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TAWNY FROGMOUTH

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Trust President: Brian Sherman
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Publishing Manager
JENNIFER SAUNDERS, B.SC.
email: jennys@austmus.gov.au

Editor
GEORGINA HICKEY, B.SC.
email: georgieh@bigpond.com

Photo Editor
KATE LOWE
email: klowe@austmus.gov.au

Design & Production
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FRONT COVER

The Tawny Frogmouth (*Podargus strigoides*) is found in most open, wooded habitats throughout Australia.

PHOTO BY JOHN SHAW/ AUSCAPE.

up front

Choosing a mate is not an easy task for a female. Get it wrong and the price can be very high indeed. So how do you tell if that male is the right male? Is it how well he fights, how strong he is, how beautiful he looks? Or is it related to the interest he shows in you, the time he spends courting you? It is a traditionally held belief that the processes of sexual selection lead to the evolution of the same sorts of traits. So a male's fighting ability can also function as a mate guide for females. But traditionally held beliefs are there to be questioned and that's exactly what Bob Wong did when he decided to investigate whether it is true that females always prefer to mate with dominant males. Enter the Pacific Blue-eye, a beautiful freshwater fish from Queensland that many people like to keep as pets. The males sport lovely long fins and are aggressive with other males. In Bob's experiments he enabled females to choose their mates free of any risk of coercion or harassment. So what type of males did females choose? Find out on page 42.

GUNTHER SCHMIDA

Pacific Blue-eye.

Cunningham's Skinks are the Brady Bunch of the reptile world—they are all about family and home. The adult pair forms a faithful bond and exhibits long-term monogamy. They are serious homebodies, occupying the same rock crevices for long periods of time. To top it off, the kids stay at home with the parents for the five to six years it takes for them to reach maturity, so a family group can grow to mum, dad and about 25 kids. But there are threats to this rosy family structure and how the lizards deal with these threats will decide their future.

Also in this issue we take a look at a conspicuous Melbournian resident, the Fox; discover why the Superb Fairy-wren is a bird on the ball; meet an amazing mammal that plants trees; and unearth a beetle that likes to do all sorts of things with dead bodies.

Jennifer

— JENNIFER SAUNDERS
Publishing Manager

ADAM STOWE

Cunningham's Skinks.

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letters

When Left Means Right

I refer to the interesting Nature Strips item "Dogs Get the Point" (*Nature Aust.* Autumn 2004). Our Border Collie has been taught to go left or right by obeying either of the commands 'Left' or 'Right' when he is running ahead and encounters a fork in the path through the woods. This he has learnt to do very reliably.

Sometimes when he is well ahead, too far perhaps to hear accurately, he turns to face me for a verification of the command. When he hears it, he goes to my right, or my left. In other words, he uses my point of egocentric localisation, rather than his own. This might be analogous to the way a teacher initially indicates right and left hands to preschoolers, using opposite hands in the demonstration while facing the children, since young children cannot yet make the mirror transposition.

The only time there is any confusion with our Dog is when, after he correctly turns left, I thoughtlessly add, "That's right", whereupon the silly thing immediately turns and goes the other way!

—Philip de Lacey
Camden, NSW

Puggle Puzzles

In regards to your Q&A on the derivation of the name 'puggle' for a baby echidna (*Nature Aust.* Summer 2003–2004), I have another reference that may be of interest. I came across a photo of David Fleay holding a Short-beaked Echidna in the 1988 edition of *Australia's dangerous creatures*, published by Reader's Digest. The caption, on page 103, is "David Fleay at the Gold Coast reserve he founded, with Puggles the echidna." This date is later than the 1979 reference you give, but the text and photo may well date from an earlier time.

—Sally Swan
Mont Albert North, Vic.

The photo published in the 1988 edition of the Reader's Digest book was taken by Paul Riley, originally for an article that was published in 1986 in the Sydney Morning Herald's *magazine* The Good Weekend *(8 November 1986, p. 28). Unfortunately David Fleay died in 1993, so I cannot ask him when, exactly, that particular echidna was acquired or given its name. His daughter Rosemary Thomson was unable to find any reference to "Puggles" in his articles and correspondence. Nor did the David Fleay Wildlife Park have any written record of an echidna called "Puggles". However, considering that an echidna may live for 50 years (in captivity) and well over 10 years in the wild, it is possible that this echidna could have been alive before the critical 1979 date. Still, this doesn't tell us anything about whether it had been christened by then. If anyone can shed light on the matter, please let us know.*

—G.H.

COURTESY PAUL RILEY

The late David Fleay, with an echidna called Puggles, at his wildlife park in 1986.

Threat of Disease

Your article on the threats facing the Blind Gudgeon of North West Cape (*Nature Aust.* Autumn 2004) overlooked one significant threatening process—disease. In 2001 I visited a sinkhole on the outskirts of Exmouth and found it teeming with Guppies that someone had released there. When people tire of pet fish they often free them in nearby ponds and streams, and around Exmouth the only available wetlands are those supporting Blind Gudgeons and Blind Cave Eels. These fish have evolved over many millions of years in isolation from all other fish, and they would be expected to have little resistance to fish diseases.

especially those carried by imported aquarium fish. There is a real risk of some foreign pathogen entering the cave system and wiping out vast numbers of fish. This risk could be reduced by a publicity campaign aimed at pet-owners in Exmouth.

—Tim Low
Brisbane, Qld

Bioidentities

I loved the Last Word suggestion in the latest *Nature Australia* (Autumn 2004) that we all be given three totems to help us link to the environment. It might help if at least one of these was common in the State of registration, so that we all had some chance of observing our totems. It might also be a good idea to add an environment to the totems. For example, coastal heath dreaming.

Perhaps you could start setting them up as a gift system—we give the totem plus something about the totem.

—John Davidson
Chapel Hill, Qld

Rods & Cats

Ren Barnett's Letter "Aboriginal Puddy Cats" (*Nature Aust.* Autumn 2004) is very instructive in that it gives not only Warlpiri words for Cat (*minija* and *ngaya*), but also one that looks very like a pidgin word (*pujukati*). The courtesy of Aboriginal people who use what they know of the language of the person they are talking to, is typical. It is also typical of the courtesy they expect from each other, but so rarely receive from white settlers.

I also agree with Pat Flecker's comments on snake staffs, and the well-deserved compliments on the quality and presentation of your publication. May I add that Mercury was not only the messenger of the gods, but himself God of Thieves and Merchants?

—John Killick
Balgowlah, NSW

Terrick Slip

My compliments on a magazine that is consistently riveting and stunning! I enjoyed seeing Terrick Terrick National Park in photos by Kevin Hone (*Nature Aust.* Autumn 2004). It's a park I frequently visit because it seems to have a marvellous 'sense of place' about it. A small slip in the caption on page 70, though: Terrick Terrick National Park is situated on an outlier of the Northern Inland Slopes bioregion, landlocked *within* the Victorian Riverina. Ever an avid reader (perhaps also a pedant)!

—Leigh Ahern
Yarra Glen, Vic.

For the Record

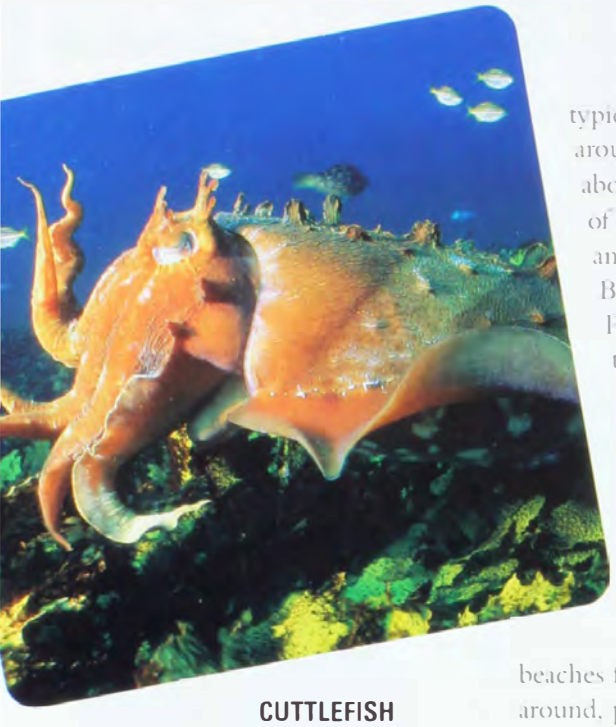
The photo of the swan being weighed on page 41 of the Autumn 2004 issue of Nature Australia *was taken by Carol Hall; the Pic Teaser photo (page 83) was taken by Mike McKelvey; and W. Peckover's owl photo (page 64) was supplied by VIREO. We apologise for these errors.*

—G.H.

Nature Australia **requests letters be limited to 200 words and reserves the right to edit them for sense. Please supply a daytime phone number and type or print your name and address clearly. The best letter in this issue will receive a copy of *The future of life*. The winner this issue is Sally Swan.**

Winter

Compiled by Geordie Torr and Martyn Robinson



Giant Cuttlefish.

CUTTLEFISH CONVENTION

Each year, from early May to mid-August, Giant Cuttlefish (*Sepia apama*) gather in their hundreds of thousands to spawn on the reefs of Spencer Gulf in South Australia. This annual cuttlefish convention has been described as one of the most spectacular events in Australian marine waters.

These super-sized cephalopods choose to hold the event at this particular spot for one reason—hard rock. Literally. The females need a solid surface on which to attach their eggs, which typically number around 200 and are about the diameter of a 20-cent piece, and the reefs of Black Point and Point Lowly are the only suitable places in the area. After spawning, the cuttlefish die and their huge cuttle-bones, also known as sepions, wash up on beaches for kilometres around, providing a bounty for pet shop proprietors, who sell them to Budgie owners for their birds to sharpen their beaks on. The flesh of the dying molluscs, which can grow to more than a metre in length, also provides a sumptuous feast for numerous seabirds, dolphins, seals and fishes. Should you come across a whole sepion washed up on the beach, look closely and you should be able to see the marks of the scavengers' beaks and/or teeth scratched across its surface.

To learn more about these gentle giants, visit **www.bbc.co.uk/nature/wildfacts/factfiles/3074.shtml**

WHERE HAVE ALL THE SPIDERS GONE?

You may be wondering what's happened to that big fat spider whose web you used to walk into around the back of the clothes line. Well, I hate to come over all *Charlotte's Web* on you, but I'm afraid she's probably dead.

Most araneomorph spiders (the typical web-building spiders and huntsmen) do the 'live fast, die young' thing. Many breed towards the end of their first year and then never get to see their offspring (which is probably a good thing, as some mothers would probably eat them otherwise).

The 'elderly decline' of these spiders is perhaps most noticeable in the orb-weaving species. Garden orb-weavers such as *Eriophora transmarina* normally build, tear down and eat their webs each night, but around this time of year they will start leaving them up permanently. Golden orb-weavers (*Nephila* spp.), which always leave their webs up, will be getting less fussy about repairing any holes. And St Andrew's Cross Spiders (*Argiope keyserlingi*), normally so neat in their webs, will begin to lose their symmetrical stance.

These are all signs that winter is upon us and the spiders will soon disappear. They no longer seem to have the energy or the silk to make repairs, but may well be trying to catch a few of the dwindling insects still about to provide enough energy for

St Andrew's Cross Spider.

S. WILSON

Common Eastern Froglet.

one last egg sac.

In contrast, the more 'primitive' spider forms—the mygalomorphs such as funnel webs—live for many years and simply become less active in winter, many waiting out the cold safe in their burrows.

For more about the spiders in your garden, check out **www.amonline.net.au/factsheets/#spiders**

AS COLD AS A FROG

Winter isn't usually thought of as a time when you'd find frogs, let alone find them breeding—surely most frogs would be hunched up somewhere safe. Well, it's that very point that has allowed some species to specialise as winter breeders. Braving the elements allows these hardy amphibians to avoid competition with all the frogs that prefer the warmer weather.

Along Australia's east coast, from south-eastern Queensland to south-eastern South Australia and Tasmania, the frog most commonly heard during winter is the Common Eastern Froglet (*Crinia signifera*). This small brown frog is variably patterned—some individuals are striped, while others have spots or blotches on their backs. Its ability to withstand the cold is quite extraordinary—males will even call when there's snow on the ground.

Although winter is when it comes into its own, this diminutive croaker—it grows to less than three centimetres in total length—actually calls throughout the year, often forming large choruses beside temporary ditches, ponds, and shallow creeks. It can even be heard calling from freshwater soaks less than a metre above the high-tide mark along some Sydney beaches. The choruses are interesting in that roughly half of the frogs call together, immediately followed by the other half, producing a see-sawing 'creeeek creeeek' effect.

A few more facts about Common Eastern Froglets can be found at **http://frogs.org.au/frogs/signifera.html**

FROM THE COLLECTION

*This specimen of a Short-beaked Echidna (*Tachyglossus aculeatus*) has the earliest date of any echidna held in the Australian Museum. It was collected by a J.F. Wilcox in the Clarence River area of northern New South Wales and purchased in 1866 by George Masters, Assistant Curator, for the Museum collection.*

Winter isn't a very good time to see echidnas as many enter torpor during the colder months. Dropping their body temperature below 10° C and breathing just once every three minutes—and consequently greatly reducing their metabolic rate—they survive on their body fat, which can make up as much as 40 per cent of their total weight. Every few weeks, over a period of 12 hours, their body temperature slowly rises to 32° C— their normal operating temperature—before they drop back into torpor again. When the weather warms up and the ants become more active and produce more of those tasty winged queens and fat grubs, the sleepy monotremes fully awaken and set about replenishing their fat stores.

For more on these pungent ant-snufflers, grab a copy of Echidnas of Australia and New Guinea *(1993) by Mike Augee and Brett Gooden.*

STUART HUMPHREYS/NATURE FOCUS

Geordie Torr is a freelance science writer and Martyn Robinson is the Australian Museum's resident Naturalist.

nature strips

COMPILED BY GEORGINA HICKEY

RICHARD FULLAGAR, KARINA HOLDEN, KAREN MCGHEE, RACHEL SULLIVAN, ABBIE THOMAS, GEORDIE TORR AND PAUL WILLIS ARE REGULAR CONTRIBUTORS TO **NATURE STRIPS**.

Fish-Lizard's Last Supper

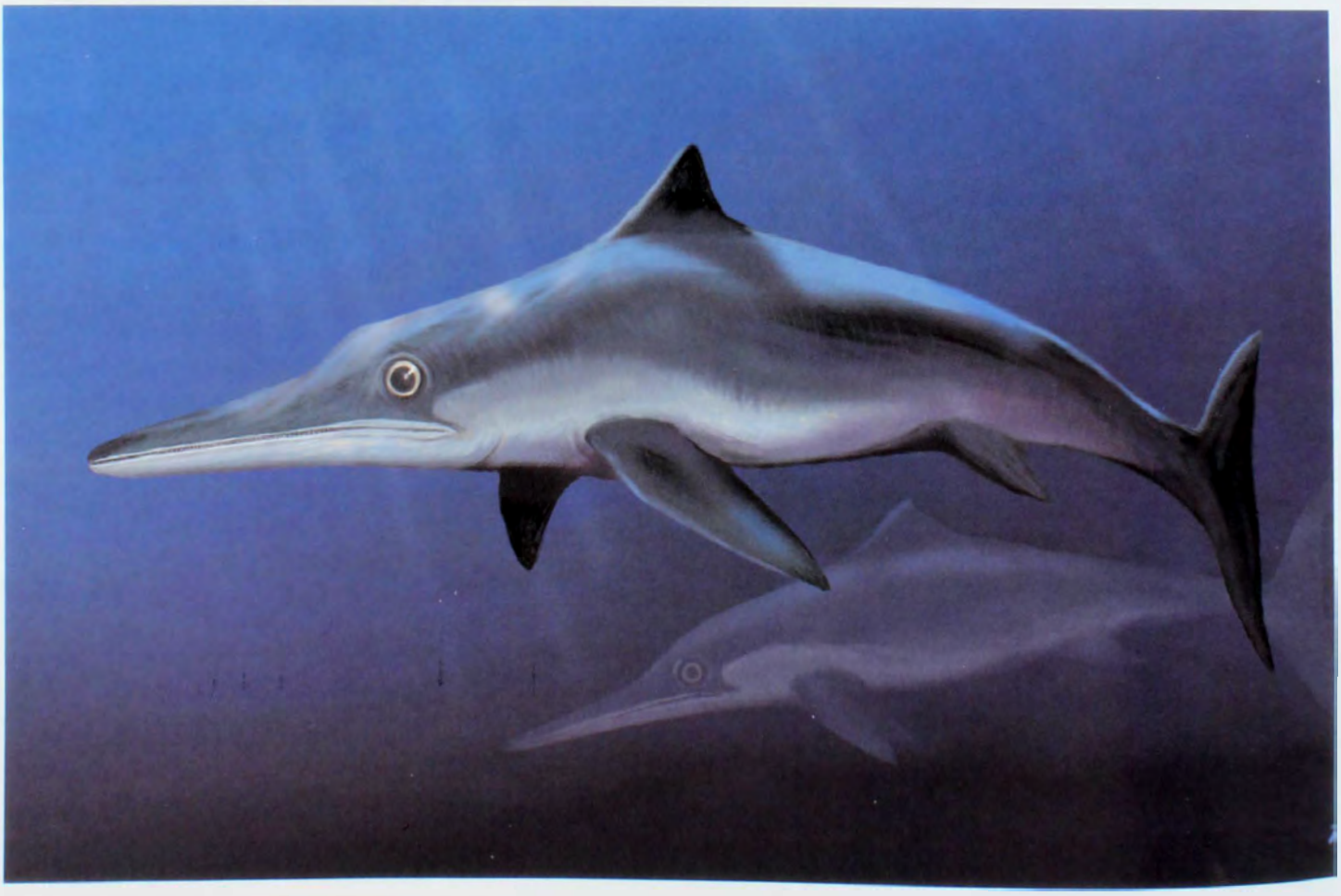
It had long been assumed that ichthyosaurs, with their dolphin- or tuna-like shape, were high-speed pursuit predators of the Mesozoic oceans. Their gut contents and coprolites (fossil turds) also support this idea, because they are sprinkled with the remains of fish, squids and other high-speed prey that would have required a lightning-fast predator to catch them.

But the recent findings of gut contents from an Australian ichthyosaur (*Platypterygius longmani*) appear to challenge this comfortable dogma. Ben Kear (South Australian Museum) and colleagues describe bones of young turtles and a bird in the stomach of an ichthyosaur from Queensland (*Proc. R. Soc. Lond.* B 270: 206). Slow-moving juvenile turtles would have been easy prey, and the bird would most likely have been a scavenged carcass washed out to sea from nearby land. The gut contents of this individual also included the remains of a number of fish. These ingested bones show no acid pitting that would be expected if they had been sitting in the stomach for a long time.

Does this mean that a major rethink is required on the eating habits of these marine reptiles?

Perhaps not. This is the first record of birds and turtles as gut contents in ichthyosaurs despite hundreds of ichthyosaur specimens being found. And the specimen Kear *et al.* describe is a rare individual in a number of ways. Besides the stomach contents, it has an almost full-term foetus inside its body.

Could the apparently unusual diet of this



BRIAN CHOO

Not all ichthyosaurs restricted themselves to a 'fast-foods' diet.

Do ball-rolling dung beetles navigate by the light of the moon?

STAN OSOLINSKI/OSF/AUSCAPE

individual have been influenced by its pregnancy? Perhaps under specific conditions, ichthyosaurs would resort to scavenging and preying on slow-moving prey as well as their more typical fast foods.

—P.W.

Counting Coots

Mention brood parasites and most people will think of cuckoos that parasitise the nests of other species. But a study of American Coots (*Fulica americana*) has revealed not only do they lay eggs in other coots' nests, but they can tell their own eggs from a parasite's, and count them too (*Nature* 422: 495).

Over four breeding seasons, Bruce Lyon (University of California) checked between 50 and 100 nests daily, comparing numbers of eggs and using each female's distinctive pattern of egg-speckling to distinguish between those laid by the host and parasite.

He found that 41 per cent of nests were affected by parasitism, accounting for 13 per cent of all eggs laid in the study population. However, after they finished laying, almost half the study pairs rejected at least one foreign egg, either through burying them deep in the nest where they would fail to hatch, or by banishing them to an inferior incubation position at the edge of the clutch.

Lyon found that eggs that were rejected outright looked noticeably different from the hosts' eggs, but says that the second strategy (where the eggs were pushed to the edge of the clutch) may be used for eggs that are distinguished with less certainty. As the interlopers may still hatch, the effects of this method are less effective than outright rejection, but it isn't as costly to the hosts as accidentally banishing one of their own.

Evidence for the birds' counting ability was unexpected. Coots lay one new egg per day until some external cue tells them when to stop. Previously it was assumed that they used their sense of touch to 'feel' when enough had been laid (average of eight in unparasitised nests). But Lyon says that, if this was the case, then the presence of parasitic eggs should cause the host female to lay fewer of her own. He found instead that when female coots recognised alien eggs, they did not reduce their own clutch size; those that didn't recognise them, however, laid one fewer egg for each parasitic egg they received.

—R.S.

Moonlighting Beetles

Dung on the plains of Africa is a valuable nutritional resource. So when an African dung beetle (*Scarabaeus zambesianus*) finds a fresh pile of herbivore waste it works fast to secure its share, creating balls that it rolls away from competitors with great skill and proficiency.

Usually, that is. As Marie Dacke (University of Lund) and colleagues noticed, the hasty retreats of these nocturnal beetles are not nearly as efficient when conditions are cloudy, their journeys taking far more erratic routes than they do on clear nights. Could the beetles be relying on moonlight as a navigational tool?

As light from the sun strikes particles in the Earth's atmosphere, it is scattered, creating polarisation patterns. The human eye can't perceive polarised light but some animals such as Honey Bees can and use it to

JEAN-MARC LA ROQUE/AUSCAPE

accurately guide their travels.

It was discovered a few years ago that moonlight too creates polarisation patterns, albeit a million times fainter than polarised sunlight. Are African dung beetles capable of detecting and using it?

To answer the question, Dacke's team carried out experiments using filters to change the angle of polarised moonlight reaching the beetles by 90 degrees (*Nature* 424: 33). Sure enough, the beetles responded by altering their course by exactly the same angle.

This is the first confirmation of an animal using moonlight as a 'compass' but is, the researchers speculate, unlikely to be the last.

—K.McG.

Country Living Stunts Trees

Trees grow twice as well in pollution-laden cities than in nearby rural areas, a US study has found.

What started out as a baseline study to show the bad effects of smoggy city air on trees has produced a paradoxical discovery that is quite counterintuitive, report Jillian Gregg (Cornell University) and colleagues (*Nature* 424: 183).

While pollutants such as heavy metals can inhibit plant growth, others such as carbon dioxide boost it, so the researchers decided to test the net effect of these multiple and opposing factors.

They planted clones of Eastern Cottonwood (*Populus deltoides*) in sites within New York City and also near country towns up to 90 kilometres north and east of Manhattan, in identical soil and water for three consecutive growing seasons. Despite car fumes and industrial pollution, the city trees grew twice as large as their country clones.

After checking for the effects of 18 different pollutants, Gregg *et al.* found the only pollutant higher in the country than the city was ozone, and laboratory growth trials proved this chemical significantly inhibited tree growth.

It's not that there was naturally more ozone in the country; rather, it had been blown there from the city. While one-hour peak exposures are often higher in urban environments, ozone is quickly scavenged by high levels of nitric oxide, an urban pollutant from car and factory emissions. But nitric oxide levels are far lower in rural areas, so any ozone blown there will remain in the air longer rather than break down, resulting in higher levels than in the city if averaged out over 12 or 24 hours.

Trees in the city thrive compared with their nearby country cousins.

So if you're a tree, you might be better off struggling in the big smoke rather than living downwind in the countryside.

—A.T.

Spider Off the Hook

The jury's verdict is in. In the case of *The People vs The White-tailed Spider*, the defendant has been found

not guilty.

Over the past 20 years or so, white-tailed spiders (*Lampona* spp.) have acquired a most heinous reputation. These small, rather innocuous arachnids were accused of causing a horrific, seemingly incurable flesh-eating disease. But Geoffrey Isbister (University of Newcastle) and Michael Gray (Australian Museum) were skeptical. Was it all just a media beat-up? They gathered together evidence from across Australia—details of 130 bites where the culprit was positively identified as a white-tailed spider—and set about mounting a case for the defence (*Med. J. Aust.* 179: 199).

