A RESOURCE FOR TEACHERS AND STUDENTS

BAT PACK

Bat Resources (((*Bat Activities*

This teacher's resource was originally compiled by Anthony Flaherty of the Gould League of SouthAustralia as part of a 'Save the Bush' and Primary Industries Forestry 'Forest Awareness package' in 1994. Neville Forde, Ruth Pratt and Arthur Pratt, also worked on the original project.

The updating of this document has been carried out by the Goolwa to Wellington Local Action Planning Board (GWLAP), with support from the South Australian Museum, Department for Environment and Heritage (DEH), Mid-Murray Local Action Planning Committee (MidLAP), Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR) Board, South Australia Murray-Darling Basin Natural Resources Management (SAMDB NRM) Board and the Australasian Bat Society (ABS).

The following people are acknowledged for their contributions to this publication:
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Funding for this project was provided through GWLAP, SAMDB NRM Board, DEH and Mid-Murray LAP.

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INTRODUCTION

This package is designed as an activities workbook focusing on Australian bats. It targets science and a range of other subjects in later primary and early high school, but it is also relevant to senior high school science. The resource section (Part I) provides background information. The activities section (Part II) provides lesson ideas labeled by subject area.

This package is supportive of the concepts of environmental education, aesthetics, ecosystems, heritage, resources, growth, environmental ethics, decision making and participation and suggests a range of cross-curricular activities in the Australian Curriculum, including arts, science, languages, maths, society and environment, technology and health and personal development.

Recently Australian bats have been found to host some viruses that can be harmful to humans.
If bitten or scratched by any bat, it is essential to wash the wound immediately and seek medical help.

INTRODUCTION

Dear Teacher,

Bats are truly remarkable animals—if you are not familiar with them, then you are about to be delighted with your new acquaintances.

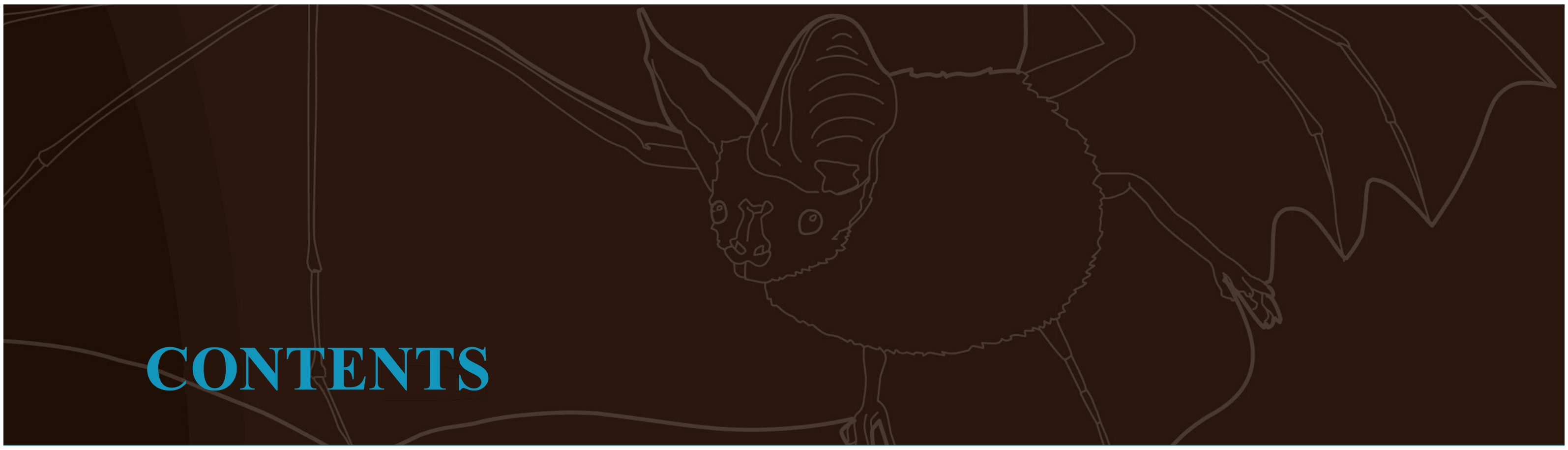
They are native mammals, no less native to Australia than our more familiar marsupials, and they play a critical role in the ecosystem.

It is unfortunate that many people are so fearful of bats. From our experience, both young and adult people warm to bats when they have the opportunity to learn more about them and particularly when we have been able to show live bats close at hand.

Bats are fun to work with, they are attractive, mysterious in habit and are one of the few native mammals that remain relatively common in urbanised areas.

We hope that you and your students enjoy learning about bats through this resource.

The contributors;
Brian Gepp, Tony Flaherty, Simon Langsford, Belinda Gunn, Chris Grant, Terry Reardon, Aimee Linke, Brad Law, Marg Turton, Maree Kerr.



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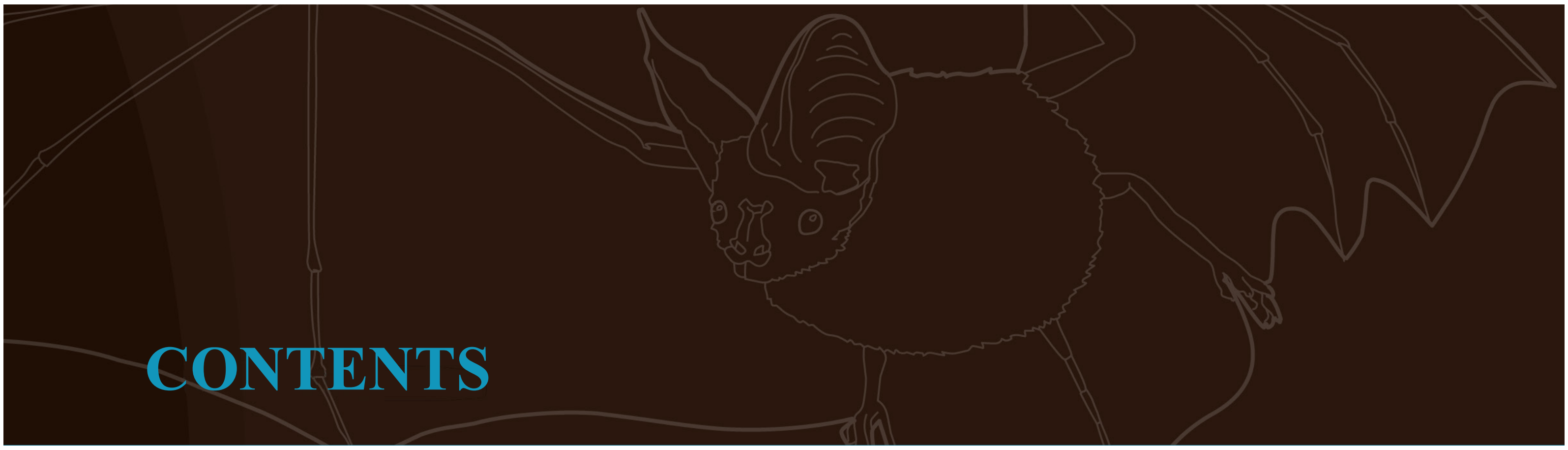

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BAT BASICS

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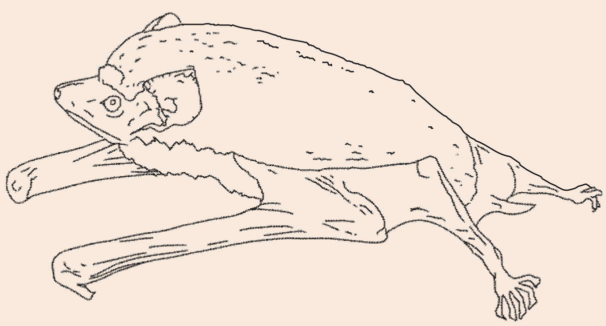
Bat facts

- Bats are mammals: they are warm-blooded, have hair and feed their young on milk.
- Most bats are relatively long lived, from three to 10 years, and in some cases 20 years.
- Bats are 'placental mammals': young bats develop within their mothers' uteri. Most mammals are placental, including dogs, cats and people. Other types of mammals are the pouched marsupials (kangaroos, possums etc.) and egg-laying monotremes (echidnas and platypus).
- Bats are nocturnal, or awake and active during the night. They have special adaptations, like echolocation, that help them navigate in the dark.
- Bats are the only mammals that actively fly (as opposed to glide). Their wings are formed by a light membrane of skin stretching between the arms and legs (and sometimes the tail, as well).
- Bats fly with their hands. It is the very long arm and finger bones that form the supporting struts of the bat's wing. The scientific name for the group or order of bats is Chiroptera, which is Latin for 'hand-wing' (Cheiros=hand; Pteros=wing).
- Though most of the arm and finger bones are highly modified to make the wing, most bats retain the thumb as an external claw. They can use it to move around when roosting.
- Bats have special adaptations that allow them to hang upside down. They use the strong claws on their feet to grip and special blood vessels stop blood rushing to their heads.
- Bats are often split into two broad groups: fruiting and blossom-eating 'megabats' and mostly insect-eating 'microbats'. Recent evidence suggests the relationships within bats is more complex.
- The English word for bat is thought to be derived from the Icelandic word blaka, which means 'to flutter'. So, we could call bats 'flutterbys'!



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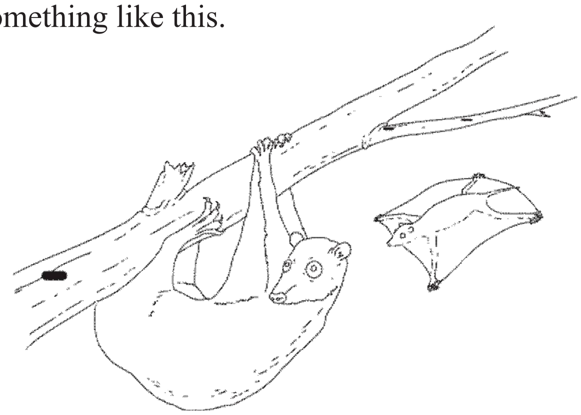
Bat fossils and ancestors

How bats developed from prehistoric relatives is a mystery, but we can make guesses by looking at fossils and today's animals.

It seems likely that bats evolved over millions of years from tree-gliding relatives that have since disappeared. No 'missing link' fossils have yet been found to trace the development of bats from gliding ancestors and though some gliding mammals exist today, they are not related to bats (see Bats in flight section).

Though today's gliding mammals are not related to bats, scientists can still use them to guess at the characteristics of bat ancestors. The Colugo (Cobego or Flying Lemur) of the Philippines and Malaysia is the best example. It has a large cloak of skin that stretches from the sides of its body to its arms and legs. It also has webbing between its fingers, toes and tail. The stretched membrane allows it to glide from tree to tree. There are also gliding squirrels and possums, with gliding membranes not as developed as the Colugo. The early ancestors of bats may well have looked something like this.



Early bat ancestors may have looked like Colugo, or 'flying lemur' of South-East Asia.

Some scientists think megabats and microbats may have had different ancestors. Microbats may have evolved from a shrew-like insect-eater which used ultrasound to communicate. Megabats may have evolved from a primate-like animal similar to our own ancestors. If this theory is correct, it means separate groups of ancestors developed similar form and structure for flying.

The earliest complete bat fossils are about 50 million years old and are very similar to today's microbats. Australia has some of the richest bat fossil deposits in the world; fossils found at Riversleigh in northern Queensland date back to 25 million years. These fossils indicate a diverse microbat population in our prehistoric rainforests. Surprisingly, there are no records of megabats in these older Australian fossil deposits; known megabat fossils in Australia only date to about 10,000 years ago.

At Murgon in south-eastern Queensland, Dr Suzanne Hand and other palaeontologists found one of the world's oldest bat fossils—a bat tooth dating back 55 million years. These fossil discoveries may change our concepts of bat origins because bats were once thought to have come to Australia via the Asian super-continent only 'recently' in geological terms.

More recent 'sub-fossils' (bat remains in owl pellets and mummified bats not yet turned into fossils) show a recent decrease in the range of some bats. For example, the Ghost Bat is now found much further north than the range indicated by sub-fossil remains in South and Central Australia.

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Bats today

Of more than 4300 types or species of known mammals living in the world today, greater than 1,000 of these are bats. This means almost one in four mammal species are bats! In the mammalian world, bats rank second in diversity of species, after the rodents.
In Australia 26% of native mammals are bats (51% are marsupials, 22% are rodents, and the remaining 1% includes the monotremes and the dingo). Australia has about 80 species of bats, three of which are presumed extinct.

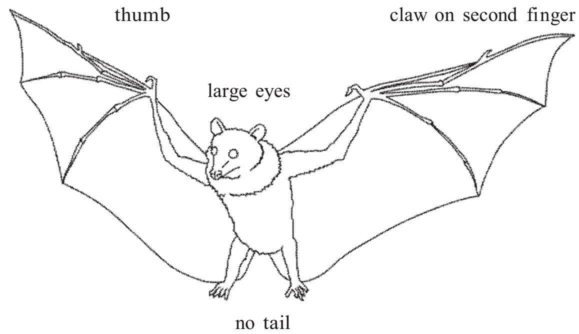
Basic bat question-and-answer

What are the types of bats?

The main order of bats is the Chiroptera. Under this order, bats are placed into two main groups, or sub-orders: the Yinpterochiroptera (includes fruit bats and echolocating horseshoe bats, leaf-nosed bats and ghost bats) and Yangochiroptera (all other echolocating bats). For simplicity, this Bat Pack uses the terms microbats and megabats as a convenient way of highlighting the main differences between them, but acknowledging it does not reflect the true taxonomic relationships that exist within this fascinating group of animals.

Megabats

The megabats are usually large—up to a kilogram—with wingspans of almost a metre. As their common names suggest, they eat a range of fruits, nectar and pollen from flowers. Megabats have large eyes with special tissues that help to collect and reflect light to let them see in the dark. Their ears are fairly large and they have long snouts with sensitive noses that give them a good sense of smell.



A typical megabat

Megabat facts

- There are about 175 species of megabat in the world.
- The largest bats are the Indian Fruit Bat (*Pteropus giganteus*), Indonesian Fruit Bat (*Pteropus vampyrus*) and Philippines Fruit Bats (*Acerodon jubatus*). These bats have wingspans of almost two metres and masses of over a kilogram.
- Twelve species of megabat are found in Australia—mainly in the east, north and northwest.
- Australia's largest bats are the Black Flying Fox (*Pteropus alecto*) and Grey-headed Flying Fox (*Pteropus poliocephalus*). These bats have masses of a kilogram or more and wingspans of up to 1.6 metres.
- The smallest Australian megabat is the Northern Blossom Bat (*Macroglossus minimus*), with a mass of about 17 grams.
- Fruit bats, flying foxes and blossom bats are all megabats.
- The long snouts of the megabats give many of them their foxy faces—thus why we call them 'flying foxes'.

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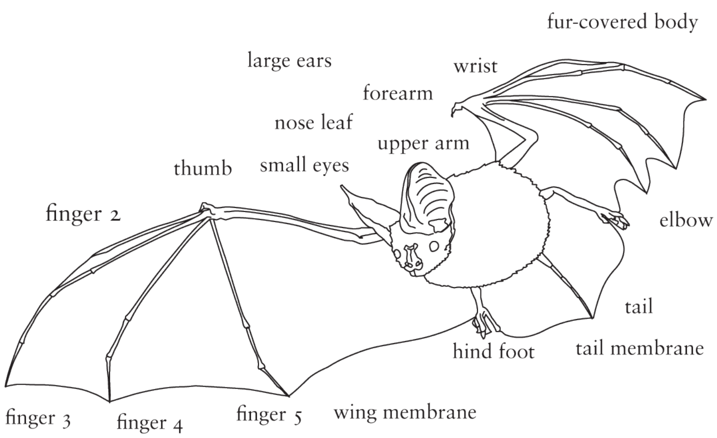
- Fruit bats use their strong feet to hang upside down from branches or rock overhangs to rest and wrap their wings around them like a cloak.
- Many flying foxes have a distinct musty odour.

Microbats

The microbats are usually small bats, from 2–170 grams, with wingspans of 30 centimetres or less. Most microbats are insect eaters, but some feed on larger animals. Others outside of Australia feed on flowers and fruits.

Microbats have small eyes and large ears, often making them look bizarre. Their unusual faces are highly specialised for using sound to 'see in the dark'.

Microbats use sound to navigate and find food in the dark. They emit complex patterns of high frequency sound, called 'ultrasound'. The echoes that bounce back to the bat's ears allow the bats to build a sound picture of their surroundings. This process is called echolocation (for more information, see Section 3—Bats and sound).



A typical microbat and sovme of its features

- The microbats are a very diverse group—they make up over 80% of the world's bat species!
- Australia has almost sixty species of microbat.
- The largest Australian microbat is the Ghost Bat (*Macroderma gigas*), with a mass of 150 grams and a wingspan of 300 millimetres.
- The smallest Australian microbats are the Forest Bats and the Timorese Pipistrelle (*Pipistrellus tenuis*), with masses of only three to four grams and wingspans of 130 millimetres.
- One of Australia's rarest mammals is a microbat, the little known Tube-nosed Insect Bat (*Murina florium*), which was found living in the misty mountain forests of tropical Queensland in 1981.
- One of the world's smallest mammals is the Bumblebee Bat (*Craseonycteris thonglongyi*) of Thailand—it weighs only one and a half grams and has a wingspan of only 130 to 145 millimetres.

Where are bats found?

Bats are found in almost every part of the world, except for the cold polar regions and some remote islands. They live in a variety of environments from rainforests and woodlands, shrublands to deserts, cities to farmlands.

Most megabats are tropical because fruit-and-flower feeders need an environment where these foods are available all year round. Microbats are able to live in cooler climates because many of them are insect-feeders and are able to hibernate.

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A diverse range of bats live in rainforests because they provide a range of habitats and food. Over two-thirds of Australia's bats are found in the tropical Cape York area of Queensland.

Where do bats live?

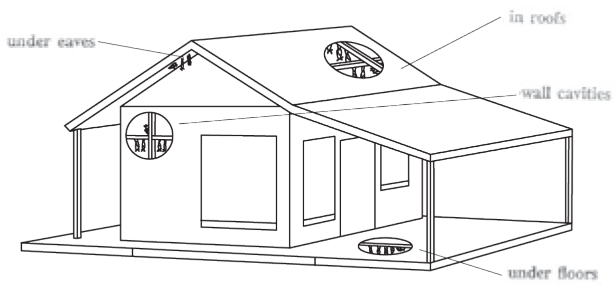
Bats live in various habitats, depending upon the species food, shelter and other requirements.

Bats spend the daytime in sheltered and dark roosts, coming out at dusk and night to feed. Roosts provide bats with protection from predators and give them a stable environment in regards to temperature and humidity. The level of humidity is important to bats because the bare skin on their wings and faces can lose water by evaporation.

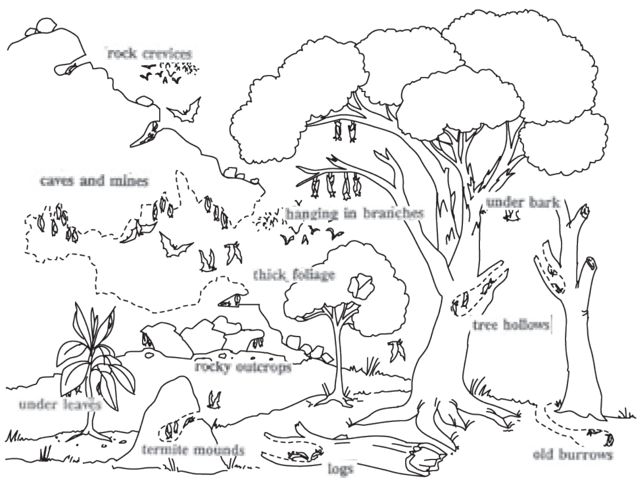
Bats may have various roost sites at different times of year. They may change a roost site in response to seasonal weather, breeding seasons or in order to form maternity colonies for rearing young. Fruit bats and blossom bats can be particularly nomadic, often moving to find new food trees.

Bats use a number of places as roosts, including:

- buildings and other human-made objects (in roofs, walls, cavities and even old cars)
- caves and mines (on ceilings and walls)
- rock outcrops and overhangs (in nooks and crevices)
- trees and plants (on branches, in tree hollows and trunks, in thick foliage, under leaves or bark)
- termite mounds and burrows.



Buildings can provide roosts for bats.



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What do bats eat?

Many bats feed on nocturnal insects. Others feed on fruit and seeds or nectar and pollen. Some microbats are carnivorous and a few even feed on animal blood.

Because bats fly and are often small, they use a lot of energy and need quite a lot of food relative to their size. Microbats have been observed to eat up to 1000 insects in an hour! Some fruit bats can eat twice their own mass in three hours.

