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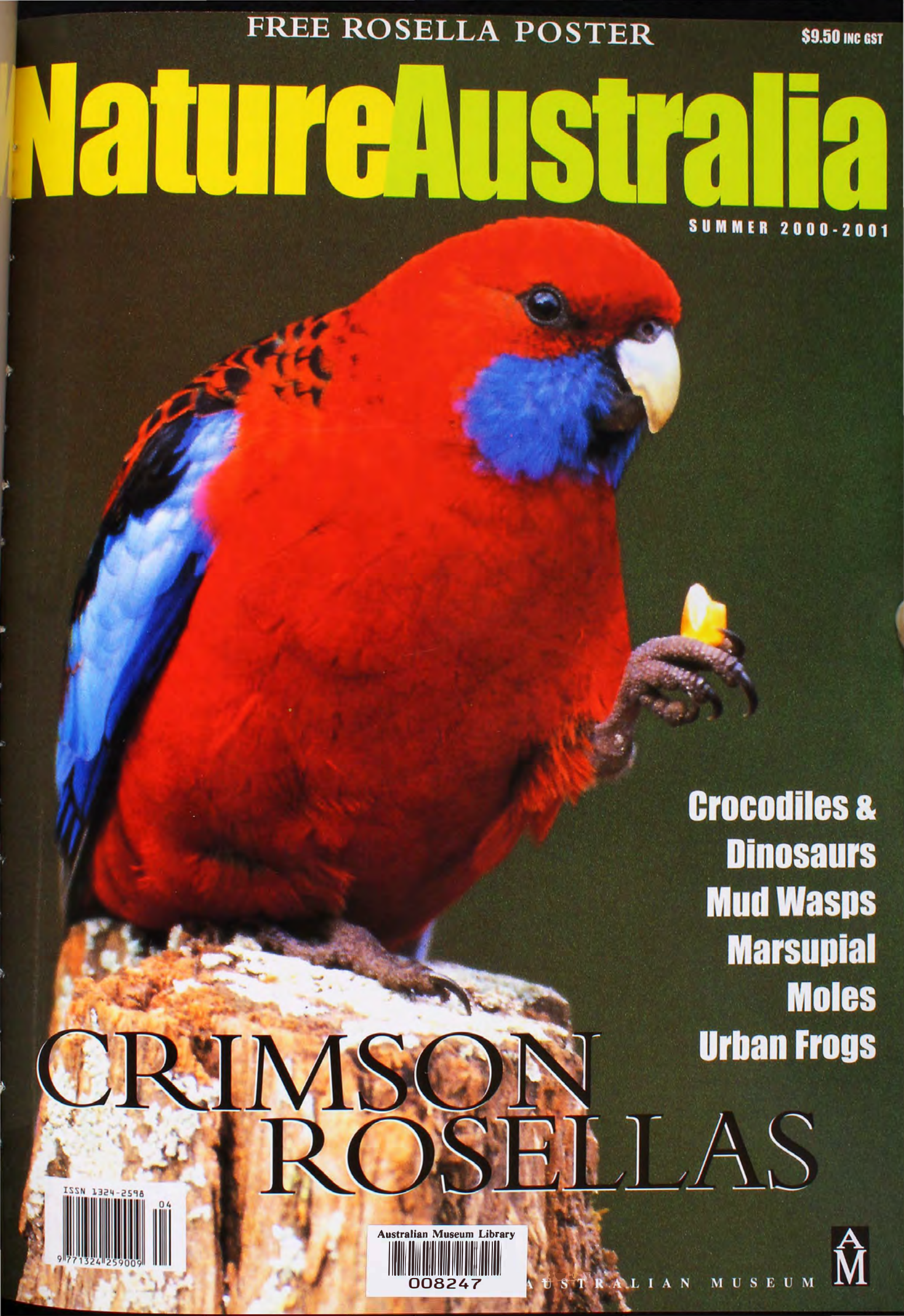