When they collated the data, they found that bites

White-tailed spiders aren't the villains they've been made out to be.

(by *Lamprona cylindrata* and *L. murina*) typically took place in the warmer months, the vast majority happened indoors between 4pm and 8am, and the offending spiders were typically hiding in bedclothes, towels and clothing. All of the victims experienced some pain with about a quarter describing it as severe. They often exhibited a red mark around the bite and some itchiness. But crucially none of them experienced any of the necrotic ulcers for which the spiders have become notorious.

So the real culprit—more than likely a bacterial or fungal infection—is still out there.

—G.T.

Two-faced Predator

Eyespots that distract and disorient predators are well known in the animal kingdom: on the wings of butterflies, the backs of caterpillars, even on the fins of fish. These deceptive patterns act as camouflage and reduce the risk of predation. But what advantage would there be in having eyespots if you were a predator? The Northern Pygmy-owl (*Glaucidium gnoma*) is one such hunter. It is small—often the same size as the birds it hunts—and has prominent eyespots on the back of its head. How could the false winkers help it nab its prey?

To answer this question,

KEN GRIFFITHS

MILO BURCHAM

Northern Pygmy-owl: it pays to have eyes in the back of your head

Caroline Deppe (University of Montana) and colleagues created wooden models of the owls, painting half of the dummies with the conspicuous markings. They then placed the replicas in native pine forests. Over a period of three months, they waited and watched to see what small forest birds would do about the presence of an enemy in their neighbourhood (*The Auk* 120: 765).

They didn't have to wait long. The models were constantly mobbed by the birds, intent on getting the dummy pygmy-owls to leave. Thirty-one different species of birds, all part of the pygmy-owl diet, dive-bombed the wooden owls. Yet their approach differed depending on the type of model. Those without painted eyespots on their necks elicited dive-bombing from the rear, whereas those with the eyespots were met with a full frontal attack. It seems that eyespots protect pygmy-owls from surprise swoops from behind, and perhaps even give the owl the potential to pick off any bird that comes too close.

Eyespots literally send the mobbing birds flying into the face of danger. This hunting advantage suggests that, for the Northern Pygmy-owl, it pays to have eyes in the back of your head.

—K.H.

Ghost Busters

British scientists may have identified the reason why we often experience weird eerie sensations in old houses and cathedrals and during thunderstorms, and it has nothing to do with God or ghosts.

In a unique experiment, Richard Lord (National Physical Laboratory) and Richard Wiseman (University of Hertfordshire) surreptitiously subjected 750 people at a contemporary music concert to infrasound—deep sound pitched lower than 20 Hertz, which the human ear is barely capable of perceiving (**http://www.infrasonicmusic.co.uk/**).

They used a seven-metre-long pipe to produce infrasonic pulses throughout certain pieces during the concert, and then later polled the audience about their listening experience. Almost a quarter reported having unusual sensations during the pieces that were laced with infrasound. They detailed inexplicable feelings of fear, sadness, anxiety and even revulsion, along with physical sensations such as chills down the spine and coldness.

Infrasound is produced widely by both natural and human sources, including thunderstorms, volcanic eruptions, crashing ocean waves and nuclear explosions. Elephants communicate over vast distances using infrasound and certain whales are thought to use it as a weapon. The acoustics in large empty old buildings can also produce infrasound, as can the long organ pipes in many churches and cathedrals.

What possible evolutionary advantage there might be for our apparent reactions to infrasound is yet to be explained. But, for the moment, it helps sceptics dispel supernatural reasons for many previously inexplicable phenomena.

—K.McG.

Fish FRTs

Some might say I have a fetish for farts. And they'd be right. Farts fascinate me. Over the years we've learnt how snakes fart in the face of fear (*Nature Aust.*, Autumn 2001), and that whales do it

because...well, I guess they'd burst if they didn't (*Nature Aust.* Autumn 2004). But allow me to feed my fetish even further with a tale of two fishes.

Ben Wilson (while at the Bamfield Marine Science Centre, British Columbia) and colleagues were studying sound production in Pacific and Atlantic Herring (*Clupea pallasii* and *C. harengus*). They captured wild herring and placed them in large holding tanks, and then listened with an underwater microphone to the sounds they made. The most distinctive sounds came during the night and these consisted of a series of high-pitched (1.7–22 kilohertz) pulses that lasted between 0.6 and 7.6 seconds, with the pulses petering out (slowing down) towards the end (*Biology Letters Suppl.* 3). Video analysis of individual fish showed bubbles streaming out of the anal pore (the combined exit hole for the gut and swim bladder) at the exact time that the sound was produced. The researchers, appropriately, dubbed these sounds 'fast repetitive ticks' or FRTs for short. (To hear one for yourself, go to **www.zoology.ubc.ca/~bwilson/herring.html**).

But where were the bubbles originating? Wilson's team found that fish deprived of food continued to produce FRTs, suggesting they are not a product of digestion and hence, strictly speaking, not true farts (although close enough for me!). However, fish that were prevented from gulping air at the surface (which is the way herring fill their swim bladders) produced fewer FRTs the following night than those that had free access to the surface. So the gas appears to be coming from the swim bladder, and the noise is the sound it makes on the way out through the anal pore. This is the first report of such sound production in fishes.

Allow me to feed my fetish even further with a tale of two fishes.

And what, if anything, could be the function of these FRTs? Could they be fear-induced? No, because when the researchers fed water from a predatory shark tank into the herrings' tank, the rate of FRT production did not change. What they did notice was that FRT sounds increased with the number of fishes present. They therefore suggest that FRTs are used in social communication, perhaps as contact calls to help herring form their surface shoals at night.

—G.H.

Toxic Flying-foxes

A taste for flying-foxes may be behind the puzzling paralytic disease suffered by many of the Chamorro people of Guam. For more than half a century, the Indigenous population of this tiny Pacific Island has been devastated by an illness they call lytico-bodig, an extremely rare mental disease that leaves people listless as their muscles waste away. The disease, which neurologists call 'amyotrophic lateral sclerosis/parkinsonism–dementia complex' (ALS-PDC), has no cure and is virtually unknown in the outside world. Initially it was thought there might be a genetic basis to the disorder, but studies by Paul

PAUL ALAN COX

Guam's flying-foxes (*Pteropus mariannus*) accumulate toxins in their meat from eating cycad seeds. Eat the flying-foxes, and you'll go batty.

ESTHER BEATON

Did Tasmanian Aborigines know how to make fire?

Fire and Tasmanian Aborigines

The idea of any group of people not knowing how to make fire seems offensive because fire is one of those quintessential things that make us human (or at least it was). No doubt modern city-dwellers dropped into the Tasmanian wilderness would freeze and be forced to eat their meat raw, if indeed they could find any. And yet, this is what academics made of the historical evidence: although Tasmanian Aborigines carried smouldering sticks for cooking, warmth and clearing country, they could not generate fire, relying instead on lightning strikes. New evidence in 1991 questioned this argument, and now Beth Gott (Monash University) has rejected it completely.

Gott describes four Aboriginal methods used to ignite tinder on mainland Australia, as a baseline for assessing the Tasmanian evidence. 'Percussion' involves striking suitable stones together to produce a spark. The 'drill' requires spinning a thin wooden shaft on another piece of wood to create frictional heat. The 'saw' entails a wooden knife that is drawn rapidly across a cleft in a stick. And the 'fire-plough' works by rubbing a thin stick longitudinally in a wooden groove. Aborigines use a variety of stones, timbers and tinder for starting fires across Australia, and suitable fire-making materials are well documented in Tasmania.

Gott then re-examines the historical evidence, and concludes that other scholars overlooked or wrongly rejected reliable accounts of fire-making, including compelling evidence for the use of percussion, the fire-plough and the drill (*Current Anthropol.* 43: 650). Of these, the drill may have been learned from Victorians, but the fire-plough and percussion seem to have been part of traditional Tasmanian culture. She speculates that the mistaken interpretation of a fireless people flared up because it matched prevailing views of a technologically depauperate, if not primitive, society, and justified the European colonists' belief in their rights to take over the island.

So Tasmania is not such a strange place after all, and anyone who can light a fire in its windswept, damp, cold corners has my greatest respect.

—R.E.

Cox (Institute of Ethnobotany, Hawaii) and Oliver Sacks (Albert Einstein College of Medicine, New York) pointed to the flying-fox as the likely culprit (*Neurology* 58: 956).

Further examination of the diet of the Chamorro people by Clark Monson (University of Hawaii) and colleagues has confirmed that ALS-PDC is linked with consumption of flying-foxes (*Conserv. Biol.* 17: 678). Flying-foxes living on Guam (*Pteropus mariannus*) forage heavily on cycad seeds, which are laced with a deadly neurotoxin. This is produced by cyanobacteria (blue-green algae) that live in the roots of the cycad tree. Whilst it has no effect on the flying-foxes, the toxin becomes more concentrated each step up the food chain. In another study led by Cox, researchers found high levels of the neurotoxin in brain tissues of Chamorros with the disease but not in healthy people (*Proc. Natl Acad. Sci. USA* 100: 13380).

Flying-foxes are eaten on ceremonial occasions such as weddings and fiestas where bats are boiled and eaten whole. Even the brains, guts, fur and wings are consumed. But the demand for this Chamorroan delicacy has resulted in the over-harvesting of the species, a situation made dire with the introduction of firearms for hunting. The local population of flying-foxes has plummeted from more than 60,000 animals to fewer than 200 today.

Not so good for the flying-fox, but a fortuitous event for the Chamorro people, who now consume imported bats from other islands. These South Pacific bats don't forage on toxic

cycads and, as a result, mental illness on Guam is declining.

—K.H.

Tongue-clicking Hunters

The Hadzabe people in Tanzania and the Ju'hoansi (!Kung) San people of southern Africa have a strange way of speaking. They use a combination of voice (spoken words), signs and curious tongue-clicking sounds (two of which are indicated by the symbols | and !; for others see **http://www.sacred-texts.com/afr/sbf/sbf01.htm**). Alec Knight and Joanna Mountain (Stanford University) and colleagues were puzzled by the similarity of this unique language feature, given the geographical separation of

COURTESY ALEC KNIGHT

A click-speaking Jul'hoansi woman and child from Namibia.

some 2,000 kilometres, and the observation by linguists that the languages show little if any resemblance other than the clicks. So they decided to study the genetics of the populations in the hope that it would provide some insight into the history of click languages.

The researchers analysed DNA (both Y chromosome and mitochondrial DNA) from many African populations and found that the click-speaking peoples were more distantly related than any other two groups (*Current Biol.* 13: 464). The genetic mutation rate required to explain this difference, combined with archaeological evidence of

A female Satin Bowerbird checks out the quality of the male's bower.

modern human expansion out of Africa, suggests that these two populations last shared a common ancestor at least 40,000 years ago.

Given this enormous genetic divergence, could the click languages have evolved independently? The complexity of the shared clicks and rarity of click languages in general would suggest not. It is more likely that click languages have very deep roots and that they have been retained over the millennia because they confer some sort of advantage. While stalking game, for example, the Ju|'hoansi 'devoice' and communicate almost entirely with signs and clicking tongues, which prey could mistake for the rustling of leaves, allowing the hunters to get closer for the kill.

To hear an example of a click language, go to **http://www.nationalgeographic.com/ngm/0102/online_extra.html**

—R.F.

Bowerbirds' Mixed Messages

Looks aren't everything. Real estate's important too. As it is in humans, so, it seems, it is in Satin Bowerbirds (*Ptilonorhynchus violaceus*).

When it comes to choosing a mate, females of most species use some sort of signal to assess the quality of their prospective partner. But it's long been suspected that females use more than one signal when making their choice.

Stéphanie Doucet and Robert Montgomerie (Queen's University, Canada) studied Satin Bowerbirds to see if this multisignal hypothesis was true (*Behav. Ecol.* 14: 503). Working in the Queensland rainforest, they first assessed the quality of males' bowers by scoring each one for symmetry, stick size, density and overall quality of construction. They then captured the male birds and used a full-spectrum light source and a spectrometer to measure the plumage colouration and brightness of several parts of their bodies. Finally, they counted the males' parasite loads—both external (lice) and internal (blood parasites).

They found that the quality of the bower was a good indicator of the level of lice infestation and the male's body size. The ultraviolet colouration of the plumage, on the other hand, was related to the number of parasites in the blood, along with the growth rate of his feathers and, once again, body size.

So female Satin Bowerbirds do indeed have two different signals they can use to assess the quality of a potential mate, although, at present, there is only evidence of them using the bower.

—G.T.

Female Moas Wore the Pants

Female moas were nearly three times as large as males, DNA analysis has shown, solving a decades-old mystery about these extinct flightless giants of the bird world.

A team led by Alan Cooper and Michael Bunce (University of Oxford) extracted 800-year-old nuclear DNA from three species of *Dinornis*, the largest of the 11 currently recognised species. Accurately classifying moas has always been difficult, with over 38 species identified at various times.

The three *Dinornis* species had been separated on the basis of a marked variation in size. But the team was amazed to find their DNA was the same (*Nature* 425: 172). Then they 'sexed' the extinct birds, looking at DNA from their sex chromosomes, and discovered that what had been thought were the larger species were in fact just females.

Moas, along with kiwis, Emus and cassowaries, belong to a group called ratites—birds that often show reversed sexual dimorphism, where the female is larger than the male. But while female kiwis are just 20 per cent bigger than their males, the Oxford team found that female *Dinornis* were up to 1.5 times taller and 2.8 times heavier than males.

When fossil deposits were re-examined, the sex ratios of male and female *Dinornis* were found to be close to equal, although in swamps, the heavier females seem to have become trapped more often. It has been suggested that, because female ratites lay such large eggs, they need to be larger. However, considering the weird reversed world of the ratites—where the males do most of the hard work like incubating and raising chicks— it could be that, for female moas, the larger and showier you are, the better you can compete for that perfect husband.

—A.T.

The endangered Woolly Flying Squirrel has an insatiable appetite for pine needles.

Pino-keen Squirrels

Pine needles may look (and smell) good around Christmas time, but certainly not good enough to eat. Now one Himalayan squirrel has been found to feed exclusively on pine needles—the only mammal,

QUICK QUIZ

1. *Where is the best place to see Quokkas in the wild?*
2. *What does CE, which replaces AD (= Anno Domini), stand for?*
3. *Which country was the third to launch a human into orbit?*
4. *What do umbraphiles love?*
5. *In which national park is the recently discovered Eagle's Rock rock-art site?*
6. *How many nanometres are in a metre?*
7. *Which well-known Australian bushman died in November 2003?*
8. *What is the name given to the under shell of a turtle?*
9. *In which country would you find the largest living rodents?*
10. *What do you call a male swan?*

(Answers on page 82)

Who Cares?

Humans can inflict and survive a variety of nasty diseases, deformities, physical disabilities and ghastly wounds, but recovery is often with a bit of help from our family and friends, if not the doctor. A similar degree of support was attributed to Neanderthals based on a scarred and nearly toothless fossil jaw from Aubesier, France, whose impairments were said to have required extra care for survival (see "Neanderthal Nurses", *Nature Aust.* Spring 2002). But new research by David DeGusta (Stanford University) challenges this evidence for compassion and social support among Neanderthals.

DeGusta points out that the degree of tooth loss found in the Neanderthal jaw is also found in a variety of other primates, such as Chimpanzees, which do not practise human-like caretaking behaviour (*J. Hum. Evol.* 45: 831). Field studies of wild primates, such as lemurs, also show they sometimes survive tooth loss and other diseases on their own. Clearly, bad or missing teeth do not demand special care from the troupe. Likewise, a Neanderthal with a sore jaw and a gummy grin could have mashed his own food and taken care of himself.

This study shows that definitive evidence of increasing care among archaic humans requires more than just dental disease.

—R.F.

PIR, BSIP, AUSCAPE

Researchers argue that Head Lice (shown here) parted genetic company from Body Lice when humans started wearing clothes.

and one of the few vertebrates, to do so.

Until recently, little was known about the habits of the endangered Woolly Flying Squirrel (*Eupetaurus cinereus*), which lives in caves in the high, cold desert area of northern Pakistan. All anyone really knew was that it had a highly unusual (for a squirrel) 'hypsodont' dentition—high-crowned, flat-surfaced teeth. Animals with this type of tooth structure normally specialise in abrasive food items, leading to speculation that this squirrel might subsist on lichens and mosses scraped from rocks.

To investigate, Peter Zahler (Wildlife Conservation Society) and Mayoor Khan (University of Karachi, Pakistan) hand-caught six Woolly Flying Squirrels from their mountain caves, transferred them to a cage overnight and, in the morning, collected and analysed their faecal samples (more than 950 from one animal alone). They were surprised to find that their diet consisted almost entirely of two local species of pine needles (*J. Mammal.* 84: 480).

The researchers say that the squirrel's unusual tooth structure is an adaptation for breaking down the thick, waxy, hard-to-digest pine needles. Because of the limited nutritional value of a pine-needle meal, the animals must also eat huge amounts, a theory borne out by the prodigious quantities of faecal matter collected. Large quantities of water may also be needed to counteract and help purge the toxic compounds found in pine needles, which the researchers suggest would make them highly water-dependent—and, indeed, most of the squirrels were found within 100 metres of a permanent water source.

—R.S.

Lousy Clothes

When did we start wearing clothes? And I'm not talking bearskin rugs here, but fitted, layered garments. Useful archaeological indicators, such as the oldest delicate bone needles, indicate we were sewing clothes at least 40,000 years ago. But now Ralf Kittler and colleagues (Max Planck Institute for Evolutionary Anthropology, Germany) argue that DNA from the Body Louse provides a new clue to the origin of clothing (*Current Biol.* 13: 1414).

Unlike the Head Louse (*Pediculus humanus capitis*), which lives and feeds exclusively on the scalp, the Body Louse (*P. h. humanus*) feeds on the body but lives in clothing. This ecological difference, the researchers argue, would have evolved at about the time that humans started wearing clothes.

DNA analysis of 26 Head and 14 Body Lice collected from around the world indicates that the two subspecies parted genetic company 72,000 ± 42,000

years ago. (The calculations were based on a molecular clock that assumes human and Chimpanzee lice diverged at the same time as their hosts about 5.5 million years ago.) They also found that the diversity of African Body Lice is greater than elsewhere, indicating that lice, like humans, originated there. The time period of 30,000–114,000 years ago is critical in human evolution as this is when we begin to find evidence of modern human behaviour, first within, then out of Africa (see "Becoming Human", *Nature Aust.* Summer 2001–2002).

Wherever clothing was invented, it must have been an important factor that enabled humans to colonise the Arctic and other climatic extremes.

—R.F.

Empathetic Yawning

Here's an experiment you can try anywhere, whenever you're in the company of others. Tilt your head back, open your mouth wide, have a lovely long yawn and watch the chain reaction it initiates among others nearby.

In fact, chances are that merely reading this has already set you off. (Just writing about it has got me going and it's certainly not, my editor will be pleased to know, because I'm bored!)

The contagious nature of yawning in humans is a well-documented phenomenon. One popular theory is that it helps synchronise activity levels, an evolutionary hangover from when it was critical to our survival that we behaved and responded as a group (see "Guaranteed to Make You Yawn", *Nature Aust.* Winter 1989).

Now the latest research in the area, by Steven Platek (Drexel University) and colleagues, shows we're not all equally susceptible to the contagious nature of yawning.

Platek and his team observed and recorded the way college students responded to videos of people displaying a range of facial expressions and activities including yawning and laughing (*Cognitive Brain Research* 17: 223). Using standard psychological tests, they then assessed the students' capabilities for processing information about themselves and others.

Students who displayed contagious yawning were better at assessing the mental states of others and faster at recognising their own faces from those of strangers. The results suggest those people who are more self-aware and more empathetic to others are more likely to be contagious yawners.

The researchers predict that schizophrenic patients, who have problems identifying with their own and other people's states of mind, should be immune to catching yawns. Similarly, only those species (humans, Chimpanzees, Orangutans) that exhibit self-recognition and mental state attribution, should include contagious yawners.

—K.McG.

FURTHER READING
References for the stories that have appeared in this edition of Nature Strips are available online:
www.natureaustralia.net

Yawning can be contagious, but not for everybody.

Tawdry frogmyths

In its final stiff, imperiously wooden pose, the frogmouth is usually ignored by the rest of the world.

THE ONLY BIRD'S BEAK I HAVE EVER had to prize open with a screwdriver belonged to an angry Tawny Frogmouth clamped onto a mate's arm. On that occasion I remember thinking that, given the choice between the frogmouth, a Turkey Vulture, my mother-in-law's bum-picked chooks and a scrotum-necked Malibu Stork, the prize for the world's most unfortunate-looking bird must surely go to that golden-eyed, lock-jawed frogmouth.

Many of us have seen a Tawny Frogmouth but, sadly, to most it constitutes no more than road kill...a cold grey pizza of smashed feathers and mushed gristle blown around between traffic lanes. To others it's a faceless creature that chants a monotonous bedtime mantra from somewhere out in their backyard. And then to a few wildlife orphan carers, it's a fluffy white Muppet in a cardboard box that chortles all day for baby mice and grasshoppers.

What kind of bird is this fantastic Aussie phoenix that copped the fire in its eyes but never shook off the ashes? Mostly it's not what we think it is.

1. The Tawny Frogmouth is tawny. No, not usually. When I was in the North Epping Cubs, each snarling litter of eight-year-old boys had its own jungle colour signified by a little patch of felt that was sewn onto our sleeves by our mothers and then eaten off by moths. I belonged to the "tawny" pack, and my felt triangle was coloured a yellowish brown. A few years later when I discovered that the big grey birds that sat in our ironbark were called Tawny Frogmouths, a lifelong chromatic confusion took root. Since then I've found out that all male Tawny Frogmouths are grey, and that, while females can be grey, rufous or chestnut, most of them are also grey! We Aussies are simply creatures of habit when it comes to old names tagged onto familiar objects. It's like the way we call that revered, pigless bun full of salad and minced ears...a 'hamburger'!

2. The Tawny Frogmouth is a stick. No, but soft feathers don't come any stickier.

When a Tawny gets wind of an intruder it does a bizarre thing. Instead of giving a squawk, emptying its bowels and flying off, it quickly and quietly transforms itself into a branch. Watching a Tawny shift into stick mode is to see its fluffy plumage suck in and flatten into strips of flaking bark, its eyes squint to thin strings of oozing sap and its beak to poke out like the dry, horny end of a snapped limb. In its final stiff, imperiously wooden pose, the frogmouth, looking every bit like a Federal Treasurer, is usually ignored by the rest of the world.

It is remarkable that almost as an accompaniment to the cold pillar look, the Tawny Frogmouth can, when the weather is bleak enough, slip into a shallow torpor (semi-hibernation) where its energy reserves are extended by lowering its body temperature by as much as 10° C.

Although the Tawny's stick routine probably evolved to reduce its chances of daytime predation and mobbing by other birds, it's not 100 per cent safe, as was once demonstrated in a big blood-wood near our driveway. A crow must have seen a frogmouth shuffle on its nest and, not fooled by the stern looks and frosty stares, knew that it was practically defenceless. And so, with the frogmouth gurgling and shrieking, the crow yanked and tugged at its tail and wings, trying to unseat it from the nest. Each time the Tawny came unstuck, the crow lunged in and tossed out one of the chicks. After 20 minutes the show was over, the nest empty, the frogmouth flown away and the crow eyeing off the fluffy takeaway below.

3. The Tawny Frogmouth is a Banksia Man. No, Banksia Men aren't half as scary! Sydney's children of the '50s were afraid of only two things:

Tawny Frogmouth

Podargus strigoides

Classification

Order Caprimulgiformes (nightjar), family Podargidae (frogmouths). One of 14 spp., 3 of which occur in Aust.

Identification

Kookaburra size about 42 cm long. Usually mottled grey. Broad, flat beak, spiky monobrow, huge orange-yellow eyes. Call, mostly a monotonous 'oom-oom-oom'.

Habitat and Distribution

Most open, wooded habitats throughout Aust.

Biology

Nocturnal. Breeds Aug.–Dec., 2–3 white eggs on flimsy platform of sticks built on exposed horizontal branch. Incubation 30 days, by male (day) and female. Fledge at 30 days. Home range 10–80 ha. Eats mostly large arthropods, but also frogs and reptiles, occasionally mice and small birds. Largest bird known to enter torpor.