Many bats limit flight time in order to conserve energy. Some insect-eating bats only feed for thirty minutes at dusk and dawn, spending the rest of their time roosting. Some fruit bats travel up to 50 kilometres each night to find food.

Fruit and flower-eating bats

Australia has nine living species of fruit bat and two species of blossom bat, all of which are megabats.

Fruit bats are bats that eat fruit or feed on pollen and nectar from flowers. These bats are usually found in tropical areas where a wide range of fruiting and flowering plants can be found all year round. Large night-adapted eyes and a good sense of smell helps them find their food.

Fruit-eating bats are usually slow-flying. Their stout jaws help them to bite through fruit skins and carry them away. Blossom-eating bats also fly slowly and some actually hover at flowers like a hummingbird.

Many fruit-eating bats also feed on pollen and nectar. Nectar is mainly a sugar solution (good at providing energy) and has low amounts of proteins, minerals and vitamins. Pollen is rich in proteins and is often eaten to provide these nutrients. These bats have long snouts and tongues for getting into flowers. Some have tongues with brush-like tips like honeyeaters, to help feed on the nectar and pollen.

Blossom bats' teeth are small and their jaws are not as good for chewing as fruit bats. They may also feed on smaller, thin-skinned fruits, or ones that are already opened.

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Pollination and seed dispersal

Nectar is a sugary solution produced by plants to encourage animals to visit them. Pollen can coat the animal while it feeds and can be carried to other plants of the same species. This cross-pollination helps keep plant populations healthy. They are able to produce more viable seed than if each individual plant fertilised itself (i.e. there is greater genetic mixing).

Many flowers are adapted to be pollinated by specific types of animals. The fewer types of flower that a certain animal visits, the better chance there is of the animal pollinating plants of the same species. A number of plants have flowers specially adapted to be visited by bats, although bats also pollinate other, non-specialised flowers.

Bat-pollinated flowers need to be open at night. They are often white or light green or brown so they stand out against the foliage in the dark. Specialised bat flowers are usually large and have musty or sour odours. Other less bat specialised flowers may be smaller but bloom in large clusters (e.g. eucalyptus, banksias and melaleucas) so a bat can land on them.

Bats are very important for plants in the tropics. Nearly 70% of commercial fruits in South-East Asia are pollinated or have their seeds dispersed by bats. Many Australian hardwood trees used for timber are pollinated by bats. Experiments indicate that some trees pollinated by bats set more seeds than those pollinated by birds and bees.

If plant seeds germinate too close to a parent plant, they may have to compete for nutrients or may be shaded out by mature plants. Many plants use animals to get their seeds away from the parent plant.

Bats are good seed dispersers because they fly and can travel large distances. They pick and carry fruits to another perch to eat, discarding the seeds and skin, or they eat the fruit and the seeds are passed out later as they fly away. Bat-dispersed fruits usually have one large seed (like an avocado) or many slippery seeds (like a fig).

Bats can be extremely important seed dispersers in areas where large amounts of forests have been cleared. Many daytime seed dispersers in a rainforest will not venture out into cleared areas because of the danger of being seen by predators. However, bats travel at night and fly over these areas without fear of many predators. Bat-dispersed seeds are often the first colonisers of cleared rainforests. These plants grow and provide the conditions for other plants to re-colonise. Studies on Australian fruit bats have shown that many seeds germinate more successfully after being eaten and passing through the digestive systems of bats.

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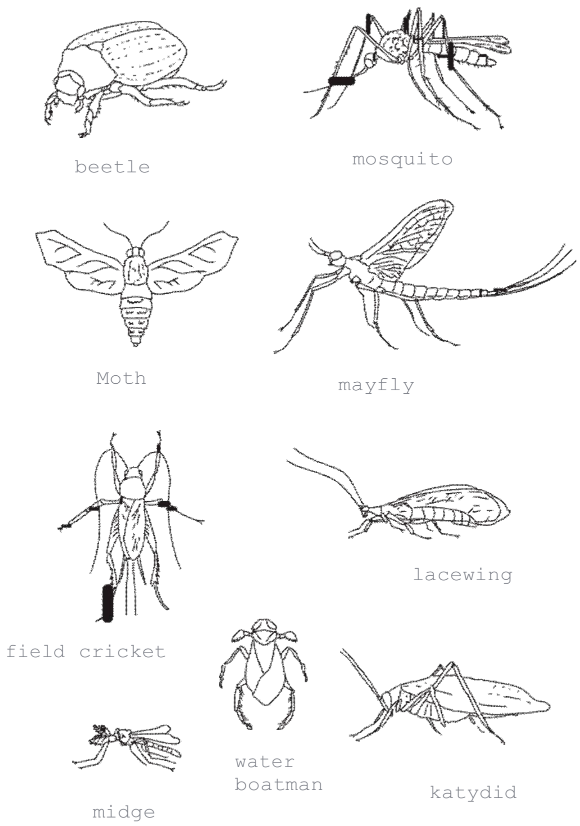

All sorts of insects are eaten by bats: beetles, mosquitoes, moths, mayflies, crickets, midges and katydids. Different types of bats coexist by feeding on different insects or feeding at different times, heights or places. Note: The 'flight paths' illustration on page 35 illustrates these feeding patterns.

Insect-eating bats

Bats are some of the most important controllers of nocturnal insects in the world. One bat may catch and eat 500 to 1000 mosquito-sized insects in an hour. About 70% of bats are insect-eating microbats. They use sounds and echoes to hunt insects and their faces are dominated by the special 'equipment' needed for echolocation.

They are swift fliers and must be agile to catch their prey on the wing. Many use their tails or wings to scoop up insects in flight and then transfer them to their mouths. Their sharp teeth can chomp insects up quickly to aid digestion.

All sorts of insects are eaten by bats: beetles, mayflies, midges, moths, mosquitoes, crickets and katydids. Different types of bats coexist by feeding on different insects, feeding at different times, or hunting at different heights (discussed further in Section 4—Bats in flight).

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Carnivorous bats

Some microbats eat other small animals, as well as insects. Some carnivorous bats in Central America use their sense of smell to find roosting birds.

The Australian Ghost Bat (*Macroderma gigas*) is large and feeds on insects, frogs, lizards, small birds, mammals like mice and rats, and even other bats. It swoops down on its prey and kills with powerful bites. The Greater Broad-nosed Bat (*Scoteanax rueppellii*) of eastern Australia feeds mainly on small flying beetles but is also known to prey on other small animals—including other bats.

In Central and South America, some microbats have become specialist feeders. The amazing Frog-eating Bat (*Trachops cirrhosus*) uses echolocation and listens for the calls of mating frogs to swoop down and snatch frogs up in its mouth. These frogs have a problem: they must call to attract a mate—but don't want to become a bat's dinner! Thus, these frogs have come up with a number of behaviour strategies, such as keeping very quiet whenever they see a bat!

In the Caribbean and Central America, the 'fishing bats' (*Noctillo leporinus* and *Pizonyx vivesi*) use their long feet and toes to rake through the surface of the water to catch fish and aquatic insects. They use echolocation to detect ripples on the water where fish come to the surface. In Australia, the Large-footed Myotis, or Mouse-eared Bat (*Myotis macropus*) feeds on flying insects above the water and also uses the feet-fishing technique to catch aquatic insects like the Water Boatmen. Scales of small fish have even been found in their droppings.

Blood-drinking bats

Among mammals, one of the most unusual diets is that of vampire bats. There are three species of vampire bat which are found only in the American tropics. The Hairy-legged Vampire Bat (*Diphylla ecaudata*) feeds on the blood of sleeping birds, the White-winged Vampire Bat (*Diaemus youngi*) feeds on bird and mammal blood, while the Common Vampire (*Desmodus rotundus*) feeds on mammal blood, including that of people.

An agile bat, even on the ground, vampires use their good senses of smell and vision to find their victims. Their echolocation appears to be best for detecting larger objects. Parts of their noses are heat sensitive and can detect blood-filled tissues, letting them find a good place to bite. They creep up and make a small cut with their sharp incisor teeth. The bat then uses their special grooved tongue to lap up the blood, assisted by capillary action.

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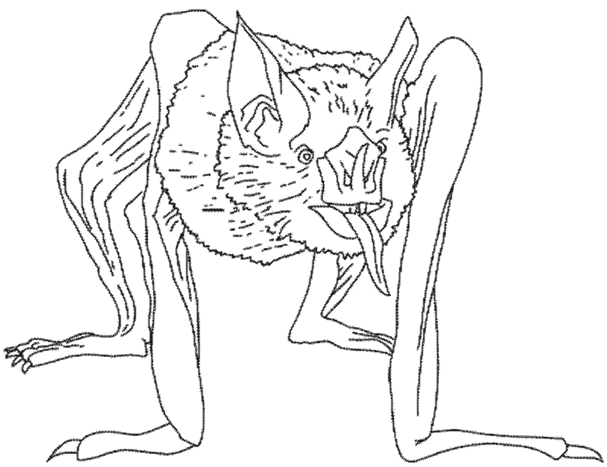

Vampire bats can walk on their thumbs and feet. They make cuts in the skin with their sharp teeth and lap up blood with their tongue.

The saliva of the vampire bat contains an anticoagulant to make the blood flow more freely. This can cause problems for the victim, as the wound may bleed for some time after the bat has finished feeding. On a positive note, the anticoagulant in their saliva is very effective and vampire bats may be invaluable in medical research on prevention of blood clots in people.

What eats bats?

In Australia, owls, other birds, cats, foxes, snakes, frogs, crocodiles—and even other bats—feed on bats.

Birds that hunt at night, like owls, have good night vision and can catch bats on the wing. Some day birds, like hawks, may wait near a roost to catch bats as they leave at dusk. Pied Butcherbirds, Currawongs and even Magpies are also known to wait for bats at roosts.

Some bats like Gould's Wattled Bat (*Chalinolobus gouldii*) and the Lesser Long-eared Bat (*Nyctophilus geoffroyi*) often fly low to the ground or even land to catch insects. This can lead to them being caught by foxes and cats.
Following are some predators of bats and the manner of their feeding.

- Hawks and eagles may catch fruit bats which roost in large groups in trees.
- Spiders have been known to catch small bats in their webs.
- Predators like snakes and black rats can climb up to roosts in trees and caves.
- Children's Pythons wait at the entrances to caves and snatch bats as they stream out in crowded flocks at dusk.
- Green Tree Frogs wait to catch fallen bats.
- Other predators—including foxes, cats, snakes, frogs and even beetles—may also wait on the floor of caves to catch baby bats that fall from maternity colonies.

In northern Australia, crocodiles wait under flying fox camps in mangroves for bats to fall. Sometimes the crocodiles knock the trees with their tails or leap up to pull down bats roosting on low branches.

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In many places in the world, humans also eat bats (see Section 2—Bats and us). Though people are probably the biggest threat to bats, it is not because we eat them. Ever-increasing human populations are contributing to more clearance of habitat and increased use of natural resources (see Section 5 — Bat conservation).

How do bats communicate?

Bats have complex social lives and they communicate with each other both through sound and scent.

Communication by sound is very important to all bats. For example, the Huge-nosed Hammerhead Fruit Bat (*Hypsignanthus monstrosus*) of Africa honks out calls to attract mates. Epauletted Fruit Bats also honk and use showy, scented shouldertufts and wing flapping displays to court female bats.

Many bats also use smell as a means of communicating. For example, flying foxes have a musty odour that is most noticeable in males ready to breed. In Central America, the male Sac-winged Bat (*Saccopteryx billineata*) has a special scent gland on its wing. It roosts and shakes its wings to release scent to mark its territory and attract females. This bat performs aerial displays and sings long and complicated songs audible to humans. For more information on bat communication, go to Section 3 — Bats and sound.

What are bats' strategies for survival?

Nightlife

Many animals come out only at twilight or night (known as being nocturnal). This keeps them safe from many daytime predators such as hawks and eagles.

In hot climates, nocturnal activity can also be a useful way to keep cool and prevent water loss. Bats have large areas of bare skin on their wings and face that can lose water through evaporation. To avoid this, many bats have glands between their eyes and nostrils that produce oil, which they use to clean their skin and protect it from drying out. Staying out of the sun and avoiding dry air also helps—most bats choose roosts with a high humidity and stable temperatures, such as caves and hollows.

Protection from predators

Most bats shelter during the day and stay hidden from predators. Roosts are often well-hidden in hollows or crevices or high up in cave ceilings or tree tops.

Some flying foxes hang high up in branches during the day in 'camps'. These can be very large, from a hundred to tens of thousands of animals. They are

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often noisy and staying hidden does not seem to be very important. These bats protect themselves by having lookouts to watch for danger and warn the group. Their large numbers may confuse predators like eagles, making it hard to single out a target.

In contrast, the Tube-nosed Fruit Bat (*Nyctimene robinsoni*) is a solitary animal. Roosting in dense vegetation, it wraps its wings around itself like other fruit bats. Its wings are brown with irregular yellowy spots like a rotting leaf, providing camouflage in the dappled light of the forest.

Many bats use camouflage—they are black or shades of brown, which blends into the night sky or a dark roost. Others are coloured red or orange, which may also help them blend in with cave walls or vegetation. Other bats are spotted or streaked with white which may help break up their outline or be helpful in recognition. Some bats may be 'bleached' to a lighter colour by the ammonia fumes in their poorly ventilated caves. On the other hand, some bats are white and no one yet knows why! One of the white tent-making bats of Central America lives under leaves. Perhaps white does not show through the leaves as much as black would?

Bats' colouring is probably used more for protection from predators, rather than communication with other bats. This is because microbats are probably colourblind, although some megabats may see in colour.

Hibernation

In more temperate areas, cold can be a problem for bats. There may not be enough insects about during winter, and more energy is needed to stay warm and active.

To cope with this, some bats become inactive during cooler months. Their body functions slow, and remain inactive to conserve energy, living off body fats stored in the warmer months. Short periods of inactivity are called torpor. Longer periods are called hibernation.

A number of Australian bats hibernate. Some, such as the Large Forest Bat (*Vespadelus darlingtoni*) wake up at certain times during winter and hunt for a brief meal before returning to their roosts.
In hot areas, bats may go into a similar state of reduced activity (torpor), but in this case it is to avoid water loss. Inactivity during the summer is called aestivation.

Migration

Bats may migrate to warmer areas to escape the cold or to find more suitable sites for maternity colonies to raise their young. Many Australian fruit bats move large distances to take advantage of flowering and fruiting trees, and form breeding colonies. This does not always take place in the warmer months, indicating that their movements are considered to be more nomadic than migratory.

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In spring, many Southern Bent-winged Bats (*Miniopterus bassanii*) congregate at Naracoorte in South Australia to form maternity colonies. Up to 150,000 bats have been counted in the caves at these times. They may migrate up to 200 kilometres from other caves in south-eastern Australia where they have spent the winter.

Reproduction and development

Bats need to fly to find their food and carrying too many developing young would hinder a mother's ability to fly and feed. Therefore, bats usually give birth to only one or two young. They usually give birth once or twice a year. In some species, female bats form large groups when they give birth, called maternity colonies. Often the same site is used year after year, such as the Naracoorte Caves in South Australia.

After birth, the baby bat clings to its mother's fur and it uses its milk-teeth to grip onto the mother's nipple. The young bat's feet and claws are well developed so it can hang on. Some bat mothers carry their young in flight for up to three months, but other baby bats are left in the roost while their mothers go out to feed.

Microbats are born with little or no fur and are blind. Mother bat and her baby communicate with each other very soon after birth, through echolocation. The young microbats learn to use echolocation very early because they need to be able to navigate before they leave their dark roost for their first flight.

In contrast, megabats are born with fur and open eyes. Young fruit bats are often carried out to feeding sites by their mothers. They need to learn where to find the right fruits and flowers at different times of year. A baby fruit bat licks the fruit juices from its mother's lips and thus learns the smells and tastes of edible fruits.

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BATS AND US

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Bats and human culture

World-wide views on bats

Different cultures have varied views on bats. They can be seen as good luck charms, bad omens, medicinal aids, and even as food.

Fruit bats are eaten by humans in many places across the world. In Guam, the Seychelles, Africa, Melanesia, Asia, New Guinea and in Australia, bats have been a part of people's diet.

Ancient Egyptians believed bats prevented diseases and ailments such as poor eyesight, tooth-ache and baldness. A bat hung over the doorway could stop the 'demons' that carried these diseases from coming in.

Many cultures associate bats with the night, darkness and death. In Africa and the Caribbean, bats are used in voodoo ceremonies. The Roman poet Virgil related them to the 'winged monsters' of Homeric legend. The Mayan Indians of Central America depicted bats as creatures of the Underworld, ruled by a Bat-god with the wings and head of a bat but the body of a human.

In Polynesian mythology, bats were amongst the hordes sent by the evil Whiro to attack the hero, Tane', on his ascent to heaven. Tane' defeated them and brought them back to earth as prisoners along with mosquitoes, sandflies, and owls.

On the other hand, the ancient Macedonians and Gypsies considered bats lucky, and parts of bats were carried as good luck charms.

The Chinese also traditionally regarded bats as symbols of good luck and happiness. The Chinese characters for bat and luck are both pronounced fu (although the characters are different), and bat designs appeared on clothing, jewellery, art and crafts. Chinese mothers often sewed jade bat buttons onto caps worn by babies.

In some countries, bat colonies are protected because of their presence in temples or sacred places. The Balinese cave temple of Goa Lawah serves as a refuge for fruit bats, protected by the holiness of the temple. Local beliefs were influenced many centuries ago by Hinduism, which promoted a respect for other forms of life. The Goa Lawah bats tolerate people and are not disturbed by the ceremonies below. Sacred snakes also live in the cave.

In Thailand, Buddhists consider flying foxes a symbol of long life and of the cycle of reincarnation. Large numbers of bats roost in the temple of Wat Ta Sung near Bangkok. After funeral ceremonies a fire-cracker is let off to signal the departure of life from the body. The bats fly up and swirl around in large flocks, eventually returning to roost.

In Samoa, words relating to fruit bats are sometimes used to describe people. 'As lazy as a bat' refers to the daytime roosting of flying foxes and there are expressions that refer to bat smells and eating habits that are used to describe people.

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Bat guano

Bat droppings (guano) were traditionally collected and used in many countries as a valuable fertiliser. There are old bat guano mines in the Flinders Ranges and the South-East of South Australia that were used by farmers up until the 1930s. Now, the use of bat droppings is generally restricted to developing countries.

In Thailand, one monastery manages its bat caves to ensure the continued supply of this valuable resource. Local people are only allowed through the cave temples gates at certain times, and are only allowed to gather in chambers with high ceilings where the bats will not be unduly disturbed. The people collect their supply of guano under the supervision of the monks.

Bat droppings from flying fox camps in mangrove areas provide valuable nutrients for these ecosystems, and whole communities of organisms thrive in the guano-covered floors of bat caves.

The nitrates in bat guano make it good fertiliser, but nitrates are also used in making munitions. For this reason, guano was mined to make gun powder during the First World War!

Indigenous Australians

Introduction to Totemism and Stories

In traditional Aboriginal life, plants and animals play an important role in spiritual life and culture.

Many indigenous people have plant and animal totems, whose naming and significance is very complex. Totems have connections with the world of spirit ancestors and the people have special ties with the particular plant or animal in the natural world. Totems help bind people to the land, giving them a sense of belonging with the land, and a sense of community amongst themselves.

Stories, or 'dreamings', about totems and other characters often have a ritual association; they are more than just entertainments. The stories could provide unwritten maps of areas and natural features and an oral encyclopedia of the environment. Stories can relate to the origins of laws, rituals and traditions, and outline social relationships, and as well, serve as warnings, and highlight punishments for breaking laws.

Taken out of the context of their culture, dreaming stories can sometimes appear to have limited relevance or meaning. Many modern recollections of such stories do not mention how they fitted into aspects of the culture; they are simply presented as 'curiosities' and entertainments. When using dreaming stories in education, it is important to relate back to their role in traditional culture. Some stories can be used to help introduce topics and themes, or to link concepts and provide a focus for activities and discussion.

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Indigenous Australian views on bats

Bats have been associated with both creation and death in Aboriginal culture. To some people they are beneficial ancestors, saving fire for the people, defeating enemies and helping to put the world in order. To others they are fierce warriors, quarrelsome clans and slayers of other ancestors.

Bats have varying significance in Aboriginal societies. Fruit bats are used by some as food, and feature in stories, to some they were a totem and feature in ceremony and song, whereas in other areas there is indifference and little mention of them.

In some Aboriginal groups, bats were considered a men's totem and owlet nightjars a women's totem.

In a study relating traditional Adnyamathanha culture to mammals found in the Flinders Ranges of South Australia (Tunbridge 1991), old people were amused at the suggestion that bats may have been a totem. Only two names were recorded in the Adnyamathanha language, one for small bats (mika) and one for the larger Ghost Bat (Ngarlamikanha), which is now locally extinct in South Australia. The word mikawira, meaning 'batwings', features in the Adnyamathanha language as the name for a bicycle!

