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Autumn 1985

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AUSTRALIAN HIMALAYAN EXPEDITIONS

Australian Natural History

from the INSIDE

The Koala is sick. Numbers of this internationally popular marsupial are dwindling due to a disease of the reproductive tract, the "wet backside syndrome" and a form of pneumonia. The cause of these problems has now been isolated and a vaccine is being developed. The Koala's saviours, biologists at the University of Queensland, report exclusively for *Australian Natural History* on their vital research and its results.

The Riverina and surrounding areas are only now recovering from Australia's worst locust plague in 30 years. The plague, however, could have been more serious. Read about its successful containment by the Australian Plague Locust Commission. We feature a debate on animal-based research between a scientist who experiments on sheep and an impassioned anti-vivisectionist. Do the benefits from the advances in medical science brought about by animal experiments outweigh the costs of inflicting varying levels of pain on animals?

I expect you'll enjoy our extensive photographic essay on Australian Aborigines and the hauntingly surreal photos of marine worms. The strange noises made by some invertebrates and the vast variety of smells found in the Australian bush are the topics covered in two other articles that will definitely stimulate your senses. This edition's liftout poster of Aboriginal dancers in Arnhem Land celebrates the opening of the Australian Museum's permanent Aboriginal Gallery.

Rob Cameron, Editor.

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Cover: The grooved feeding tentacles of this cirratulid polychaete worm function as vacuum cleaners, cleaning the substrate for fine particles of food. Numerous branchial filaments extend down the body. They contain many fine blood vessels that increase the surface area over which oxygen can be absorbed, enabling it to live in muddy environments where oxygen is low. Photo: Kathie Atkinson.



▲Aborigines at Utopia, 250 kilometres north-east of Alice Springs, successfully claimed a cattle station in 1983 and now hold title to their land. They also operate a Women's Batik Co-operative. In preparation for a women's ceremony, the women are painted with their appropriate clan designs, using red and white ochres ground on a stone slab and applied with a shredded stick brush. Photo: Penny Tweedie.

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The Editor welcomes articles or photographs in any field of natural history.

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KOALA DISEASE BREAKTHROUGH

Vaccine to be tested this year

by Steve Brown and Dr Frank Carrick

There is an appalling lack of knowledge of Australia's favourite marsupial, the Koala. At least 45 per cent of this neglected species is infected with disease, causing blindness, pneumonia, reproductive tract infections and other fatal complaints. Fortunately, the infection-causing bacterium has now been isolated and a vaccine is being developed. This important breakthrough is the result of work by Steve Brown and Dr Frank Carrick from the Veterinary Anatomy Department at the University of Queensland.

In 1798, a decade after the arrival of the First Fleet, the Koala was first reported to European science. With the approach of the Bicentennial, the Koala is one of the most identifiable and internationally popular of the world's mammals. However our knowledge of many of its biological aspects are little advanced from what was deduced in the first century after its discovery.

By 1887, outbreaks of disease severely affected Koala populations, and were thought to have been a major contributor to a drastic decline in numbers in Victoria and the extinction of the Koala in South Australia. Early records describe a severe outbreak of an ophthalmic disease from 1887 to 1889, causing the death of millions of Koalas. Sick animals were found at the base of trees, no longer capable of climbing, and slowly dying of starvation, dehydration and infection. At the turn of the century, another ophthalmic disease outbreak devastated Koala populations for three years. Then a disease of the reproductive tract of female Koalas was discovered in 1919, further elucidating the problems confronting Koalas.

Other well known, but poorly documented, outbreaks of disease occurred in the 1920s and 1930s with Koalas dying from pneumonia and ophthalmic disease. The past 50 years have seen numerous references to diseases in Koalas but, in most cases unfortunately, no causes were known.

A significant breakthrough came in 1974 when Cockram and Jackson, working at Armidale (New South Wales), isolated a bacterium, *Chlamydia psittaci,* from the eyes of blind Koalas.

Chlamydiae is a family of fascinating disease-causing organisms. They are very small bacteria that live most of their lives inside the cells of their hosts, similar to many viruses.

In animals, *Chlamydia psittaci* causes arthritis in lambs and dogs, conjunctivitis in cats, abortion in sheep and cattle, psittacosis (pneumonia) in birds, and brain and lung infections in Opposums. In fact, very few animals escape infections by *C. psittaci.* A closely related organism, *Chlamydia trachomatis,* occurs only in humans causing trachoma (the largest form of preventable blindness in the world), affecting 50 million people. It is also known to infect the urogenital system of a further 500 million men and women, causing myriad diseases such as pelvic inflammatory disease, which can result in female infertility. Chlamydial pneumonias are also recorded in young human babies.

The authors' interest stems from observations by ecologists working

with Koalas in Queensland and Victoria. They found that some populations of Koalas had very low fecundity or reproductive rates. We discovered that this was due to a disease of the female reproductive tract (which had earlier been called "cystic ovary disease"). After examining and rejecting many possible causal factors, with the collaboration of Ron Grice from the Queensland Health Department, we found that this reproductive tract pathology was caused by *Chlamydia psittaci,* the same enigmatic organism that had been isolated from the eyes of blind Koalas nearly a decade before. As a bonus, we also found that this same organism caused the other two common and fatal diseases of Koalas, "wet backside syndrome" or "dirty tail disease", and a rhinitis pneumonia complex.

An extensive survey of over 1,000 Koalas throughout eastern Australia in the past six years has shown about 45 per cent of the sampled population to be affected by *C. psittaci.* Because the Koala usually has a long lifespan, about ten years on average in the wild, studies of Koala population dynamics must be long-term. The best data showing the impact of disease comes from Dr Greg Gordon's work at the Queensland National Parks and Wildlife Service. Gordon revealed that a population of wild Koalas at Oakey in southern Queensland was more than halved over the last decade after suffering a greater than 50 per cent incidence of *C. psittaci* infection. An almost disease-free population at Springsure (Queensland) has doubled in the same period.

Four different techniques were utilised to evaluate Koala infection by *C. psittaci.* Autopsies were performed on severely traumatised or sick or dead animals to record the presence of all chlamydial diseases. Blood samples were taken looking for the presence of antibodies to *C. psittaci,* which would suggest a past or current infection. Radiographs of female Koalas were taken and large ovarian cysts recorded. Bacterial samples by isolation and culture also determined the presence of *C. psittaci.* An excellent correlation existed between all results obtained utilising such techniques.

Over the past six years, eight study sites throughout Australia were monitored for the presence of chlamydial infection (estimated by the presence of antibodies). The most infected areas were Phillip Island (92%) and Walkerville (86%) in Victoria. High incidences were recorded at Oakey (53%) and Moreton (39%) in Queensland. Adelaide (South Australia) recorded 13%, whilst a low level of infection was monitored at Springsure (5%) in Queensland. Bollon in Queensland and Kangaroo

A Koala ponders the future. Photo: R. & D. Keller NPIAW



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Blindness caused by *Chlamydia psittaci*.
Photo: Steve Brown

Island recorded no infection, based on serological examination.

Of some significance is the fact that 78 per cent of the blood samples that showed the presence of antibodies to *C. psittaci* also had one or more of the four chlamydial diseases: blindness, infertility, rhinitis/pneumonia and "dirty tail disease". However, this is liable to be an underestimate, since 17 per cent of Koalas with blood samples showing no antibodies in fact had one or more of the chlamydial diseases. For some presently unknown reason, Koalas can take up to four months from the time of infection to produce antibodies to *C. psittaci;* whereas most mammals take only 14 days. This delay may help explain why so many Koalas become so severely affected.

Now that we know the cause of the four most common and fatal diseases of Koalas, we should be able to find a treatment. Antibiotic therapy against Chlamydiae in animals and humans has proven successful, especially with the use of tetracycline and erythromycin. However, the Koala relies heavily on the symbiotic bacteria and other micro-organisms normally found in the gut of Koalas. These are necessary for digestion of gum leaves and possible detoxification of the plant secondary compounds commonly found in their diet. Antibiotics used in Koalas to kill chlamydial organisms also kill these vitally important bacteria, rendering their host malnourished and possibly toxaemic. As a preventative, however, a vaccine may be the answer. Similar vaccines have been used in the United States and United Kingdom for chlamydial infections in sheep, cattle and cats with some success, although anti-trachoma vaccines in people have been disappointing. A vaccine is to be tested in Koalas this year by the authors at the University of Queensland.

With the advent of a chlamydial vaccine for Koalas, management and disease control could be significantly improved. Future research will be directed towards a better understanding of the susceptibility of Koala colonies to chlamydial infections and the treatment and prevention of such diseases. At present, we are totally unaware of the source of infection, how the disease is spread, what limits its distribution and why some populations appear to be more susceptible to infertility while others are more susceptible to blindness. We also need to know a great deal more about another big killer of Koalas, "Stress Syndrome". Other scientists, including Cockram, Dickens, Gordon, Jackson, Martin and Obendorf, have observed the effects of this "Stress Syndrome" on wild populations of Koalas and all suggest the need for further investigation. For example, monitoring of two Koala populations by the Victorian Fisheries and Wildlife Division over the past 40 years has

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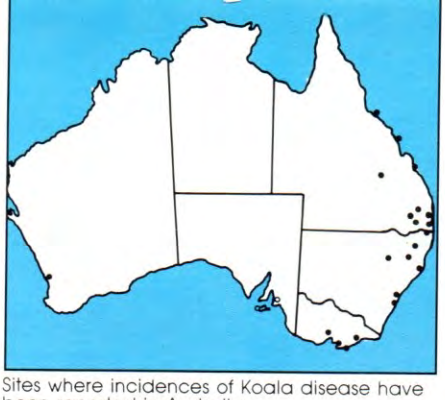
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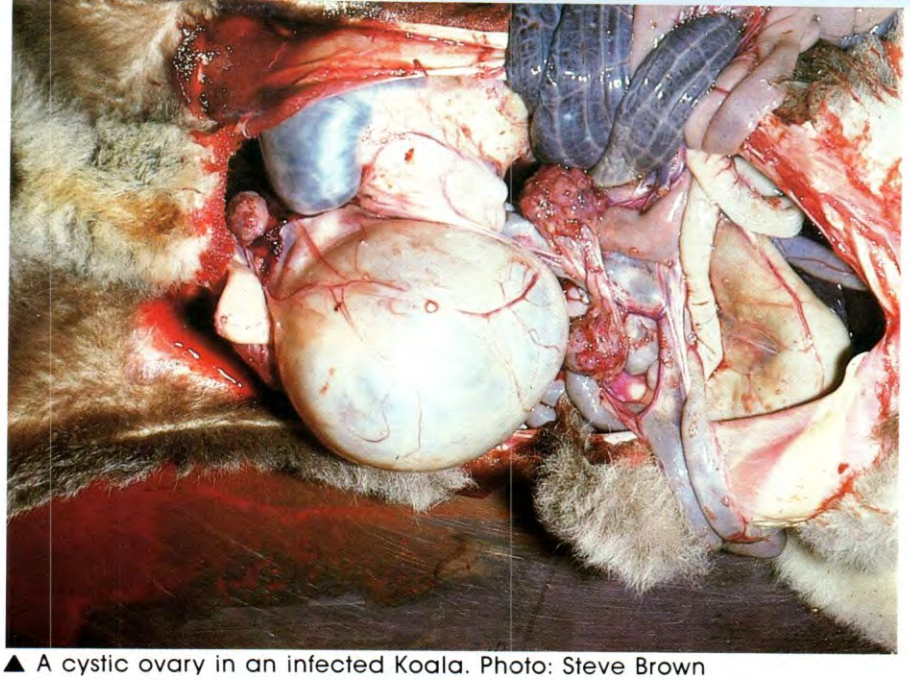
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Sites where incidences of Koala disease have been reported in Australia.

shown a remarkable difference between the reproductive rates of two island colonies. Phillip Island, with its numerous stresses (tourists, vehicles, limited habitat, agricultural pressure, limited migration from the island, etc.), is seriously affected by *C. psittaci* with a low reproductive rate, while French Island is apparently little affected. David Obendorf has urged a great deal of caution when Koalas are relocated, especially from Phillip Island, for fear of further distribution of *C. psittaci* throughout Australia.



▲ A cystic ovary in an infected Koala. Photo: Steve Brown

▼ The fatal "wet backside" or "dirty tail" disease. Photo: Steve Brown





Weeping eyes of Koala suffering from conjunctivitis. Photo: Steve Brown

Although our recent studies, viewed in conjunction with history, show that disease is a potent factor in Koala biology, it is obvious that other factors such as habitat alienation and its possible effects on, for example, diet selectivity, are likely to be important to the long-term survival of the Koala.

It is rather sobering that almost a decade after the first Koala Symposium held at Sydney's Taronga Zoo in 1976, virtually nothing has been done to implement the resulting Round Table recommendations, other than as an expedient to clear the way for the export of Koalas overseas. Perhaps the support of a task force to make a major assault on our appalling lack of knowledge of the Koala would make a very fitting Bicentennial project! □



Densey

. . . LIZARDS WITH CONTACT LENSES AND WINDSCREEN WIPERS

To the leaftail geckoes, my house is probably just another rocky outcrop in Sydney's bushland. The basement is a cool, dark cave to hide in by day. At night, brick walls give rough foothold for creeping, courting, stalking and leaping, and of course there's the added luxury of built-in, automatic insect lures.

Soon after dark I watch the first of the geckoes leave the basement snout-first through a ventilator, one round, delicately-veined eye checking for danger. There's no hurry — the hunting's good on a warm summer night when the house lights are on.

The gecko takes up her ambush station under a lighted window, flat against the off-white bricks, claws spread to grip and hold. Which end is which? Front and hind limbs are mirror-imaged, with elbows and knees angled towards each other. Although her broad tail comes to a point and her snout is rounded, at a quick glance she could be facing either way.



When this Southern Leaftail Gecko (*Phyllurus platurus*) moults, the transparent "fixed eyelid" peels off with the rest of the skin. Photo: Densey Clyne.

Among reptiles only the geckoes seem to have become inquilines in human houses, sharing man's shelter though not his food. Most tropical countries, including northern Australia, have their domestic geckoes. They creep out from behind pictures and curtains and lavatory cisterns after dark — pale, black-eyed little extroverts that hunt and fight and mate and mess up the walls and ceilings quite openly — and noisily.

Vocalisation in lizards is rare. Only a few, including the geckoes and their close relatives, the snake-lizards, can produce sounds from their mouths. Have you ever heard a bluetongue bleat or a goanna groan or a Frillneck . . . fulminate? No! A hissing and a rustling is about all you'd ever hear from those lizards. Many outback geckoes, however, actually open their mouths and bark when they're attacked. Disturb a Knobtailed Gecko for instance, and it will swell up and "yap" aggressively while it does press-ups or makes



Threat display by the Wood Gecko (*Diplodactylus vittatus*) may include "barking". Geckoes often bite when handled but their small teeth do no harm. Photo: Densey Clyne.



Clyne looks at.....

threatening little runs at you. All bluff, of course . . . Their bite's hardly worth an ouch.

If bluff and bluster don't work, a gecko has a second line of defence. Grabbed from the rear it can voluntarily sever its tail from its body and make a quick getaway. Geckoes share this ability with skinks and snake-lizards. A new tail grows after a while but it never looks quite the same. Two of the leaftails around my house have shiny, dark brown tails, no longer leaf-like, more like some kind of seed pod. Somebody's cat is probably to blame. Not mine.

The leaftails don't come indoors much. Not that the hunting isn't good — they just don't have the feet for it. Many geckoes have specialised feet with expanded, disc-like toe-pads giving them traction on smooth surfaces. That's why tropical house geckoes can cling to window panes and run upside-down on ceilings. Leaftails, however, belong to the other group of geckoes that have more bird-like feet. They depend on their claws to grip irregularities in rough rocks and tree trunks.

I mentioned the snake-lizards (family Pygopodidae), also called legless or flap-footed lizards, that have close links with the geckoes. These little lizards have neither claws, nor toe-pads, nor even legs, so they're confined to the ground. All they have left in the way of limbs is a pair of scaly flaps just in front of the vent, vestiges of hind legs that still contain tiny leg bones. As a rule the flaps are small and hard to see, held close against the body. But a few pygopodid species with bigger flaps will stick them out when disturbed. It's almost as if they still had the urge to run rather than slither.

One of these, the Common Scalyfoot, *Pygopus lepidopodus,* lives around my garden. Although they're daytime hunters of insects, I usually find these lizards coiled up under a rock and my first thought is: snake or lizard?

Although pygopodids move like snakes, look superficially like snakes and, more often than not, get themselves killed because of it, they're strictly harmless. No Australian lizards have venom. They kill their prey by chomping on it.

There are several easy ways to tell a snake from a snake-lizard. For one thing, no snake has an external ear but most snake-lizards have an ear-hole just behind the eye. However, the best way to find out is to watch it for a while. Whether it's a snake or snake-lizard, it will probably start flickering its tongue to get some information about you. If the tongue is narrow and forked it's a snake. A snake-lizard, like a gecko, has a broad tongue with only a slight notch at the tip.

Speaking of tongues leads me — you'll see why in a moment — to eyes. There's something both geckoes and snake-lizards do have in common with snakes: they can't blink. Movable eyelids are replaced by fixed, transparent scales that protect the eyes against dust and dryness. These "contact lenses" (which are not lenses at all) peel off with the rest of the skin when the lizard moults, leaving a replacement pair underneath.

The "lenses" are themselves vulnerable to dust and splashes of rain and no doubt fogging-up, so it's useful to have something like a built-in windscreen wiper. For geckoes and snake-lizards, this is the long, strap-like tongue. It's licked upward from the corner of the mouth in slow easy stages until one eye is reached and wiped clear. Then it does the other eye.

This is an arrangement that can only be envied by the bespectacled photographer when a raindrop or a speck of dust or a sudden fogging-up has just ruined some never-to-be-repeated wildlife shot. □

A Knobtailed Gecko (*Nephrurus asper*) may disconcert a predator by inflating its body and "standing tall", thus appearing to be too much of a mouthful. Photo: Densey Clyne.



Fraser's Snake-lizard (*Delma fraseri*). Snake-lizards and geckoes use their long, broad tongues to clean the fixed, transparent "goggles" that replace the blinkable eyelids of most other lizards. Photo: Densey Clyne.



AUSTRALIAN ABORIGINES TODAY

A man has a block of land, Dambun. This land is for hunting, living upon. One man never trespasses onto another man's land without permission.

A man's mother come from one block of land and her mother comes from another block. The man's father comes from yet another block of land. This means, that man owns three blocks of land, his birthright or Yarriwarda.

Everyone is like this. The man's father, the ground and the earth in that block of land is Rumbad. The man's fathers, mother's land is Rumbad too. The land, the people are all united to nature and the creation. All are one.

All stories come from the land. They are all straight. We have Ungud names for the trees, the clouds, fish, snake and Kangaroo. Our names come from the animals, trees and stones. The earth, the land, our mother.

This is our philosophy and identity. It is in our bones, flesh and blood. All are connected to us and the land. We are one entity.

The Wandjina looking over all you see. The Wandjina travels to area to area each Wandjina for different tribal land.

This is our ancestry, our nature going back thousands of years.

Here around us today you see these things. All together for all people to see.

The land is our mother. It's our womb.