BY STEVE VAN DYCK

MIKE GILLAM/AUSCAPE

The Tawny Frogmouth in typical stick mode.

Grey Nurse Sharks (thanks to a beat-up of shark-attack misinformation) and Banksia Men (thanks to May Gibbs and her Snuggle Pot and Cuddle Pie bedtime stories). The first time I ever encountered Tawny Frogmouths was halfway up a huge Banksia tree. I was trying to reach some cicadas when suddenly the trunk opened up. I can still see those huge, sulphurous, steam-shovel beaks lunging at me, the blinking of great wild yellow eyes, the snapping and clapping and hissing and wings flapping all over the place. Even before hitting the ground I remember thinking how Banksia Men, with their scrawny naked bodies and knobbly knees, were jackstraw compared to the cauldron of camouflaged rage I'd just baled out of.

4. The Tawny Frogmouth is an owl. No, it is a nightjar, but on the matter of knobbly knees, it was the peculiarly weak, un-owl-like legs that gave the Tawny's genus its name *Podargus*, which comes from the French *podarge* ('gouty feet'), referring to the feeble toes and short legs found in all the frogmouths. The hugely broad beaks, tufty monobrow and long tails are also frogmouth features not found in owls. But in an odd turnaround, the specific epithet *strigoides* means 'owl-like'! So don't feel embarrassed if you thought your first frogmouth was an owl; everyone else did too.

For all its gruesome appearance there is no doubt that most Aussies, happy to identify with things less than perfect, embrace the Tawny with custodial affection. It doesn't really matter if you call it an owl or a Banksia Man or a mopoke, there is only one thing you have to get right with a frogmouth; if you grab one, make sure you shy away from its bear-trap beak. This is one case where, if you don't have a toolbox handy, you don't want to get the wrong end of the stick! □

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DR STEVE VAN DYCK IS A SENIOR CURATOR OF VERTEBRATES AT THE QUEENSLAND MUSEUM WHERE HE HAS WORKED SINCE 1975.

Loggerhead Turtle

Several decades may pass before Loggerheads reach maturity.

BY ROD KENNETT

THE LOGGERHEAD TURTLE (*Caretta caretta*), so named for its large head and heavy jaws, is something of an enigma to the Aboriginal people (Yolngu) of north-eastern Arnhem Land. Although Yolngu encounter Loggerhead Turtles or 'Garun' at sea, they have never seen them nesting and believed that they laid their eggs underwater. Loggerheads plough up the substrate with their flippers in their search for molluscs and crabs, and in this way are reminiscent of nesting turtles on land, perhaps contributing to the Yolngu belief. Indeed, underwater nesting seems a more plausible explanation than the story that Yolngu are now familiar with—that the turtles travel many thousands of kilometres south to nest.

Sea turtles are renowned for their long-distance migrations from home foraging grounds to nesting beaches. Loggerhead Turtles tagged while nesting on beaches in south-eastern Queensland have been recorded travelling up to 2,600 kilometres to the waters of north-eastern Arnhem Land, while others have crossed international borders to return to Indonesia, Papua New Guinea, New Caledonia and the Solomon Islands. Turtles tracked by satellite show remarkable navigation skills, often travelling a near-direct route and up to 70 kilometres a day. They are believed to use many navigational cues, including magnetic maps, the smell or taste of the water, and visual landmarks, but a full understanding of how they do it is still a long way off.

In Australia, most Loggerheads Turtles nest at Shark Bay and North West Cape in Western Australia, and in the southern Great Barrier Reef and the Bundaberg coast in Queensland. In the Mon Repos Conservation Park near Bundaberg from October to March, Loggerheads can be seen crawling up the beach at night-time to dig a nest and lay about 120 eggs. Although they rarely feed during the nesting season, individuals repeat this up to six times before departing for their home foraging grounds and won't nest again for another two to five years. Eggs that aren't dug out by goannas, Foxes, Dingoes or crabs take 50–60 days to hatch, and hatchling sex is determined by the temperature of the nest. Warmer nests (above 30° C) produce mostly females, while cooler nests produce mostly males. Upon emerging *en masse* from the nest, the four-to-five-centimetre-long hatchlings race to the water and swim seaward, running the gauntlet of crabs, birds and fish. Only about one in 1,000 to one in 10,000 eggs end up producing adult turtles.

Out at sea, hatchlings swim strongly to find ocean currents or 'gyres' in which they circulate for the next 15–20 years, living amongst mats of *Sargassum* weed and feeding on plankton. These are the so-called 'lost years' as little is known of their fate until they reappear as 70–80-centimetre-long juveniles in continental shelf waters, before taking up residence on a foraging ground. Several decades may pass before Loggerheads reach maturity, at which stage they are about a metre in length and 100 kilograms in weight. They then begin the first of many migrations back to a beach in the region where they were born.

Loggerhead Turtles have long had a pan-global distribution in tropical and temperate waters, but their numbers have declined dramatically in recent times. Now they are listed as endangered, both nationally and internationally. In Australia, Loggerhead nesting numbers have declined by 50–80 per cent in the last few decades. Prior to the mandatory introduction of 'turtle excluder devices' (a type of escape-hatch for turtles caught in trawl nets), incidental drowning in trawl fisheries

DOUG PERRINE AUSCAPE

was a major cause of mortality. Entanglement in crab-pot float lines, boat strike, ingestion of plastics and fishing line, and other human-related factors have also contributed to their death. A successful Fox-baiting program on the Bundaberg coast, undertaken by Queensland Environment Protection Agency since the mid-1980s, has substantially reduced the numbers of nests depredated by Foxes. Steady nesting numbers since the mid-1990s are a positive sign that the decline of the Loggerhead may have been arrested, but much remains to be done to secure its future. □

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DR ROD KENNETT IS AN ADJUNCT FELLOW AT THE NORTHERN TERRITORY UNIVERSITY AND NATURAL RESOURCE MANAGEMENT PROJECT OFFICER IN KAKADU NATIONAL PARK.

Born to burn

Buttongrass will burn even when cold and dripping wet from heavy dew.

Some habitats are so flammable that hot fires obliterate everything, permitting some plant species to later claim a larger share of the landscape. This is, or was, coastal woodland in northern New South Wales.

ONE NEED ONLY GO WALKING about in the months after a bushfire to be convinced that vast numbers of plants are superbly adapted to fire. Endowed with insulating bark, resprouting rootstocks or fire-resistant seedpods, they regreen burnt landscapes with amazing speed. But do plants ever go further than this? Are some plants designed to fuel fire?

Eucalypts shed great loads of bark, sticks and leaves that pile up below, as if to tempt wandering flames. Their leaves are laden with flammable essential oils, and their open crowns and dangling leaves promote updraughts and a drying of the understorey. They have much to gain from fire, which eliminates certain competitors, notably rainforest trees, cypress pines and casuarinas.

But this kind of thinking invites caution, because eucalypt design can be interpreted in other ways. Essential oils render gum leaves less palatable, and dangling leaves conserve water on hot days. Proving that these features also evolved to promote fire is very difficult, perhaps impossible. One may also question whether flammability could ever evolve. Under natural selection an individual born with some advantage leaves the most descendants, but when that 'advantage' is greater flammability, the individual may stand to lose more than it gains.

American ecologist Robert Mutch first popularised the idea of flammability as an adaptation in 1970, drawing on many Australian examples. He was criticised for not explaining how the phenomenon could evolve, but models developed since then overcome the problem. If a plant that promotes fire also kills some of its neighbours, and its offspring claim the vacant space, evolution could favour flammability, even if the parent plant dies. It is worth noting that grasses and eucalypts—dominant in many flammable communities—usually lack adaptations for seed dispersal, dropping their seeds close by where they can capitalise on the death of adjacent plants.

Theories about flammability are very appealing because it is obvious in Australia that fire regularly dictates plant success. The evidence is clear that frequent bushfires allow spinifex (*Triodia* species) to replace Mulga (*Acacia aneura*), eucalypts to displace rainforest, and Buttongrass (*Gymnoschoenis sphaerocephalus*) moors to replace forests. Some weeds also thrive on fire. African grasses, imported as Cattle feed because they grow so thickly, fuel very hot fires that promote their spread. Stands of Buffel Grass (*Cenchrus ciliaris*), Mission Grass (*Pennisetum polystachion*) and Gamba Grass (*Andropogon gayanus*) expand rapidly after fire, displacing native grasslands and dry rainforests—an invidious problem with no obvious solution. Their dramatic conquest provides some of the best evidence for flammability as a winning strategy, as does the invasion of Florida by the Australian Broad-leaf Paperbark (*Melaleuca quinquenervia*), a plant noted for its flammable papery bark and oil-laden leaves.

Flammability is most likely to benefit plants that can form communities of closely spaced individuals able to advance in broad fronts. Among native plants Buttongrass, spinifex, Kangaroo Grass (*Themeda triandra*), Bunch Speargrass (*Heteropogon contortus*) and various eucalypts are obvious candidates. Buttongrass (which is actually a sedge) thrives in the cold wet landscape of south-western Tasmania where it will burn even when cold and dripping wet from heavy dew. Clumps can be ignited at night during fog, or when frost is forming, at temperatures below 1° C. Jon Marsden-Smedley, from the Tasmanian Parks and Wildlife Service, studied the fuel properties of this plant and suggests it may have an 'optimal packing ratio' for carrying fire, with leaves of ideal width and spacing. As in many grasses, the old dried leaves are

BY TIM LOW

retained aloft where they burn freely and spread flame. If fires are kept out of Buttongrass moors, woody plants including rainforest trees take over. As a very different kind of example, banksias (*Banksia* species) rely largely on heat to open their seed capsules, and they may have evolved flammable cones—with persistent stamens serving as fuel—but the plant as a whole does not seem designed to burn.

Flammability should be taken into account when assessing the role of Aborigines in shaping landscapes. Some experts contend that, because Aboriginal people managed the land with fire, Australian ecosystems are human artefacts. This conclusion overvalues the act of ignition and ignores the central role played by plant evolution. Aborigines could burn so freely only because flammable vegetation had already evolved and spread over much of the Australian landscape as the climate dried. Lightning was sparking fires millions of years before people arrived, and what Aborigines did was to extend an entrenched natural process rather than initiate something new. Flammable communities are not human creations, but rather the outcome of a symbiotic relationship between people and certain plants. Aborigines helped shape the Australian landscape, but so too did certain eucalypts and the grasses that thrive beneath them. □

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TIM LOW IS A BRISBANE-BASED BIOLOGIST AND WRITER, WHOSE MOST RECENT BOOK, *THE NEW NATURE*, WON THE 2002 WESTFIELD/WAVERLEY AWARD FOR EXCELLENCE IN RESEARCH.

PHOTO: TIM LOW

The very intensity of many bushland fires in Australia suggests that some plants may be adapted to burn.

As the Musky Rat-kangaroo hopped away, I shook my head and thought, did that animal just plant a tree?

MARSUPIAL GARDENERS

BY ANDREW J. DENNIS

Young Musky Rat-kangaroos begin to explore their surroundings on their own or as sibling pairs soon after pouch eviction in October. They remain near a maternal nest where the mother periodically returns to feed them until they become independent in about January.

IN A DRIPPING AND GLOOMY rainforest in Australia's Wet Tropics, I watched as a small and dark brown kangaroo hopped around on all fours on the forest floor. Its tail was held suspended above the ground, as if it didn't want to get it soiled in the damp leaf mould over which it foraged. Although many of the colourful fruits it was searching for were obvious from my vantage point, suspended several metres above in a hammock, this small marsupial seemed to use only its sense of smell. It soon located a fruit and picked it up in its mouth. It then sat back on its haunches and passed the fruit to its hands with which it turned the fruit around while chewing off the flesh. It then put the seed back into its mouth, hopped a few metres away from the tree and, to my everlasting astonishment, proceeded to plant the seed. It first scraped away the leaf litter with its hands, before dropping the seed onto the bare soil and pushing it into the soil with its nose, using a series of body convulsions to give it extra force. The ritual was concluded by carefully replacing the litter over the now-planted seed, each individual leaf and twig being picked up in its mouth and placed over and around the site before it was all patted back into place with both hands. As the animal hopped away and out of sight, I sat back in my hammock, shook my head and thought, did that animal just plant a tree?

THE AVERAGE *adult weight is a mere 520 grams, only one-hundredth the size of the largest kangaroos.*

The animal I was observing, as part of a long-term study, was a Musky Rat-kangaroo (*Hypsiprymnodon moschatus*). Musky Rat-kangaroos or 'Hypsis' are currently considered to be the sole extant members of the family Hypsiprymnodontidae, and are by far the smallest members of the kangaroo superfamily (Macropodoidea), the average adult weight a mere 520 grams, only one-hundredth the size of the largest kangaroos. Unlike other kangaroos, Musky Rat-kangaroos run on all fours, have a hallux (opposable first toe on the hind foot), and regularly give birth to twins. These characteristics, along with having a second pair of lower incisors and a prehensile tail, are features shared by possums and some early fossil kangaroos. This has led to the belief that Musky Rat-kangaroos are a living ancestral relic of the kangaroo group. However, more recent studies suggest they probably resemble an early offshoot that led to the potoroos, rather than one that led to all kangaroos.

Until recently, little was known of the behaviour and ecology of Musky Rat-kangaroos in the wild, because of their shy nature and dense rainforest habitat in Australia's far north. However, through regular trapping, some radio-tracking, spool-and-line tracking, direct

STANLEY BREEDEN

The author inspecting fruit found along 2.1 kilometres of transects. These transects were walked monthly to monitor the availability of fruit and to determine in which ones Musky Rat-kangaroos left their tell-tale teeth marks.

Musky Rat-kangaroos are fastidiously clean. They rarely have any ecto-parasites, constantly groom and manage to avoid the numerous leeches that abound on the forest floor. When hopping they hold their tails out above the ground and even when 'sitting' on their hind legs, only the tip of their tail contacts the forest floor.

observation and faecal analysis, I have been able to piece together much new information about this secretive animal.

Musky Rat-kangaroos are primarily frugivorous and eat a wide variety of fleshy fruits of all shapes, sizes, colours and structures. I compiled a list of 39 species that Musky Rat-kangaroos consumed in one 300 x 300-metre area, which included large species such as rainforest gourd (*Trychosanthes* sp. Mt Lewis), Boonjie Blush Walnut (*Beilschmiedia volckii*), Watergum (*Syzygium gustavioides*) and Ivorywood (*Siphonodon membranaceum*); small species such as Rough-barked Satinash (*Syzygium trachyphloium*) and Lignum (*Austromyrtus dallachiana*); and many in between including well-known species such as Blue Quandong (*Elaeocarpus grandis*) and Banana Fig (*Ficus pleurocarpa*), and less-well-known species such as Austrobaileya (*Austrobaileya scandens*) and Plum Boxwood (*Niemeyera prunifera*). They also consume invertebrates and the fruiting bodies of fungi that grow out of rotting logs and the leaf litter. Musky Rat-kangaroos usually drink water from pools that collect in hollow logs or low tree forks and do not need access to free-flowing water.

The activities during a Musky Rat-kangaroo's year are largely determined by seasonal changes in the abundance of fruits. In the forest behind Mt Bartle Frere, where I conducted my study, March to August was the period of fewest fruits and a time when Musky Rat-kangaroos lost weight and had high levels of mortality. Invertebrates, while consumed at all times, were sought mostly during the middle of the year when fruits were few. Fungi were sought most frequently during the late wet season when they were most abundant, which also coincided with the start of the low-fruiting period. The

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Musky Rat-kangaroo

Hypsiprymnodon moschatus

Classification

Superfamily Macropodoidea, family Hypsiprymnodontidae.

Identification

Small (about 520 g), dark reddish brown kangaroo, with naked, scaled, prehensile tail used for carrying nesting material. Hops using both hind and forelegs on forest floor. Hind foot has a hallux (opposable thumb) not evident in any other kangaroo.

Habitat and Distribution

Tropical rainforests of north-eastern Qld from Wallaman Falls (near Ingham) north to the Big Tableland (near Cooktown), from sea level to 1,400 m altitude.

Behaviour

Solitary and promiscuous. Produces 1–3 young (usually 2) per year. Young evicted from pouch in Oct., when they are cared for at maternal leafy nest on forest floor. Each individual has several nests in use at any one time. Active by day, shelters in nest at night or during heavy rain.

Diet

Fleshy fruits, litter invertebrates, fungi, and occasionally seeds and flowers.

change in abundance of fruits was enormous. In 1991, for example, the biomass of fruits available to Musky Rat-kangaroos was 2,000 times greater during the peak than in the low period. In the next, more fruitful year, the peak in fruit biomass was 300 times greater than the trough, and the annual production nearly ten times that of the previous year. These enormous seasonal and yearly differences in food availability have far-reaching implications for the life history of Musky Rat-kangaroos.

One of the most obvious changes in Hypsis is in male reproductive condition, measured by the size of the testes. I noticed that, as fruit abundance increases through the dry season, the testes of males more than triple in size

DAVE WATTS/COCHMAN TRANSPARENCIES

and seem to dangle uncomfortably between their legs. They remain large from October until March or April, when, coincident with the decline in fruit availability, they shrink again. During the period of enlarged testes size, particularly in the early part of the breeding season, the normally tolerant males become more aggressive with one another, actively chasing each other around. Although males with enlarged testes are present in the population for about seven months of the year, mating probably occurs only during a short period from late January to April when females are receptive.

Birth of twins, triplets, occasionally singletons and even quadruplets occurs between February and April, resulting in the relatively undemanding young being carried in the pouch during the low-fruiting period. However, come early October, the young are evicted from the pouch. The synchrony of eviction of young was surprisingly consistent across all females in my study, despite a broader period in which births occurred. Young then remained in a maternal nest and were periodically visited and suckled by their mother. After a short while they began to forage for themselves around the nest, usually as sibling pairs. They continued to suckle and expand their wanderings until January when they were weaned and became independent. Some individuals seemed to then leave the maternal range, while others remained in the

(Left) Cable roots and fallen logs become frequently used highways for Musky Rat-kangaroos. Individuals were recorded travelling as much as 60 metres along these highways without setting foot on the forest floor.

(Above) Musky Rat-kangaroos eat mostly the fleshy fruits of trees, shrubs and vines after they have fallen to the rainforest floor. They also spend considerable amounts of time foraging through the litter and debris of the forest floor in search of a wide variety of invertebrates.

T. PARER & E. PARER-COOK/AUSCAPE

Unlike all other members of the kangaroo superfamily, the smallest species runs on all fours rather than bounding on its hind legs. However, it is frequently seen sitting on its hind legs sniffing the air or manipulating food.

general area, creating population densities of up to five individuals per hectare.

WHILE IT IS OBVIOUS THAT THE availability of fruits from rainforest trees, shrubs and vines have a big impact on the life history of Musky Rat-kangaroos, the reverse is also true. These diminutive creatures are exceptional dispersers of rainforest fruits and seeds, and rival Southern Cassowaries (*Casuarius casuarius*) and Spectacled Flying-foxes (*Pteropus conspicillatus*) in the range of fruit sizes they disperse. As I watched the Hypsis going about their daily business, it was soon clear how they achieved these vital services.

Often, when an individual approached a fruit fall, another Hypsi would already be feeding there. Usually, the animal already at the fruit fall picked up a fruit and ran off to consume it in peace. The newcomer then had a short time to forage before the first animal came back, having finished its meal and wanting another. Then the roles reversed and the newcomer would pick up a fruit and depart to eat in peace. The seeds of the fruit were occasionally consumed as well (10 per cent) but most often they were dropped on the surface of the litter or cached (hidden). This pattern resulted in many seeds being carried between 5 and 68 metres (mean = 17 metres) away from their source.

Musky Rat-kangaroos also practise what is called 'scatter-hoarding', which for Hypsis involves removing a fruit or seed from a source and temporarily caching it by burying it, on its own, as described earlier. Caches are generally scattered in a wide area around the source. This behaviour is common to a range of ground-dwelling mammals in tropical and temperate areas around the world. Most scatter-hoarding mammals are rodents and include agouties, acouchies, squirrels and many rats, including the Giant White-tailed Rat (*Uromys caudimaculatus*) of Australia's tropical forests. The Musky Rat-kangaroo is the first marsupial known to scatter-hoard fruits and seeds, although it is now known that Brush-tailed Bettongs (*Bettongia penicillata*) do it too.

The fruits and seeds are hoarded in this manner as a short-term storage so that they can be re-found and consumed at a later date. Musky Rat-kangaroos tend to revisit their caches very rapidly, probably because the fleshy fruits they tend to store are quick to deteriorate. In my experiments most of the caches were revisited within three days of being established and after that they were not revisited for the two months of my monitoring. Some caches were recovered, partially eaten and re-cached up to three times, with the seed always left buried at the end. Because many caches remained un-retrieved and Musky Rat-kangaroos only eat a small proportion of seeds, their caching behaviour results in a large number of seeds planted or dispersed throughout the forest. I estimated this to be up to about 1,000 per hectare in the peak fruiting month, which has positive

consequences for the plants whose seeds are being moved.

Native rats consume seeds from the fruits of many species also eaten by Musky Rat-kangaroos, resulting in fewer seeds available to germinate for those plants. In some instances experiments have shown that rats may cause 100 per cent mortality for the seeds of certain species. My work showed that the scatter-hoarding behaviour of Hypsis reduced the predation levels on these seeds and significantly improved their chances of surviving to germination—by three to seven per cent, depending on the species. In my experiments, rodents consumed all seeds left on the surface of the leaf litter. Only those seeds buried in the manner of a Musky Rat-kangaroo cache survived, and for one plant species, only seeds carried away from the parent and buried survived. Those buried under or near the parent remained undisturbed by rats but succumbed to fungal attack instead.

STUDIES AROUND THE WORLD have demonstrated that seed dispersal and predation are critical processes maintaining the diversity of plants in tropical forests because of their impacts on the next generation of plants that establish. It is often only through the actions of seed-dispersing animals that new plants are recruited into the population. Seed and seedling predators, and diseases, often ensure that any one species doesn't dominate a particular area. Seed dispersal, combined with mortality from predators and diseases, helps maintain the incredible diversity seen in tropical rainforests. The caching behaviour of Musky Rat-kangaroos clearly conveys significant advantages to the plants whose seeds are dispersed by allowing a higher proportion to escape fungal attack and predation than would normally survive. In addition, Hypsis carry and cache fruits and seeds of all sizes, up to the largest in our forests, and so play a major part in maintaining or directing the structure of the forests in which they live.

Musky Rat-kangaroos are one of only three frugivores that are able to disperse fruits of all sizes, but they offer a unique service by burying seeds throughout the forest. Also like many other frugivores, Hypsis tend to disappear from all but the largest fragments of forest. This means that the seed dispersal services in most forest fragments are deteriorating. Australia's smallest kangaroos have a key ecological role in the recruitment of plants and the maintenance of diversity in our tropical forests. Fortunately, they appear secure in our World Heritage-listed forests and large national parks in the Wet Tropics. Yet how their absence will affect many small rainforest fragments in the long term remains to be seen. □

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DR ANDREW J. DENNIS IS A RESEARCH SCIENTIST AT CSIRO DIVISION OF SUSTAINABLE ECOSYSTEMS AND THE RAINFOREST COOPERATIVE RESEARCH CENTRE BASED AT THE TROPICAL FOREST RESEARCH CENTRE ON THE ATHERTON TABLELAND, QUEENSLAND. HE IS CURRENTLY RESEARCHING THE PROCESS OF SEED DISPERSAL IN AUSTRALIA'S TROPICAL FORESTS.

