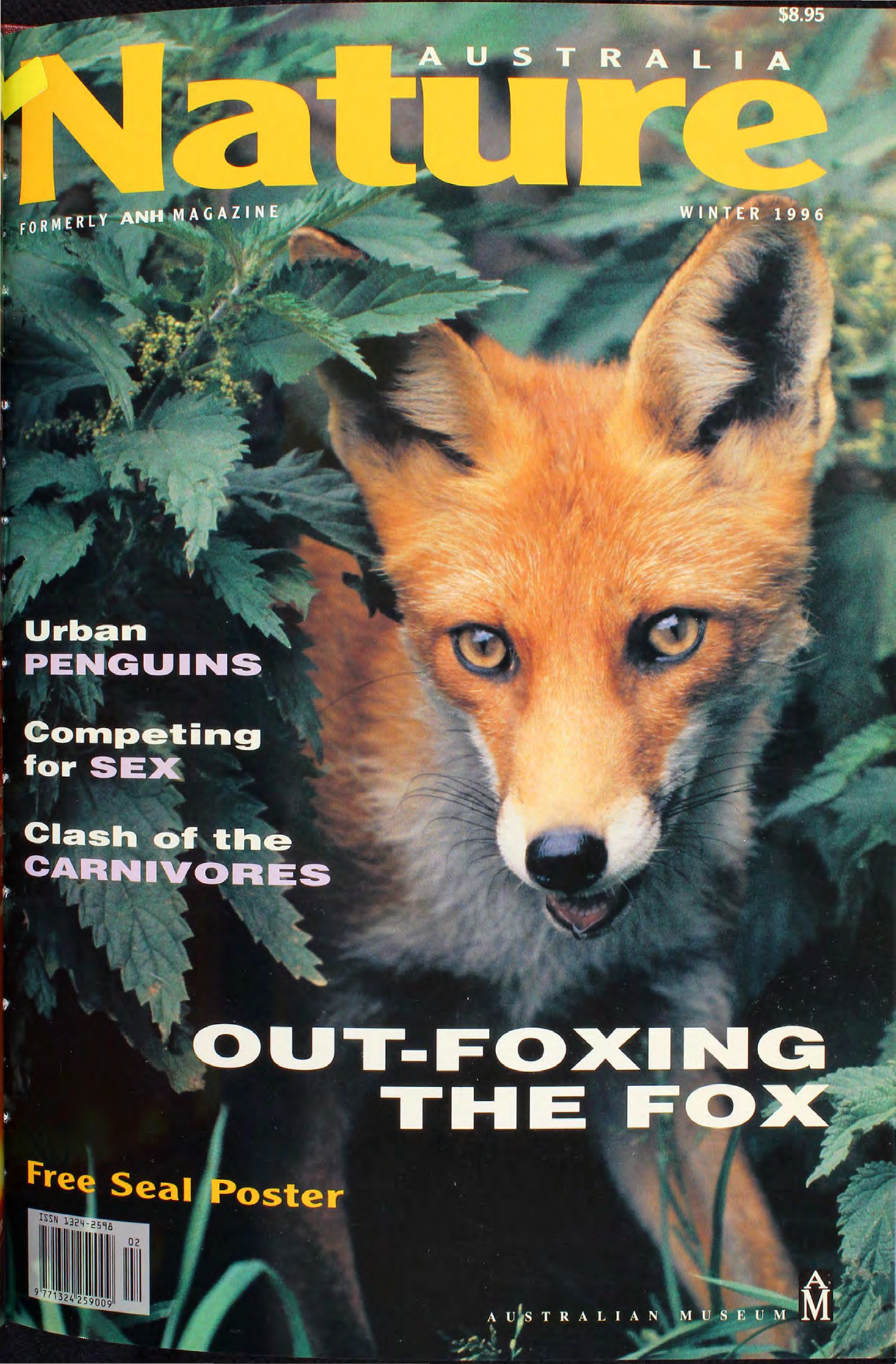
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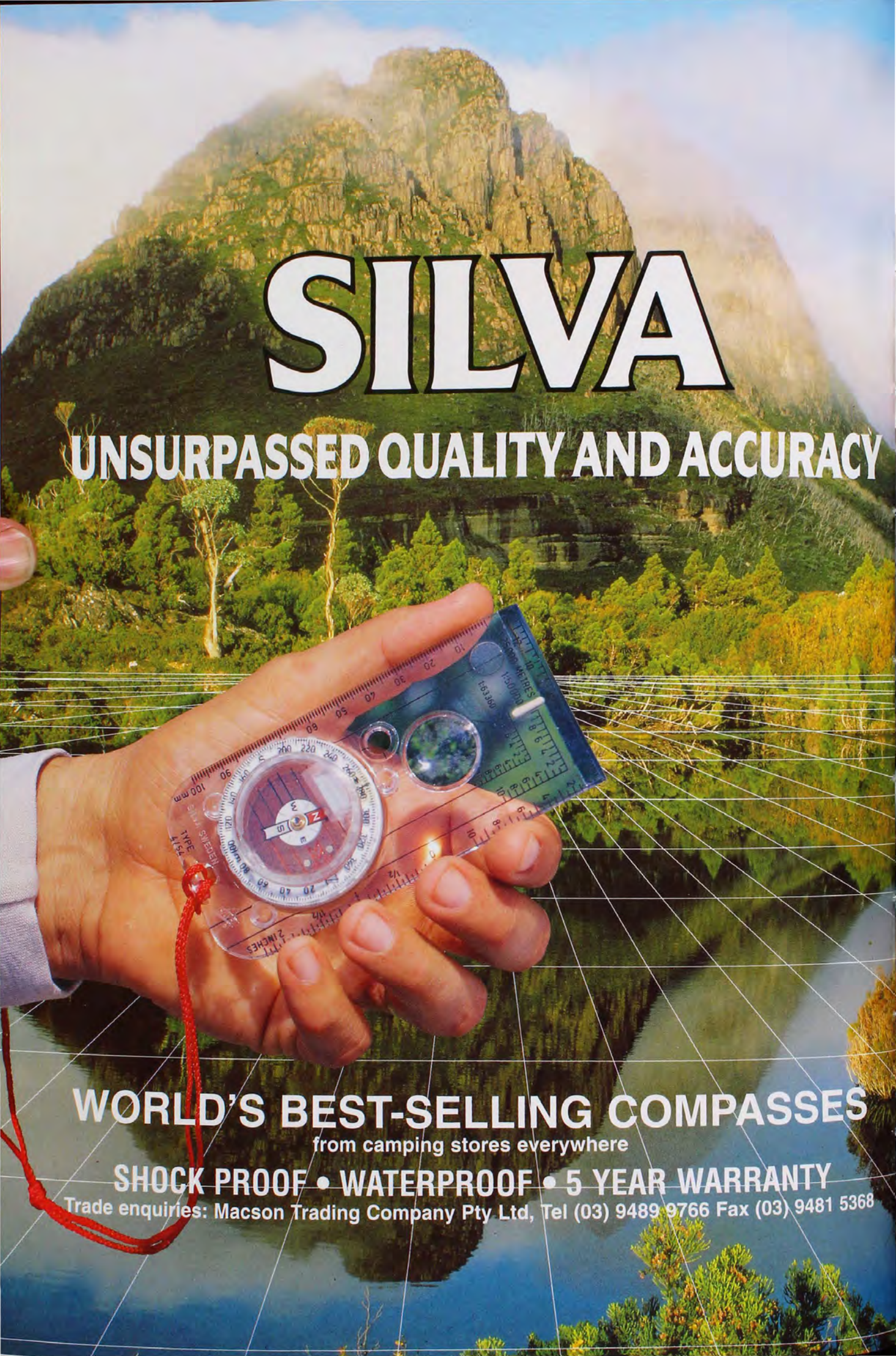
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Up Front

HANS & JUDY BESTE/AUSCAPE INTERNATIONAL

Fairy Penguin (*Eudyptula minor*).

In my small inner-city backyard I am lucky enough to have a lovely mature gum tree. In the short time I've lived there, I've noticed it has provided a successful nesting site for two separate pairs of Red Wattlebirds (*Anthochaera carunculata*) and a pair of Spotted Turtle-doves (*Streptopelia chinensis*). This same tree is also home to stick-insects, a wide array of beetles and spiders, and, in summer, a literally deafening number of cicadas. And I have no doubt that this small list represents only a tiny fragment of the life on and around that tree. So often we fall into the trap of thinking nature is something that happens out there somewhere, and not in our own backyards. Well, in this issue we prove that's just not the case.

In Victoria there is a successful colony of urban Fairy Penguins. Travel with us to St Kilda and find out why they choose to live just five kilometres from Melbourne's CBD. We also take a look at nest boxes. For many of our native birds and mammals, tree hollows are crucial, yet they are being rapidly depleted. Nest boxes can be a valuable tool in aiding the survival of these animals, and it is something we can all become involved in. But be warned, as Associate Professor Rob Morrison explains, there is more to it than you may think.

N.N. BIRKS/AUSCAPE INTERNATIONAL

The introduced European Red Fox (*Vulpes vulpes*).

And our cover story looks at an unwelcome overseas visitor that appears to be here to stay—the European Red Fox. This pest is now as much an urban problem as it is a wilderness one. But how to control it? Clive Marks and Professor Roger Short examine the issues and pose a possible solution.

Away from the urban environment, we take a ringside seat for the clash of the carnivores in Tasmania; explore the plight of the magnificent Golden-shouldered Parrot; visit the breath-taking windswept shores of sub-Antarctic Macquarie Island; and look at the amazing world of male–male competition.

—Jennifer Saunders

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Front Cover
European Red Foxes (*Vulpes vulpes*) were successfully introduced into Australia in the 1870s and have gone on to become one of our biggest environmental problems. Photo by Danegger Manfred/Jacana/Auscape International.

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LETTERS

The forum for readers to air their views about their concerns, past articles and interesting personal events.

Comments from Abroad

I wanted to mention how much I enjoyed seeing your magazine. It took me ages to read the Tasmanian Devil article (Summer 1994–95) because I was at work and everyone who came into my office seemed to have had a lifelong interest in Tasmanian Devils and had to hear all about them. I don't know what it is about those little guys that captivates people, but I too have always liked them. I also found the medicinal frog article fascinating (Autumn 1995). The magazine strikes an interesting balance between scientists and laypeople. I got the feeling I was peeking into a scholarly journal yet it was all so interesting, and I understood everything even though I haven't taken a science class since grade 8.

—Paula Costello
Toronto, Canada

The Truth About Tarantulas

In the Winter 1995 issue of *Nature Australia*, there is an article by Uwe Proske titled "Itch, prickle and tarantulas". I would like to make a correction to the text under the Mexican Red-kneed Tarantula photo on page 57. The caption states that the long, fine, light-coloured hairs on the spider's abdomen are urticating hairs. This is not true. The long hairs are not urticating hairs; they are guard hairs, which are sensitive to air movements and vibrations. The short, velvety darker hairs that resemble the fur on a short-haired dog are the urticating hairs. Anyone who has ever owned one of these tarantulas can tell you that in time a bald area frequently forms on the back upper surface of the abdomen, especially if the spider is irritated frequently. On the same page the article states that "The spider lifts one of its legs and brushes it rapidly across the abdomen, releasing a small cloud of hairs". This species of spider, *Eualthus smithi*, more often uses both hind legs at the same time, brushing alternately, to brush and break off the small hairs, and the resulting small cloud of fine hairs is usually visible to the naked eye.

Recently in Calgary, Alberta, a child had to have a serious eye operation to remove a tarantula's urticating hairs. The boy had held the spider near his face when the spider released the urticating hairs. The urticating hairs are shaped like small porcupine quills; that is, they are barbed at one end. They are attached to the abdomen but, just 100 micrometres or so from the surface of the abdomen, there is a thinned area. The hair breaks off readily at this point. Under the microscope, the surface of a bared abdomen looks like the face of a man who has not shaved for several days.

Finally, the stance or position of the spiders in the pictures in this article appears to be peculiar, almost as if the spiders were cooled or drugged to prevent them from moving before the shots were taken. This is especially true of the Mexican Red-kneed Tarantula and the Australian Whistling Spider. The colours of the Mexican Red-kneed Tarantula suggest that it has only recently moulted.

—Robin Leech
Alberta Biological Company
Canada

RIC BOLZAN/NATURE FOCUS

A Mexican Red-kneed Tarantula having just moulted.

Naming the Wollemi Pine

After reading your Rare & Endangered article on the Wollemi Pine (*Nature Aust.* Spring 1995), the following question came to mind: if the Wollemi Pine (*Wollemia nobilis*) is thought to belong to a genus previously known only from fossil records of Tasmania and New Zealand, then why has it been described as a new genus?

—E. Schmutz
Collinswood, SA

There are no priorities for fossil names over living names. Only if we are 100 per cent sure that the living specimen is iden-

The Great Bowerbird is a skilled mimic of a wide variety of sounds ranging from the call of another bird to a conversation over a two-way radio.

tical to the fossil do we assign it to the fossil genus. In the case of the Wollemi Pine, the leaves are very similar (although not 100 per cent identical) to fossil leaves in the genus Araucarioides, *and the pollen is most like the fossil pollen in the genus* Dilwynites, *both of which occur together in Tasmanian and New Zealand deposits. Because we cannot be certain that the new pine is the same as either of these fossils, (or even that the fossil leaves and pollen are not actually from the one plant), we must place it in a new genus.*

—G.H.

Supine Stitchbirds

I presume Stitchbirds were not embarrassed by the voyeurism that led to the description of their mating in the Winter 1995 issue of *Nature Australia*. However, if the female Stitchbird lies prone, it would be impossible for the male bird to adopt the missionary position. Being a chronic selector of pediculous ova [nit-picker], I must point out that the hen would have to be supine. My thanks to you for the production of an invariably interesting magazine.

—Pat Flecker
Townsville, Qld

Magnificent Mimics

I wonder how many of your readers have had a chance to make observations of the Great Bowerbird (*Chlamydera nuchalis*). As far as I know, it ranges from northern Queensland to the Pilbara in Western Australia and is a superb mimic of other bird calls. It appears to make a repertoire of these other bird calls for use in its mating procedure but I've also noticed it uses the calls of particular species in specific situations to deter potential enemies without the need for direct confrontation. Recently I encountered a puzzling situation while out walking around the hills and creeks surrounding the town here. Having pulled up and dismounted from my motorcycle, I was alarmed to hear rocks being thrown into a steel container apparently directly above my position at the bottom of a steep hill. I knew of a slate quarry a short distance away and thought someone was throwing rocks recklessly into a trailer. The sound was accompanied by a garbled voice over a two-way radio as if a mining company vehicle was also present. On looking up I noticed a Great Bowerbird dart from the oak tree under which I'd parked and fly a short distance along the creek to another tree. The series of sounds was repeated there and a few minutes later at a third tree.

I could only see one bird so it didn't appear to be part of a mating routine. I wonder whether this particular bird had adopted the sounds as a signature for its claim to a territory. Perhaps I had blundered into the bird's territory and sparked the response. I'd be interested to hear of other readers' encounters with the Great Bowerbird and learning why these birds use calls other than their own. Whatever the reason, I can't help marvelling at the bird's versatility in mimicry.

—L. Barker
Paraburdoo, WA

Bowerbirds of the genus Chlamydera *commonly produce mimicry when approached by a human (or any other potential predator). Females do this when their nest is approached and males do it when approached at the bower. In the case of females, the mimicry produced is mostly that of predatory birds, but may even include the sounds of a cat or human. This is not territorial calling.*

Why do bowerbirds mimic the sound of predators when approached by another predator? We do not know, but if you wish to distract a predator (particularly a territorial one, such as a bird of prey, kookaburra or currawong), there may be no better way than to give the call of that species.

—C. & D. Frith
Malanda, Qld

NATURE AUSTRALIA **welcomes letters for publication and requests that they be limited to 250 words and typed if possible. Please supply a daytime telephone number and type or print your name and address clearly on the letter. The best letter in each issue will receive a $20.00 gift voucher from the Museum Shop catalogue. The winner this issue is E. Schumtz.**

Nature Strips

COMPILED BY
GEORGINA HICKEY

Monkey Yawns

Although common in many vertebrate species, yawning has been poorly studied and much misunderstood. Not so long ago, it was dismissed as a simple respiratory response but research is indicating that, in primates at least, yawning is far more complicated.

One of the most recent studies was led by Bertrand Deputte, from the CNRS in Paimpont, France. Deputte observed two species of Old World monkeys: Grey-cheeked Mangabeys (*Cercocebus albigena*) and Long-tailed Macaques (*Macaca fascicularis*).

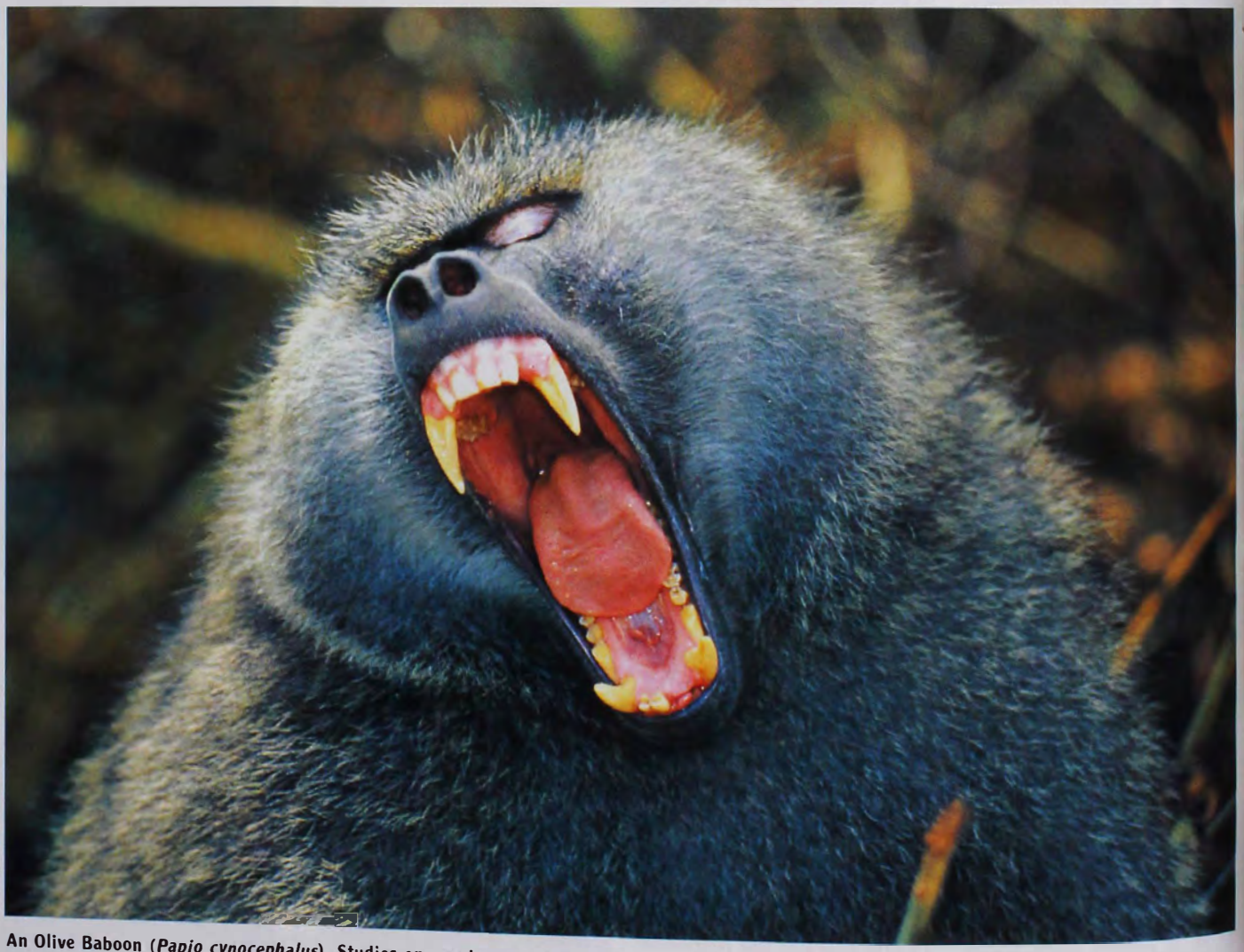
Yawning in these species is similar to that in humans and many other primate species, and is defined as a "maximal gaping of the mouth associated with a deep inhalation". It has three phases: an 'active inspiratory' phase, an 'acme' phase that involves partial or total closing of the eyes, and a 'passive expiratory' phase characterised by a noisy exhalation.

Deputte's study has provided strong support for a primary physiological cause for yawning, related to activity levels. He found that 90 per cent of primate yawns could be labelled 'rest' yawns and accompanied transitions from rest to activity. These were common in both sexes and across all ages. (Yawning in humans is also more common after waking than before sleeping.)

The other ten per cent of yawns were more aptly described as 'emotion' or 'social' yawns. These were triggered by a variety of social stimuli characterised by psychological tension or mild stress and were more frequent in adult males.

Deputte observed that, generally, yawning frequency was higher in males than in females, and increased in older males. This conforms with the results of other research on non-human primates (no sex difference in yawning frequency has been detected in humans). It suggests a relationship between yawning and male hormones, especially testosterone. This has been demonstrated in several studies, notably one that concluded that castration induced a significant decrease in yawning frequency.

—K.McG.



FERRERO-LABAT/AUSCAPE INTERNATIONAL

An Olive Baboon (*Papio cynocephalus*). Studies on non-human primates have shown yawning to be more common in males than females.

JEFF FOOTT/AUSCAPE INTERNATIONAL

How do North American Bighorn Sheep survive the huge impacts experienced during head-to-head combat?

Head Butts: Surviving the Impact

Many animals fight by locking horns and engaging in head to head combat, with no long-term damage to the combatants—no mean feat when you consider that, during combat, the skulls of ferocious fighters like the North American Bighorn Sheep (*Ovis canadensis*) are estimated to experience forces up to 60 times more than that needed to crush a human skull.

But what prevents these animals from cracking their skulls open? According to Carolyn Jaslow (Rhodes College, Memphis) and Andrew Biewener (University of Chicago), animals that butt heads have very efficient shock absorbers built into their skulls.

Goat skulls have a number of specialised features including an enlarged forehead and broadly zigzagging skull sutures (wavy hairline cracks that occur where the bony plates in the skull meet). These sutures were thought to dissipate stress across the skull but, until now, no-one had ever investigated their exact function.

Using the skulls of freshly killed Domestic Goats (*Capra hircus*), the researchers attached strain gauges to some of the bony plates and sutures that make up the skull. They then struck the horns with a two-kilogram weight to simulate the impacts sustained during battle. They found that force is transmitted unevenly over the goat's skull, with the sutures acting as springs or hinges (depending on where they are situated) to prevent the skull from being ripped apart.

All vertebrates have skull sutures, which allow the bony plates to move slightly relative to one another, but the sutures of goats and other head-butting animals are much more widely zigzagging. This increases the strength of the sutures and allows them to absorb much of the shock of impact during head-to-head combat.

—R.S.

Forget the Calamari!

A giant squid (*Architeuthis* sp.), recently found floating off Cape Banks near Mt Gambier, South Australia, has created much public interest and speculation about these monsters of the deep.

Giant squids and octopuses are the stuff of legends. Descriptions of these mythical monsters, the 'Kraken', were usually much exaggerated and hence mostly unbelievable. The fact that giant squids really do exist was generally not accepted until the late 1800s when several strandings of these animals provided indisputable proof of their existence.

Specimens of *Architeuthis* have been recorded from most of the world's oceans, most frequently from northern Europe, Newfoundland, New Zealand and Japan. Nearly all of these records are those of strandings or from the stomachs of Sperm Whales (*Physeter catodon*), which are their major predators. In Australia there have been occasional but unconfirmed reports of large dead squids floating off the southern Australian coast. Some of these sightings are probably of another large squid, *Taningia danae*, which is known to occur in the region but others most likely represent *Architeuthis* species, as confirmed by the recent South Australian find*.

The first confirmed record of *Architeuthis* from Australian waters was a specimen washed ashore at Wingan Inlet, Victoria, in September 1948. It had a mantle (body) length of 2.3 metres but the two prey-catching tentacles and internal organs were missing. Another two specimens were obtained from the stomachs of Sperm Whales at Albany, Western Australia, in late 1978. The largest specimen weighed 280 kilograms. In comparison, the South Australian specimen weighs a mere 86 kilograms. Nevertheless it is still a monster with a head and body length of 1.85 metres, the longest of its eight arms measuring 1.75 metres, the longest tentacle 7.39 metres, an eye orbit of 17

** Since the time of writing a slightly larger specimen was caught off King Island, Bass Strait, and is now preserved in the Museum of Victoria; and an even larger specimen (about eight metres long) was captured 500 kilometres off the South Island of New Zealand.*

THE ADELAIDE ADVERTISER

Martin Von Stanke, a South Australian fisherman, with his prized catch: a giant squid.

centimetres diameter and a total length of just over nine metres. Dissection of the specimen revealed fully formed ovaries with small white eggs, indicating it to be a subadult female.