We are born out of it and when we die we return to it.

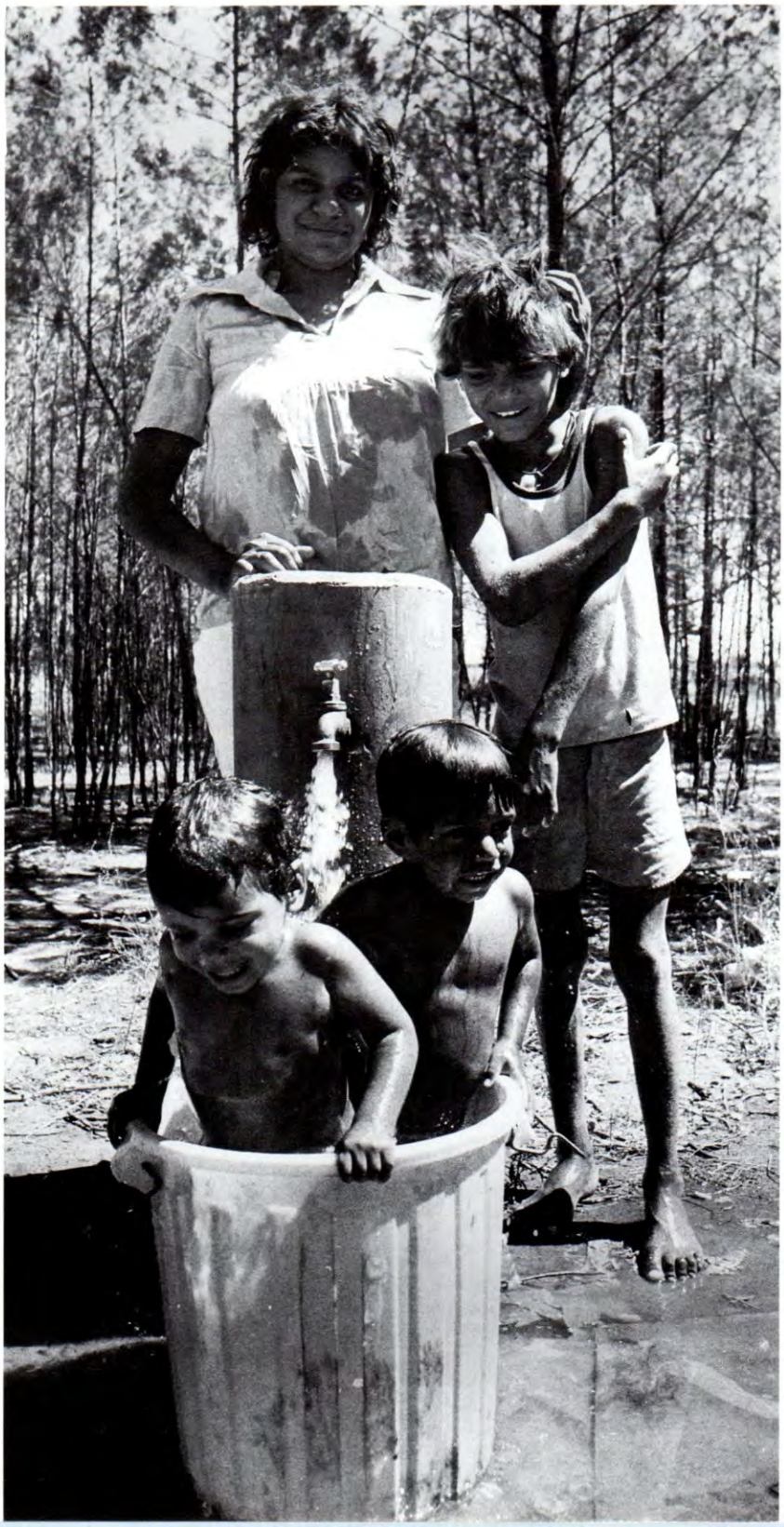
The land taught me how to speak. It has given me my own law to abide by.

I'm married to the land, and married to the law.

My spirit soars when I return to the land.

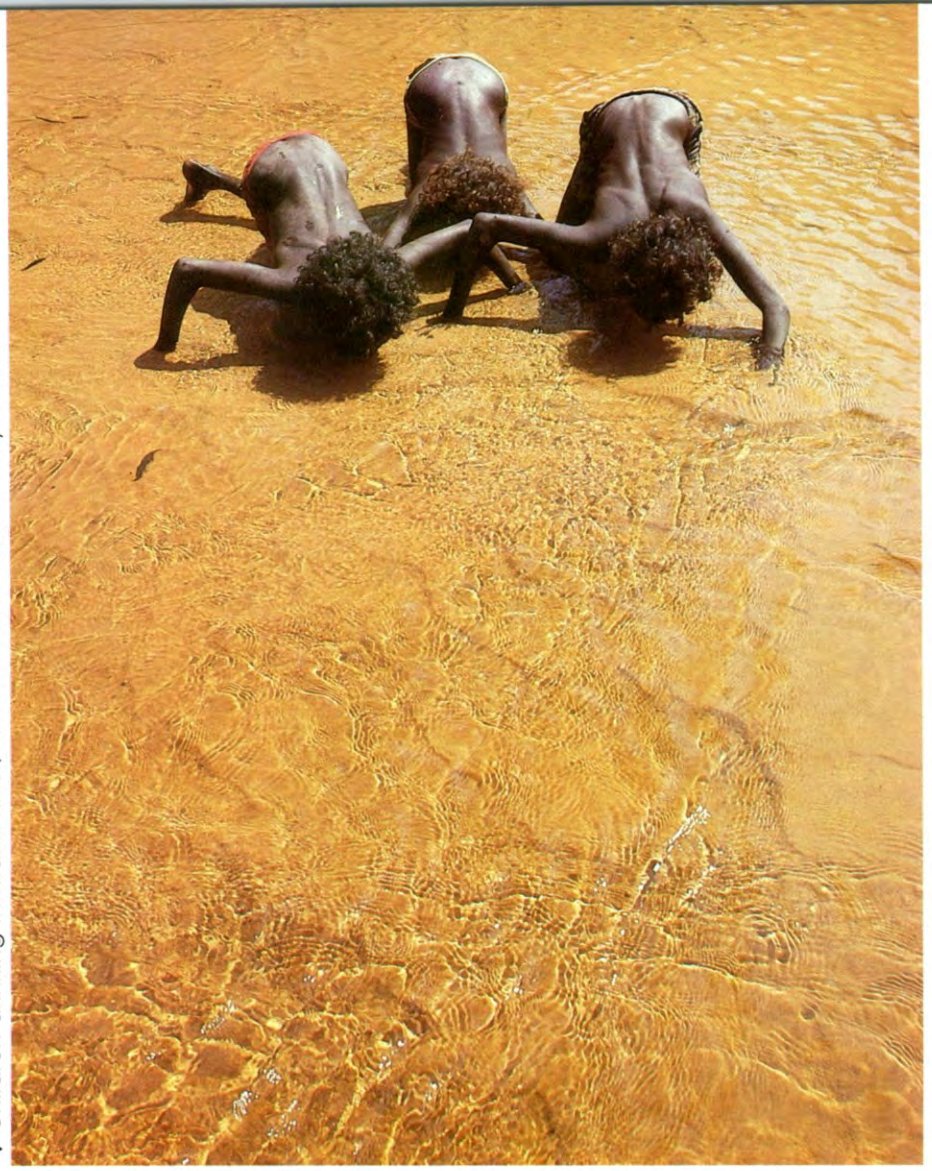
It restores my strength when I see it.

by David Mowaljarlai, Elder of the Ngarinjin tribe, Mawanjum, The Kimberleys, Western Australia



In Wee Waa, New South Wales, ▶ Aborigines come from hundreds of miles away to work in the cotton fields during the cotton chipping season. A camp with limited facilities is provided for the workers. Photo: Penny Tweedie. Opposite: Waterlilies provide an important source of food throughout the year. Every part of a waterlily is edible: flowers, stem, roots and corm. In central Arnhem Land they are worn by children for decoration. Photo: Penny Tweedie.



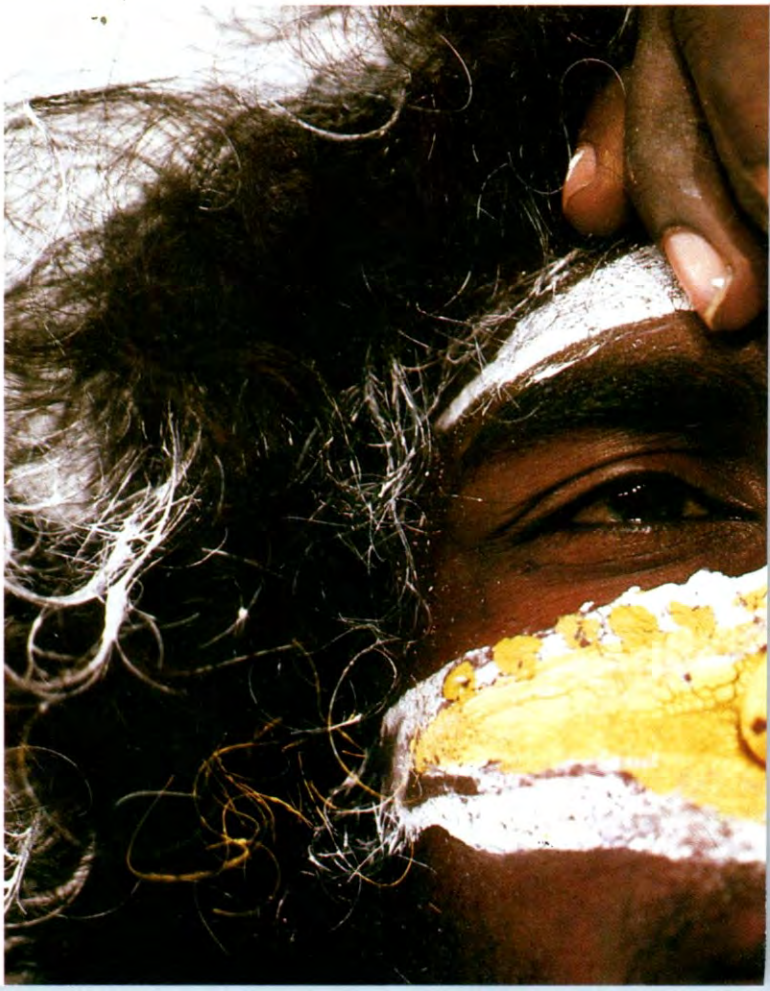


▼Children drinking in Mann River, Arnhem Land. Photo: Penny Tweedie.



"I had a problem with alcohol and a network of people helped me through it and in turn I helped a lot of people", says Ray Leslie, photographed at Bathurst Gaol where he works rehabilitating Aboriginal prisoners. Ray also counsels alcoholics and is President of Towri Aboriginal Corporation.
▼Photo: Elaine Pelot-Kitchener.







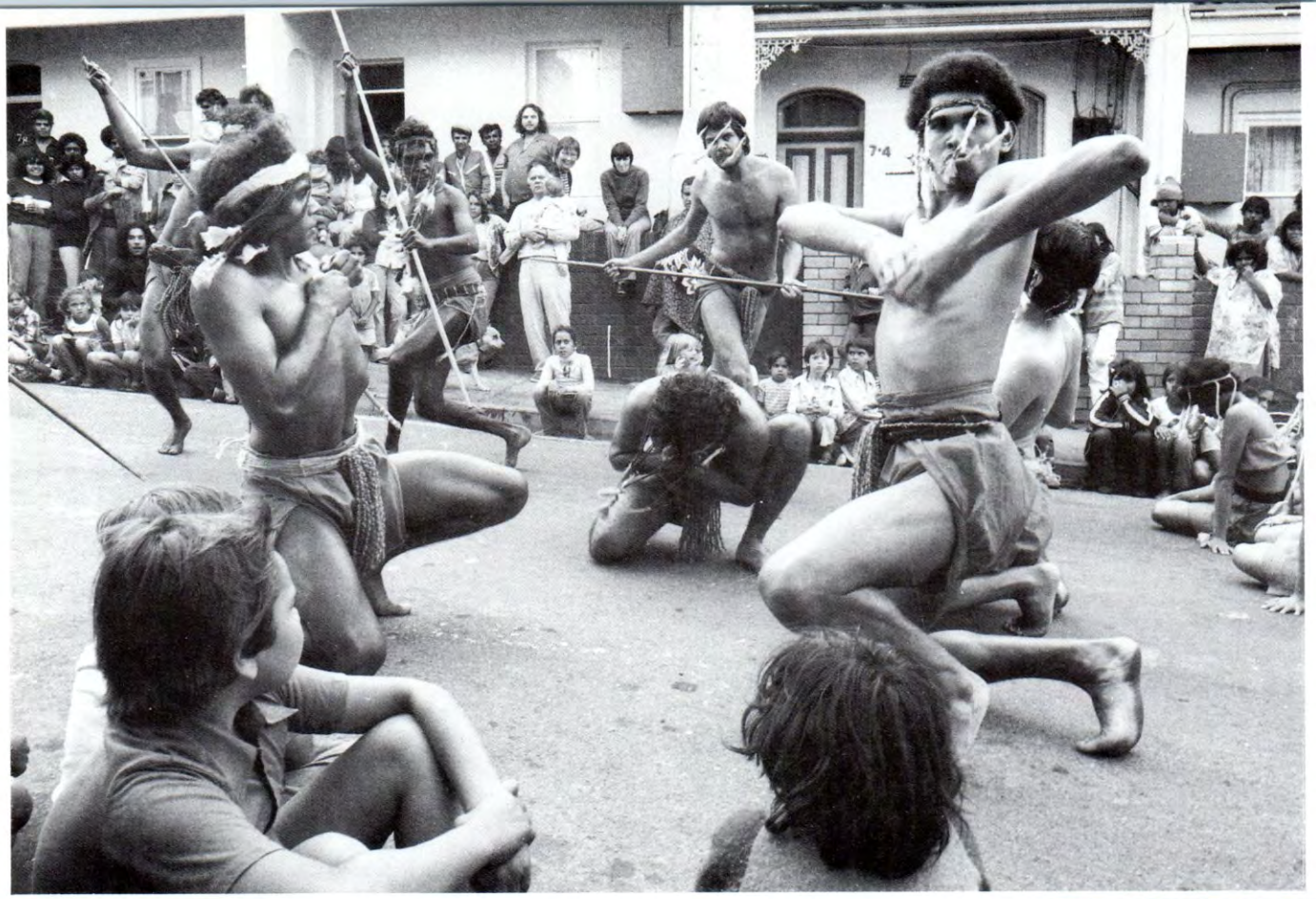
◀ Two Aranda children from Yipiringur School, Alice Springs, explore the rocks at Emily Gap during a school outing to learn about their country and the gathering of bush tucker. Photo: Penny Tweedie.





▲ A successful Aboriginal enterprise 1984: the recently established gymnasium and recreation centre at Redfern, Sydney, administered by the Aboriginal Housing Company Limited. Photo: Penny Tweedie.

◀ A young man prepares for a ceremony, Arnhem Land. Photo: Kathie Atkinson.



An urban corroboree in the predominantly Aboriginal Sydney suburb of Redfern, celebrating the opening of Murawina Child Care Centre, 1980. The elders who taught this dance are from Yirrkala led by Magungan Wanubi. The dance portrays kangaroo hunting. Photo: ▼ Elaine Pelot-Kitchener.

Clifford Possum Japaljarri, one of the Papunya Tula artists, paints a large canvas near ▶ Papunya, north of Alice Springs. Photo: Penny Tweedie.



Two Pitjantjatjara women spinning, Ernabella Mission, south of Alice Springs. Photo: Penny ▼ Tweedie.





◀Lightning Spirit and Mimi Ceremony at the Footbridge Theatre, Sydney, combining traditional and contemporary dance. Photo: Elaine Pelot-Kitchener.

Horace shows us his successful vegetable garden at Katjikatjijarra, south of Alice Springs. These vegetables supply a nearby outstation (homeland centre). Horace sells the surplus at Ernabella. Photo: Penny ▼Tweedie.





▲"Dodge City", on the outskirts of Brewarrina, New South Wales. Twenty nine houses built by the government in the 1960s house more than 250 Aborigines. There is no permanent employment for Aborigines in the town. Photo: Penny Tweedie.

At the Kalobidada outstation (Arnhem Land), a member of the Rembarnga clan paints a bark in the shade of ▼ a single bark hut. Photo: Penny Tweedie.



LOCUSTS

The Plague of '84

by Philip Symmons

The most extensive and severe locust plague for 30 years devastated the agriculture of western New South Wales late last year. Due to the efforts of the Australian Plague Locust Commission in Canberra, the plague was controlled in quick time. In this article, the Commission's Director, Mr Philip Symmons, explains how, for the first time in Australia and probably the world, such a large plague was beaten; and how potentially millions of dollars damage was avoided.

The spring of 1984 saw the worst locust plague in Australia for 30 years. But for the first time in Australia and probably in the world, a major plague was effectively eliminated by spraying. To understand how this plague came about and how it was beaten, one needs to know something about locusts and, in particular, about the species that caused the plague, the Australian Plague Locust *(Chortoicetes terminifera)*.

Locusts

Locusts lay their eggs in the ground in batches or pods. Each locust pod will contain from 40 to as many as 200 eggs depending on the species; and nearly all mature females will lay one pod and many will lay two. In each generation, therefore, there is a very high potential multiplication. The eggs require warmth and moisture to develop and hatch. Most locust species lay only in wet soil and the eggs immediately absorb all the moisture they need. The Australian Plague Locust, however, may lay in dry soil in which case the eggs go into a suspended state (quiescence) until rain falls.

In mid summer, Australian Plague Locust eggs that have been laid in wet soil hatch after about 12 days. Laid in other seasons, however, development is slower. Eggs laid in the autumn do not hatch until the spring; and those laid in winter do not develop at all. The nymph or hopper, which emerges from the egg, goes through a number of stages or instars, shedding a skin between each. The Australian Plague Locust has five instars but most locusts have more. At the final moult, often called fledging, the locust has fully developed wings but it takes several days for the wings to harden before the young adults can fly. The adults often remain immature for several months. When this happens, a change in the environment, such as drought-breaking rain, is usually needed before females can mature and lay.

When numbers are low, locusts are solitary animals. However, if numbers and densities increase so that they cannot avoid coming into contact with each other, they "learn" to behave gregariously; the nymphs form dense marching bands and the adults form flying swarms.



▶ Profile of the Australian Plague Locust, *Chortoicetes terminifera*, the dominant plague locust species in New South Wales. Photo: Kathie Atkinson.

Locusts make long-distance migrations. In the case of the Australian Plague Locust there must be green pasture to feed on at the time of fledging (so that the young adults can build up reserves of fat), followed by a warm night (adults cannot fly below 20°C) and, in the case of swarms, a windy day (so that minimum energy is used in flying). Take off then occurs shortly after sunset; the locusts climb to 500 metres or more, and are carried downwind as much as 500 kilometres in a single night.

The 1984 plague

Now let us look at the events that produced the plague of last spring. The year 1982 witnessed one of the serverest droughts in eastern Australia. By the time the drought broke in January 1983, very few locusts had survived. Throughout the rest of 1983 and most of 1984, widespread rain occurred repeatedly, allowing breeding after breeding to occur. There was a rapid build-up in locust numbers, suggesting unusually low natural mortality.