Crocodiles &
Dinosaurs
Mud Wasps
Marsupial
Moles
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CRIMSON ROSELLAS

ISSN 1324-2598 04

AUSTRALIAN MUSEUM

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THE 2001 EUREKA PRIZES

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FRONT COVER

Although Crimson Rosellas happily feed in yards and gardens, their fate, like that of many other parrots, ultimately rests in having access to sufficient breeding hollows. Photo by Kathie Atkinson.

up front

Marsupial moles really are the most amazing-looking animals. Whenever we're sent photos of them, everyone in the office is always fascinated by their strange appearance. Add to this their preference for living underground in our hot sandy deserts and the fact that they get about by 'swimming' through the sand, and you have some incredible little Australian marsupials. Unfortunately, marsupial moles are nowhere near as well known as many of our other marsupials; in fact, I doubt whether many Australians would even know that they exist at all. In the hope of increasing their profile, our article on page 26 tells of what happened after the rare capture of a live marsupial mole in Western Australia. This single individual provided scientists with the opportunity to better understand their physiology. And I guarantee you'll be fascinated by the photos. We certainly were.

WITHERS/THOMPSON

A rare opportunity: a marsupial mole in captivity.

One thing you cannot say about rosellas is that they are little known. These parrots are large, colourful and so successful they can be found just about everywhere in Australia. And of the rosellas, Crimson Rosellas have got to be one of our favourites. With their spectacular bright red and blue plumage they are certainly hard to miss. Surprisingly, these beautiful birds do have something in common with marsupial moles, and that is there is relatively little known about their habits. In order to correct this, Elsie Krebs, fascinated by these beautiful birds, set out to study their breeding behaviour. What she discovered is that Crimson Rosellas like to do things a bit differently when it comes to raising their young.

Compared to the care and attention Crimson Rosellas give their young, mud-dauber wasps seem to be towards the other end of the parenting spectrum. The female wasp builds a nest, lays her egg, stuffs in some food, and seals the whole thing up nice and tight. She then flies off, safe in the knowledge that she has provided a secure haven for her young. Unfortunately, this can be far from the truth and there is a wide cast of players waiting in the wings to pillage and plunder that 'safe' little larva and its food supply.

Just how do you study the body temperature of dinosaurs when they have been extinct for millions of years? The answer came to Frank Seebacher after he had spent quite a few seasons out in the bush measuring the body temperatures of both Freshwater and Saltwater Crocodiles. His article, "Crocodiles as Dinosaurs", is fascinating reading and draws some very interesting conclusions on what life might have been like as a dinosaur.

We also take a close look at the sex-changing habits of coral-reef fishes, weigh up the pros and cons of having butcherbirds in your backyard, and explore the reasons why Brisbane has become a city of frogs.

—JENNIFER SAUNDERS

letters

Which Century?

"For our first issue of the 21st century..." (*Nature Aust.* Autumn 2000). I know the time has passed, and who needed an excuse for a celebration anyway? And, besides, why should facts get in the way of a good story? But allow me to express my disappointment that the Editor of a prestigious scientific magazine should bow to popularisation and refer to the Autumn 2000 issue in the above manner. At least you have not gone to the extent of glorifying it as the first issue of the new millennium!

Mathematics is an exact science, and we could prove the above statement to be in error by simply counting the years since the time we generally accept as being the birth of Christ. But journalists and the poor old Joe Publics have neither the time nor the inclination to do that, hence the enormous hoo-ha at the end of last year with the so-called start of the new millennium.

Allow me to give two simple examples that demonstrate quite clearly that we are still in the last year of the present decade, century and millennium.

First, assume we had an interest-free and fee-free loan of $2,000 from a bank. That bank would want its entire $2,000 back before discharging the loan. It would not settle with $1,999, but would insist the 2,000th dollar was safely in its coffers, would it not? Call the dollar notes years and it is clear that it is not the end of the last decade, century or millennium until this 2,000th year is over.