In contrast, in Central Australia bats occur as ancestors in ceremonies of the Southern Aranda people. They are fierce warriors and one song tells of a bloody ambush by bat ancestors. The Ghost Bat ancestors (irkentera) join forces with the common bat people (ulbolbuna, or the Lesser Long-eared Bat) to attack a camp of other bat men (ntjepera). The bat ancestors swarm out of tree hollows and fly to the camp of the enemy where in the early morning they assume human form and ambush the camp (Strehlow, TGH, 1971). Ghost Bats were also important in ceremonies in Northern Australia. The roost caves are regarded as sacred sites.

In eastern and northern Australia, flying foxes were used as food and feature in a number of stories. The quarrelsome nature of flying fox camps was often related to squabbles and disputes amongst clans.

The Nurrunga people of Southern Yorke Peninsula have a dreaming story that tells of a journey and great fight of an ancestor Buthera and a bat ancestor, Mudichera. In the battle the bat-man was cut in two by Buthera's knife and the halves turned into two bats and fluttered away.

In comparing different Aboriginal cultures, it would seem that (as with many plants and animals) the number of stories and words referring to bats is related to their importance as a resource.

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Contemporary Australian views on bats

Since European settlement bats have had a negative image in non-indigenous Australia, with many attitudes adopted from European and English folklore.

Bats in the house are sometimes considered an unlucky omen, a portent of illness or loss of money. There are a number of expressions that relate to bats, few of which have any basis in fact. Many have a negative vein, such as ‘blind as a bat’, ‘bat out of hell’, and ‘bats tangled in your hair’.

Because they are creatures of the night, bats have long been associated with mystery, darkness and the unknown, witches and vampires. Ancient legends of blood-sucking creatures are found in a variety of cultures. The association between bats and vampires in western culture is, however, relatively recent. It was not until the sixteenth century that Spanish explorers brought back tales of the blood- drinking bats of Central America. Since the 1900s, stories and movies have popularised the connection between bats and vampires.

Bats are often considered a pest in houses, to fruit crops and as carriers of diseases, and their benefits to humans are often overlooked. However, people are slowly becoming aware of the importance of bats in the environment.

Interactions between bats and humans

Bats in our houses

Bats shared the caves of our ancestors and they share our houses today. With the loss of many natural habitats, buildings provide important roosts for many bat species. Bats in houses can be a nuisance. Large colonies accumulate droppings with pungent odours, and the noise of bats can be disturbing to other tenants of the house. However, many people do not even realise they have bats sharing their houses. In Australia there is little health risk associated with bats in a home.

Bats and our health

Recently in Australia, bats have been found to host some viruses that can be harmful to humans. The Australian Bat Lyssavirus (ABL) is closely related to rabies and has resulted in three human deaths in Queensland as a result of bites from infected bats. Both flying foxes and microbats are known to carry this virus. People who handle bats are vaccinated for rabies and wear gloves to provide protection against the Australian Bat Lyssavirus. If bitten or scratched by any bat, you should wash the wound with soapy water for 10 minutes and seek medical help immediately to receive post-exposure vaccinations. Hendra virus is another virus that is transmitted from flying foxes to horses. The virus can then be transmitted to humans when there is close contact with an infected horse. It is not transmitted directly from bats to humans. Five human deaths have resulted. Horses are at risk where they are stabled beneath flying fox feed trees and confined paddocks where flying foxes are feeding. A Hendra virus vaccine for horses is available from veterinarians.

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There are some fungal respiratory infections associated with bird and bat guano, especially in humid tropical conditions, but avoiding large guano deposits minimises risk of infection.

Bats should never be handled by a person who has not been vaccinated against ABL. If you find a bat that appears ill or injured, call your local wildlife rescue organization.

Bats are important controllers of insect numbers. They may be extremely important in controlling mosquito populations and limiting the spread of insect-borne diseases such as malaria and Ross River fever.

Like all animals, bats are host to a range of parasites. It is thought that bed bugs began as bat parasites. The bugs adapted to use people as hosts when humans used caves as shelters. Later, as these people moved to other lands, bed bugs spread all around the world.

Bats and our fruit crops

In the 1930's Francis Ratcliffe undertook one of Australia's first detailed studies of flying-foxes. He concluded that 'contrary to general belief, the flying fox is not a serious menace to the commercial fruit industry'.

Since then large areas of native forest and woodland have been removed for housing and agriculture causing flyingfoxes to turn to commercial orchards and garden fruit trees, when droughts or prolonged rain causes shortages of their natural foods. They can cause substantial damage to crops, but the occurrence is intermittent, with little damage in some years.
Previously, widespread destruction of fruit bat colonies was carried out by fruit farmers and local councils. This still occurs overseas and there are continuing calls to allow it to happen in Australia again. With the increasing awareness of the importance of bats as pollinators of important hardwood trees and native fruit trees, and their role in seed dispersal in re-afforestation, non-destructive means of control are being favoured. Installation of full exclusion netting to protect commercial fruit crops from flying-foxes and birds is recommended by all State Governments. It is illegal to shoot flying-foxes in Victoria and South Australia. In NSW licences to kill flying-foxes in commercial orchards are being phased out and funds are available for several years to assist growers to install full exclusion netting in the most affected region.

http://www.environment.nsw.gov.au/wildlifelicences/s120Licence.htm

The Queensland Government recommended issuing of licences to shoot flying-foxes in commercial orchards in 2013.

Cruelty is unavoidable in shooting flying-foxes. 'The animal welfare issues that result from shooting, as a method of mitigating crop damage caused by flying-foxes, are unacceptable ethically and legally.' This is a quote from the NSW Flying-Fox Review Panel 2009. The RSPCA and many other community organizations agree.

Backyard fruit tree netting

Protect your fruit crop in your garden without hurting wild animals especially flying-foxes. There are some useful hints on this website:
http://www.ehp.qld.gov.au/wildlife/livingwith/flyingfoxes/netting_fruit_trees.html

SECTION 3

BATS AND SOUND

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How do bats 'see' in the dark?

One of the unusual characteristics of microbats is their use of ultrasound echolocation to create a three dimensional 'picture' of their world.

The oldest bat fossils date back to fifty-five million years ago. These fossil remains include bats of various types, suggesting that at that time, bats had already undergone a considerable period of evolution. Fossils show that bats had already developed the ability to use echolocation. It is not yet clear how such an ability evolved, although it is thought that the ancestors of microbats were shrew-like insectivores. Present day shrews are capable of crude ultrasound production.

Birds were present at this time. Nearly all of them were active during daylight or diurnal hours, thus leaving a niche—that of the night skies and its abundant insects. The evolution of flight and echolocation allowed bats to exploit this rich resource.

It is perhaps surprising that birds did not evolve to compete with bats for this niche. Some birds use echolocation (the swiftlets, oilbirds and possibly some shearwaters and storm petrels) but they are relatively few and their echolocation is not as sophisticated as that of bats.

Discovery of bat echolocation

The discovery of bats echolocation is a fascinating story It encompasses the principles of the scientific process, and also raises the issues of animal ethics and experimentation. (Story compiled from Hill, J.E. + Smith, J.D. 1984; Morris, P.A. + Yalden, B.W. 1975; and Street, P. 1976.)

It is only since the development of electronic equipment in the 1900s that the full intricacies of bat echolocation were able to be appreciated. Long before, however, people had sought to explain the ability of bats to fly in the dark.

In 1793, an Italian naturalist, Lazaro Spallanzani, observed that owls had difficulty flying in complete darkness, yet bats could fly unhindered. Spallanzani originally thought that eyesight was important for bat navigation. Initial experiments involved placing a light-proof hood over their heads so they could not see. These bats were unable to navigate properly. As a control, he used a transparent hood and found that the hooded bats were also unable to fly in the dark without avoiding obstacles.

Spallanzani then surgically blinded a number of bats. Releasing them in a room with obstacles he found they could fly without colliding. Next he caught and blinded bats from a local roost and then

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replaced them. Returning four days later he caught the bats and dissected them. He was surprised to find that their stomachs contained as many insects as those of sighted bats.

Hearing of Spallanzani's work, a Swiss naturalist, Charles Jurine, repeated the experiments with blinded bats. However he also blocked the bats ears with wax, observing that they were unable to navigate and flew into objects helplessly.

Before he died in 1799, Spallanzani repeated the blocked ear experiments with the same results, noting that once the ear plugs were removed the bats could fly successfully. Next he used small brass tubes placed in the bat's ears to see whether it was the discomfort or weight of the tubes that affected the bats. They still flew successfully but when the tubes were blocked they could not. Spallanzani was unable to explain how the bats used their hearing to navigate as it seemed they were silent in flight.

Other scientists thought that bats may have been sensitive to air pressure as they flapped their wings, or had a 'sixth sense'. In 1800, without carrying out any experiments of his own, the influential French scientist, Baron Cuvier, offered the explanation that bats used a heightened sense of touch. Spallanzani's theories were dismissed and it was not until the 1900's that it was realised that there were sounds used by bats that were inaudible to people.

In 1912, after the Titanic sunk in a collision with an iceberg, an inventor Hiram Maxim thought that a sonic warning system may be helpful in navigation. He thought that bats might use sound for navigating but that it was a low frequency sound (infrasonic), below the level of our hearing. He suggested that bats used the noise from their flapping wings and the echo from objects.

In 1920, an English physiologist, Hartridge, became interested in a bat as it flew through his open window to catch moths. He turned out the light and observed that the bat could find its way about. During the First World War the use of high frequency sound waves and their echoes underwater (SONAR or ASDIC) was developed to help detect submarines. Hartridge suggested that bats produced high frequency sounds, ultrasounds that people could not hear. However, the equipment to demonstrate his theory was not developed until later.

In 1938, an American zoologist, Donald Griffin was interested in bat navigation. He had blindfolded bats and covered their ears to observe how well they navigate. He also found that covering a bat's mouth limited a bat's ability to navigate. Professor Pierce, a physicist at the same university as Griffin, was studying insect sounds and had made a device which could detect ultrasonic calls, and convert them to frequencies audible to humans.

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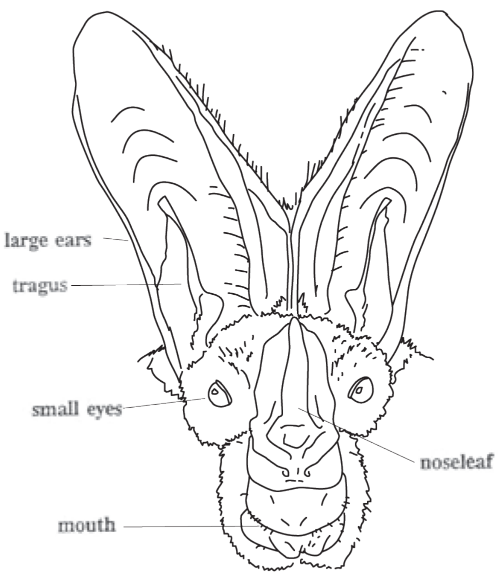
Griffin brought a cage of bats to Pierce's laboratory and they found that microbats produced a range of ultrasonic calls. At last the great mystery was solved and bat's amazing use of sound was revealed.

Bat echolocation

Ultrasound

Ultrasound is very high pitched sound usually above human hearing. Frequencies of over 20,000 Hertz (Hz.) are beyond our hearing. Sounds lower than 20 Hz are also beyond our normal hearing and are called infrasound.



Head of an echolocating microbat

Ordinary sound waves spread out in all directions. Because of their high frequencies, ultrasounds do not—they can be directed similar to a beam of light. This makes them very useful as a means of communication and for navigation.

A variety of animals use ultrasound for communication, producing it in several ways. Crickets rub rough surfaces of their legs together make sounds. Some moths have special soundproducing organs on the sides of their bodies. Dolphins 'hum' the sound through a 'melon' on their forehead. Microbats have specialised voice boxes and shout out the sound through their mouths or hum it through their nose.

Bats produce sounds with a range of frequencies. Some bat sounds are within our normal range of hearing, but others with frequencies as high as 180 kHz are well beyond our hearing. The Tomb Bat (*Rousettus aegyptiacus*) is a megabat which produces sounds audible to people. This bat slaps its tongue in its mouth in order to echolocate and navigate to its dark cave and temple roosts.

Ultrasound in bats is produced for two reasons. First, to communicate with one another and second, as a means of echolocation. Two important components of bat ultrasound calls are the frequency and the repetition rate.

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The higher the frequency or pitch of a sound the better it is for navigating. Low frequency sounds have long wavelengths. These are not as effective for picking up closely spaced objects.

A bat squeaks for an incredibly short amount of time (1/1000 of a second). The rate of squeaks changes with distance from an object. If a bat is flying in the open away from obstacles it squeaks infrequently, maybe four or five times a second. As soon as sound bounces back to the bat it knows it is near an object and the rate of squeaks increases, up to a hundred per second.

Microbat ultrasounds are very powerful. It is a good thing we cannot hear them, as they would be quite loud. Some ultrasound bat calls are as loud as 90 decibels, or the equivalent of a jack hammer in a small room. It would be difficult to get to sleep at night if we could hear the bats!

Bat calls need to be loud because sound dissipates quite quickly as it spreads. The returning echoes are much fainter than the original sounds. A bat's ears need to be extremely sensitive to these echoes, yet somehow not be damaged by the loud calls. Unlike people, bats can momentarily disconnect their ear bones so that their loud shout does not interfere with hearing the echoes.

Bats need to ensure they are not calling when an echo comes back. An analogy of this is a ship's horn. Before radar and sonar were developed, ships navigating in the cold, foggy North Atlantic would blow their horns to let other ships know they were about. They would also use horns to try to detect large icebergs, sounding the horn and then listening for an echo which might bounce off any bergs present. However, if an iceberg and another ship

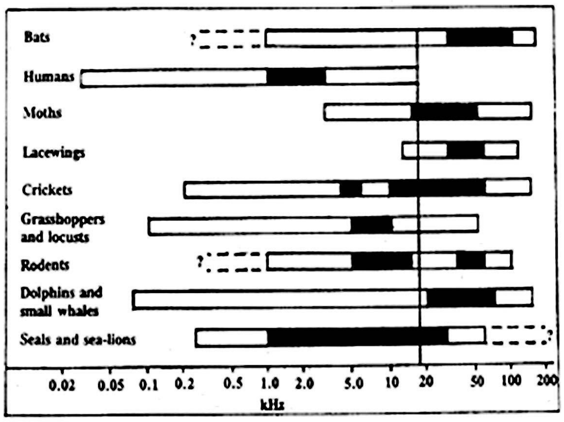

Chart showing the ranges of hearing of some animals that use ultrasound in relation to the range of hearing of humans. People can monitor ultrasound using electronic devices that convert the ultra-sound to frequencies within the range of human hearing. The darker areas of the chart show the frequencies to which the animals are most sensitive. The category 'crickets' includes common, mole and bush varieties, and 'moths' refers to the ultrasound sensitive sphingid and noctuid moths (After Sales and Pye 1974).

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were present, the fainter echo may return while the longer ship's horn was sounding and... crunch! The ship would hit an iceberg! Unlike the ship's horn, the sounds a bat sends out are short. It is easier for the bat to pick up the echoes without the sounds masking each other.

Most bat calls are not a uniform pulse of sound. The frequency changes over the time of the call; it is frequency modulated (FM). For example, many bats have a call that would start at a high frequency such as 60 kHz and sweep down to the lower frequency of 40 kHz. The other type of call used by bats is a constant frequency call (CF), which is essentially a single frequency call.

Most bat species have calls of distinctive frequency ranges and repetition rates. These 'signature calls' can be identified by using an electronic bat detector which converts the ultrasound calls into audible frequencies.

Eating in flight can be a problem for a bat. If you have a moth in your mouth it is hard to call out to echolocate. Some bats can 'call' through their noses to overcome this. Other bats land to eat. Many bats hunt in familiar areas. When they catch an insect, they go into a fixed flight pattern in a clear area above the tree canopy or understorey. Feeding over open water is also a good way of avoiding obstacles while eating.

When you think about how a bat can navigate in the dark and discriminate on hearing alone between what is edible and what is not, it is a little overwhelming. Even the sophistication of modern radar that can seek out encroaching bad weather and be used for numerous navigation and military functions, falls short of the discriminating ability of bats.

Echolocation and the Doppler Effect

As a bat flies towards an object, the distance the echo travels back to the bat is less than the distance the bat's squeak travelled to the object. Although the speed of sound in air is constant, the echo appears to return faster. This is heard as a change in frequency or pitch, called Doppler Shift or the Doppler Effect after its discoverer.

A good example of this effect is the sound of an approaching car—the car's noise sounds higher as it approaches and lower as it passes. As the car approaches, the sound waves are compressed and

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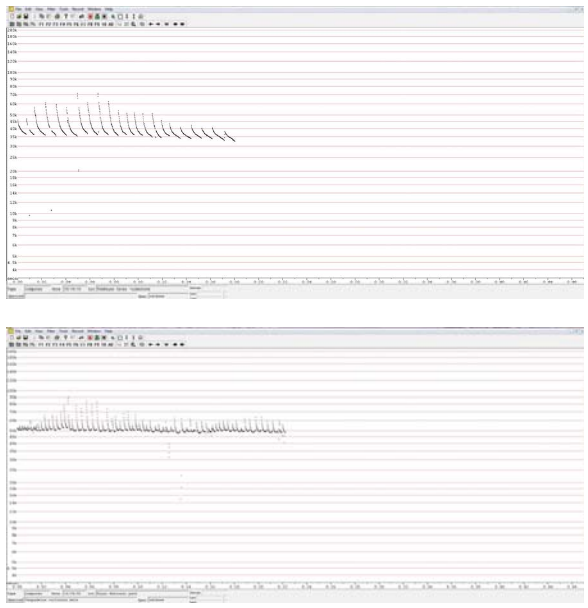
the shorter wavelengths result in a higher frequency. As the car passes, the soundwaves are lengthened and the frequency is lower.

Bats can use this effect to help them catch prey, especially those bats that only use constant frequency calls. If a moth is flying at about the same speed as the bat, there will be no Doppler effect. But if the moth is flying towards the bat, then the echo will return to the bat at a higher frequency.

Human use of ultrasound

Electronic ultrasonic devices are used by people for a variety of tasks. An ultrasound 'torch' connected to headphones can send out beams of sound. The echoes can be converted to audible frequencies to help blind people find their way around. Ultrasonic echoes can be converted to images on a television screen for us to interpret. Engineers can use ultrasound to detect hidden cracks in metal or buildings. Doctors use low energy ultrasound to create pictures of foetuses developing in the womb. Ultrasonic beams can be used to break up kidney stones without surgery. High energy ultrasonic beams can be used to clean a ship's hull or even clean dishes! Very high frequency sounds can even shatter objects.



Graphs showing ultrasonic calls of two different bats. The bat sounds are sent out in distinct pulses. These graphs were produced by a computer from recordings of bat sounds using an electronic bat detector. Readouts like these can help researchers to identify different bat species from their signature calls, although there are still difficulties in identifying some species.

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Moths strike back: Insect counter-measures against bats.

Some insects have developed protective strategies against bat attack. Many nocturnal moths can detect the ultrasonic calls of bats. Some have ultrasonic sensitive ‘ears’ on their abdomens or bristle-like structures on their heads. When a bat approaches the moths detect their calls and take evasive action, looping and spiraling. As the bat gets closer, some moths close their wings and go into a crash dive to the ground. Another insect group, the lacewings, also seem to be able to detect bat sounds, dropping out of the air to the ground when they hear a bat call.

Some species of moths can even produce ultra sonic pulses to jam the bat’s calls, making it difficult for them to locate the moth. Other moths emit sonic pulses to warn bats that they are bad-tasting. Once a young bat has caught one it quickly learns to recognise the moth’s call and avoid others. Some tasty moths mimic the calls of bad tasting moths to avoid being caught.

SECTION 4

BATS IN FLIGHT

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Flying animals

Only four groups of animals have developed true flight: birds, insects, bats and pterosaurs. We are familiar with the birds and insects, and somewhat less familiar with the night-flying bats. The long extinct group of flying reptiles, the pterosaurs, are the fourth group—but we only know these as fossils.

Insects developed flight some 300 million years ago, and had the air to themselves until the Pterosaurs evolved about 200 million years ago. Bird flight developed about 140 million years ago. Fossils of bats with well developed wings are known from about 50 million years ago.

Why fly?

There a number of advantages to be gained by flying and gliding, including being able to:

- escape from predators
- catch flying prey or surprise prey on the ground by swooping on it
- reach fruits and flowers high up in trees—and not have to come to the ground to get to an-other tree
- travel long distances quickly, which helps to find food and new resources; to avoid hard times and extreme seasons; and to find new mates.

What is flight?

Things that fly need forces to support their weight in the air (lift), and to move them through it (thrust). The angle and shape of an aircraft's wing gives it the support or lift necessary when the power of its engines moves it through the air.

