reflective colour bands have also been used for identification in flight. Of a maximum expected number of 19 species of bats - 16 have been caught. Over 2,000 have been banded - consisting mainly of the following species - *Nyctophilus gouldi, Eptesicus pumilus, E. darlingtoni* and *Chalinolobus morio* . Breeding in most species occurs in late November, early December. From recaptures home ranges appear small and with the aid of radio transmitters we hope to discover more on habitat use, home range and roost sites.

MECHANISMS OF VERTICAL LOCALIZATION IN *EPTESICUS FUSCUS*

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We measured the transfer function and impulse response of the external ear of *Eptesicus fuscus* for 10-to-100 kHz FM sounds from different directions. At the eardrum, the vertical direction of sounds is represented in the impulse response by reverberation between the pinna and the tragus (25-40 µsec) or by notches in the transfer function at frequencies related to reverberation timing. This reverberation appears at its correct delay in the images perceived by bats in echo-jitter discrimination experiments. We are using a real-time technique to measure the bat's head-aim during tracking to determine if external-ear reverberation indeed serves as the principal cue for vertical localization of targets.

CALBINDIN LABELS AUDITORY NUCLEI IN THE MUSTACHED BAT

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Echolocation places a premium on processing rapid acoustic events which in turn may correlate with fast recovery in auditory neurons. One proposed function of Calbindin is that of an intraneuronal calcium buffering system which could enhance temporal coding. We thus used antibodies against Calbindin to examine auditory pathways in the mustached bat. The primary antibody was rabbit anti-monkey cerebellar serum monospecific for 28 kD CaBP (courtesy K. Baimbridge), the Calbindin D-28k prominently stained some auditory nuclei. In Cochlear Nucleus, large multipolar cells of the marginal division of anteroventral CN were dark and numerous. Small spherical cells of the anterior division were unstained but were surrounded with dark endings. Dorsal CN and posteroventral CN had some stained somata and endings. The Olivary Nuclei had few to no stained cells while Periolivary Nuclei and Medial Nucleus of the Trapezoid Body were immunoreactive. In the Lateral Lemniscus, the ventral and intermediate nuclei stained while the dorsal nucleus did not. Labeled cells were scattered diffusely throughout the Inferior Colliculus. The Medial Geniculate contained many darkly labeled somata and immunoreactive neuropil.

SHORT COMMUNICATIONS

PREDATION BY A BUSH RAT (*RATTUS FUSCIPES*) OF BATS CAPTIVE IN A HARP TRAP

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Harp traps (Tidemann and Woodside,1978, modified according to Emison et al, 1984) are used extensively in Victoria to trap microchiropterans. Once caught, bats are usually safe from predation. Schulz and Meggs (1986) reported an instance of a predator of unknown identity killing and partially devouring three bats from a harp trap. Reported here is another instance of predation, but in this case the predator was identified as a Bush Rat, *Rattus fuscipes.*

While trapping at Coranderrk Bushland Reserve, Healesville (37° 41's, 145° 31'E) on 17 March 1989 a harp trap was set over the Badger Creek in order to trap Large-footed Myotis, *Myotis adversus.* The creek at this point was only just wider than the trap, with branches over the water on one side to within approximately 30 cm of the hip of the trap, and a shrub bordering the trap on the other side. The trap was set low, with the bottom of the collecting bag just above the water. At 2315 h the trap was checked and found to contain two Little Forest Eptesicus, *Eptesicus vulturnus,* which were left inthe trap. By morning 15 more bats were in the trap, including three that had been freshly killed and partially eaten. Still alive in the trap were seven *M. adversus,* three *E. vulturnus,* two Chocolate Wattled Bats, *Chalinolobus morio,* one Gould's Wattled Bat, *C. gouldii* and one Lesser Long-eared Bat, *Nyctophilus geoffroyi.* The remains of the three dead bats were lying in the bottom of the bag, on top of each other, ventral surfaces uppermost. Ten rodent scats were also found in the bottom of the bag which had a large hole (26 x 14 mm) chewed in the canvas.

Assuming the bottom individual was killed first, the likely order of consumption of the three prey species was: 1 *Eptesicus* sp. (either *E. vulturnus* or *E. regulus*) all that remained of this bat was the extremities of both wings from the wrists down; 2 *Myotis adversus* - adult the body had been completely eaten leaving only some body fur and skin connecting the intact hind legs, tail and one wing. the other wing was detached but complete from the forearm down. the lower jaw was connected to the fur and part of the skull was found separately; 3 *M. adversus* adult female. this bat was on top of the pile and so presumably was the last to be killed, by which stage the rat must have been almost replete, as this one was more intact. the chest cavity was open and some of the internal organs had been eaten. the face was still present but had been inverted and the brain appeared to have been consumed. the wings, feet, tail anfd lower part of the body were intact.