Second, count your fingers! Barring an unfortunate accident or genetic abnormality, there will be ten. The first one is 'number one' and the tenth one is 'number ten'. Again, call them years. It is the tenth year that ends the decade. Extrapolate to 100 and 1,000. It is the 100th year that ends the century and the 1,000th year that ends the millennium. The year 2000 ends the second millennium and 2001 starts the third.

So, we do not enter the 21st century, nor even the next decade, let alone the 3rd millennium until 1 January 2001. Hence the Autumn 2000 issue of *Nature Australia* is not the first issue of the 21st century, merely one of the last of the 20th century.

—Alan Moskwa
Kensington Park, SA

Possum Predators

In Tamra Chapman's article on Kangaroo Island Glossy Black-Cockatoos (*Nature Aust.* Summer 1999–2000), allusion was made to predation by the Common Brushtail Possum. Evidence is cited of hairs matching the possum's being found on destroyed nestlings and eggs. One usually interprets the word 'predator' as applying to an animal that kills and eats its prey. Is it indeed possible that the Brushtail actually eats nestlings, or is the term to be understood in a looser manner? Both my biological and zoological dictionaries clearly affirm the process of eating as part of the food chain.

—Anne Drover
Wollstonecraft, NSW

Lynn Pedler collected possum hairs not only from the broken egg shells of Glossy Black-Cockatoos but from the chewed feathers of chicks that had been

PAVEL GERMAN/NATURE FOCUS

Do Common Brushtail Possums eat Glossy Black-Cockatoo eggs and chicks?

healthy and growing rapidly a few days earlier! (See Garnett et al. 1999, Emu 99: 262–279.) We never saw them make the kill but the evidence that they kill and at least partially eat the chicks is pretty over-whelming. I believe Common Brushtail Possums have also been filmed on several occasions robbing Kokako nests in New Zealand.

—Stephen Garnett
Qld Parks & Wildlife Service
Cairns, Qld

In Defence of Reality

I was disappointed, upon reading Letters published in the Winter 2000 issue of *Nature Australia*, to think that in this enlightened age there are still people who think they have a right to enforce their point of view by denigrating and denying others their right to express theirs.

I interpreted Steve Van Dyck's recent article, referring in part to the human consumption of kangaroo meat (*Nature Aust.* Spring 1999), as an effort to highlight the plight of our diminishing native fauna (and flora) by promoting the fact that many of our unique species are worthy of preserving, not only because they are endangered but because they are of potential value in ensuring the survival of our own species in a continent that is so unforgiving of our modern ways.

With population pressures encroaching upon the natural domains of endemic species worldwide, it is inevitable that the only species that will continue to survive in the presence of humankind will be those that we find valuable enough to share our living space with.

If we want our future generations to experience the joy of seeing a joey peering out of its pouch, we are going to have to justify that our marsupial neighbours have as much right to coexist with us as Cattle, Sheep, Pigs and poultry. It is perhaps unfortunate that pressure on land and resources in the future will require that only those species that can be exploited by mankind will be guaranteed survival, but that's reality.

If Mallee Fowl were domesticated for the production of their eggs, kangaroos farmed for their meat and hides, and Bilbies kept as companion animals, like our crocodiles, Emus and Budgerigars, they would be as commonplace as farm animals, Cats, Dogs and guinea pigs and be in no danger of extinction.

—Peter Edwards
Langwarrin, Vic.

Native Matters

I read with interest the article by Tim Low on cryptogenic species (*Nature Aust.* Summer 1999–2000). While he exhorts scientists and naturalists to practise more care in assuming the indigenous credentials or lack thereof for some species, we are left wondering what exactly defines a native species. How long does a species have to have been in Australia before it may be considered a dinkum Aussie? According to Environment Australia, a species is considered native if it cannot be proved that it was introduced after the arrival of the First Fleet.