Just how large these animals can get is open to speculation. Extraordinary sizes have been estimated from sucker scars left on the skin of whales. However such estimates are very unreliable as the scars (unless fresh) grow with the whale. The largest specimen recorded in the scientific literature was found stranded on a beach in New Zealand and measured about 20 metres in total length of which 10–12 metres can be attributed to the tentacles. Specimens as large as this have never been weighed but it is not unreasonable to expect them to weigh up to 1,000 kilograms. The eyes of such specimens would be about 25 centimetres across, which makes it the largest eye in the animal kingdom.

The South Australian animal represents one of the best preserved specimens in any Australian museum and one of the more complete specimens in world collections. Only the tips of its arms, the eyes and half a tentacle are missing. Its relatively good condition is particularly significant because no live adult has ever been captured and then retained for scientific purposes. (Those caught by trawlers are usually cut up for fish bait.) Most stranded specimens are partly decomposed and incomplete, as are specimens from whale stomachs. This animal was so fresh that tissue samples were taken for future biochemical analysis. The specimen is currently being studied at the South Australian Museum.

If you are contemplating going fishing for one of these monsters in the hope of a good feed of calamari, then forget it! The flesh has a relatively high concentration of ammonium ions, making it taste bitter and giving the animal a strong smell. The ammonium ions have a specific gravity lower than that of sea water, thus enabling the animal to maintain its buoyancy without having to expend energy by constantly swimming. The presence of ammonia in the flesh probably explains why dead or dying animals float to the surface and are then often washed ashore.

There are few reports of encounters with living animals, but Mrs Val Martin, an ex-nurse from Mt Barker in South Australia, recently sent me a letter relating how she had tended a chap in his 70s who had large circular scars on his body just like those found on Sperm Whales. When questioned, he claimed to have been a British sailor during World War 2. His ship was sunk but he managed to scramble into a life raft with three others. They drifted about for several days when one day huge tentacles reared out of the water and lashed across the raft. One chap was dragged overboard and disappeared, and the sailor in question was also grabbed but his mates managed to hang on to him while they hacked away at the tentacle. Eventually the squid let go and sank to the depths but, where the cup-like suckers had attached to the sailor's body, the flesh was ripped out. Fortunately they were picked up the following day and he received medical attention, the scars forever a reminder of his misadventure with the 'Kraken'.

—Wolfgang Zeidler
South Australian Museum

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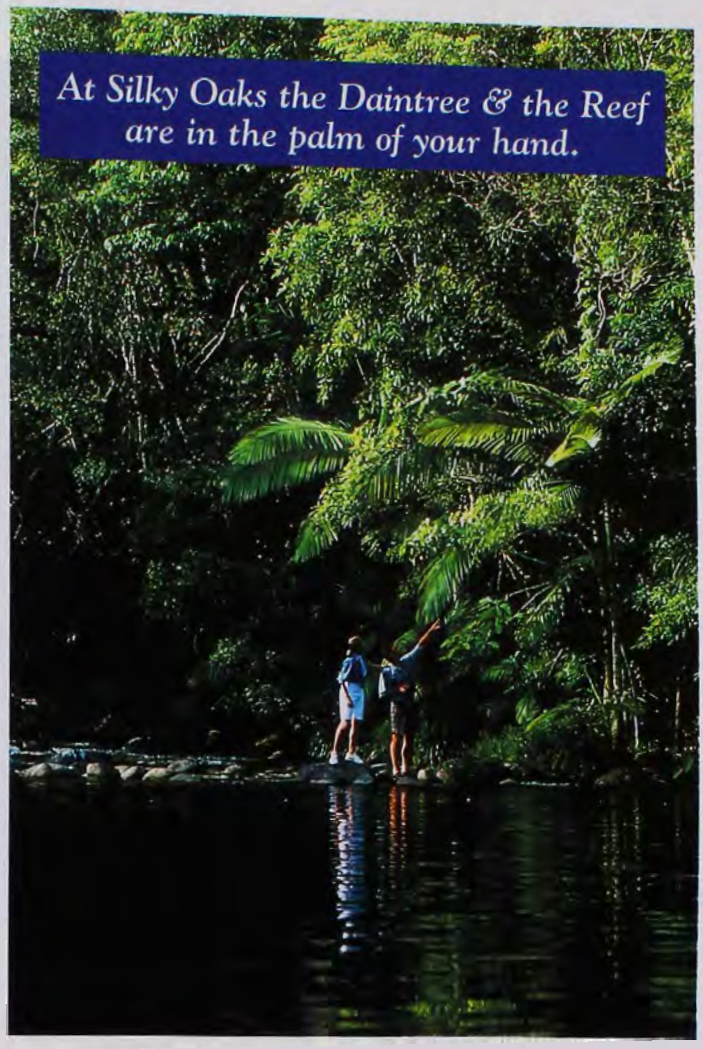

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The Nine-banded Armadillo discriminates who's who by their smell.

An Armadillo Nose its Kin

In many mammal species, social interactions and population structures hinge on family groups, making the ability to know sisters, brothers and other close relatives crucial for survival.

Behavioural scientists believe that even in the relatively asocial armadillos, the ability to discriminate between kin and non-kin could be important. But how would these almost blind and mostly non-vocal creatures identify family?

Studies by James Loughry and Colleen McDonough, from the Biology Department of Valdosta State University in Georgia, USA, have revealed that infant Nine-banded Armadillos (*Dasypus novemcinctus*) can detect and discern the scents of different individuals within their own species. In a series of sniff tests, young armadillos showed that they could discriminate self from stranger, sibling from stranger and self from sibling. These results are surprising since Nine-banded Armadillos are born in litters of genetically identical quadruplets, indicating an environmental influence.

How kin discrimination might benefit an armadillo needs further research. The source of the odours also remains unclear. Armadillos have paired anal glands and the creatures have been observed sniffing each other in this region. Faeces may also be important because armadillos have been seen burying their wastes as if they are using them to scent-mark a home range.

—K.McG.

Free Rides out of Frog Hollow

We generally don't think of frogs as candidates for mother of the year but many are known to go well beyond the call of duty in caring for their offspring. A perfect example is the female gastric-brooding frog that broods the eggs in her stomach and then belches up fully formed froglets.

Now Rudolf Diesel, from the Universität Bielefeld in Germany, and colleagues have discovered another case of an overworked mother frog. They were studying a Jamaican member of the genus *Eleutherodactylus*, the world's largest vertebrate genus, containing over 500 described species. Many of these frogs have done away with the tadpole stage, laying large eggs that develop directly into froglets. In some species one or both parents attend the eggs until they hatch, but females of the species that Diesel and colleagues were investigating, *E. cundalli*, were found to go one step (or one hop) further.

Male *E. cundalli* call from rocks in the entrance passageways of cave systems, and the researchers found one frog almost 90 metres inside the cave. Gravid (egg-bearing) females were soon encountered making their way down the passages, eventually stopping beside their chosen mates. After laying their eggs on small terraces, depressions or crevices within the caves they settled over them, presumably guarding the eggs from predators and fungal attack. Two mothers even bit the end of a pencil used to dislodge them from their brood.

This was the first time a frog had been observed breeding inside a cave, but it wasn't until the eggs hatched that another surprise came. As each egg hatched, the froglet climbed straight onto its mother's back. When all of her offspring were aboard (all 72 of them in one case) she set off for the mouth of the cave, hopping up to a metre at a time without losing any of her passengers.

Although a cave may be a relatively safe place for egg incubation, it does not offer enough food for growing frogs. The researchers therefore suggest that this novel form of frog transport evolved to safely deliver the young outside the cave where food is more abundant.

—G.T.

Spinning to Order

It had always been thought that members of a spider species spun the same type of web and ate whatever happened to blunder into it. But one South American spider was recently observed building two very different webs at various times of the day to accommodate periodically fluctuating food sources.

Parawixia bistriata is a common colonial orb-weaving spider found in Brazilian savanna vegetation. Each day at sunset all the members of each colony simultaneously spin small, finely meshed webs to catch their staple diet of small flies. But during a three-year study of the foraging and social behaviour of *Parawixia*, Cristina Sandoval (now at the University of California, Santa Barbara) noticed that each year during September, most of the normally sunset-active spiders constructed webs during the day as well. Even more unusual, these daytime webs were up to three times the size of the normal sunset webs and had a much larger mesh.

When she compared web size and architecture with the size of the prey captured,

Sandoval found that construction of the larger webs coincided with the capture of termites. Presumably the daytime web's bigger mesh is more effective at catching these much larger insects. Also, the larger webs were spun only when termites swarmed, while the smaller webs were spun daily, at sunset, when tiny flies had their peak of activity.

Previously researchers had assumed that a species' web size varied only in response to physical factors, such as restricted space, wind, rain etc. *Parawixia bistriata*, however, seems to be a specialised predator that is able to adjust its web size according to the type of prey available at the time.

—R.S.

To meet with success, the sperm of the Grey Short-tailed Opossum must swim head-to-head.

Double or Nothing

Synchronised swimming isn't only a macro phenomenon of humans and fish. It also occurs in the Lilliputian world of sperm. When sperm of South American opossums race up the female's reproductive tract, they usually swim in pairs with their heads side by side, flicking their tails in time. Harry Moore from Sheffield University, UK, and David Taggart from Monash University in Melbourne believe this may help them get through the thick mucus lining the female opossum's reproductive tract.

To investigate, the researchers collected sperm from the Grey Short-tailed Opossum (*Monodelphis domestica*) and used a technique called 'computer-aided semen analysis', normally used in the study of human sperm, to measure how fast the sperm swam, both singly and in pairs. They varied the viscosity of the mucus through which the sperm swam to see if this affected sperm speed.

They found that at low viscosities there wasn't much difference: lone sperm and paired sperm swam equally well. But when the going got tough, the lone sperm just couldn't compete. They swam in circles with their heads bent to one side while their paired compatriots raced on ahead. The researchers' theory is that, in pairs, the sperm are able to generate the forward thrust they need to get through the thick mucus.

The sperm of Australian marsupials also have thick mucus to contend with, but they get through it in other ways. For instance, rather than pairing up, the sperm of bandicoots and dasyurids have evolved a more efficient, snake-like swimming stroke, which can produce speeds up to six times that of human sperm.

—C.B.

COURTESY D.A. TAGGART

Sex (or Lack of It) in Mole-rat Society

Talk about a dictatorship! In the underground colonies of the highly social Damaraland Mole-rat (*Cryptomys damarensis*) reproduction is a privilege, not a right. At any one time, only one female and one or two males are reproductively active. The single reproductive female or queen chooses her consort, courts him in a curious ritual involving head mounting and rapping of the hind feet, and then remains paired with him for many years.

The Damaraland Mole-rat, like its better-known relative the Naked Mole-rat, has a social system very like that of certain bees, ants and, more particularly, termites where only a few colony members reproduce, the others carrying out the more menial work of gathering food and caring for the young. This system is known as eusociality and these two species are the only eusocial mammals we know of to date.

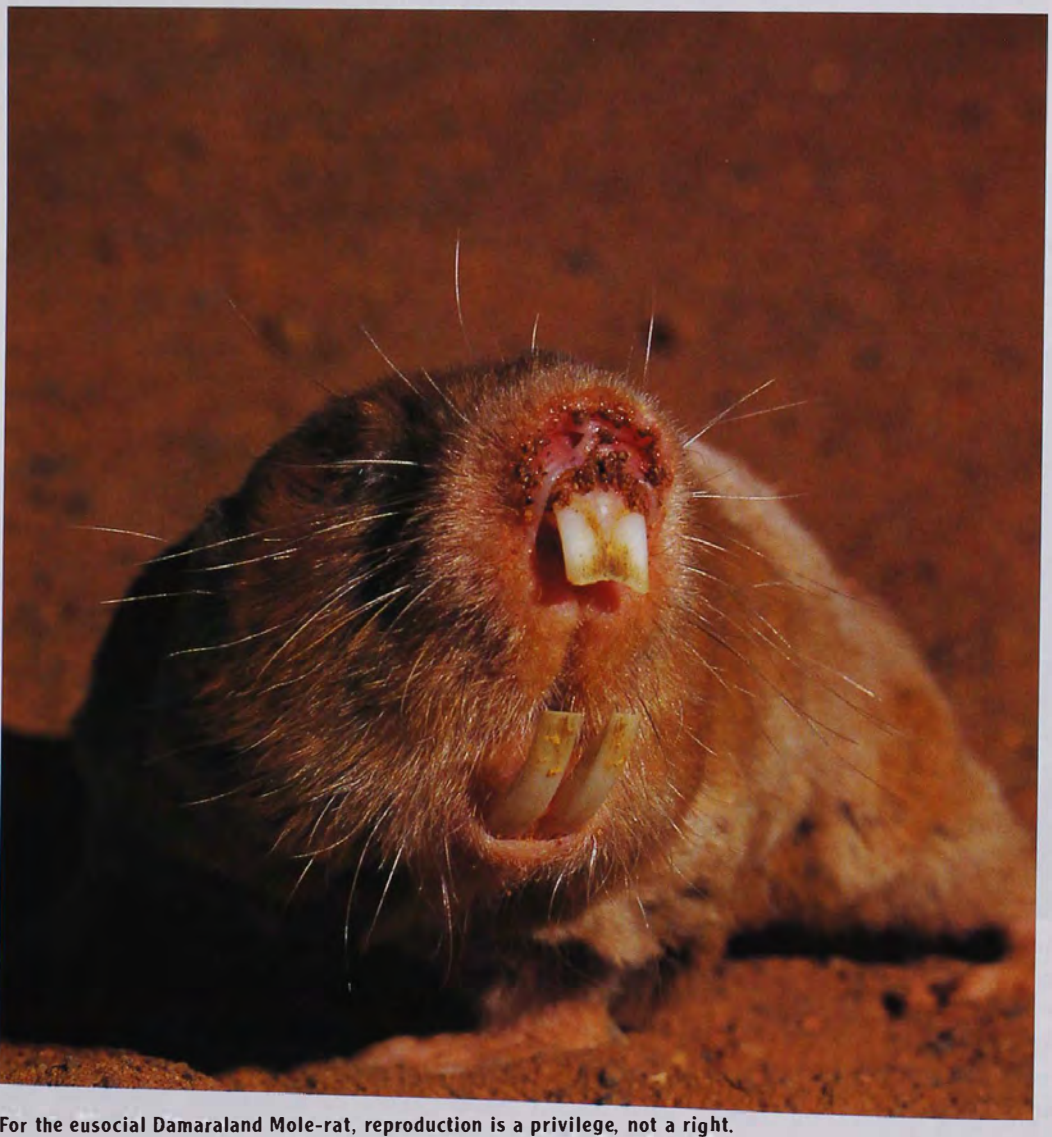
Nigel Bennett, formerly of the University of Cape Town and now at the University of Pretoria in South Africa, has set up his own colony of 12 Damaraland Mole-rats in a Perspex burrow system so that he could peer into the private lives of these bizarre animals. He wanted to know just how the reproductive activity of the other mole-rats was being suppressed.

Once a week for two years Bennett collected urine samples from every colony member and analysed it for concentrations of the sex hormones testosterone and oestrogen. He found that the non-reproductive females had low concentrations of oestrogen and consequently did not ovulate. As long as there was a reproductive female in the colony they were rendered 'infertile' and never participated in courtship or copulatory behaviour.

The males, on the other hand, all showed the same concentrations of testosterone, whether they were in breeding favour or not. All of the male mole-rats were capable of producing sperm at any time. It appeared that the only thing stopping them was fear of the more dominant reproductive male(s) and the lack of solicitation by the queen.

And why all this elaborate sexual tyranny? In Damaraland Mole-rat colonies the reproductive male and female are the parents of the other colony members and it is thought that reproductive suppression may reduce the chance of incest (with its associated genetic problems) occurring within the colony.

—G.T.



T.P. JACKSON

For the eusocial Damaraland Mole-rat, reproduction is a privilege, not a right.

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COURTESY MICK ELLISON/DVP/AMERICAN MUSEUM OF NATURAL HISTORY

A nearly complete specimen of an *Oviraptor* dinosaur embryo preserved in its eggshell.

From Egg Robber to Caring Parent

In 1923, at Flaming Cliffs in Mongolia, scientists found the first fossil specimen of a rare and unusual-looking dinosaur. It had an upright body and a beak like a parrot but no wings and was on top of a nest of oblong-shaped eggs. The eggs were assumed to belong to the herbivorous dinosaur *Protoceratops*. The beast above them was thought to be a carnivore that had died in a sandstorm while feeding on the eggs. Scientists named it *Oviraptor* (Latin for 'egg seizer').

Now, a recent find in Mongolia's Gobi Desert, at a site just 300 kilometres from Flaming Cliffs, has dramatically altered science's interpretation of that famous fossil scene. Mark Norell, dinosaur curator at the American Museum of Natural History in New York, and colleagues have found a fossil nest dating back about 75 million years ago with a tiny, almost complete skeleton of an *Oviraptor* embryo poking through an egg identical to the ones in that original scene. The dinosaur discovered in 1923, it seems, was tending its own nest and not stealing the eggs of another species.

This discovery illustrates how identification of fossil eggs can only be certain when they are found with embryos enclosed within them.

More recently another *Oviraptor* specimen has been discovered, but this time it is an adult seated on top of a clutch of 15–20 eggs. The dinosaur's legs are tucked tightly beneath its body, and its arms are turned back, encircling the nest in a protective posture. According to Norell, this latest find provides the first direct evidence that dinosaurs took an active role in the care and protection of their offspring, and reveals that the nesting behaviour we see in birds today actually originated long before the rise of the modern species.

—K.McG.

Feeding on Flattened Food

It's a common assumption that snakes only consume live prey (hence the Gary Larson cartoon of a mother snake asking her son to "jiggle Grandpa's rat so it looks alive"). However, recently I came across evidence that this is not always true.

Driving through Queensland's Paluma Range National Park with a colleague one night, we came across a Brown Tree Snake (*Boiga irregularis*) on the road in the process of consuming a Pale-yellow Robin (*Tregellasia capito*). This in itself was not unusual as Brown Tree Snakes are well-known predators of birds, being implicated in the decline and possible extinction of more than ten species on the Pacific island of Guam where they were accidentally introduced (see *Nature Aust.* Winter 1995). What was strange was that the bird had clearly been hit by a car and must have been

GEORDIE TORR

Who says snakes only eat live prey? This Brown Tree Snake was caught eating a Pale-yellow Robin that had been killed by a car.

dead when the snake found it.

Behaviour such as this may not be as rare as first thought. Gavin Bedford of the Northern Territory University has documented several cases of snakes consuming road kills, including Keelbacks (*Tropidonophis mairii*) eating frogs (*Litoria dahlii*), and Black-headed Pythons (*Aspidites melanocephalus*) eating goannas (*Varanus scalaris*) so flat that the snakes had to peel them off the bitumen.

After my own encounter I decided to investigate whether or not such behaviour had previously been observed in Brown Tree Snakes and discovered that, although they'd never been found eating road kills, a snake in Guam had snuck into a kitchen and consumed three cooked pork spare ribs.

—G.T.

QUICK QUIZ

1. In which year did the controversial flooding of Tasmania's Lake Pedder take place?
2. How many chromosomes are there in normal human cells?
3. Name one of the Pacific atolls on which the French have carried out nuclear tests.
4. What type of animal is depicted on the ten-cent coin?
5. Off which State would you find Barrow Island?
6. Approximately how long is an El Niño–Southern Oscillation cycle: 10, 20 or 30 years?
7. For what are the colours 'champagne', 'pink' and 'cognac' used to describe?
8. Name the rabbit disease caused by the virus that was accidentally released onto mainland Australia in October 1995?
9. What is another common name for peripatus?
10. What does SETI stand for?

(Answers in Q&A)

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The soldiers, which may account for up to about 15 per cent of the colony, represent a weird concoction of bizarre, monstrous war-heads.

TERMITES: BEHIND THE VENEER

BY STEVE VAN DYCK

MOST OF MY GENERATION who were conceived under a grey army blanket, and subsequently raised and preserved above a mirage of creosote fumes and slopped dieldrin, might find a discussion on termites (white ants) a bit of a yawn. There is nothing much you can teach us about these little rotters. Most Aussies accept and despise termites like rate notices and hangovers; we can no more escape them than vultures can halitosis.

To be fair though (or at least fashionably tolerant), there are some remarkable things that termites do with their mandibles and alimentary canals that should earn them a bit of begrudged respect from us; perhaps even a tear or two when next the pest exterminator visits.

Consider the termite workers. Workers are one special class or caste within a termite colony. A colony may number from as few as 100 individuals to more than a million, depending on which of the more than 2,000 worldwide species of termites it is made up of. Workers are wingless, defenceless foragers; the harvesters, the masticators, the builders, the carers, all rolled into one.

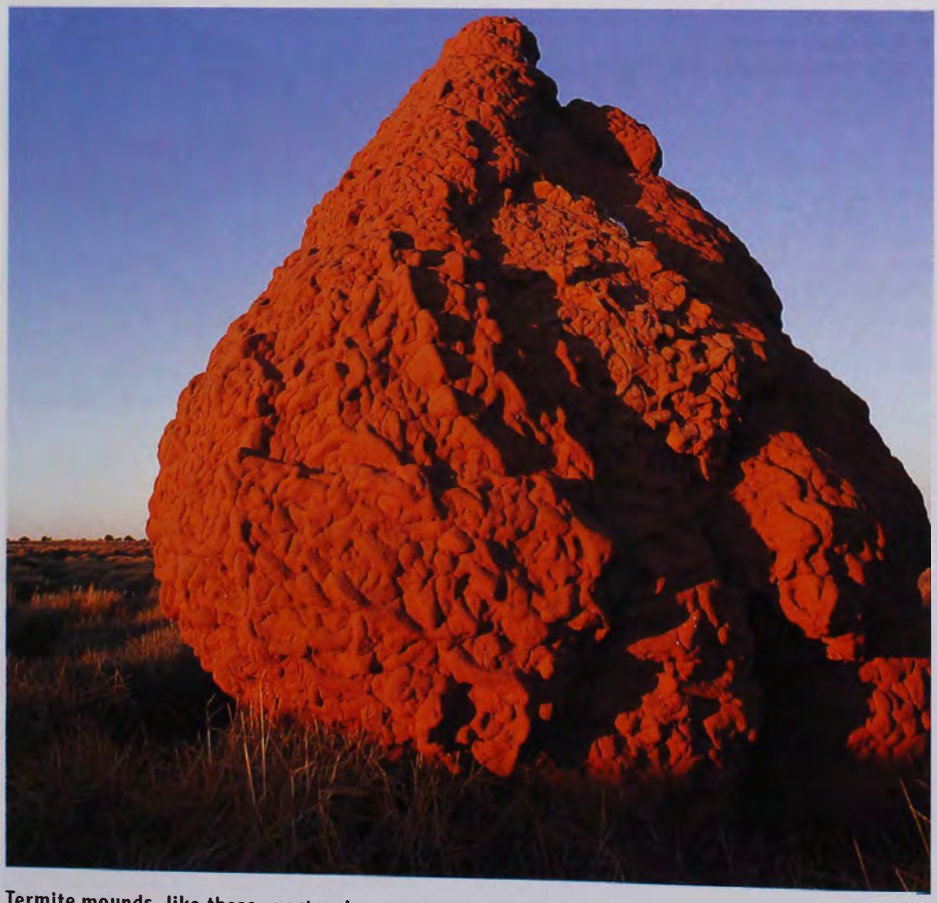
The other members of the colony—the soldiers, the larvae and the reproductives (the king, the queen, stand-by queens and the nymphs, which later develop into the winged, virgin air force)—all depend on the workers for handouts. If a baby termite is hungry, it flicks the antennae of an attendant worker and in so doing is pleasantly rewarded with the contents of the worker's stomach. If any other member of the colony (including another worker) taps on the antennae, it may find its dinner at the opposite end of the counter, where the much relieved worker will offer the contents of its bowels.

Nothing is wasted in white ant cuisine: intestinal micro-organisms sniff a meal where we see only indigestible cellulose; shed skins from growing termites are immediately eaten by the workers; and dead comrades are but bread and butter to the resourceful but compulsive chewers. Not only do the workers trudge up to 250 metres away from the nest to collect grass and eat wood, but they digest it, feed everyone else, tend the eggs and larvae, and, if they are a mounding species, are responsible for the repair and enlargement of the mound with its intricate system of air-conditioned catacombs, ducts and galleries.

Mound building, like all other activities, is done in a state of complete blindness (eyes are usually absent in the workers), and the task, undertaken from the inside out, may take the structure to a height of seven metres (in *Nasutitermes triodiae*) and an age of several decades or more.

Inside these complex structures the relative humidity of the nursery can approach saturation, and temperatures rise and fall slowly without dramatic and damaging fluctuations. The nests of two species of *Amitermes* (known as 'magnetic termites') from tropical northern Australia orient north–south and take on a wedge shape to achieve shading effects that can result in an 80°C difference between the east and west faces of the mound. During the summer wet season, when the termites are unable to seek refuge in the waterlogged soil below ground level, they move between the east and west sides of the mound (up to a metre through), seeking out the cooler side.

The soldiers, which may account for up to about 15 per cent of the colony, represent a weird concoction of bizarre, monstrous war-heads. They too are blind (only the reproductives get to see it all happening), but are equipped with sabre-like needles, snapping scissors, or



JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

Termite mounds, like these spectacular constructions near Lake Auld in the Great Sandy Desert, are the result of the tireless labours of blind worker termites.

hooked, gaffing pincers. Soldiers of *Nasutitermes* species (such as *N. walkeri*, common in east-coastal trees) have a bulbous, pear-shaped head that squirts a sticky secretion onto marauding ants and other nest intruders.