The Australian Plague Locust Commission's field officers attempted to find out where the build-up was occurring but flooding made survey in the interior of Queensland and South Australia impossible at the critical time. Indeed, the situation did not become clear until February 1984. By then widespread laying was occurring in a belt in southern New South Wales (from Narrandera and Finley in the east to White Cliffs, Broken Hill and Wentworth in the west with an extension into South Australia). We now think that large numbers of non-swarming locusts had invaded the Riverina from the extreme southwestern corner of Queensland on 5 and 6 and again on 12 and 13 January 1984, and had laid almost immediately. The resulting hoppers did not form bands, nor did the young adults, which emerged in early March, form swarms. It was possible then to find three, four or even five adults in virtually any square metre of the Riverina. To have sprayed the whole area would of course have been out of the question.



An adult Australian Plague Locust, *Chortoicetes terminifera*, digging a burrow in which she will lay her eggs. Photo: Kathie Atkinson.

Later in the month, the weather changed from being cool and windy to warm and calm; the adults flew and began to form swarms, and it suddenly became clear to everyone what a dangerous situation we faced.

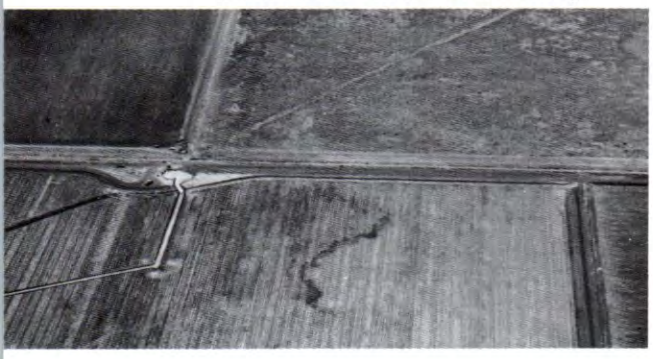
The Australian Plague Locust Commission sprayed about 1,400 square kilometres of the densest swarms using 46 tonnes of insecticide — technical fenitrothion. However, the majority of the locusts were not in swarms. I remember driving from Condobolin to Hillston, a distance of about 200 kilometres, in early April and never being out of flying locusts but without coming across a sprayable swarm. The adults started to lay in late March; laying continued during April although by the end of that month most of the parents had died. The Australian Plague Locust, when in swarms, always lays very densely in well-defined egg beds; the beds in the autumn of 1984 were the largest on record with, in many cases, hundreds of pods (tens of thousands of eggs) to the square metre. Very few eggs were parasitised.

The late winter and early spring were exceptionally cool and wet, so hatching started several weeks later than usual. Near Hillston hatching started in late September but near Jerilderie it was mid October before the first hoppers emerged. I had hoped that as the plague progressed, the locusts would behave more gregariously, that is would form bands, so that they would be better targets for spraying . . . And so it proved. West of Hillston the bands formed in the second instar — a stage earlier than usual; and, despite a dense cover of grass, the bands could be seen easily from the air.

Fortunately, but somewhat to our surprise, most of the spring bands were not in the areas where we had sprayed the swarms in the autumn. It seemed that our attack on the autumn swarms had been more effective than we had first thought.

The bands were most numerous and densest west of Hillston but they were attacked so successfully that only a few small swarms resulted. In all, the Commission sprayed about 65 tonnes of insecticide on the hoppers; landholders, using chemicals supplied by the New South Wales

An aerial view of a hopper band (black, wavey line in centre) in a crop north-west of Hillston, New South Wales. This is the Australian Plague Locust, *Chortoicetes terminifera*. Photo: C.A. Henley.



Department of Agriculture from the Noxious Insect Fund, sprayed an amount equivalent to about 34 tonnes of the Commission's insecticide. Landholder control occurred mainly in the cropping and better grazing country on the eastern and southern fringes of the main infested area.

At this stage in the campaign, that is in mid November, we did not know what overall effect hopper control had had. We did not know how many adults would come from the bands we knew existed but which we could not see from the air and which landholders might have missed. Many large, dense swarms did form but, to our satisfaction, not where bands had been sprayed, and not so many that their control seemed impossible.

In late November I began to think we might come out on top. Swarms became difficult to find first at Wentworth and then at Balranald, but there were still huge numbers of locusts between Ivanhoe and Hay and north of Deniliquin and Jerilderie. The New South Wales Department of Agriculture attacked swarms in the Griffith area and some near Condobolin with great vigour. Then quite suddenly in mid December it was all over. All we could find were some very small, although quite dense, swarms north of Conargo. On 18 December 1984 the campaign ended with only a few low density swarms and some scattered locusts remaining. These were mostly in dry country and were unlikely to breed successfully.

We had expected to spray in South Australia in the region of Yunta and in the north of the Flinders Ranges. Fortunately, only relatively small-scale hatching occurred, which was dealt with by the South Australian Department of Agriculture.

Spraying methods

Before I summarise the campaign and the lessons we can learn from it, a word about our spraying methods. The Commission sprays only undiluted technical fenitrothion at dosages of about 300 millilitres per hectare. Fenitrothion is an organophosphate liquid that breaks down completely in a relatively short time and has a low toxicity to mammals.

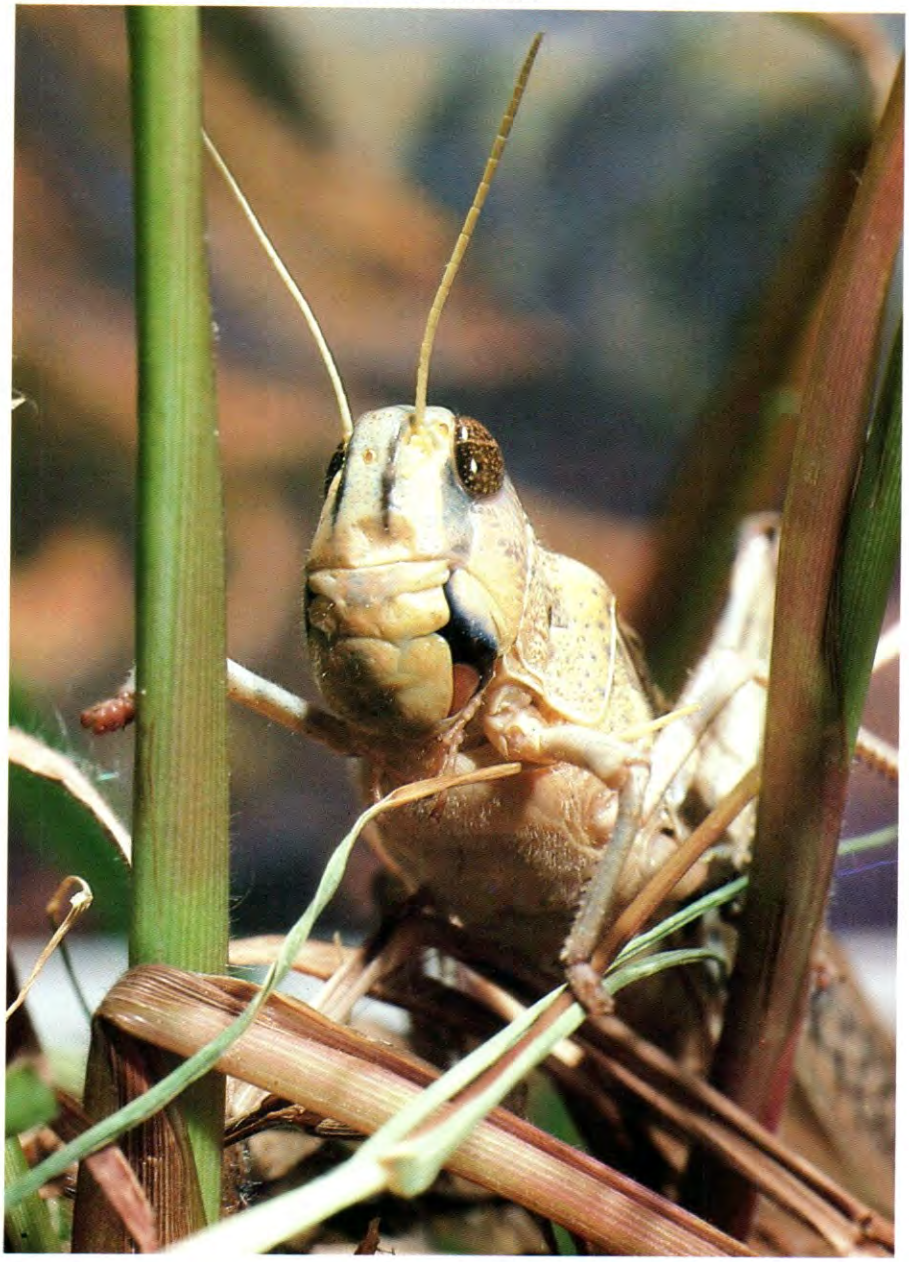
Hoppers and settled swarms are only sprayed in a steady wind. The reasons for this are two-fold. Firstly, a wind is needed to impact the small droplets of insecticide onto the vegetation; and secondly, a steady wind provides controlled (not erratic) drift. Once the wind speed and direction is known, we can calculate where the spray will land. With this method the runs can be spaced 100 metres apart — about three times the spacing used for most crop spraying; this means that relatively few aircraft are needed and flying costs are kept low.

State Departments of Agriculture usually use the same insecticide and methods as the Commission, although last spring the New South Wales Department used up a large quantity of malathium (a very safe but less effective chemical) that it had bought some years ago. The

A scientist investigates a locust swarm in a lucerne crop, 30 kilometres east of Hay. Photo: C.A. Henley.



There are various species of locust in Australia. The species shown here is *Locusta migratoria*, a predominantly Old World locust that, in Australia, rarely forms swarms. Photo: Kathie Atkinson.



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landholders that ground-spray usually use fenitrothion but in an emulsifiable form so that it can be diluted with water.

Effectiveness

In total, the Commission sprayed about 105 tonnes of fenitrothion; State Departments of Agriculture sprayed the equivalent of about 59 tonnes; and landholders the equivalent of about a further 34 tonnes, making 198 tonnes in all. Complete returns are not yet available so these figures may be wrong by a few tonnes. The insecticide cost about $1.8 million so that the total cost for the campaign, including hire of aircraft, was about $2.5 million.

Was it worth it? It is difficult to estimate the damage caused and still more difficult to say what damage might have occurred. We have, however, collected information that will allow us to make estimates. I think it will show that somewhere between one and two million dollars worth of damage occurred mainly near Hillston and Hay. Since only relatively small numbers of locusts reached Victoria and the main crop areas of New South Wales and South Australia, the potential loss must run into tens of millions of dollars.

Why was this campaign so successful? There are two main reasons. Firstly, the increase in locust gregariousness mentioned earlier meant that nearly all the locusts were in bands or swarms that could be sprayed; and secondly, the scale of aerial spraying, especially against the hoppers in grazing country, was much greater than previous campaigns.

There are many reasons why past campaigns have been less comprehensive. One would surely be the former, widespread conviction that a major plague could not be stopped by control. It was a reasonable conviction when you realise the huge areas involved, the remoteness of many of the infestations, and the small number of people available for help; and a conviction, I must confess, I too shared. However, ignoring this conviction, the Australian Plague Locust Commission, with its large-scale aerial band spraying, certainly gave it a go. I should also point out that "the Commission" included officers from the Victorian Department of Agriculture and, in effect, rangers from several Pastures Protection Boards who worked virtually as extra field officers. Indeed we could not have functioned without the co-operation of the Pastures Protection Boards and, through them, the landholders.

Were we lucky with the weather? Not particularly so but we had a real stroke of luck last autumn. There was one night in late March, when it seemed that mass migration to Victoria must occur on northerlies ahead of a cold front. With much apprehension I watched the progress of the front on the charts of the Bureau of Meteorology. Fortunately, the front accelerated so that by nightfall it had crossed the infested area, the temperature had fallen and the winds had swung round to the south-west. This spring the weather again favoured us. There were good rains last winter but late October, November and December were in the main dry. If enough rain had fallen in December, allowing survivors to lay, we would have been definitely unlucky, since the Riverina is an area of winter not summer rainfall.

Did control really cause the decline in numbers or was it due to natural mortality? There was a very good cover of dry grass throughout the Riverina in November and December, and the early summer was relatively cool. Under these conditions adults survive for many weeks. There was no trace of significant parasitism or predation. All the evidence points to control being the cause of the reduction in locust numbers.

Is there any alternative to chemical control? Chemical control is not an ideal solution. Our success this spring is purely temporary. There are already locusts in substantial numbers in southwestern Queensland. If breeding is successful there this summer, swarms could once again invade the lands to the south-east in the coming autumn, facing us with the same situation next spring. There is, however, no immediate alternative to chemical control. The migratory characteristics of locusts and the fact that most species exist in normally dry areas, make them very bad candidates for biological control, that is control by introduced parasites, predators and diseases, or by techniques like sterile male release and genetic engineering. We now know the Australian Plague Locust can be contained, at a cost, by spraying and what can be done once can be done again. But that will mean maintaining a locust surveillance and control system and, from time to time, mounting large and expensive control campaigns. □



A newly emerged adult Greengrocer is resting on its pupal skin. It is about four centimetres long. Photo: David P. Maitland.

SPINELESS
BUT NOT SPEECHLESS
A Selection of Invertebrate Sound

by Pamela and David Maitland

Most of us have heard the insect sounds that fill the air in summer, particularly cicadas, but have you ever heard a moth hiss, or a caterpillar scratch on a leaf? David Maitland, from the School of Zoology at the University of New South Wales, and his wife Pamela have. Insects are not the only arthropods that make noise. The versatile exoskeleton of the arthropods is used by certain crabs to communicate to their fellows, as well. Cicadas, the Privet Hawkmoth, the "Hatterpillar" and ghost crabs are all very common in and around Sydney and much of Australia. Read on and find out how these creatures produce sound, and why.

Of all the insects, cicadas have one of the most effective and specialised means of producing sound. Only the males produce the song, which is a mating call to attract the females. Because of this, it is very important that each species of cicada has its own particular song. The calls are species specific, that is, the females recognise only males of the same species and they differ not only in frequency but are sung at different times of the day. In this way, many different cicadas can live in the same area, each one occupying its own sound niche.

Greengrocers and Floury Bakers

The Greengrocer, *Cyclochila australasiae,* one of the most familiar and spectacular cicadas, gets its name from its leafy green colour. There is also a yellow form of this species called a Yellow Monday. If you examine a male Greengrocer you will notice four flaps at the junction of the thorax and the abdomen, two above and two below. The top ones are the tymbal covers, which enclose the sound producing apparatus, the tymbals. In some cicadas, however, such as the Floury Baker, *Abricta curvicosta,* the tymbals are naked and instead the wings act as covers. The lower flap or operculum on each side covers a white skin-like structure called the tympanum, which is believed to be part of the sound receiving organ.

The tymbal is a cuticular sheet and is unmistakeable for its ribbed appearance. Considerable stress is placed on the tymbal during the course of singing and so the ribs and the cuticular sheet are specially strengthened. Attached to the inner surface of the tymbal is a powerful muscle which, with each contraction, causes the tymbal to buckle in and produce a single cracking sound, just like that of a tin ladybird clicker toy! As the tymbal buckles, the tymbal muscle relaxes. The natural elasticity of the tymbal makes it return to its original shape and the muscle starts to contract again and the whole process repeats itself. Cicadas' tymbal muscles contract with such rapidity that to our ears the individual cracking sounds sound like a continuous high-pitched rattle. This effect is the same as seeing a film as continuous movement although we know that it is made up of single frames.

As mentioned above, the tymbals are ribbed. These ribs are not of uniform length, however, and longer ones alternate with much shorter, fatter ones. It is along the lines of the shorter ones that the tymbal buckles to produce the sound. The pattern of rib structure of the tymbals varies from species to species and this is part of the reason why each species of cicada has its own characteristic call. As an example, the tymbal of the Floury Baker has about 11 long, thin ribs as opposed to the Greengrocer's thicker five or six. The result

is that the song of the Floury Baker is not as coarse-sounding as the Greengrocer's. Also, when the Floury Baker's tymbal buckles in, the ribs do not all bend at once as in the Greengrocer, but in succession. Therefore, when the Floury Baker's tymbal buckles once, not just one pulse of sound is produced, but many. The Floury Baker's unmistakeable hiss-like song is introduced with a series of short, quick phrases. The effect is: "rrp, rrp, rrp, rrrp, rrrrrrrrp" etc. During this song the tymbals buckle as many as 1,000 times per second! In each short "rrp" phrase, the abdomen is curved up towards the wings so that the vibrating tymbals come into contact with the wings, at which point the phrase ends and the abdomen returns and another phrase begins. If you watch a Floury Baker during this build up to its long song, they appear to be pumping themselves up. It is as if they are taking deep breaths for the next blast of sound!

The private parts of the Privet Hawkmoth?

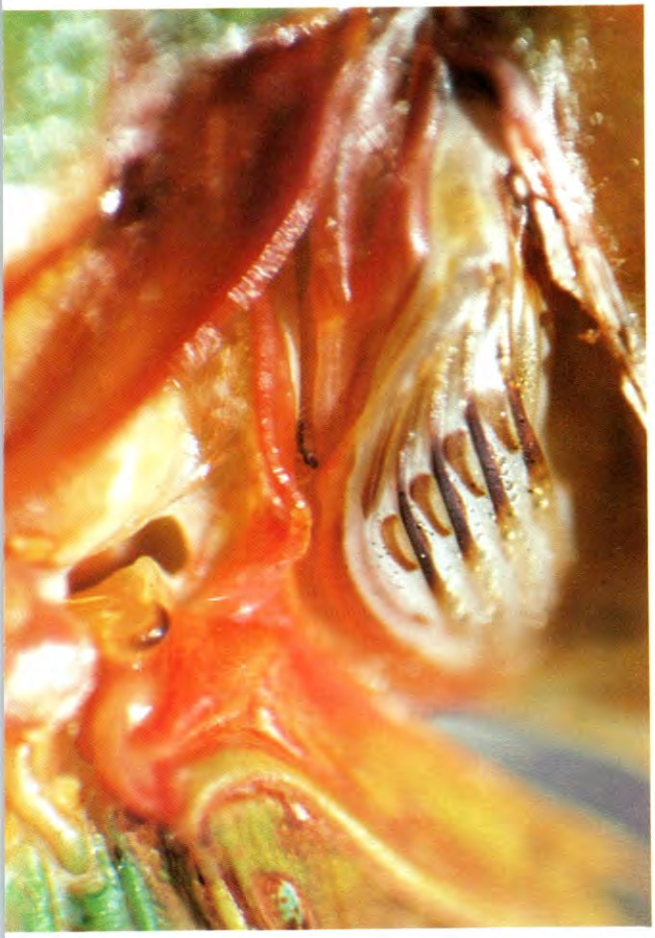
Cicadas, along with grasshoppers and crickets, are probably the insects that most people associate with making noise. Many other insects, however, are also responsible for the production of sound. One of the most surprising sounds is produced by the very common Privet Hawkmoth, *Psilogramma menephron*, so named because the caterpillars feed mostly on privet. The moth itself is large and mostly grey in colour with black markings on its wings. It is extremely unusual in that it is one of the few lepidopterans (moths and butterflies) capable of making noise (at least noise audible to humans). During the day, the Privet Hawkmoth rests well-camouflaged against a fence post or tree trunk. If disturbed, however, it rears up on its legs so that its body quickly comes out at you and it makes its quite loud "tss tss" sound. The total effect is very startling and unexpected. The moth will also make this sound if alarmed when flying and it is almost certainly a defence mechanism.