The second issue is whether or not it matters if we assume a species is native when it is not, and if it does matter, why? Tim emphatically says it does matter, but doesn't adequately explain why. To me the important point is not whether a species was in Australia before or after a particular point in time, but rather what it is doing now it is here. There are numerous examples of innocuous exotic species that quietly eke out an existence without creating concerns greater than the momentary ascetic consternation over whether a plant in a sand-dune is a pretty wildflower or an ugly weed. On the other hand, there are many examples of dinkum Aussie native species that run rampant when moved to parts of Australia from which they did not originate. Examples such as Koalas on Kangaroo Island, Ivyleaf Violet (*Viola hederacea*) in my garden and, if I am not mistaken, Laughing Kookaburras in Western Australia, illustrate the point that being native does not mean being in balance. To paraphrase the noted cartoonist Gary Larson, it is all too easy to vilify some species and romanticise others when you do not appreciate the interactions.

—Paul De Barro
CSIRO Entomology
Indooroopilly, Qld

Nature Australia requests letters be limited to 250 words and typed if possible. Please supply a daytime telephone number and type or print your name and address clearly on the letter. The best letter in this issue will receive a copy of _Green power: the environment movement in Australia_. The winner this issue is Paul De Barro.

nature strips

COMPILED BY GEORGINA HICKEY

DANIELLE CLODE, RICHARD FULLAGAR, KARINA HOLDEN, MICHAEL LEE, KAREN McGHEE, DANIELLE-LOUISE QUINN, RACHEL SULLIVAN AND ABBIE THOMAS ARE REGULAR CONTRIBUTORS TO **NATURE STRIPS**.

The Case of the Shrinking Iguanas

Food shortages wrought by El Niño regularly devastate the famous Marine Iguanas (*Amblyrhynchus cristatus*) of the Galapagos Islands. These prehistoric-looking lizards normally graze on nutritious green and red algae, which is replaced by tough, inedible brown algae at such times. Up to 90 per cent of the population can perish during particularly severe events. However, while monitoring the latest cycles, Martin Wikelski (University of Illinois at Urbana-Champaign) and Corinna Thom (University of Würzburg) noticed that the iguana population shrank in another way. The lizards not only became fewer, they became shorter, with some shrinking in length by as much as a fifth. And what's more, when food was restored in subsequent non-El Niño years, the lizards rapidly expanded again.

Individuals that shrank the most tended to best survive the food shortages, presumably because small grazers are generally more efficient foragers and require less food than larger grazers. Exactly how they accomplish their incredible shrinking act, however, remains baffling. Humans usually lose a centimetre or two as they age, but this is caused entirely by compression of the elastic tissue separating the individual vertebrae. Such tissue only accounts for ten per cent of the length of an iguana; to shrink by 20 per cent, the lizard's bones must also be getting smaller. Wikelski and Thom noticed that, during famines, the lizards spend very little time moving and foraging, and suggest this idleness, in combination with the food stress, causes the bones to become partly resorbed.

Large pythons and some long-distance migrating birds have a related ability—during prolonged periods of starvation, large proportions of the gut are resorbed, but are quickly regenerated when food is eaten. The case of the shrinking iguanas, however, is special because it is not just 'soft' tissue that is shrunk (as happens to all animals during famines), but 'hard' bony tissue as well.

—M.L.

Marine Iguanas shrink in length when food is scarce.

COURTESY ANTONI MARGALIDA

Why do Bearded Vultures paint themselves with red soil?

Vulture Cosmetics

Cosmetics is a time-honoured industry, made most famous by the Egyptians thousands of years ago. But the Old World Bearded Vultures (*Gypaetus barbatus*) were into it long before it became vogue in humans.