The king, who shares the royal chamber with his queen, is a modest, unimpressive creature compared to his corpulent mate whose body is swollen to bursting proportions. With legs buckling under her, an elephantine abdomen capable (in some species) of pumping out 3,000 eggs per day, and a captive in her own bedroom, this mother of millions can look forward to well over 20 years (even up to 50) of glorious parenthood.

In the words of Maurice Maeterlinck (in *The life of the white ant*, 1927) "...beneath a low, murky dome, there sprawls, like a whale surrounded by minnows, the enormous, flabby, inert, greasy, whitish mass of appalling idol. Thousands of worshipers are incessantly licking and fondling the monster." When she becomes unproductive or dies, her place can be taken by one of the less productive substitute queens waiting in the wings. If there are no stand-by queens, the colony dies with her.

The crowning glory of the termite colony's year comes with the release of the 'flying ants' (alates). Timed around late spring to early summer, or autumn, when conditions are warm and humid, a breach is made by the workers, and the virgin males and females flutter out to begin new colonies elsewhere. The wings that carried them away on their nuptial flight are shed quickly, and are permanently traded for the royal crown. All the nests of a particular species in one area may coordinate a simultaneous lift-off. This is the time of year when, if like us you don't have flyscreens, it's best to eat dinner with the lights out, or with the sucking end of the vacuum cleaner sticky-taped to the ceiling an inch away from the fluoro.

Some of the most extraordinary stories of property loss have termites at their roots. But one told by W. Lavallin Puxley in his *Wanderings in the Queensland bush* (1923) takes the cake. A stockman was apparently caught out in the bush after dark and he lay down to sleep on the ground, wrapping himself up in his blanket. When he woke up, he couldn't move his hands or feet, and he feared his mates had found him, mistaken him for dead and buried him. He tried to struggle free but could not. He was getting stifled by the hot suffocating air around him. "At last in his desperation he shouted with all his force, and mercifully he was heard by one or two men who...had come to look for him.When they found that the sounds proceeded from beneath their feet...they began to dig away the mound...

"At last they caught sight of a human boot, and after a little more digging the buried man sat up. At first he thought it was a practical joke, but when he saw that they were as puzzled as himself to account for the accident it dawned upon them all that it was really due to the action of the white ants, who had begun a nest over his supposed remains." (Just in case the critical-minded might query such rich Australian folklore, I casually asked around work for some sensitive assessment of this story's veracity, and my hard-nosed colleagues willingly worked themselves into a lather of debate. The divided opinions left the arguing entomologists in two camps: the Puxley-detractors, who maintained that Puxley must have been thoroughly plastered when he was told the tale; and the pro-Puxleys, who maintained that the story may well have been true provided the stockman had had two wooden legs and been even more plastered (to the point of paralysis) than Puxley was when he heard it. But at least there was consensus on one point: if you write Australian bush stories or go droving through white ant territory, don't mix your workers and your Walkers!) ■

IRI LOCHMAN/LOCHMAN TRANSPARENCIES

Worker termites from south-western Australia.

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Steve Van Dyck is a Curator of Vertebrates at the Queensland Museum where he has worked since 1975.

TERMITES

Classification
Order Isoptera. 5 families: Mastotermitidae, Termopsidae, Rhinotermitidae, Kalotermitidae and Termitidae.

Identification
Ant-like; workers up to 12.5 mm long (*Mastotermes darwiniensis*), queens up to 30 mm. Well in excess of 300 Australian species. Identification performed on the basis of the soldier caste's head shape.

Distribution and Habitat
In the warmer regions of the world, from the Mediterranean to the tropics. Australia-wide but more abundant in tropical and subtropical Australia. Major pest species not present in Tasmania. Uncommon in rainforests; damage to living trees and timber products greatest in dry inland where moisture is scant. Nests may be ground mounds, arboreal or subterranean.

Food
Wood, wood products, grass, leaves, bark, digested by intestinal micro-organisms in the hind gut through the production of the enzyme cellulase, or by externally grown fungi (fungus gardens).

Life Cycle
Newly hatched larvae take several months to go through 4–7 moults before becoming mature workers, soldiers and alates ('flying ants'). Soldiers and workers may live up to 3 years. Alates leave mature colonies and, as pairs mate, form new colonies.

The Peninsula is touted as one of Australia's last great wilderness areas. How is it that the parrots could be disappearing from an area so unsullied?

GOLDEN-SHOULDERED PARROT

BY STEPHEN GARNETT & GABRIEL CROWLEY

THE GOLDEN-SHOULDERED PARROT (*Psephotus chrysopterygius*) is a little larger than a Budgerigar, the male turquoise, trimmed with yellow and salmon pink, the female green and blue. Once the species occurred throughout Cape York Peninsula, Queensland. Today it persists only near Musgrave in the centre of the Peninsula and in a small area west of Chillagoe. Only a few thousand remain and each year the numbers get fewer.

Why? The Peninsula is touted as one of Australia's last great wilderness areas. How is it that the parrots could be disappearing from an area so unsullied? The reason is that the landscape of the Peninsula was in fact created by humans and it needs skilled human managers to maintain it. And, as for so much of Australia, it is on the management of fire that the landscape and parrot depend.

Judging from the records of European explorers on the Peninsula last century, fires were lit by Aboriginal people whenever it wasn't actually raining. The result appears to have been a complex mosaic of burnt areas, with early fires constraining later fires and protecting fuel that could be burnt still later in the year.

To an extent this fire regime has been maintained by some pastoralists, who began arriving with their cattle in the 1870s. However, when properties change hands it can take years before the new owners understand what will happen if they don't burn, or how much burning is required. And it is the lack of frequent burning that has brought the parrot to its parlous state.

Golden-shouldered Parrots appreciate all types of fire. During the dry season, fires expose grass seed so it can be found quickly. This allows the parrots to spend most of each day perched safely in trees where, despite their bright colours, their camouflage is almost perfect.

Golden-shouldered Parrots appreciate all types of fire. During the dry season, fires expose grass seed so it can be found quickly. This allows the parrots to spend most of each day perched safely in trees where, despite their bright colours, their camouflage is almost perfect. Even hot fires at the end of the dry season do not burn all the fallen seed, instead exposing a new area of uneaten seed. Later, during the early wet season, fires kill off the grass seeds that have started to germinate, allowing the parrots to find any that remain. Early wet-season fires also stimulate increased seed production and extend the period over which some important grass species are available. Finally, frequent fires, particularly hotter fires, keep the grasslands open so the parrots are less vulnerable to predators.

This last function of fires seems the most important for the parrots. Grasslands that are not burnt often enough are invaded by tea trees (*Melaleuca* spp.). Although tea tree suckers are prevalent in most grassland, they are usually kept at ground level by frequent fires. After a few years without fire the grassland becomes woodland and only a very hot fire will reverse the process. Even then it is difficult because the more the tea trees grow, the less grass grows beneath them, reducing the intensity of any fire that does come through.

In the middle of the wet season most parrots feed on the edge of increasingly wooded grassy flats. Many feeding bouts are ended suddenly by pouncing Pied Butcherbirds (*Cracticus nigrogularis*). Later in the wet season the parrots excavate their nests in termite mounds beside grassy flats. Over a period of eight weeks a pair of parrots can rear up to six young. Food at this time is plentiful and, although visited only five times a day, the crops of the young parrots are usually bulging with fresh seed. Where the flats have been closed over by tea trees, however, the adults and young are more likely to be killed by goannas or butcherbirds. Overall the rate of predation through the wet season appears to exceed the rate of reproduction and, since at least 1991, the area over which the parrots breed has steadily contracted.

Fortunately the parrots do have friends among the pastoralists of Cape York Peninsula, who also are keen to halt the loss of grasslands, for these are important to cattle as well as birds. In the area where the parrots survive, land managers regularly burn their properties. Others, mainly new arrivals in the district, are keen to learn how. Over the next few years, with help from the Queensland Government, a variety of measures will be tried by these land holders with the aim of restoring the grasslands and reversing the decline of the Golden-shouldered Parrot. This program will have important implications for habitat management over the whole of Cape York Peninsula. Perhaps in time much of the Peninsula will again be occupied by these exquisite little birds. ■

The research by biologists Stephen Garnett and Gabriel Crowley on the Golden-shouldered Parrot was supported by the Queensland Department of Environment and Heritage, the Australian Nature Conservation Agency and World Wide Fund for Nature (Australia).

AUSTRALIAN PICTURE LIBRARY/BOB WALDEN

Only in Australia are the dominant trees pollinated by birds, and only in Australia and nearby lands are the pollinating birds so big.

LAND OF NECTAR

BY TIM LOW

AUSTRALIAN FORESTS ARE exceptionally well endowed with nectar-loving birds and bird-pollinated flowers. More than 70 different honeyeaters and lorikeets are nectar-feeders, and over 1,000 plants are bird-pollinated. South-western Australia alone has more than 600 different plants with flowers attended by birds.

By comparison, Europe has no bird-pollinated flowers at all. Outside Australasia, bird pollination appears to be best developed in the South African fynbos heaths, where there are more than 200 bird-pollinated plants, but only six major bird pollinators. Overall, southern Africa has 22 sunbirds and sugarbirds, compared to 67 nectar-feeders in the eastern States of Australia, an area of similar size. Africa's largest sugarbird is less than one-third the weight of Australia's Rainbow Lorikeet (*Trichoglossus haematodus*).

Bird-pollination has been central to Australia's evolution as a distinct continent. It involves dominant plant genera—*Eucalyptus, Grevillea, Banksia* and *Melaleuca*—and two of our major bird families, the honeyeaters (Meliphaidae) and parrots (Psittacidae, particularly the lorikeets). Only in Australia are the dominant trees (eucalypts) pollinated by birds (although not exclusively), and only in Australia and nearby lands are the pollinating birds so big. Our lorikeets and large honeyeaters are enormous compared with the tiny hummingbirds, sunbirds and honeycreepers that pollinate overseas. They are also exceptionally common and conspicuous in the fauna.

PHOTOS: TIM LOW

Around Sydney, Aborigines sucked nectar from the scarlet blossoms of the Honey Lambertia (*Lambertia formosa*), a shrub pollinated by honeyeaters.

Swamp Banksia (*Banksia dentata*) was the main source of nectar for Aborigines in northern Australia. Women with coolamons could harvest up to half a litre of its nectar in a single outing.

John Gould was one of the first Europeans to witness the huge and rowdy congregations of nectar-feeding birds that characterise Australia. In 1845 he wrote of the lorikeets: "The incessant din produced by their thousand voices, and the screaming notes they emit when a flock of either species simultaneously leave the trees for some other part of the forest, is not easily described, and must be seen to be comprehended." Only in Australia, New Guinea and nearby islands do nectar-feeding birds create spectacles like this.

Biologists have yet to explain why nectarivory (nectar feeding) by birds is so prevalent in Australia. It may date back at least 50 million years, for a fossil banksia cone of that age (*Banksia archaeocarpa*), closely resembling the living Slender Banksia (*B. attenuata*), has been found in Western Australia. One suggestion is that nectar-feeding birds proliferated in the absence of large social bees. Birds are probably more effective pollinators than insects or wind, and the adoption of bird pollination by eucalypts probably contributed to their rapid evolution into hundreds of species in the recent past.

Australia's Aborigines benefited greatly from the proliferation of bird-pollinated flowers. Such flowers produce copious nectar to attract their very large pollinators. Some banksias secrete so much honey it drips to the ground below. Aborigines harvested this treat by sucking the flowers or by soaking them in bowls of water.

The flowers harvested included those of banksias (*Banksia* species), tea trees (*Melaleuca* species), eucalypts (*Eucalyptus* species), grevilleas (*Grevillea* species), hakeas (*Hakea* species), grasstrees (*Xanthorrhoea* species), Waratah (*Telopea speciosissima*), Wild Bauhinia (*Lysiphyllum gilvum*) and Parrot Bush (*Dryandra fraseri*).

In Western Australia, where bird-pollinated flowers are most prolific, Aborigines doted especially upon the blossoms of banksias. Colonist G.F. Moore told of the "honeysuckle tree" (a banksia) producing an "abundance of honey, which the natives are fond of regaling upon, either by sucking or soaking the flowers in water". Another colonist wrote in 1839 that "the natives, men, women and children live for five to six weeks particularly upon the honey which they suck from the flowers of this fine tree". Western Australian Aborigines also brewed alcoholic drinks by fermenting banksia and grasstree nectar in bark vats.

Not surprisingly, nectar was a more important human food in Australia than elsewhere in the world. The only other region where it appears to have been significant was southern Africa, where the nectar of proteas was gathered for food and medicine. In Zimbabwe the flower heads of Northern Protea (*Protea angolensis*) or 'Sugar Bush' were simmered in water and the liquid reduced to make a traditional syrup, drunk as a treat or taken as a cough mixture. In South Africa, cough syrup called 'bossiesstrop' was made from *P. repens* and *P. speciosa*.

A similar remedy was made in New South Wales from banksia blossoms, members of the same plant family (Proteaceae). Colonial writer Dame Mary Gilmore told of how "bottlebrush (banksia) soaked in soft water yielded syrup for sore throats and colds". ■

Golden Grevillea (*Grevillea pteridifolia*) was a nectar source for Aborigines in northern Australia. It is one of the parent species of the popular cultivar Grevillea 'Sandra Gordon'.

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Tim Low is a Brisbane-based nature writer, photographer and consultant. He has visited southern Africa to observe proteas and sunbirds.

Penguins are very conservative in their habits and, once a place has been selected to breed, they return there for life.

URBAN PENGUINS

BY MIKE CULLEN, NEIL BLAKE & MARK BICKHAM

PENGUINS ARE CUTE, AND THIS IS certainly one reason why half a million visitors a year come to watch the Penguin Parade at Phillip Island, Victoria. Every night of the year at dusk, between 100 and 2,000 Little or Fairy Penguins (*Eudyptula minor*) come ashore to return to their nesting burrows in the sandhills. They have become accustomed to the floodlit beach and crowded public viewing stands they pass on their way. Three things have made the Penguin Parade special: the tolerance of the birds, built up over the years with gradually increased illumination of the beach; the accessibility of the colony, less than two hours by road from Melbourne; and good management of the colony, balancing the well-being of the birds with providing the public with a unique wildlife experience.

KATHIE ATKINSON

A Little Penguin on its nest in a rock crevice. These penguins usually lay two eggs and both parents are involved in raising the young.

HANS & JUDY BESTE/AUSCAPE INTERNATIONAL

What is less well known is that Little Penguins nest in other colonies along the southern coast of Australia and New Zealand, especially on islands where they are (or used to be) safer from introduced mammalian predators like dogs, cats and, worst of all, foxes.

A surprising discovery in 1974 was that there was a colony at St Kilda, only five kilometres or so from Melbourne's Central Business District. Gavin Johnstone from the Department of Science's Antarctic Division, then located in Melbourne, was walking on the breakwater one day and noticed a Little Penguin under a rock. Follow-up observations by another ornithologist showed there were a couple of nesting pairs. And there the matter stopped, reported as a short note in a local bird journal but quickly forgotten by most people, and deliberately kept a secret by the penguin lovers for fear of possible vandalism.

And so it remained until 1986 when public concern was raised in connection with proposals to develop a marina at St Kilda harbour. One of us (Mike Cullen), who had been involved with research on the penguins at Phillip Island, was asked by the municipality to assess the situation. We made our first visit to the breakwater one evening in June, and found 38 birds there, one pair with an egg, and another bird with a six-pack yoke (which we removed) around its neck. Since then, a small group of half a dozen volunteers have been visiting the breakwater fortnightly to band and weigh birds, check on numbers and monitor the breeding situation.

The breakwater is comprised of large boulders and smaller rocks, and the penguins inhabit the crevices among these. By day there's nothing to be seen, with most birds foraging at sea and those that remain hiding well within their burrows. By night many of the birds are ashore but move quickly to the safety of their

Every night, the penguins at Phillip Island come ashore onto a floodlight beach and make their way to their nesting burrows.

burrows. Their braying calls can sometimes be heard from deep among the boulders. Working always at night, we banded all the birds we could reach with individually numbered flipper-tags, and found after a few months that we encountered few new birds. This suggested we had marked most of the birds, or at least the ones we could get to. By then we had banded over 100 penguins and we took this to be the minimum population size at that time. Many of them we encountered again and again, nearly always in the same burrow or within a metre or two from it, but not on every visit.

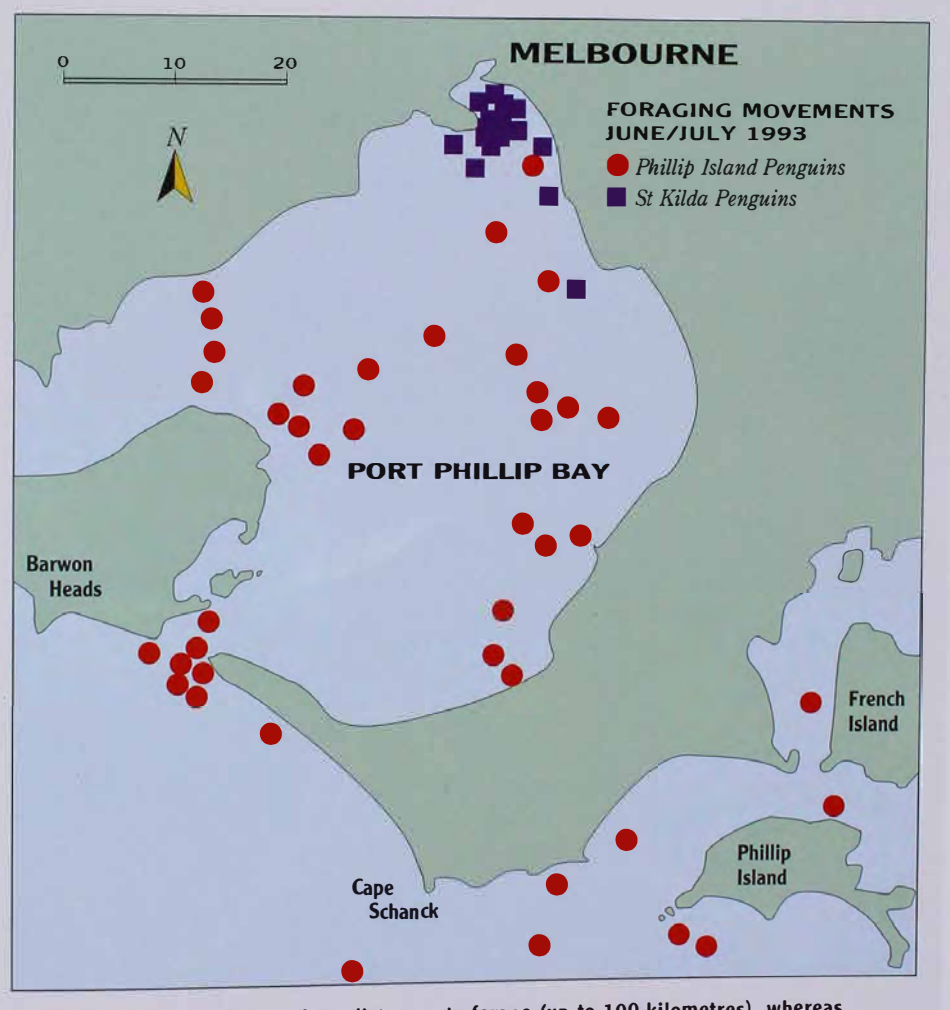
All species of penguins are adapted to live at sea and do not need to return to shore every night. At particular times in their lives they may be at sea for months at a time. Some Little Penguins are present at St Kilda throughout the year but numbers are greatest towards the end of the year when breeding is at its peak.

THE ST KILDA COLONY HAS PROVED TO BE interesting for a number of reasons, some connected intrinsically with its location, others because of its differences from the much larger colony at Phillip Island, 120 kilometres as the penguin 'flies' (literally) under water.

After nine years of collecting data we know that the breeding season of the St Kilda penguins is somewhat longer than at Phillip Island: birds start nesting earlier (June or July rather than August or September), with birds from both colonies continuing to lay eggs until the end of the year. This difference is surprising, given that factors like day length, commonly believed to determine the onset of the development of breeding in birds, are almost identical. Perhaps it's the bright lights of St Kilda, but then the lights at the Penguin Parade don't seem to have the same effect.

The breeding season is long enough to allow birds to raise more than one brood of young (two eggs are almost always laid, but one chick commonly dies before fledging). At around six weeks of age the chicks are ready to leave the nest and go to sea. Fledgling chicks are heavier at St Kilda than they are at Phillip Island. This weight is an important indicator of their future survival and it may be a clue to the difference between the two colonies. Little Penguin chicks are normally fed most nights by one or both parents and put on weight accordingly. If the parents bring

We made our first visit to the breakwater one evening in June, and found 38 birds there, one pair with an egg, and another bird with a six-pack yoke around its neck.



Phillip Island penguins travel long distances to forage (up to 100 kilometres), whereas St Kilda penguins tend not to venture more than 20 kilometres because of a good local food supply. This map shows the foraging movements of penguins from St Kilda and Phillip Island in June and July 1993 as determined by radio-tracking.

MARK BICKHAM

The centre of Melbourne is only a few kilometres from the penguin rookery.

small meals or none, the chicks grow more slowly and will eventually die. We suspected that St Kilda penguins lived closer to their feeding grounds than the birds of Phillip Island did. This would allow them to make shorter foraging trips and so digest less of the food they have caught before feeding it to the chicks. They would also be able to return more frequently. St Kilda adults also weigh more than their counterparts at Phillip Island, as might be expected if they expend less energy travelling to and from their feeding grounds.

Mark Collins, based at the Phillip Island Penguin Reserve, has been tracking Little Penguins at sea using tiny radio-transmitters attached to their backs. His results confirm that St Kilda birds spend most of their time foraging at the north end of Port Phillip Bay,

HANS & JUDY BESTE/AUSCAPE INTERNATIONAL

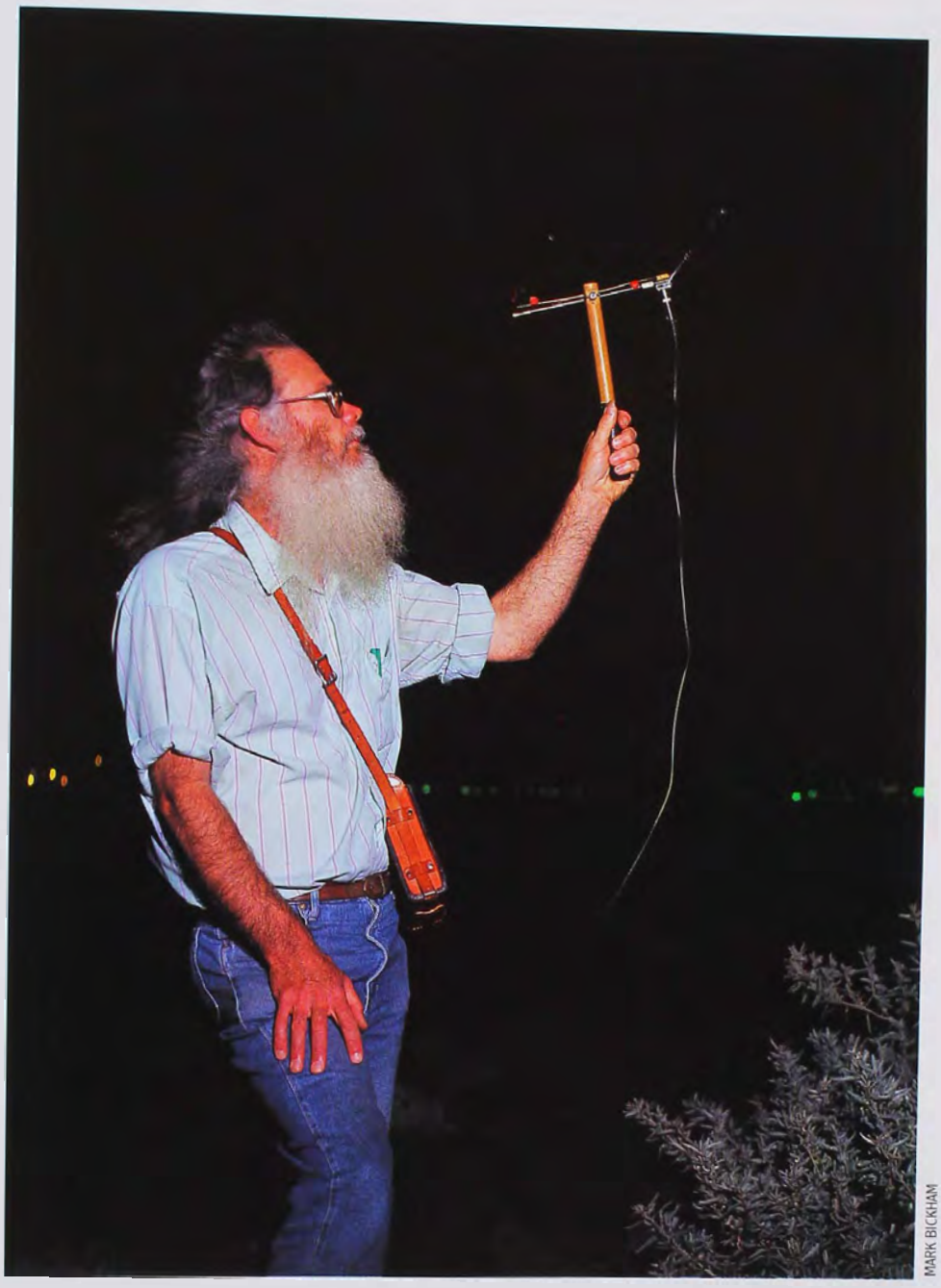
Despite being perfectly adapted to living at sea, many Little Penguins choose to come ashore in the evening and spend the night asleep in a burrow.

within 20 kilometres or so of their home colony, while Phillip Island birds may travel over 100 kilometres to forage (see map). It can be no coincidence that the northern corner of Port Phillip Bay is also the most productive area for commercial fishermen catching Pilchards (*Sardinops neopilchardus*) which, together with Australian Anchovies (*Engraulis australis*), are the principal food fish of Little Penguins in Victoria.