Only the male Privet Hawkmoth produces the "tss tss" sound. One might normally suggest that the sound is used to attract females in courtship but because sound production is so clearly used in defence, why the females do not produce the sound remains a mystery.

Some moths are able to detect the ultrasonic, prey-locating calls emitted by certain bats. Some



The Hatterpillar (the caterpillar of the moth *Uruba lugens*) has so many head capsules (or hats) stacked up that they appear ready to totter over any second. The stack of head capsules, along with the sound the Hatterpillar makes by rubbing its mouthparts on leaves, help warn predators of its distastefulness. Photo: David P. Maitland.



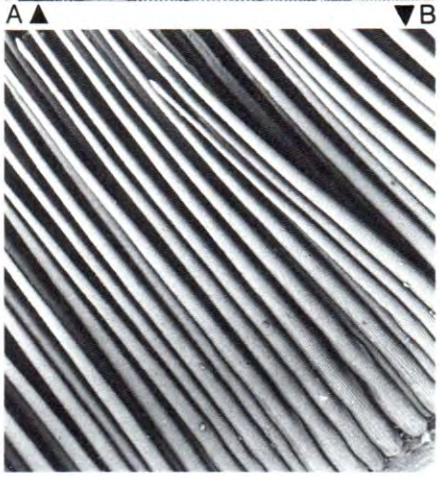
The tymbal cover has been lifted to expose the tymbal of the Greengrocer. The tymbal buckles in along the line of the four shorter ribs (right of centre), producing a single pulse of sound. Photo: David P. Maitland.



The tymbal (left of centre) of the Floury Baker has many more ribs than the Greengrocer, hence its more hiss-like song. An unusual feature of the Floury Baker's tymbal is that the ribs buckle in succession, not all at once as in the Greengrocer, and each one produces a sound. Photo: David P. Maitland.



A▲ ▼B



Under the scanning electron microscope the scales on the claspers (A) and the spines on the last abdominal segment (B) of the male Privet Hawkmoth are seen to be ridged. Because of this, when the scales and spines are rubbed together, a fine hissing "tss tss" sound is produced. Photo: David P. Maitland.

hawkmoths of the family Sphingidae respond immediately with erratic and evasive flying manoeuvres. Other moths of the family Arctiidae respond by emitting ultrasonic clicking noises that confuse the bat, causing it to veer off course and thus missing its prey. Perhaps the Privet Hawkmoth is capable of such tricks too? But even if so, it does not help explain why only the males make the noise.

The males produce sound by a mechanism similar to running a finger along the teeth of a comb, that is, by stridulating. At the end of the male's abdomen is a pair of claspers that are used to hold the female during mating. On top of these claspers is a region where the scales are specially strengthened and are a much darker brown than the surrounding ones. Directly above the claspers and overlapping them somewhat is the last abdominal segment. The rim of this segment bears specially modified scales in the form of long, stout spines, each with a slightly swollen base. Both types of scale are ridged parallel to their long axis. When the moth wiggles its claspers from side to side, the thick-ridged scales rub against the spines above, producing a series of "tss tss" sounds.

The Mad Hatter?

Throughout the summer on the undersides of any red gum in any park are the caterpillars of the moth *Uruba lugens,* or "Hatterpillar". They are so called because every time the caterpillar moults, its skin is discarded but not its head capsule, which is retained and attached above the head. With each successive moult, a new, larger "hat" is added at the bottom of the stack and the Hatterpillar gains its bizarre appearance. It is believed that the tall stack of head capsules reminds birds and other predators that the Hatterpillar is covered with tufts of distasteful spines!

Usually young Hatterpillars are found living massed together on the underside of red gum leaves. As they grow they gradually become less gregarious and can be found one to a leaf. While picking some branches of red gum to feed some Hatterpillars we had at home, we heard a soft swishing sound. We turned a leaf over and there was a fully grown Hatterpillar, about one centimetre long, sweeping the front of its body to and fro along the undersurface of the leaf, making a noise as it did so. It was scratching its mouthparts across the small ridges and veins in the leaf. Although the sound produced by an individual is not very loud, when groups of Hatterpillars swish their heads back and forth the sound is certainly audible. One can guess that this, along with the unusual head gear and stinging spines, acts as a warning signal to a potential predator.

Ghost crabs: upside-down and inside-out guitarists

The insects are not the only arthropods to make sounds. Other unexpected noise-makers are the ghost crabs, which are quite common on some of our city beaches provided there are regions that are comparatively undisturbed. Maroubra Beach in Sydney is a good example. Ghost crabs are semi-terrestrial and do not live in the sea as do most other crabs; instead they burrow in the sand at or above the high tide mark. They are aptly named because they are the same

This is the last abdominal segment of the male Privet Hawkmoth with the spines protruding from it. Underneath are the specially strengthened, dark brown scales of the claspers, against which the spines rub to produce a "tss tss" sound. Photo: David P. Maitland.





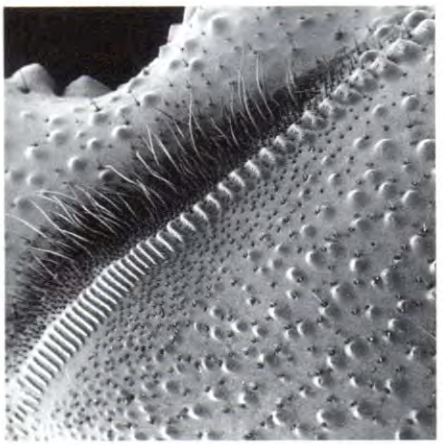
A male Horn-eyed Ghost Crab (*Ocypode ceratophthalma*). When in its burrow it can make a whirring noise using special structures, the rasp and the plectrum, on its larger, clawed arm to ward off intruders. Photo: David P. Maitland.

colour as the sand. There are two common species of ghost crab: the Horn-eyed (*Ocypode ceratophthalma*) and Golden Ghost Crabs (*O. cordimana*). The Golden Ghost Crab is the smaller of the two and does not have the spines on top of the long-stalked eyes that give the Horn-eyed Ghost Crab its common name (and quite a bit of character!).

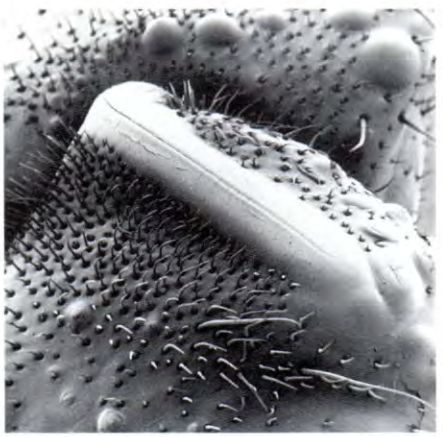
If you are patient and sit next to a crab hole and gently scratch the sand around the rim, you may cause the occupant to respond with a series of rapid beats. Both males and females produce this sound — warning potential intruders that the burrow is occupied. Sound is also produced by the male ghost crabs to attract females to their burrows.

The way in which ghost crabs make this noise is like that of the Privet Hawkmoth and the Hatterpillar, that is, by stridulation. They do this by using the larger of their two claws. On the inner face or "palm" of the claw is a vertical rasp consisting of a series of small ridges, while on one of the basal joints (the third) of the arm there is a long smooth crest or plectrum against which the rasp rubs when the whole claw is folded.

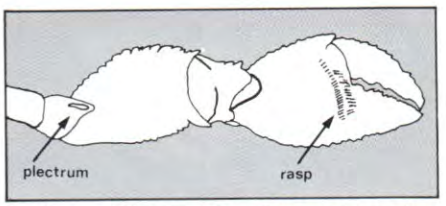
When ghost crabs stridulate they fold their claws against the plectrum and vibrate the palms up and down very rapidly. The movement is very similar to a guitarist except that things are in reverse: the guitar pick is like the plectrum and the strings are like the row of ridges on the claw: that is, in the crab's case, the pick is stationary and the guitar is moved up and down! In addition, the crab is able to change the "tune" it plays because the rasp consists of a stretch of short ridges set far apart and a series of longer ones set closer together. The longer, finer ridges have a higher pitch than the shorter, fatter ones.



In this scanning electron micrograph it is seen that on the inside of the Horn-eyed Ghost Crab's claw is the rasp made up of many ridges. At the bottom of the rasp they are long and thin and at the top they are short and fat. The gradation in size of these ridges allows the crab to make a relatively complex sound. Photo: David P. Maitland.



This is the plectrum that the rasp of the Horn-eyed Ghost Crab rubs against. It is at the base of the arm. When the arm is folded and moved up and down, the rasp is rubbed against the plecrum and a whirring sound is produced. Photo: David P. Maitland.



A view of the inside of the claw of a typical ghost crab, showing the location of the plectrum and the rasp. Drawing: Pamela Maitland.

The burrow acts as a resonator and the sound is transmitted out of the hole and through the sand. Although the sound produced by ghost crabs is clearly audible to us as a whirring noise, the crabs themselves probably do not hear it in this way. Ghost crabs do not have ears as we do but instead "hear through their legs"! They have special receptors in their "knees" (the meral-carpal joints) that are extremely sensitive to vibrations. Thus an intruder, investigating the mouth of an occupied hole, will feel the vibrations caused by the stridulating occupant and go away.

Sounds like ...

These are only a few examples of invertebrate sound. The cicadas have special sound-producing organs (the tymbals), whereas the other invertebrates mentioned in this article have improvised already existing structures for the production of sound: the scales of the Privet Hawkmoth, the mouthparts of the Hatterpillar and the arm segments of the ghost crabs. Another difference between the cicadas and the others is that the cicadas vibrate the air directly with their tymbals to produce sound. The rest produce sound by stridulatory mechanisms, that is, they rub two structures together and produce sound secondarily. In all of these arthropods it is the rigid but elastic exoskeleton that is used to make sound and it is this feature that predisposes the phylum, in general, to the evolution of sound-producing structures.

The sounds of the "speaking" invertebrates mentioned here can only be described because they happen to be audible to us (and, in fact, we probably hear them in a very different way from the noise-makers themselves, which have very different sensory structures to ours). But think of all the other creatures that produce sound that we do not hear because we are limited by our own perceptions! How do they produce sound, and why? □

FORUM

ANIMAL-BASED RESEARCH

Can it be justified?

Animal research is probably the most emotive issue in science today. Much controversy surrounds the basic question: do the benefits from the advances in medical science brought about by animal experiments outweigh the costs of inflicting pain on animals?

Elizabeth Ahlston is a vocal anti-vivisectionist and is President of the Association for Humane Research. Dr Eugenie Lumbers is a developmental physiologist at the University of New South Wales. Her work involves studies on the foetus *in utero* using the sheep, trying to determine how it copes with the maternal environment. "We operate on the sheep's foetus, return it to the uterus and study it in a situation where it is not disturbed or upset by anaesthetics or stress", says Dr Lumbers.

With *Australian Natural History's* Rob Cameron in the middle, Dr Lumbers and Ms Ahlston argued, at times heatedly, for an hour and a half. Here is an edited version of that debate.

(A.N.H.) Eugenie Lumbers, what sort of pain do you need to inflict on these sheep?

Because we work with chronic sheep and because our pregnant ewes have to be well, we are very conscious of keeping pain to an absolute minimum. We anaesthetise the sheep for surgery, we always have analgesics on hand if we need them post-operatively. Anyway, we find most sheep are up eating and drinking within half an hour after surgery. Your experiment won't work if you have an upset animal. There is always some stress for an animal involved in an experiment but you have to equate that against the overall suffering of all animals. Let's take a simple example: Banting and Best's discovery of insulin. I don't know how many, but let's say they worked on 100 dogs before they were able to find insulin in the pancreas. Those dogs probably suffered from having intravenous injections and being anaesthetised. Think of the millions of people who are now no longer suffering because of that discovery. Animal-based research is the one form of animal usage that will reduce the total suffering of all animals.

(Elizabeth Ahlston) Insulin is a perfect example of animal-based research which never leads to cures. It only leads to palliatives. In the early part of this century, diabetes was a very rare disease . . . it is now a modern day scourge. By artificially inducing conditions in animals you are only looking at the disease process — you are not looking at all the other factors which are so important in human disease. While we are dealing only with symptoms and not looking at causes, we will never find real cures.

How else can we find the cause without doing the experiment?

Through clinical research, by which so many major medical discoveries were made in the early part of this century, that is, before the current obsession with testing everything on animals.

There is an incredible amount of clinical research done throughout the world. Man is the biggest experimental species in medicine today. Animal-based research won't answer all questions, but neither will its exclusion.

Elizabeth, what sort of physical or psychological pain do animals experience and how do we equate this experience with the pain felt by humans?

This is one of the most difficult questions to answer. When you go to the doctor and he asks you what type of pain you have, it's very difficult to describe that pain. Animals are not human. By trying to extrapolate data from animals to humans, you are missing out the most important factors of all which are emotional, socio-economic and environmental factors — factors that are very important in any illness.

Man is not like a rat, but there are certain overall control systems which are very similar in a rat to what they are in a man, and those are the systems you look at. For example, one of the things we're interested in is what happens if the pregnant rat does not have an adequate water intake? Does the foetus become dehydrated while in utero? The control systems we are looking at in that experiment are the same type of control systems that you and I possess. So what we find there can be applied to humans. But obviously I can't put a sheep in a city block and expect it to interact with all those social factors, neither would it be relevant for me to do so.

Elizabeth, you are assuming levels of pain that animals experience while undergoing research and that none of us really know.

We rest our case on the fact that, if animals are like us, they therefore have similar nervous systems. Otherwise, why would they use them for pain research? We have no right to use them if they are sufficiently similar to us. If they are not similar to us in that way, there isn't any point in using them.

> I'm quite sure that if I thought I was going to be used for torture I'd rather not have been born at all.

Eugenie, why do we use animals for pain research?

You have to look at what level you

are looking at. If you are trying to study the endogenous opiate system, which we and animals seem to possess and which seems to suppress pain, it may be necessary to evoke pain to study that system. That's at a very simple level of pain perception response. Whether there are other levels of pain, that's a question that needs to be debated. For example, we have no idea whether an animal can perceive like we can. If I approached you with a syringe-full of nembutal, you would be fairly upset and agitated, because you know what's coming. An animal has no knowledge of what that syringe might contain.

Animals only exist because we have manipulated their environment. The Australian merino hasn't a hope in hell of surviving unless it is nurtured and cared for.

How can you study pain in animals when they can't describe the pain to you? You are having to guess whether the animal is feeling the pain. Animals are like humans, and react in different ways. Animals can be very stoical about pain. How do you then know whether they're in agony?

Assessment of intensity of pain is a very difficult subject. The type of response you're looking at 'though, will be at a much more simplistic level. It may be whether pain does or does not occur. As to knowing whether an animal feels pain or not, in the situation in which I work, we know our animals. . . They have particular personalities and behaviours. We know straight away if an animal is feeling off-colour.

I don't see how you can see pain in animals. You can ask a human being probing questions but not an animal. To me it shows that animal research is a pseudo-science and that we should have concentrated all our efforts on clinical research. If Frances Cobbe had succeeded in 1876 in banning animal experiments in the U.K., clinical research by now would be so sophisticated that we probably would have cured most of mankind's disease.

Is it right that 50 per cent of dogs died from distemper before they developed a vaccine? Is it wrong that dogs are protected from anthrax? Is it wrong to treat diabetic dogs with insulin? Is it wrong to treat dogs with antibiotics? All the modern surgical techniques and experimental methods that have been developed by man for man have been passed on very rapidly into the animal world. And I'm talking about the development of the techniques, about knowing the best way to do it . . . whether you can, in fact, sew two blood vessels together, whether you can take a heart from one animal and put it into another successfully. That has to be done from animal experiments.

This is a short-term answer. You're all the time looking at patching people up. In the case of transplants, they benefit only a tiny proportion of people. It's not getting at the causes. I think it's an indictment of the medical profession, an admission of failure. It is technologically brilliant but has damn-all to do with health. The whole approach of allopathic medicine is obsessed with disease and illness. We should try the ancient Chinese system where you pay your doctor when you're well and stop paying him when you are ill because he is falling down on his job. If we did this, we'd find a lot more healthy people, a lot of doctors out of work, and all animal researchers out of a job.

I agree we have to go to the causes of disease, but you have to have the knowledge. You can't develop an antibiotic unless you know the bacteria that you're developing the antibiotic against. You cannot look at a cardiovascular system and prevent the onset of cardiovascular disease without knowing the factors that lead to that disease, such as diet. That knowledge comes from animal-based experiments. I'll give you an example. In the 1950s we didn't know that the human infant controlled its own body temperature. That is, we thought it was like a snake; that its body temperature moved up and down with the ambient temperature. However, it does try to maintain its body temperature constant. Once this was realised, the humidicrib was introduced and the mortality rate dropped. Lack of knowledge causes too much suffering for my liking. Animal-based research is one of the areas where we find this information out.

Eugenie, why is it that we don't know enough about the suffering inflicted on animals? Shouldn't we be doing more research into this area?

That research is being done.

Monkeys have the same neuro-chemical pathways which mediate effective states such as anxiety and apprehension. These are emotions that we feel as human beings. Do monkeys feel them as well?

I've never been able to ask a monkey, and that is one of the big problems. The higher up the primate scale an animal is, the greater the likelihood it will feel pain like we feel pain. The sensations will be similar.

If it is established that monkeys feel a similar level of pain, would that be a strong enough reason to oppose animal-based research?

I am interested in reducing the total amount of suffering of man and all animals and, if some animals have to be sacrificed for that total overall reduction, then that is morally acceptable.

America has the greatest number of animal-based experiments of any country in the world, and yet lies 17th on the World Health Organisation's list of healthy countries. There doesn't seem to be any parallel between the number of animals dying in the laboratory and the health of people supposedly benefitting from animal-based research.

As scientists we find out a certain amount of information. Sometimes it's applied quickly, sometimes it's applied very slowly. The rate at which a given society applies its acquired knowledge is a social rather than scientific problem. We still allow cigarette advertising at sporting matches and alcohol advertising on TV when children are watching. And yet these are condemned practices.

Mankind has a choice whether he smokes, drinks alcohol, takes drugs, or eats junk food. Animals we are experimenting on have no choice whatsoever.

Animals don't even have a choice in their existence.

Well, it's a moot point whether it would be better to not exist at all or exist to be experimented on. I'm quite sure that if I thought I was going to be used for torture I'd rather not have been born at all.

I object most strongly to the term torture.

Eugenie, many animal-based experiments are unnecessary, carried out purely as an intellectual exercise even though the results are already known.