To actively fly, animals have:

- wings for lift to support themselves in the air
- muscles for power and thrust to propel themselves through the air
- streamlined bodies for efficient flight.

Flying animals get both lift and thrust from their wings. When a bat or a bird flies air is forced down and backwards to provide both lift and thrust on the downstroke. The upstroke of a wing must be changed in some way so that it does not cancel out the effects of the downstroke. A bird or bat reduces the size of its wingspan and changes the angle the wing moves through the air (the angle of incidence).

Flying is different from gliding, as described in the 'gliding animals' (overleaf).

Wingbones of a bat

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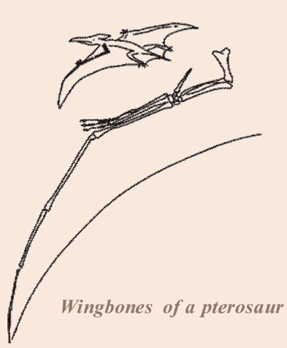
Insect, bird and pterosaur flight.

Bat, bird and pterosaur wings all have the same arrangement and similar structure, having evolved from the forelimb. Insect wings are very different.

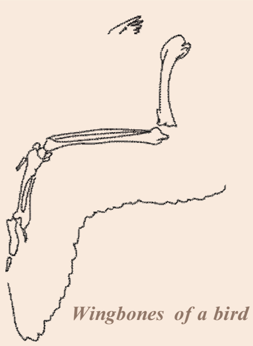
Insects
Insect wings act like propellers, beating all the time to pull the animal through the air. These wings are attached to the insect's exoskeleton, and muscles inside rapidly squeeze and relax the body, thus moving the wings.

Pterosaurs
In pterosaurs, the forearm and one finger bone became elongated to form a long wing strut. The thumb and two other fingers acted as short claws, probably much like a bat's, for hanging on and grasping. The last finger was lost.

The pterosaurs bones were light and air-filled like a bird's. The wing had an elastic skin covering. There is some debate as to the flying ability of pterosaurs. Some scientists think it was primarily a soaring and gliding animal, but it seems likely pterosaurs were able to actively fly to some degree.



Wingbones of a pterosaur



Wingbones of a bird

Birds
The bird wing shows quite a reduction and fusing of forelimb bones. The thumb and third fingers are reduced and the little and ring fingers have been lost. The main strut of the wing is formed by the forefinger and the arm. Unlike a bat or pterosaur, the legs of a bird are not attached to the wing, so birds can still walk on the ground.

Feathers form the bird's main flight surface. There are long, stiff, primary feathers for support and lift. Shorter, stiff, secondary feathers and smaller, softer, covert feathers give the wing its shape and contour. A cross section of a bird's wing is similar to a plane's. Birds have little ability to change the curvature of their wings. However, because the feathers overlap, the bird can draw its wings together so the area is reduced to glide faster or 'stoop' at great speed (such as a diving falcon). The wing can be folded compactly along the body. Feathers are made of non-living cells like hair. They wear out and need to be replaced by moulting and regrowing new ones.

Birds have hollow bones, beaks instead of teeth and heavy jaws. This reduces the amount of weight at the front of their bodies. Birds do not need to carry their young in flight because they lay eggs and use a nest.

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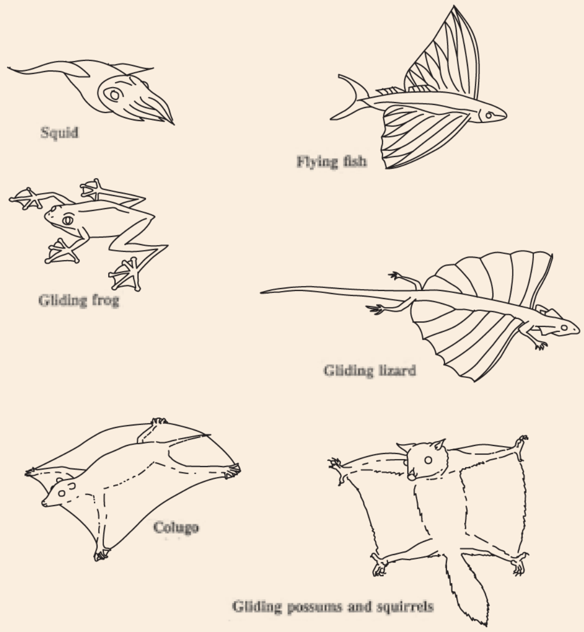
Gliding animals

Gliding usually involves a decrease in height over distance. A number of animals have special adaptations that allow them to glide successfully, however they cannot actively fly.

Flying fish use their tails to gain speed and launch themselves over the surface of the water and glide using their large pectoral fins to escape predators. Some squid use speed and their fin-like mantles to become airborne and glide over the water. There are a few tropical frogs and reptiles in Asia that can glide from trees. The frogs (*Rhacophorus sp.*) have large webbed feet and light flattened bodies. The Gliding Lizard (*Draco volans*) has special ribs that it can stretch out to support a skin membrane. The Gliding Gecko (*Ptychozoon homalcephalum*) has folds of skin around its body, tail and webbed feet to parachute from heights, while the Golden Tree Snake (*Chrysopelea ornata*) flattens its body out to glide from tree to tree.

Some mammals climb a tree and launch themselves into the air. They use membranes of skin stretched between their legs and bodies or fingers and toes. Mammals which glide include the ‘flying’ squirrels of America, the marsupial Gliding Possums and Sugar Gliders of Australia, and the Colugos or ‘Flying Lemurs’ of Malaysia and the Philippines.



A variety of gliding animals

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Aspects of bat flight

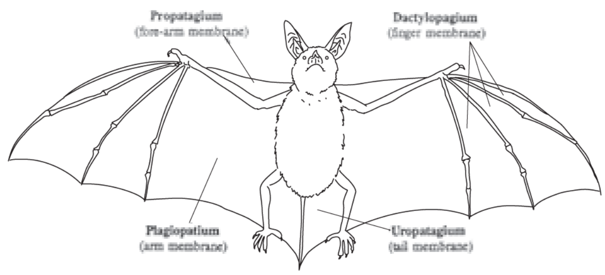
Bat wing

The bat wing shows little reduction or loss of forelimb bones. The upper arm is short. The thumb is reduced, or even absent in a few species. The other finger bones are greatly elongated to form supportive struts for the wing. The wing is formed by a skin membrane that stretches over the bones of the fingers and is attached to the side of the body down to the back leg and often the tail.

The wing membrane is actually formed by two layers of skin and is living tissue with a network of tiny blood vessels. The wing membrane has many wrinkles with many tiny muscles that allow it to bunch up and 'shrink' when not in use. It is not quite as compact as a bird's wing, and folds up rather bulkily. Most microbats fold their wings up by their sides when they roost, megabats hang down and wrap their wings around them like a cloak. The skin is quite tough and can heal if damaged.

The finger bones and the flight membrane are very controllable, and a bat is able to change the contour or curvature of its wing quite radically, giving it great maneuverability. Because there are a number of bones that support the wing, a bat can still fly if a finger is broken.

Bats use their wings for more than flight. Many insect-eating bats can scoop prey up as they fly. Flying foxes flap their wings like fans to help cool down and they can wrap their wings around themselves like a rain coat. Some bats use their wings in displays to attract a mate.



The four main areas of a bat's wing membrane.

The bat wing is composed of four main areas.

- The forearm membrane, or propatagium, is the membrane between the shoulder and wrist which forms the leading edge of the wing
- The arm membrane, or plagiopatium, is the large part of the wing between the fifth finger and the leg to the body. This part of the wing provides the lift for flight
- The finger membrane, or dactylopagium, is the area between the fingers providing the power for flight. Movement of the fingers also changes the contour of the wing
- The tail membrane, or uropatagium, is the skin between the leg and the tail of the bat. The presence or absence of a tail and uropatagium varies between species. It helps to increase the lift area of the wing and can also be used as an air brake and for scooping up insects in flight.

Bats and birds use different muscles for flying. A bird moves its wings in a figure-eight manner, whereas a bat moves its wings like a swimmer doing the butterfly stroke. Birds have a strongly developed breast bone or keel, to which the main flight muscles are attached. Bats use a number of

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muscles in their shoulders and chest. Because they do not have such a large breastbone, they are able to squeeze into narrow crevices and hollows. Unlike the wings of a bird that are covered with insulating feathers, the bat relies on its furry body for insulation. Also unlike birds, bats have teeth, which are relatively heavy. They tend to have short necks to counter-act this weight.

Take-off

The difference in form between birds and bats affects their strategies for a very important aspect of flight—taking off. Unlike bats, bird's legs do not form a part of their wings. They are able to run, spring or leap to get enough air speed to start flying. Some birds have wings which give them enough lift to fly straight off the ground.

The bat's feet are actually attached to its wing membrane. Bats are therefore not usually capable of running or launching themselves into the air from the ground. Bats usually need to launch themselves from their roosts (although there are also some bats that can fly straight up from the ground). Some bats roost high up and free fall to get enough air speed before spreading their wings to fly. Others hold on with their feet and flap their wings to get enough lift before letting go.

Before take off, bats defecate to reduce their flight weight. Most birds and bats have very fast digestive processes, food passes through quickly so there is less weight to carry.

Batty tails

The tail bones of some bats are thin and straw-like to reduce weight, while some bats do not even have tails.

The sort of tail and amount of skin around the tail varies on different species and can be used to classify bats. Tail names sometimes feature in the common names of bats: sheath-tailed and free-tailed bats, for example.

Tails are important in flight for many bats. They act as a wing surface for lift, are used to catch insects and are used as an airbrake. Some bats even use their tails to catch their babies as they are born because they give birth upside down!

Wing shapes and flight paths

The size of a wing is related to the body size of the animal. A larger or heavier animal needs a larger wing area to provide sufficient lift to fly. On the other hand, wing shape is not related to body size and can vary. Different wing shapes affect the speed, agility and gliding ability of an animal.

Bats with short, broad wings (called a 'low aspect wing') are usually slow fliers, but they can be very manoeuvrable. Bats with long narrow wings ('high aspect wing') are usually swift fliers. A fast airspeed is needed to keep narrow wings flying, due to the reduced lift of the wing. The longer wing means these bats are less manoeuvrable.

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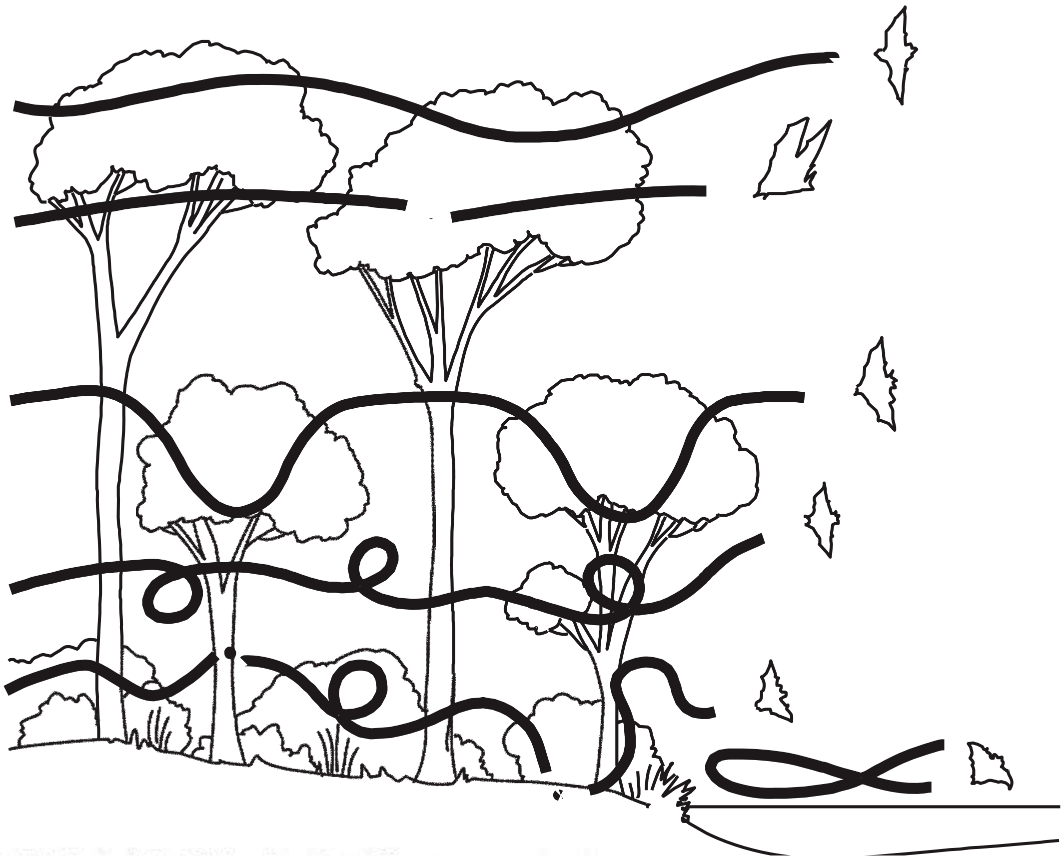

A High and fast flying insect catchers.
B Megabats that land on trees to feed.
C Swift hunters in the lower canopy.
D Insect-hunting fluttering bats in the low canopy.
E Bats that swoop on prey from above.
F Bats feeding above water.

Flight paths.
Different bats fly at different heights and speeds to catch their prey. The sketch shows examples of some of the places different bats fly to feed.
(After M. Gorman in Geo 1988 and Stebbings 1991)

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Flight patterns

Bat flight patterns and wing shapes relate to their feeding strategies. Some categories are:

- very fast, high fliers which feed in the open air or above forest canopies
- fast, direct fliers which feed for insects below the canopy but above the understorey
- generalist insect feeders that feed around the understorey and catch insects in flight or take them from foliage—some also feed over water
- 'flycatcher' bats with slow but highly maneuverable flight, which hover or sit and wait to pounce on insects in the leaf litter
- fruit-eating bats with enduring straight flight that can glide for long distances—they are not very maneuverable and land to feed
- nectar feeding bats which are slow flying and hover or land on vegetation to feed.

Bats are a very successful group of animals. Their ability to fly has enabled them to take advantage of food sources unavailable to other mammals and colonise even remote islands. Their different styles of flight and feeding enable many different species of bats to live in the same areas without competing for food. Places to live and roost may be the main limit to bat numbers.

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BAT CONSERVATION

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Threats to bat survival

With their importance as pollinators and seed dispersers in tropical countries, and as controllers of insects throughout the world, bats are a 'keystone' species. Removed from an environment, a whole series of linked extinctions or imbalances could occur amongst inter-dependant organisms.
Because of their value in the environment and to humans, it is important that an understanding of bats and their conservation be encouraged.

Bats are at risk for many reasons. For example, bushfires and cave collapses can destroy bat colonies. However, people are the most serious threat to bats. Ever-increasing human populations are putting more and more pressures on remaining habitats.

Some of the human threats to bats include:
- disturbance of roost sites and colonies
- destruction and clearing of habitat
- over-exploitation, including over hunting for food
- pollution and use of pesticides
- killing as pests.

The threats listed above can affect whole populations of bats. Other human-caused hazards, including electricity lines, kill a limited number of bats and do not greatly threaten bat populations. Windfarms are an emerging threat, but their full impact is not known.

Destruction of habitat

Deforestation and land clearance
Deforestation and land clearance affects bats directly by destroying roost sites and habitat for feeding. It can also remove important food sources for fruit bats and thus cause increased raids on fruit crops, leading bats to be destroyed as pests.

Invasion of weeds and non-native plants into habitats can endanger food sources and roost trees. At Wingham Brush, a remnant rainforest in New South Wales and an important flying fox camp, introduced vines and creepers were displacing native seedlings and the dank conditions of the thick weed mats were rotting the buttress roots of old trees.
A community effort eradicated the weeds with minimum disturbance, thus saving the forest and important bat habitat.

Mining
Some mining activities can destroy bat caves or disturb traditional roost and maternity sites. Limestone quarrying at Mount Etna in Queensland destroyed Ghost Bat (*Macroderma gigas*) colonies, and guano mining in Jamaican bat caves has disturbed colonies to such an extent that the animals have abandoned the caves.

Mining activities can also create bat habitats. After mining activities have ceased, many mine-shafts are used by bats as roost sites.

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Dams

Dams can flood bat habitats or affect food supplies. In North America, siltation related to dams has affected the breeding of mayflies which are an important food source for colonies of Grey Bat (*Myotis grisescens*).

Urban renewal

'Urban renewal' can result in the removal of older-style buildings, which are often more suitable than modern architectural styles for bat roosts.

Visitors to bat caves

Visitors to bat caves can disturb bats and cause the death of young bats in maternity caves or lead to the abandonment of the roost. Bat caves need to be well managed to ensure minimal disturbance.

Over-exploitation

Most bats breed at a relatively slow rate and are long-lived. They can therefore be quickly overexploited.

Fruit bats are used as food in many parts of the world and provide an important source of protein in many underdeveloped countries. Unfortunately, over-hunting has severely decreased some bat populations, and even caused extinctions in some cases.

In Guam, the restaurant trade seriously threatened fruit bats in the Pacific. It probably caused two of Guam's three fruit bat species to become extinct, as well as threatening populations of bats in Samoa and other countries where they were hunted for export. Over 40% of Guam's plants rely on fruit bats for pollination or seed dispersal, and the decline in bat numbers could affect the whole ecology of the island. In 1989, laws were introduced to limit the bat trade.

With sensible management and habitat conservation, it might be possible for communities to continue to use bats as a food source. In Australia traditional hunting of fruit bats by Aboriginals is allowed in some states. With proper management they might become another 'bush tucker' food in restaurants.

The sale of the world's smallest bat, the Bumblebee Bat (*Craeseonycteris thonglonyai*), may lead to its eventual extinction. This tiny bat is found only in a small area of Thailand. Tourist demand for preserved specimens as souvenirs was so high that by 1981 the Bumblebee Bat population was reduced to one known cave. One colony was reduced from 200 to 30 in a period of nine months.

Campaigns to eliminate vampire bats in Central America have lead to the indiscriminate destruction of large colonies of other bat species which are important controllers of insects.

Pollution

Microbats eat large numbers of insects and can be affected by a build-up of chemicals in their bodies because they eat insects affected by pesticides. Adult bats with a plentiful food supply can tolerate certain levels of pesticides. However, a young nursing bat may receive harmful quantities in its mother's milk.

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Insects can quickly develop tolerances to some pesticides and increase in number, but bat and other animal populations may recover at a slower rate. This, in turn, limits their ability to act as a natural control and may result in the use of more insecticides.

How you can help bats

Education and awareness are very important to highlight the role bats play in the environment, and to minimise vandalism of bat boxes and disturbance of roost sites. Your school can help make the community aware of bats and how to help them.

Study them

The keys to bat conservation are education and awareness of how bats interact with the environment and of their benefits to people.

In the 1930's Francis Ratcliffe conducted the first detailed scientific study of bats in Australia. His aim was to determine how serious a pest flying foxes were to the fruit industry. Ratcliffe relied on his own observations and talked to many people in areas where fruit bats occurred to find out what locals knew. Sometimes, what people told him was wrong. Other people, who had made careful observations over a long period of time, were of great help to him. Ratcliffe visited as many colonies as he could along the east coast, collecting bat specimens to examine their breeding condition, diet and anatomy. After two years of study, he concluded that fruit bats were not a serious threat to the commercial fruit industry.

Relatively little is known about Australian bats. Even the exact number of species is unclear, as there are a few problems associated with identifying and classifying bats in the field. There are surprisingly few definite records of many microbat species and it is necessary for researchers to take specimens of some species for museum identification. Sometimes the only way to distinguish species is to look at their skulls and anatomy or at their complex genetic make-up from tissue samples.

Bats that look very similar, but are classed as different species, may have different living requirements (such as microhabitat use). It is important to know these different needs so that appropriate decisions can be made when areas are being considered for conservation, land clearance or development. Museum specimens and collections are still very important for research, identification and conservation of animals in Australia.

The ecology of the common flying foxes is gradually being unravelled, but there are still few bat researchers in Australia and there is a lot to be learnt about bats in this country, especially the smaller microbats. Modern bat researchers catch bats and put numbered bands on their wings to identify them. If the tagged bats are caught later it indicates how long they live and where they travel. Modern technology allows researchers to study bats in the dark. To obtain more detailed information, radio transmitters can be used to track animals and find their roosts. Even radar has been used to observe the movements of large flocks of bats. Small chemical lights attached to bats (which the bat later

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removes when it cleans itself) can help researchers observe bat feeding habits, as can the use of night vision scopes.

The latest in bat research is the use of electronic bat detectors that record and analyse their ultrasonic calls to identify them. The calls of many species are becoming increasingly well known though researchers still need to catch bats so they can be identified and their calls recorded to add to the library of bat sounds. Much of the high technology equipment involved in bat research is expensive and can be beyond the resources of individuals studying bats.