THE PROXIMITY OF THE ST KILDA COLONY to the metropolis highlights the anthropogenic dangers, both organic and inorganic, facing penguins. With docks only ten kilometres away and boat traffic all around, there is the hazard of oil spills. So far no large spills have been detected. A more obvious danger includes the massive amounts of plastic discarded on beaches or washed into the bay from street drains. We see these affecting the penguins in two ways. The six-pack yokes can snag around their heads, and discarded fishing line can wind itself around their legs and cut off circulation, resulting in loss of a foot if it tightens around the limb. Such birds sometimes survive, and we have even had a one-footed bird raising chicks, but it had to hop up the rocks with the support of its wings. Another bird, a female with fishing line so deeply embedded we could not remove it, was taken to the casualty department of the Alfred Hospital where the line was cut out. We then returned her to the breakwater and have seen her a number of times since. One less fortunate bird swallowed a fishing sinker and died of lead poisoning.

The colony is also potentially threatened by feral and not so feral animals. Foxes inhabit the foreshore of St Kilda 600 metres away but we have found no evidence of their scats on the breakwater. More worrying, dogs with and sometimes without their human owners go out onto the breakwater. Notices forbidding dogs are ineffective. A wire fence expressly set up to discourage people venturing onto the colony area is only partially effective. However, in spite of this lack of success, we have seen little sign to date that humans or their pets have harmed the penguins in their underground hiding places.

Another potential threat is the impact of major maintenance works on the breakwater and, in addition, a proposal to construct a 10,000-square-metre hard stand (for storing yachts out of water) in an adjacent area of the harbour. We do



MARK BICKHAM

Wildlife officer Neil Blake radio-tracking Little Penguins during a three-month research project on the colony at St Kilda.

LITTLE PENGUIN
Eudyptula minor

Classification
Family Spheniscidae (penguins)

Distribution
New Zealand and southern Australia, approx. from Coffs Harbour to Perth. Mostly on islands.

Identification
Smallest species of penguin, indeed the smallest fully warm-blooded animal to live in the sea. Av. weight 1,100 g, with males slightly larger than females. Sexes similar in appearance, with blue-grey upper parts, white below.

Biology
Nests in burrows or under vegetation throughout most of its range, and usually in colonies. Two eggs laid, with often only one chick fledging. Both parents share incubation of eggs and feeding of young. Mature at 2 or 3 years of age. Av. life span after maturity is a further 3.5 years, although some individuals have survived over 20 years in the wild.

Diet
Mainly fish with some squid and krill.

KATHIE ATKINSON

Little Penguins are the smallest of all the penguins, and the only one to breed in Australia.

not know to what extent the penguins will be affected by such developments. While it may be possible to minimise the impacts of the construction phase, the longer-term effects of the developments cannot be gauged with certainty. Such proposals require rigorous scrutiny, and the community benefits claimed must be measured against the possible effects on this unique colony.

The breakwater in which the colony is situated was built for the yacht races of the Melbourne Olympics in 1956. No-one is sure exactly when the first birds arrived. Nothing is documented until 1974, as already mentioned, although local fishermen have told us they saw penguins coming ashore before then. The colonists probably came from Phillip Island. From extensive banding and radio-tracking studies it seems that every year penguins from Phillip Island come into Port Phillip Bay to feed in the winter months, and some of these evidently found the breakwater an attractive place to nest, despite the presence of humans. Penguins are very conservative in their habits and, once a place has been selected to breed, they return there for life. The St Kilda population is probably now virtually self-sustaining. But a low level of interchange still takes place with the colony at Phillip Island. We have seen two birds breeding at St Kilda that had been banded as chicks at Phillip Island, and one St Kilda bird has made the reverse journey.

Over the last eight years the colony appears to have increased slightly, even allowing for the fact we have become better at locating the birds. Its future will no doubt depend on three conditions: that the food supply remains plentiful, that human interference does not impede life among the boulders, and that an oil spill does not wipe out the population. None of these can be taken for granted and an active local conservation group campaigns so that the penguin colony will survive and flourish. ■

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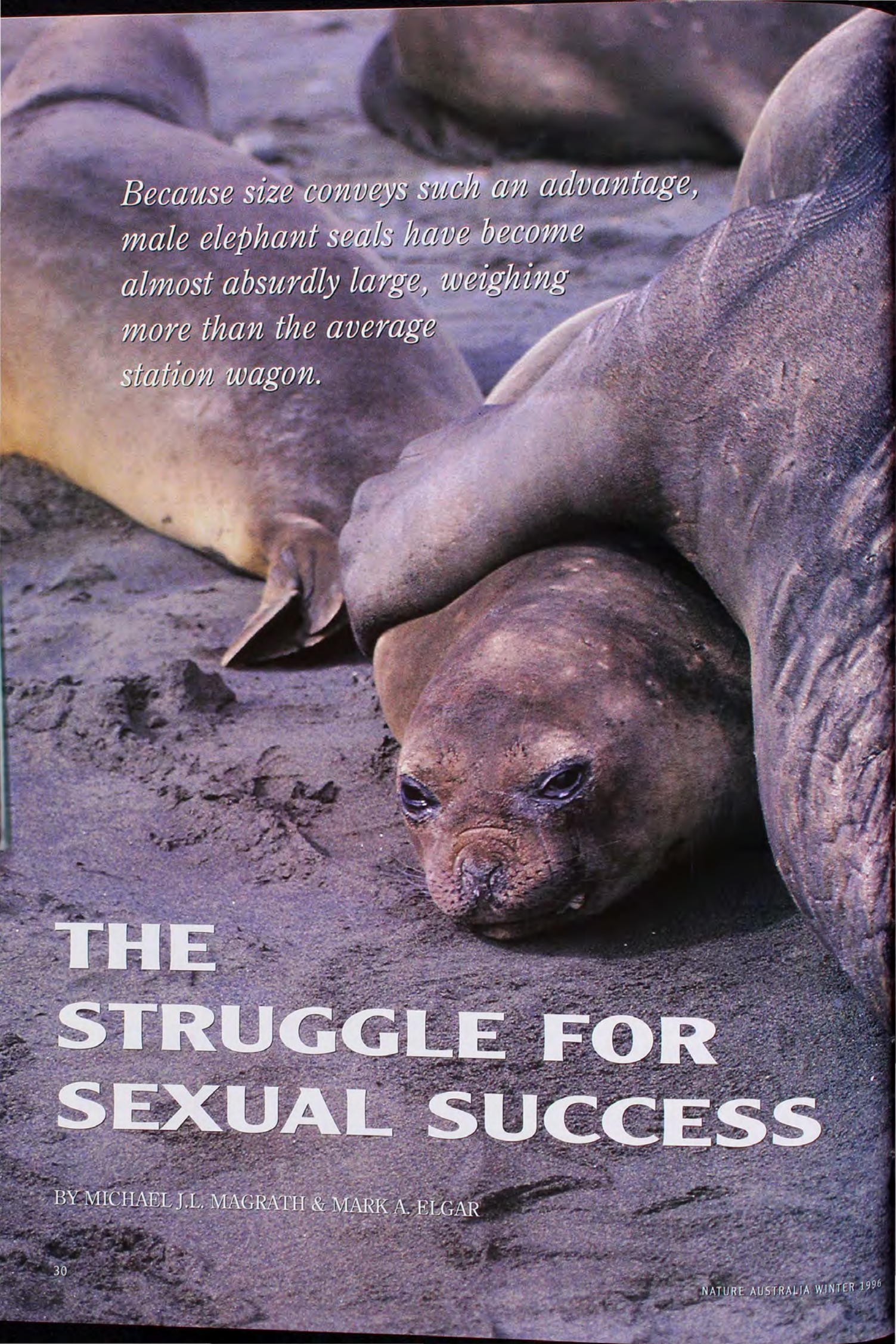

Because size conveys such an advantage, male elephant seals have become almost absurdly large, weighing more than the average station wagon.

THE STRUGGLE FOR SEXUAL SUCCESS

BY MICHAEL J.L. MAGRATH & MARK A. ELGAR

Life in a world where size is everything: the male Southern Elephant Seal (*Mirounga leonina*) with one of the females from his harem.

DR NICK GALES/LOCHMAN TRANSPARENCIES

BIG BOOFY BLOKES JOSTLING ONE another around is a common weekend scenario on football fields around the world. These encounters usually involve displays of strength, stamina and skill, with the aim of out-scoring the opponent and basking in the spoils of victory. At best, some folk find such human behaviour unusual; but out in the scrub, contests between males are rife in all number of species. In fact, competition between males is an extraordinarily widespread phenomenon across the animal kingdom, and even occurs in some plants. While the intensity of these male contests can surpass anything one might see on a football field, they can also be more subtle, occurring in remarkably diverse ways, many of which have only recently been appreciated by biologists. Unlike sporting contests, the objective of these encounters is usually of a more amorous nature: to gain mating opportunities with females, and ultimately for genetic representation in the following generation.

Competition between males is an extraordinarily widespread phenomenon across the animal kingdom, and even occurs in some plants.

Perhaps the most obvious form of competition between males involves threat displays and physical combat. Male elephant seals (*Mirounga* spp.), for example, engage in long and bloody battles with rivals in order to establish and maintain dominance in the breeding grounds. As females gather in large groups at these breeding sites, males that triumph in the battle for dominance will often gain mating access to hundreds of females. The majority of males, however, remain on the periphery of these female aggregations and are unlikely to father any young that season. Because size conveys such an advantage in these dominance contests, male elephant seals have become almost absurdly large, weighing more than the average station wagon, and up to seven times the weight of the female. Larger male body size is common in mammals, but also occurs in many birds, reptiles, fish and amphibians.

Males of some species have a range of more sophisticated features, such as horns, antlers and tusks, that function specifically to assist them in combat with other males. The remarkable sword-like tooth of the male Narwhal (*Monodon monoceros*), for example, may grow up to three metres long or more than half its own body length. Large scars on the forehead of males are testimony to its use in fights with other males. Although antlers and tusks could aid their owners in defence against predators, as do the defensive spines of echidnas, this is unlikely to be their primary function because they are not usually possessed by females, and are often lost by the male outside the breeding season.

Specialised characters that assist the members of one sex to gain mating access to members of the opposite sex are referred to as secondary sexual characters. These characters arise through the process of sexual selection, which was first described over a century ago by Charles Darwin. More specifically, characters that assist individuals of one sex to compete among each other for opportunities to mate with members of the other sex, evolve through a process called 'intrasexual selection'. This process is also referred to as 'male–male competition', because males are typically the more competitive sex. The other group of secondary sexual characters, such as the brilliant plumage or extravagant tails possessed by the males of some birds, is believed to have arisen from a second form of sexual selection known as 'intersexual selection' or 'female choice'. The process of female choice was detailed in a previous article (*Nature Aust.** Summer 1994–95) and essentially involves female selection of mates according to the quality of the male's ornaments or displays. In this article, we focus on the process of sexual selection that involves direct contests between males.

PHYSICAL COMBAT IS BY NO MEANS THE only way in which males may compete with one another for mates. Endurance, rather than strength or size, is what counts in some species. In these animals, the most successful individuals are those that can remain at the breeding sites for the longest. Typically, attendance at mating sites is incompatible with feeding activities, so males with the greatest powers of endurance are those that are in superior body condition.

Endurance contests have been taken to an extreme in antechinuses (*Antechinus* spp.) where males remain at the mating sites, often great distances from their foraging grounds, until their death. When breeding commences, males congregate (or form leks) at particular trees where they are visited by females. The longer a male can remain at the lek site, the more matings he is likely to secure. By the end of the mating period, all males in the population will die of stress-related diseases, to be replaced in the following season by the sons of the more successful stayers.

Simply finding mates before rivals can be an effective way of winning the competition. Males of many insects emerge as adults from the pupal case before the females, a tactic known as protandry. This allows males to locate females as

DAN COX/WILDLIGHT/LIAISON

The spectacular antlers of this male Alaskan Moose (*Alces alces*) exist only to enable him to gain mating access to the females via combat with other males.

they emerge, thereby increasing the number of females they may encounter during their short life span. In the Australian Imperial Blue Butterfly (*Jalmenus evagoras*), males usually emerge earlier than females and can determine chemically if a pupa is about to emerge by tapping the cocoon with their antennae. Sometimes a cluster of males, only one of which will be successful, will stake out a soon-to-emerge pupa in order to mate with the female even before her wings have expanded. Interestingly, males cannot determine the sex of the pupa, so groups of hapless males can often be found waiting on the emergence of a male.

But why settle for only a single method of contest? In a range of insects and some vertebrates, males of the same species have two or more quite different mating strategies and these individuals may even possess remarkably distinct morphologies. Some males of the North American Bluegill Sunfish (*Lepomis macrochirus*) do not mature until they are about seven years old, at which age they build and defend nests to which females come to mate and lay eggs. Other males are considerably smaller and reach maturity much earlier. In fact, these smaller males usually die before the larger males even start to reproduce. Female-like in appearance, the small males deceive the larger males into permitting them access to their nests. And when a female lays eggs in the nest, the female mimics are on hand, releasing

**Previously ANH*

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

Female Zebra Finches may store sperm for up to ten days, increasing the opportunity for sperm competition between males.

sperm that competes for fertilisations with the sperm of the nest owner.

ONE MIGHT ASSUME THAT, ONCE COPULATION has occurred, the successful male is guaranteed of fathering the offspring, and the competition between males is over. Indeed, this was the prevailing view until 1970, when Geoff Parker from the University of Liverpool drew attention to the fact that females of many insects commonly mate with more than one male during a single reproductive cycle. This is also the case in many mammals and birds. Consequently, the eggs laid by a female for a single clutch or litter may be fertilised by the sperm of different males. With sperm from more than one male in the female reproductive tract, the contest resumes, this time between rival sperm in a race to fertilise available eggs. Over the past few decades an increasing number of studies has shown that 'sperm competition', as it has become known, can have far reaching implications for the genitalia and reproductive behaviour of males.

The formidable horns on this Black Atlas Beetle (*Chalcosoma atlas*) from Borneo are used in battle with other males over access to females.

Testis size among the primates, for example, appears to have evolved in relation to the risk of sperm competition. Male Gorillas (*Gorilla gorilla*) weigh about four times that of male Chimpanzees (*Pan troglodytes*) yet, rather surprisingly, the testes of the Chimpanzee are about four times heavier than those of the Gorilla. Female Gorillas invariably mate with only one male during their oestrous cycle, whereas female Chimpanzees usually mate with several males. It seems that large testes in the Chimpanzee enable production of more sperm per ejaculate, increasing the chances of fertilisation should these sperm be in competition with those of rivals. This relationship between mating behaviour and testis size is remarkably general across both mammals and birds. For the record, human testis size, relative to body mass, falls about half way between the promiscuous Chimpanzee and the highly monogamous Gorilla.

The contest resumes, this time between rival sperm in a race to fertilise available eggs.

An important factor promoting sperm competition is the capacity of females to store viable sperm in their reproductive tract for extended periods. Because sperm storage extends the window of time over which a copulation can result in fertilisation, there is greater potential for the sperm of several males to mix and compete to fertilise eggs. Duration of sperm storage varies dramatically in different taxonomic groups, ranging from only about 24 hours in most mammals to a staggering six years in some ants. In birds for which data are available, storage varies from about ten days in the Zebra Finch (*Taeniopygia guttata*), to over 60 days in the Great-winged Petrel (*Pterodroma macroptera*).

One way of avoiding sperm competition is to prevent the female from mating with other males. The first thing some male *Linyphia* spiders do after locating the web of a virgin female is to completely destroy her web. Only then will he attempt to copulate with her. Such

KATHIE ATKINSON

In an effort to be the first one on the scene, male Imperial Blue Butterflies emerge from their cocoon before females. They then congregate around other cocoons in the hope that the soon-to-emerge pupae will be female.

anti-social behaviour occurs because the silk of her web contains pheromones, volatile chemicals that attract other males. By destroying the web, the male reduces the risk of other males locating the female. Males of many insect species prevent females from mating by transferring, within the ejaculate, a chemical 'anti-aphrodisiac' that induces a 'refractory period', during which the female will not mate with other males. Meanwhile the male is free to pursue other females. Additionally, males of the vinegar fly *Drosophila melanogaster* inject what may be a spermicidal substance into the female before introducing their own sperm. The spermicide appears to incapacitate the sperm of males that have mated previously with the female, increasing the last male's share of paternity.

Physical rather than chemical means are employed in a range of other species where part of the male ejaculate coagulates to form a plug, reducing the success of subsequent copulations by other males. Common in many insects, copulatory plugs also occur in some marsupials including the Tammar Wallaby (*Macropus eugenii*) and Common Wombat (*Vombatus ursinus*), where they may function to reduce sperm competition.

Males can also discourage the attentions of other males by remaining very close to their partner during her fertile period, a behavioural strategy known as 'mate guarding'. Guarding is common in many birds, but also occurs in a wide range of invertebrates. Male and female damselflies can often be seen attached to one another before, during and after copulation. Initially, the male seizes the female just behind her head, first with his legs and then with his anal appendages. The pair stays in this position for a short time before the male and female's genitals come into contact in a configuration known as the 'wheel of love'. Love is perhaps a loose term for this physical arrangement, in which the male uses his penis to scrape out rival sperm from the female's reproductive tract before introducing his own (see *Nature Aust.** Summer 1988–89). The pair may remain attached, even while the female lays her eggs, thereby reducing the risk of her mating with another male.

Mate guarding, however, is not always possible, especially in many birds of prey and colonial breeders. In these species, the primary form of paternity guard appears to be frequent 'within-pair copulations'. For example, during the fertile period of his partner, the male Northern Goshawk (*Accipiter gentilis*) must spend much of the day foraging for both himself and his mate. But the limited time together is not wasted, as the pair may copulate over 600 times in the six to seven weeks that precede laying. Frequent copulation has the effect of diluting the sperm of rivals, and increasing the male's likelihood of being the last male to copulate before fertilisation. Even more enthusiastic is Smith's Longspur (*Calcarius pictus*), a bird found in the Canadian tundra, that may copulate over 100 times per day during the five or so days that the female is receptive. These birds live in groups of both sexes, and females mate with up to three different males. Clearly males should copulate as much as possible to ensure they have some share in the paternity of offspring. Interestingly, the females encourage this extraordinary copulation rate as they actively solicit matings from most males in the group. This is a rather clever tactic because she will subsequently get help in feeding her young from those males with whom she copulated.

The overwhelming diversity of mechanisms that thwart the fertilisation opportunities of rival males suggests a conflict of interest between the sexes over the number of partners taken by a female. For example, females of many insects have complex reproductive tracts that may have evolved to prevent males interfering with the stored sperm of other males. These sperm storage facilities may also allow the female greater control over which male(s) father her offspring. In various bugs, including bed bugs (*Cimex* spp.), the male avoids this problem by abandoning the usual form of copulation. Instead, he penetrates the external wall of the female's abdomen with his dagger-like aedeagus (= penis), injecting his sperm into a specialised tissue mass located just below the surface of the female. The sperm eventually makes its way along various channels to the eggs. While this unconventional, 'traumatic insemination' may allow the sperm to by-pass the female's reproductive tract, it seems to have precipitated an even more sinister strategy of male-male competition. The male anthocorid bug (*Xylocoris flavipes*) also mates by traumatic insemination. Curiously, males sometimes inseminate other males in the same manner. One explanation for this apparently bizarre behaviour is that the sperm injected into another male could subsequently get transferred into a female with whom the

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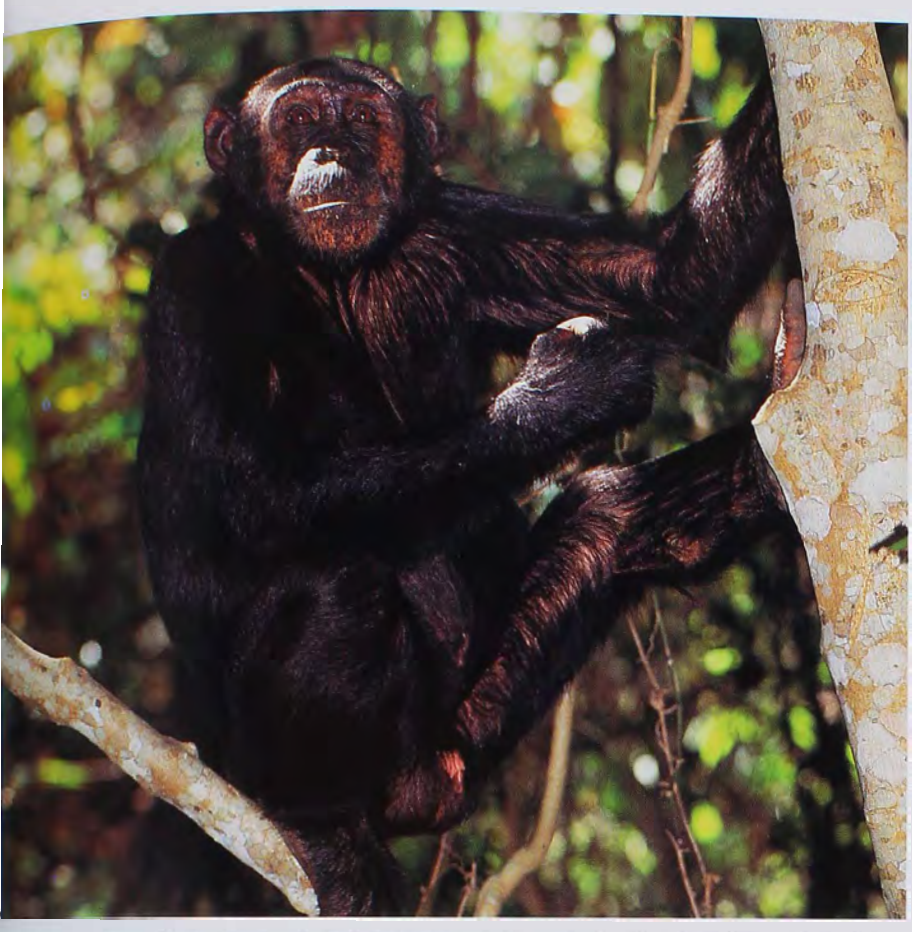

Sperm competition can be intense in Chimpanzees and so consequently males have extremely large testes for their body size.

second male mates. Not particularly sporting, but evidently all is fair in sex and sperm competition. ■

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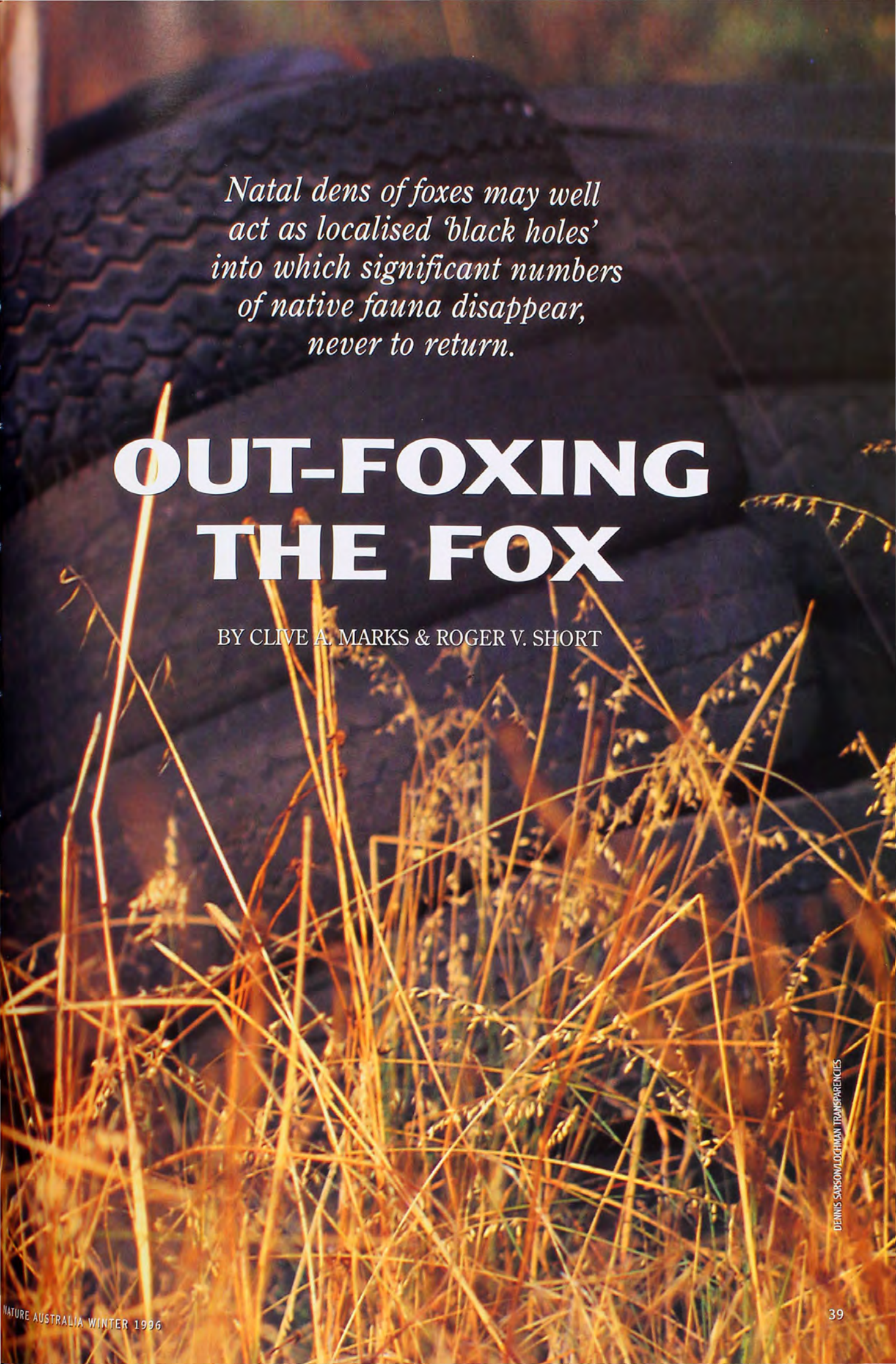
Natal dens of foxes may well act as localised 'black holes' into which significant numbers of native fauna disappear, never to return.