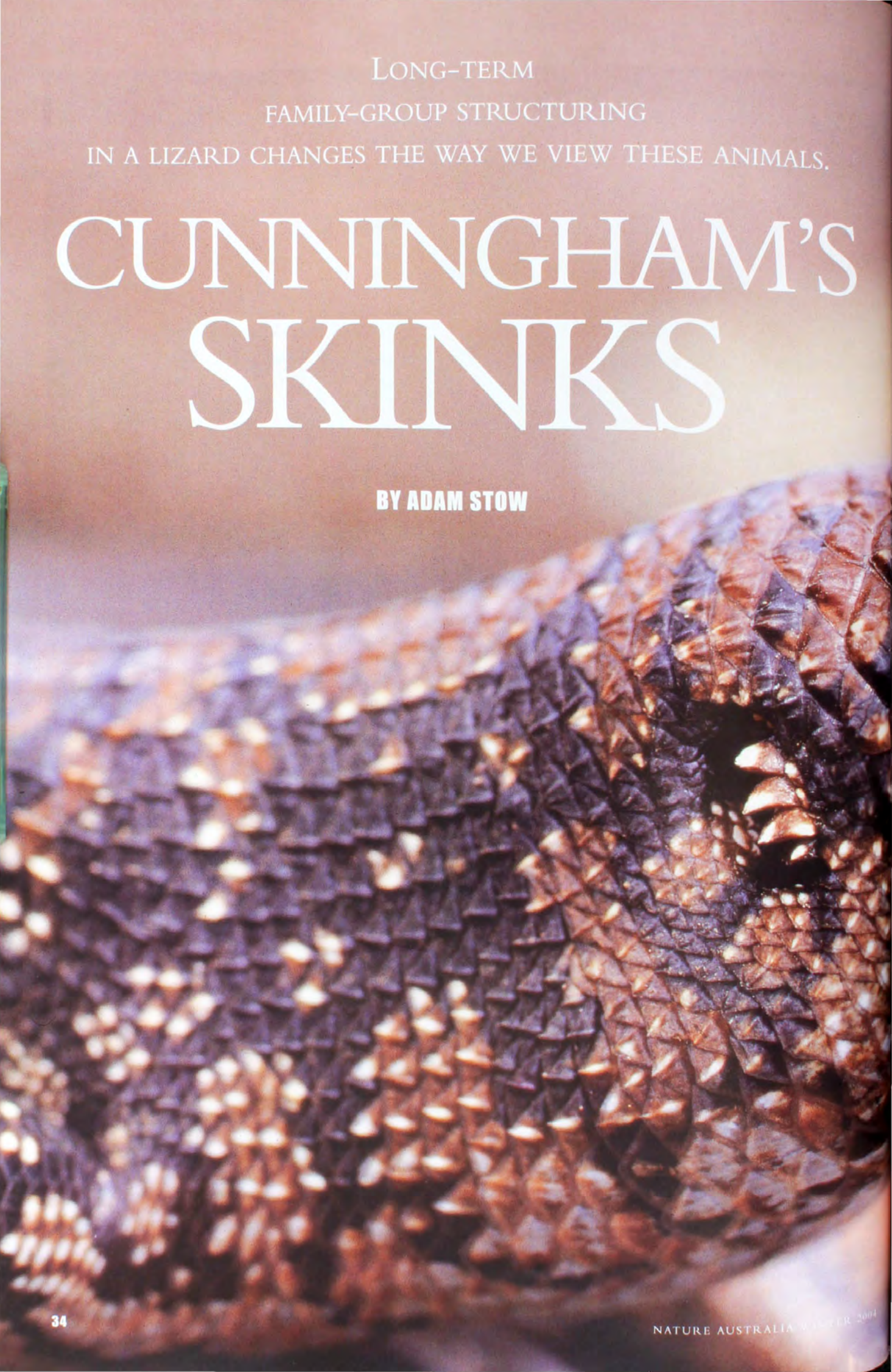
ANDREW J. DENNIS

Fruits of the rainforest come in a wide array of colours, shapes and sizes, and Musky Rat-kangaroos eat species from the full range. Although they have a preference for the large and juicy fruits, they also consume some very small species and some that have dry corky flesh, as well as firm seeds that they gnaw.

LONG-TERM FAMILY-GROUP STRUCTURING IN A LIZARD CHANGES THE WAY WE VIEW THESE ANIMALS.

CUNNINGHAM'S SKINKS

BY ADAM STOW



The striking patterning on Cunningham's Skinks is surprisingly good camouflage in their typical rocky habitat. Their spiny scales increase the difficulty of removing these lizards from their rock-crevice retreats.

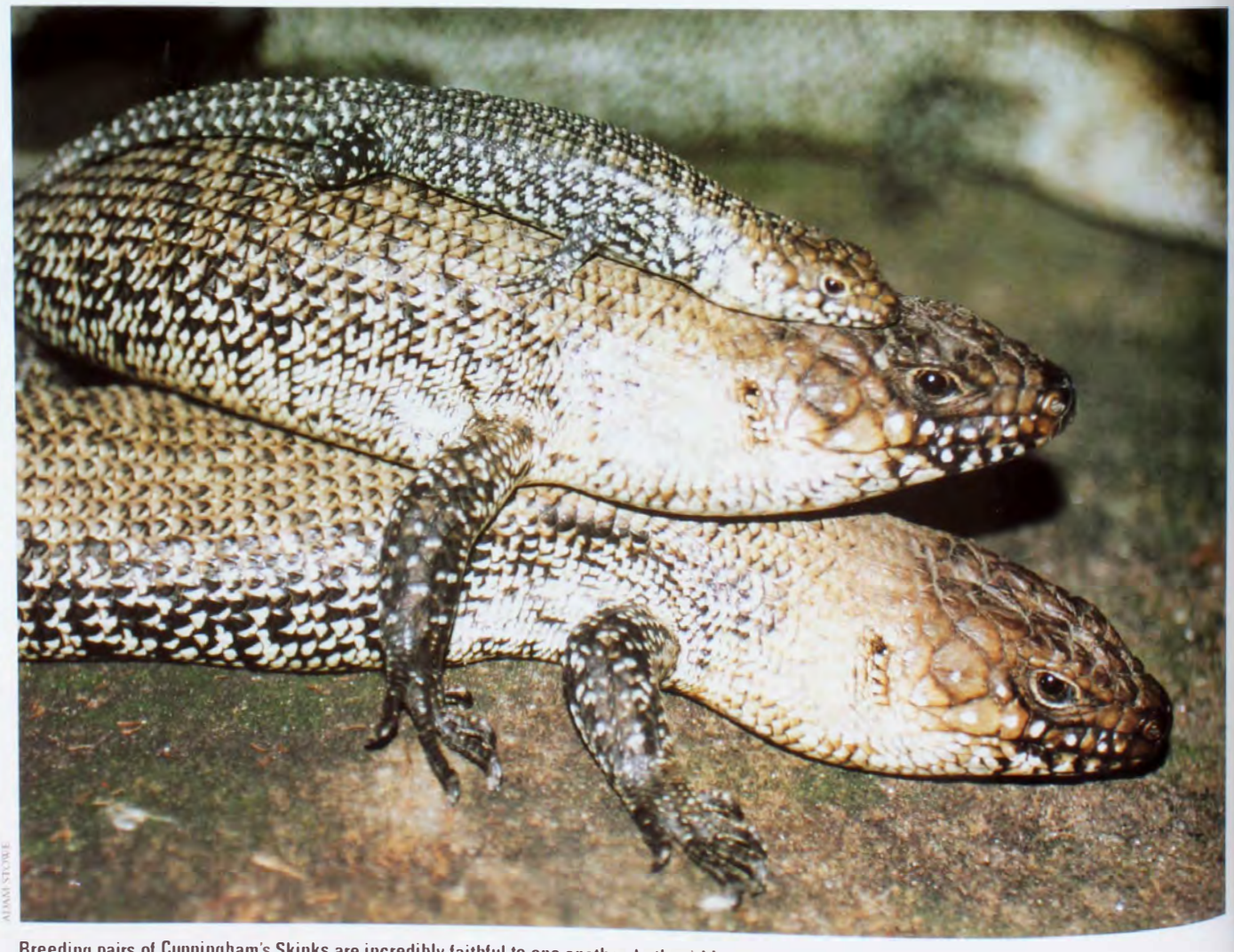
MICHAEL MAY/AUSCAPE

THE SUN IS JUST HIGH enough to lift the fog, revealing granite rock outcrops scattered across a sea of grass and into the forested nature reserve beyond. The rocks are slightly warm to touch and the first of the Cunningham's Skinks emerge from their deep rock crevices. Soon groups of lizards of various sizes are sunning themselves on many of the outcrops. I wondered whether the individual lizards that lumped together did so by accident or on purpose. In other words, did the particular lizards in a group just happen to stumble across the same cosy outcrops, or was there something more complex going on? I was intrigued by the possibility that these skinks were forming social groups, a situation not often associated with reptiles. I also wanted to know whether clearing of native vegetation around the lizards' rocky outcrops affected their ability to move between sites, which would in turn influence group structure. So began my long-term study of Cunningham's Skinks (*Egernia cunninghami*) on the Central Tablelands of New South Wales, comparing skinks living in a natural vegetated reserve with those in an adjacent area that had been cleared over 70 years ago. But first, to catch some skinks.

When groups of Cunningham's Skinks sun themselves, it is inevitable that, as you approach, at least one will raise its head and look your way. Soon all the skinks will make a dash for home, wedging themselves snugly into deep crevices. Given that these lizards are almost impossible to sneak up on, I had to capture most of them in traps, after which I recorded their location, marked them with a microchip, took their body measurements, obtained a small tissue sample from the tip of their tail, and then returned them to the crevice from which they were caught.

After five years of fieldwork it became clear to me that Cunningham's Skinks occupy the same crevices for long time periods. I marked over 400 lizards and, of these, only a few adult males were seen to move between rock outcrops. Many of the offspring born into a group were also staying at home, at least for much of the five to six years it takes to reach maturity. It seemed likely that the parents would also be in the same group. To test whether this was the case, and to discover more intimate aspects of these lizards' lives, I analysed the DNA from the tissue samples.

After I identified the parents of over 200 immature lizards, a picture of the mating system and kin structure within the groups began to emerge. It became apparent that, during the breeding season, Cunningham's Skinks are very faithful to their partners with only a low proportion of males (14 per cent) squeezing in an affair. Even more striking was the degree to which these



ADAM STEWART

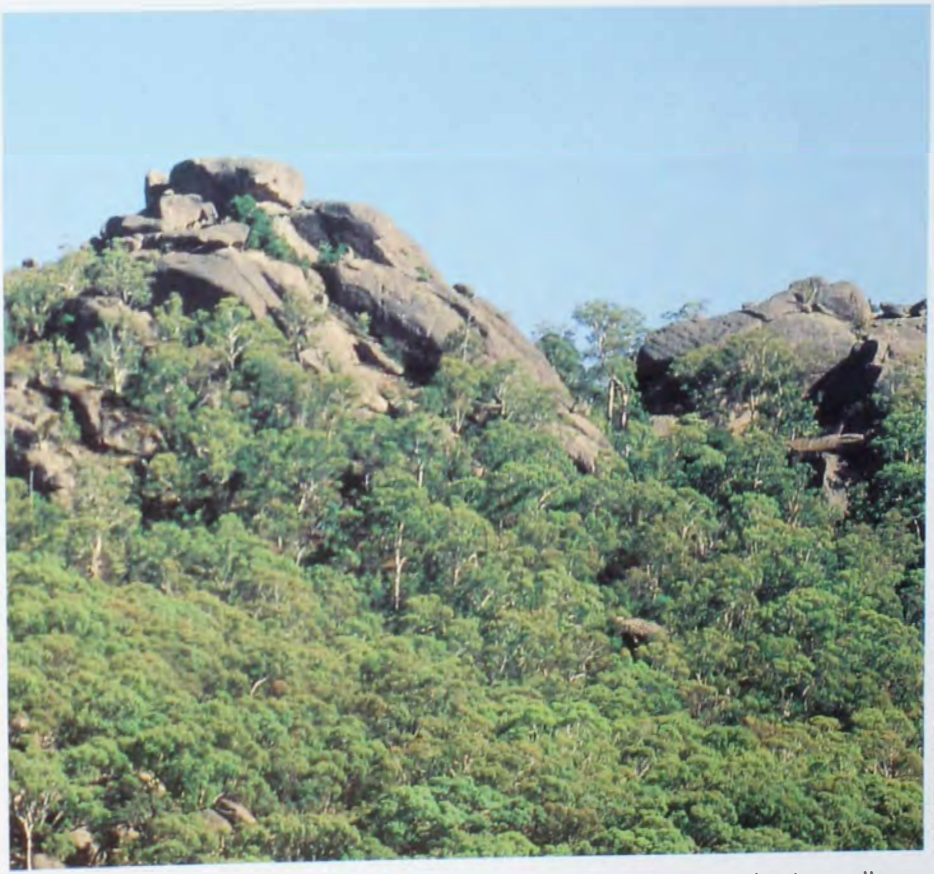
Breeding pairs of Cunningham's Skinks are incredibly faithful to one another, both within seasons and over several years.

CORIN SADLIER

Cunningham's Skinks have favoured basking sites, at which they will often spend much of the day.

lizards are faithful across seasons, with many pairs staying together for three or more years. Long-term monogamy in lizards appears to be rare, although recent research is indicating that it may be prevalent in other Australian lizards, particularly those belonging to the genus *Egernia* and some closely related skinks such as the Sleepy Lizard (*Tiliqua rugosa*) (see "Sleepy Lizards: Paired for Life", *Nature Aust.* Summer 1996–1997).

Long-term monogamy wasn't the only unusual feature of Cunningham's Skinks. Within each rock outcrop I found there was usually only one breeding pair. And where were the offspring? As suspected, at home with the parents—a family-group structure, more typical of many birds and mammals. Most rock outcrops supported large aggregations of lizards (up to 27), which consisted mostly of immature siblings born over several years. The finding of long-term family-group structuring in a



ROSS SADLIER, AUSTRALIAN MUSEUM

The amount of dispersal in Cunningham's Skinks was assessed in both deforested and naturally vegetated areas.

CUNNINGHAM'S SKINKS

are surprisingly fastidious when it comes to forming relationships and only an unrelated mate will do.

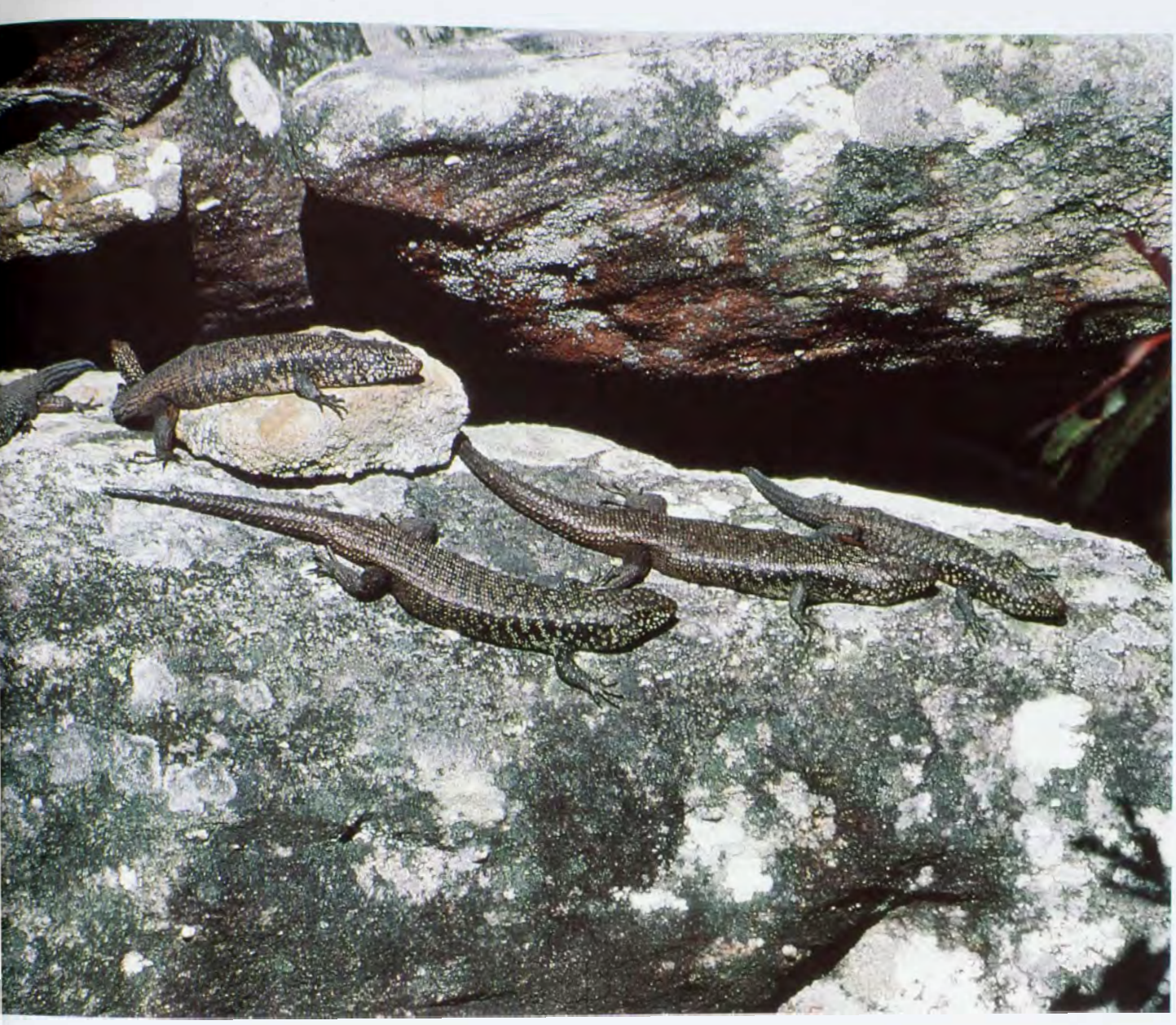
lizard changes the way we view these animals, which traditionally have not been thought of as being particularly 'social'. At this stage, I haven't investigated what advantages there may be for Cunningham's Skinks to maintain such long-term groupings, although research on other *Egernia* species provides a clue. Benefits may include having 'many eyes' on the lookout for danger, or it's possible that cuddling up on cold winter nights may act as a thermal buffer, preventing body temperatures dropping to lethal levels. Interestingly, in the Black Rock Skink (*E. saxatilis*) there is evidence for an indirect form of parental care. Young Black Rock Skinks are less likely to be attacked by an unrelated lizard lurking within their territory if their mother is present.

AND WHAT OF THE DIFFERENCES between skinks from the native and cleared populations? For many animals, changes to the environment (such as deforestation) between suitable habitat patches (in this case the rock outcrops) can alter an individual's ability to disperse, often with detrimental 'flow-on' effects that lower the whole group's survival. Given the generally low levels of dispersal in Cunningham's Skinks, I wasn't sure whether dispersal in deforested habitat would be any different to that in the natural habitat. The genetic analyses, however, showed that adult lizards were dispersing less in deforested habitats, increasing the proportion of near relatives within the same and on nearby rock outcrops and the numbers of adults within groups.

Breeding between close relatives (inbreeding) can result in offspring with less chances of survival, a particularly worrying prospect for Cunningham's Skinks if they form such long-term partnerships. Nonetheless, Cunningham's Skinks are surprisingly fastidious when it comes to forming relationships and only an unrelated mate will do. So, despite increased risk of inbreeding in deforested habitats, Cunningham's Skinks appear to have evaded this particular problem. The genetic data give no indication of any more inbreeding in deforested habitats than in the natural vegetated reserve. At least for the 70 or so years of deforestation, recognition and strong avoidance of mating with close kin has provided a buffer against the problem of inbreeding.

It makes sense for Cunningham's Skinks to have the ability to be choosey with whom they breed, given their long-term investment in one partner while living within groups containing many close relatives. But how do they do it? Scent is likely to play an important role in recognising relatives. Whether Cunningham's Skinks use familiarity to avoid breeding with close relatives (such as brothers or sisters with

A group of full siblings captured within the one rock crevice. Cunningham's Skinks form long-term family groupings, usually comprised of a faithful breeding pair and several age-cohorts of offspring



Deep rock crevices are the favoured retreat site for Cunningham's Skinks. Such homes are well insulated against climatic extremes and provide good protection from predators.

which they lived before maturity), or some means to identify true (genetic) relatedness, is not yet resolved.

The ability to recognise relatives or group members has also been shown in other *Egernia* species. In the Gidgee Skink (*E. stokesii*), for example, mothers and their offspring can recognise each other via scent. Intriguingly, several *Egernia* species, including Cunningham's Skink, tend to pile their scats near their retreat sites. In mammals, scat piling may serve a variety of social functions, such as territory marking. It could be that scat piles are simply formed at favoured morning basking sites where the lizard first reaches the required temperature to defecate. How-

Cunningham's Skink

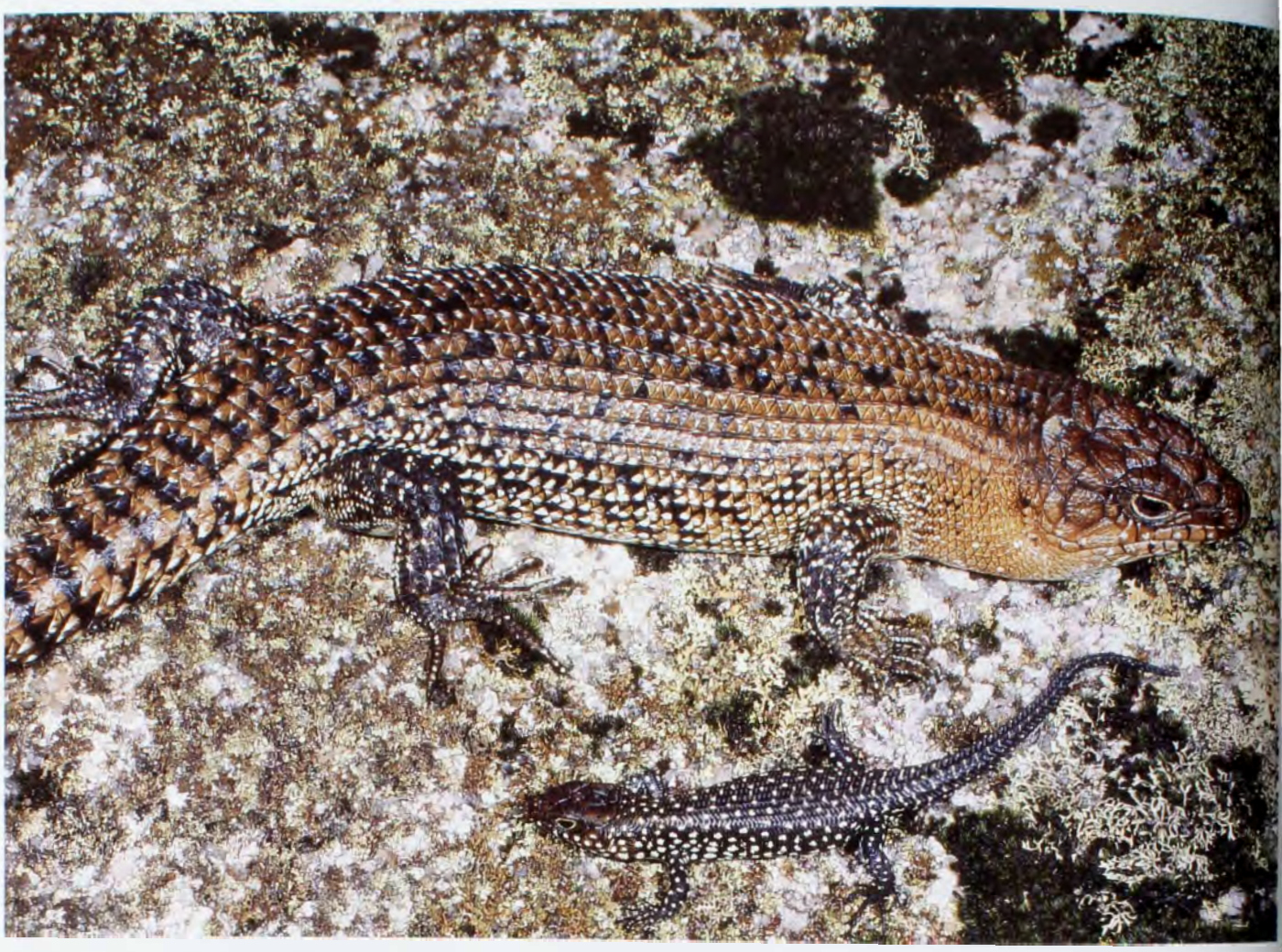
Egernia cunninghami

Classification
Family Scincidae.

Identification
Snout–vent length 250 mm, tail same length. Colour variable, often brown to black above with white to yellow blotches. Spiky scales.

Habitat and Distribution
Rocky areas in south-eastern Aust. from southern Qld to SA.

Biology
Long-term monogamy and stable family groups. Females viviparous, having up to 1 litter/year (usually 4–8 young) during summer. Adults omnivorous, with vegetation comprising large part of diet.