Researchers work to guidelines established by scientific ethics committees which scrutinise their work and assess the need to harm or kill animals. For example, most researchers now no longer kill bats to look at their stomach contents to find out what they eat. By examining roosts and collecting bat droppings or pollen samples sticking to a bats fur, they can then painstakingly compare these with a selection of pollen grains, seeds or insects collected from the area.

In the future, with further study and improved techniques in genetics and ultrasonic detectors, it may be possible to rely upon non-destructive blood sampling and sound recordings to identify bats and unravel their life histories and ecology. Such data is needed in order to plan for the conservation and management of bats.

Habitat for bats

One major problem in conserving bats is not knowing exactly how many species of bats there are. In a recent review of Australian bat conservation, nearly 25% of our bats were thought to be rare.

EXTINCT	3 species
ENDANGERED	3 species
VULNERABLE	7 species
RARE	13 species
INSUFFICIENTLY KNOWN	11 species

The cost to research, assess and conserve all the species would be millions of dollars, and take a long time. To safeguard our bats it is important to define critical conservation areas. Bat researchers have estimated that 15 key areas are needed to conserve all of the 46 species found only in Australia. Of these areas, seven already have reserves in them. In addition, there are five areas in Queensland, two in Western Australia and one in New South Wales, where the creation of reserves would greatly help to conserve Australia's bats.

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Watch them

Bats are active outside of school hours and can be difficult to find, which means a little more effort needs to be made to see them. Many zoos and wildlife sanctuaries have megabats. Microbats are a bit harder to keep in captivity. In the eastern and northern states, visits to fruit bat colonies can be arranged. There are also people, who raise orphaned fruit bats to be reintroduced to the wild, who are willing to visit schools.

In South Australia, visits to the Naracoorte bat caves can be arranged through the National Parks and Wildlife Service and in Queensland the Mount Etna bat colonies can also be visited. Bat colonies should not be disturbed. Quietly waiting near the entrance of the colonies at dusk is the best way to observe the bats.

Many museums have bat specimens on display, as well as other gliding and flying animals. Museums and universities are also involved in research into bat biology and ecology and may be able to help organise a bat watching activity.

In urban areas, bats can sometimes be observed feeding around streetlights. Students can wait at dusk to watch bats leave bat boxes or known roosting sites. On school camps, spotlighting around dams and over streams can also prove successful.

You may be able to borrow an electronic bat detector to listen to bats. Simple bat detectors can be made. (A circuit diagram is provided in Brock Fenton's Just Bats, 1983).

Seeing bats close up is a fascinating and rewarding experience, and education and public awareness are the keys to helping conserve our bat fauna.

Make bat-friendly habitats

As for most plants and animals, conserving habitats is one of the key means of conserving bats.

Protecting roosting caves from disturbance will help bats. Active roosts can be protected by installing grills or bars that allow bats to fly through but stop people disturbing the bats.

Planting habitats will help future bats. Understorey shrubs and ground covers provide habitat for insects to attract microbats. Tree planting will eventually provide hollows for roosting and canopy foliage for high-flying bats to feed over. It can take up to two hundred years for trees to form large hollows. Bats can take advantage of very small holes and so may be some of the first animals to benefit.

In areas where fruit bats occur, planting native fruiting and flowering trees will help. This may also provide extra food in hard times so bats do not have to raid farmer's fruit trees.
Where bat habitat is poor, people can help quickly by making and installing bat boxes to provide roost sites (see the Activities Guide for more information).

SECTION 6

FURTHER INFORMATION

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Batty Organisations

Australasian Bat Society
Involved with bat conservation, research and raising awareness of bats in Australasia. Publishes a newsletter for members and coordinates annual Bat Night each autumn.
http://ausbats.org.au/
http://www.facebook.com/AustralasianBatSociety

Sydney Bats
http://www.sydneybats.org.au/
Is maintained by Ku-ring-gai Bat Conservation Society Inc. This society assists with the habitat restoration of Kuring-gai Flying-fox Reserve and educates people about bats in Sydney.

International

Bat Conservation International
An international organisation concerned with the conservation, research and public awareness of bats. Publishes a newsletter for members.
http://www.batcon.org/

Bat Conservation Trust
A British organisation concerned with bat conservation, research and public education.
http://www.bats.org.uk/

Sick or injured bats

Call your local wildlife care group or RSPCA in your state. To find your nearest bat rescue organisation, if not listed below, search:
http://www.fauna.org.au/faunasearch.htm
Always call to pick up injured or sick bats. Do not handle bats yourself.

ACT

RSPCA
http://www.rspca-act.org.au/wildlife/
02 6287 8100 (BH)
13 22 81 (Canberra Connect – After hours)

SA

Adelaide Bat Care
Education and Bat Care
www.adelaidebatcare.com.au
https://www.facebook.com/pages/Adelaide-Bat-Care/304669582892715?fref=ts
http://www.youtube.com/watch?v=RezUWCgRefo
0422 182 443

Fauna Rescue SA
Flying-foxes and insectivorous bats.
http://www.faunarescue.org.au
O8 8289 0896

Victoria

Wildlife Victoria
http://www.wildlifevictoria.org.au
13 000 94535

QLD

Tolga Bat Rescue and Research
http://www.tolgabathospital.org/
Bat care, education and tourism

Australian Bat Clinic
Clinic for sick and injured bats. Gold Coast.
http://australianbatclinic.com.au/?page_id=2

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Bat Conservation and Rescue QLD Inc.
Bat Rescue service that covers the Greater Brisbane Area. 24 rescue hotline 0488 228 134
http://www.bats.org.au/

Bat Rescue Inc.
Promotes Bat education and conservation.
Bat Rescue Hotline (07) 5441 6200
Nambour West
http://www.batrescue.org.au/website/index.php

Bats QLD.
Bat Rescue Organisation
Gold Coast (0447) 222 889
Lockyer Valley (07) 4697 5177
http://www.batsqld.org.au/

Australia Zoo Wildlife Hospital
Clinic for injured wildlife
http://www.wildlifewarriors.org.au/wildlife_hospital/Beerwah
24 hour contact: 1300 369 652

Far North QLD Wildlife Rescue
Wildlife Rescue Organisation - Cairns
07 4053 4467
http://www.fnqwildliferescue.org.au/a/Home

NSW

WIRES
Wildlife Rescue
http://www.wires.org.au/
Phone: 13 00 094 737

SydneyWildlife
www.sydneywildlife.org.au
Rescue hotline: 02 9413 4300
Coordinates care and rescue of native animals. For injured or sick bats, call SMWS – do not handle bats yourself.

FAWNA
Wildlife Rescue Organisation. North Coast
24 hour hotline (02) 6581 4141
http://www.fawna.org.au/index.php?option=com_content&view=featured&Itemid=101

Wildlife Rescue - South Coast
Kiama to Batemans Bay – 0418 427 214
Mogo to Victorian Border – 0417 238 921
http://www.wildlife-rescue.org.au/

Where to see bats

There are many places throughout Australia that you can see bats in the wild, from Naracoorte Caves in South Australia, for southern bent-wing bats and Bat Cleft at Mt Etna for the flyout of little bent wings, to numerous flying-fox flyouts in Eastern Australia including taking a Batty Cruise on the Brisbane River. To see a list check the Batty Tourism page on the ABS website: http://ausbats.org.au/

In some parts of Australia you may be able to arrange a bat visit to your school or visit education bats in a park, zoo or other wildlife facility. These are also listed on the ABS website.

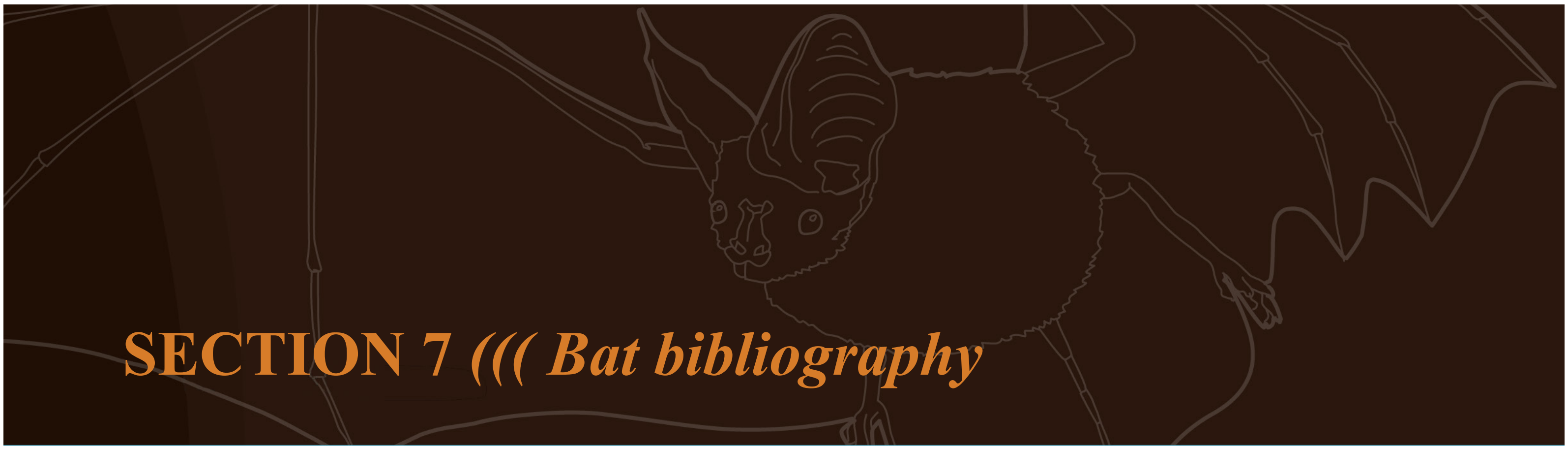
Other Educational Resources

All About Bats
An extensive educational resource about Flying Foxes. Units from Year 4 to 9.
http://www.allaboutbats.org.au/15/Flyingfox+Education+Kit

Australasian Bat Society
Bat Fact Sheets
A range of fact sheets on bats can be found at:
http://ausbats.org.au/#/bat-fact-packs/4562894228

SECTION 7

BAT BIBLIOGRAPHY



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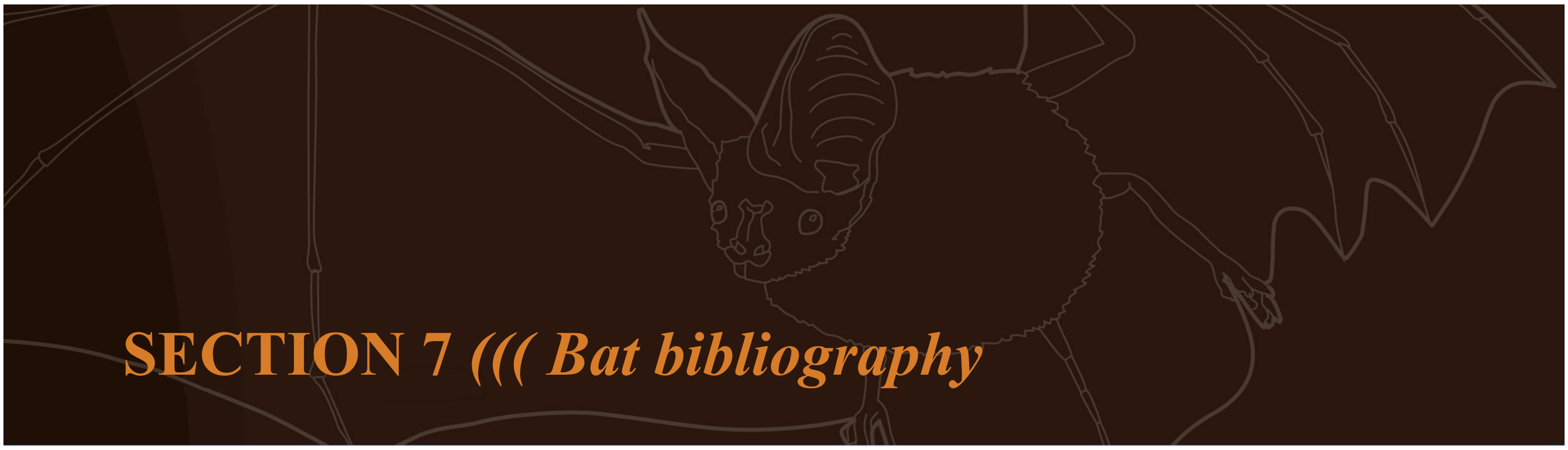

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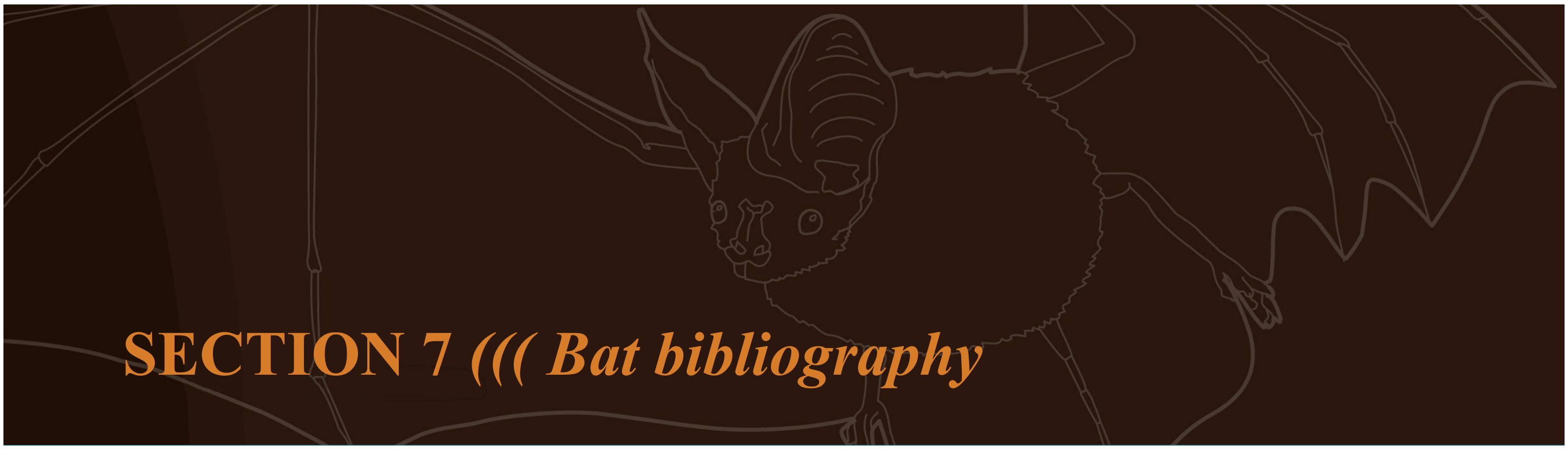

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Ch.8 p.91 'Finger-winged Night Workers': managing forests to conserve the role of the Grey Headed Flying Foxes as pollinators and seed dispersers, by P. Elby.
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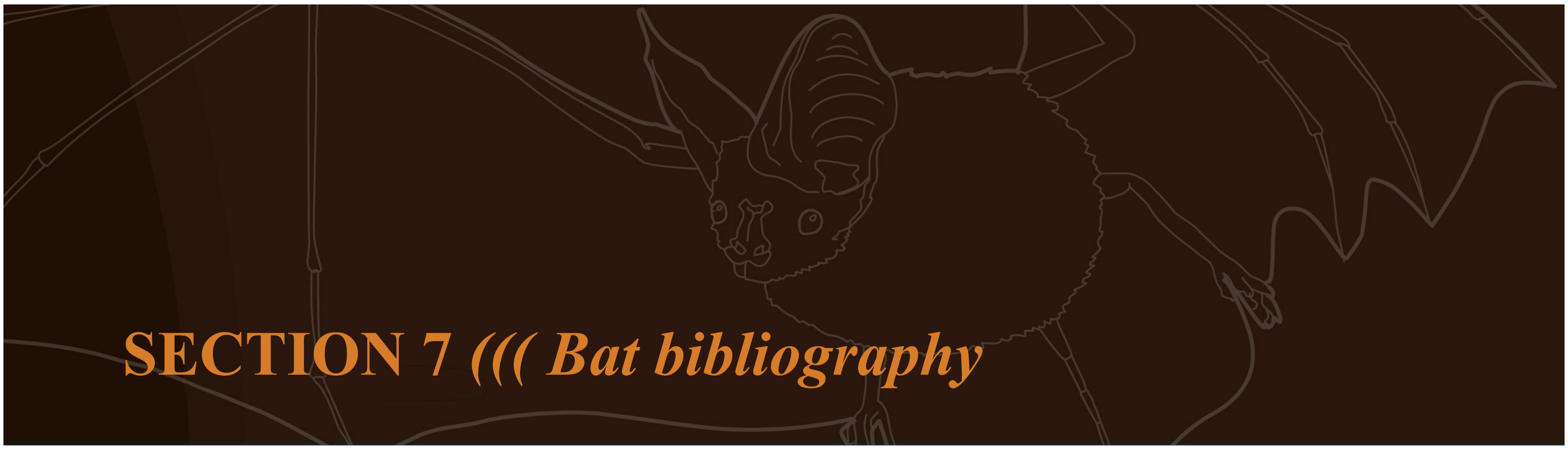

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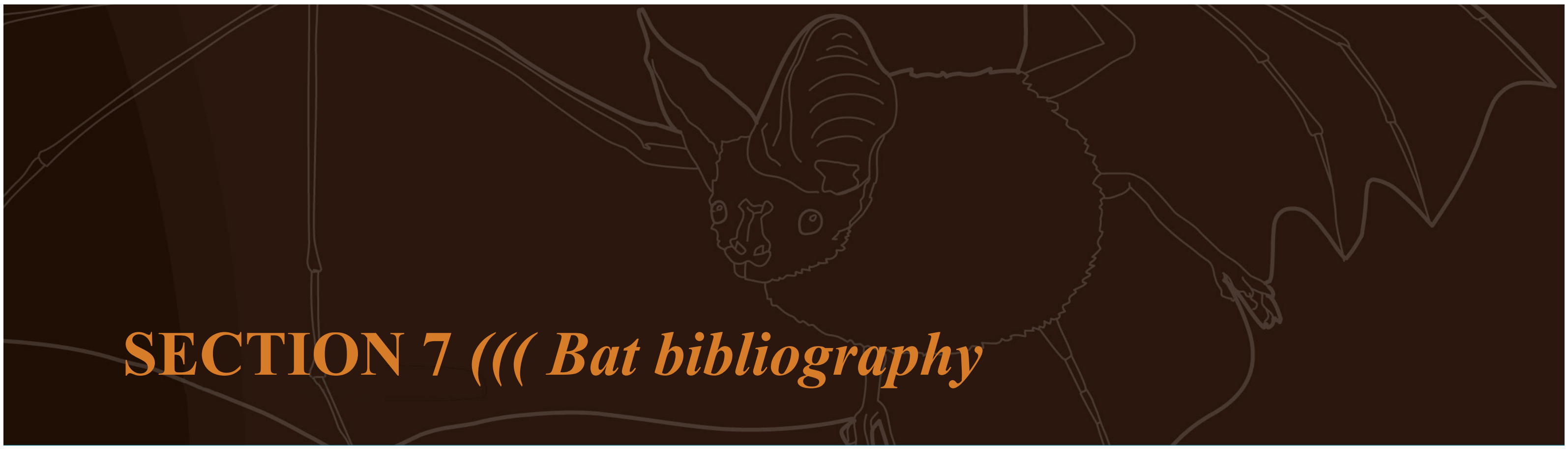

SECTION 7 (((*Bat bibliography*

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ACDT, May 1989.
(Activity focuses on hybrid fantasy insects but could be adapted to a bat theme).

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ACDT, May 1989.
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Flying Fox Camps.
WA Autumn 1991, pp.19-22.
(Natural history and threats to Fruit bats in Qld).

Law, Bradley and Lean, Merrilyn,
To Track a Bat.
WA Winter 1992, pp.8-9.
(Radio-tracking studies of Blossom Bats in NSW).

DVD's

Discover Bats
Bat Conservation International

The Flying Foresters
BBC Wildlife on One, Miles Barton and Barrie Britton, narrated by David Attenborough.

The Secret World of Bats
Bat Conservation International, Survival Anglia.

Quantum
Australian Broadcasting Corporation.
A number of Quantum segments relate to bats. One on the rediscovery of the rare Bulmer's Fruit bat in New Guinea, another on Grey Headed Flying Foxes, and a feature about Flying Foxes on the Question of Survival Quantum program. Contact the ABC programs library sales.