OUT-FOXING THE FOX

BY CLIVE A. MARKS & ROGER V. SHORT



DENNIS SARSON/LOCHMAN TRANSPARENCIES

N.N. BIRKS/AUSCAPE INTERNATIONAL

A fox feeds on the carcass of a feral goat in the Flinders Ranges, South Australia. This is suggestive of possible important ecological relationships between foxes and other pest species.

In 1855, the arrival of two male Red Foxes (*Vulpes vulpes*) at Sydney Harbour created a great deal of excitement among the members of the newly formed Hunt Club. They were the first of a series of foxes that were brought from England to Sydney, and later to Melbourne, in order to satisfy the desires of colonial hunters. While the dingo (*Canis familiaris dingo*) had provided some level of sport, the fox was regarded as a true gentleman's quarry, and the only animal that would satisfy the Anglophile hunters of New South Wales and Victoria.

However, Hunt Clubs cannot claim the dubious honour of having successfully introduced the fox to mainland Australia. While we may never know for sure, it is probable that two separate introductions to Victoria in the 1870s established a resident breeding population. This was soon followed by a spectacular radiation of foxes across the southern half of the continent as they exploited a wide variety of new habitats. By 1943 foxes were seen in the Kimberleys in the far north-west of Australia, although (thankfully) they have never been successfully introduced into Tasmania. The distribution of the fox has, in general, followed that of the European Rabbit (*Oryctolagus cuniculus*), its principle prey. Rabbits were first successfully introduced into Australia in 1859.

The rapid expansion of the fox, and its attacks on lambs and poultry, meant that it quickly became established as a pest species. In those early years, little consideration was given to the potential impact of foxes upon native wildlife although, being such an opportunistic

pre ator, it was quick to exploit the rich native fauna of small to medium-sized mammals. Since these animals had not co-evolved with a terrestrial predator comparable to the fox, they were particularly vulnerable. The arrival of the fox, coupled with the environmental changes associated with human settlement and agriculture, resulted in many native species either becoming extinct, or being dramatically reduced in their range. Australia has the world's worst record of mammalian extinctions over the last 100 years.

It is only comparatively recently that we have begun to understand the true impact of the fox upon our native fauna, some of which have only managed to retain a toe-hold on survival. Some bandicoot species, such as the Eastern Barred Bandicoot (*Perameles gunnii*), may now only be found in small isolated colonies in areas that are less accessible to foxes. The fox may be directly implicated in the demise of this species on mainland Australia. Intensive fox control has become the key to the successful reintroduction of endangered species to the wild. Without it, the reintroduction and conservation of wild populations of the Eastern Barred Bandicoot would not have been possible in Victoria. Today, wildlife managers in all mainland States are engaged in a constant battle with the fox in an attempt to control its impact upon wildlife and farm livestock.

It was not until the 1930s that foxes were first seen in the city areas of Melbourne. However, the extensive colonisation and exploitation of urban environments by the fox was probably a post-World War 2 phenomenon, encouraged by the changing urban landscape. Our city planners had unwittingly created a fox utopia. The patchwork of urban reserves, parks and gardens greatly favoured the survival of the fox, coupled with the ever-increasing supply of waste food from an increasingly affluent society. Private gardens and green belt areas provided shelter, and introduced trees with luscious foliage encouraged urban population growth of the Common Brushtail and Ringtail Possums (*Trichosurus vulpecula* and *Pseudocheirus peregrinus*), which have become staples in the diet of the urban fox.

By 1993 a survey revealed that foxes had colonised every municipal area in Melbourne. In some of the coastal and leafy suburbs, there have been conservative density estimates of over 12 foxes per square kilometre immediately after the spring breeding season. Such densities are more than twice those found in most rural areas of Australia. At present, the highest Melbourne density estimates are still below those calculated for some British cities such as Bristol,

RED FOX

Vulpes vulpes

Classification
Family Canidae

Distribution
Native to the UK, Europe, North Africa, Indo-China, Russia and North America. Introduced to Australia, where it is widely distributed over the mainland, but absent from tropical north and some islands, including Tasmania.

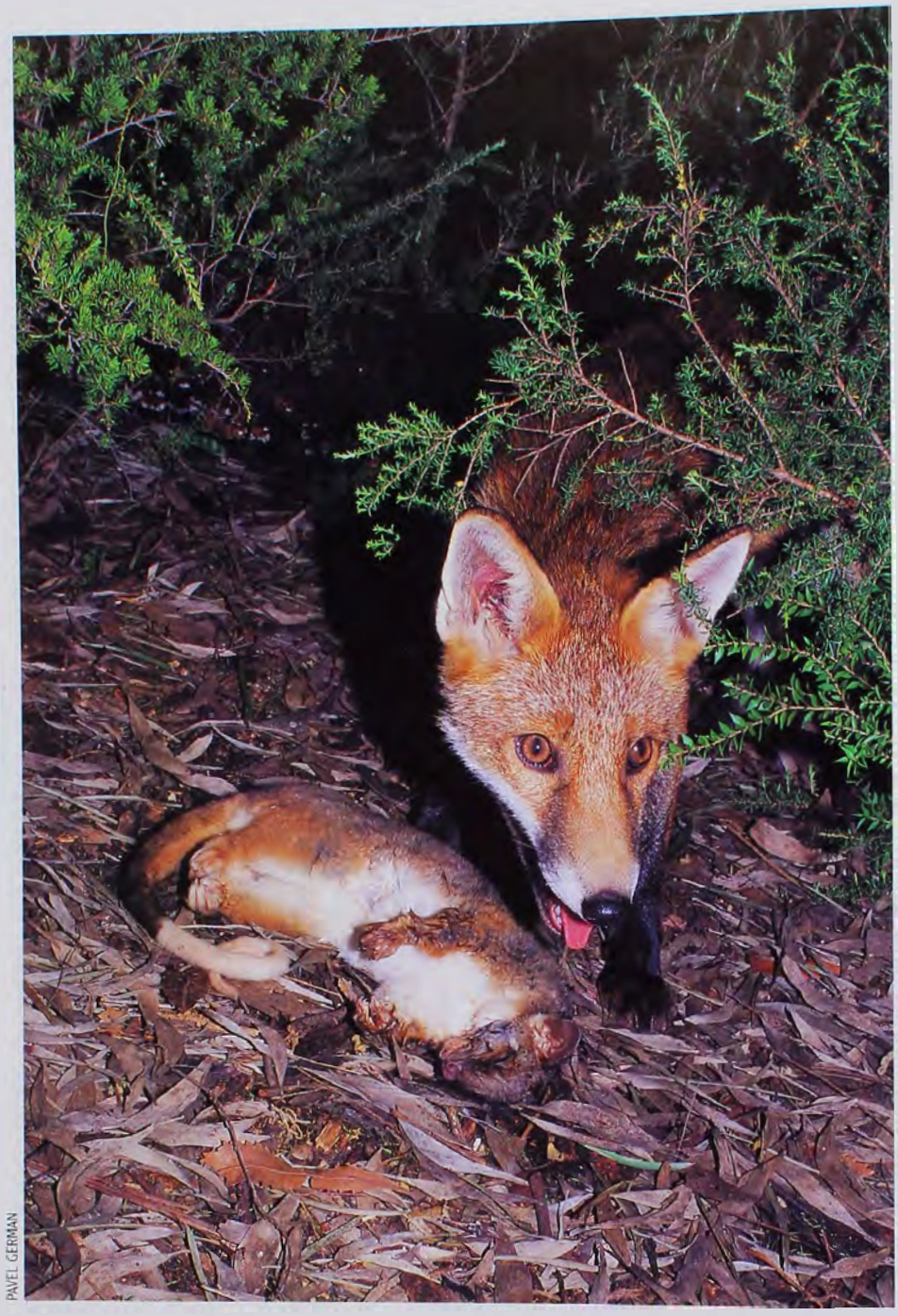
Habitat
Diverse; found in urban and agricultural areas, grassland, woodland, open and closed forest, and alpine and arid zone habitats.

Reproduction
Seasonally monoestrous; breeds only once each year in spring; usually 3–6 cubs per litter.

Social Organisation
Still unclear in Australia. Known to exist in family groups in some habitats (e.g. urban areas), but mated pair(s) may be found in other habitats (arid zone and some agricultural habitats).

Diet
Varies both geographically and seasonally. An opportunistic predator and scavenger that will exploit a wide range of vertebrate and invertebrate prey, fruits and carrion.

Status
A major pest in Australia, implicated in predation of wildlife and livestock. Declared as a pest or vermin species under appropriate State legislation where it occurs. A potential host and reservoir species for rabies if the virus were to be introduced to Australia.



PAVEL GERMAN

The Common Ringtail Possum is a frequent prey item in the diet of both urban and rural foxes.

where there are up to 3.6 family groups (or more than 20 foxes) per square kilometre in some parts of the city. Cursory surveys in Australia's other major cities have revealed that foxes are now found in Canberra, Perth, Adelaide and Brisbane. While foxes are commonly sighted in the outer suburbs of Sydney, there is still relatively little evidence to suggest that the city contains an extensive population of foxes in the inner suburbs. Perhaps the colonisation of Sydney has gone undetected, or is yet to happen. It is very probable that, before the year 2000, foxes will be a conspicuous part of all the mainland capital cities, with the exception of Darwin (foxes have not colonised areas in the tropical north).

Where overseas tourists had once expected to see kangaroos bounding down the streets of Australian cities, they are now far more likely to see a fox.

Where gullible overseas tourists had once expected to see kangaroos bounding down the streets of Australian cities, they are now far more likely to see a fox strutting along the pavement in the course of its nocturnal wanderings.

In Melbourne, the abundance of foxes living close to human inhabitants has led to some inevitable conflicts. In the centre of Melbourne, one fox set about progressively excavating the croquet lawn at Government House. The smell of putrescent possums, stored beneath houses by foxes, is also offensive to many householders. So too are the noisy exploits of cavorting fox cubs beneath the floorboards. In some locations, shoes go missing from doorsteps, only to turn up in mysterious piles of assorted footwear next to a fox den. The reason for the fox's apparent liking of footwear is still unclear; however, unusually large numbers of leather items such as gloves and clothing, which are found at some dens, suggests that leather rather than smelly feet may be the attractant!

As the tide of public complaints grew in Melbourne, wildlife officers became acutely aware of the fact that they were virtually helpless in controlling foxes in the urban area. The traditional methods of poison baits, shooting or trapping could all jeopardise the safety of humans and domestic pets, and so could not be used. The 'urban fox' problem was even more complex than initially realised. High densities of foxes had also become established in urban settlements bordering rural areas, which were close to wildlife that was highly susceptible to fox predation. The threatened Mountain Pygmy Possum (*Burramys parvus*), for example, exists within a major tourist resort at Mt Hotham in Victoria, and hence is particularly vulnerable to fox predation. Urban areas that support high densities of foxes also provide reservoirs that can replenish rural fox populations.

The establishment of a natal den, the maintenance of pregnancy and lactation, and the weaning of cubs are all energy-intensive processes for the vixen. This results in increased foraging efforts, and hence a greater impact upon the susceptible fauna. The weaning and feeding of cubs require large amounts of protein, which in many areas invariably comes in the form of mammalian or bird prey. Natal dens of foxes may well act as localised 'black holes' into which significant numbers of native fauna disappear, never to return. Furthermore, the dispersal of subadult foxes from these dens in the early part of the year may also cause a major wildlife management problem in some areas. At Phillip Island in Westernport Bay, Victoria, intensive efforts have been made to control foxes in the areas surrounding a colony of Little Penguins (*Eudyptula minor*), which are a major Victorian tourist attraction (see article, this issue). Quite apart from the unique conservation

value of the colony, it has been estimated that the nightly Penguin Parade exhibit, a favourite with Japanese tourists, is worth $80 million annually to the Victorian economy. Foxes are the primary cause of land mortality in Little Penguins, which are extremely vulnerable to fox predation. Such predation is typically not a slow process of attrition, but a series of dramatic events where the 'surplus killing' behaviour of foxes causes many penguins to be killed in a single evening, perhaps by one fox. The majority of such kills are not eaten or cached, and the penguin carcasses that litter the beach provide a powerful demonstration of the impact of foxes on this species.

Most penguin kills at the colony occur at the time when young foxes are dispersing from the dens where they were born. Many of the dens are located within the urban settlements of the island, where control is difficult to implement. If we could prevent foxes breeding in these areas, we would greatly assist in the conservation of this and other vulnerable species.

FERTILITY CONTROL OF FOXES IS ONE potential solution to the problem. Scientists at the CSIRO Division of Wildlife and Ecology have been trying to develop virally vectored immunosterilants for foxes and rabbits, so far without success. Their approach is to genetically engineer a virus that infects foxes, so that it carries proteins characteristic of fox sperm or eggs. When the fox becomes infected, in theory it should mount an immune response to the virus, and also to the sperm or eggs, thereby preventing fertilisation and rendering the fox infertile. This approach, while very attractive to the animal welfare lobby and the general public, is technically very difficult, not least because of the problems of identifying a suitable fox virus as a vector.

Fox cubs are frequently born in natal dens located beneath houses in the urban area. On occasions cubs have been found within the dwellings. This cub emerged through the heating ducts of a house in the suburb of Burwood in Melbourne.

VERTEBRATE PEST UNIT/KEITH TURNBULL INSTITUTE

The escape of rabbit calicivirus disease (RCD) from quarantine on Wardang Island, South Australia, during October 1995 has highlighted concerns that foxes may respond to crashing rabbit populations by 'prey switching' to vulnerable native species to supplement a diet that was once substantially reliant upon rabbits. The escape of RCD gives new urgency and relevance to the development of alternative fox control techniques.

Working at Melbourne's Monash University and the Keith Turnbull Research Institute of the Victorian Department of Conservation and Natural Resources, we decided to take a different approach to fox control. We investigated the possibility of using a relatively new drug, Cabergoline®, to terminate pregnancy in vixens. Cabergoline has been used by veterinarians in Europe to treat phantom pregnancy in dogs, and it has also been shown to produce abortion if fed to dogs or cats in the second half of gestation. The reason why it causes abortion is not yet fully understood, but it is probably related to the fact that Cabergoline suppresses secretion of the pituitary hor-

REG MORRISON/AUSCAPE INTERNATIONAL

Fox 'trophies' hang on a fence near Rainbow in north-western Victoria. This would be a single evening's work for a shooter.

J.E. WAPSTRA/NATURE FOCUS

The Eastern Barred Bandicoot is Victoria's most endangered mammal, and its conservation and survival in the wild is dependent upon continued intensive control of foxes.

mone prolactin, which may be necessary for the maintenance of the later stages of pregnancy in these species (see box). Cabergoline is also very effective in inhibiting lactation and, if administered prior to weaning, would cause death of newborn young. By using Cabergoline in isolated fox populations where conventional control techniques cannot be used, we hoped that the births and subsequent dispersal of young foxes could be decreased to the point where wildlife impacts caused by urban foxes would be reduced.

Vixens breed only once each year, in the spring, and if that pregnancy is terminated, they must wait a whole year before becoming pregnant again. Spontaneous abortion occurs frequently in foxes in the wild. In theory, it might be possible to distribute Cabergoline-impregnated meat baits in urban areas once a year in the spring, during a two-week period when all the vixens would be in mid to late pregnancy. Owners of pregnant dogs or cats would have to be advised not to let their animals roam about during the baiting program, but the drug is harmless to non-pregnant animals, and is rapidly degraded. Foxes readily take buried baits, which further reduces the chance of non-target species being affected.

In the spring of 1994 we decided to undertake a preliminary field trial to see if Cabergoline baits could inhibit fox reproduction if placed close to dens used for cubbing. Fifty-one natal dens, in both urban Melbourne and rural Bendigo, that were known to have been used by vixens to give birth to cubs for the last three years were used for the study. On 1 August and again on 1 September, when most vixens should be in mid to late pregnancy, eight meat baits, each containing 170 micrograms of Cabergoline and a biomarker that would subsequently make it possible to confirm whether a fox had eaten the bait, were buried near 30 of the dens. The remaining 21 dens were left as untreated controls. If Cabergoline was effective, vixens should not produce viable cubs in the treated dens.

Cubs are usually born between September and October, and first emerge from the dens about a month later. Therefore all the dens were closely observed until late December for signs of cub emergence. Three dens were destroyed by building operations during the course of the study and had to be excluded. Cub activity was recorded in 15 of the 20 remaining control dens, but at only six of the 28 treated dens, a highly significant difference. The biomarker that had been placed in the baits was not present at autopsy in three vixens that had produced cubs in the treated dens, showing that they had not consumed the bait. These preliminary results suggested that Cabergoline had successfully controlled the fertility of most vixens in the dens where it had been applied.

ABORTION PILL FOR FOXES: HOW DOES IT WORK?

The pituitary gland at the base of the brain releases the hormone prolactin which, in rodents and carnivores, maintains the corpora lutea in the ovary. The corpora lutea in turn are the structures responsible for the production of the hormone progesterone, which is essential for the maintenance of pregnancy. Cabergoline acts by suppressing the pituitary secretion of prolactin and, as a result, the corpora lutea stop secreting progesterone. If the uterus is deprived of progesterone, it starts to contract, expelling any embryos or foetuses that might be present. Cabergoline will also stop the mammary glands making any milk, since, as its name implies, prolactin is essential for normal lactation. Preliminary results suggest that marsupials may be much less sensitive to Cabergoline than carnivores or rodents; and there is no evidence to suggest that Cabergolin is abortifacient in humans.

WILL IT NOW BE POSSIBLE TO ERADICATE foxes from urban areas in Australia with Cabergoline? Unfortunately, it is not that simple. First, it will never be possible to get 100 per cent of vixens to take the Cabergoline bait at the critical stage of pregnancy, so some cubs will always be born even after intensive baiting with Cabergoline. But of greater concern is the fact that, after each breeding season, dispersing foxes from outside the control area are likely to recolonise these highly favoured urban areas. One of the great problems of fox control is the logistic difficulty and expense of conducting coordinated control operations over large areas. It is unlikely that Cabergoline would be used alone to control foxes, but it might be particularly valuable for control in urban areas. It could also be used in combination with shooting and poisoning in areas such as Phillip Island and Mt Hotham. It will need extensive field trials to see if such an approach really will be beneficial.

At present there are concerns about the cost of the drug, and its availability. Cabergoline is manufactured by Farmitalia, an Italian subsidiary of the Swedish drug firm Pharmacia. It is already being used clinically in Europe to treat infertility in women resulting from high prolactin levels, and is in clinical trials for the treatment of Parkinson's disease. The company may find that its use for aborting foxes presents a marketing conflict of interest with its more profitable clinical uses. However, there are plenty of precedents; anticoagulants, for example, are marketed over the counter as rat and mouse poisons, but are also used clinically in the management of blood-clotting disorders. Let's hope that Pharmacia will continue to make the compound available for fox control, for it is potentially a valuable new weapon for controlling the urban fox. ■

Further Reading

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WAYNE LAWLER/AUSCAPE INTERNATIONAL

A fox contemplates a group of Black-tailed Native-hens (*Gallinula ventralis*) on the shore of Lake Yantabangee in north-western New South Wales. The Red Fox is an opportunistic predator, and coastal areas and lake shores often provide rich sources of prey.

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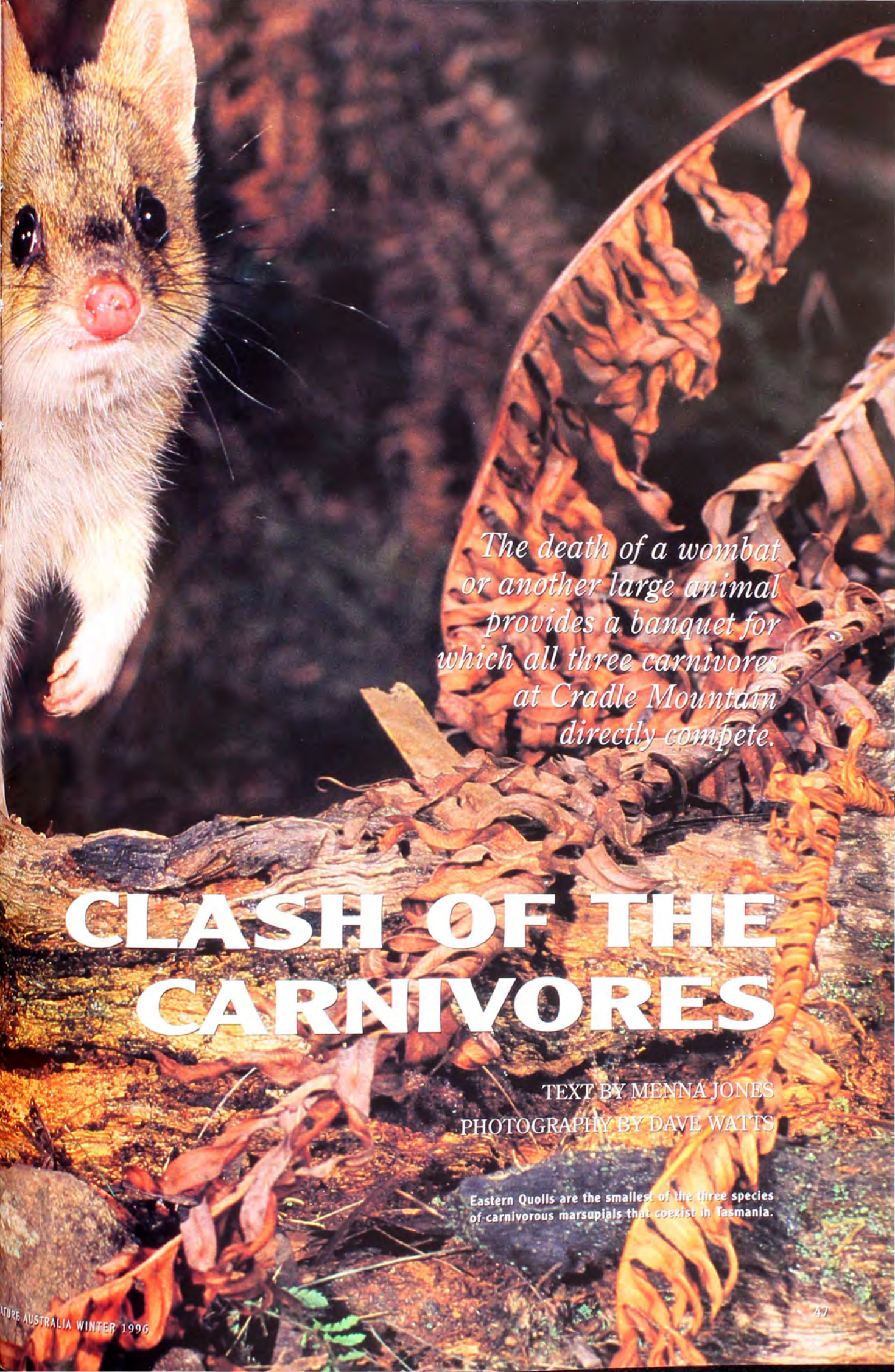
Clive A. Marks is the leader of the Vertebrate Pest Research Unit at Victoria's Keith Turnbull Research Institute. He has studied the foxes of urban Melbourne for the past four years and is currently leading projects investigating the control of foxes, feral cats and browsing pests. Roger V. Short is Professor of Reproductive Biology in the Faculty of Medicine at Monash University, and has a long-standing interest in methods of fertility control in animals and humans.