That's not true. Let me give you a good example. There is an experimental model of developing hypertension which involves a renal clip on the kidney. That experiment has been repeated many times since 1934. If you go into depth in this area, you will find that every experiment is finding a new piece in the jigsaw puzzle. So they're not doing the same experiment. They may be using the same model but, as new techniques develop, they go back and find a little bit more information that makes the picture more comprehensible. Knowledge builds up by tiny accretions. You don't make big leaps.

Many experiments are done so that people can write papers about them and move up the academic ladder.

Well, that is claimed, but let me tell you the work is hard. We work seven days a week because we have animals to look after. I can't tell you how nice it is to be in the season when we don't have animals to look after; how lovely it is when you don't have to worry about weekends. Our animals are cared for as carefully as any patient in a hospital ward. In the context of total suffering, we as scientists are being humane.

But we bring so much of the suffering on ourselves, and I just cannot accept that the innocent should suffer for the guilty. Animals don't smoke, animals don't drop bombs, animals don't wear cosmetics.

Animals only exist because we have manipulated their environment. The Australian merino hasn't a hope in hell of surviving unless it is nurtured and cared for. There are very few animals left in the wild and let's, for heaven's sake, preserve those.

We're doing our very best to wipe them out. The vast majority of problems in the world are being created by man. Why should animals suffer for us?

There is an enormous amount of difference between us and every other species. Basically, we create the environment. We are doing all sorts of terrible things but animal-based research is not to blame. If we have knowledge we can become wiser.

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poster

Aboriginal Dancers, Arnhem Land



In the Dreamtime when the land was being formed, the Earth was inhabited by great Ancestral Beings. The activities of these Beings are told today in lengthy ceremonies. One of the most important ceremonies involves initiation, when young boys become adult members of their tribe. The liftout poster in this edition of *Australian Natural History* shows a re-enactment of the Dreamtime activities of a special totemic fish found in the waters of northern Australia. Written without texts, the Aborigines pass on legends through dances and songs. The photograph was taken by one of Australia's finest photographers, Sydney-based Penny Tweedie. Her sensitive portrayals of Aborigines have featured in exhibitions world-wide and in many books.

Many thanks to The Broken Hill Proprietary Co. Ltd for their generous poster sponsorship.

The poster celebrates the opening of The Australian Museum's major new gallery "Aboriginal Australia". The gallery looks at colonisation and its effects on Aborigines, at their traditional life, and the present.



ROBYN WILLIAMS

A.B.C. RADIO SCIENCE SHOW

Give Me the Facts

This is Question One from an examination paper set by a Professor Grant of London in 1860:

"By what special structures are bats enabled to fly through the air? and how do the galeopitheci, the ptermys, the petaurus and petauristae support themselves in that light element? Compare the structure of the wing of the bat with that of the bird, and with that of the pterodactyl; and explain the structures by which a cobra expands its neck, and the saurian dragon flies through the atmosphere. By what structures do serpents spring from the ground, and fishes and cephalopods leap on deck from waters? And who do flying-fishes support themselves in air? Explain the origin, the nature, the mode of construction, and the uses of the fibrous parachutes of arachnidians and larvae, and the cocoons which envelop the young; and describe the skeletal elements which support, and the muscles which move the mesoptera and the metaptera of insects. Describe the structure, the attachments, and the principle varieties of form of the legs of insects; and compare them with the hollow articulated limbs of nereides, and the tubular feet of lumbrici. . ." (Quoted in *The Art of the Soluble* by Sir Peter Medawar.)

In fact, that's only *half* the question. Imagine what cartloads of information were required of the hapless students then.

Things were only slightly better in my days at the University of London. I went there having just been around the world and not having looked at a science book for some five years. I was older than average and, I trust, more mature. But my first encounter with my lecturer in Introductory Botany showed that, to her, I was only a juvenile to be chastised. On that day I entered the laboratory for my first-ever botany practical (all the other students had done the subject at high school) and saw the cryptic instruction on the board: "Place the onion in the pith provided and cut your section. Draw the result."

This, to me, was meaningless. So I did what any experienced 24 year old world-traveller might do when facing a snag — I asked the student next to me. She had the manner and bearing of a terrified nun. I received no reply — only a fleeting glare, then she cringed back to her microscope. So I turned to the person on my right. This time I was more fortunate and began to get some helpful tips from the jolly Welsh girl, as she proved to be, when there came a terrible voice from the front of the lab. There was the lecturer, about 50, with the visage and tones of Margaret Thatcher on a bad day but without the charm; a woman (if that's the right term) I knew to be married to the authoritarian head of the biology faculty.

"You!" she cried. "Resume your seat with your back straight and your right eye to the microscope and get on with your work, or leave this laboratory immediately."

I went to reason with her. But the subtleties of persuasion that had served me in 30 countries were inadequate this time. I resumed my seat and stared, bewildered, at my pith and my onion until it was time for tea. And so the course continued: we sat in mystification for three years as vast quantities of information poured over us like a tidal wave. Somehow, most got degrees. Today I can hardly remember a scintilla of all that anatomy, that naming of parts, or of the plants and beasts that died in vain to display their innards to us post-pubescent hippies, world-travellers and Nigerians in suits.

We were the last to take that course. We were the final generation to tackle a degree more or less invented a hundred years before by T.H. Huxley and his fellows, to which all the new fields had simply been tacked on: genetics, physiology, biochemistry, ethology, ecology and so on. No system, no argument, no philosophy of purpose. Simply an unloading of information on innocent heads. And they remained innocent. Those of us who persevered with science as post-graduates were, at best, what Lord Rutherford called "stamp collectors".

My point is that we should not too readily dismiss today's courses as "soft options". Environmental studies, ecology, nature courses, etc., may be vague umbrella terms but the science can be challenging, valid and appropriate. That the student is required to study relationships instead of dead parts means that exam questions become less precise and therefore, perhaps, more arduous to mark. It also means that the less gifted will try to get away with silly waffle (like with humanities, it's assumed we know most of the subject without needing to read deeply — Nature? that's easy!).

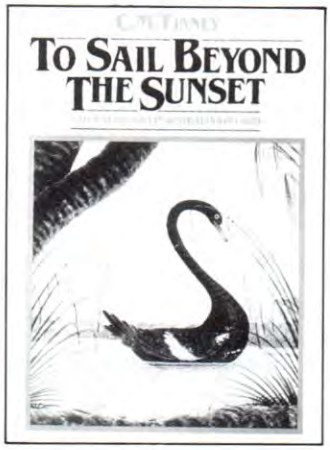
But the standard need not be lower than that required when "classical" biology was studied. I made the point that, to most of us, it was so much classical garbage, delivered without point or coherence. Now, having had the chance to read more widely in both "old-fashioned" biology, as well as the space-age stuff, I no longer see the distinction. There are only living things out there, together with traces of their forebears, and it's our challenge to try to fathom their secrets. Whether you do so by examining their organs with a lens, their kinships with a systematic family tree, or their alchemy with a million dollar gismo from IBM, it's your choice. Whatever your option, please tell me and my fellow innocents what you see as the point of the exercise. Put it into some context, with history, a little philosophy, some people indeed, with names. Then we'll understand and, in all likelihood, remember.

I burnt my university notes the other day. Before I did so I glanced through the pages. They meant nothing to me. □

books books books books books books

To Sail Beyond the Sunset — Natural History in Australia 1699-1829

C.M. Finney. Rigby, Adelaide, 1984. 206pp.



As we approach the Bicentenary of European settlement in Australia we also find ourselves in the midst of a technological revolution. This revolution has created a great sense of insecurity which has brought with it a profound desire to look back, to feel and examine our roots, and to establish an environmental base line, so we can try to see in context the changes that are occurring now. Colin Finney's book, *To Sail Beyond the Sunset — Natural History in Australia 1699-1829,* is timely and important because it goes a long way toward satisifying these needs. And further, in these days of space travel and ever widening horizons, it provides an account of an exploratory breakthrough almost as profound in concept as the exploration of another planet.

Finney evokes the excitement and wonder of the discovery and early exploration of Australia by documenting chronologically the discovery of its plants, animals and geology. From the first brief visit to the shores of Western Australia by William Dampier in 1699 until the British settlement finally (by 1800) took root and began to grow on the east coast of the continent, Finney describes the hesitant, almost bewildered, stumbling discovery of a fauna and flora so new, so bizzare to European eyes that artists seemed only able to draw caricatures of the creatures they saw. With meticulous attention to detail, and working from original sources, Finney describes not only the natural history of those early days, but puts the discoveries in the context of political events of the time, and describes the personal qualifications, ambitions and foibles of the people who were involved. Indeed, the natural history viewpoint, previously not explored in such detail, gives considerable new insight into the characters and motives of men we know quite well from other angles, such as Joseph Banks, James Cook, William Bligh and Arthur Phillip, to name but a few.

As the history progresses from its stumbling beginnings, the wonders of Australian natural history unfold in quantity and detail, and a cast of fascinating characters is described — the men who collected, illustrated and described the animals and plants, and the men far away in Europe who manipulated, paid for and profited from the discoveries.

This book is written by a scientist, with a scientific attention to accuracy and detail. Finney is, however, a scientist who has a profound sense of history, and his narrative style is clear and simple. The book is also remarkable for its illustrations. All are reproductions of original drawings and paintings of Australian plants and animals as they were first depicted by the men who collected or described them. Many have never been published before. There are many full page colour reproductions of exquisite beauty, as well as amusing crude sketches made by sailors, convicts and explorers who could find few words to describe the unfamiliar creatures that they found.

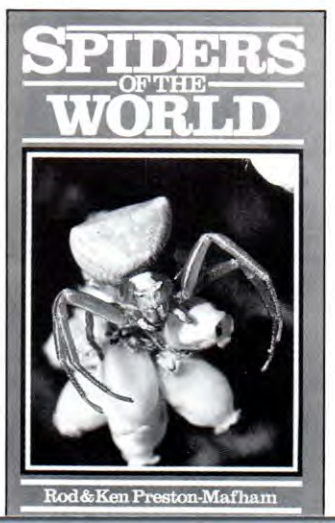
Many of the plants and animals described as being abundant in those early years of settlement are now either extinct, or threatened with extinction, and the face of the continent has drastically changed. I feel that most readers of this book will be led to consider the effect these changes are having on the quality of our life as we "progress", headlong towards the Bicentenary.

— Dr Lyndall Dawson

Spiders of the World

Rod and Ken Preston-Mafham. Blandford Press, Dorset, 1984. 191pp.

Despite its somewhat grandiose title, which the authors qualify in the introduction by noting that they can "only scratch the surface" of the subject, this book is a well-presented and readable introduction to the spiders. It concentrates, understandably, on the biology of spiders rather than their identification. Though the emphasis is undoubtably European, the authors do provide a respectable and interesting sprinkling of examples from other parts of the world.



The text is introduced by a section dealing with other arachnid groups. This is followed by chapters on the structure and classification of spiders. The classification section is mostly devoted to brief summaries of 26 labidgnath (araneomorph) families, which are placed a little archaically these days into ecribellate and cribellate sections. The orthognaths (mygalomorphs) are dealt with rather briefly here on a collective rather than family basis — a pity considering their interest. However, they do get adequate coverage elsewhere in the book.

The remaining two-thirds of the book deals mainly with the behavioural biology of spiders (apart from a final chapter on "Spiders and Men") and is probably the most interesting part. Successive chapters on courtship and mating, life history, prey capture and defence mechanisms provide good insights into many aspects of spider behaviour using examples culled from both temperate and tropical faunas. The chapter on defence mechanisms provides a particularly good summary of the field.

A noteable feature of the book is the excellent colour photography which, along with the black and white photographs and diagrams, provides a well-illustrated book. There are, however, some blemishes, including a misleading lack of proportion in the diagrams of burrows, one of which *(Stanwellia)* is given a superfluous trapdoor.

In general the book is an excellent introduction to the spiders and should appeal to anyone with an interest in them. It is written for the non-specialist and the clear text and excellent photography make it a worthwhile purchase.

— Michael Gray

letters

Population Explosion

I must make comment on the article in A.N.H. Vol. 21, No. 7 by Robyn Williams. I am surprised that Mr Williams, with his obvious intellect and enquiring mind, looks no further than the immediate present and takes no cognisance of aspects of the past and future except with tunnel vision.

Man's enquiring mind is responsible for our "pre-eminent position" today and will be in the future. This has resulted in our advanced technology which requires the destruction and despoiling of the surface of the planet upon which we live.

Man was "created in the image of God" (or vice versa if you wish), in which philosophy Man is encouraged to view himself as the supreme being and the plants and animals as have been put there for his "use".

For those who think of the environment, the real problem is overcoming the sanctity of human life and the compulsion to proliferate. The one thing missing from their argument is the basic human cause, population spread. The reason we destroy forests and dam rivers is to provide for the needs of increasing numbers of mankind.

Man lived symbiotically with his environment when he numbered about 50 million. Now that he is approaching 2,000 million, and shows no signs of slowing, more of the environment will be "raped".

No-one will agree to rubbing one's hands together to provide warmth and gather fruits, seeds and berries available within walking distance, so some semblance of rationality must prevail. We either live with population explosion and shrinking nature and the problems of monoculture, lack of assistance from nature (predators), resistance to chemicals, or do something positive to at least arrest the trend and hopefully, for the enjoyment of our successors, reverse the direction in which we are heading. The effort must be worldwide.

Perhaps to do this we must lose the thing I value most — to be free to do as I please so long as it affects no-one else. For future survival in a pleasant environment, Man must be compelled to limit his family to one child.

Call me a Malthusian or fascist if you wish but I feel I am in good company — Lee Kuan Yew and the present leadership of China. I view certain prominent eclesiastics (Moslem and Christian) who promote population explosion as being politically motivated towards supremacy of their religion, ignoring the consequences to the world at large.

Science has allowed Man to conquer his enemies — disease, catastrophe (fire), environment, food availability. Man now has to conquer himself and his fecundity.

K. Beehag
Blakehurst, N.S.W.

Electronic Scarecrows

I draw your attention to the article on flying foxes (A.N.H. Vol. 21, No. 7). In the article a statement is made (p. 307) that the electronic scarecrow was "released" by the New South Wales Department of Agriculture. This is incorrect.

The electronic scarecrow is manufactured and distributed by Hi Tech Control Systems, a company based in Lismore. The electronic scarecrow is one of a number of fruit bat control devices which the Department of Agriculture is currently evaluating.

The Department does not manufacture or distribute any fruit bat control devices. Its prime function is to assist fruit producers through the provision of accurate information on the control of fruit bats and the relative economic and technical merits of the control devices available.

To ensure the Department is able to provide such information, evaluation trials on a range of control devices (including the electronic scarecrow) are presently being conducted under the supervision of Mr David Robinson, Research Officer, Vertebrate Pests.

P.C.Davey
Regional Director of Advisory Services,
Department of Agriculture,
North Coast Region

Natural History?

It might appear rather pedantic on my part to point out that the journal you edit is called *Australian Natural History* and that full value should be given to each word in the title.

It goes without saying that your impulsive gesture to help a struggling PhD student in the publication status, by publishing what is largely unnatural European history, was far from wise. Stated mildly it was not what one expects from a journal of such standing in the world of natural history.

Speaking as a regular listener to the A.B.C. Science Show, I hope that Robyn Williams' first appearance in A.N.H. is his last! Robyn Williams is best suited to the medium of wireless. Unfortunately the printed word can be fully analysed. When this is done one can easily see how insubstantial his outpourings are. His thoughts are of little value to Australian natural history.

P.R. Smith
Blackburn, Victoria

All articles published in A.N.H. have been written by those "in the know" with the topic concerned — "struggling" PhD students, professors or just plain laypeople with a genuine and well-researched interest in the subject. Aboriginal legends, iron-deficiency porphyria disease and South American vampire bats (seemingly unrelated ideas) are, nevertheless, all aspects of natural history. Yes — I agree — one aspect is very non-Australian, but certainly of great interest to Australians. We are now including more such internationally related articles in the magazine.

Editor



Why Worms?

by Pat Hutchings
Head of Invertebrate Zoology Australian Museum



This *Marphysa* sp. is a scavenging eunicid worm and grows up to six centimetres in length. Like most eunicids, this animal has an iridescent sheen.
Photo: Kathie Atkinson.

I am often asked why I work on worms and how I became interested in them. My standard reply is that worms are beautiful, show an amazing diversity of form, feeding and life habits, and play a major role in all marine and estuarine environments.

The worms I refer to are the polychaetes or sea worms. They belong to the phylum Annelida, which also includes the earthworms and leeches.

Polychaetes are segmented worms and about 20,000 species have so far been described in over 70 families. In Australia, only a relatively small proportion of the polychaete fauna has been identified to species. New species are still being described from around Sydney and some faunas of remote areas, such as the North West Australia Shelf in Western Australia, haven't begun to be described.

Polychaetes occur in all marine and estuarine habitats, from intertidal to abyssal depths. They may live in the plankton, may be buried in the sediment or rock, or may be found nestling amongst seaweed or encrusting solid substrates. Only a few species of polychaetes are found in fresh water.

Polychaetes exhibit a tremendous array of feeding strategies: they range from carnivores, omnivores, mud swallowers and filter feeders to surface deposit feeders. The deposit feeders have grooved tentacles, which they spread out over the surface of the sediment, and each tentacle functions as a vacuum cleaner, collecting fine sediment particles that are then transported along the grooves to the mouth. The worm obtains its nutrients not from the sediment but from the fine layer of microbial organisms that live on the surface of the particles. Some polychaetes are parasitic, living inside the body cavity of larger polychaetes, and others are commensal, living on echinoderms or in burrows of other organisms.

Typically, polychaetes are male or female, but a few species are hermaphrodites. They exhibit a tremendous diversity of reproductive strategies: from giving birth to miniature adults, to shedding vast quantities of gametes into the water. In the latter case, prior to spawning, some species undergo certain morphological modifications such as the development of large eyes and enlarged parapodia (swimming paddles). These species, which typically live in the sediment or on hard substrates, respond to an environ-



The scavenging beach worm, closely related to the eunicids, may grow up to one or two metres in length. It is commonly used for bait by anglers and lives intertidally on the surf beaches along the New South Wales coast. Photo: Kathie Atkinson.

mental cue (such as a rise in water temperature or a particular phase of the moon) by swimming to the surface of the water. On arrival at the surface, and this may occur once a year, these normally sedentary animals perform a sort of nuptial dance with pheromones being shed into the water. The gametes are then shed and the adults, now limp and flaccid, drift away to die or be eaten. Fertilisation occurs in the surface waters and the pelagic larvae are produced. These larvae may spend anything from a few days to several months among the plankton before settling and metamorphosing into adult worms.

Polychaetes exhibit a tremendous range in morphology. Because polychaetes are usually small and because they lose much of their colour and form when preserved in formalin, in order to see them alive they must be looked at under a microscope. The photographs of live polychaetes in this article were taken using various close-up lenses and extension tubes and without any anaesthetic, so that the worms were still very active and healthy. These photographs attempt to illustrate some of the diversity of body shape and colours found in the group.

Scale worms, as the name implies, have a series of dorsal scales covering their back. The scales, which vary in number from 12 to over 40 pairs, are often brightly coloured and minutely ornamented. Scale worms are active carnivores and, in some cases, set up discrete territories into which no intruders are allowed except during the breeding season. Examples can be found living under rocks intertidally along the coast.