Downloads

Bats: Myth and Reality
Bat Conservation International
http://www.batgoods.com/category/BCI-e-Publications-45

Rainforest Allies
Bat Conservation International
http://www.batgoods.com/category/BCI-e-Publications-45

Batchat (explains echolocation)
Bat Conservation International
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PART II (((*Bat Activities*

SECTION 1

BAT BASICS

SECTION 1 (((*Bat basics*

Activity 1: Batty visits

Science
Organise a visit to a zoo, sanctuary or museum to see bats. Visit Naracoorte Caves or a bat cave in your area to watch the mass spectacle of roosting bats. Discuss the management of bats with the ranger. Batty boat trips are run in Brisbane to view Flying Fox colonies on islands in the river, and educational tours of Ku-ring-gai bat colony in Sydney can be arranged.

How might tours affect bat populations? Who manages bat colonies? What laws protect bats? What are the benefits of 'eco-tourism' and what are the problems that may arise?
Discuss and refine ways to count bat populations before visiting a population to evaluate ideas.

Activity 2: Mystery animal

English / Science/Visual Arts
Identifying animals can be difficult task. Naturalists and scientists train themselves to observe key features. They make themselves familiar with what to look for in the short time an animal may be visible. This activity, (based on Cornell 1989), uses imagination and curiosity to inspire learning and to develop listening and descriptive skills. Ideally it can be used before the subject of bats is mentioned to form an introduction to the topic.

Students are told they are going on an imaginary trip to see a mystery animal. They must pay close attention to everything they see and hear and feel as they will need to produce a description of the animal and its habitat to show to other scientists.

A description of a journey is read to the group highlighting all the senses, noises, heat, darkness, humidity, smells, etc. David Attenborough's books and narratives provide good examples of this as do some lead-ins for magazine articles.

At the end of the reading the students are asked to create visual images of the creature and its habitat. Poetry and descriptive writing can also be used. After these are completed the animal's identity is revealed.

Discussion can then lead into bats and their diversity and what students already know about them and people's perceptions of them.

SECTION 1 (((*Bat basics*

Example Story:
We had walked a long way through the steamy rainforest to this hillside. Spider webs and the mud nests of wasps hung in shadows on rock ledges above our heads. Water seeped from the rock walls, and fallen soil had dammed a small pond. This was a foul-smelling brew, the colour and texture of watery chocolate pudding. A dark cave lay ahead of us. Boulders and fallen stones stood like huge teeth around the entrance.

We waded through the shallow pond and into the dark chasm. It was like crawling into a huge dragon's mouth. Warm, fetid breath-like air surrounded us. Lights strapped to our heads cast beams into a large cavern. Sweat ran down our faces stinging our eyes. A soft twittering sound could be heard at the back of the cave where it narrowed.

Scattered on the floor were many small bones, and the mounds of animal droppings. A moving carpet of cockroaches and beetles squirmed beneath our feet. We walked on towards a smaller tunnel. Our torch-beams shone on a mass of tiny, mouse- sized animals clinging to the walls. Thousands of brown and some orange, fur-covered balls hung by thin legs. They twisted their heads towards us. Weird mask-like faces with small, black beady eyes watched us nervously.

Large delicate ears, the size of coins, poked up from their heads. Their noses were flat and it looked as if a small leaf had been stuck over each animal's two small nostrils. Open-mouthed they squeaked, showing tiny sharp teeth. Their calls were rather like hard to hear whisperings. Finger-length, bony, stick-like arms were held by their sides. Some used hook-like claws on their arms and long toes on their feet to scurry clumsily along the wall. Disturbed as we moved closer, many started to move. Their arms spread out to reveal pairs of delicate dusky wings, the size of a starling's. The fluttering caused a slight breeze in the still humid air, but the warmth from their bodies made the air even more suffocating.

Suddenly a large mass of creatures erupted into flight. A rain of animals flew past us into the main chamber. Penned in by the daylight outside and us in the cavern, they circled around us like a vast cloud of leaves in a whirlwind. The beating of their wings and their squeaks filled the air. As they flew in the dim light we marveled that they did not collide with one another. We retreated outside to the forest, sorry to have disturbed this vast group of delicate-looking fliers.

We waited as dusk settled over the forest. Clouds of mosquitoes descended upon us, whining in our ears. A stream of small bodies emerged from the cave, flying head to tail through the narrow rocky mouth. Some flew right past us, and as if forgiving us for our earlier disturbance, they snatched up some of the mosquitoes above our heads. The creatures still emerging from the cave, spread out over the tree tops and flew into the night.

SECTION 1 (((*Bat basics*

Activity 3: Bat wise

English
Organise students to go on a bat treasure hunt through your resource centre. Ask them to research children's literature on bats in the library, and develop a list of bat terms to increase their 'bat literacy'. Write a children's story on bats (bat loves the night).

Activity 4: Bat words

English
Ask students to think of words with bat in them; wombat, cricket bat etc. Ask them to draw these as bats and compile them in a class book.

Activity 5: Bats and symmetry

English/Visual Arts
Let students use a variety of references and pictures of bats and bat habitats to produce art and enhance their awareness of the diversity of bats.

Activity 6: What's in the box?

English/Science
Place a picture or model of a bat in a box. Students must ask questions to guess what's in the box.

Activity 7: Stamp of approval

English/Science
Design a bat stamp for the post office. What are some batty addresses to send your bat mail to? Importance of increasing public awareness of bats by putting them on stamps.

Activity 8: Dear diary

English
Write a diary of the life of a mother bat. Finding a roost, caring for a baby bat and teaching it to fly and feed. Write a narrative of a night in the life of a bat.

Activity 9: Batty thinking

English
Use topic words similar to those used in the Bat Connections activity (Activity 19 page 62). Ask students to arrange the words on cards to show how they relate to one another. Use simple words and statements to link the words.

Activity 10: 'Habi-bat'

English / Science
Write a conversation between a bat family looking for a new home. What would they look for, what would be safe, what are the dangers?

BAT RESEARCH SHEET

Investigator................................

Common name of bat ....

....

Scientific name (can you find out its meaning?)

....

....

....

What would you call this bat? ....

....

What does it look like?
Draw or write about your bat below

Where does it live in Australia?
Shade in where it lives on the map below

Does it live in other countries? Yes *or* No

If so which country?

....

In what type of place is it found? ....

....

....

What does it eat? ....

....

....

How does it get its food? ....

....

....

Is it useful to people and the environment? ....

....

....

Does it cause problems to people? ....

....

....

....

What are threats to your bat?...................

....

....

....

SECTION 1 (((*Bat basics*

Activity 11: Future bats

English / Science/Visual Arts
Outline a story of a remote, future volcanic island of Batavia. Ask students to design future bats that fill the roles of other animals. Look at animal field-guides and scientific descriptions to see how the information is presented. Ask students to produce a field-guide to the 'Bats of Batavia', presenting information on their future bat's size, diet, habitat, behaviour and predators. Or give students different habitats and ask them to design bats that could live in those habitats.

How would they classify their bats. Use a latin english dictionary to make up scientific names for the bats. Use the Future Bat theme for design and art activities to make sculptures and three dimensional representations. Students can design card mock ups before producing plywood sculptures.

The Gould League's Time Travellers's Guide to the Future outlines possible scenarios for future environments and the paths the future may follow based on people's use of the world now.

Activity 12: Bat perfume

Science
Many megabats have distinctive scents. Obtain some musky odours and perfumes to present to the class. What animals have distinctive scents and how do they use them? How do people use smell to communicate? Why is perfume so popular?

Activity 13: Bat silhouettes

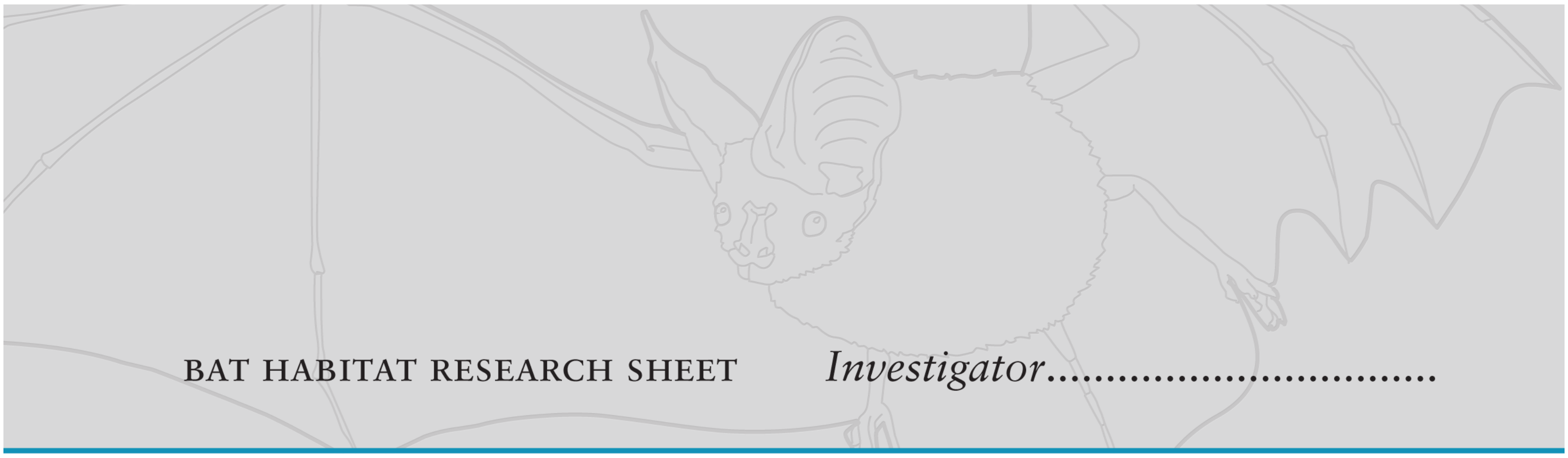
Science / Visual Art
Using folded card, students draw 1/2 bat silhouettes using double lines. Pre-designed templates can be used for younger children. Cut out the shapes and inside double lined areas. Manipulation skills in cutting intricate patterns are developed as are the concepts of symmetry and design.
Unfold and mount the completed bats on background scenes designed by students. These scenes could be made by the whole class or by individual efforts, with the themes of where bats live, bat habitat or the night sky. Moth and other prey silhouettes could also be incorporated into the designs to highlight predator - prey relationships. (Based on an insect related design activity 'Beautiful Beasties', by Roslinda Dawson in Art and Craft, April 1989.)

Activity 14: Moths and mangoes!

Science / Visual Art
Devise a menu for a bats birthday party. Invite megabat and microbat guests and design menus, invitations and table settings etc.

Activity 15: Bat mobiles

Science / Visual Art
Get students to research types of bats, postures and shapes to produce hanging mobiles. Introduce prey and predator animals and plant foods for fruit and blossom bats. Use Origami bat patterns to make decorative mobiles. Use plant and other materials to make your bats, banksia bodies, hakea nut ears and big leaf wings etc. Use this activity to lead into the construction of food chains and webs.



BAT HABITAT RESEARCH SHEET

Investigator................................

All the things that make up the place where a plant or animal lives are called its habitat.

My bat habitat is ....

....

....

Other animals that live here are ....

....

....

....

Some plants in this habitat are ....

....

....

....

This habitat provides bats with ....

....

....

....

Things that people do to disturb or change this habitat are ....

....

....

....

If I were a bat, my favourite thing in this habitat would be ....

....

....

....

My least favourite thing in this habitat would be ..

....

....

....

My habitat looks like?
Draw, write a poem or description about your bat habitat below

SECTION 1 (((*Bat basics*

Activity 16: Belly bats

Science / Art
Design posters or models that show what bats eat and what eats bats. One format is to make a bat with a hollow stomach, filled with all the things a bat eats. Hang them up and surround them with the animals that eat bats. Another format is to design bats with flip up stomachs that open. Link to food chains and webs.

Activity 17: Bat catch

Science
Use this activity to find out what students know about bats.

Use a ball or even a big rubber bat or stuffed toy which students throw to each other, or is thrown by the teacher to students and then thrown back. Each time the bat is caught the student catching it must make a statement, or complete a sentence about bats. If you are studying a language other than English, use a foreign language in this activity.

Record the statements and after the activity identify key words and classify topics for further activities and discussion. Keep the statements for future discussion when children have learnt more about bats.

Activity 18: What is a bat?

Science
Show students pictures of a variety of bats, and using the question 'What is a bat?' record their ideas on a chart. Return to these basic concepts and expand on them as students learn more about bats.

Activity 19: Batty connections

Science
This activity helps students place bats and other organisms in context within the total environment, and allows them to express their levels of understanding which provide a focus for further theme development.

Students identify themselves with a particular bat related animal or resource. Have students design labels, masks or picture headbands to identify themselves. They then connect themselves with string to show the relationships between the resources and organisms. Show how many other organisms are affected by taking away certain elements of the intricate web. Discussion can relate to bats as keystone species in the environment and the interdependency of organisms.

A listing of organisms and resources for the activity might include: sun, soil, air, water, fruit bat, microbat, people, blossom bat, cave, dead tree, fruit tree, flowering gum, shrub, moth, caterpillar, python, etc.

SECTION 1 (((*Bat basics*

Activity 20: Tongue talk

Science
Build and test a model of a nectar-feeding bat's brush-tipped tongue. How well does it work to lap up nectar, how does it differ from your tongue, what have similar tongues, eg. honeyeaters, etc.? Which tongue in the class works best?

Activity 21: Hollow lives

Science
Look for hollows in your area where bats might be found. Map them out, estimate size and height. What animals might use them? How could more hollows be provided? Make lifesize cut-outs or models of hollow dwellers; insects, spiders, bats, possums, birds, reptiles. Would they fit in the hollows you find? How does the number of hollows affect the types of animals found in your area?

Make different models of hollows or use real ones. Measure temperatures inside a hollow and outside at different times of day. Are hollow temperatures more uniform? What about size and different materials, ie rocks or wood? What about humidity? Does water evaporate slower or faster in a hollow? Put marked glasses of water inside and outside the hollow models to find out.

Activity 22: Window visitors

Science/Maths
Microbats eat a wide variety of night-time insects. This activity, which also relates to animal diversity and habitat, gets students to look at nocturnal insects, and develop observation, recording skills. Needs diagram so students can identify insects.

Many insects are attracted to lights at night. Bats take advantage of this and often hunt under street lights. Scientists use lighted traps to collect night insects for study. Night insects appear to use distant points of light like stars to navigate. They fly at constant angles to the light. Bright lights may 'short circuit' their behaviour. Many moths fly in spirals around lights. They eventually land and become inactive in the artificial daylight. Scientists notice that there appear to be less moths attracted to lights on moonlit nights. Cloudy, wind-free, warm nights may be best for attracting night-time insects.

After dark, at home, students conduct a survey of insects attracted to the window of a lighted room. The areas of the windows studied should be the same, and students can tape a card 'quadrat' to mark a set area on the window.

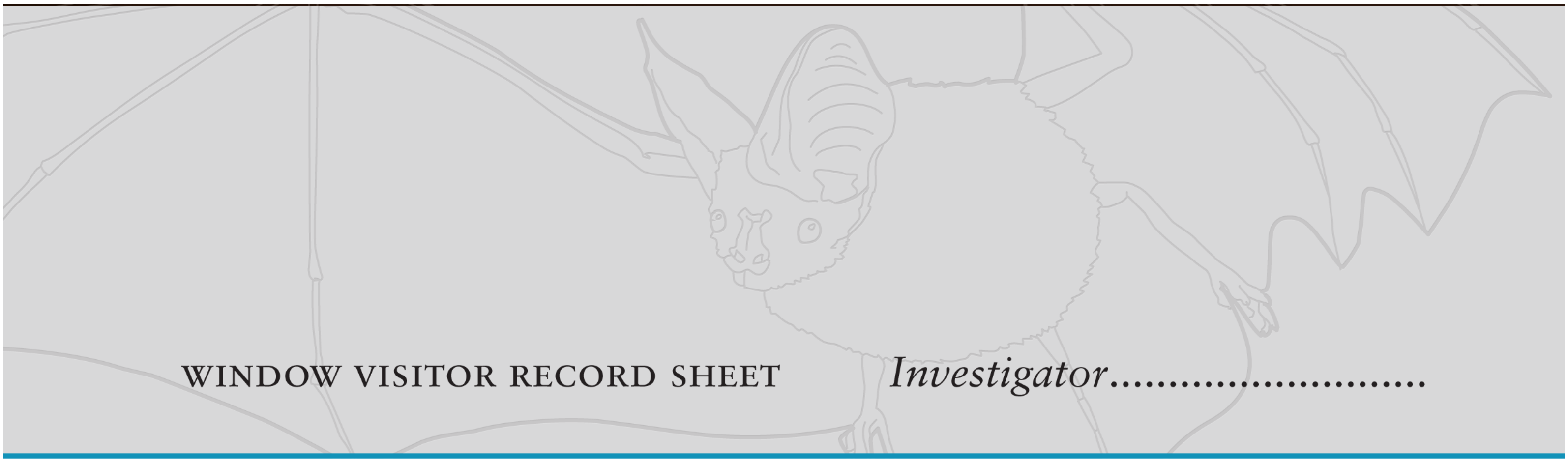
Identify insects into broad groups, Moths, Mosquitoes, Mayflies, Midges, Beetles, and count numbers of each. The time taken for the count should be the same for each student, (ten to fifteen minutes), and the time the room was lit before the count should also be noted.

Not all night-time insects are attracted to lights and your window visitors represent only a small range of the insect prey available to bats.

Also recorded should be the type of habitat surrounding the house: trees, shrubs, lawns, ponds or creeks.

What temperature was it on the night, hot, cold, and humid? Were bats active that night? Could students hear or see any? What was the largest insect? What was the smallest? How many small insects would a bat need to eat to get the same amount of food as a large moth? What are the best nights for bats?

Design ways to present your results, such as graphs of insect numbers, histograms, etc.



WINDOW VISITOR RECORD SHEET

Investigator..........................

Date . . . .

Time survey started . . . .

Habitat near your window:

Trees: lots some few none

Shrubs: lots some few none

Lawn: lots some none

Ponds: Yes or No

Creeks: Yes or No

Other notes . . . .

. . . .

. . . .

Temperature: Hot Warm Mild Cold

Humidity: Very Humid Humid Dry

Total number of Moths . . . .

Total number of Mosquitoes . . . .

Total number of Midges . . . .

Total number of Mayflies . . . .

Total number of Beetles . . . .

Other visitors . . . .

. . . .

. . . .

Total number of visitors . . . .

Draw some of the visitors below

Largest Visitor . . . .

Size. . . . .

Most Common Visitor . . . .

Size. . . . .

Smallest Visitor . . . .

Size. . . . .

Time survey finished. . . . .

SECTION 1 (((*Bat basics*

Activity 23: What a lot of bat!

Maths
Graph the percentages of Australian native animals that are Bats, Monotremes, Marsupials and other mammals (ie the Dingo). Use other statistics in the text to produce graphs, charts or histograms.

Activity 24: Bat maths

Maths
A microbat can eat 500 to 1000 insects in an hour. Some bats only feed for two 30 minute periods every twenty four hours. How many insects could a bat eat in:

- a day?
- a week?
- a month?
- a year?

Up to 150,000 Bent-wing Bats live in the bat caves at Naracoorte. Using the previous calculations as a guide, how many insects might the colony eat in:

- a day?
- a week?
- a month?
- a year?

Some fruit bats can eat up to two times their own mass in fruit in three hours. Weigh a banana. If a fruit bat weighs a kilogram how many bananas will it eat in:

- three hours?
- two hours?
- one hour?

Activity 25: You old bat!

Maths
Bats are quite long lived for their size. Research the longevity of other animals in comparison to bats. Display your results.

Activity 26: Bat rap

Music / Drama
Ask students to compose a rap song to make people aware of bats, bat boxes etc.

Activity 27: A batty world

S&E
Ask students to find examples of bats from around the world and design a large world map display to present their findings of the bats. Include information on size, habitat, diet etc.

SECTION 1 (((*Bat basics*

Activity 28: Bats about?

Geography
Give students maps of Australia on overhead transparencies. Ask them to choose a bat from a list of Australian bats and draw a map of its distribution on the overhead transparencies. They should also need to find details of its habitat requirements and food (use Strahan 1983, the Mammals of Australia, or bat field guides like Reardon + Flavel, 1987, Bats of South Australia). Project the transparencies overlapped with one on which the school's position is marked to find out what bats are likely to occur in the area.

Distribution maps are based on records of animals collected or described by researchers. The actual number of definite records is usually low and researchers make assumptions on the likelihood of an animal being found there. To find out if bats whose mapped distributions occur in the schools area, students will need to compare the bat's habitat and food preferences with resources available in the school's area.

After students have compiled this, they may then wish to confirm their deductions by writing to a bat researcher, the state museum or National Parks office to see if the bats they think may occur in their locality have been definitely recorded in the area.