(Above) An adult Cunningham's Skink with its young, approximately three months old. (Right) Cunningham's Skinks appear to have good vision and rely heavily on sight to avoid predators (and researchers!).

ever, it is alluring to consider scat piling as having a social function—a possibility in Cunningham's Skink, and other *Egernia* species, where individuals can discriminate between group and non-group members on the basis of chemical cues within scats.

So far, stubborn reluctance to breed with close relatives has protected Cunningham's Skink from the potential inbreeding problems that could have arisen after deforestation. Nonetheless, in the longer term this could pan out to be a double-edged sword: strong avoidance of breeding with close kin in conjunction with reduced dispersal may leave more adults without mates. The family-group structuring in these lizards points to the importance of dispersal in finding a mate. Stranded on rocks with only close kin, these lizards still appear to take the moral high ground, preferring total abstinence than pairing up with a relative. In deforested habitats, continuing accumulation of close relatives would make finding a mate an increasingly difficult task. However, while clearing of native vegetation inhibits adult dispersal overall, deforestation also seems to be forcing some lizards (mostly males) to 'jump rock' in search of an unrelated mate.

For the time being, it appears that in deforested habitats enough breeding pairs have set up homes of their own for there to be no major impact of tree-clearing on birth rates. Even under 'stress' imposed by habitat change, many Cunningham's Skinks manage to achieve what some of us strive for—faithful partnerships within a stable family household. □

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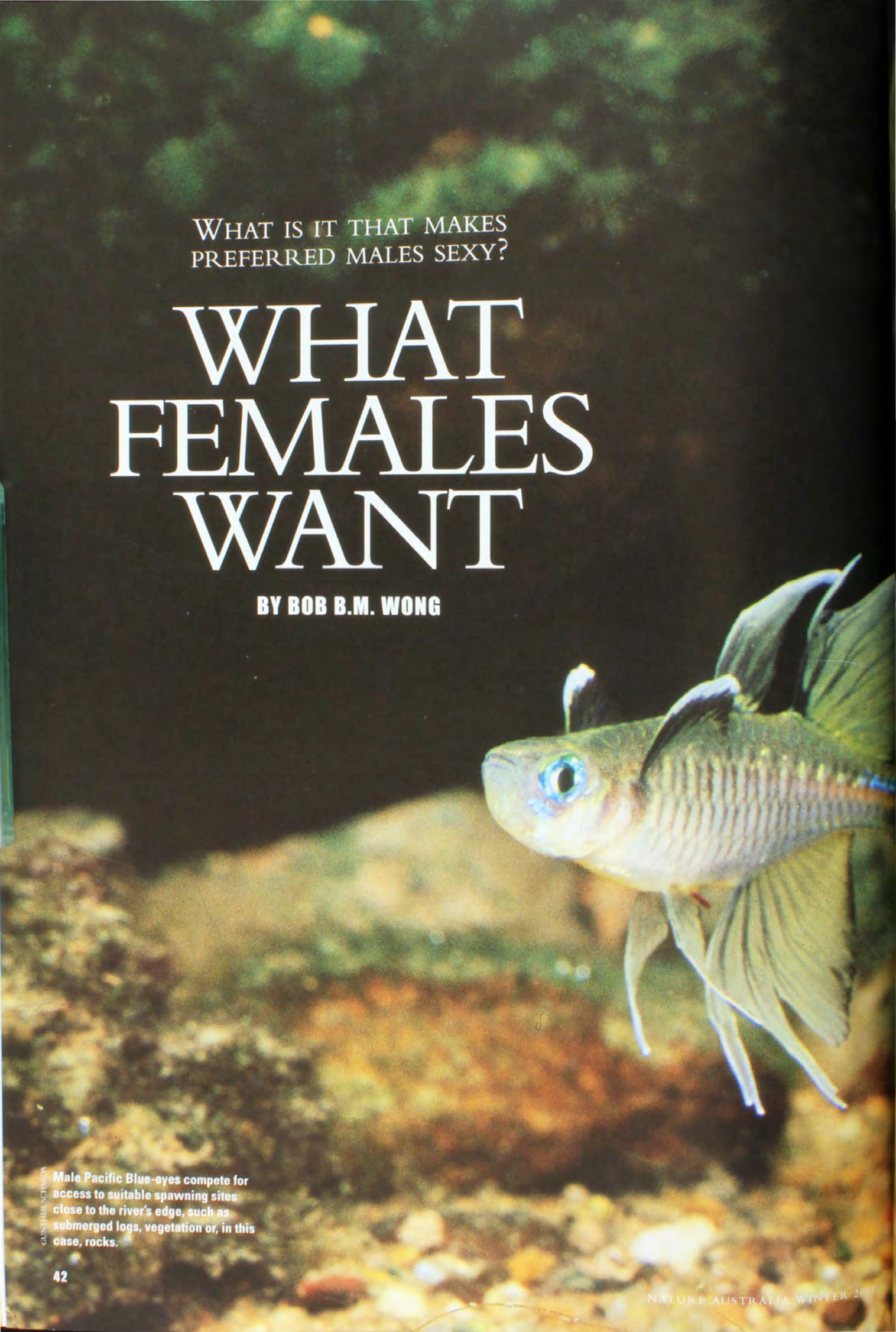
DR ADAM STOW COMPLETED HIS PH.D. ON THE IMPACT OF HABITAT FRAGMENTATION ON CUNNINGHAM'S SKINK AT MACQUARIE UNIVERSITY IN THE SCHOOL OF BIOLOGICAL SCIENCES, WHERE HE CONTINUES HIS RESEARCH INTO POPULATION GENETICS AND REPTILES.

WHAT IS IT THAT MAKES PREFERRED MALES SEXY?

WHAT FEMALES WANT

BY BOB B.M. WONG



GUNTHER SCHMIDA

Male Pacific Blue-eyes compete for access to suitable spawning sites close to the river's edge, such as submerged logs, vegetation or, in this case, rocks.

I PUT ONE FOOT INTO THE stream and gasped. It was the wet season in far northern Queensland and it was humid and hot. Naively, I had assumed that the water in Tregothanaan Creek would be warm too, but it was unexpectedly icy. I braced myself and slowly waded across the swollen creek towards a fallen log. The algae-covered river rocks were slippery. My sandals didn't help. They were heavy in the current but I was reluctant to take them off, ridiculously paranoid that I might tread on a freshwater scorpionfish. As I reached the partially submerged log, my fear was quickly replaced with delight. Gazing into the water, I found myself captivated by the shimmer of golden scales, the display of flashing fins, and the glitter from an unmistakable pair of tiny eyes that were as blue as sapphires.

The Pacific Blue-eye (*Pseudomugil signifer*) is a small, colourful freshwater fish found in coastal river drainages across much of eastern Australia. Male blue-eyes are larger, more colourful and have longer fins than the females. Males are also highly territorial. In fact, the display I saw at Tregothanaan Creek was sparked by a male that had ventured into the territory of another. In response, the territory owner had swum out from the log towards the interloper with his fins outstretched like the sails of a yacht. Such displays are frequent, as males compete with one another over spawning sites. The loser is inevitably driven away, his fins trailing behind him in defeat.

Females swim close along the water's edge, inspecting males along the way. Males court females by tilting their bodies forward and flashing their fins as they try to entice them towards their territories. If the male is successful in his efforts, the female will follow him to his territory and scatter her eggs among aquatic vegetation, which he promptly fertilises. Males care for the eggs by defending the spawning site. All of these behaviours attracted me to blue-eyes. They would, I suspected, make superb study animals for testing some key assumptions in the field of sexual selection.

Tregothanaan Creek in far northern Queensland—one of many streams in northern Australia where male blue-eyes hold territories close to the water's edge and feverishly court passing females.

IN MANY ANIMALS, IT IS OFTEN THE males that are the more flamboyant-looking sex. Some may possess formidable weapons such as antlers or spectacular ornaments like the Peacock's tail. How do these traits arise and what do they mean? We know that the evolution of elaborate male traits is driven by two processes: competition and mate choice. Typically, it is the males that do the competing and females that do most of the choosing. Male competition selects for traits that are important in asserting dominance over rivals. By dominating their opponents, winners hope to gain better access to females or the best resources needed to attract them. Female mate choice is believed to lead to the evolution of traits that reveal important information about the quality of potential suitors, such as good genes or parenting skills.

GUNTHER SCHMIDA

The female Pacific Blue-eye in the foreground on the right is not concerned with the fighting prowess of the two competing males on the left. She is more interested in a male that can deliver high egg-hatching success

GUNTHER SCHMIDA

It has traditionally been assumed that both processes of sexual selection are complementary in their effects, leading to the evolution of the same traits. Under this assumption, armaments that reveal clues about a male's fighting ability to his opponents would also function as sexy ornaments that can be used to guide the mating decisions of choosy females. Certainly, there appears to be widespread support for this assertion and numerous examples exist of traits that serve this dual purpose. The gargantuan curly horns of American Bighorn Sheep (*Ovis canadensis*), for example, are used as weapons during combat and males with the biggest horns invariably come out as winners. Females are also especially attracted to males with big horns. But should females *always* prefer to mate with dominant males? Recent studies on a growing number of species suggest not.

Just because a male is good at fighting, doesn't mean that he would necessarily also possess the kinds of attributes that females seek. For example, a dominant male, through his antics, could end up mating with more females simply because he is able to exclude his rivals from accessing those females. Potentially, this could mean that females miss out on mating with males they really like. Indeed, it is becoming increasingly apparent that there is no reason why the two processes of sexual selection have to

Two male Pacific Blue-eyes. The fish on the right has his fins folded in normal swimming posture. When males are displaying, they deploy their fins like sails as shown by the male on the left.

The Townsville fish were super easy to catch and I didn't even have to get into the water. I simply crouched on the bank, lowered my dip net, dropped a few bread crumbs on the water's surface and waited for the fish to come to me. Once I had them in the net, the fish were sorted, placed in bags with water and oxygen, and freighted back to the lab in Canberra. My captive charges settled quickly to life in aquaria and it was soon time to get started.

SHOULD FEMALES always *prefer to mate with dominant males? Recent studies suggest not.*

be complementary at all. It makes sense that females could rely on entirely different cues to those that signal fighting ability, especially if fighting prowess does not reflect quality in terms of what females want. I decided to test these predictions using the Pacific Blue-eye.

The fish I used for these experiments came from Ross Creek—an unassuming muddy fishing hole in the middle of Townsville city. Male Pacific Blue-eyes from this particular creek sported the longest fins of any that I had come across. The fins of some of my males trailed behind their bodies like streamers. They are so beautiful that many aquarists keep them as pets. Townsville blue-eyes look so different from other populations that some people think they could be a different species. However, results of genetic work conducted during my Ph.D. indicate they belong to the same genetic group or clade as other northern Queensland populations.

STUDIES OF MATE CHOICE IN FISH typically measure what are known as 'association preferences'. This involves offering a female the opportunity to choose between two or more males confined in separate compartments behind a pane of glass. This 'window-shopping' technique sounds extremely artificial but it seems to work; females that spend more time in front of a particular male's compartment will also spawn sooner with that male compared with females that are paired with a male she did not like, suggesting that association preferences reflect a fish's true mating intentions. Perhaps the biggest bonus of experimental lab work is that it places me in a much better position to disentangle the

(Left) Two male Pacific Blue-eyes sparring. True to their name, these males clearly show the radiantly coloured blue eyes that give this group of fish their common name. (Above) A male Spotted Blue-eye (*Pseudomugil gertrudae*) courting a female. Like the Pacific Blue-eye, males use courtship to entice females to spawn.

mechanisms of sexual selection.

My experimental design needed to separate competition and mate choice in time and space. Often the two forces operate contemporaneously, making it a challenge to determine their relative contributions. For example, how can we be sure that a female really did prefer the dominant male and wasn't simply prevented, by that male, from realising her true mating preferences for a potentially more attractive, but subordinate, suitor? The answer seemed straightforward enough: I needed to measure female preference while, at the same time, preventing males from interfering with one another.

First I staged encounters between males by allowing them to compete over a single 'mop' made from strands of acrylic yarn tied off at one end. Such mops simulate spawning territories and are a traditional device used by aquarists to get their pet blue-eyes to breed at home. I found that the winning (dominant) males were larger than their opponents and they also had the longest fins. This was hardly a revelation. In many animals, larger males tend to beat smaller opponents.

WHERE A FEMALE

was free to choose without any risk of harassment or coercion, female blue-eyes did not choose the males that had previously won fights.

However, having worked out that big males with longer fins were the best fighters, the next step was to see whether males with these same traits were sexier to females. In other words, did females really use the same cues important in signalling dominance to choose their mates? Males were placed in adjoining compartments separated by a black plastic partition that prevented them from seeing and interfering with one another. The female compartment, however, allowed the female to see and interact with the males that she liked.

In an environment where a female was free to choose without any risk of harassment or coercion, female blue-eyes did not choose the males that had previously won fights. This was contrary to traditional assumptions that dominant males are sexy and I was extremely excited by the result. But erring on the side of caution, I decided to test another possibility. Maybe

PHOTO BY GUNTHER SCHMIDA

STUDIES ON OTHER SPECIES OF FISH

show that courtship may be a valuable cue to females in selecting good fathers.

females can't tell which male is a better fighter based on physical appearance alone. Maybe females really do prefer dominant males but actually need to see some fighting for themselves.

Studies on other animals have documented bizarre instances where females deliberately stage or incite competition. For example, in Red Junglefowl (*Gallus gallus*), just a simple cackle from the female is enough to send two rival males into combat. The female then patiently waits for the fight to end and mates with the winner. This, however, does not appear to be the case in blue-eyes. In a separate experiment, I decided to compare female preferences for two males before and after she had the opportunity to witness the males fight. Unlike Red Junglefowl, female blue-eyes were not voyeuristic. As before, large males won the fights but they were not preferred, either before or after females had the chance to see them fighting. So if it isn't fighting prowess that females are looking for, what is it that makes preferred males sexy?

Preferred males spent more time courting females. Studies on other species of fish show that courtship may be a valuable cue to females in selecting good fathers. In damselfishes, for example, courtship intensity is correlated with a male's condition. Choosing males that are in good condition is important because males must invest considerable energy in guarding eggs. Moreover, males in poor condition could end up eating the eggs or the babies, as demonstrated in several species of Japanese cardinalfish. I decided to compare the egg-hatching success of preferred and non-preferred mates.

Females were allowed to pair with either their preferred suitor or the one they had rejected during the mate-choice experiments. After they had spawned, the females were removed. I then tested the males' guarding abilities by introducing another male into the tank to act as a potential nest challenger and egg predator. After ten days, I counted the number of embryos to compare egg-hatching success when guarded by preferred and non-preferred males. It turns out that preferred males

Pacific Blue-eye

Pseudomugil signifer

Classification
Family Pseudomugilidae.

Identification
Small (< 6 cm) freshwater fish. Males larger, more colourful and possess elaborate fin extensions.

Habitat and Distribution
Common in coastal drainages across eastern Aust. from southern NSW north to Cape York. Occurs in variety of habitats from rainforest streams to swamps, tidal mangrove creeks, estuaries and offshore islands.

Biology
Breeds all year round with a peak during summer months. During breeding, males defend spawning sites close to water's edge and court females. Pairs spawn after elaborate courtship with females scattering their adhesive eggs. Eggs take several weeks to hatch depending on temperature.

GUNTHER SCHMIDA

Two colourful male blue-eyes (*Pseudomugil cyanodorsalis*) threaten one another.

actually brought more of a female's eggs to the hatching stage. So females were using courtship as a cue to choose good fathers! And what about hatching success when eggs were guarded by dominant versus subordinate males? In this regard, I found that dominant males actually made mediocre fathers, as they did not achieve better hatching success than subordinates.

My studies suggest that, contrary to traditional views, male dominance is not necessarily sexy because fighting prowess does not always reflect what females want. Instead, female blue-eyes would rather mate with potentially good fathers, chosen on the basis of the time and effort spent wooing them. Perhaps there's a lesson in that for all of us. □

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BOB B.M. WONG IS A PHD STUDENT AT THE AUSTRALIAN NATIONAL UNIVERSITY WORKING ON SEXUAL SELECTION IN THE PACIFIC BLUE-EYE.

WHY SHOULD FAIRY-WRENS EVOLVE THE ABILITY TO DETECT CUCKOO CHICKS WHERE OTHER HOSTS HAVE NOT?

CANNY CUCKOOS & WILY WRENS

BY NAOMI LANGMORE

MENTION CUCKOOS AND you immediately think of birds that lay their eggs in other birds' nests, abandoning them to the care of the foster parents. However, this enduring image of the cuckoo family is based on the European Common Cuckoo (*Cuculus canorus*), and many people are surprised to learn that, not only are most cuckoos not parasitic, but that there are cuckoos in Australia too. In fact, Australia is home to the most diverse group of cuckoos in the world, ranging from the world's smallest (the 17-gram Little Bronze-Cuckoo, *Chrysococcyx minutillus*), to the world's largest (the 610-gram Channel-billed Cuckoo, *Scythrops novaehollandiae*). Overall, 11 species of cuckoo belonging to five genera breed in Australia. One other species, the Oriental Cuckoo (*Cuculus saturatus*), is a non-breeding migrant.

Of the world's 136 species of cuckoos, only the 54 species in the subfamily Cuculinae are obligate 'brood parasites'. But of these, it can be said that the females are among the world's greatest birdwatchers. A female will quietly observe the nest-building activities of her chosen 'host' species from a discreet distance and memorise the location of all the nests in the area. When she is ready to lay an egg, she chooses a nest in which the host has already started to lay a clutch. She quietly flits down to the nest, removes one host egg, lays a single egg of her own and departs again, all in the space of a few seconds. Often this is her entire investment in the fortunes of her chick, which is thereafter abandoned to the care of the host parents.

For many years there was debate as to

RAOUL SLATTER-LOCHMAN/TRANSPARENCIES

A cuckoo chick uses its flattened back to eject the eggs of its robin host.

whether the cuckoo laid directly into the nest or placed her egg into the nest with her bill. This issue was so hotly debated in Britain that one naturalist, Edgar Chance, wagered £500 that direct deposition was the only method. The debate was laid to rest in Britain in 1921 when Chance photographed Common Cuckoos laying directly into the nest. In Australia many hosts build a dome-shaped nest with a small entrance hole, and some naturalists thought it unlikely that a cuckoo could fit inside to lay an egg. However, pioneering work by Michael and Lesley Brooker (CSIRO) in the late 1980s demonstrated conclusively that bronze-cuckoos lay directly into the host nest without causing detectable damage to the entrance.

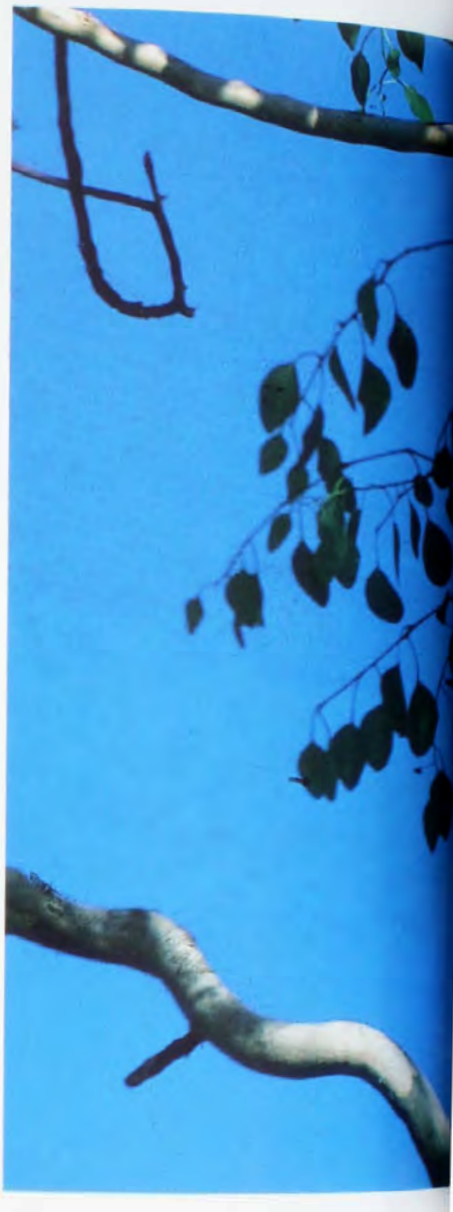
When the cuckoo chick hatches, and while still naked and blind, it sets about disposing of its nest mates. Any egg belonging to the host is balanced on the cuckoo's specially flattened back and lifted up over the edge of the nest and allowed to fall. If any host chicks have hatched, they are subjected to the same treatment. The cuckoo chick is left as the sole occupant of the nest and can feast on all the food brought by its host parents without competition.

This parasitic strategy carries high costs for the host bird, both in terms of the loss of their own offspring and the time and effort required to rear a cuckoo chick. Not surprisingly then, host birds have evolved strategies to defend themselves against cuckoos. Many hosts will mob cuckoos ferociously and throw any odd-looking eggs out of their nests. Not to be outdone, cuckoos have retaliated by laying their eggs as quickly as possible, and by evolving eggs that match the colours and patterns of the host eggs. This escalating battle of ever better tricks by the cuckoo, and ever better defences by the hosts, is a classic example of a 'coevolutionary arms race'.

Now we come to a puzzle. Although many hosts show remarkable skill at discriminating between their own eggs and cuckoo eggs, any cuckoo chick that makes it through to hatching is accepted unquestioningly by the host parents. Hosts invariably rear the impostor even though it may grow to over ten times their own size. This has been one of the biggest challenges to explain in the study of coevolution between cuckoos and their hosts. Why should hosts evolve such skill at recognising subtle differences in foreign eggs, yet fall short of recognising a giant, alien chick?

ATHAL TOLHURST

Superb Fairy-wrens cannot detect cuckoo eggs, perhaps partly because of poor visibility in the dim interior of their dome-shaped nests.



OUR STUDY OF HORSFIELD'S Bronze-Cuckoos (*Chrysococcyx basalis*) in Canberra has provided some answers to this puzzle. The primary hosts of Horsfield's Bronze-Cuckoos are fairy-wrens (*Malurus* spp.). Rebecca Kilner (University of Cambridge) and I, with the help of many talented researchers, monitor all the Superb Fairy-wren (*M. cyaneus*) nests in Campbell Park, Canberra, and observe the response of fairy-wrens to parasitism by cuckoos. Fairy-wrens build dome-shaped nests of grass and spider webs,

HANS & JUDY BESTE/OCHMAN TRANSPARENCIES

(Above) Australia's largest cuckoo, the Channel-billed Cuckoo, parasitises crows, magpies and currawongs.

lined with feathers, thistle down or kangaroo fur. They are usually tucked low in grass tussocks, clumps of everlastings or dense bushes. In Campbell Park the favourite nest site is a thorny clump of Sweet Briar (*Rosa rubiginosa*), ensuring that we get thoroughly pricked and scratched with every nest we check. It is all worthwhile though, when a routine nest check reveals the exhilarating sight of a cuckoo egg nestled amongst the fairy-wren eggs.

For their body size, Horsfield's Bronze-Cuckoos lay a relatively small egg, which closely matches the delicately speckled eggs of their fairy-wren hosts. The cuckoo egg is the same colour, pattern and width as the fairy-wren eggs. The only clues we have to detect the cuckoo egg are that it is fractionally longer than a fairy-wren egg (about two millimetres) and that the speckling over the egg surface is fairly uniform, whereas fairy-wren eggs often have a band of denser speckling at the blunt end. These differences usually (but not always!) enable us to detect a cuckoo egg, but they seem to be too subtle for a fairy-wren to spot in the dim interior of its dome-shaped nest.

As long as the cuckoo lays her egg at the right time, fairy-wrens are unable to detect the cuckoo egg in their nest (52 out of 53 Horsfield's Bronze-Cuckoo eggs laid during the host's laying period were accepted). However, if the cuckoo gets the timing wrong and deposits her egg into an empty nest, the fairy-wren female sews the cuckoo egg into the lining of the nest, thereby ensuring that it will fail to hatch (13 out of 15 cuckoo eggs that were laid too early were sewn in). If the cuckoo lays her egg too late, and accidentally disturbs the female fairy-wren incubating her clutch, the fairy-wren will desert her clutch and set about building a new nest (seven out of eight nests in which the cuckoo laid late were deserted). It obviously pays the cuckoo to time the laying of her eggs accurately, and most do just that.