DENNIS SARSON/LOCHMAN TRANSPARENCIES

A fox fitted with a radio-collar. Radio-tracking has been an invaluable technique for understanding the ecology of foxes in both rural and urban areas of Australia.



The death of a wombat or another large animal provides a banquet for which all three carnivores at Cradle Mountain directly compete.

CLASH OF THE CARNIVORES

TEXT BY MENNA JONES

PHOTOGRAPHY BY DAVE WATTS

Eastern Quolls are the smallest of the three species of carnivorous marsupials that coexist in Tasmania.

THE EASTERN QUOLL STOPS TUGging at the dead wombat and leaps nimbly on top of the carcass, rearing on its hind legs, every sense alert. With a short, sharp shriek it speeds off into the darkness. Shortly a Tasmanian Devil lopes into sight, blinking in the dim overhead lights, and rapidly gnaws and tears its way into the carcass through the belly skin. As the Devil becomes engrossed in feeding, the Eastern Quoll returns, darting back and forth, searching for scraps and peering at the carcass. When it gets too close, the Devil snorts, but the quoll becomes bolder, even sniffing the Devil's tail. Turning with a growl, the Devil chases it away. Not easily deterred, the quoll disappears only with the arrival of another Devil.

Observing from a hide in northern Tasmania's Cradle Mountain National Park, I know that the quoll will now have to wait until the Devils are sated, or until the carcass is dismembered. This is the tax it must pay to the Devil for opening the thick (and, to a quoll, impenetrable) skin of the wombat.

Three species of marsupial carnivores (primarily flesh-eating rather than insectivorous or omnivorous) coexist in Tasmania. These are, in order of increasing size, the Eastern Quoll (*Dasyurus viverrinus*), the Spotted-tailed Quoll (*D. maculatus*) and the Tasmanian Devil (*Sarcophilus harrisii*), all in the family Dasyuridae. In the recent past, a fourth and larger species, the Thylacine (*Thylacinus cynocephalus*, family Thylacinidae) was also part of this suite of marsupial carnivores (see box), that is until sheep farmers and the Tasmanian Government's Bounty Program in the 1800s and early 1900s hunted it to extinction.

All of these species once lived on the mainland of Australia. Dingoes arriving from South-east Asia about 4,000 years ago helped sound the death knell for Thylacines and Devils, which became extinct in the south-east of Australia 3,200 and 5,000 years ago, respectively. Eastern Quolls disappeared on the mainland in a rapid 30-year period from the 1930s to the 1960s, coinciding with the spread of European foxes that were

introduced for sport hunting. Of the four large Tasmanian carnivores, only the Spotted-tailed Quoll still occurs on the mainland, but it too has declined there dramatically.

Consider these four marsupial carnivores. How do (did) they manage to live together on the small island of Tasmania? In theory, unless numbers of animals are kept down by other forces such as predation or droughts, similar species will compete for food. Active competition for food can depress populations of animals so that species that are good at competing will be more abundant than those that are poor competitors. Competition between similar species is likely to be reduced by the evolution of different body sizes or body form (morphology), which enables them to use slightly different foods. This concept is known as the 'Competitive Exclusion Principle', which holds that similar species coexist by differing in one or more aspects of their food or habitat requirements.

So, is there any evidence that the Tasmanian marsupial carnivores are competing for food, and does competition influence the abundance of any of the species? Are there differences in habitat use that may reduce competition? Also, has competition for similar foods influenced the size and morphology of the Tasmanian marsupial carnivores? The answers all seem to be yes, and the story is complex and exciting.

A young male Spotted-tailed Quoll sets off on a nights foraging in Cradle Mountain's temperate rainforest, unwittingly carrying a spool-and-line tracking device and leaving a trail of thread that will reveal precisely where it went.

The author adjusts the radio-collar on a female Spotted-tailed Quoll before it is released and followed to its den.

IF COMPETITION OCCURS OVER A LONG enough period of time, it may result in changes in morphology or physical appearance of the animals. American ecologist and father of modern competition theory, Joe Connell, called this phenomenon 'the ghost of competition past'. For changes in morphology we have to look at the structures most closely related to the way in which the animals compete for food: their teeth.

The strength of the canine teeth is and was important for killing prey in all four of these large marsupial carnivores. Both species of quolls kill their prey by crushing the back part of the skull. When very large prey are killed, the killing bite is necessarily adjusted. A small female Spotted-tailed Quoll was seen killing a sick pademelon four times its size, leaping on its back and suffocating it or crushing vertebrae with a tenacious bite on the side of the neck. Devils kill by attaching themselves to the head or chest region of the prey, adjusting their bite and hanging on until the animal succumbs. And, although prey-killing behaviour of the Thylacine can only be surmised from bushmens' anecdotes and comparisons of Thylacine tooth shape with other carnivores, a gripping bite was probably used.

That competition has probably been important among the Tasmanian carni-

An open-mouth defensive posture, similar to that used by Tasmanian Devils is displayed by a captive Thylacine, revealing the long, narrow snout and gracile teeth.

vores on an evolutionary time scale, and that it has resulted in a change in morphology, is demonstrated by the even distribution of canine tooth strength among the quolls. In order of increasing tooth strength are female, then male, Eastern Quolls, followed by female, then male, Spotted-tailed Quolls. But the difference between each is the same. Theoretically, because strength of the canine teeth is closely related to the size of prey that can be killed, this even distribution results in the maximum separation of prey size that each sex of each species can eat, thereby reducing competition. However, museum specimens of quolls collected from the south-eastern mainland of Australia, where there hadn't been any competition from Devils and Thylacines for a long time, do not exhibit this even pattern of canine tooth strength. This giant natural experiment thus tends to confirm competition as the cause of change in tooth strength in the Tasmanian quolls.

Further evidence of competition would be if animals used the habitat in different ways. I looked at this using spool-and-line tracking, a neat technique where sewing thread, wrapped in sticking plaster, is Supa-glued to an animal's fur. The animal is then released after tying the thread to a nearby bush and then the thread—up to 1,200 metres of it—is followed the next day. This gives the researcher an insight into exactly where the animals go and often what they do while they are there.

Using this technique it became clear that Eastern Quolls spend much of their time hunting in open grassland. Spotted-tailed Quolls and Devils, by contrast, are both forest dwellers, but Spotted-tailed Quolls prefer wetter and denser forests than Devils. Spotted-tailed Quolls spend more than a tenth of their time above the ground, frequently climbing big trees and using fallen logs as roadways, often travelling 100 metres or more without touching the ground. Being the middle-sized species (see box), the prey size range that Spotted-tailed Quolls eat includes most of the tree-dwelling mammals (possums and gliders). As a result, Spotted-tailed Quolls have evolved an exceptionally long tail for balance, and an opposable thumb on the hind feet and special ridges on the pads of their feet to aid in gripping branches; all morphological features absent in the other species. They have been seen catching Common Ringtail Possums (*Pseudocheirus peregrinus*) in the canopy and knocking sleeping birds off branches at night, catching them on the way to the ground. By contrast, both the largest and smallest prey species that Devils and Eastern Quolls eat respectively are ground-dwelling.

Devils are also capable tree climbers, but rarely climb more than a few metres and then only up trees that have small or sloping trunks or numerous branches. The smaller and younger the Devil, the more they climb, but still not as much as Spotted-tailed Quolls. This is reflected in the dietary overlap between juvenile Devils and Spotted-tailed Quolls. Young Devils eat the same number of tree-dwelling mammals, although fewer birds, as Spotted-tailed Quolls.

So while competition between the three living species may have been reduced by evolutionary changes in tooth strength, tree-climbing adaptations and habitat use, these have not been completely effective. Competition still appears to be an active force among the marsupial carnivores in Tasmania, particularly for Spotted-tailed Quolls.

which suffer more competitive overlap than the other species.

SPOTTED-TAILED QUOLLS ARE RARE throughout their geographic range. This is of conservation concern on the mainland where the combined effects of fragmentation of their forest habitat for farming and logging, and competition with and predation by introduced cats and foxes, have contributed to an up to 70 per cent decline in their range and abundance this century. In Tasmania foxes are absent, all attempts to introduce them having failed. Populations of Spotted-tailed Quolls have even increased slightly in the last 15 years and yet they are still rare. I trapped only 19 individual Spotted-tailed Quolls in my two-and-a-half-year field study at Cradle Mountain, compared to 126 Devils and 49 Eastern Quolls. Competition for food can be inferred as the cause.

In winter, both male Spotted-tailed Quolls and adult Devils overlap in the prey species they eat, mainly Tasmanian Pademelons (*Thylogale billardierii*) and Red-necked or Bennett's Wallabies (*Macropus rufogriseus rufogriseus*). In summer, when inexperienced juveniles of all species are out of the pouch, Devils switch to eating large numbers of young Common Wombats (*Vombatus ursinus*), prey items that are too tough for Spotted-tailed Quolls. The male Spotted-tailed Quoll still has to share its table, however, because in summer there is a cohort of young Devils that are the same size and body weight, and are competing for their dinner of pademelons, Common Brushtail (*Trichosurus vulpecula*) and Common Ringtail (*Pseudocheirus peregrinus*) Possums (see box). The story is no better for the female Spotted-tailed Quolls. In winter, females are competing with Eastern Quolls for small mammals and birds, and sharing a diet of possums and pademelons with males of their species and Devils. In summer both female and newly weaned young Spotted-tailed Quolls, which are now of the same size and weight as an Eastern Quoll, are competing with Eastern Quolls for small mammals, birds and insects. So, while both Devils and Eastern Quolls have some time of year and stage of life when they are free of dietary competition with another species, the Spotted-tailed Quoll must share its food supply with either a larger or a smaller species at all times. This extra competition may be enough to keep its numbers low.

The death of a wombat or another large animal provides a banquet for which all three carnivores at Cradle Mountain directly compete. Devils are the supreme scavengers; with their immensely powerful jaws and teeth, they are capable of completely dismembering and consuming a carcass (see *Nature Aust.* * Summer 1994–95). Being the largest, they dominate at carcasses. Age, degree of hunger and sexual dynamics of the individuals involved in the contest, however, also influence the outcome. As demonstrated earlier, Devils are reasonably tolerant of Eastern

Spotted-tailed Quolls have been seen knocking sleeping birds off branches at night, catching them on the way to the ground.

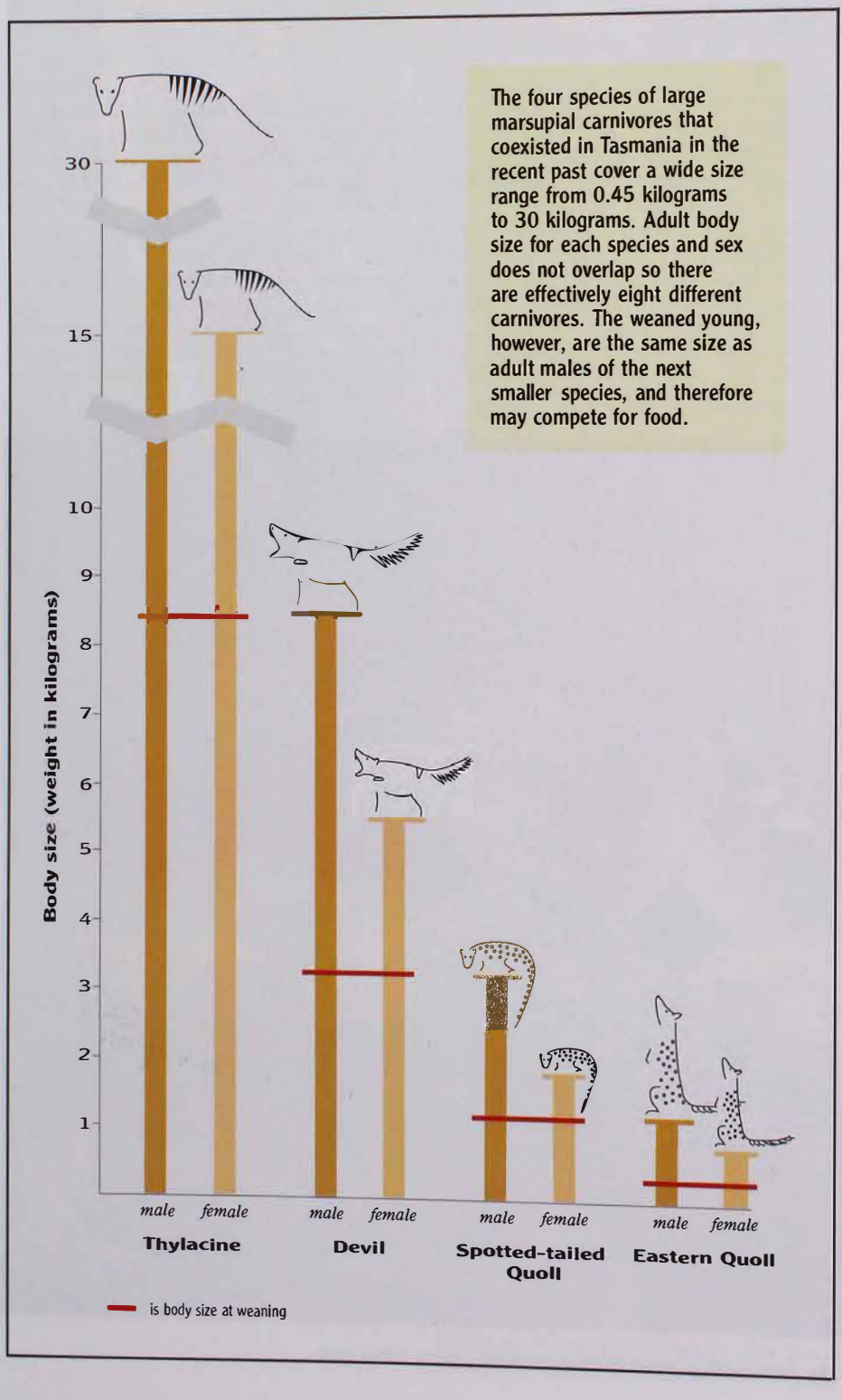
*Previously ANH

Spotted-tailed Quolls spend more than a tenth of the distance they travel in trees or moving along fallen logs.

Quolls darting in for mouthfuls, but probably only because they don't eat much. I have, however, seen a petite but hungry adult female Spotted-tailed Quoll chase a larger but young Devil off a carcass.

Although competition for food seems to have been and may still be an important force shaping the marsupial carnivore fauna of Tasmania, it is not the only one. An interesting and complex interplay of factors has influenced the body size and canine tooth strength relationships among the four species of the recent past. Sexual selection, where large body size and large canine teeth confer a competitive advantage in male–male combat for mating access to females, results in size differences between the sexes. In all four species males are larger and have proportionately bigger canine teeth than females (see box).

Carnivore body size is also affected by the size distribution of the mammalian prey species. Those at Cradle Mountain are of two size groups: small mammals, which increase in size gradually from the 30-gram Swamp Antechinus (*Antechinus minimus*) to the 125-gram Sugar Glider (*Petaurus breviceps*), and large mammals, which range from the 750-gram Common Ringtail Possum to the 25-kilogram Common Wombat. This size clumping of prey species has consequences for carnivore body size. The diet of Spotted-tailed Quolls spans the size gap. Both sexes of Eastern Quolls and female Spotted-tailed Quolls eat small prey species, and male Spotted-tailed Quolls and both sexes of Devils eat large prey species. Apart from keeping Spotted-tailed Quoll numbers down, this increased competitive pressure from greater dietary overlap has resulted in a much bigger size difference between male and female Spotted-tailed Quolls (mean difference 193 per cent) than between either Eastern Quolls or Devils (both 156 per cent).



The four species of large marsupial carnivores that coexisted in Tasmania in the recent past cover a wide size range from 0.45 kilograms to 30 kilograms. Adult body size for each species and sex does not overlap so there are effectively eight different carnivores. The weaned young, however, are the same size as adult males of the next smaller species, and therefore may compete for food.

AN UNUSUAL FEATURE OF THE MODERN Australian mammalian carnivore fauna compared to those of other continents is the paucity of species. A trip to a savanna national park in Africa will amaze you with the diversity of mammalian carnivores, with 20 or more species coexisting in the same location. And yet in historical times in Australia there have been at most only four coexisting species, those in Tasmania, and in total only six species (two other quoll species—the Western Quoll, *Dasyurus geoffroyii*, and Northern Quoll, *D. hallucatus*—occur on the mainland). (The placental Dingo did not evolve in Australia. A recent invader from Southeast Asia, it replaced the Devil and the Thylacine on the mainland; see *Nature Aust.* Summer 1995–96.) Why does modern Australia have such a low diversity of large mammalian carnivores compared to other continents? With its smaller landmass compared to Africa, North America or Eurasia, we would expect a few less species but not the degree of paucity that exists. The answer lies in the climatic and geological history of Australia (see *Nature Aust.* * Winter 1991).

In his work on fossil faunas, Michael Archer from the University of New South Wales has shown that there have in the past been many more kinds of marsupial carnivores with several kinds

*Previously *ANH*

A radio-collared Tasmanian Devil lies up in a hollow log.

of flesh-eating kangaroos, marsupial lions (many kinds), large bandicoots, many kinds and sizes of thylacines, probably partly carnivorous possums and others. Indeed, being more closely related to Koalas than quolls, the marsupial lions may have been the proverbial 'drop-bears'. Many of these marsupial carnivores vanished, however, with the complex rainforests of ancient Australia between 15 and five million years ago as Australia's climate became cooler and drier. After this time, there was only one thylacine, two devil-like large dasyurids, six quolls, two marsupial lions and four large carnivorous kangaroos. By the end of the Pleistocene, this number had been reduced to one thylacine, one devil and four quolls. With the increasing aridity and appearance of grasslands being relatively recent events in Australia's history (in the last few million years), there has not been the opportunity for a diverse

Eastern Quolls come in two colour phases; most are fawn while about 15 per cent are black, which contrasts stunningly with the white spots.

MARTY LAARN

A wild female Spotted-tailed Quoll killing a sick Tasmanian Pademelon four times her body size.

savanna marsupial carnivore fauna to evolve.

A consequence of the ten-year El Niño oscillation is that Australian deserts are characterised by periods of heavy rain followed by long droughts, conditions to which reptiles, with their slower metabolism, are better adapted than are mammals. At least since the continent warmed up after the Ice Ages, Australia has had the most diverse radiation of carnivorous reptiles (*Varanus* spp.) in the world. But while the reptiles have dominated the warm arid zone, they appear not to have excluded the remaining marsupial carnivores. Western Quolls, Devils and Thylacines occurred in numbers on the Nullarbor Plain 4,000 years ago and at least Western Quolls persisted in more arid parts of the continent until recently.

The geological history of Australia also plays a role in the low species diversity of marsupial carnivores. Unlike other continents, Australia is geologically very old with little tectonic uplift or vulcanism to create new rocks and soils. Leached over millions of years, the soils are extremely low in nutrients. Recent work by scientists from the CSIRO and James Cook University has shown that the abundance of possums and gliders and the number of bird species in eucalypt forests are directly limited by soil fertility. The effect of low-nutrient soils impacts through the food chain and may well have limited the number and abundance of marsupial carnivores.

The paucity of modern marsupial carnivore species in Australia does not mean that competition is any less severe here than on the African savanna. The big threat to our carnivores today is not so much competition with each other for food, but competition with a modern Western society that is ever-encroaching on their living space, and competition with the familiar sport and companion animals that early European colonists brought to this country. Foxes and cats displace our native carnivores, either through competition for food or by killing them. Dingoes wreaked havoc

As the supreme scavengers, Devils dominate at carcasses, although the smaller Spotted-tailed Quoll would be able to chase off the juvenile Devil on the right if it was alone.

among Devils and Thylacines on the mainland when they arrived in Australia, but have reached a new balance in the last few thousand years. In fact, they now provide some protection for Spotted-tailed Quolls and other endangered marsupials on the mainland by killing cats and foxes.

Of our six marsupial carnivores, the Thylacine is officially extinct, the Western Quoll is endangered and maintained in the wild only by constant targeted fox-baiting programs, the Spotted-tailed and Eastern Quolls are listed as potentially vulnerable, and decline has been noticed in the Northern Quoll. Only the Devil seems secure at present. The loss of any of these unique species, the largest marsupial carnivores in the world, would be an international tragedy. Every effort must be made not just to conserve these species, but to educate Australians so that in time we are as familiar with Devils and quolls as we are with Simba the Lion and Wile E. Coyote. ■

The Spotted-tailed Quoll's clawless thumb, ridged hind feet and long tail are all adaptations to tree dwelling.

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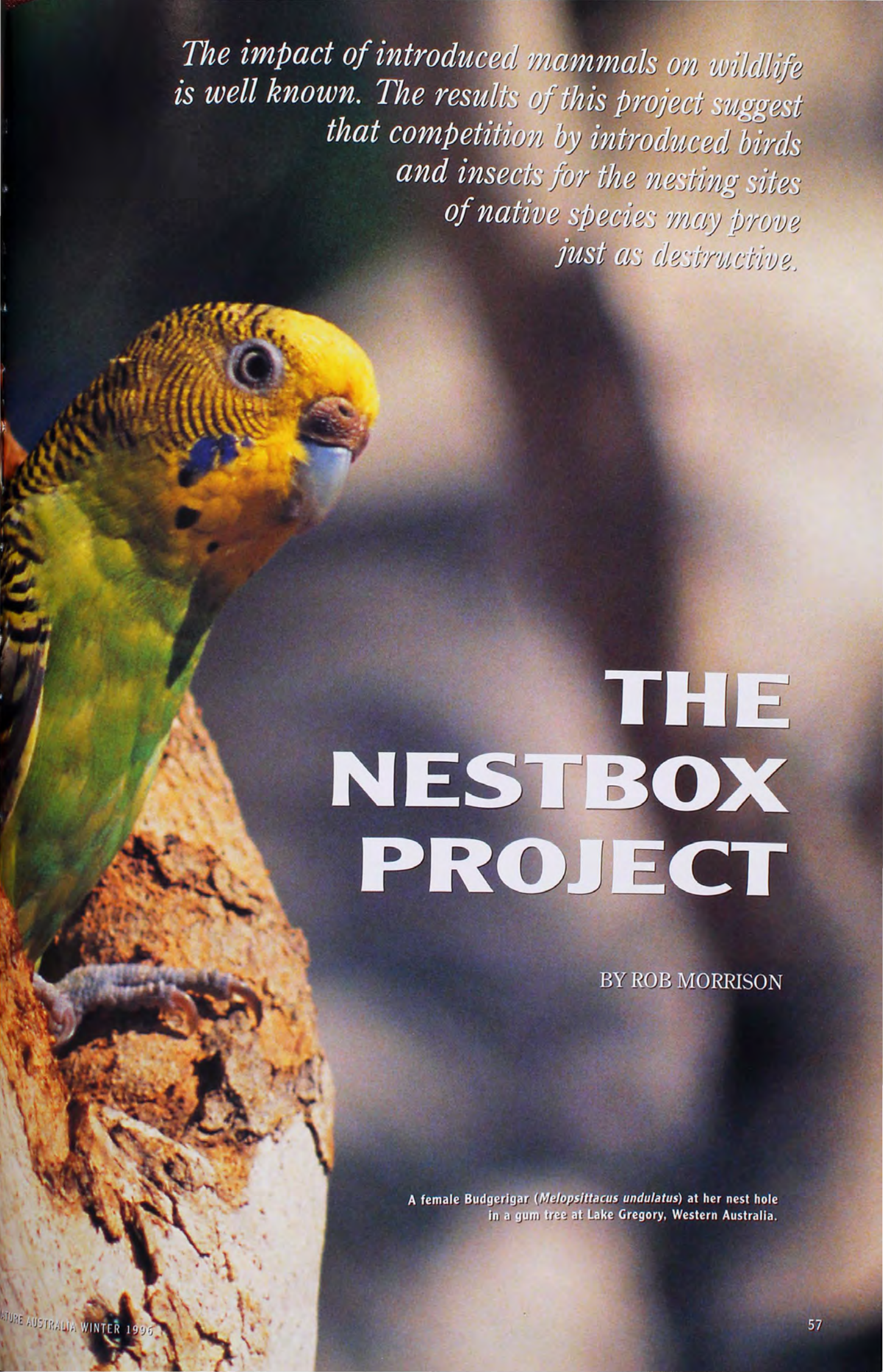
Dr Menna Jones obtained her PhD on Tasmania's marsupial carnivores from the University of Tasmania in Hobart. Her research interests include the evolution of their mating systems, community ecology and conservation biology.

GARY STEER/TERRA AUSPICALIS PHOTO AGENCY

The impact of introduced mammals on wildlife is well known. The results of this project suggest that competition by introduced birds and insects for the nesting sites of native species may prove just as destructive.

THE NESTBOX PROJECT

BY ROB MORRISON



A female Budgerigar (*Melopsittacus undulatus*) at her nest hole in a gum tree at Lake Gregory, Western Australia.

IN OUR LOCAL WOOD YARD, HUNDREDS of tonnes of cut red gum are stacked in piles, waiting for heaters to consume this winter. It is the same each year. In South Australia alone, 25 per cent of homes now use wood for heating. Combustion heaters are favoured for their economy but also for environmental reasons, because they use renewable rather than fossil fuels. It is true that the wood in old trees can easily be renewed, but the hollows in them cannot.