Activity 29: Hanging around

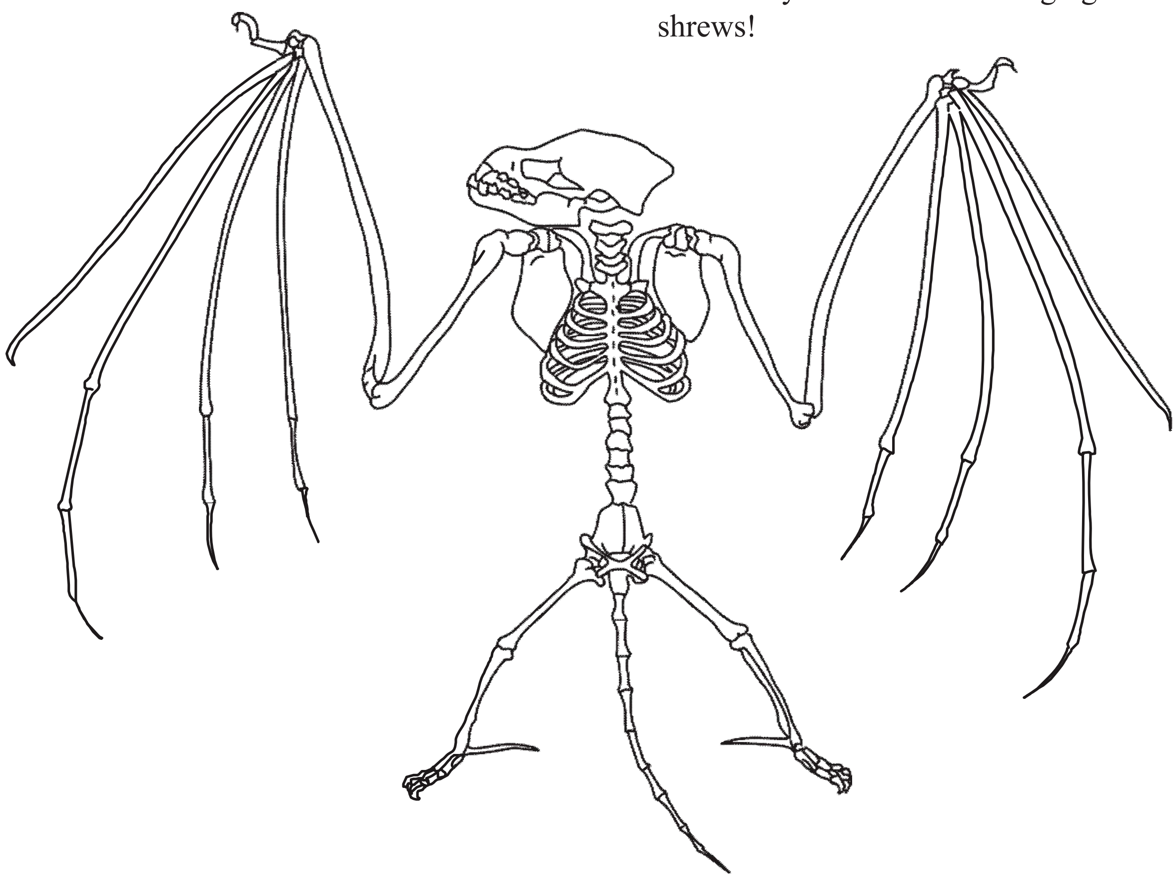
Health/Science
Ask students to hang upside down in the playground. Discuss the difficulties and advantages of this position. Bats have special valves in their blood vessels to stop the blood rushing to their heads. Special clawed feet let the force of their mass help them to hold on to objects as they hang

Activity 30: Jigsaw bat bones

Science

Enlarge the drawing of the bat skeleton and paste it onto card and cut it out to make a bat bone jigsaw. Can the students guess the identity of the animal from just its bones?

Discuss how palaeontologists identify animals from bones. Some scientists think there may be older bat teeth fossils than the Murgon tooth already in museum collections, but that those teeth have been mistakenly identified as belonging to ancestral shrews!



A typical bat skeleton. Wings are formed from extended arm and finger bones. Many bats have a pair of fine bones at their ankle, the calcaneum, which helps to support the tail membrane. Not all bats have tails, and megabats usually have another large claw on their second finger (After Hill and Smith 1984).

SECTION 2

BATS AND US

SECTION 2 (((*Bats and us*

Activity 31: Bats around the world

English/Language
Ask students to find examples of batty stories from around the world and design a large world map display to present their findings. What are names for bats in other languages? ie; French = chauve-souris (bald mouse), German = fledermaus (flying mouse), Spanish = murcielago, Japanese = komori. If other languages are studied or spoken at school, design a multilingual pamphlet on bats.

Activity 32: A bat on the barbie

Health
In many countries, including Australia, bats have been used as food. In some places bats were drastically reduced in number or even hunted to extinction. Discuss the benefits and limitations of the bat food trade? Design a survey to obtain and measure people's responses.

Assess the value of bats as bush tucker in Australia? How could a trade be managed without harming bat populations. Should bats be taken from the wild or farmed? How would you run a bat farm? Design a bat farm. What do bats eat? Where would you get food? How could you market bats as food?

How would you cook a bat? What other bush foods are marketed commercially? Are they well managed? What are the benefits of using native animals and plants for farming?

Produce a street or school yard 'attitudes video'. Ask people if they would like to try samples of cooked food (use chicken wings or something similar) without telling them what the food is. After people have tried it, tell them it is bat meat. What is their response?

Afterwards, tell them it is not really bat meat and ask for opinions and attitudes towards bats.

Activity 33: Public image

Visual Art/English
You run an advertising agency which has been asked to promote bats and their benefits. How would you design a batty campaign (commercials, posters etc) to educate people about bats?

Activity 34: Bat networking

Technology
Use Telecom/Nexus computer network to search for AAP news service articles on bats. How do bats feature in the news? Do they get 'bad press'? Look at the use of value-laden terms.

SECTION 2 (((*Bats and us*

Activity 35: What a load of guano!

English / Science
Construct a nutrient cycle which explains the cycling of nutrients in a bat cave. What other things are used as fertilisers and why? Why does bat guano make a good fertiliser?

Activity 36: Bat attitude

Maths/Science
Bats are a good example of discrimination. They are very important and beneficial animals, yet they are often persecuted or destroyed. Often this is out of ignorance and misunderstanding. The following activity, whilst good for increasing students' awareness about bats, can also be used to highlight prejudice and discrimination.

Use the example 'Bat Attitude' worksheets as a guide or ask students to devise a questionnaire to find out people's opinions and attitudes to bats. Emphasise that they will need to be able to interpret and present their results in some way. A PNI (Positive, Negative and Interesting) chart may be a good way to present the data. Discuss the results and ask students what they think. Are people's attitudes a result of ignorance or misunderstanding? Run an information campaign in school and then retest students.

Activity 37: 'Bat brothers, nightjar sisters'

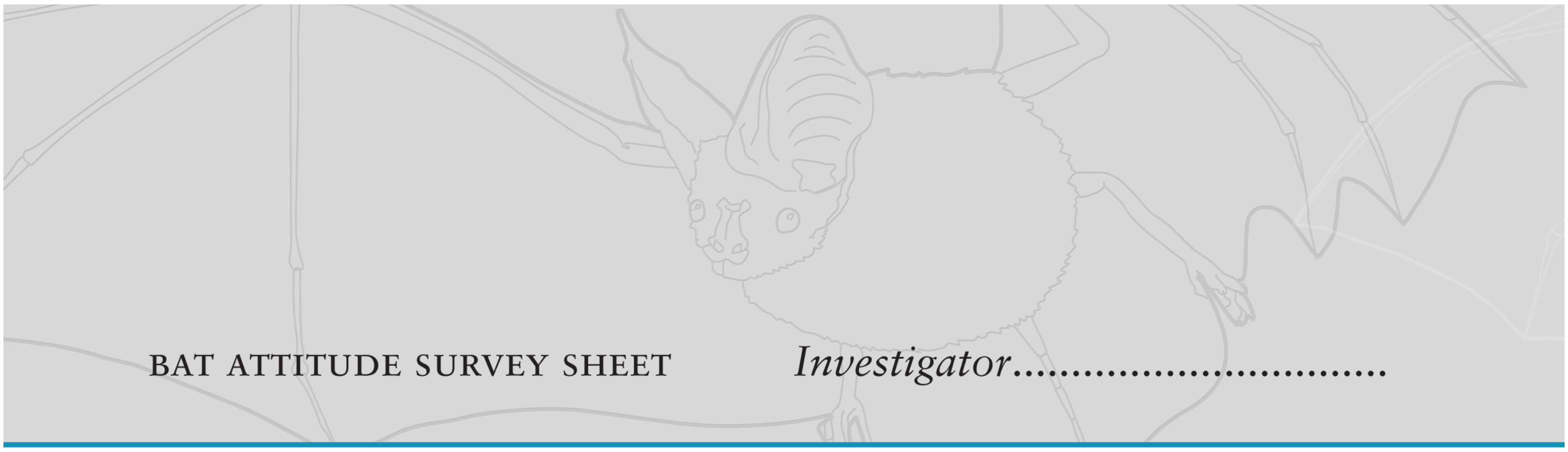
Geography/Science
Discuss the role of totems and the relation of Aboriginal people to plants and animals. What plants or animals would students choose for their totems? Why were there male and female totems? Discuss the roles of men and women in indigenous cultures. How do they differ?

Activity 38: Bat motion

Drama / Dance
In a number of Aboriginal stories bats are portrayed as dancers at a corroboree. Use a story as a basis for music and movement activities. Incorporate traditional movements and music, or use recordings of bat sounds. Are there local Aboriginal people who know traditional dances and stories? Use Aboriginal stories as a theme for producing a picture story or animation.

Activity 39: Shadow bats

Drama / Dance/English
Shadow theatre is a traditional Indonesian art. Ask students to write a batty story, and create a shadow puppet production. Choose a theme or story from any culture or develop a story about the Bats living in Balinese temples with sacred snakes! Use the play to highlight the life of a bat or conservation issues.



BAT ATTITUDE SURVEY SHEET

Investigator................................

We are asking people some questions to find out what they think about bats. Can you please help us by answering our questions? It should not take long.

Age. . . . .

Occupation . . . .

. . . .

Can you say something about bats, in one sentence?

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

Have you ever seen a bat? Yes or No

What did you think when you saw it? . . . .

. . . .

. . . .

. . . .

. . . .

. . . .

Are bats blind? Yes No Unsure

Do you know how bats fly in the dark? . . . .

. . . .

. . . .

. . . .

Where do bats live? . . . .

. . . .

. . . .

. . . .

What do bats eat? . . . .

. . . .

. . . .

. . . .

Are there really vampires? . . . .

. . . .

. . . .

Do bats get caught in peoples hair? Yes No Unsure

Should we try to conserve bats? Yes or No

Why? . . . .

. . . .

. . . .

. . . .

SECTION 3

BATS AND SOUND

SECTION 3 (((*Bats and sound*

Activity 40: Sound map

Geography
Bats create a 3-D image of their surroundings using sound and echoes. In this activity students try to make a map of sounds to increase their appreciation of the sense of hearing, and focus on observation and awareness skills. It can also be used as a mapping and information processing exercise.

Students are given cards with a centre mark. Working individually or in pairs with one child as a scribe, they find a comfortable place to sit with their eyes closed and listen for sounds over a ten minute period. They mark their cards with symbols to mark sounds and their relative distance.

Discussion can relate to types of sounds, symbols used, what made them, best sounds, bad sounds. Could you or someone else navigate with your sound map? Try to guide someone through the area using only your sound map. Discuss echolocation and bat's use of sound (Based on a Gould League Activity and Cornell 1989).

Activity 41: Seeing with sound

Science
Organise to visit a hospital to see how an ultrasound machine works. Discuss other applications of sound technology and use by humans.

Students may need an introduction to some of the features of sound itself, echoes and sound as a wave. Big wiggly springs can help demonstrate wave and sound principles. Students can stretch the springs out to different distances and observe how long the 'echoes' take to return. See if blindfolded students can guess distances from the return of the stretched spring's 'echoes'.

The effects of sound, the vibration of air, can be demonstrated by sprinkling salt on 'drums' made from tightly stretched sheets of plastic wrap. Loud noises will cause the plastic to vibrate and the salt will bounce up and down. In much the same way works an ear drum, a vibrating membrane connected to bones with the vibrations being converted to electrical nerve impulses.

Musical device helps blind to walk

MELBOURNE: A Victorian man has developed a world-first electronic device that will make walking a much easier task for the blind.

Dr Tony Heyes, a Royal Guide Dogs Associations of Australia research and development manager, made the breakthrough after 10 years of painstaking tests.

The result, the Sonic Pathfinder, warns visually impaired people about objects in their path by emitting musical notes on a sliding scale.

It warns the user of any collisions that may take place in the next two seconds. The pitch varies according to object closeness and position is signalled by sounds in the left, right or both ears.

Dr Heyes lost his sight 30 years ago but regained it in one eye after eight operations.

The device is given free.

SECTION 3 (((*Bats and sound*

Reflections of sound and echoes can be demonstrated in ponds or using large water filled trays. Waves from constant drips will spread out and be reflected off objects similar to sound waves. Tinting the water makes it easier to see. The outgoing waves can be directed slightly using curved surfaces. Discussion should emphasise the directionality of ultrasound and its difference to water waves.

Echoes and the bouncing of sound can also be demonstrated using hollow tubes to direct sound. A long tube is placed against a flat vertical surface and a noise making object, like a ticking clock, is placed at the outer end. The end of another 'listening tube ' is placed next to where the first tube meets the surface. The noise of the clock will be bounced off the wall and through to the other end of the listening tube where the students can listen. Experiment with different reflective surfaces. Can blindfolded students tell the difference between soft and hard surfaces?
Explore relationships between frequency/wave-length in musical instruments.

Activity 42: Big-eared bats

Science
Have students design bat ears they can wear to increase their hearing powers.

Blindfold students and ask them to call out 'aahhhhh' loudly and sustainedly. Ask another student to pass their hand across the front of the 'bat's' face about ten centimetres from its nose. The 'bat' should be able to tell when the hand is in front of its face by the change in the reflected sound. Ask students to walk blindfolded towards a wall clicking their fingers, and listen for the approach of the wall. Experiment with distances and without the ears or with just cupping a hand to the ear. Whose ears work best? What are the limits to the size of a bat's ear? Could a bat fly if its ears are too big?

Activity 43: The discovery of echolocation

Science
Ask students how they would design an experiment to find out how bats navigate in the dark. Guide the students through Spallanzani's experiment. Discuss the processes of scientific method, the concept of scientific freedom of information and why scientists publish results.
Do they think Spallanzani's experiments are ethical? Would scientists still do experiments like this? What are students' concepts on animal ethics, vivisection, animal euthanasia? Conduct a survey of students' attitudes. The 'Killing Animals' activity in the Gould League's Feral Peril book can be used as a guideline. Organise a debate on Spallanzani's experiments.

SECTION 3 (((*Bats and sound*

Activity 44: Doppling away

Science
The Doppler Effect or Doppler Shift is the change of frequency of a sound as an object moves towards or away from a listener. The typical example is the change in pitch of a passing car siren.

This is readily demonstrated by asking a student to make a noise, and quickly run, or ride a bicycle, towards and past a group of students. Blowing a whistle or pegging cardboard to the spokes of the wheel will provide a constant sound. The students should be able to hear the change in pitch. Discuss how bats could use this phenomenon to their advantage when catching insects in the dark.

Activity 45: How can they tell?

English / Science
Discuss the ability of bats to discriminate between objects. A bat can tell the difference between a small stone thrown up into the air and a moth. How?

Bats direct the ultrasound pulses like a torch beam. However by moving their heads from side to side as they fly: to 'sweep' an area, they can 'hear an image' of a much larger area. An analogy of this is using a torch in a dark room. If you hold the torch steady you only focus on what the beam illuminates, but if you quickly sweep the light beam back and forth you can get a broader picture of the room than just that lit by the torch's narrow beam.

Activity 46: Animal x-rays

Science
This exercise can be used to show animal similarities and the inter-relatedness of animals and the possibilities of similar ancestors. Many back-boned or vertebrate animals have similar bones, even though they may look quite different on the outside.

On the worksheets are 'X-ray' pictures of the forelimbs of seven animals. These are illustrated and identified below (Australian Academy of Science's The Web of Life). Students are asked to identify the limbs with the correct animal. These sets of bones all have the same arrangement and similar structure. They have all developed from the forelimb. This activity can be used to lead into the next activity which looks at wings more closely.

ANIMAL X-RAYS WORKSHEET

Investigator................................

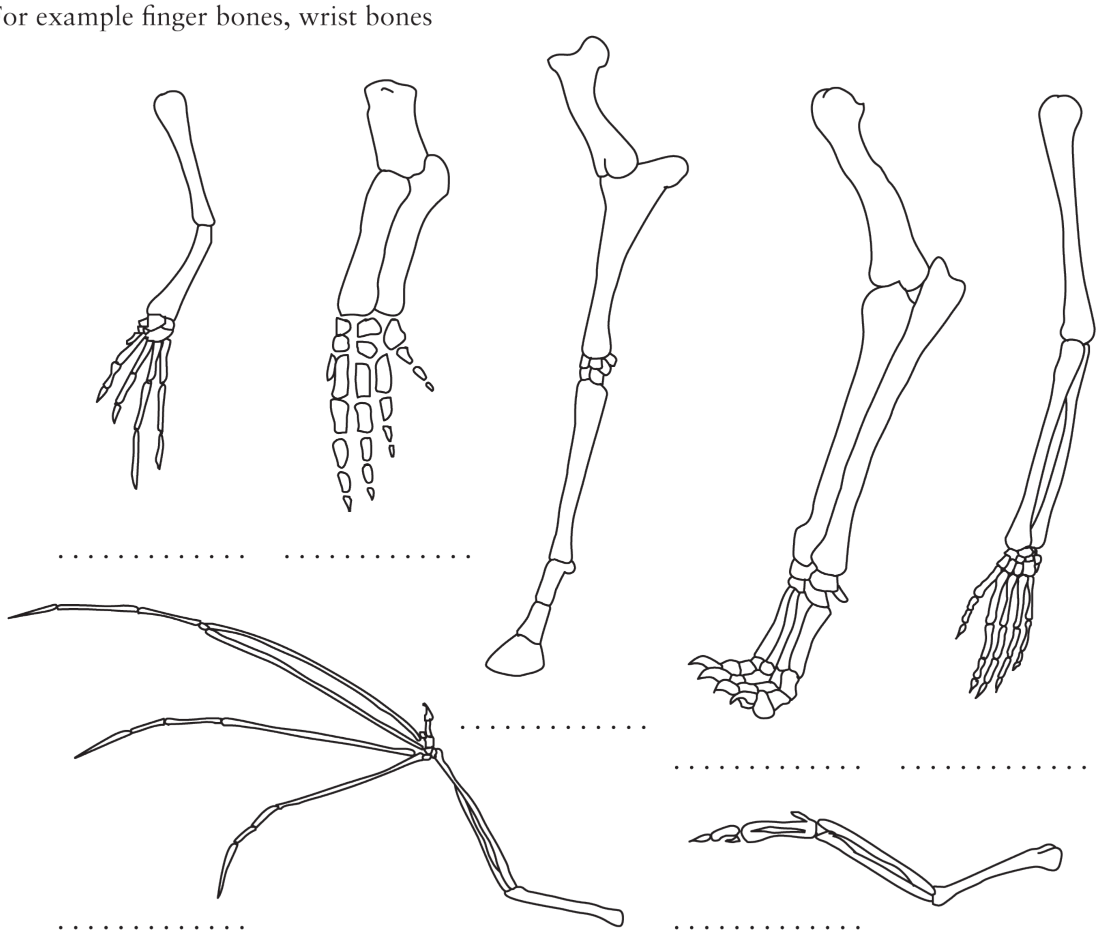
Many back-boned or vertebrate animals have similar bones, even though they may look quite different on the outside.

Look at the ‘X-ray’ pictures of the forelimbs of animals shown below.

Can you match limbs with the animals named?

Can you find sets of bones you think are similar in each animal? For example finger bones, wrist bones arm bones.

These sets of bones all have the same arrangement and similar structure. They have all developed from the forelimb. The wings of a bird and a beetle are both used for flight. However, although they serve the same purpose, they do not have the same structure or form.



BAT

HUMAN

WHALE

FROG

BIRD

LION

HORSE

SECTION 3 (((*Bats and sound*

Activity 47: Bats and moths

Health / PE / Drama/Science
Use a large play area. Divide the group into bats and moths. Blindfold the students and have them stand ten paces apart. The bats call out 'bat!' to which the moths must reply 'moth!' The bats then take two steps in the direction towards a moth call. The moths are allowed to take one step away to evade the bats. The game continues until all the moths are caught. The moths could be given a 'sonic evasion' chance when the moth thinks it is in dire peril. The moths are allowed one 'crash dive' of five paces in one direction. But be careful as it may place you in the reach of another bat! The Gould League's Outdoor Environmental Games has bat games where players join hands to form cave walls; caught moths rejoin the walls.