Does this mean that cuckoos have 'won' the arms race against fairy-wrens? By evolving an egg that is so similar to their host's egg, they seem to have thwarted the defences of their host. However, the crafty fairy-wrens have a new trick up their sleeve. Unlike any other known cuckoo host in the world, Superb Fairy-wrens seem to have evolved an ability to recognise cuckoo chicks as foreign.

In 40 per cent of Superb Fairy-wren nests containing Horsfield's Bronze-Cuckoo chicks, the foster parents

NAOMI LONGMORE

A Pallid Cuckoo (*Cuculus pallidus*) egg (top) in the nest of a White-plumed Honeyeater (*Lichenostomus penicillatus*) in Campbell Park, ACT.

ceased feeding the chick when it was a few days old and left it to die of cold or starvation. The female fairy-wren invariably detected the impostor first and, while the cuckoo chick was still alive and begging plaintively, she began building a new nest nearby. The fairy-wren males were generally a bit slower on the uptake; they carried on feeding the cuckoo for several hours or even days, before they too left it to its fate.

HOW MIGHT FAIRY-WRENS RECOGNISE cuckoo chicks? There are several possibilities; perhaps the cuckoo chick looks or sounds different from a fairy-wren chick, or perhaps fairy-wrens use a simple rule of deserting any chick that is alone in the nest. We tested how fairy-wrens recognised cuckoos with an experiment involving another species of cuckoo, the Shining Bronze-Cuckoo (*Chrysococcyx lucidus*). Shining Bronze-Cuckoos normally lay their eggs in the nests of thornbills (*Acanthiza* spp.) but they occasionally exploit fairy-wrens as well. We searched for thornbill nests in Campbell Park and transferred eight Shining Bronze-Cuckoo eggs into fairy-wren nests. We left the fairy-wrens to incubate the eggs and when they hatched we observed their response with daily 'nest watches'.

An unexpected discovery dismissed the possibility that fairy-wrens recognised cuckoos by their appearance. When the Shining Bronze-Cuckoo chicks hatched from their olive-green eggs, it turned out that they had two distinct colour morphs. Half were black, whereas the others were the same pale pink as fairy-wren and thornbill chicks. If fairy-wrens recognised cuckoos by their appearance, we'd expect them to accept all the pink morphs and desert all the black ones. However, fairy-wrens deserted *all* the Shining Bronze-Cuckoo chicks, regardless of their colour. They must have been using some other cue to recognise cuckoo chicks.

Perhaps fairy-wrens distinguish cuckoo chicks by their begging calls? We tape-recorded the chicks of Shining Bronze-Cuckoos, Horsfield's Bronze-Cuckoos and Superb Fairy-wrens using 'tie-clip' microphones clipped outside the nest entrances. Horsfield's Bronze-Cuckoo chicks made a 'cheep' call that was very similar to that of fairy-wren chicks, whereas Shining Bronze-Cuckoos made a rasping call like a thornbill chick. The rasping calls of Shining Bronze-Cuckoos would sound strange and unfamiliar to fairy-wrens, and this may explain why they were all deserted. Equally, it is possible that some Horsfield's Bronze-Cuckoo chicks were better than others at mimicking the calls produced by host young. Perhaps only the poorer mimics were deserted. These results also tell us that the coevolutionary arms race between Superb Fairy-wrens and Horsfield's Bronze-Cuckoos has escalated to a new stage; not only can fairy-wrens detect cuckoo chicks in their nests, but Horsfield's Bronze-Cuckoos have retaliated by evolving a fairy-wren-like begging call, which goes some way towards reducing the likelihood of desertion by the hosts.

Another clue that might help fairy-wrens to detect a cuckoo is the pres-

KATHIE ATKINSON

Superb Fairy-wrens are the only known cuckoo host to have evolved the ability to recognise and reject cuckoo chicks.

NAOMI LONGMORE

(Right) Shining Bronze-Cuckoo chicks have two distinct colour morphs: a pale morph, shown here (centre) with two Superb Fairy-wren chicks, and a black morph.

ence of a single chick in the nest. Ordinarily fairy-wrens would have three to five chicks in the nest, so there is a good chance that any single chick is a cuckoo. We found that, on the rare occasions when only a single fairy-wren chick hatched, it was sometimes deserted in the same way as a cuckoo chick, whereas broods of two or more fairy-wren chicks were never deserted. It seems that Superb Fairy-wrens use a combination of cues to recognise cuckoo chicks, including whether the chick is alone in the nest and the accuracy of its begging call. Perhaps by using several cues to decide whether or not to abandon the nest, the fairy-wrens

ESTHER BEATON

Despite the relatively large size of cuckoo chicks, most host species fail to realise they are imposters. Here a Channel-billed Cuckoo fledgling begs for food from its Pied Currawong (*Strepera graculina*) host.

Horsfield's Bronze-Cuckoos are engaged in an escalating 'evolutionary arms race' with their fairy-wren hosts.

reduce the risk of mistakenly deserting their own young.

Finally, why should fairy-wrens evolve the ability to detect cuckoo chicks where other hosts have not? There may be several reasons. First, rejecting cuckoo eggs is always better than rejecting cuckoo chicks, because rejecting a cuckoo egg can save the rest of the clutch. Most hosts can recognise cuckoo eggs at least some of the time, but Superb Fairy-wrens were never able to detect a cuckoo egg—they 'lost' the arms race at the egg stage. Second, Australia's long, glorious summers make deserting cuckoo chicks more profitable for a fairy-wren than for many cuckoo hosts in the northern hemisphere. This is because, if a fairy-wren deserts a cuckoo chick, there is usually plenty of time to rear a new brood. Many hosts in the northern hemisphere have such a short season in which to breed that, even if they detected a cuckoo chick in their nest, they still wouldn't have time to re-nest and rear a brood of their own. Perhaps because of these factors, Superb Fairy-wrens are the only hosts studied so far that can recognise impostor chicks in their nests, but in this escalating battle of tactics and counter-tactics, who knows what new strategies may appear in the future? □

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DR NAOMI LANGMORE IS A POSTDOCTORAL RESEARCHER AT THE SCHOOL OF BOTANY AND ZOOLOGY, AUSTRALIAN NATIONAL UNIVERSITY, WHERE SHE CONTINUES TO STUDY AUSTRALIAN CUCKOOS.

ROB DRUMMOND

Horsfield's Bronze-Cuckoo

Chrysococcyx basalis

Classification
Family Cuculidae (cuckoos), subfamily Cuculinae (Old World parasitic cuckoos).

Identification
Small, sparrow-sized cuckoo, 15–17 cm long, 23 g. Pale brown above with glossy green sheen; off-white below with incomplete dark barring; prominent white eyebrow. Call is a clear, descending 'tseeuw'. Cuckoo chicks can be distinguished from host chicks by having 2 forward-pointing and 2 rear-pointing toes (hosts have 3 toes pointing forwards and 1 back), and by their prominent, rounded nostrils.

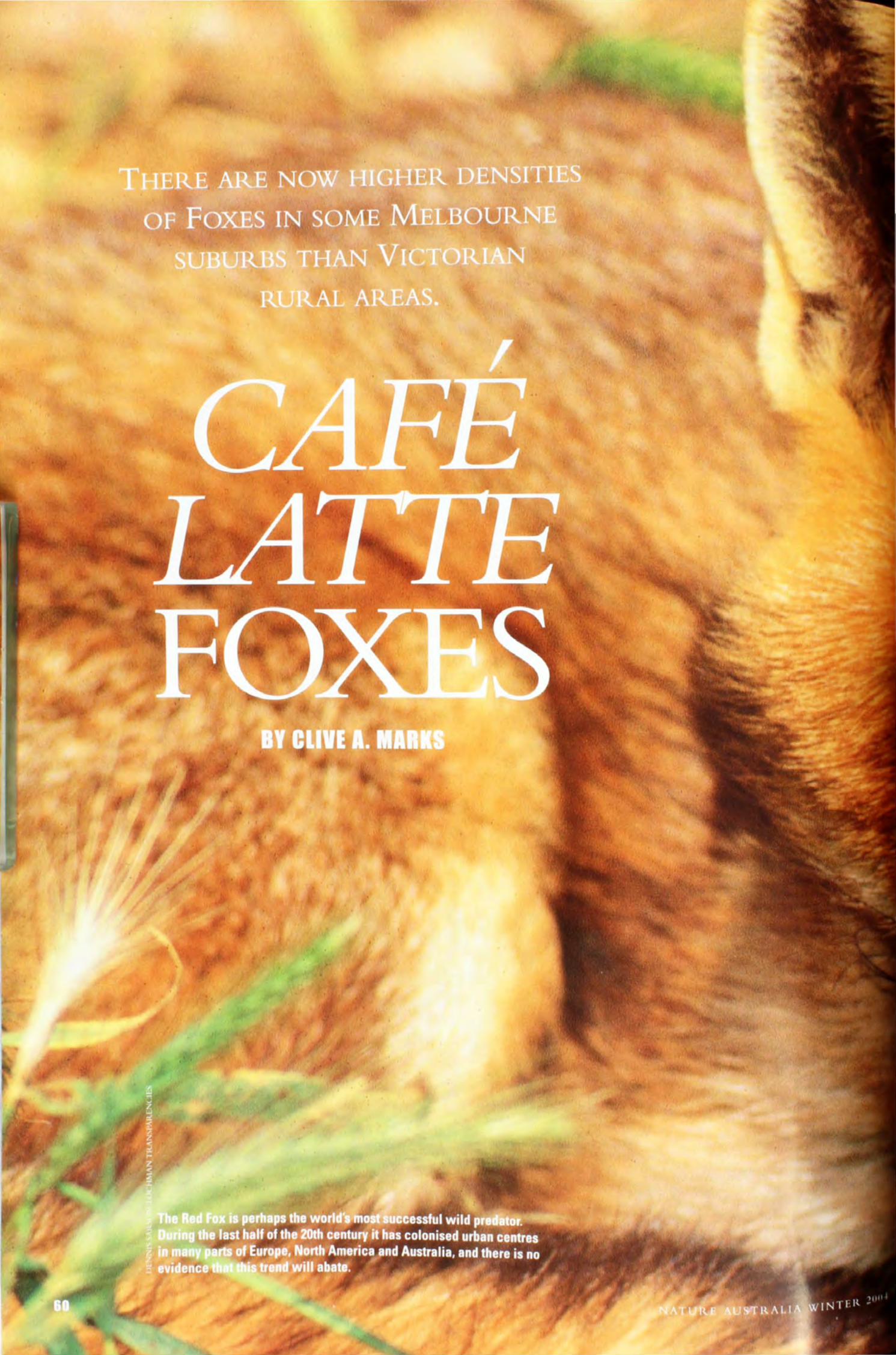
Distribution and Habitat
Throughout Aust. in a wide range of habitats including woodlands, mallee, mulga, saltbush, saltmarsh, mangroves, roadsides and golf courses.

Biology
Resident in northern Aust.; migrant to southern Aust. where it breeds June to March. Parasitises nests of fairy-wrens, thornbills, robins, chats and whitefaces.

THERE ARE NOW HIGHER DENSITIES OF FOXES IN SOME MELBOURNE SUBURBS THAN VICTORIAN RURAL AREAS.

CAFÉ LATTE FOXES

BY CLIVE A. MARKS



DENNIS SAUNDERS/LEICHMANN TRANSPARENCIES

The Red Fox is perhaps the world's most successful wild predator. During the last half of the 20th century it has colonised urban centres in many parts of Europe, North America and Australia, and there is no evidence that this trend will abate.

IF YOU ARE A LATE-NIGHT TAXI driver, police officer on the graveyard shift, or an insomniac prone to wanderings around 3.00 am, you are probably well aware that Melbourne is full of Foxes. As Foxes busy themselves with nocturnal escapades, they pass within metres of slumbering Melbournians, many of whom are oblivious to their presence. There are now higher densities of Foxes in some Melbourne suburbs than Victorian rural areas. They are also common in Perth, Adelaide, Sydney and Brisbane; in Canberra they have been sighted almost on the steps of Parliament House. Darwin remains the only mainland capital free of Foxes and it may be that the absence of Rabbits in the Top End deprives them of a major food resource, but the exact reasons await discovery. Australian cities are not unique in playing host to Foxes, as they are also now present in many European and North American cities in an on-going colonisation process that began in the middle of last century.

AS FOXES *busy themselves with nocturnal escapades, they pass within metres of slumbering Melbournians.*

The first reliable sighting of a Fox (*Vulpes vulpes*) in central downtown Melbourne was in 1943, but they were present in the bayside suburb of Ormond by the 1930s. Perhaps this is not surprising, since one of the two major releases of Foxes generally accredited with their successful establishment in Australia occurred in the western district, not far from Melbourne, in the 1870s. The expansion of Melbourne's suburbs, particularly after World War 2, probably isolated Foxes in rural patches, which became surrounded by urban development. From suitable islands of parkland, Foxes gradually explored and colonised more challenging habitats. But, in at least one case, a Fox reached the city by assisted passage. In the 1950s, one was released into the Royal Botanic Gardens in an attempt to control Rabbits that were munching their way through lawns and valuable plants. Other urban legends tell of Fox stowaways travelling on train carriages from country areas, yet the extent to which humans assisted Foxes in their colonisation of Melbourne may never fully be known.

I first started to study Melbourne's Fox population with my colleague Tim Bloomfield (Victorian Department of Primary Industries) in the early 1990s. Our aim was to find out just how extensive Melbourne's Fox population was. Geneticist Nick Robinson (also at the Victorian Department of Primary Industries) collaborated on a key study into whether city populations had the potential to become disease reservoirs. Overseas, Foxes are implicated in the spread of rabies. Plans to quickly eradicate this disease should it ever be introduced into Australia depend upon a good knowledge of the ecology and social structure of Foxes.

Our recent genetic studies have shown that Melbourne's Foxes are class conscious. There is evidence that Foxes still prefer to cling to islands of open space within the city. But rarely will a Camberwell Fox, for example, mix it with one from central Melbourne, nor will individuals from either population exchange genes with Foxes from Port Melbourne. The distinctive genetic composition of Foxes from our study sites adds weight to the probability that our present-day Fox population sprang from a number of small, colonised islands in the urban area. The Melbourne Fox population can probably be thought of as distinct islands within a sea of suburbia, which is good news as such a distribution is less likely to promote contact between subpopulations and thus the spread of disease. However it may only be a matter of time before Foxes learn to adapt to ever more urban environments. While sightings of Foxes in the CBD's Lonsdale and Spring Streets are comparatively rare today, they may become commonplace within the next decade.

FOR SUCH AN ELUSIVE AND CRYPTIC species as the Fox, finding suitable shelter in the city is a major challenge. There are two main types of shelter that Foxes require. A breeding den, which is established from June each year, is where cubs are born and raised in a shelter that is almost always formed

In the suburbs of Melbourne there are Foxes moving beneath your feet. Stormwater drains form a convenient network that allows them to avoid running the gauntlet across busy roads.

from a burrow dug into the ground. Disused house blocks, cemeteries, industrial land, the banks of urban creeks, or large parks are common places where dens are found. Most are situated beneath buildings, particularly if they are unoccupied. For the rest of the year, adult Foxes use a number of aboveground sites that are often covered by impenetrable exotic weeds. Some even shelter beneath ornamental hedges and trees that provide dense leaf cover. One radio-collared Fox was found five metres up a cypress, giving new meaning to high-rise living!

Foxes usually avoid human contact, but they are best treated with respect if they do come close as they can inflict a painful bite. One early-morning jogger had a rare encounter with a young Fox along the inner-city jogging track adjacent to Albert Park Lake. It ran at his heals for several consecutive mornings, but surprised him one day by shooting out from the shadows and biting him on the leg. The following day the Fox was dissuaded with blows from a recently purchased copy of *The Age*! The only other recorded case of an unprovoked attack in the inner city has a similarly comic flavour. A Fisherman's Bend security guard ventured into an unlit toilet block, unaware that it was occupied by a Fox. Unwittingly he cornered the animal against the urinal and sustained a nasty bite that could have been very difficult to explain! These encoun-

JEAN-PAUL FERRERO AUSCAPE

Fox

Vulpes vulpes

Classification
Family Canidae

Distribution
Native to UK, Europe, North Africa, Indo-China, Russia and North America. First introduced to Aust. in the 1850s, where it is now common in both rural and urban areas, including Melbourne, Perth, Adelaide, Canberra, Sydney and Brisbane.

Biology
Breeds once a year and produces 3–6 cubs from late winter to mid spring. Lives in social groups, often composed of related animals from previous generations. A dominant pair will breed each year, yet other subordinate females may also become pregnant, especially when there is an excess of food and shelter.

Diet
Varied. In cities, includes Common Brushtail Possums, insects, rubbish and pet food.

Foxes use a wide range of daytime shelter sites and are quite adaptable to various city environments. At Webb Dock, rockfill within the breakwater makes a convenient location, although dense vegetation is also highly favoured.

ters though are the exception to the rule, as Foxes are almost always timid and unwilling to become acquainted with people.

Domestic Fowl, Rabbits, Guinea Pigs and other small pets are at risk, especially if left to roam freely in the backyard at night. The frequency and location of attacks are difficult to predict, and some people may keep animals for many years without incident. When attacks do occur the effects may be devastating as Foxes can systematically kill every animal in a concentrated population; typically each chicken in a pen will be killed or injured in a frenzied attack. This behaviour is known as 'surplus killing' and is a well-recognised behaviour of Foxes and some members of the dog family. There appears to be an increase in the frequency of attacks

on Domestic Fowl from September to December each year, which corresponds with the Fox-breeding season and their attempts to obtain suitably large food items for cubs in the dens. It is imperative during this time that Domestic Fowl or other susceptible animals are kept safely penned at night.

While Foxes tend also to avoid Dogs, injuries to small breeds have been recorded and seem to be most common when the Dog ventures inside or close to a breeding den. Larger breeds are less at risk as they are quite capable of killing adult Foxes if encountered. Radio-tracking studies in some Balwyn parks also suggest that Foxes and Cats generally ignore each other, tending to treat each other with aloof disdain. On very rare occasions, Foxes have been known to kill kittens but if Cat does appear on the urban Fox menu, it is almost always opportunistically scavenged after the Cat has been killed by a motor vehicle.

STUDIES SUGGEST *that Foxes and Cats generally ignore each other, tending to treat each other with aloof disdain.*

In some areas of Melbourne, particularly the eastern suburbs, Foxes regularly kill adult Common Brushtail Possums (*Trichosurus vulpecula*). However, their diet is diverse and very opportunistic. Some Foxes are adept scavengers of left-over pet food in backyards. Frequently, Foxes can be seen foraging for large invertebrates on lawns. For many months, one Fox persisted in digging holes in the crochet lawn at Gove ment House in Melbourne, much the displeasure of the grounds st Urban areas offer a smorgasbord of fo opportunities for Foxes, and they m well have as much choice in cuisine the human inhabitants of Melbourne.

While rabies has never been intro duced into Australia, Foxes can carry a range of other diseases and parasites. Approximately eight per cent of Foxes within the urban area are infected with heartworm, which is not surprising since the parasite is commonly found in Dogs (pet and wild), particularly in northern Australia. The disease is passed from infected animals by a number of mosquito species, at least two of which are present in Melbourne. The most significant aspect of this finding is that the disease exists in a wild animal living in the city where it is not easily managed. Rather than being a cause for undue alarm, this observation reinforces

ROBIN SMITH

Any widespread control effort aimed at eradicating Foxes in urban Melbourne is doomed to fail as the population is vast and our current iques are relatively inefficient.

the need for Dog owners to follow existing advice from veterinarians concerning heartworm treatment for their pets.

MANY PEOPLE ARE SURPRISED TO learn that there is no active campaign to eradicate Foxes from Melbourne, even though there are extensive efforts to control them in rural areas. Realistically, given the limitations of current Fox-control methods, we have neither the techniques nor resources to do this—even if it were warranted (see "Out-foxing the Fox", *Nature Aust.* Winter 1996). Poison baiting, shooting or even widespread trapping is discouraged in the city, given the risk to humans and pets. Furthermore, there is little point in attempting to control a pest species without a clear goal or benefit. The population of Foxes in Melbourne is now so extensive that small areas where Foxes are controlled are soon repopulated, indicating that any control effort must be sustained indefinitely.

RESIDENTS OF CITIES *must acknowledge that they are sharing common space with an animal that will continue to adapt, respond and surprise.*

There are only a few examples in the metropolitan area where Foxes need to be controlled to conserve wildlife. The Little Penguin (*Eudyptula minor*) colony on the St Kilda breakwater (see "Urban Penguins", *Nature Aust.* Winter 1996) could well be highly susceptible to predation from urban Foxes. But the bulk of problems that Foxes cause in Melbourne are nuisance activities. Even so, a den beneath your floorboards together with a collection of malodorous possum carcasses is an unpleasant burden to live with! They also dig inconvenient holes in lawns and golf courses, and sometimes bark obsessively at night—the cause of more than one neighbour's Dog being unfairly demonised. Equally, some parents have even found that hiding chocolate Easter eggs in the garden the evening before the traditional hunt is a good way to disappoint their children—and feed their resident Foxes (foil and all!). However, the response to these problems needs to be appropriate and measured, and large-scale control is unlikely to significantly address them.

FOXES IN TASMANIA

The malicious and premeditated introduction of up to 19 European Foxes into Tasmania in 2000 must rate as one of Australia's worst ecological disasters. Charges against the perpetrators are unlikely to be laid, due to the six-month statute of limitations on wildlife offences in Tasmania at the time. This situation not only intensifies the mystery and futility surrounding the introduction, but also creates a further conundrum where many Tasmanians refuse to believe Foxes remain on the Apple Isle, some even claiming the whole thing was a hoax.

Foxes have left limited irrefutable evidence of their existence since their introduction, principally due to their low numbers and wide distribution—this is to be expected. The best evidence so far is a young, sexually immature female Fox found on the Bass Highway in Burnie. The animal was dead but still bleeding when discovered, and x-rays confirm it had been hit by a vehicle. Other evidence includes Fox grooming hair in a scat and Fox footprints, both independently confirmed by mainland experts, together with the shooting of an adult male Fox about 20 kilometres south of Launceston. Although doubt surrounds other reported shootings, the stomach of this shot Fox contained the partly digested remains of the Tasmanian endemic Long-tailed Mouse (Pseudomys higginsi), evidence that would be particularly hard to forge. Reported sightings are now common (over 600) and, although varying in quality, 20 are outstanding both in detail and the credibility of witnesses.

Innovative science will be the key to confirming the existence and distribution of Foxes in Tasmania. Carnivore scats collected by the Fox Free Taskforce and by the public are currently being analysed genetically at the University of Canberra. The recently perfected rapid-screening technique can accurately distinguish Fox scats from other species even when they are up to 12 weeks old. This will provide indisputable evidence of the presence of Foxes. To fully capitalise on this technology a Statewide predator scat hunt is necessary.

There is no reason to suspect that the impact of Foxes in Tasmania will be anything less than catastrophic. To have any chance of eradicating Foxes from the State before they establish, all Tasmanians must actively contribute to collecting and reporting Fox evidence. Only a high level of political and community commitment will ensure that Tasmania may once again become Fox-free.

—STEVEN LAPIDGE (PEST ANIMAL CONTROL COOPERATIVE RESEARCH CENTRE, CANBERRA) & OLIVER BERRY (UNIVERSITY OF CANBERRA)

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Inner Melbourne has an extensive belt of parkland and DNA studies have shown that some groups of Foxes appear to cling to these.

The removal of exotic weeds is probably the most promising way to reduce Fox abundance in some urban environments, as this deprives them of favoured daytime shelter sites. Ensuring also that your pet-food bowl and bird-feeding tables are not acting as a smorgasbord for resident Foxes will further discourage them from visiting your backyard.

The human residents of Australian cities must acknowledge that they are sharing common space with an animal that will continue to adapt, respond and surprise. The Fox is as much a misplaced animal in the city as it is in rural Australia. A fleeting glimpse of a Fox traversing a city street may produce a momentary thrill for some; we may even admire its tenacity. But such a sighting could also remind city dwellers of the ongoing battle to protect many of our endemic animals from extinction, a process begun or compounded as soon as we helped the Fox to reach our shores.