The next night the trap was elevated and vegetation cleared to prevent access to the bag. Five Elliott traps were set around the trap in runways and on branches leading to the bag. Three adult female *R. fuscipes* were caught and scats were collected from the traps. These scats were the same size and shape as those found in the harp trap on the previous night. The original scats, while contaminated with

bat fur on the outside, consisted mainly of plant material. Some of those from the captured *R. fuscipes* contained tufts of bat fur within the scat. Bat fur is very distinctive both in structure and diameter and can be readily distinguished from other mammalian fur (Brunner and Coman, 1974).

Hence it appeared that the *R. fuscipes* that had found its way into the harp trap and eaten three bats on the first night had returned on the second night, possibly for more. *R. fuscipes* has an omnivorous diet, consisting mainly of vegetation and invertebrates, however mammal remains have been recorded (Warneke, 1971). Being an opportunistic feeder, vertebrate prey is likely to be taken whenever available.

Bats in harp traps are rarely predated. I have trapped approximately 9000 bats in harp traps over recent years and this is the first evidence of predation I have encountered; complete removal of bats by a predator could, however, pass undetected. Access by potential predators to the bag of the harp trap should therefore be considered when setting traps close to vegetation.

I would like to thank Barbara Baxter and Jerry Alexander for confirming the identification of the bat fur, Bob Warneke and Jerry Alexander for commenting on this note and Healesville Sanctuary for allowing access to the Coranderrk Reserve.

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BOOK REVIEWS

The short-tailed fruit bat. A study in plant-animal interactions. Theodore H. Fleming. 1988. Wildlife Behaviour and Ecology Series. University of Chicago Press, Chicago, xvi + 365 pp, illustrated. Clothbound, $49.95. Special mail order offer: $29.95.

The scenario for this book opens in a dramatic and charming manner describing how with the settling dusk and with the return of diurnal birds and mammals to their roosts in Costa Rica, the principal subject of this monograph, the short-tailed fruit bat, *Carollia perspicillata*, emerges. The study includes results of a long-term project which spanned over ten years, 7174 net-hours and 5627 captures of

Carollia. Individual chapters discuss in detail the evolution and ecology of phyllostomid bats, mutualistic interactions between bats and plants, the study area, demography, social organization, diet and food choice, foraging behaviour, energetics, ecological relations with other animals, botanical consequences of the foraging behaviour of *Carollia*, and bats, frugivores and tropical forests followed at the end by eight very useful appendices. Each chapter is written like an individual article beginning with introduction, on many occasions sources of data, ending with a summary. Chapters are profusely illustrated with a total of 104 histograms, regional maps, black and white photographs, line drawings and graphs, and 61 tables not including the eight in the appendices. There are about 525 references cited, some through 1987. All figures are reproduced well except the 23 photographs, most of which have turned out too dark. This work sorely needs a good sharp portrait of *Carollia perspicillata*. Figure 7.2 on pages 186-187 should have been reduced and thus accommodated within the margins.

The book is set in pleasantly readable type, on a light cream coloured paper, 15.7 x 23.7 cm. Use of first person singular throughout the book is very striking, and so is the frequent use of abbreviations, the meaning of which must often be looked for in a key some 150 pages away in Appendix 3. The frequent use of structures such as '*Carollia* bats' (p xiv), and other such uses *in passim*, '*Carollia*'s DEB's and TNZ's etc, are often distracting. It was amusing to read of the 'sons' of *Carollia* (p 149). The subject index which incorporates the animal and plant species is characteristically deficient and disappointingly incomplete. It was strange to see that *C. perspicillata*, the main subject of the book was not indexed. A separate animal and plant species index perhaps would have been most useful. It is now well known that *Diaemus* does not have 20 teeth as mentioned (p 17), but 22. The informal use of the terms 'mega-' and 'microbats' (p 301) is unconvincing. Page numbers are lacking in places (317-320), 324). Also the title of the book should have included the scientific name of the study animal. After all, how many bat biologists would even know *Carollia* as 'the short-tailed fruit bat', when according to the author *C. perspicillata* has no generally accepted common name (p xiii). Errors of omission and type-setting are few and noticeable only to a most discriminating eye. The book appears overpriced.

Ted Fleming has posed very intelligent and penetrating questions answering most of them, and being a noted scholar of the mutualistic bat-plant interactions, he has provided a classic study of *Carollia* which is likely to become a role model for other such studies to be attempted in the future. This delightful work is recommended to <u>all</u> bat researchers.

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Ecological and behavioural methods for the study of bats. Thomas H. Kunz, editor. 1988. Smithsonian Institution Press, D.C., xxii + 533 pp., illustrated. Clothbound, 18.5 x 26 cm, $50.