Bearded Vultures have a rich orange colour on their underparts, neck and head. Once thought to come from carotenoid pigments (until it became clear there were little, if any, such pigments in their bone-only diet), we now know that it comes from the birds deliberately bathing themselves in red soil stained by iron oxides. Captive birds without access to red soils remain white, but as soon as they are presented with suitable soil, they rub their bellies in it. They then use their beak and talons to spread the soil to their upper back and shoulders, and swing their head back and forth until it too acquires the orange colour. Bearded Vultures are very secretive about their soil-bathing activities. Indeed, few incidences have been observed in the wild, and captive birds quickly stop if disturbed. The behaviour is also innate (unlike the human use of colour), as young captive birds reared in isolation respond the same way when offered red soils.

Humans decorate themselves with colour for a number of reasons—to increase sexual attractiveness, threaten enemies, protect the skin, or to act as camouflage. So why do Bearded Vultures do it?

Camouflage seems unlikely in a bird with no natural predators; besides, if anything, the red colour would make the birds more conspicuous. Protecting the feathers from wear or parasites also seems unlikely, as white feathers aren't any more worn than stained feathers; and studies on chewing-lice show they are little affected by iron oxides.

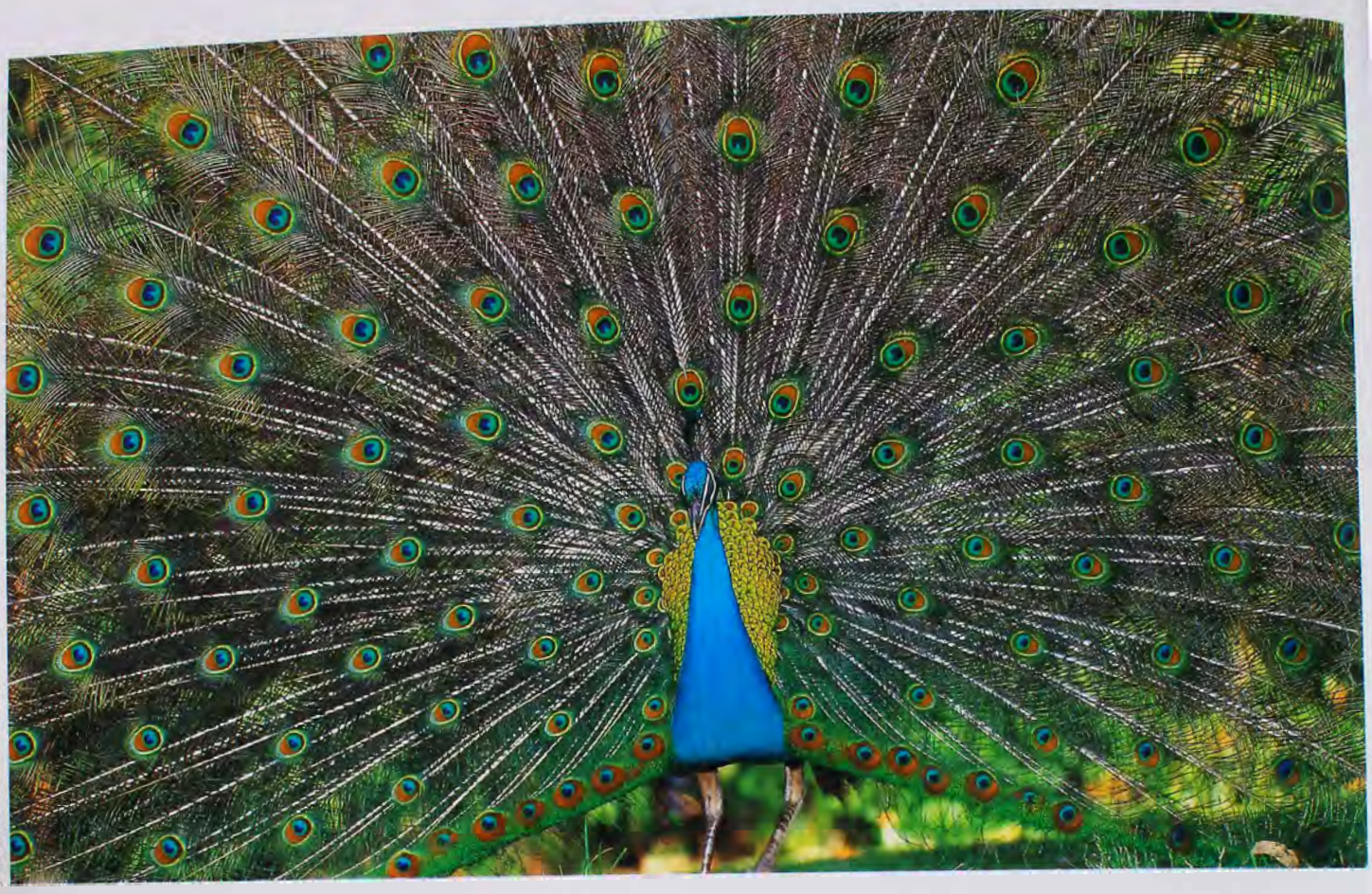
Juan Negro (Spanish Council for Research) and colleagues believe the red-stained plumage is a signal used by the birds to convey status to rivals or mates. During fights over food, for example, the neck feathers are erected and the head swung to and fro, providing plenty of opportunity to show off the colour. But to be an honest signal of status, it must come at a cost, and Negro *et al.* believe this to be the time and distance spent searching for limited bathing sites. If a bird can suss out good bathing sites, it must be fit, and have good searching skills and a thorough knowledge of its local surroundings (including the location of unpredictable food resources). It would thus pay to give in to such individuals during fights, or to choose them as mates.