Unfortunately, humans still continue to aid and abet the spread of Foxes in Australia. In 1998 one Melbourne Fox travelled to the Tasmanian city of Burnie upon a cargo vessel that had berthed at the Webb Dock container-terminal in the mouth of the Yarra River. Until then Tasmania was Fox-free, which is one of the main reasons that the State has remained the last stronghold of many Australian native species. Whether this particular Fox was a stowaway or an unwilling recruit remains a mystery. Tragically, only a few years later, in Australia's most depressing case of environmental vandalism, it is believed that up to 19 Foxes were intentionally introduced to Tasmania in a premeditated and well-organised action (see box). We await to see if they will become established. To the Australian biologist, the Fox's colonisation of the city is a depressing demonstration of its legendary adaptability and resilience—and a monument to the folly of human beings. □

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CLIVE A. MARKS WAS THE FORMER DEPARTMENT HEAD OF VERTEBRATE PEST RESEARCH AT THE VICTORIAN INSTITUTE OF ANIMAL SCIENCE. HE IS NOW DIRECTOR OF NOCTURNAL WILDLIFE RESEARCH PTY LTD AND A MEMBER OF THE ANIMAL WELFARE SCIENCE CENTRE IN MELBOURNE. HIS COMPANY IS DIRECTED TO INNOVATION AND EDUCATION IN VERTEBRATE PEST MANAGEMENT.

A juvenile praying mantis (*Hierodula patellifera*) posing on bracken fern.

A pair of Brown Honeyeaters (*Lichmera indistincta*) snoozing under the canopy of a Marri tree (*Eucalyptus calophylla*).

A moth (Geometridae) perches on the tip of a fern frond.

night moves

BY CHRIS SURMAN

A gecko (*Christinus* sp.) hunting among the spines of Prickly Moses (*Acacia pulchella*).

A large red bulldog ant (Myrmeciinae) on a Marri flower.

A female grasshopper (Catantopinae) caught napping on a Marri.

Tales from the crypt

For burying beetles, a hidden, preserved, hairless corpse is the perfect nursery.

A burying beetle (*Nicrophorus orbicollis*) feeds its begging larvae with regurgitated fluid.

In New Zealand's Canterbury Museum basement, in an old wooden cabinet with glass-topped drawers, are six very ordinary-looking orange and black beetles that were collected in England in 1898. Commonly called burying beetles (genus *Nicrophorus*, family Silphidae), they are found throughout the northern hemisphere, and live mainly in temperate and alpine habitats. Their lives are far from ordinary and feature murder and dismemberment, infanticide and cannibalism. There's even necrophagy and bizarre sex scenes with embalmed bodies. And most of it takes place in an underground burial crypt, where the offspring are raised in a nest on a corpse. The story starts with a mouse running across the English countryside.

In a moment of time, the heart of that mouse stops beating and the animal dies. When the odour of decay spreads the news of its death, flies and the beetle equivalent of gravediggers respond by winging their way to the corpse. So much of the lives of burying beetles is tied up with finding and guarding the body of a small dead mammal or bird. They are strong flyers and have powerful legs for moving the corpse and digging—so powerful that a 0.5-gram beetle can move a 100-gram carcass. Even the female's ovaries do not develop until she finds a body and a mate, since carrying developed ovaries would only increase the payload the wings have to travel around with.

BY SIMON D. POLLARD

While flies lay eggs on the body of the mouse, the male gravediggers start fighting each other, often biting off each other's legs and antennae, while a female stands by. The largest male is the winner, and soon he and the female are alone with the body. They move underneath the carcass and begin digging a grave into the soil below where the mouse has collapsed.

Once the mouse is buried, the beetle gravediggers become beetle embalmers. They remove the mouse's hair and walk round and round the corpse, covering the body with secretions that slow down decomposition. They roll it into a ball, clearing the soil directly around the corpse, effectively creating a burial chamber or crypt. For burying beetles, a hidden, preserved, hairless corpse is the perfect nursery so, in between bouts of drooling over the deceased, the beetles mate. The female then lays eggs in the soil nearby and, after the eggs hatch, the larvae crawl towards the parents, which sit expectantly in a scooped-out 'nest' on top of the corpse.

Both parents initially feed the offspring with regurgitated fluid they have taken from the embalmed body. In what to many will be a grotesque version of bird chicks begging to a parent for food, the beetle larvae wave their bodies around in the 'nest', trying to get one of the beetle parents to regurgitate liquid into their mouths. The larvae even try to climb up the forelegs of the parents to get closer to the source of food. If there are too many mouths to feed, the parents kill some of their offspring to give the rest a better chance of survival. The number of eggs a female lays is related to the weight of the corpse she and her partner have interred. Apparently, when the female moves under the body in preparation for burying it, she can estimate its weight. It is a better strategy to lay more eggs than the corpse can support and practise infanticide, than lay fewer eggs and waste corpse tissue that could be turned into larvae.

Even after the carcass is buried, this valuable resource can be discovered by other burying beetles intent on driving off one of the resident beetles and killing

PHOTOS: STEPHEN TRUMBO

Burying beetles' lives are far from ordinary and feature murder, dismemberment, infanticide and cannibalism.

all the offspring. If male, a successful rival will mate with the female, which may then lay a new batch of eggs; if female, she will start her own brood with the resident male as father. However, during the course of breeding, the resident beetles' hormones and odours change so that they acquire a "breeder's badge". Non-breeding rivals do not carry this badge and are quickly recognised for what they are and attacked by both residents. Often the rivals end up dismembered, cannibalised by the parents and regurgitated to the offspring. Although it is very unusual for insect males to help rear offspring, the male's chances of getting his genes into the next generation are more likely if he stays around to defend the valuable yet necrotic resource.

As they grow older, the larvae develop mouthparts of their own, they feed directly off the mouse's body and the parents leave the crypt. Once the body is completely eaten, the larvae pupate, before emerging as adults and flying away in search of fresh death. Sometimes, though, they leave with helpful hitchhikers.

The beetle larvae often have to compete with the offspring of flies that lay eggs on the body before it is buried. However, in the unsavoury world of maggot wars, the beetles have a secret weapon, which travels with them from corpse to corpse. It's an army of small mites that fly beetle airlines, and disembark on the body the beetle flies to. The mites eat the fly eggs, but not those of the beetles. When the beetle larvae become adults and leave the crypt, the mites hitch a ride on the new generation and take off to corpses unknown. □

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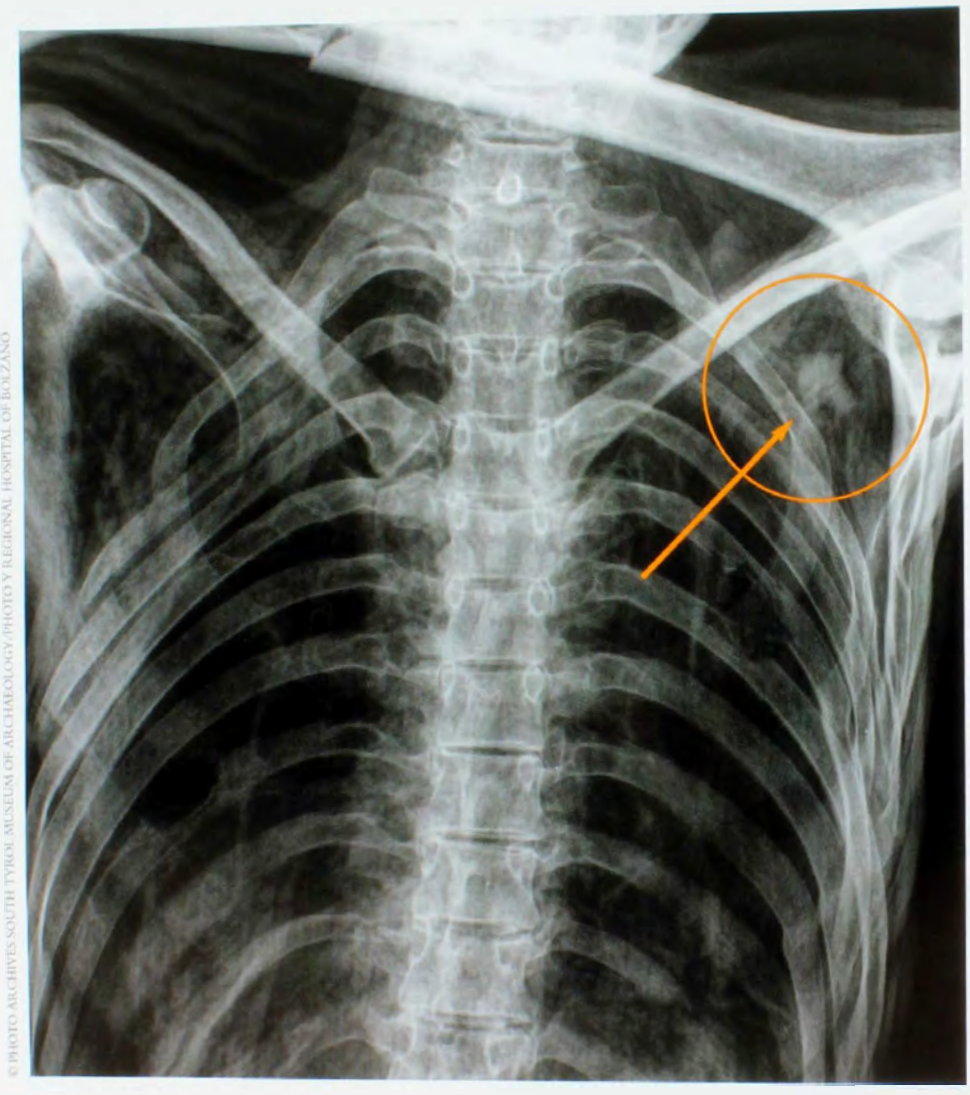
DR SIMON D. POLLARD IS CURATOR OF INVERTEBRATE ZOOLOGY AT CANTERBURY MUSEUM, AND SENIOR FELLOW IN THE SCHOOL OF BIOLOGICAL SCIENCES AT THE UNIVERSITY OF CANTERBURY, IN CHRISTCHURCH, NEW ZEALAND.

Ötzi spills his guts

Ötzi is one of the greatest archaeological discoveries of the 20th century.



X-ray of Ötzi's torso, taken from the front, showing the embedded arrowhead above his second left rib.

On Thursday 19 September 1991, a couple of mountain climbers (Erika and Helmut Simon) headed back to their base at the Similaun refuge in the Ötztal Alps (South Tyrol Province, near the Austrian–Italian border). They noticed what they thought was some litter on the ice, sadly common in these remote locations. But when they got closer they could see it was a person. Another mountaineering accident, they assumed.

Variously called the Glacier Mummy, Tyrolean Iceman, Similaun Man and Ötzi, the discovery is still making archaeological history. First impressions were indeed mistaken, and we now know that Ötzi (rhymes with 'curtsy') was not a recent mortality but had died about 5,300 years ago. Nor was Ötzi actually found in Austria, as first thought, but just inside the Italian border. This resulted in the body being moved in 1998 from Austria's Innsbruck University, where Konrad Spindler led the initial archaeological research, to the South Tyrol Archaeological Museum in Bolzano, Italy. However, by that time, researchers thought they had pretty much worked out the basic facts, as they understood the situation.

The facts seemed clear: Ötzi was definitely a he (with intact genitals), in his mid 40s, and with broken ribs. Perhaps he died of exposure. But what was Ötzi doing in the high alpine pass? His woven grass cloak, shoes and bearskin hat indicated he might have been a shepherd, caught out in bad weather while moving his flock. However, artefacts found near his body—a bow, a quiver of arrows, a copper axe, a fire-making kit, a backpack and a flint dagger—suggested he may have been a hunter or even a warrior (see "Ice Man", *Nature Aust.* Spring 1998).

For the first nine years after his discovery, Ötzi was kept in cold storage matching the glacial conditions of his alpine resting place. Then in 2000 full defrosting allowed a detailed analysis of his last meals, which could be tracked at various stages down the colon. DNA extracted from gut samples showed that Ötzi last sat down to some Red Deer and cereal, which followed an earlier feast on Ibex and various plant foods. Exquisite preservation of pollen in his gut also pinpointed the time of his death to late spring–early summer, and put his homeland to the south of where he was found.

A particularly intimate moment is suggested by Ötzi's ingestion of a moss. Moss fragments were also found on his clothing but there is no evidence that humans have ever eaten moss intentionally. Before bubble plastic and toilet paper, mosses served for wrapping, stuffing and wiping—and are common in medieval cesspits. So what was this moss doing in his gut? Perhaps Ötzi had been carefully packing his gear, or lining his underclothes. Or maybe he was in too much of a hurry to wash his hands!

Curious about the broken ribs, Bolzano scientists Paul Gostner and Eduard Egarter Vigl decided to take more x-rays. They discovered that the

BY RICHARD FULLAGAR

fractures were well healed, indicating Ötzi had survived the injuries, but something else caught their attention: a stone arrowhead embedded near the second rib behind the left shoulder. The arrowhead is typical of specialised weapons found in contemporaneous archaeological assemblages. Crime scene investigations and forensic science showed the arrow came from behind and below; in other words, Ötzi had been shot in the back! The wound probably caused massive bleeding, possibly death, but someone else must have removed the arrow shaft, unless Ötzi was a contortionist.

Relying on the principle that stress slows down the progress of food through the gut, which normally travels at a rate of two metres per hour, Franco Rollo and colleagues (University of Camerino, Italy) suggested that Ötzi did not die immediately from the arrow wound but would have suffered greatly.

The latest (unpublished) evidence was released on video footage in October 2003, and is fresh out of the laboratory of Tom Loy (University of Queensland) who has analysed DNA preserved in blood films found on Ötzi's leather tunic, knife blade and one of the two arrows. Loy isolated the DNA fingerprints of four human individuals, at least one of whom was probably responsible for his death. It is possible that one of the DNA profiles belongs to Ötzi, but further research is required. An unhealed stab wound in his right hand suggests he may have put up a fight, and forensic study of blood pooling indicates he was moved before he died. Was he attacked by a gang? Who was with him?

Wolfgang Müller (Australian National University) and colleagues recently compared the isotopic composition of strontium, lead and oxygen in Ötzi's teeth and bones with that of local soils and waters, which enabled them to pinpoint his exact location at various stages of his life. The geochemical pattern of his teeth (laid down when he would have been just 3–5 years old) is most compatible with that of the Eiseck Valley, about 60 kilometres south-east of where he died. Similarly, tiny fragments of mica (from seed-grinding stones) found in his gut came from Vinschgau, about 50 kilometres west of his likely birth place. Clearly Ötzi had travelled widely and could have secured alliances at distant places...and also enemies.

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Painstaking studies of Ötzi have revealed many of his secrets, but we may never know the full story of his death.

Ötzi is one of the greatest archaeological discoveries of the 20th century, in part because his preservation is about as good as it gets. Here is a case where a variety of archaeological, forensic, genetic and other molecular techniques can be pushed to the limit. But well-preserved mummies are found in the Peruvian Andes, the Egyptian pyramids, the bogs of Western Europe and other places around the world. What makes Ötzi so special? His antiquity is part of it; he was buried for longer than any of the others. And the fact that his belongings were not arranged artificially (as in a ritualised burial) provides us with a unique glimpse into everyday Neolithic life. But the mystery surrounding his death adds an extra dimension and, if he was murdered, why wasn't he robbed of his valuable tools?

Everybody loves a good murder mystery, especially when it's at a safe distance, and Ötzi does have all the elements of an unsolved homicide. Even with continuing investigations, we may never know the true story of what happened in that remote alpine pass. □

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DR RICHARD FULLAGAR IS A SENIOR RESEARCH FELLOW IN ARCHAEOLOGY AT THE UNIVERSITY OF SYDNEY. HE IS PARTICULARLY INTERESTED IN ARCHAEOLOGICAL INDICATORS OF HUMAN BEHAVIOUR.

The red sea

If evolution had tracked a little differently, the land might be covered in red plants.

HAVE YOU NOTICED THAT, while most land plants are green, there is a preponderance of ruddy plant relatives in the sea? The red and brown seaweeds are the most obvious examples, but there are many more 'red' representatives in the microscopic plankton. If evolution had tracked a little differently, the land might be covered in red plants, with green plants an interesting oddity. Just think, we'd have Reds fighting for the environment (and I presume Greens for communism), books such as *How red is my valley*, and so on.

I must admit the whole concept seems less bizarre after my recent visit to the east coast of New Caledonia where the gardens are full of vivid-leaved crotons and cordylines. There are of course many reddish garden plants in Australia, such as Sacred Bamboo (*Nandina domestica*), flowering cherries (*Prunus* cultivars) and red-leaved maples (*Acer* cultivars). For temporary red colour there is the new growth of many eucalypts, and the autumn leaves of Liquidambar (*Liquidambar styraciflua*) and Claret Ash (*Fraxinus* 'Raywood'). The red colour in most of these ostensibly green plants is due to a flavonoid called anthocyanin.

As an aside, recent research points to an important role for anthocyanin as an 'antioxidant' in plant leaves, mopping up potentially harmful free radicals (chemicals with unmatched electrons produced by a reaction with oxygen). Anthocyanins also protect leaves from bleaching, by absorbing green wavelengths, which are of no use for photosynthesis. However, plants need light energy for photosynthesis, and anthocyanin reduces the total amount of useful sunlight reaching the light receptors. For this reason, many trees produce anthocyanin only in autumn, apparently to shield the leaves from excess sunlight long enough for the tree to withdraw vital nutrients. Most of the year, nearly all land plants are green.

To find out why, we need to go back a few million years. One of the most important and intriguing developments, in terms of today's diversity, is the origin of the bits and pieces inside cells, the organelles. It is now undisputed that the major organelles (including plastids, the site of photosynthesis in plant and algal cells) have what is called an endosymbiotic origin. This means, as Jeffrey Palmer of Indiana University puts it, that they arose through the engulfing and enslaving of cells by another cell. The engulfed cell lived and reproduced inside the host cell, eventually becoming an organelle. The first captives were bacteria, but eventually the host cells themselves became engulfed by other cells, sometimes twice over (that is, a tertiary level of engulfment).

So why the difference on land and sea, and why are land plants green?

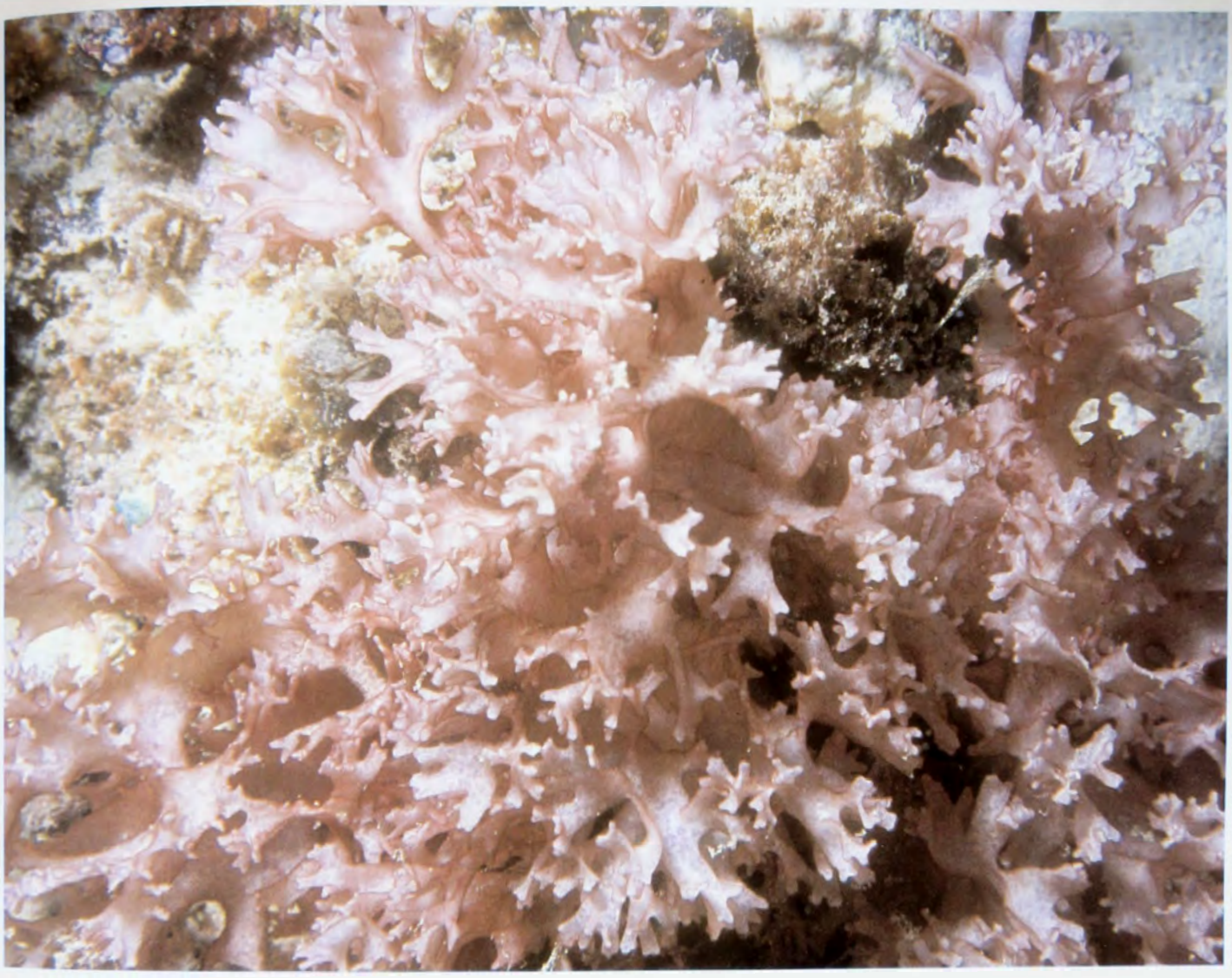
The evidence so far seems to support a single origin for plastids. In other words, we can trace back every plastid in a current-day cell to one photosynthetic bacterium. Within today's 'plants' (the plastid-bearing organisms), we can discriminate two major groups—a green and red lineage. The greens, all members of the kingdom Viridiplantae, include the land plants and the green algae. Except for a couple of groups of microscopic algae, there was only one endosymbiotic event in this green line.

The red line (including red, brown and other variously coloured algae) is much more interesting, and diverse. The 'red algae' themselves (red seaweeds and a few close relatives) resulted from a primary endosymbiotic event, but the rest of the group—a huge array of algae with different life histories, biochemistries and shapes—have plastids that resulted from secondary and tertiary endosymbioses. Here is the real diversity of plant life, the main boughs of an evolutionary tree with the green land plants representing just one minor branch.

The red in red algae is quite different to the anthocyanin found in autumn leaves and New Caledonian gardens. It's an 'accessory' pigment called phycoerythrin, which traps light and transfers the energy to nearby chlorophyll. The other members of the red line draw on a different palette of accessory pigments, and end up as various shades of yellow or brown. The microscopic and somewhat tortuously named haptophytes, cryptophytes and raphidophytes, along with the diatoms and brown seaweeds, dominate the sea now in the way green plants have ruled the land for at least the last 400 million years. So why the difference on land and sea, and why are land plants green?

The success of a plastid, in a world created by endosymbiosis, comes down to how well it can support and reproduce itself. The 'portable plastid hypothesis' states that the likelihood of a plastid being enslaved should increase with the amount of genetic material it contains and therefore its independence. Consistent with this theory, the plastids in the red line have a large genotype and

BY TIM ENTWISLE



ALAN MILLER, ROYAL BOTANIC GARDENS

The red pigment in red seaweed is very different from that found in autumn leaves.

retain greater self-sufficiency in important cell processes such as photosynthesis. Consequently, endosymbiotic events were more common in the red line, with twice as many secondary engulfings compared to the green line. As the aquatic environment changed dramatically at the end of the Permian (some 250 million years ago), the reds were more likely to be 'engulfed and enslaved' by organisms that were under great pressure to become self-sufficient (for example, by photosynthesising). At least that's the current theory.

Inconsistent with this and other hypotheses, however, is the actual rarity of red algae in today's ocean phytoplankton. To understand this you need to ask what it is that the engulfing cell brought to the symbiotic relationship. In most cases it was protection—protection from a vast array of hungry grazers. The red evolutionary line is full of silica shells and scales, calcareous coatings and cellulose walls, all missing from the primary endosymbionts, the red algae. In freshwater lakes and pools, where there are fewer grazers, the armourless greens (but interestingly few red algae) dominate the phytoplankton. From such habitats the green line could expand onto dry ground, perhaps retreating at first to swampy refugia to reproduce.