Tom Kunz has assembled another useful book dealing with ecological studies of bats. This book has 29 chapters written by 35 authors. Kunz himself has authored four of these. Individual chapters covering a variety of subjects include: Capture methods and holding devices (Kunz & Kurta), Reproductive assessment (Racey),

Age determination (Anthony), Marking and observational techniques (Barclay & Bell), Survey and census methods (Thomas & LaVal), Detecting, recording and analyzing vocalizations (Fenton), Radiotelemetry (Wilkinson & Bradbury), Photographing (Altenbach), Allozyme techniques and kinship assessment (McCracken & Wilkinson), Mark-recapture estimates (Keen), Food habit analysis (Whitaker), Prey availability assessment (Kunz), Diet analysis of plant-visiting bats (Thomas), Fruit availability estimation (Stashko & Dinerstein), Nutritional ecology of plant-visitation (Herbst), Maintaining bats (Wilson), Training bats (Gaudet), Energy budget analysis (Kunz & Nagy), Microclimate methods (Bakken & Kunz), Thermoregulatory design and interpretation (Kurta & Fujita), Metabolic rate measurement (Stack & Rossi), Water balance determination (Basset & Studier), Body composition analysis (Pierson & Stack), Microscopical techniques (Forman & Phillips), Karyotyping (Baker & Qumsiyeh), Specimen preparation (Handley), Ectoparasite collection (Whitaker), Ecological studies of endoparasites (Coggins), and health precautions for bat researchers (Constantine).

Individual chapters follow somewhat similar approaches in discussing the subject matter and are illustrated where necessary. There are tables, useful appendices containing complete addresses from where equipment and other materials are obtainable. No prices are given. References to mid-1985 are pertinent. The book is set in pleasantly readable type, two columns to a page. Line drawings are particularly sharp, even though in some cases details are lost due perhaps to reduction from otherwise excellent original artwork. Photographs have not reproduced well. Formulae and circuit diagrams profusely illustrate the text. Certain chapters could have used illustrations to advantage. Figure 7 on page 122 makes difficult reading as the symbols are placed on an axis different from that of the reader. Inclusion of certain chapters can even be questioned in a book on ecological methods as the good information there may remain unknown to non-ecologists. Despite the title of the book there only a few chapters which actually deal with the so-called behavioural methods. For a book of this size, it is surprising to see that it is nearly free of the usual errors. On a personal note the chapter running heads are titled much better than the actual titles. This excellent treatise lacks a species index, which is an absolute necessity and should therefore be added in its second edition. Of lesser importance, but also valuable, the missing author index could also be useful.

Tom Kunz, who carried his idea of such a creative work to fruition, the Smithsonian Institution, and all contributors deserve high compliments for providing the state-of-the-art knowledge on their subjects. At a time when ever-increasing emphasis is directed towards bat conservation, Tom's new book on ecological methods is a most welcome and much needed addition. I would not hesitate to recommend this book for the library of <u>all</u> bat researchers regardless of their specializations.

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NOTICES

NINTH INTERNATIONAL BAT RESEARCH CONFERENCE
August 3-7, 1992, Madurai, India

The Ninth International Bat Research Conference will be held in Madurai, India in 1992. Detailed information will appear in future issues of this journal and will also be mailed to all prospective delegates. Please address correspondence to Professor Dr. M.K. Chandarashekaran, Convenor, Department of Animal Behaviour and Physiology, School of Biological Sciences, Madurai Kamaraj University, Madurai, Tamilnadu 625 021, India (telephone: 85216; telex: 445-308 MKU-IN). Area coordinators are: Australia; Dr. Michael Augee, Department of Zoology, University of New South Wales, PO Box 1, Kensington, NSW 2033; Europe; Professor Gerhard Neuweiler; North America; Dr. Kunwar Bhatnagar.

Radio tracking of the spectacled flying-fox, *Pteropus conspicillatus*

I am working on the intercolony movements and colony usage of *P. conspicillatus*. Each animal captured from the colony sites is fitted with a transmitter. Each colony is coded with its individual frequency in the 151 MHz band and the animals are coded as to sex - females have a fast pulse rate - approximately 0.8 sec interval, while males have a slow pulse rate - 1.5 sec interval. I expect to collar about five animals per colony and each transmitter should have an operating life of about 1 to 1.5 years. The colony frequencies are:

151.000	Cairns	151.020	Deeral	151.040	Kuranda
151.060	Bloomfield	151.080	Daintree/CT	151.100	Innisfail
151.120	Ingham	151.140; 151.160; 151.180; 151.200 not yet allocated.			

These animals are being monitored automatically with a recording scanning receiver at each colony site which monitors for the presence of radio-tagged animals three times a day, and also monitors for activity in the colony by recording a 20 sec sample of ambient noise. Volunteers will be used to monitor population levels and activity of the bats at regular times during the year. This project will be operating from December 1989 for about three years.

Dr. Hugh Spencer, Cape Tribulation Field Studies Centre, PMB 5 Cape Tribulation, via Mossman, Qld. 4873.