—G.H.

Good Things Come in Tall Packages

It's official. Women do prefer taller men.

A team of scientists led by Boguslaw Pawlowski (University of Wroclaw, Poland) analysed the medical and family-history records of 4,419 healthy Polish men aged between 25 and 60. The data were controlled for



JEAN-PAUL FERRERO/AUSCAPE

When it comes to forming mating groups, Peacocks like to keep it in the family.

variables that are known to affect height, such as educational achievement and residential address (taller men tend to be better educated, and city-dwellers are generally taller than rural men), leaving them with a sample size of 3,201 men. The researchers found that, overall, men with children were significantly taller than their childless counterparts. Moreover, bachelors were significantly shorter than married men, indicating that women actively seek out taller men.

Taller men were found to be reproductively more successful than shorter men in all age categories except for those in their 50s. This group, born during the 1930s, became eligible for marriage just after World War 2, at a time when the population's sex ratio was skewed in favour of women. This shortage of men would have forced women to be less choosy about height. However, as the sex ratio became more balanced, women once again were free to pick as they pleased, choosing men they could literally look up to.

—D.-L.Q.

Sexual Fraternities

The males of many bird species come together in large groups known as leks to strut their stuff in the hopes of attracting females. Generally, the bigger the group, the more females are attracted, and yet usually only one or two of the males end up with all the matings. Why, you might wonder, do the other males bother hanging around?

According to two recent studies on Black Grouse (*Tetrao tetrix*) in Finland and Peacocks (*Pavo cristatus*) in the United Kingdom, brotherly love plays an important part in lek formation. By displaying with relatives, males that are overlooked by females still gain indirectly by boosting the success of their family members. The benefits of helping a closely related dominant male attract more females seem to outweigh the subordinate males' own meagre mating opportunities.

Sexual fraternities were identified among Black Grouse by Jacob Höglund (University of Uppsala, Sweden) and colleagues, who found related males lek together when they return to their place of birth in winter. DNA fingerprinting confirmed these family ties. However, in the Peacock study by Marion Petrie (University of Newcastle, UK) and co-workers, the association of sex and kin was even more fascinating. Many of the Peacocks had been hatched artificially and raised among non-relatives before being returned to the study area. Yet several years later when the birds reached sexual maturity, lek sites were still established between genetically related males. This implies that brothers were able to identify each other through some type of phenotypic matching, such as similar calls, plumage or odour. The ability of birds to recognise one another, even when they hadn't been raised together, sheds a new light on avian social interactions.