Eunicids are often used as bait by anglers and the beach worm is closely related to this group. Eunicids characteristically have an iridescent sheen and finely feathered gills are attached above the parapodia on anterior segments. Often eunicids are scavengers and are found in a wide variety of habitats. Many reef species of eunicids spawn only once a year on a particular night in November and the famous Palolo worm of the Samoan Islands belongs to this group. Samoans can predict exactly when the worms are going to swim



Sabellids or fan worms live in muddy, soft tubes. The branchial crown (the fan) is extended into the water for filter feeding. Photo: Kathie Atkinson.

to the surface to spawn; and, because egg-bearing Palolo worms are considered delicacies to the Samoans, this information is considered invaluable.

Chaetopterus or parchment worms live in solid tubes and the parapodial flaps pump streams of water through the tubes and through bags of mucous, which the worms produce. These mucous bags extend from the body wall to the sides of the tube. As water is filtered through these bags, fine particles are trapped. Periodically the worms stop pumping and the mucous bags are rolled up the body towards the head, where the small palps wrap up the mucous ball and direct it into the mouth where it is eaten. Another mucous bag is then produced and the process is repeated. The tubes are often home for commensal fish, crabs and bivalves.

The terebellid worms look superb alive, with their long feeding tentacles spread out over the surface of the sediment. The blood can be seen pumping through their fine feathery gills, which normally occur just below the tentacles. The tentacles function as vacuum cleaners in a manner typical for deposit feeders. The majority of terebellids are tubiculous (that is, they live in tubes) but some live naked in the sediment.

Sabellids or the fan worms live in muddy, soft tubes. A large, brightly coloured, fan-like circle of feathery arms, the branchial crown, is extended into the water for filter feeding. These worms can respond to shadows and immediately withdraw their arms into their tubes. If they are not quick enough and lose their crown to a passing predator, they can rapidly regenerate it.

These examples illustrate only a small fraction of the diversity of form, feeding and life habits shown by polychaetes. Other species are equally as unusual and spectacular in appearance. Perhaps you can now appreciate my response when asked, Why worms? I hope I have also shown that beauty need not necessarily be confined to the eyes of the beholder. □



Sabellariid worms, which are about two centimetres long, live in hard, sandy tubes. While removing this individual from its tube for photography, it spawned a large number of yolky eggs into the water. Normally spawning occurs once or twice a year and only in the presence of males. Photo: Kathie Atkinson.

THE LEATHERY TURTLE



The Leathery Turtle, *Dermochelys coriacea*. Photo courtesy of Queensland National Parks and Wildlife Service.

The Leathery Turtle (*Dermochelys coriacea*) is the sole member of the family Dermochelyidae. It is the largest living marine turtle in the world, adults weighing up to 550 kilograms with carapace lengths of up to two metres. Apart from its extraordinary size, the feature that serves to distinguish this turtle from all other sea turtles, and enables instant recognition from photographs, is its carapace: a leathery structure, containing many unfused bones, with seven distinctive, longitudinal ridges converging to a tapered point over the short tail.

The Leathery Turtle feeds mainly on large jellyfish and other scyphomedusae. As in other sea turtles, its oesophagus is lined with backwardly-pointing spines, which, amongst other things, aids in the swallowing of this soft, slippery prey. It has been observed feeding at the surface of the water and up to 50 metres depth.

The Leathery Turtle has a worldwide but sparse distribution in tropical and temperate seas, extending further into the colder waters of higher latitudes than other sea turtles. It appears that its large size favours heat retention, thus enabling it to maintain a higher body temperature than the surrounding water and allowing it to venture into colder waters.

In Australia, there have been numerous reports of Leathery Turtles feeding in coastal waters. Nesting females, however, have only been observed nesting on the soft sandy beaches of the central Queensland coast, from Roundhill Head south to Mon Repos Beach (near Bundaberg), and one at Maningrida, Northern Territory. It is most concentrated on the 22 kilometres of beach near Wreck Rock (north of Bundaberg) where up to three nesting females per year have been observed.

After mating, the female labours her cumbersome mass up the beach past the high water mark and digs a shallow body pit. She then excavates a chamber in which she lays about 90 eggs the size of billiard balls. After covering them with sand, she returns to the sea. About ten weeks later, approximately three-quarters of the eggs will hatch. Weighing less than 50 grams and about six centimetres long, the hatchlings must run the gauntlet of predatory birds and crabs to reach the sea and, once there, are still easy prey for larger fish.

Although international trade in Leathery Turtle products is virtually non-existent (there is no valuable hard shell), there is much local harvesting of eggs and young in some countries. In Malaysia, for example, people patrol the beaches all night during the breeding season to collect the eggs. Because the cash value of the eggs is so high, only a small proportion can be bought back by local government agencies for re-incubation and hatching. Nearly all the rest are sold in local markets and eaten.

In Australia, foxes, dingoes, wild pigs and sand goannas appear to be the more avid predators of Leathery Turtle eggs. Almost all turtle eggs in the Wreck Rock area are destroyed by foxes within two nights of being laid. A study of Leathery Turtles in southeastern Queensland in 1984 suggested that low hatching success might also be due to eggs being laid in sand that is too fine — early embryonic death occurring as a result of insufficient gas exchange between the eggs and their surroundings.

The latest world population estimate for mature females has been calculated (perhaps optimistically) at 115,000. Although nearly three times greater than previous estimates, on a global basis this figure remains relatively low; and, because of severe stresses on all major populations of the species, its endangered status is still very much justified.

Steps must be taken to protect nesting Leathery Turtles in Australia. This can only effectively be achieved by the conservation and management of the 22 kilometres of Wreck Rock Beach and adjacent offshore habitat, where density of nesting females is greatest. Currently there are proposals for an environmental and national park, which would cover major portions of the relevant nesting area. Early gazettals for each is imperative for the continued breeding success of *Dermochelys* in Australia. Meanwhile, plans must be developed to eliminate the fox and other (particularly introduced) predators from the area. □

Georgina Hickey
Australian Museum



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COMMON SCEN

by Denise Greig
National Photographic Index of Australian Wildlife



A pretty mat-forming plant of the alpine tract, *Dichosciadium ranunculaceum var. ranunculaceum.* Photo: Denise Greig.

Our sense of smell plays a vital role in recalling to memory scenes and experiences of long ago. Most of us who have spent any time in the bush will recall its distinctive but impossible-to-describe fragrance. However, not everyone's sense of smell reacts in exactly the same way. What is pleasant to one person may be unpleasant or even repulsive to another, while to some there may be a vague smell or none at all. And to confuse the issue further, Australian plant species are so variable that occasionally specimens growing in one district may be scented but in another area are scentless.

The Australian bush is renowned for its aroma and is extraordinarily rich in plants yielding essential oils. The Myrtaceae, the dominant oil-bearing family in many plant communities, includes a wealth of plants with scented foliage. These range from the many hundreds of eucalypts, melaleucas, tea-trees, bottlebrushes, thryptomenes to little ground-hugging baeckeas and astarteas. *Baeckea citriodora* has powerful lemon-scented leaves reminiscent of several other myrtaceous plants such as *Eucalyptus citriodora,* which in early days was used to scent linen.

Essential oils from the leaves of eucalypts have attracted interest since the earliest days of settlement. In 1788 one of the first articles of export was a quarter of a gallon of an essential oil steam-distilled from the leaves of Sydney peppermint, *Eucalyptus piperita.* Although Australia is rich in naturally occurring, oil-yielding plant species, very few are exploited for their essential oils. Only nine eucalypt species are used commercially, the most successful being blue mallee, *E. polybractea.* Since the late 1940s production of essential oils in Australia has declined. Several Australian species of *Eucalyptus* are grown overseas for oil extraction on a far larger scale than in Australia. The main world suppliers are Portugal, Spain, China and southern African countries and Australia now imports the bulk of its eucalyptus oil requirements. The tea-tree oil of commerce is steam-distilled from the foliage of *Melaleuca alternifolia.* About 80 per cent of the oil produced in Australia is exported and marketed overseas.

Once when photographing a fly-attracting fungus in a Queensland rainforest, a bushwalker asked "Can you smell the cunjevoi?". I certainly couldn't because I had my nose to the humus-enriched floor of the forest but sure enough, shortly down the track, was the elegant baby-powder-smelling flower of the lily-like *Alocasia macrorrhiza.* This fragrant plant, reputed to be an antidote to the sting of the stinging tree, *Dendrocnide excelsa,* was once described by the Rev. H.M.R. Rupp as smelling like "Pears transparent soap". Many of the tall rainforest trees and their epiphytic orchids produce perfumed flowers but, because the flowers are borne high above the ground, it is impossible to enjoy their fragrance. Some, however, have become successful in cultivation and, in open positions, take on a lower spreading growth and flower more profusely. For sweet fragrance, try smelling a domesticated native frangipani, *Hymenosporum flavum,* the deliciously honey-scented *Flindersia schottiana* or the lilac-coloured and scented flowers of the white cedar, *Melia azedarach var. australasica.*

Returning to the forgotten fungus, it was playing an important part in decomposing organic material on the forest floor and it is this thin damp layer and the rotting dank wood that

TS OF THE BUSH

emits the unforgettable rich, sweet scent of all closed rainforests. If only my compost heap would smell as good!

Mint-bushes (*Prostanthera* spp.) belong to the same botanical family (Lamiaceae) as the kitchen garden mint and like this herb have highly aromatic foliage, especially when brushed against or after a shower of rain. *Prostanthera cuneata,* the alpine mint-bush, grows abundantly around the popular ski resorts. Even the most disinterested person couldn't miss its rich, sharp scent. In summer these lovely plants display masses of attractive blooms of pale mauve, spotted, throated flowers.

Higher up the slopes and near or past the tree line, it is necessary to seek out and drop to the knees to smell some of the tiny plants that bloom after the winter's snow. *Stackhousia pulvinaris* is an attractive, dense, moss-like plant with tiny, yellow, star-shaped flowers. These flowers, arranged on a bed of tightly packed emerald leaves, are beautifully fragrant, especially at night. Another sweet-scented, yellow flowered alpine is the spectacular rock-hugging *Kunzea muelleri,* which appears as massed, yellowish patches covering hillsides and boulders with pretty, lightly scented, fluffy flowers. One of the prettiest mat-forming plants of the alpine tract is *Dichosciadium ranunculaceum var. ranunculaceum*. The dainty, white, buttercup-like flowers are scentless but, although it is not recommended that you pull them up, it has been suggested that when fresh, the tap-root has a distinct "parsnip-like odour". Whilst on the subject of food, J.H. Willis likens the smell of the sweetly perfumed, pink flowers of *Pimelea alpina* to that of paw-paw and the aromatic alpine pepper, *Tasmannia xerophila,* gets its common name from its sharp, peppery-tasting foliage.

Close to Sydney, the extensive sandstone areas of heathlands and sclerophyll forests provide the home for some of the bushland's toughest shrubs and small trees. On a warm spring day the air can be full with the fragrance of the blossoms of myrtle wattle, *Acacia myrtifolia,* the sweet-scented wattle, *A. suaveolens,* and the masses of perfumed, yellow balls of *A. decurrens.* While the flowers of eucalypts and members of the family Proteaceae provide the heady, sweet perfume of honey-laden blossoms, it is once again the species with highly odoriferous foliage that gives off the predominant aroma in the bush on a hot or rainy day. A list of plants with aromatic foliage would be endless but families such as Myrtaceae, Lamiaceae and Rutaceae are among the most notable of these groups. Even their dried, fallen leaves contribute to the general fragrance when crushed underfoot. In late winter splashes of the bright pink *Boronia ledifolia* will arrest your attention but to me it is the wonderful, spicy foliage of this pretty plant that epitomises the Sydney bush smell. Its leaves were recently described in a field guide as having a "strong and unpleasant odour when crushed". This difference in appreciation of certain smells lends further truth to the adage "beauty is in the eye of the beholder".

I do, however, agree tha the foliage of *Boronia anemonifolia* smells downright terrible, particularly in an enclosed car. A sample I was given in Tasmania of this showy plant, with the unfortunate vernacular of stinking boronia, promptly had to be banished to the boot of the car.

Boronia ledifolia. **Photo: Denise Greig.**



The border illustration is painted by Wayne Fogden. The bright pink flower is Red Boronia (Boronia heterophylla); the pale pink one is Stinking Boronia (B. anemonifolia).



POSSUMS and GLIDERS

Ed. by A. Smith and I. Hume

Uni. of N. England, Armidale, NSW, Aust.



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The cunjevoi, *Alocasia macrorrhiza.* Photo: Denise Greig.

One of the most powerful and unusual perfumes of the bush comes from the rich, chocolate-brown belled flowers of the widely acclaimed *Boronia megastigma.* Its perfume is of such intensity that, at close range, the olfactory nerves are affected and the scent is frequently undetected. It occurs naturally in swampland of southwestern Western Australia and is extremely well-camouflaged and hard to find. Perhaps the strong scent is required to attract its pollinators. Other sweet-smelling boronias include *B. heterophylla,* also from Western Australia, which has a sweet scent in both leaves and flowers, and the native rose, *B. serrulata,* confined to coastal heaths around Sydney and noted for its fragrant, pink flowers and lemon-scented, rhomboidal leaves.

Scent in the plant kingdom is not restricted to the flowers, roots and foliage — many species have scented barks and fragrant timbers. Sandalwood, *Santalum spicatum,* is one of the best known of the fragrant timbers; in fact, it is this fragrance that has greatly reduced the sandalwood population. Its heartwood produces one of the most valuable of Australian essential oils and is used in the perfume industry. Weeping myall, *Acacia pendula,* has timber with the perfume of violets and was once used in the making of glove boxes. A few species have received their vernacular names from the characteristic odour of the timber as in the case of rosewood, *Dysoxylum fraseranum;* raspberry jam, *Acacia acuminata;* and onionwood, *Owenia cepiodora.*

The Senses Trail of the Ku-ring-gai Wildflower Garden is a worthwhile place to visit for its collective group of plants of the "crush and smell" foliage varieties. Aimed at the disabled and blind, this short walk, with guide ropes connecting to information posts, cuts through thick bushland. The plantings, regularly nurtured by members of the Society for Growing Australian Plants, consist of dozens of sweet-smelling species of *Prostanthera, Boronia, Leptospermum* and *Backhousia.* It is hoped that within the next 12 months, braille plates will be placed along the trail. □



photoart











South Australian Landscapes

Michael Kluvanek was born in Czechoslovakia in 1954 and came to Australia in 1967 where he studied photography at the South Australian School of Art. Michael has exhibited widely in several States and has had his work published in a number of magazines and journals. He is represented by the Developed Image Gallery in Adelaide and recently exhibited in a group exhibition at The Australian Centre for Photography.

Michael says of his work — "Landscape is one of the great themes of photography. At first my landscape photographs were small, intimate and largely urban, with social documentary overtones. Over the past three years I have attempted to deal with a larger landscape, the often 'empty' landscape of the Australian countryside. I have come to realise that the 'landscape' as such does not exist, that the land/sea does not begin or end. The photographer imposes his point of view and his frame nets the infinite. The landscape as presented here exists only here. It is a product of a point in space and time, a point which is only one of a limitless number of possible points. They are the ones that made sense to me."

All photographs by Michael Kluvanek, selections made in co-operation with The Australian Centre for Photography, 257 Oxford Street, Paddington, NSW 2021.

SOUTH AUSTRALIAN MOUND SPRINGS

Relict faunas in the desert

by Winston F. Ponder

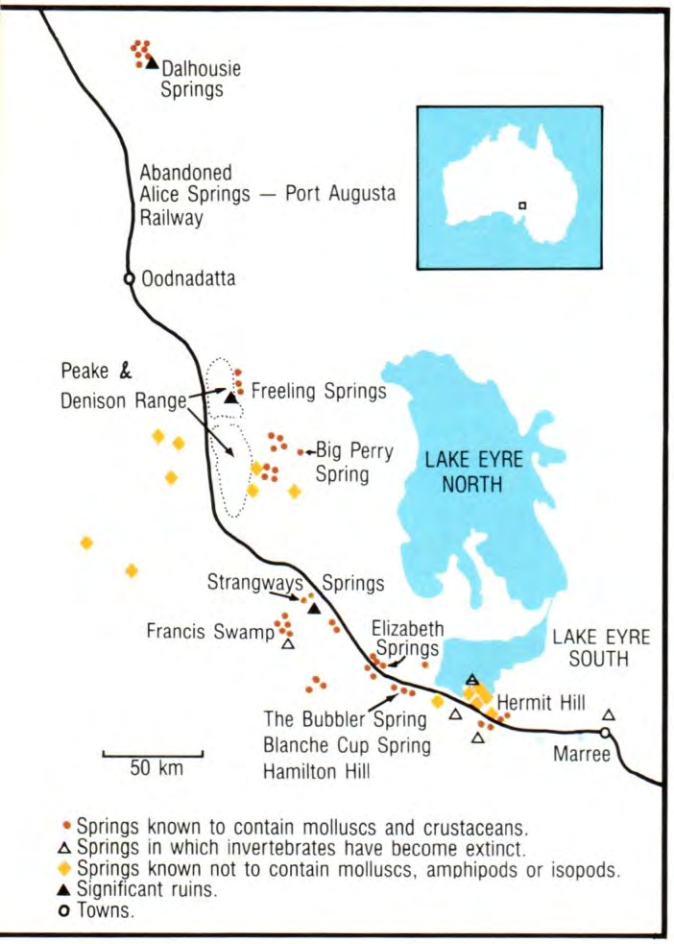
Winston Ponder is a Principal Research Scientist at the Australian Museum. He has been working on South Australian mound springs for about four years and is particularly interested in the evolution and biology of their endemic snail fauna. Here he discusses the springs' early European history, their fauna and flora, their scientific importance, the impact of man and, in the light of these topics, the case for the conservation of these mini oases of the desert.



In the arid north of South Australia, along the remains of the Ghan railway between Marree and Oodnadatta, are the ruins of overland telegraph stations and the crumbling walls of stone homesteads. The railway and the buildings follow a line of small, natural artesian springs, the only permanent drinkable water in an almost waterless land. The springs often flow from miniature hills and are, for this reason, usually known as mound springs.

The Aborigines used the springs as camping sites and in many places stone flakes and other artefacts litter the ground. These springs also feature prominently in their mythology and almost every spring is of significance.

Map showing location of mound springs



The springs

There are about 90 mound springs or complexes of springs known in South Australia, the largest of these being the Dalhousie group, north of Oodnadatta, with about 60 active springs. The flow of water from the springs is also greatest at the Dalhousie group where discharges of up to 85 litres per second from one spring have been recorded. Most springs have a much lower flow rate.

The springs follow the southwestern edge of the Great Artesian Basin. Their water is derived from the basin, seeping up through faults in the impervious rocks overlying the porous rock forming the aquifer. The water carries sediment particles to the surface and these, together with chemical precipitates, create the mounds. These mounds are often several metres high and are sometimes large enough to be seen from a considerable distance. The water typically flows from the top or side of the mound and may form a small marsh before disappearing into the sand and stones at the base. Some mounds are rock-hard, the carbonate precipitates binding the sediments into calcrete. Other mounds are composed almost entirely of sand or clay.