Apart from a few exceptions such as a red alga that grows on top of soil, the red line never colonised the land. A key innovation in the green line, multicellular growth, is absent from most of the red line except for the red and brown seaweeds. The other members of the red line are single cells that don't form tissue of any kind. It was the development of multicellular growth that gave the greens the edge on land, while at sea, the ability to be a self-reliant guest and to form expedient partnerships with armoured cells, seems to have been the secret to evolutionary success for the red line. Maybe if the grazing in early swamps was a little more intense, we wouldn't have to leave Earth to discover the red planet. □

FURTHER READING

Grzebyk, D., Schofield, O., Vetriani, C. & Falkowski, P.G., 2003. The Mesozoic radiation of eukaryotic algae: the portable plastid hypothesis. J. Phycol. *39: 259–267.*

Palmer, J.D., 2003. The symbiotic birth and spread of plastids: how many times and whodunit? J. Phycol. *39: 4–11.*

Gould, K.S. & Lee, D.W. (eds), 2002. Anthocyanins in leaves. Adv. Bot. Res. *37: 1–222.*

DR TIM ENTWISLE IS EXECUTIVE DIRECTOR OF THE BOTANIC GARDENS TRUST, SYDNEY.

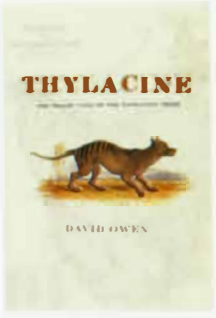
reviews

Eagles, Hawks & Falcons of Australia

By David Hollands. 2nd edition. Bloomings Books, Melbourne, 2003, 212 pp. $49.94 rrp.

AUTHOR/PHOTOGRAPHER DAVID HOLLANDS HAS PRODUCED SEVERAL ATTRACTIVELY illustrated books on Australian birds. *Eagles, hawks & falcons of Australia* is a welcome re-issue of what is probably his best-known book. First published in 1985, it won the Whitley Award for Best Illustrated Australian Natural History Book for that year. The new edition has been revised and expanded, without compromising those features that made the original outstanding. The heart of the book remains the species accounts and photographs. Hollands is an engaging writer, and the text is based on his personal experiences with the birds-of-prey he has followed and photographed in the field. These accounts have been expanded in the new edition. The photographs are the highlight of the book and a tribute to his skill. Here, too, more have been added. There is a new section—a field guide—that augments Hollands's personal accounts with more technical information on each species. The production values of the book are high, appropriate for the quality of the content. This book is a nice addition to the library of anyone interested in birds or natural history.

—WALTER E. BOLES
AUSTRALIAN MUSEUM

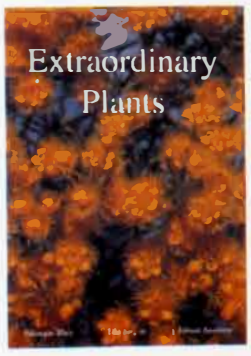


Thylacine

By David Owen. Allen & Unwin, NSW, 2003, 228 pp. $29.95 rrp.

THE BEAUTIFULLY WRITTEN BOOK DETAILS THE STORY OF THE THYLACINE, OR TASMANIAN Tiger, from first contact with early Tasmanian settlers to the death of the last captive Thylacine. Author David Owen, better known for his fiction (with many of his novels set in Tasmania), perfectly captures the sense of tragedy and mystery evoked by this doomed, magnificent carnivore. Owen has carefully researched his subject, reading voluminous records, testaments and diaries, and talking at length to researchers, wildlife officers and museum authorities. I found the first-hand accounts of encounters with Thylacines especially illuminating and thought-provoking. Tasmanian history, its environment and its ongoing conservation battles are all woven together expertly to put the Thylacine story into context. Owen details the efforts of the Tasmanian Sheep industry to demonise the Thylacine in order to divert attention from the poor performance of an industry ill-suited to the harsh conditions of the island State. Owen also describes the many attempts made since the 1930s to find a living Thylacine, and controversial efforts by the Australian Museum to attempt cloning of the Thylacine. Owen's small book is a gem—required reading for anyone interested in Australian natural history and the perfect companion to take with you on your next trip to Tasmania.

—ANNE MUSSER
AUSTRALIAN MUSEUM



Extraordinary Plants

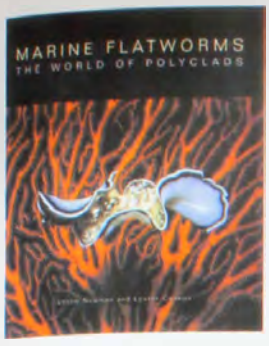
By Palenque Blai, Tiki Swain and Damon Annison. University of Western Australia, Gravity Discovery Centre Foundation Inc., 2003, 106 pp. $16 rrp.

WHAT THE TITLE DOESN'T SAY IS THAT THIS BOOK PORTRAYS 60 OR SO WILDFLOWERS, A fungus or two, and even a few insects, from the Gingin area just north of Perth. What it does tell you, quite truthfully, is that these 'plants' are indeed extraordinary.

Although this is a mere taster for the rich and bizarre flora of Western Australia, the combined talents of botanist (Blair), journalist (Swain) and photographer (Annison) result in a great book. It is sharply written, and packed full of fascinating facts and gorgeous pictures. I particularly like the easy mix of stories from Aboriginal, European and evolutionary history that interlace a wealth of biological information. Did you know, for example, that the young tips of the Biara, or Candlestick Banksia, were used by the Nyungar people as a chewing gum, while the early European settlers soaked the nectar-rich flowers in water to make a sweet drink?

Refreshingly, the authors don't bother with padding: some subjects get a paragraph, others a whole page. You can't help but be inspired and informed by this unpretentious little publication.

—TIM ENTWISLE
BOTANIC GARDENS TRUST, SYDNEY

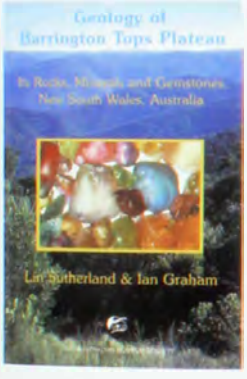


Marine Flatworms: The World of Polyclads

By Leslie Newman and Lester Cannon. CSIRO Publishing, Vic., 2003, 112 pp. $39.95 rrp.

Leslie Newman and Lester Cannon provide a fine introduction to the world of marine polyclad flatworms. Few have heard of, let alone seen, a flatworm, yet they live in virtually every marine habitat. A quick flick through this profusely illustrated book will show that their colours can rival even the best orchids. But this is not a mere picture book. Everything from feeding to mating, mimicry, toxins, anatomy and classification is covered. The more serious reader will appreciate the reference list, glossary, and the many identified species shown. The authors certainly know their subject, but are fully aware that there is still much to learn. Hence a full chapter devoted to the specialised collecting, handling and preservation techniques necessary to study flatworms. Finally, the title *Marine flatworms* is somewhat deceptive, as we're also given a detailed yet compact outline of the other major marine worm-like groups. *Marine flatworms* is a must-have book. It is one of those rare works that are informative, enjoyable and useful at both a general and technical level, for the specialist and non-specialist alike.

—Shane Ahyong
Australian Museum



Geology of Barrington Tops Plateau: Its Rocks, Minerals and Gemstones, New South Wales, Australia

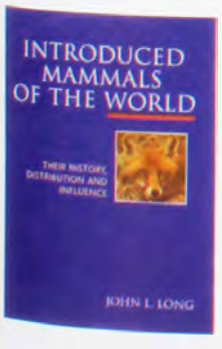
By Lin Sutherland and Ian Graham. The Australian Museum Society, Sydney, 2003, 56 pp. $15 rrp.

The Barrington Tops Plateau in eastern New South Wales is noted for its spectacular scenery and lush forests. It is also the site of an ancient volcano and contains the largest deposits of highest-quality rubies yet found in Australia.

While much has been written about the fauna and flora of the region, this book tells a less familiar story—that of the rocks that underlie the rugged scenery. The plateau lies within an area known as the Tamworth Belt and it contains rocks up to 360 million years old. One of its prominent features is the Barrington Volcano, which sporadically erupted over about eight million years during the Tertiary (starting 65 million years ago).

The authors present a comprehensive, beautifully illustrated review of the geological history of the area and the different rock suites it contains. This is followed by a detailed discussion of the evolution of the Barrington Volcano and its associated gem deposits of ruby, sapphire and zircon. A comprehensive glossary of geological terms is also included.

—Brenda J. Franklin



Introduced Mammals of the World: Their History, Distribution and Influence

By John L. Long. CSIRO Publishing, Collingwood, Vic., 2003, 589 pp. $135.00 rrp.

This book was a great labour of love, the author beginning it in 1969 and working on it up to his unfortunate death from cancer in 2000. It aims to document every mammal species ever introduced anywhere in the world, either accidentally or deliberately, and whether successfully or not, beginning in prehistoric times. The author has produced an invaluable work of reference, fully referenced, but his goal was so ambitious that various introductions were inevitably overlooked. No mention is made, for example, of all the marsupials introduced into Wilsons Promontory in the 1910s and '20s, or of Irian Jaya's feral Crab-eating Macaques (monkeys). Long has incorporated conservation reintroductions, including endangered marsupials returned to their former haunts, although these are not usually

considered 'introduced mammals'. Their inclusion makes it difficult for the reader to form an overall impression of the scale of exotic introductions, although it is clearly vast. Bizarre examples include elephants in the Andamans, rock-wallabies in Hawaii and porcupines in Europe.

—Tim Low

A Complete Guide to Reptiles of Australia

By Steve Wilson and Gerry Swan. Reed New Holland, Sydney, 2003, 480 pp. $49.95 rrp.

This is a comprehensive field guide that illustrates almost all of the reptile species (and subspecies) described up to late December 2002 and recorded from Australia, including Norfolk and Lord Howe Islands.

Although compact enough to fit in a car's glove box, the book is crammed with descriptive information and superb photographs. Each family and genus has details of appearance, ecology and distribution. Each species has a concise individual account that includes scientific name, common name (when one is in use), size, colouration, habitat preferences, conservation status, and a photograph and distribution map. Important diagnostic features are highlighted in bold text.

The general layout is stylish and pleasing, with each species having its account, map and illustration on opposing pages, relieving the need to flick through pages looking for that accompanying photograph.

The taxonomy used is up to date and avoids some of the more controversial changes proposed by recent authors. There is little to criticise about this book. Overall it is a well-presented guide and I wouldn't go bush without it.

—Paul Horner
Museum and Art Gallery of the Northern Territory

A Field Guide to Insects in Australia

By Paul Zborowski and Ross Storey. 2nd ed., Reed New Holland, Sydney, 2003, 208 pp. $32.95 rrp.

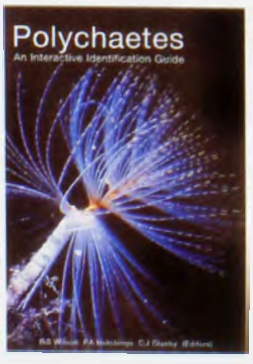
The great diversity of Australian insects is often daunting to novices who wish to identify them. However, this very useful book will enable identification of most Australian insects to the level of order and, in some cases, to family.

An introductory section outlines insect structure, life cycles, crypsis and mimicry, describes a collection of insects, and provides a simple order-level key. The next section has detailed descriptions of Australian insect orders. This second edition gains a short multimedia bibliography, 16 new colour images, and updated references.

The strength of this book is the simplicity of the descriptions and the excellent colour photographs of living insects. The posture and habits of live insects often enhance identification, and many users will prefer to identify live insects. While the information content is accurate, southern Australian readers may be frustrated to find that many of the illustrated insects are from northerly localities.

The first edition won the 1996 Whitley Certificate of Merit for Best Field Guide, and this edition certainly builds on this platform.

—David Britton
Australian Museum



Polychaetes: An Interactive Identification Guide (DVD)

Ed. by R.S. Wilson, P.A. Hutchings and C.J. Glasby. CSIRO Publishing, Vic., 2003, $145.00 rrp.

Beach worms, bristle worms, fan worms, blood worms—polychaetes are among the most abundant marine invertebrates. Not surprisingly, they are difficult to identify, making "Polychaetes" a most welcome addition. For the first time, the world's families and genera, and more than 1,200 Australian species, can be identified on a single CD. The core of the guide is an interactive database that leads the user step by step until a final identification is determined. Add to that illustrations of all the anatomical features used in the process and one has a remarkably powerful, yet user-friendly tool. The work is also a general reference guide to the polychaetes, providing taxonomic diagnoses, ecological information, and numerous references. Numbers of as-yet-unnamed species are included, indicating that knowledge of polychaete biodiversity is far from complete. This work makes specialist knowledge readily accessible to non-specialists, will hopefully raise the bar of public knowledge, and perhaps see accelerated progress in scientific research. This is a fine work for which the authors are to be congratulated.

—Shane Ahyong
Australian Museum

SOCIETY PAGE

Get involved! Across Australia there is a network of active societies, large and small, local and national, that 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.

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Ph: 08 8278 7866
Web: *www.birdssa.asn.au*
Contact: Dr David Robertson

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Contact: Trevor Evans

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c/- Lane Cove National Park
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Web: *http://users.bigpond.net.au/folnp*
Contact: Noela Jones

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Contact: Michael Brennan

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Contact: Douglas Raupach

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Contact: Nick Harvey

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INSECTS

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56 Looker Road
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VIC. 3094
Ph: 03 9435 4781
Web: *www.vicnet.net.au/~vicento*

Society for Insect Studies
12 Park Avenue
ROSEVILLE NSW 2069
Ph: 02 9417 6171
Contact: Hon. Treasurer

MICROSCOPY

Postal Microscopical Club of Australia (PMCA)
36 Western Avenue
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Ph: 02 4739 1528
Contact: Tony Ellis

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q&a

KATHIE ATKINSON

Sight or Sound?

Q: *We are visited by Magpies and Laughing Kookaburras, both of which love the worms in our lawn. However, they have quite different foraging strategies: while the Magpies wander about on the grass in search of worms, the Kookaburras sit on an archway overlooking the lawn and only pounce, presumably, when they spot a worm. Is it true that Magpies search by sound and Kookaburras by sight?*

—Stuart Reid
Highlands, Vic.

Do Kookaburras hunt by sight alone?

A: Magpies locate their prey by listening to the very slight sounds made by moving soil-dwelling larvae, worms and insects. One study in the 1980s showed conclusively that Magpies find scarab larvae by sound alone (and maybe vibratory cues), and not by olfactory or visual cues. The hearing ability of Magpies is thus extremely acute, while vision in Kookaburras is likely to be exceptional, although there are no studies to confirm this. We do know, however, that Common Starlings and American Robins find earthworms from the minute mounds of dirt above the ground that are left behind when worms move beneath the surface. Perhaps Kookaburras do the same.

—Gisela Kaplan
University of New England

Lorikeets Down Under

Q: *When we were at Currumbin on the Gold Coast, we saw Rainbow Lorikeets coming and going from a small gap between the ground and a concrete slab that supported a picnic table. Would these birds have been nesting and, if so, is it usual for them to nest underground?*

—Brendan Taylor
& Karen Williams
New Brighton, NSW

A: *The handbook of Australian, New Zealand and Antarctic birds* does not list underground hollows among the sites used by the Rainbow Lorikeet (*Trichoglossus haematodus*). Almost all nests are in trees, usually in broken limbs, although one has been recorded on a building in a crevice next to a chimney. The only Australian parrot that consistently nests among rocks and crevices is the Rock Parrot (*Neophema petrophila*). Nonetheless, your observation appears to be of birds at least investigating a potential nesting site. It is possible that they may attempt to lay eggs; lorikeets can be quite persistent once they have selected a hollow. Whether or not it would be successful is another question. In this position, the nest would be accessible to any number of potential ground predators.

—Walter E. Boles
Australian Museum

Answers to Quiz in Nature Strips (page 17)

1. *Rottnest Island* **2.** *In the Common Era* **3.** *China* **4.** *Shadows* **5.** *Wollemi* **6.** *A billion (10⁹)* **7.** *R.M. Williams* **8.** *Plastron* **9.** *South America* **10.** *A cob*

COURTESY BRENDAN TAYLOR

A feather from a Rainbow Lorikeet outside the underground nesting site it was investigating.

AUSTRALIAN MUSEUM NATURE FOCUS

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 copy of the video "Attenborough in Paradise". Autumn's Pic Teaser was the egg of a Short-beaked Echidna (*Tachyglossus aculeatus*).

Painful choices

We need to open our minds to the fact that business as usual is impossible.

BY DAVID BOWMAN

IMAGINE AN OPPORTUNITY THAT would provide a revenue stream to fund land management, ecological restoration, education, health, scientific programs, and much more.

Storage of nuclear waste might offer such an opportunity. Currently there are 250 odd tonnes of plutonium begot from scrapped cold-war nuclear weapons and reprocessed spent reactor fuel—enough to build more than 30,000 Nagasaki-type bombs. This deadly metal must be quarantined from civilian economies given the threat of terrorism. But the rub is, where? Australia's insularity, geological quiescence, sparse population and stable democracy could make the perfect repository for plutonium and the growing mountains of other high-level nuclear waste. Perfect, at least, for those that don't live here.

Such a scenario is presently the province of maverick Northern Territory politicians, or the obscure outputs of esoteric think tanks. However, I suspect that, as environmental conditions continue to deteriorate worldwide, governments will be forced to make increasingly difficult choices. Most fundamentally, we will accept that the magnitude of environmental problems far outweighs available funds. Consequently, I believe that solutions for the ecological rehabilitation of the south and the sustainable development of northern Australia lie well outside the box.

As Tim Flannery (South Australian Museum) notes, many of the current debates about the environment have fallen into complacent or philosophically hidebound thinking, often suffused with "beautiful lies". We need to open our minds to the fact that business as usual is impossible, including the comfortable yet stale symmetry of the environment–development debate. Allow me to sketch a possible scenario for northern Australia, the last great Australian frontier.

To avoid repeating the mistakes made in southern Australia, proposed agricultural development in the north must be modest, to protect the infertile soils that are particularly vulnerable to erosion during the wet season. Here the opportunity remains to conserve biodiversity by eschewing large-scale land clearing yet still using land for pastoralism while simultaneously achieving so-called 'off-reserve conservation'. Aboriginal lands will also conserve biodiversity by sustainably harvesting wildlife for subsistence and profit. 'National parks', critically important insurance policies against the global-extinction crisis, will continue to morph from the narrow concept of wilderness areas to where Indigenous communities have a stake in park management. Mining will remain an important source of economic activity providing revenue to fund environmental management.

I can hear some howls of outrage at these heterodox views—the same idealistic repudiation that greets other novel responses to sustainable futures such as one-kilometre-high solar 'power towers' in the outback, 'ugly' wind farms, forestry in native forests, hazard-reduction burning in bushland surrounding urban areas, the role of recreational hunting in the conservation of wetlands, the commercial harvest of kangaroos, and the acceptance of feral animals as part of the biota. In this context it is important to note that some of these 'out-there' ideas have already been accepted. Consider Kakadu National Park, a jewel in the biodiversity crown of Australia, which also happens to contain a uranium mine (and therefore a source of nuclear waste that is looking for a home).

I am not advocating that we go forth and trash nature, far from it. Rather I believe that, to save natural systems upon which our future depends, we must be receptive to new and probably painful choices on the strict proviso that we gain direct environmental and social benefits from any concessions associated with economic development. As an extreme example, if the price for global nuclear disarmament is our storage of plutonium, then that price may be worth paying, as the alternative is too horrible to contemplate.

The impending, massive ecological and social transformation that the north is facing has probably coloured my thinking. Living here demands big questions: how should Australia, situated in an arc of political instability, maintain first-world quality of life, control natural population growth and legal and illegal migration, stop the descent of the Indigenous population into a deepening poverty trap, and fund the Herculean task of managing and restoring our ecosystems? The answers to these questions will, I suspect, be found by making painful choices. □

FURTHER READING

Flannery, T., 2003. Beautiful lies: population and environment in Australia. *Quarterly Essay No. 9. Black Inc.: Melbourne.*

DR DAVID BOWMAN IS THE DIRECTOR OF THE KEY CENTRE FOR TROPICAL WILDLIFE MANAGEMENT, CHARLES DARWIN UNIVERSITY, WHERE HE SEEKS TO REALISE A SUSTAINABLE FUTURE FOR THE MARGINAL LANDS OF NORTHERN AUSTRALIA.

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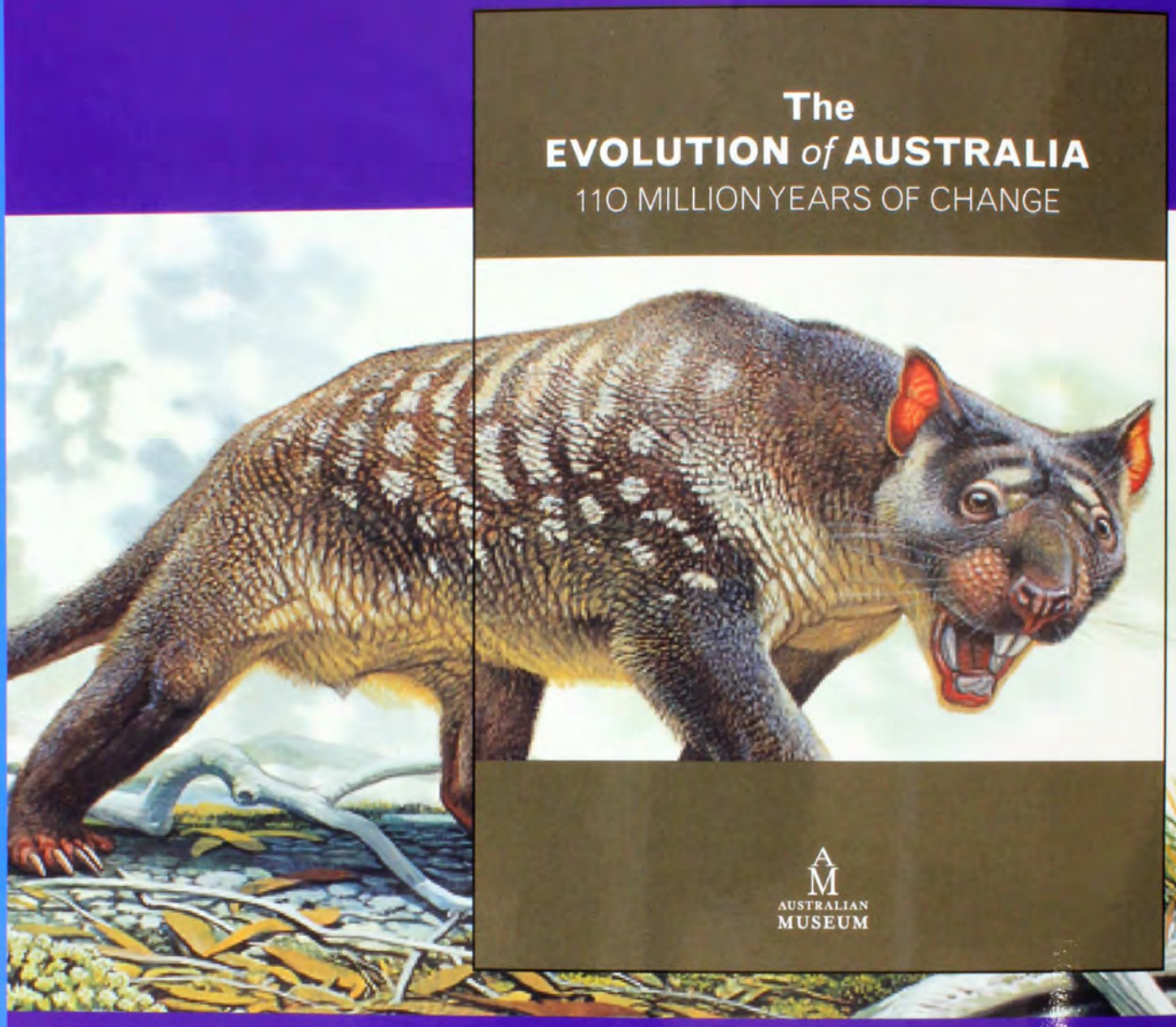

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