Hundreds of native species rely on these hollows. Although the number of invertebrate species that do so is unknown, 20 per cent of Australian birds and virtually all arboreal marsupials, except the Koala (*Phascolarctos cinereus*), use them. In areas that have been extensively cleared, such as most of South Australia or the wheat belts of Western Australia, New South Wales and Victoria, hollow shortages are becoming critical. Elsewhere, forests that have been retained for reserves and wood production provide a larger margin of safety for the survival of hollow-dependent species.

None of these animals can create hollows for themselves, and it may take a century or more for termites, fire, fungi and bacteria to form hollows that are large enough for them to use, but by then the tree is often dead or dying and is cut down for firewood, for safety, or to tidy up the landscape. The hollows lost in the process are, in some cases, the only natural sites where large vertebrates can shelter or breed.

It must be noted that the purchase of hollow logs only adds to the destruction of hollows in the bush.

This concern lay behind the Nestbox Project, in which participants, mostly school students throughout South Australia, were encouraged to install artificial nest boxes and then monitor the animals that used them. Ostensibly, the project sought to discover how to build better nest boxes. In reality, it was designed as an educational project to heighten awareness of the importance of natural hollows, and the impact of their destruction on wildlife.

An information kit, complete with background information, box plans, activities and data sheets, was mailed to all participants, who built and placed more than 1,000 boxes. While they showed less enthusiasm for the paper work, they did collect data that captured a snapshot of life in 200 of the boxes during the two consecutive breeding seasons of 1992 and 1993.

LIKE NATURAL HOLLOWS, ARTIFICIAL NEST boxes are not all the same. They can be horizontal or vertical, of different volumes, with or without perches, with varying entrance sizes and wall thicknesses, and positioned at different heights and facing different directions. There is a lot of folklore about which of these characteristics make nesting hollows attractive to various species, and a few generalisations emerged from the project.

Species seemed to vary in their readiness to use artificial boxes rather than natural hollows. Some, like the White-throated Treecreeper (*Cormobates leucophaeus*), inspected small boxes but did not use them. Lorikeets (*Trichoglossus haematodus* and other species) appeared

A Common Ringtail Possum peers from a nest box. Although possums don't have to use hollows to maintain their populations, they do like them.

ROB MORRISON

As natural forests are cleared, artificial nest boxes become increasingly important in providing nesting and roosting hollows for hundreds of native species.

ROB MORRISON

Starlings seem to prefer horizontal boxes, in which they invariably construct their nests as far as possible from the entrance hole (under the hinge). Unless they are discouraged, they can lay a clutch of four to eight eggs several times each season.

to find horizontal boxes made from sections of hollow limbs more attractive than any boxes made from pieces of timber. It must be noted here, however, that the purchase of hollow logs only adds to the destruction of hollows in the bush. As long as people buy these, timber yards will continue believing there is a market for them.

Of the birds that accepted artificial nest boxes, the introduced Common Starling (*Sturnus vulgaris*) showed a slight preference for horizontal designs, in which birds invariably built their nests in the corner farthest from the entrance, while parrots, almost entirely Adelaide Rosellas (*Platycercus elegans adelaidae*), preferred vertical boxes, especially if they were deep. No other species were recorded nesting in the artificial nest boxes.

Attached perches are said to attract starlings rather than parrots, but while the study showed that boxes with perches were used more commonly than those without, they attracted starlings and rosellas equally. Similarly, the aspect of a hollow or its opening is said to be an important factor in determining

GARY WEBER

The introduced Common Myna, along with a number of other introduced birds, mammals and insects, competes with native species for the use of both natural and artificial breeding hollows.

A Common Ringtail Possum makes use of a natural hollow. It may take well over a century for hollows to form before they are suitable for use by our native birds and mammals.

which species will use it. Both starlings and rosellas used boxes erected on all aspects of tree trunks. They did so with equal frequency for those that faced east and west, but starlings showed a higher tendency than parrots to use northern boxes, while the rosellas favoured those facing south.

The boxes were erected at heights between three and nine metres, with starlings showing a slightly greater tolerance than rosellas for lower heights. Both kinds of birds seemed attracted by entrance hole diameters of around 65 millimetres, with starlings preferring the range of 60–65 millimetres and rosellas preferring larger holes (65–80 millimetres).

While the project allowed us to compare the attractiveness of the designs to the various species, its greater significance was in showing the extent to which introduced animals are now competing with native species for whatever hollows can be found. The impact of introduced mammals on wildlife is well known, through predation or competition for food. The results of this project suggest that competition by introduced birds and insects for the nesting sites of native species may, in the longer term, prove just as destructive.

Of the boxes built for the project, 38 per cent were occupied by Adelaide Rosellas, but almost as many (32 per cent) were occupied by Common Starlings. This is even more serious than it seems because starlings have a much greater breeding potential, breeding earlier and more regularly than rosellas and being less easily driven from their nesting sites. The introduced House Sparrow (*Passer domesticus*) and Common Myna (*Acridotheres tristis*) are also known to compete for nesting hollows. Strangely, although House Sparrows occur in South Australia and have been recorded using artificial nest boxes, none was recorded in this study.

Of course native mammals and native birds also compete with one another for nesting sites. Despite their small size and entrance holes, six per cent of the boxes attracted possums, both Common Ringtails (*Pseudocheirus peregrinus*) and Common Brushtails (*Trichosurus vulpecula*). That figure is almost certainly an underestimation, as the presence of possums can often only be determined by climbing up to a box and peering into it, a task not undertaken by many participants. Where this inspection was regularly made, the number of boxes occupied by possums at some stage of the year was found to be about 50 per cent. (Although both these possums don't need nesting hol-

lows to maintain viable populations, they do *like* them and, as a result, occupy them to the exclusion of birds that do *need* them.) No bats were recorded in this project, but similar boxes installed in forests attract them, so they must be added to the list of native species that will use artificial hollows.

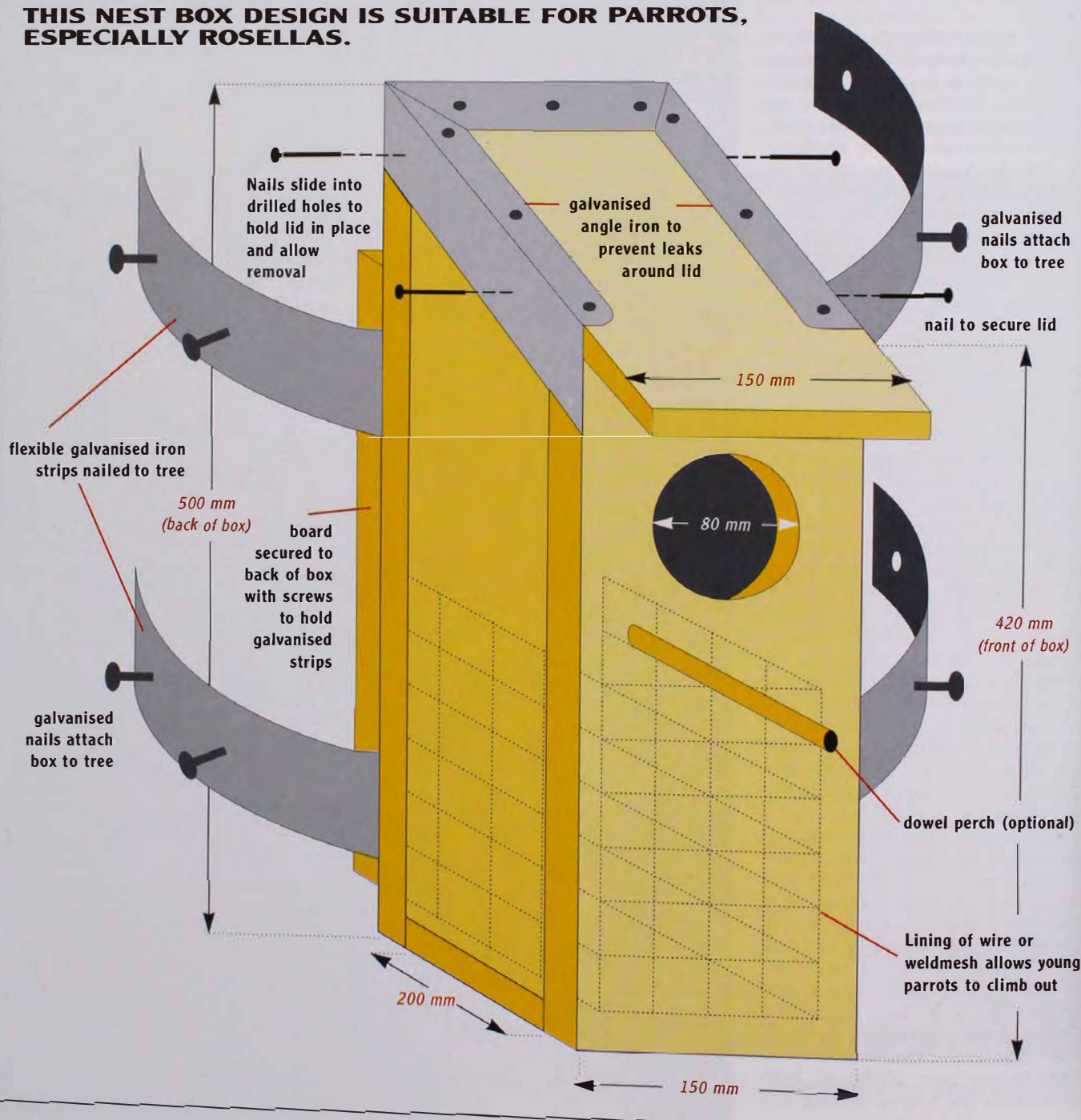
Introduced mammals in the form of rats (probably Black Rats, *Rattus rattus*, although they were not identified) took over two per cent of the nest boxes, even those higher than six metres; but, after starlings, European Honey Bees (*Apis mellifera*) emerged as the next most common invaders. Honey Bees have been suspected of over-pollinating native plants and competing with native animals for food and hollows, but their activity has been hard to quantify (see *Nature Aust.* * Winter 1990). Installing so many nest boxes over a short period of time made it possible to do so.

Ten per cent of the nest boxes were taken over by Honey Bees during the two years of the project, giving an annual colonisation rate of between five and ten per cent. Over a period of time, this represents a considerable problem because, although starlings may colonise a higher proportion of boxes in any one season, they depart at the end of it. Bees remain in the boxes they select, making them permanently inaccessible to other species.

Participants were urged to destroy starling nests and bee hives. Most did so, but many regarded the appearance of bees and starlings in their boxes as a failure, and returned no data for them. The combined annual colonisation rate by both species should therefore probably be higher but, even at the conservative estimate of 35–40 per cent, it shows that artificial nest boxes should never be installed unless they are actively managed for removal of these animals. This is possible in domestic gardens, suburban parks or forest reserves, but is expensive and difficult to do in remote regions where boxes have sometimes been installed to provide additional nesting sites for endangered species.

PUTTING ALL THESE ELEMENTS TOGETHER presents a worrying picture. Nesting hollows are being lost as old trees are cut down. At the same time, the remaining hollows are being taken by introduced animals that not only have greater reproductive potential than native species, but also compete for hollows more successfully and may then

THIS NEST BOX DESIGN IS SUITABLE FOR PARROTS, ESPECIALLY ROSELLAS.



COURTESY ROB MORRISON

occupy them permanently.

In normal populations of animals, older members are replaced by equal numbers of young, the average age of the population remains constant, and there are always many individuals with reproductive potential. When outside factors reduce the reproductive rate of a species, the effects depend on the life-span of the animal involved.

These effects are most quickly seen in short-lived species. Old animals are not replaced and, because they soon die, the size of the population decreases sharply. In long-lived species, such as kookaburras, parrots and cockatoos, the effects are much less immediately obvious. The population's size may remain fairly constant for a long while but, without recruitment, its average age steadily increases. Eventually, when old animals begin to die, many others will be past their breeding prime and the population is well on the way to extinction.

Australia has over one-sixth of the world's parrots but one-third of them are already endangered. The extent to which their populations, and those of other native species, are declining because of the loss of nesting hollows is unknown, but the potential for future population collapses among many of them is clearly there.

This problem of population reduction through loss of reproductive potential has been regularly recorded for many species. It applies to birds as diverse as the Yellow-eyed Penguin (*Megadyptes antipodes*) and Gouldian Finch (*Erythrura gouldiae*), crabs, frogs and tortoises, and fish ranging from the Pedder Galaxias (*Galaxias pedderensis*) to sharks. Among the mammals it has been shown for Ghost Bats (*Macroderma gigas*), Koalas and native rodents. It has been advanced as one reason for the loss of the dinosaurs and sounded as a warning for many parrots, even the ubiquitous Galah (*Cacatua roseicapilla*). The loss of breeding sites has already helped place the Glossy Black-Cockatoo (*Calyptorhynchus lathami halmaturinus*) on the brink of extinction on Kangaroo Island, where possums and bees now invade the large artificial hollows erected in a last-ditch effort to save these birds.

This summer I have monitored my own nest boxes for the third successive season. Of the six that I can see from my window, three contain Adelaide Rosella chicks, two are homes for Common Ringtails and one holds a Common Brushtail. It is an ecological full-house, but the trees that bear the boxes are still young and, without my boxes, none of these animals could be there. Without my added intervention, two of those nest boxes would be rearing starlings and another would now be a bee hive.

In the bush, where no such intensive management is possible, the natural hollows continue to disappear, and feral invaders are increasingly claiming those that remain. ■

IAN HUTTON

As the availability of natural hollows decreases, native species are forced to look elsewhere for possible breeding sites. In the spring of 1994 and 1995 a pair of Eastern Rosellas (*Platycercus eximius*) bred in this roof cavity, which was made accessible when a light fitting was removed. The birds entered the hole by first landing on a nearby air-conditioning box.

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*Previously ANH

Macaroni Penguins (*Eudyptes chrysolophus*) are found only on Macquarie Island and are thought to number in excess of one million pairs.

Antarctic Kelp (*Durvillaea antarctica*) is found all around the coast of Macquarie Island.

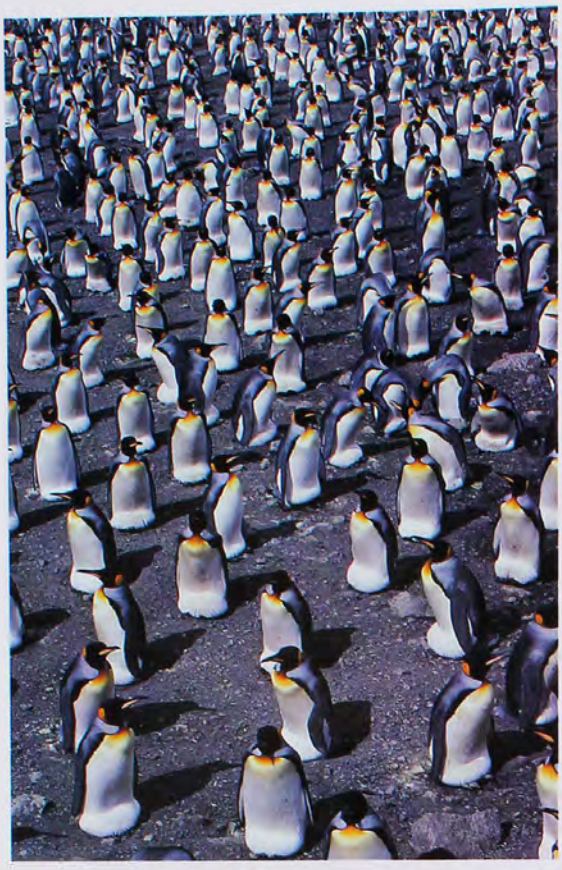
Only low-lying moss and cushion plant communities can survive on the highest and most exposed parts of the plateau.

PHOTOART

MACQUARIE ISLAND

BY NOEL CARMICHAEL

Macquarie Island (55° South, 158° East) is a stormswept speck of land in the vast expanse of the Southern Ocean. A little known, sub-Antarctic part of Tasmania, it is a nature reserve where multitudes of seabirds and seals come to breed. Noel Carmichael is a Tasmanian Parks and Wildlife Service Ranger who has lived and worked on Macquarie Island for three years.



King Penguins (*Aptenodytes patagonicus*) do not build nests, but instead brood their eggs on their feet.

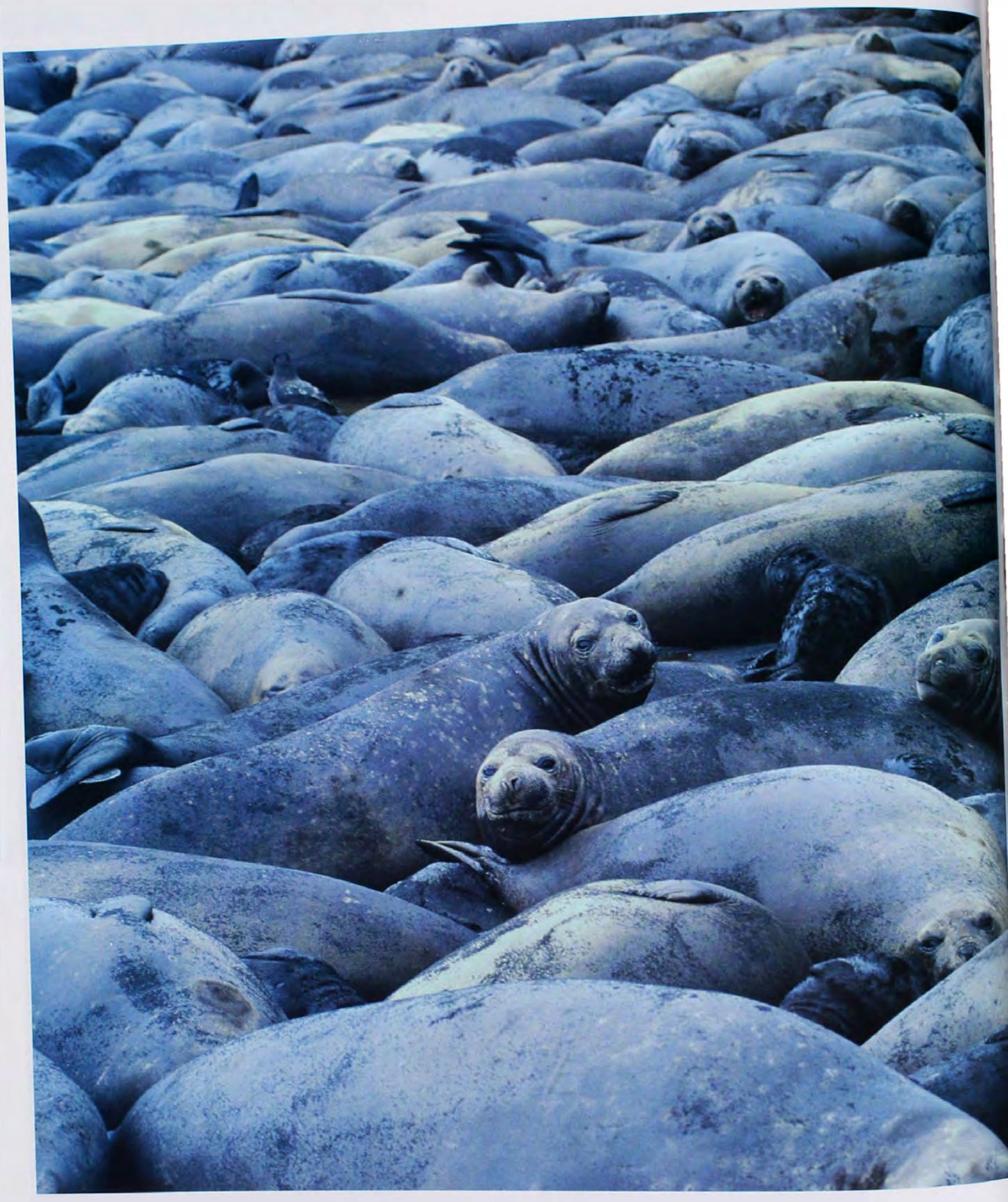
Conspicuously large noses are a feature of adult male Southern Elephant Seals (*Mirounga leonina*).

MACQUARIE ISLAND

Sheltered, low-lying valleys can support a mosaic of plant species, often dominated by *Pleurophyllum hookeri*.

P H O T O A R T

A young King Penguin chick.



Numerous male Southern Elephant Seals each with a harem of up to 20 females form on the crowded beaches during September.

MACQUARIE ISLAND

Dead animals such as this Macaroni Penguin, picked clean by the Island's resident scavengers, are a common sight around the beaches.

King Penguins have an unusually long (13 months) breeding cycle. The snowstorms of winter find King Penguin rookeries still crowded with chicks.

That night I slept with it next to my pillow hoping it would kick-start some bright insight but in the morning it was still tantalisingly strange.

POSSUM PATTERNS PLUCKED FROM STONE

BY MICHAEL ARCHER

BEADS OF SWEAT GATHERED on the backs of my hands as I dragged my knapsack out of the tent. Although still early in the morning, the cool waters of the Gregory River already looked appealing. I tipped the knapsack upside down to get rid of any unnecessary baggage (like the unbelievably huge huntsman spider that had leaped out the day before). A small stream of white sand rushed out to disappear into the soil at my feet—a reminder of the many years spent wandering the sand dunes and salt lakes of South Australia's Tirari Desert searching for rare fossil mammals. It was only after 1983, when Riversleigh gave us a glimpse of the libraries of prehistory packed into her comparably aged limestones, that our trips to the Tirari Desert became much less frequent. Although the Tirari's sands hide fantastic discoveries still waiting to be made, the fossils from Riversleigh were all new, more diverse and ever so much easier to find. So into the knapsack went the hand sledge, the coffee flask, the site tags—and, I hoped, no spider.

It was the winter of 1984 and Queensland National Parks and Wildlife Ranger Ray Langford had just found what became known as Ray's Amphitheatre, an open-ended valley cut into a thick, fossil-rich sequence of Miocene limestones (approximately 15 million years old). Here mammal-rich sites were being discovered at a remarkable rate. First came Main Site with its giant birds and carnivorous kangaroo jaws jutting from the rock; then Skull Site with a jumble of bones and skull pieces; Ringtail Site, one of the rare Riversleigh fossil assemblages dominated by lungfish, turtles and platypuses rather than terrestrial animals; and Gotham City Site with literally millions of bones and teeth of bats, bandicoots and tiny possums. As each site was worked, other sites were found nearby. Within two days, 15 sites had been found and 20 tonnes of fossil-engorged limestone sacked, labelled and hauled on aching shoulders over endless wobbly boulders to the vehicle. It was exhausting work, but every sweat-soaked bag promised—and delivered—prehistoric marvels in abundance.

Near the end of the last day of the expedition, I thought I'd give the lowest slopes a last look. Because needle-sharp spinifex covered the ground, rocks lower than knee-height were impossible to see and so we suspected we had discovered only a fraction of the fossil deposits waiting in the amphitheatre. In one small clearing a head-sized lump of rock glowed in the late afternoon sun inviting me to bend down for a better look. There, jutting from the otherwise featureless surface, was the front of a jaw with a long incisor and a huge premolar with thick recurved ribs running up its sides towards an impressively sharp cutting edge. What on Earth was this?

With time running out, I logged the place as 'Last Minute Site', tucked the rock gently under my arm, and headed for the vehicle. That night I slept with it next to my pillow hoping it would kick-start some bright insight but in the morning it was still tantalisingly strange. I would have to wait until the acetic acid had dissolved the rest of the limestone that surrounded the jaw. When we struck camp in the morning, I rolled it up inside my sleeping bag, making sure the projecting teeth were well protected.

Weeks later at the University of New South Wales, Henk Godthelp grinned as he handed me a complete jaw, far more than I dared hope would be there. With this new information, it was clear it was some kind of giant possum, probably a cuscus but one very different from any living today in Australia. The viciously shaped premolar now made a bit more sense, living cuscuses being known to indulge in the odd bird between meals of plant.

I showed the jaw to Tim Flannery (Australian Museum) who had been researching the diversity of cuscuses and his face lit up. It was a new type of cuscus that we named *Strigocuscus reidi*, one most similar to the Small Sulawesi Cuscus (*Strigocuscus celebensis*) and the Pelang Cuscus (*S. pelengensis*), species from islands to the west of New Guinea that appear to be relicts of an early radiation of the group.

Here then was a new biogeographic mystery to replace the solved palaeontological one. Australia's living cuscuses, the Spotted Cuscus (*Spilocuscus maculatus*) and the Southern Common Cuscus

M. ARCHER

The Last Minute cuscus jaw as first seen in the Miocene limestones of Riversleigh. The lower incisor juts forward in front of the huge, serrated premolar.

(*Phalanger intercastellanus*) that inhabit the rainforests of north-eastern Queensland, also occur in New Guinea but neither are closely related to the Small Sulawesi, Pelang or Riversleigh Cuscuses.

Before these fossil discoveries, biogeographers had concluded that cuscuses as a whole originated in New Guinea and only recently, probably less than two million years ago, invaded Australia, possibly when sea levels were low. Boom-boom, end of story—until Australia's fossil record began to unfold.