European history

The first European to describe mound springs was P.E. Warburton in 1858, who stated that he had found "more springs than I could either examine or count". His glowing reports led to a rush by pastoralists to the area — after all, it would be difficult indeed to ignore a description like that. Blanche Cup Spring was described as "more than sufficient for the wants of the largest station". As pastoral leases were being taken up, John McDouall Stuart continued exploration of the area in 1859-60. His reports of further springs continued to attract settlers with their sheep and cattle.

Some of these springs were chosen as sites for the overland telegraph stations built in the 1860-70s. The extensive buildings at Freeling and Strangways Springs are now rapidly being destroyed by vandals and the elements. Despite the supply of water the land proved to be extremely fragile and the climate unkind. A major drought in the 1860s led to many of the homesteads being abandoned. Today drought still prevails and overgrazing by stock has ruined much of the land.

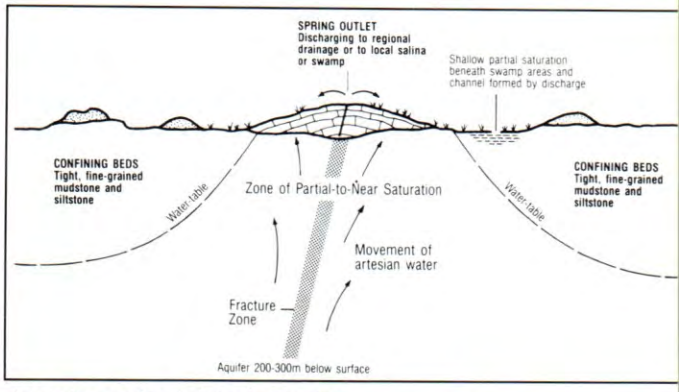
The early pastoralists were dependent on the springs for water. Typically the springs were fenced and water was delivered to stock by trough. With the introduction of bores the springs became less important and fences fell into disrepair. The trampling of stock in the head and outflow of the springs have turned many of them to bogs into which the animals did, and sometimes still, sink and die.

The fauna

The study of the aquatic invertebrates in these springs has revealed



Gosses, Springs, one of the larger springs in the group. This group and some other nearby springs are flooded when Lake Eyre floods and, presumably because of this, do not support any of the typical mound spring fauna. Photo: Winston F. Ponder.

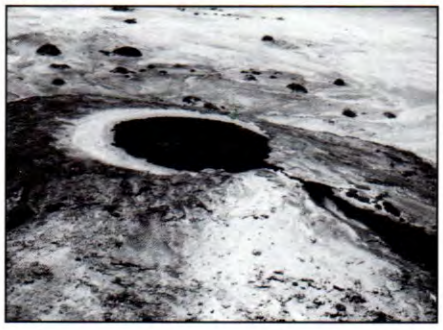


An interpreted structure of a typical mound spring.

that they have a fascinating assemblage of unique animals, many of which have only been discovered in the last ten years.

When one looks at the outflow of a mound spring such as The Bubbler or Blanche Cup, columns of small, slater-like animals about a centimetre long can be seen marching along the edges like miniature armies on the move. These are isopod crustaceans (*Phreatomerus latipes*). These unusual animals, which are believed to be of ancient stock, are but one of many species unique to the springs. *Phreatomerus* differs from ordinary slaters in being compressed sideways instead of flattened. In this respect they resemble an entirely different group of crustaceans, the amphipods. An endemic species of amphipod is also present in the springs but is harder to see, preferring to hide beneath stones or around the roots of sedges. Another species of amphipod, known only from one small seep at Dalhousie Springs, is blind. These crustaceans are being studied by Wolfgang Zeidler of the South Australian Museum who pioneered the work on the invertebrate fauna of the mound springs.

Blanche Cup Spring, a volcano-shaped mound spring that is a tourist attraction. Photo: Winston F. Ponder.



Cattle damaged spring in the Hermit Hill spring complex. Trampling turns the springs into bogs in which the cattle themselves are trapped. Photo: Winston F. Ponder.



The Ostracoda, a tiny, bivalved group of crustaceans, is also represented. A few species are widely dispersed but one endemic species, described as recently as 1979, is so unusual that it has been placed in its own subfamily. Other, yet undescribed, species of ostracods are also known to occur in the springs. Additional minute crustaceans live in the plankton in the larger springs but this fauna is unstudied at present.

The most conspicuous and abundant invertebrates in many of the springs are small black snails of the family Hydrobiidae. Most springs have more than one species and some as many as five. So far 14 species in three endemic genera are known. One genus and five species are found only at Dalhousie Springs, the other nine species in two genera being found in the springs further south. In many of these springs, between Marree and Oodnadatta, there are two different types (genera) of snail present: a flattened type that actively seeks open spaces and three species of tall-shelled snails. One of these tall-shelled snail species is amphibious and an almost identical one aquatic, the third species being aquatic and about half the size of the other two similar species. Different species make up this community in different parts of the spring system.

An unusual flatworm, found in two spring groups, was discovered in 1983. Other aquatic invertebrates include oligochaete worms and insect larvae but little is known of these animals yet. It is quite probable that additional animals remain to be discovered. The amphipods, snails and flatworm are unnamed although being studied at present.

There are nine species of fishes in the springs, although two of these (a catfish and a hardyhead) occur only in Dalhousie Springs. The detailed work of John Glover of the South Australian Museum has shown that, apart from these two species, none of the other fish are restricted to artesian springs but can live in bore drains, water holes, etc. The Desert Goby (*Chlamydogobius eremius*), is found in many of the springs. The males of this species exhibit spectacular colours on their fins.

The springs provide an important habitat for birds, 55 species

Pool formed from spring water, Hermit Hill Springs. Photo: Winston F. Ponder.



Peake Repeater Station ruins, Freeling Springs. Part of an outflow from one of the springs is marked by a line of sedges in the middle foreground. Photo: Winston F. Ponder.



being recorded in a brief survey in the vicinity of Hermit Hill. Bore drains in the same area, however, also provide a suitable environment for the birds.

A male desert goby, *Chlamydogobius eremius*. Photo: G. E. Schmida.



The flora

Unlike the arid environment in which they are found, the springs provide an excellent habitat for moisture-loving plants; several species of sedge, cutting grass and bamboo grass being found in the springs. Various algae provide a rich source of food for the aquatic invertebrates. Shrubs and small trees take advantage of the soil moisture and grow around some of the springs, providing shelter and food for terrestrial animals. One plant, Button Grass (*Eriocaulon carsoni*), was until very recently only known from boggy springs in the vicinity of Hermit Hill, near Marree. It was found in early 1984 in two small groups of springs at the northwestern end of the Flinders Ranges and, in September 1984, I found it at Elizabeth Springs near Springvale in western Queensland.

Scientific importance

The mound springs are of special scientific interest from many points of view. Hydrologists who study their water consider them to be of great importance as do geomorphologists and geologists. A diprotodont, a giant extinct marsupial, has been found at Hergott's Spring at Marree and other fossils undoubtedly exist. The calcareous rock formed by some springs often contains fossils and a wealth of information on the history of the springs and the area, in general, awaits future workers.

The unusual and diverse invertebrate fauna is of great significance. The fauna is all we have, apart from fossils, to give us clues about the



A▼



B▼

▲C

▲D





Small invertebrates are abundant on the surface of the spring outflows. A, an isopod (*Phreatomerus latipes*); B, an ostracod (*Ngarawa dirga*); and C and D, hydrobiid snails. Photos: A, C and D, Kate Lowe; B, P. DeDeckker.

invertebrates that lived in the central part of Australia in Tertiary times when it was presumably much wetter. At least two fishes and many of the invertebrates are endemic to the springs. The destruction of these habitats would, conservatively, result in the extinction of more than 24 species of animals.

There are only two other freshwater habitats in arid South Australia that are known to contain endemic invertebrates. Artesian springs at Lake Callabonna on the eastern side of the Flinders Ranges contain one species of snail and non-artesian springs in the Flinders Ranges contain a blind amphipod and another species of snail. Neither of these snails nor the amphipod is related to those in the mound springs. I recently surveyed springs and other freshwater bodies in central Australia and in western Queensland and no similar fauna was found. I have, however, found additional endemic aquatic invertebrates in artesian springs in western Queensland but they are not closely related to those in South Australia.

Because most springs are discrete bodies separated by the arid terrain, there is little opportunity for the crustaceans, snails and fishes to interbreed with individuals from neighbouring springs. Most of the springs are small and consequently the total populations are small. These conditions are ideal for speciation to occur and the snails, in particular, demonstrate this. The relatively simple communities, limited size of the springs and their variation in spacing from one another suggest that there is considerable potential for using these aquatic islands as natural laboratories for studying speciation, genetics and ecology.

The impact of European man

The plants and the water are irresistible to cattle as well as wild horses, donkeys and camels. Their trampling has devastating effects but, incredibly, the fauna often seems to survive as long as a few refuge areas remain intact.

The greatest immediate danger to the mound springs is the increasing usage of artesian water from bores. Spring discharge has been steadily decreasing because of the reduction of the available water in the Great Artesian Basin due to the sinking of bores. A group of springs in the vicinity of Bourke, New South Wales, which were active around the turn of the century, are now dry and several of the artesian springs in South Australia and western Queensland have ceased to flow in the last 100 years. Many others have considerably reduced flow rates, as can be seen when descriptions of the springs by the early explorers are compared with what they are like today. Some mound springs that have had wells dug in them have lost their fauna, evidenced by the shells of snails and ostracods in the sediments. These animals have presumably died because of interference with the water flow. A spring that might have been flowing for many thousands of years has only to dry up for a few hours for its aquatic fauna to become extinct.

The endemic invertebrates are apparently incapable of being easily dispersed. Unlike the fishes, they are not found in bore drains and do not appear to be distributed by floods. Thus, once they disappear from a spring, they do not reappear unless there is a spring very close by.

The case for conservation

The mound springs are of unparalleled importance in the history of the north of South Australia, both from the Aboriginal and European viewpoint, and provide considerable potential in future tourist development of the area. Interference with their natural flow by sinking wells or bores in the springs and continued trampling and fouling by livestock, is causing severe damage to the springs.

Because each group of springs has its own unique characteristics and each major group has a distinct fauna and flora, a proper conservation strategy, encompassing the entire spring complex, needs to be established. The creation of conservation parks around some of the best examples from each major group is an essential step in the preservation of the springs. This has been done only last year (1984) in the case of Dalhousie Springs. Such parks could also include the more significant of the remains of historical buildings such a those at Freeling and Strangways Springs. Most of the springs outside such parks or reserves should be fenced. Stock could be watered by trough and gravity-fed pipe as the early pastoralists did, but only if this does not interfere with the natural water flow.

Governmental control of bores in South Australia is improving the outlook for the future of the springs but there is still a lot to be done before their water source can be considered secure. The borefield development, for use by the Roxby Downs mining venture, could result in a major spring complex in the vicinity of Hermit Hill being adversely affected. Fortunately, however, the latest information available suggests that, because of an unexpected geological anomaly, it will seriously affect only a few isolated springs and the impact on the large Hermit Hill spring complex will be minimal. Future developments involving the use of artesian water that are likely to damage the mound springs should be carefully considered before a unique part of the Australian environment is lost. □



▼White mangroves at Careel Bay near the mouth of the Hawkesbury estuary. Photo: John Fields.

THE HAWKESBURY
NATURAL HISTORY OF AN ESTUARY

by Alan Jones

Scientific Officer, Division of Invertebrates, Australian Museum

The Hawkesbury and its tributaries drain an area of 22,000 square kilometres in the Sydney hinterland. Tributaries flow north from Goulburn, east from the Blue Mountains and south from Wollemi National Park. The estuary enters the sea at Broken Bay about 30 kilometres north of Sydney. The river traverses two main landforms: the low lying shales of the Cumberland Plain and the higher sandstone plateaux and ridges that frame the lower estuary.

What is an estuary?

One wag has said that an estuary is like pornography: very difficult to define precisely but you know it when you see it. Usually an estuary is the water body connecting the fresh water of rivers and lakes with the sea. The word is derived from the Latin *aestuarium* meaning a tidal inlet of the sea. Hence tides and a connection with the sea are important estuarine attributes, as is changing salinity or dissolved salt content. In the Hawkesbury, traces of salinity can occur 80 kilometres upstream to the Colo River junction and the tidal limit extends another 60 kilometres to the junction with the Grose River.

Because no two estuaries are alike, schemes that group them into broadly similar types have been devised. One such scheme used in New South Wales divides estuaries into three types: barrier estuaries with small entrance channels and

tides (Merimbula, Wallis Lake, Narrabeen Lagoon and Lake Macquarie); saline coastal lakes with ephemeral entrances and tides (Dee Why, Harboard and Manly Lagoons and Gosford Lakes); and drowned river valleys with open mouths and full tidal ranges (Hawkesbury River, Georges River, Port Jackson, Port Hacking). The condition of the mouth is important as it governs the degree of tidal exchange, which in turn influences sediment movements, biological colonisation and migrations, and water quality.

Origin and evolution

As with all estuaries, the Hawkesbury has a life and evolution of its own. The structure we see now has been forged by major geological events and persistent erosion over long periods. The uplifting of sandstone plateaux such as those of Kuring-gai and Muogamarra National Park started over 50 million years ago and, because of the hardness of sandstone, the river scoured a narrow, precipitous path as they rose. At the end of the Pleistocene Ice Ages, the sea level was about 150 metres lower than today. The river mouth was thus displaced seaward onto the continental shelf and the river valley was eroded to bedrock, which is now 125 metres below sea level at the mouth. When the ice caps started melting about 17,000 years ago, the sea level rose, drowning the valleys and creating the spectacular scenery of waterways such as Cowan and Berowra Creeks, as well as the Hawkesbury. For the last 6,000 to 7,000 years, the sea level has been stable, and infilling with sediment from both terrestrial and marine sources has occurred. This process will steadily continue, although, unlike other estuaries such as Merimbula, the wide mouth and strong tides will prevent the Hawkesbury from completely filling in.

Hydrology and sediments

A curious feature of estuarine flow is that water can be moving upstream along the bottom while surface water is flowing downstream. This happens because fresh water "floats" on the denser salt water and when the tide starts to flood, a dense "salt wedge" encroaches upstream under fresher water. Although this phenomenon varies greatly in degree, it is thought to be immensely important to the migrations of animals and their maintenance of position in the estuary.

Water flows are also largely responsible for eroding and transporting sediments. Because finer mud particles are more easily moved than sand, the distribution of these sediment types is a function of current velocity. Thus the sediments of the fast headwaters are sandy while the slow flows further downstream allow fine particles to settle out. Sand once again dominates at the mouth because of strong tidal currents.

Sediments are extremely important because they attract bacteria and pollutants, provide a source of construction material, nourish beaches with sand, create a nuisance when navigation channels silt up, and provide a home for many different animals. In fact, Hawkesbury mud can be so fine and creamy that it has been used for facials in beauty parlours.

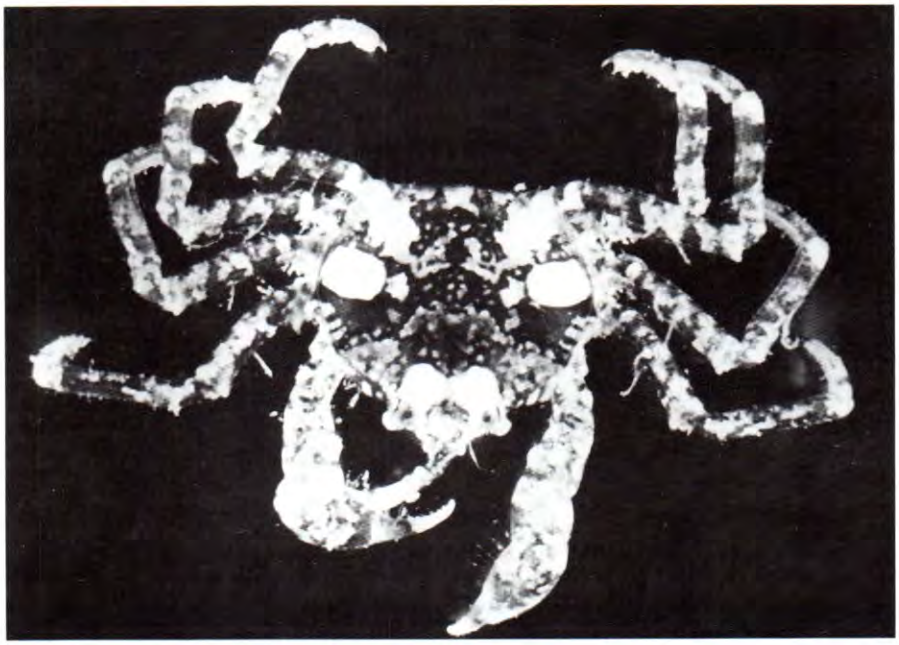
Biological diversity

Far fewer species occur in estuaries compared with the sea or fresh water and the number of species within an estuary usually falls progressively as the water becomes fresher. This is thought to be largely due to salinity conditions. Most estuarine species originated in the sea where salinity is high and varies little. The successful invasion of estuaries required adaptation to both lowered and variable salinity. As the salinity falls along an estuary, the concentration of salts in the water becomes less than the concentration in the body fluids. Water tends to flow across semi-permeable membranes such as gills or skin from lower salt concentrations to higher. An organism may bloat and even literally explode unless it can pump out the water. Hawkesbury species either have the ability to do this (school prawn) or can tolerate some bloating (brown jellyfish).

Other problems facing estuarine species include the greater variability of such factors as salinity, temperature, dissolved oxygen and turbidity. Some large groups of animals including echinoderms, corals, anemones, sponges and ascidians have been unable to solve these problems and thus have few estuarine representatives. With evolution being such a slow process and estuaries relatively young, perhaps they just need more time.

While many species live in both estuaries and the sea, some are considered truly estuarine as they have not been recorded elsewhere. Not only have they adapted well to lowered salinity and fluctuating conditions, they can also maintain their position in the face of seaward flows of water. This may be achieved by swimming or burial in sediments or even by the control of depth in the water column. Because the water at different depths may flow different ways simultaneously, species such as the brown jellyfish can hitch a ride in either direction by depth control. Yet other species have reduced or eliminated the larval stages,

A spider crab (*Halicarcinus ovatus*) from the mouth of the Hawkesbury estuary. Body length is approximately eight millimetres. Photo: Roger Springthorpe.



which are at greatest risk of being swept away.

Although true estuarine species have adapted well to regular estuarine conditions, they also need ways of coping with extreme episodic events such as floods. Do they find temporary refuges such as side channels, eddies, or burial in the sediments? Or, if they get washed out to sea, can they survive and recolonise? Perhaps migratory larvae can recolonise from other estuaries or the sea. These questions and many others await answers.

Major habitats and their fauna

Two major physical habitats exist: the water column and the estuary floor. The former provides a habitat for both swimming (nektonic) and drifting (planktonic) forms while the latter accommodates the benthic species. As usual, these biological classifications are not hard and fast. For example, many planktonic species can swim weakly, others alternate between the nekton and benthos, and yet others have complex life cycles incorporating planktonic larvae with nektonic or benthic adults.