Discuss the echolocating ability of bats and the countermeasures insects have developed.

Activity 48: Acrobatics

Health / PE
Develop an exercise routine or aerobics based on bat movements and flight. Wing-stretch, moth catch, bat scurry, roost, wing wrap, hang and flutter, etc.

Activity 49: Blind as a bat?

Maths / Science
Ask students to design an eye chart to test a bat's eyesight. Use life size cut-outs, silhouettes or drawings of bat foods and arrange them like an eyechart, from a big mango to a tiny midge. Some megabats may see in colour but microbats probably only see in black and white. How would you make a chart to test a bats echolocation? A chart with raised surfaces perhaps or a suspended 3-D mobile ?

Activity 50: A bat for the blind?

English
Write a description of a bat for a blind person. What would you feel, smell, hear? Bats can see but use sound to find their way around. How do sight-impaired people find their way around using other senses? Are there devices that help them see with sound? Can students design one? How would it work? Ask a sight-impaired person to talk to the class and discuss how they live using senses other than sight.

SECTION 4

BATS IN FLIGHT

SECTION 4 *(((Bats in flight*

Activity 51: Air bat control

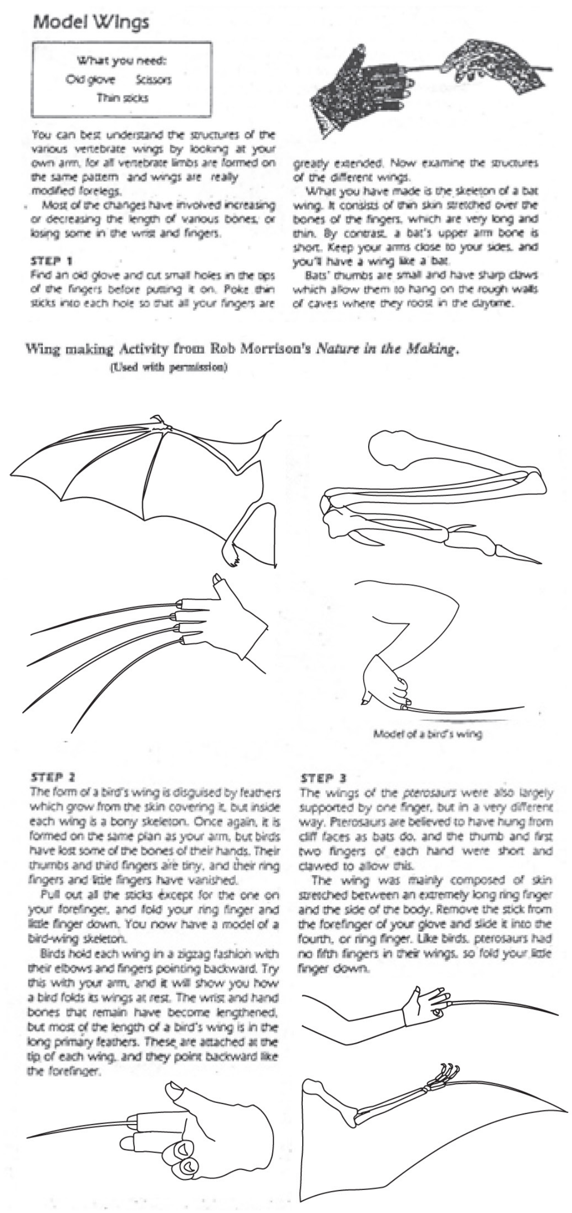
Technology/English
You are the flight controller at bat cave flight control centre. Create a story of how to deal with the bat traffic. Stories could be presented as shadow theatre using different bat silhouettes to show how they fly and feed at different times and heights.

Activity 52: Go fly a bat

Technology / Science
Ask students to design and fly bat kites. A good working design can be found in an article by Terry Kenny in Arts and Craft, July 1990.

Activity 53: Be a bat—model wings

Science / Art



Model Wings

What you need:
Old glove Scissors
Thin sticks

You can best understand the structures of the various vertebrate wings by looking at your own arm, for all vertebrate limbs are formed on the same pattern and wings are really modified forelegs.

Most of the changes have involved increasing or decreasing the length of various bones, or losing some in the wrist and fingers.

STEP 1
Find an old glove and cut small holes in the tips of the fingers before putting it on. Poke thin sticks into each hole so that all your fingers are greatly extended. Now examine the structures of the different wings.

What you have made is the skeleton of a bat wing. It consists of thin skin stretched over the bones of the fingers, which are very long and thin. By contrast, a bat's upper arm bone is short. Keep your arms close to your sides, and you'll have a wing like a bat.

Bats' thumbs are small and have sharp claws which allow them to hang on the rough walls of caves where they roost in the daytime.

Wing making Activity from Rob Morrison's *Nature in the Making*.
(Used with permission)

Model of a bird's wing

STEP 2
The form of a bird's wing is disguised by feathers which grow from the skin covering it, but inside each wing is a bony skeleton. Once again, it is formed on the same plan as your arm, but birds have lost some of the bones of their hands. Their thumbs and third fingers are tiny, and their ring fingers and little fingers have vanished.

Pull out all the sticks except for the one on your forefinger, and fold your ring finger and little finger down. You now have a model of a bird-wing skeleton.

Birds hold each wing in a zigzag fashion with their elbows and fingers pointing backward. Try this with your arm, and it will show you how a bird folds its wings at rest. The wrist and hand bones that remain have become lengthened, but most of the length of a bird's wing is in the long primary feathers. These are attached at the tip of each wing, and they point backward like the forefinger.

STEP 3
The wings of the pterosaurs were also largely supported by one finger, but in a very different way. Pterosaurs are believed to have hung from cliff faces as bats do, and the thumb and first two fingers of each hand were short and clawed to allow this.

The wing was mainly composed of skin stretched between an extremely long ring finger and the side of the body. Remove the stick from the forefinger of your glove and slide it into the fourth, or ring finger. Like birds, pterosaurs had no fifth fingers in their wings, so fold your little finger down.

SECTION 5

BAT CONSERVATION

SECTION 5 (((*Bat conservation*

Activity 54: Habitat for bats

Geography/Science
Discuss a plan of action to protect a small area of bush where bats roost in your local area. How can bats be encouraged.

Activity 55: Box a bat

English / Science
Develop and design a program to make and market bat roost boxes, and monitor the success of boxes. Produce a video or photo-board display on making bat boxes for other schools.

Activity 56: Research a researcher

English / Science
Find out if anyone is studying bats in your area. Conduct an interview to find out what they do. Organise a visit, talk, bat trapping or sound recording evening. Help raise funds for your bat box program or research with a public bat watch activity. Produce a video of a bat researcher's activities or your schools bat box project, and distribute it to other schools.

Activity 57: Bat-aware

English
Develop a display for a council foyer or shopping centre about bats, bat conservation and bat boxes. Who needs to be contacted? What is the best way to display? Plan, write and market a pamphlet to inform others about bats in your local area. Evaluate success by undertaking surveys prior to and after displays.

Activity 58: Consequences and resolutions

Geography/Science
What are the implications for the forestry industry and native forests if fruit bats are not protected? How can the problems fruit bats cause for fruit growers be resolved. Discuss these topics. Some fruit growers use netting to protect their crops, rather than kill bats, and market the fruit as bat friendly fruit. How would you design a fruit bat friendly fruit farm?

SECTION 5 (((*Bat conservation*

Activity 59: Conflicts in conservation

Geography/Science
The ability to discuss issues and opinions is an important skill. Community forums are an important part of forming management plans and decision making on development and conservation issues. Role playing can give students an appreciation of the complexity of conservation issues and the varied effects it can have on a community.

Role-playing scenarios can be based upon a number of bat-related issues. One such issue is limestone mining and the destruction of roost sites, such as happened in 1988 at Mount Etna in Queensland. Another issue is the removal of Flying Foxes from the protected fauna list in Queensland to allow their destruction as pests by fruit growers and the problems of flying foxes in fruit growing areas.

These issues are not simple and opinions on all sides usually need to be compromised for a plan to be developed. Students should assess positives and negatives of actions and then make a judgement. Roles played by students might include: mine manager, miners, tour operators, park and wildlife manager, ranger, conservationist, bat researcher, mine environmental consultant, caver, shop owner and business-person, fruit-grower, ministerial representative for mines, environment or primary industries, managing flying foxes in Botanic Gardens, etc..

SECTION 5 (((*Bat conservation*

Activity 60: Five star bat hotel

Geography / Science
Does your school or neighbourhood provide good bat habitat?
How does it rate for:

- Old trees with hollows for roosting
- Native trees and understorey plants or grassy areas where insects live for bat food, or fruit and blossom trees if fruit bats occur in your area
- Open water, creeks, dams or ponds for catching insects above and for drinking from
- Buildings with high roofs, eaves, bat boxes, or places where bats can roost
- Parks, or other areas within flying distance, with native plants, caves and old trees to which bats can fly for other roosts and food.

Activity 61: Model habitats

Science / Art
A variety of media can be used to model habitats, including bats and other animals associated with them. Ecology and web of life activities beforehand can help focus students on habitats.
Some Aboriginal dreaming stories can also be used to develop habitat themes.
Themes for habitat models may include:

- mangroves and flying foxes
- old trees and hollows
- caves and colonies
- bat migration and maternity caves
- forests and woodlands
- contrast pine plantations and native forest as habitat
- bats in belfries and other buildings
- bat boxes.

A range of media can be used, incorporating paper sculpture and paper maché, card silhouettes, fabric sculpture, wire-armature and collage.

Activity 62: Letter to the school

English / S&E
Write a letter to the principal of the school or local council with suggestions as to how the area could be improved to make it a Five Star Bat Hotel. Design a program and a budget for the project. How would it be funded? Who could help?
(Based on a bird survey activity in The Gould League's First Flight).

5-STAR BAT HOTEL WORKSHEET *Investigator*..............................

How good a neighbourhood is your area for bats?
Conduct this survey to find out what things in your area make it a good home for bats.

Give the areas chosen a star for each feature important for bats.

	School	Street	House	Park	Other
Old trees with hollows for bat roosts.					
Native trees, shrubs and grassy areas, where insects live for microbats to eat. Native flowering gums and fruit trees if megabats live in your area.					
Open water, creeks, rivers, dams or ponds, for bats to feed over and to drink from					
Buildings with high roofs, eaves, bat boxes, or other places where bats can roost.					
Other areas nearby with native plants, old trees, or caves.					

An area does not have to have all the things listed for bats to live there. The more things there are however, the greater the variety of bats you might expect to find there.

SECTION 5 (((*Bat conservation*

Activity 63: Bat boxes

Science

The loss of trees, especially old trees with hollows, has reduced the number of available roost sites for many bats. A decrease in tree hollows increases the competition amongst hole-using animals. Introduced animals such as Starlings and European Bees actively displace native animals from hollows. Schools, individuals and organisations can help native birds and bats by making and installing nest boxes. Bat boxes were used in France in 1918. European foresters knew birds and bats were useful predators of insect pests and tried to encourage them in pine plantations that did not have suitable hollows. There are a number of designs for bat boxes.

Some people recommend wood preservatives be avoided in nest boxes. There are other sources that say there are no observable problems caused by the use of preservatives in the wood.

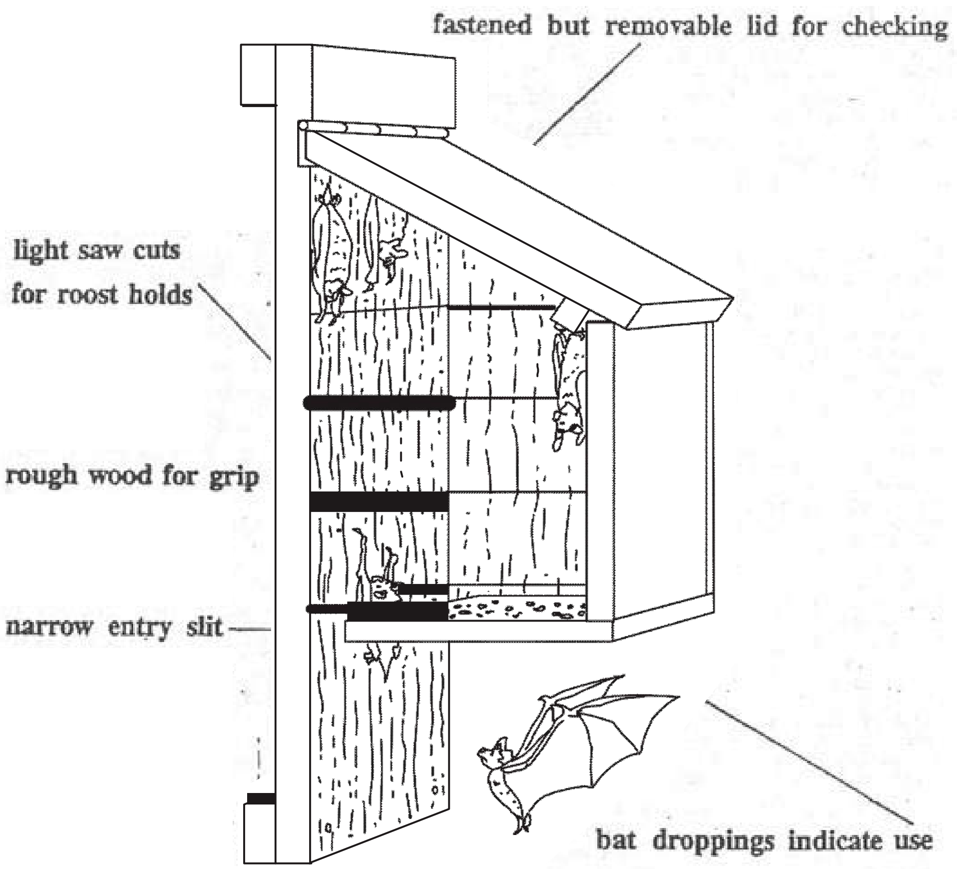
When making bat boxes, make sure they:

- are weather and draught proof
- have sturdy construction
- are sited carefully to cater for seasonal changes
- have rough surfaces, inside and out, for bats to land and crawl
- have small entry slits (15 mm to 18 mm wide) to discourage animals other than bats
- are placed at a suitable height (4 m is recommended)
- are consistently monitored to avoid injury to bats from rotting or collapse.

It is also important for the community to be aware of the boxes (or even get involved). This will help avoid disturbance and vandalism.

One study on the success of nest boxes at Cromer Forest in South Australia showed 14% of nest boxes were used by bats; 9% by birds and 77% unused over a two months period. Highest use of nest boxes appeared to occur in areas where there were few natural hollows. Some boxes may not have been used because of their newness.
Bat droppings will accumulate in the bottom of boxes. These are an indication that the roosts are being used even if the bats themselves are not seen. Students can examine the scats under a microscope to see what sorts of things bats are eating.
It is valuable to record the observations on bat box programs. The type of design, where boxes were placed, height and orientation, how long before they were used and when, etc. A sample data sheet used in a South Australian nest box project is provided as an example.

SECTION 5 (((*Bat conservation*

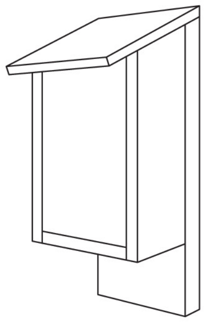


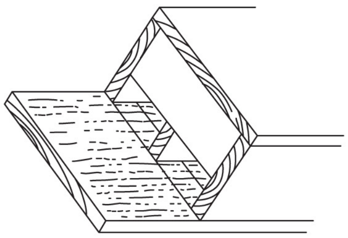
Cutaway view of a typical bat box design, with side removed. (After Stebbings 1991)

COMPLETING DATA SHEET (BATBOXES).

NUMBER OF BOX. Please number each box. It is a good idea to write the number of each box on its base with a waterproof felt pen. It can then be read from the ground. Unless the features of each box are recorded, there is no way in which those that attract bats can be identified.

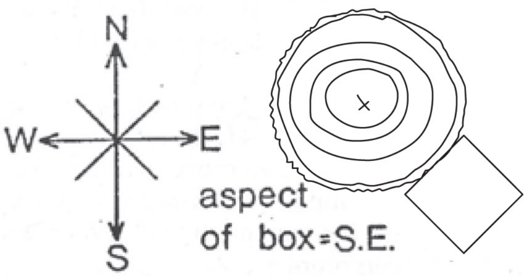
HEIGHT, WIDTH and DEPTH. This data sheet assumes that your batbox is similar to that illustrated in the guide; an upright box with a sloping lid. If you have built some other kind, please try to measure the INSIDE dimensions and record them.





WIDTH OF ENTRANCE. Assuming that the entrance to your batbox is like that in the guide, a horizontal slot, please indicate the width of that slot (i.e. its narrower dimension rather than its longer one).

ASPECT OF BOX. There is some evidence that bats select nesting sites that are adequately insulated, shaded, or not too exposed to the sun. Use compass bearings to indicate which aspect of the tree trunk (or other support) your box is attached to.

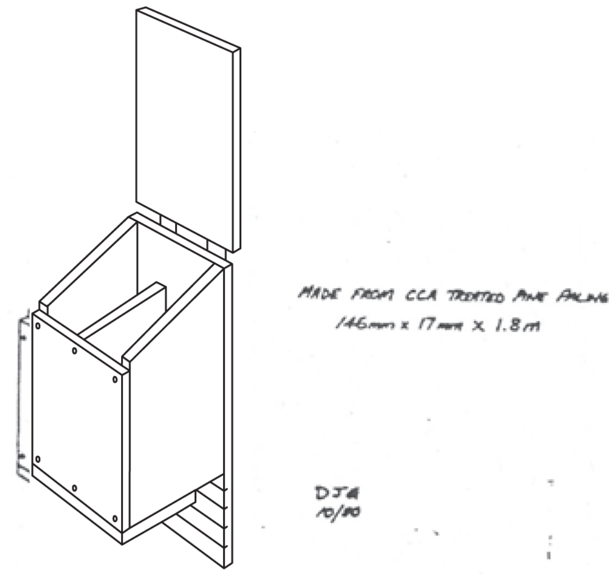


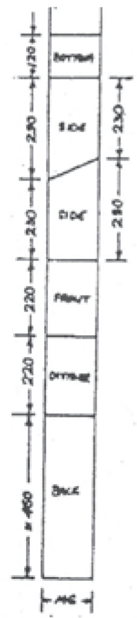
HEIGHT ABOVE GROUND. This should be the vertical height. Given that bats seem to prefer a roosting site at least 15 feet above the ground, it is sometimes easier to count the rungs of the extension ladder used to install it, and measure that length when the ladder is lying along the ground.

ADDITIONAL COMMENTS. Please include (on the back of the form if necessary) any additional information that you consider potentially significant. Bat boxes have proved successful when attached to trees (presumably as alternatives to hollow limbs), but bats also roost in caves, hollow tree trunks and other places, and some species will readily roost in houses. If your batboxes have been placed other than attached to a tree trunk, please provide details, either in the space provided or on the back of the form.

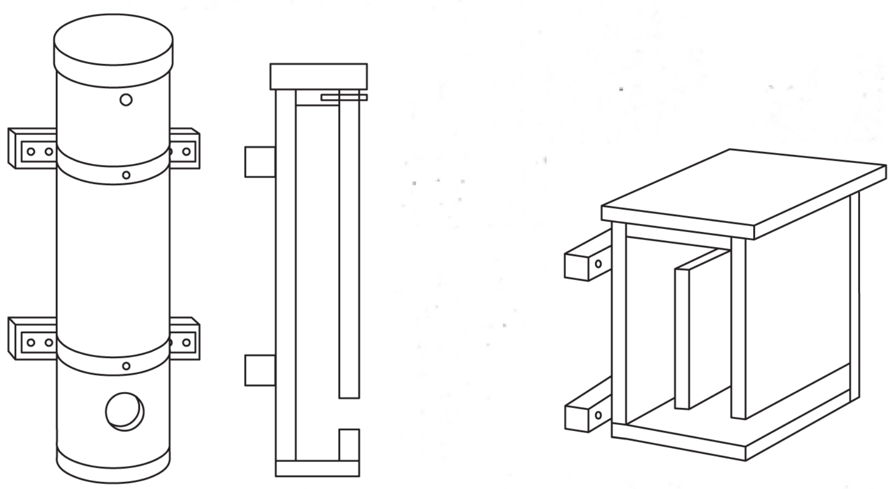
Please retain copies of your completed data sheets. They will be the only sources of information that can be used to determine the features of any boxes that do attract animals.

SECTION 5 (((*Bat conservation*





A bat box design from a school "Nestbox Project".
(Used with permission from Rob Morrison)



Bat box designs are varied, from simple hollow logs or tubes to multi-chambered boxes.