As if to drive home the need for a rethink about biogeography, at about the same time, another cuscus jaw was discovered in the 4.5-million-year-old rainforest deposit at Hamilton, south-western Victoria. Tim again had no trouble in recognising this as another, different cuscus, *Strigocuscus notialis*, one most closely related to the Riversleigh cuscus despite a difference of more than ten million years. Hence it is now clear that ancient cuscuses had a much longer, albeit relatively conservative Australian (compared with New Guinean) record than previously presumed.

One qualifier to the story of little change in Australian cuscuses between ten and 4.5 million years ago is the intriguing possibility that the Scaly-tailed Possum (*Wyulda squamicaudata*) of northern Western Australia and the species of brushtail possums (*Trichosurus*), all of which can be thought of as specialised dry-country cuscuses, may be living descendants or at least close relatives of the Riversleigh and Hamilton cuscuses. The ancient cuscuses of Australia may also have been the seeds of the subsequent cuscus radiation in New Guinea that produced at least ten living species, including the two that much later invaded the modern rainforests of north-eastern Queensland.

Unfortunately, these ancient cuscuses disappeared from Australia's rainforests sometime after the early Pliocene. Why? Perhaps because of the massive decline in area of Australia's rainforest over the last ten million years and particularly during the Pleistocene when glaciations in other areas of the world translated to ferociously dry periods in Australia. If descendants of Australia's ancient cuscuses survived in rainforest refuges such as those of the Wet Tropics, every time a bout of severe aridity clobbered Australia, they would have been under siege. The final and possibly worst bout of aridity about 18,000 years ago, which nearly exterminated the Wet Tropics rainforest altogether, may well have been the one that did the dirty deed.

Whatever the reasons for why the archaic cuscuses disappeared from Australia's rainforests, the two living cuscuses in Queensland's rainforests are, as biogeographers correctly deduced, certainly recent invaders from New Guinea where these same living species also occur, there being no traces of cuscuses of this kind in any part of the Australian fossil record. On balance it is all a bit perverse. With the new perspective of Australia's fossil record, it now appears that Australia's ancient cuscuses (with the ancestors of the Small Sulawesi and Pelang Cuscuses) may have given rise to the diverse cuscuses of New Guinea before abandoning the rainforests of Australia in the Pleistocene; then modern cuscuses that evolved in New Guinea from ancient Australian/Sulawesi/Pelang ancestors invaded vacant cuscus niches that had been abandoned in Australia's rainforests in the Pleistocene. Palaeobiogeography lurches ahead.

Many similar challenges to conventional wisdom are emerging from the enriching fossil record of Riversleigh. For example, Jenni Brammall (University of New South Wales) has just identified several specimens of a striped possum (possibly *Dactylopsila* sp.) in fossil rainforest deposits at Riversleigh giving the group a pedigree in Australian rainforests of at least 20 million years. Previously these bizarrely specialised marsupial wood-tappers were presumed to have originated in New Guinea and only much later dispersed to Australia where they occur today in the rainforest of north-eastern Queensland. Now, in complete contrast, it appears that the striped possums as a group more probably originated—and in this case persisted—in Australia, and only later spread to New Guinea.

Distribution patterns, like the animals they represent, are ever-changing, self-constructed things, reactive to opportunities and challenges of the past and with no plans or thoughts for the future. They can only be understood, and to a certain extent future changes anticipated, by study of how they have responded to changes in the past. If we want to understand the real reasons for animal distributions, besides studying the modern situations, we must look as far as possible behind the infinitely brief moment of now. ■

Further Reading

Archer, M. (ed.), 1987. *Possums and opossums: studies in evolution.* Royal Zoological Society of New South Wales and Surrey Beatty & Sons Pty Ltd: Sydney.

Archer, M., Hand, S.J. & Godthelp, H., 1994. *Riversleigh.* 2nd ed. Reed Books Pty Ltd: Sydney.

Flannery, T., 1995. *Mammals of the South-West Pacific & Moluccan Islands.* Cornell University Press: Ithaca, New York.

Flannery, T., 1995. *Mammals of New Guinea.* Reed Books: Sydney.

Professor Michael Archer lectures in biology and geology at the University of New South Wales. Most of his non-teaching hours are devoted to the study of the fossil faunas of Riversleigh, north-western Queensland.

REVIEWS

Tropical Reef Fishes: A Marine Awareness Guide

By Michael Aw. Ocean Geographic Media, NSW, 1994, 126pp. $18.00rrp.

Tropical reef fishes is the first in a series of marine awareness guides. The book is aimed at snorkellers, scuba divers and underwater photographers. It contains information on the habitats, reproductive strategies, behaviour and distinctive features of 33 families of tropical reef fishes. A photographic section for each family contains good tips on how to help you photograph the fish families discussed.

The Indo-Pacific region is home to thousands of species of tropical reef fishes. It therefore follows that a small handbook such as this makes no attempt to be comprehensive. The author states that the book details the most commonly encountered species. This must have been a difficult choice. Indeed, some of the fishes I would have expected to see included, such as the trevallies (carangids), are absent, and others that are anything but commonly seen by divers, such as the Ribbon Eel (*Rhinomuraena quaesita*) and the Whip Goby (*Bryaninops yongei*), are covered.

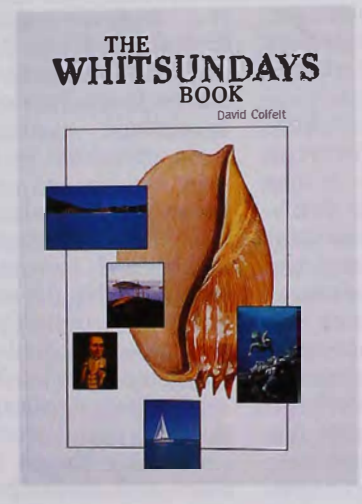
Michael Aw is well known for the magnificent photography in his book *Beneath Bunaken*. The photographs used in *Tropical reef fishes* are also first class. Those of the Bearded Scorpionfish (*Scorpaenopsis cirrhosa*) and the Black-tipped Rockcod (*Epinephelus fasciatus*) are especially good.

Having praised the photography, it's time to be a little more critical on the layout of the book and the text. The fishes are divided into three groups: the blue water cruisers, the bottom dwellers, and the hole and crevice residents. The edge of each right hand page is colour coded so it is easy to flip to the correct section of the book. While this seems like a good idea, the system breaks down in some cases. Blue water cruisers are defined as fishes that are pelagic or free-swimming and are found in the open ocean or on coral reefs. This definition is so broad that it tends to be unwieldy. The title would suggest fishes such as barracudas and some species of sharks. These fishes are included in this section along with other families such as the butterflyfishes, damselfishes and even the pipefishes, which most people would certainly not describe as 'blue water cruisers'. The problems inherent in the system are further illustrated by the introductory photograph for the section on hole and crevice residents. The photo shows four species of fishes. One is not covered in the book, two are covered in the section on blue water cruisers and only one is actually included with the hole and crevice residents.

There are at least 16 errors with scientific names, usually misspellings. Common names always present a problem and in at least seven cases Australian readers will find the names surprising. The text is written in a very colloquial and anthropomorphic style. For a popular readership this might be fine, however I found it annoying. Expressions such as fish "libido", "increasing passion", "frantic orgasmic dashes" and even a "wham bang, thank you ma'am" are all found in the reproduction sections.

Despite the numerous shortcomings, the book could be of use for people with little knowledge of fishes who want a small-sized publication that is easy to take outdoors. It could also be quite useful for the identification of the most commonly seen fish families.

—Mark McGrouther
Australian Museum



The Whitsunday's Book: A Key to Adventure

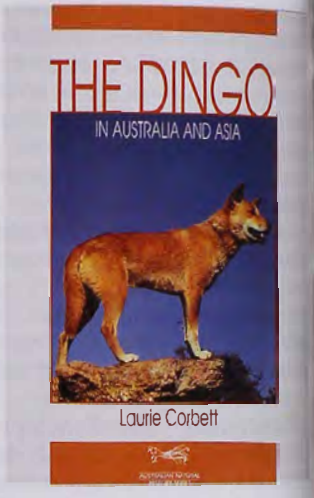
By David Colfelt. Windward Publications, NSW, 1995, 192pp. $34.95rrp (hardback); $24.95rrp (softback).

A picture tells a thousand words, but that's not always enough for a travelling enthusiast! *The Whitsunday's book* by David Colfelt is a picture book and guide combined. It is extremely thorough, combining countless maps and drawings by artist and wife Carolyn, along with charts and photographs on every page. As a result, it covers everything you could possibly want to know when visiting the area. David's photographs are included throughout the book and they really reflect his passion for the islands, conjuring up an image of a remote wilderness with adventures awaiting.

The book is a pleasure to read. There are tips on a wide range of activities including bird watching, hiking, diving and angling. The 192 pages of information presented in a neat A3 size (perfect for travelling) make the book a must for anyone discovering the Whitsunday's beauty. If an encyclopedia existed on the Whitsundays, it would look like this!

(*The Whitsunday's book* is available by writing to the author at Windward publications, 464 Woodhill Mountain Rd, Woodhill Mountain, NSW, 2535.)

—Merridy Carn-Duff



The Dingo in Australia and Asia

By Laurie Corbett. University of New South Wales Press, NSW, 1995, 200pp. $24.95rrp.

This book is magnificent. It is by far the finest volume published in the University of New South Wales Press' Natural History Series, and is certainly the most authoritative work ever published on Dingoes. As the author notes in the acknowledgments, it is the result of 30 years of research by a vast team of workers. The data in it are clearly hard won, and the conclusions drawn, particularly about Dingo management, are an invaluable contribution both to conservation and to the pastoral industry.

Laurie Corbett has taken a broad view of the Dingo. This is reflected in his reference to the basenji as the African Dingo, and the dogs of South-east Asia as South-east Asian Dingoes. His preferred scientific name for the Dingo, *Canis lupus dingo*, not only

implies that the Dingo is a single subspecies of the Grey Wolf, but that Dingo populations are uniform throughout their huge distribution in Asia and Australia.

The natural history of Dingoes in Australia is drawn from detailed, long-term studies of populations in six very different areas of Australia, ranging from the central deserts to the alpine regions. This leads to some difficulties in presenting the data, but the publisher has minimised this by a judicious use of information presented in boxes and graphs and other illustrations.

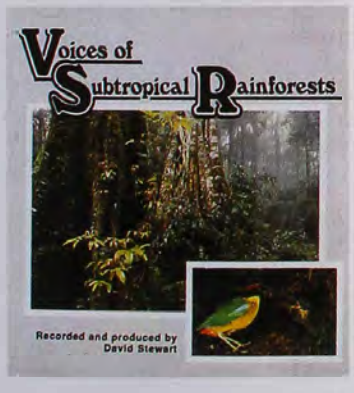
The 21 colour plates that grace the centre of the book may not be to everyone's taste. There are almost as many photographs of dead Dingoes as live ones, and the photograph of a butcher at work in a dog abattoir in north-eastern Thailand is not for the faint-hearted. Nonetheless, it must be remembered that these illustrations are not merely decorative; they are there to make a scientific point.

From a grazier's point of view, the most important part of this work concerns the interaction of Dingoes with domestic stock, particularly cattle. Corbett pulls no punches. He begins his discussion with the observation that "Dingoes do kill and eat cattle, sheep and other stock; they always have and they always will". Corbett proceeds to assess the impact of this, and to evaluate the wisdom of spending many millions of dollars trying to control Dingoes. He points out that, because of the social structure of Dingoes, some control measures have simply acted to increase Dingo density. He also states that Dingo predation on cattle can sometimes have a beneficial effect, such as when Dingoes remove sickly calves at the beginning of a drought. In order to maximise such benefits, he lays down some easy-to-follow guidelines, and one of his key recommendations is to relax Dingo control measures during droughts.

The chapters dealing with conservation should sound alarm bells. Worldwide, Dingoes are under threat, mainly through hybridisation with domestic dogs. In Thailand (one of the bastions of the Asian Dingo), the incidence of hybridisation increased 80 per cent from 1975 to 1984. In Australia the situation is, if anything, worse. Pure-bred Dingo populations are today concentrated in the north, and may well soon disappear if nothing is done.

Laurie Corbett is a great storyteller. His book is well written and even has room for humour (indeed, I could not decide whether the acknowledgment to Wendy Waggitt was a final tribute to a Dingo or a person). I can whole-heartedly recommend this book to everyone and it is a must for anyone involved in conservation or the pastoral industry.

—Tim Flannery
Australian Museum



Voices of Subtropical Rainforests

Recorded and produced by David Stewart. Nature Sound, PO Box 256, Mullumbimby NSW 2482, 1994, 60 min. $25.95rrp.

Recent years have seen a growing market for recordings of natural sounds, either on their own or with musical accompaniment. While varying in their quality, all are basically 'walls of sound', producing a pleasant background ambience. "Voices of Subtropical Rainforests", recorded and produced by David Stewart, one of Australia's foremost natural sound recordists, has taken the concept a step further. As well as providing a detailed and intricate sound portrait from nature, it is also a useful identification and reference tool for naturalists.

The recordings are from the rainforests of north-east-

The rainforest is a habitat in which animals are more often heard than seen, and the voices of its inhabitants are unfamiliar to many people

ern New South Wales, from Werrikimbi National Park, north to the Border Ranges and southern Queensland. The hour-long CD covers a day in a rainforest, from dawn until night. It is divided into 11 tracks that follow the various moods of the forest at different times of day and through changes in the weather. Two of the tracks are devoted to Albert's Lyrebird (*Menura alberti*) and the Rufous Scrub-bird (*Atrichornis rufescens*), notable vocalists and mimics that are largely restricted to this region. Included among the sounds are 65 calls of frogs, birds and mammals, accompanied by noises of the physical environment, such as waterways, storms and dripping water.

What sets this CD apart from others on the market is the ability to select not only any of the 11 primary tracks, but also any of the 65 calls. The rainforest is a habitat in which animals are more often heard than seen, and the voices of its inhabitants are unfamiliar to many people, even experienced observers. The ability to call up the desired call with a push of a button makes Dave Stewart's CD an excellent reference tool. This combination of sound quality and scientific merit should set a standard for future recordings of this style. This CD is a worthwhile acquisition for the nature enthusiast.

—Walter E. Boles
Australian Museum

SOCIETY PAGE

Get involved! Across Australia there is a network of active societies, large and small, local and national, which exist to further the cause of the subject that you hold dear. Whether your special interest is conservation, birds, science, national parks, bushwalking or a particular group of animals there's a society for you. *NATURE AUSTRALIA* is pleased to help promote the following societies:

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Ph: (03) 9329 6332
Contact: Glenys Oogjes, Director
Membership Fee: $30.00

FAWNA, For Australian Wildlife Needing Aid NSW Inc.
PO Box 41, Beechwood,
NSW 2446. Ph: (065) 856 470;
Fax: (065) 856 528
Contact: Amanda Boardman, Secretary
Membership fee: $20.00

The Marsupial Society of Australia Inc.
GPO Box 2462, Adelaide,
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Gould League of SA
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SA 5092. Ph: (08) 277 2851
Contact: Arthur M. Pratt, Treasurer
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Qld 4872.
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Gould League Vic.
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Royal Society of SA Inc.
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Phone: (06) 223 5260
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SAHG, SA Herpetology Group
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Victorian Herpetological Society Inc.
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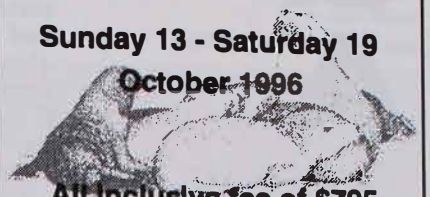

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Q&A

Mysterious Skull?

Q: *Could you please identify the animal whose skull we found nearby? This is the first 'bone' we have found that has us stumped.*

—P. Wagner & K. Drake
Chaddlewood, NSW

A: The object is not a mammalian skull; it is, in fact, an avian synsacrum, the bird's pelvic bones and underlying vertebrae fused into a single unit. The narrower section faces forward, towards the head. The holes in the side are the sites for the insertion of the head of the femur (thigh bone) and attachment of deeper leg muscles.

This pelvis is broad, rather than elongate and streamlined, so it did not come from an aquatic bird, such as a duck or cormorant. The curved faces on the sides of the forward end are the sites of muscle attachments. These areas are deep, and the muscles were large and powerful. This indicates that the bird used its legs extensively, and it can be thus deduced to have spent most of its time on the ground.

Using these initial clues, comparisons can be made with the skeletons of a range of ground birds. These show that the pelvis comes from a gallinaceous or fowl-like bird, which include pheasants, quail, turkeys, guinea fowl and brush-turkeys. More detailed comparisons among members of this group suggest that it is most likely a domestic fowl or chicken. It is not, however, the leftovers from the local chook shop. These grilled fowl are young birds, and the pelvis comes from an older bird, as shown by the advanced fusion of the bony elements and ossification of the ends of the bones.

—Walter E. Boles
Australian Museum

Hopping Blind

Q: *In north-western Australia it is common to read notices at the entrances to national parks and similar State-controlled areas forbidding the entry of dogs. Sometimes a notice several hundred yards along the track from the first one will repeat the information and demand that dogs be taken back out of the park. Because I'd always believed cats were the major problem to wildlife, I asked why dogs were particularly targeted and was told that there is a substance in dogs faeces which, when transferred to the eyes of kangaroos, makes them blind. I wonder whether this may also be the reason for blindness occurring in kangaroos in other areas.*

—Jean Whitla
Wodonga, Vic.

A: The cause of the recent outbreak of blindness in kangaroos appears to be a virus called an orbivirus. Orbiviruses are common in the Australian outback and are transmitted by biting midges (*Culicoides* spp.). These viruses do not cause disease in humans or other animals as far as we are aware and most are benign. By tracing back old records of blindness in kangaroos, some researchers have found that this disease is likely to have occurred at regular intervals in the past.

Regarding the substance in dog faeces that would cause blindness in kangaroos, you would have to contact the relevant State authorities to ask what they are referring to. It may be the common roundworm of dogs (*Toxocara canis*), the larval forms of which can make their way to the eye, in hosts other than dogs, causing blindness.

—Robyn Turner
CSIRO Division of Wildlife & Ecology, ACT

Coloured Snow

Q: *Often in the spring, snow on and around Victoria's Bogong High Plains develops a pinkish to red colour. There appears to be ice above the growth, followed by an air gap and then the growth on the snow beneath. This often occurs in shady areas and not every year. Can you please explain this phenomenon for me?*

—Anne U'Ren
Glen Waverley, Vic.

A: A pinkish to red colour in the snow of

DAVE WATTS/NATURE FOCUS

Outbreaks of blindness in kangaroos, like this Red Kangaroo (*Macropus rufus*), is usually the result of an orbivirus, which is transmitted by biting midges.

Australia's alpine areas is most likely the result of a small bloom of cryophilic algae or snow algae. The red colouration is due to high concentrations of the alga's carotenoid pigments, which mask the otherwise green colour of their photosynthetic chlorophylls. Snow algae have been reported from many alpine areas (that is, from Colorado to New Zealand and Irian Jaya to the Bogong High Plains) and generally are noticed more in the persistent snow banks in summer when the algae get the most light. At least within Australia, three species of algae are responsible for coloured snow: *Chlamydomonas nivalis* and *C. bolyaiana*, which cause the red colouration, and *Chloromonas brevispina*, which causes the yellow–green patches of snow. Frequently, the fungus *Chionaster nivalis* occurs in association with the algae. Two green algae, *Koliella nivalis* and *Raphidone manivale*, are also known to occur in the snow, but rarely do they occur in sufficient concentrations to cause a green colouration. Not all coloured snow, however, is due to algal blooms for in the Snowy Mountains, in particular, the accumulation of red–brown dust blown in from inland areas has been measured at 1,700 kilograms per hectare, a sad result of our soil erosion problems.

—Alan Millar
Royal Botanic Gardens, Sydney

Answers to Quiz in Nature Strips (page 15)

1. 1992
2. 46
3. Moruroa or Fangataura
4. A lyrebird
5. Western Australia
6. Ten
7. Argyle diamonds
8. Rabbit calicivirus disease
9. Velvet worm
10. Search for Extraterrestrial Intelligence

S. WILSON

PIC TEASER

Do you recognise this? If you think you know what it is, then send your answer to Pic Teaser, *Nature Australia* Magazine. Please don't forget to include your name and address. The first correct entry will win a $20 gift voucher for the Museum Shop Book Catalogue. Autumn's Pic Teaser was a stargazer fish (family Uranoscopidae).

Palaeontology is formulating messages of tremendous importance, but it is a science facing threats of ignorance and destruction.

VIVA PALAEONTOLOGY

BY PAUL WILLIS

IT IS EASY TO DISMISS FOSSILS AS curiosities, freaks of nature or mere oddities but, in reality, fossils are the only direct record of the history of life on Earth. In the broader sense, fossils represent a unique non-renewable scientific resource. Their significance may not be fully realised by the wider community but, unless we take action to assure the safety of our fossil heritage, we will continue to lose elements of this most important history.

It is time to treasure and protect our fossil heritage, and it is time to promote the relevance of fossils to our modern world. Palaeontology is formulating messages of tremendous importance to our modern society, but it is a science facing threats of ignorance and destruction.

Ignorance manifests itself in many forms. Palaeontology is sometimes portrayed as a dead, dry science with little room for innovation or revolutionary insight. Palaeontologists are seen as stamp collectors who slot each new fossil into a broader, preconceived picture. But this is not true. Like any science, palaeontology is continually subject to revision by new approaches with dramatically different consequences and results. The adoption of cladistics (classification of organisms according to shared, derived characters) by palaeontologists is a good example; we now view relationships between extinct and extant organisms in a fundamentally different way to the concepts employed 20 years ago. New and innovative methods of recovering and reconstructing long-extinct organisms, and the communities in which they lived, have led to dramatic changes in the way we interpret them. Palaeontology is a live and vibrant science.

Another form of ignorance concerns the relevance of palaeontology to society at large. As an historical science, palaeontology is easily dismissed as 'interesting but irrelevant', but it is the historical context of palaeontology that makes it essential to today's society. We are staring our own extinction in the face and we have only a limited understanding of what can be done and limited time in which to act. In this situation, we can learn something useful by studying extinctions from the past. As historians of life, palaeontologists can reinforce the maxim that we ignore history at our own peril.

Beyond ignorance, palaeontology is also threatened by destruction of the fossils themselves. There are many popular misconceptions concerning the ownership of fossils and the abilities of museums to acquire them. The regulations concerning the ownership of fossils in Australia vary between States and depending on where they are found but, basically, it is finders-keepers. Usually, this rule of thumb is fine; most fossils are not of a quality nor importance to make them of interest to science. However, when the occasional fossil is found that is of major scientific interest and heritage value, there is no mechanism for securing that specimen for the national estate.

Australian natural history museums are not provided with sufficient acquisition funds to purchase important fossil specimens and private benefactors are usually uninterested in their fate. This situation led to the Eric episode where it took a country-wide public appeal to purchase and save an opalised skeleton for the Australian Museum (see *Nature Aust.** Spring 1993). Specimens unique to Australia, such as opalised skeletons, must remain here as part of the national estate, but there is no legislation that demands or ensures their procurement. We need consistent, reliable mechanisms to ensure that fossil specimens of national significance become part of the national estate with suitable benefits to finders, owners and all interested parties.

It is not only individual fossils that are at risk; many of the sites they come from also need protection. There are currently no consistent policies from either Federal or State governments for the protection of important fossil sites. There is not even a set of criteria for assessing their importance. We need a consistent, nationwide approach to the identification and preservation of important fossil sites.

This situation is slowly beginning to change. In 1994 the important fossil sites of Riversleigh in Queensland and Naracoorte Caves in South Australia received World Heritage listing. But these are isolated measures that fall short of the consistent, nationwide approach that is required.

Palaeontology is a vital science relevant to modern society, but our raw data, the fossils themselves, and the sites where they are found are under threat. It is time that we carefully considered the future and protection of these most valuable resources. ■

'Eric' the opalised pliosaur was saved from an uncertain fate by a nationwide appeal and now resides at the Australian Museum.

CARL BENTO/NATURE FOCUS

The Last Word is an opinion piece and does not necessarily reflect the views of the Australian Museum. This issue's contributor, Dr Paul Willis, is a consulting vertebrate palaeontologist currently involved in book writing and education programs for children.

* *Previously ANH*

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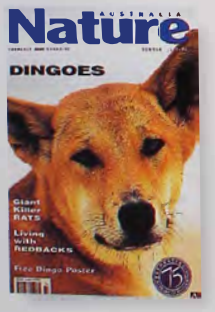

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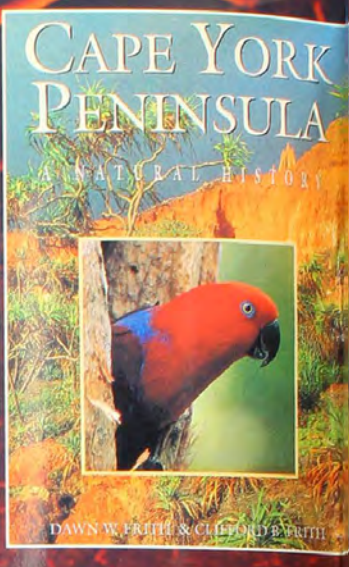

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