Nekton (swimming species)

The Hawkesbury nekton includes fishes, cuttlefish and squid, swimming crabs, prawns and even fairy penguins, which have a colony on Lion Island. With the exception of small fish such as gobies, few of these live permanently in estuaries but migrate to the sea or fresh water. In fact, estuarine fishes have been grouped according to their migratory patterns. Most estuarine fishes are the juveniles or young adults of species, such as mullet, flathead, luderick and bream, that breed in the sea or marine bays. Their young migrate to estuaries where seagrasses and mangroves act as nursery areas, providing abundant food and shelter. Some prawns and swimming crabs also follow this pattern.

Even more complicated fish migrations exist wherein the estuary serves as a highway between fresh water and the sea. Catadromous fish, such as short- and long-finned eels, are those that breed at sea and migrate to fresh water to grow to adulthood. Some eels have shown amazing adaptability in overcoming obstacles. Adults swim from eastern Australian rivers to spawning grounds in the Coral Sea off New Caledonia. The eel larvae spend at least a year at sea before returning to estuaries, becoming elvers, and swimming upstream towards fresh water. In the Hawkesbury–Nepean River system, their way is blocked by the 100 metre high Warragamba Dam. However the five centimetre long elvers are able to swim up an adjacent small stream, cross drains, roads, metre-high walls and grass and finally enter the dam waters where they grow to adulthood and complete the cycle. The construction of fish ladders would certainly make life easier.

Other fish, such as the Australian bass and freshwater mullet, breed in the estuarine part of the Hawkesbury and the young then migrate to fresh water. The common jollytail also breeds in the estuary but the larvae then move to the sea for the winter before returning to fresh water as juveniles and maturing.

Plankton (drifting species)

The little known world of plankton contains outlandish forms with long spines, antennae and strange plate-like structures. Some species resemble shimmering translucent jewels and most are tiny. They can be so abundant that light-producing species cause the water to sparkle and coloured species may stain large areas. One such plant species is thought to have caused the Nile to run red in biblical times. A similar species affects Berowra Creek when nutrients are plentiful. Animal species are dominated by copepod crustaceans, which provide abundant fish food, and by the larvae of species that live on the bottom as adults.

Benthos (bottom dwellers)

A kaleidoscope of small invertebrates occupy the Hawkesbury sediments. Some occupy the soil surface while others make burrows or live in tubes. Sizes vary from the microscopic to several centimetres with most of the latter being polychaetes (bristleworms), crustaceans (especially amphipods) and molluscs. Tens of thousands can occur in a square metre of sediment and they provide an important source of fish food.

Most species feed on detritus or microbes in the sediment or else they filter particles from the water. A variety of antennae, tentacles and siphons are used in feeding. Bivalve molluscs such as oysters pump water over an internal gill that collects both food and oxygen.

Reproductive strategies among the benthos are also varied. While some species are hermaphroditic, most have separate males and females. Fertilisation can be internal or external and eggs may be brooded in capsules or pouches or cast loose in numbers varying from a very few to millions. Eggs can also develop and hatch within the parent so that live birth occurs. The Sydney rock oyster, an important commercial species in the Hawkesbury, is hermaphroditic. Millions of eggs and sperm are released and fertilisation is external. Tiny larvae develop and form part of the temporary plankton before settling on the bottom as "spat" and developing into adults.

Plants and productivity

Plants use their green pigment, chlorophyll, to trap the sun's energy and photosynthesise the food materials on which all animals ultimately depend. Whereas the open ocean relies on the tiny floating planktonic plants, attached plants such as mangroves and seagrasses

An amphipod crustacean commonly found amongst mussel shells and mud. It is approximately one centimetre long (including antennae). Photo: Roger Springthorpe.▼

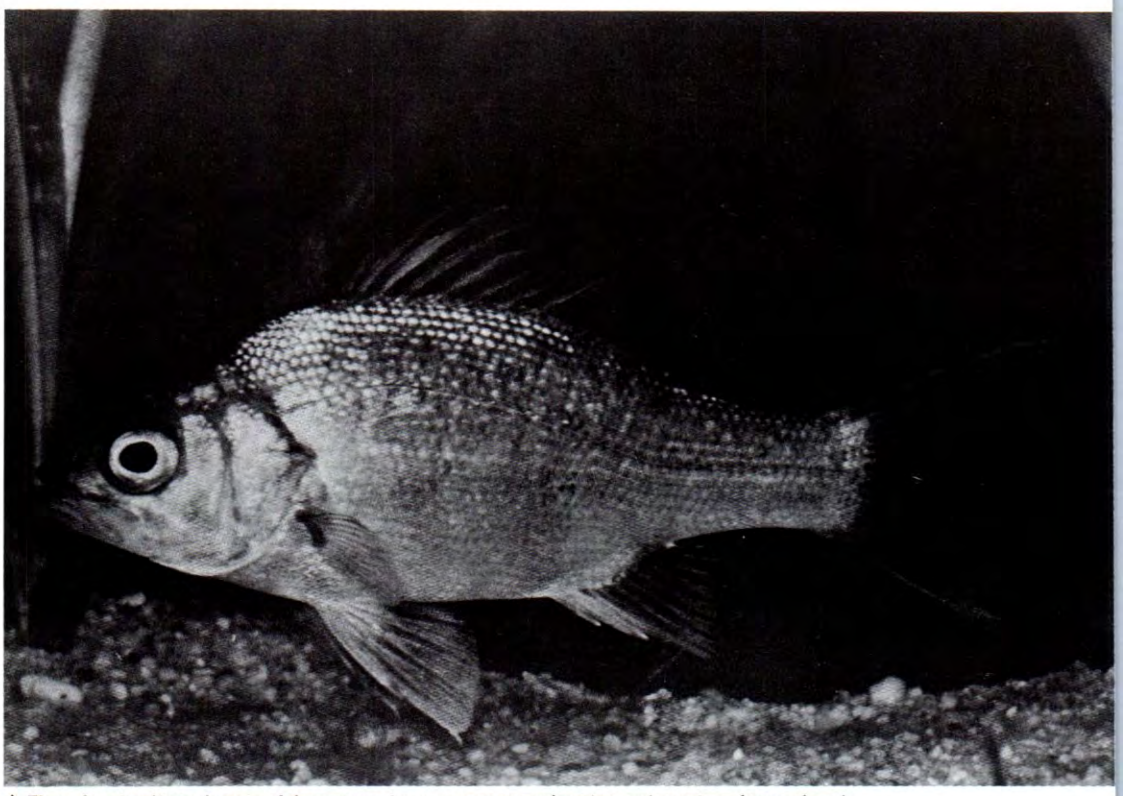


are far more important in estuaries where turbidity limits light penetration and hence planktonic production. Completely terrestrial plants such as eucalypts also contribute substantial amounts of organic matter to steep-sided estuaries such as the Hawkesbury.

The organic plant detritus is decomposed into plant nutrients by bacteria and fungi. Because decomposers are abundant on sediment particles, nutrients are recycled quickly and the attached plants can be as highly productive as intensively-managed farmland. This productivity permits mangroves and seagrasses to support large populations of fish and small invertebrates. Because many of these migrate to the sea, estuaries are exporters of productivity. As about 60 per cent of our most important commercial species are estuarine-dependent, this productivity contributes substantially to the human food supply.

Conclusion

An estuary is more than just a transition between the sea and fresh water. Estuaries have unique physical and biological attributes, high productivity, and provide essential resources, habitat and migratory routes for a host of transient species. However, we really know very little about the Hawkesbury's natural history and ecology. Many, probably most, of the invertebrate species do not even have names and our knowledge of their biology and response to natural and human influences is slim indeed. This is particularly unfortunate as the Hawkesbury is increasingly subjected to our activities. We should not presume too much on its resilience if we wish to retain its present values. □



▲The Australian bass, *Macquaria novemaculeata*, migrates from fresh water to the estuary to breed. Photo: John Harris.



Argosy of Animals:
A Wildlife Film Series



January 26, 1798 (Australia Day) was an important day for Australian zoology. On that day the wombat, lyrebird and koala were discovered. Irish convicts believing a white settlement existed over the mountains were bolting from custody in an attempt to find it. The Governor of the colony ordered a small expedition, including some convicts, to proceed into the mountains to prove that the hidden world did not exist. The expedition was led by John Wilson, a former convict, who had lived with the Aborigines for years. The Governor sent his 18 year old assistant, John Price. Wilson, like the Aborigines, was familiar with the animals but history credits John Price with the discoveries because he wrote about them.



From the pilot programme Australia's Improbable Animals *about the discovery of Australia's wildlife by European navigators, explorers and early settlers.*

A series of documentary films will tell the story of the origin, evolution, migration and adaptation of Australia's native animals. The project will soon be seeking investment for three by one hours of television programming. *Argosy of Animals* is the title for the series. A pilot programme, *Australia's Improbable Animals,* was produced and has been purchased by the 10-Network.

The film series will cover the following: origins of the marsupials; immigration of bats and rodents to Australia; the "invasion" of introduced animals, such as rabbits, pigs, goats, water buffalo, sheep, etc.; species in danger of extinction.

MARSUPIALS: the Australian marsupials are thought to have originated on the southern "super-continent" part of which is now Australia, and to have evolved as Australia "drifted" into the isolation of the South Pacific. The result was a vast array of animals with pouches. Australia has a very wide diversity of marsupials.

BATS AND RATS: at a much later date in prehistory, millions of years ago, bats and rodents immigrated to Australia. Bats flew in or were blown in by storms and rodents probably drifted in on logs, debris or rafts of pumice thrown up by volcanoes to the north of Australia.

BIRDS OF THE PACIFIC: the origin of Australian birds was traditionally thought to be Asia. These "early birds" were thought to have moved in waves down through the Indonesian Archipelago and New Guinea to Australia. It now seems that many species of typical Australian birds evolved from a few obscure ancestors within Australia. It is almost certain that birds such as cassowaries, emus, mound-builders, parrots and plains-wanderers evolved in Australia. Like bats, many other birds flew in later.

INTRODUCED ANIMALS: the dingo was probably the first animal to be introduced by humans to Australia. It was brought in about 3,500 plus years ago by some ocean-going people from the north. In the context of animal evolution, millions of years of relative isolation came to an abrupt end 200 years ago when European explorers settled Australia. The First Fleet brought with it pigs, goats, sheep, cattle and horses. These were followed by rabbits, foxes, dogs, cats, water buffalo, camels, deer, etc. It was a zoological invasion that had an enormous impact on the native species.

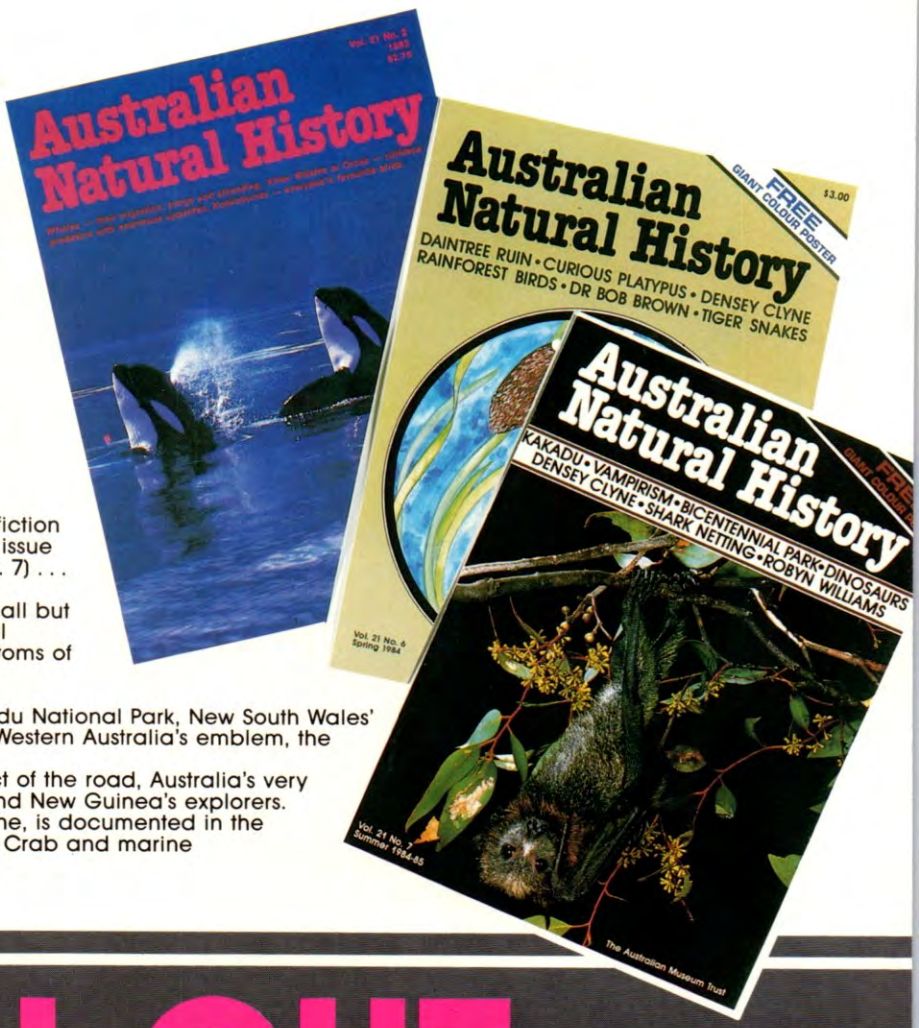
200 YEARS OF CHANGE: millions of years of adaptation to changing climatic conditions was not sufficient defence for some species against traumatic change. European occupation brought about this rapid change. Many native species have been driven to extinction or to the verge of it by 200 years of change to which they have not been able to adjust in time. A few species have been able to survive, even thrive, for example, kangaroos because of clearing of forests and extension of grasslands and some native rodents because of the introduction of sugar cane in northeastern Australia. But the majority of species appear to have decreased in range and numbers.

The films are being made for television and will also be distributed on video cassette. The producer of the series is Gary Steer and the executive producer and distributor, Channel Communications.

TAX DEDUCTIBLE INVESTMENTS: the series will be produced under the Australian Government's taxation incentive scheme for production of Australian films. Investors in the films qualify for a tax deduction of up to 133% of their investment.

Further details can be obtained from Channel Communications, 11 Kellett St., Kings Cross, 2011. Telephone: 358 3976 or 358 3442.

Read the Natural Authority



Vampires — those blood-drinking creatures of fact and fiction — make up the subject of a fascinating story in the last issue of *Australian Natural History* (summer 1984-85, Vol. 21 No. 7) . . . From the infamous Count Dracula of Transylvania to the gargoyle-like Yarama of Aboriginal legend; from the small but very real vampire bats of South America to the historical accounts of human vampirism; and, finally, to the symptoms of a rare congenital disorder found in humans, called iron-deficiency porphyria. Is fact stranger than fiction?
Northern Territory's controversial issue of tourism in Kakadu National Park, New South Wales' Aboriginal carved trees, Queensland's flying-foxes and Western Australia's emblem, the Numbat, also feature in this issue.
The spring 1984 issue dealt with Daintree and the impact of the road, Australia's very own Platypus, deadly tiger snakes of Chappell Island and New Guinea's explorers. An alleged sighting of Tasmania's own tiger, the Thylacine, is documented in the winter issue, along with mating behaviour of the Fiddler Crab and marine reserves (conservation or recreation?)

WATCH OUT IN COMING ISSUES . . .

BULLDOG ANTS: Those jaws that bite, those things that sting.

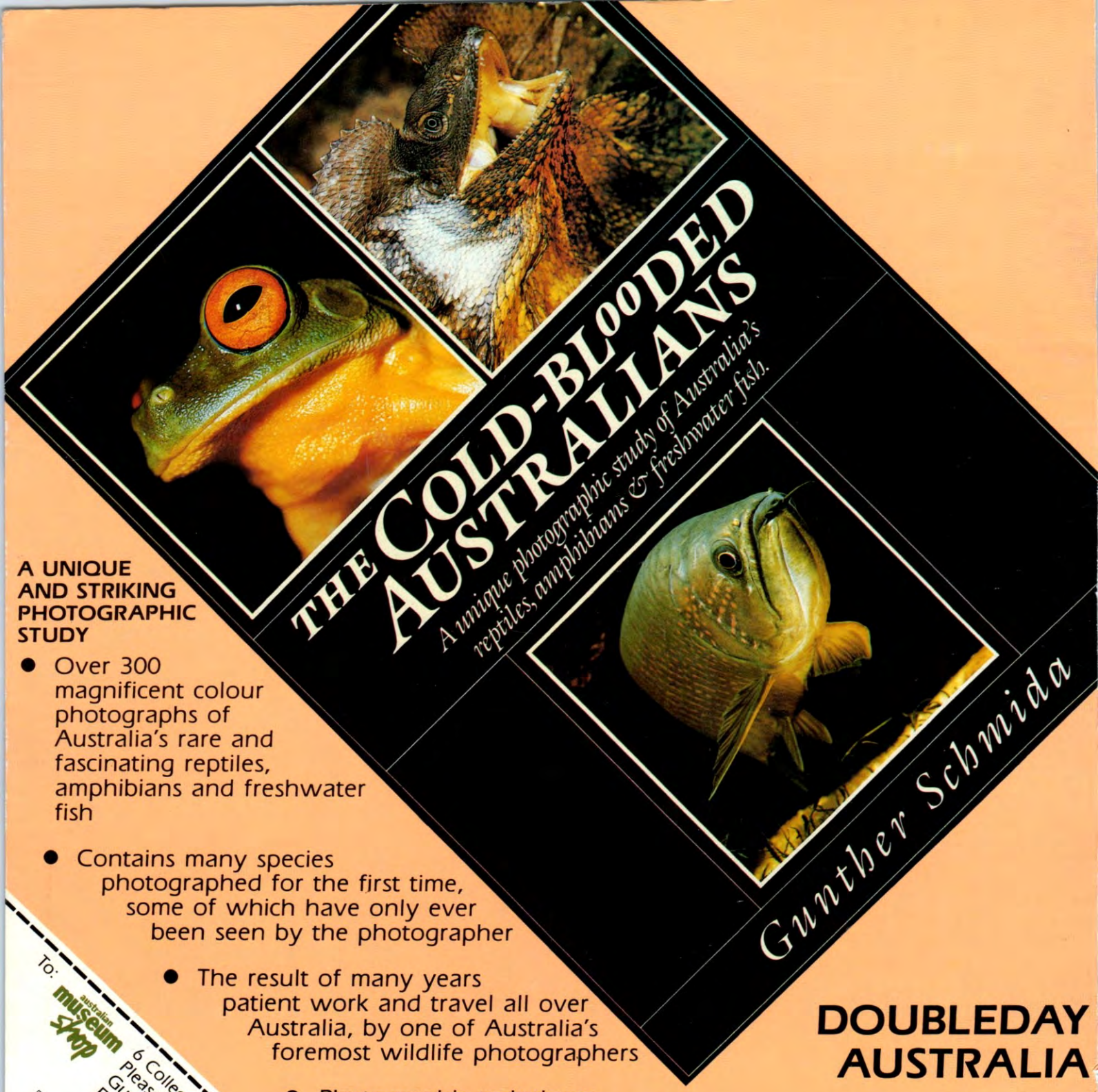
OPALISED FOSSILS: A beautiful but expensive way to look into Australia's past.

BIRDS OF PREY: Those magnificent birds in their flying machines? A success story with (maybe) a not-so-successful landing.

WOLF SPIDER FISHING: An alternative use for biting March flies.

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