—K.H.

Groovy Boomerangs

Aboriginal boomerangs have been thrown around for at least 10,000 years, and constitute a quintessential Australian icon. Many

COURTESY CENTRE FOR MEDIA RESOURCES, ADFA

Carved grooves on an Aboriginal throwing stick and boomerang—not just for decoration.

boomerangs, and also the near-cylindrical throwing sticks, have longitudinal grooves or flutes carved into them. The grooves are about five millimetres wide by 0.2 millimetres deep, and occur only on the upper, more highly curved surface of boomerangs but all the way round the circumference of throwing sticks. Previously these grooves were thought to be purely decorative or of ceremonial significance. But new research by civil engineer Ray Nelson (University of New South Wales) has shown they are more than just decoration—they enhance flight performance.

Nelson made aluminium models of a fluted and non-fluted boomerang and throwing stick (based on real fluted specimens), and carried out wind-tunnel tests to compare the lift and drag forces exerted on them.

He found that the boomerang flutes cause a turbulent boundary layer of air to start right at the leading edge. This turbulent boundary layer adheres to the roughened surface and does not separate from it until near the trailing edge (compared with the smooth model where it forms farther back from the leading edge and separates from the surface much earlier). This creates a narrower wake behind the boomerang, enhances lift and prolongs flight. Nelson likens this to the way stitching on a well-bowled cricket ball generates lift.

In contrast with boomerangs, with their asymmetrical, lens-like cross-section, no lift force acts on the throwing sticks. The only aerodynamic force operating on these near-cylindrical objects is drag, or air resistance. Drag can be reduced by higher velocities, but we cannot throw sticks at such speeds. The grooves (like the dimples on a golf ball) do the job—by creating a turbulent boundary layer of air that wraps nearly all the way round to the back of the object, thus enhancing forward motion.

Whether Aborigines made a conscious decision to carve flutes into their throwing implements for aerodynamic purposes is unknown. Perhaps fluting as an aerodynamic aid was serendipitously discovered after first decorating the tools with grooves. One thing is certain: without the flutes, some boomerangs would not have been able to fly.

—R.F.

Penguins' Faith in Leaps

Adelie Penguins (*Pygoscelis adeliae*) go on food-foraging trips that may last a full day. It's an enormous effort for the birds, which weigh only 4.5 kilograms yet bring home half a kilogram of fish. (That's equivalent to a person eating two whole Christmas turkeys!) The trip can also be fraught with danger from predators such as seals and whales. Researchers have

What's the purpose of porpoising in Adelie Penguins?

speculated how one particular behaviour, porpoising (where birds leap briefly out of the water while swimming), might help penguins survive the big trip.

Ken Yoda (Kyoto University) and colleagues decided to test one theory about porpoising—that it saves on energy. Air has far less drag than water, so if penguins leap in the air while they are swimming, they should use less energy and still maintain speed.

By gluing small devices to the penguins' backs that measured depth and acceleration, the researchers found that the average time penguins spent porpoising was less than four per cent of each trip. While penguins would save energy by leaping, they were not doing it often enough to make a significant difference.

So why leap? Yoda and colleagues calculated that the length of the leap out of water is just long enough for penguins to grab a breath of air without slowing down. They also noted that penguins usually porpoised at the beginning and end of their trips, near the colony...where Leopard Seals and Killer Whales like to hang around in the hope of grabbing a meal. Porpoising then may be the penguin's way of making a quick, safe getaway and return to home base.

—A.T.

Baby Bird Begging

Most vertebrate offspring that depend on their parents for survival have evolved signals to indicate when they're in need of a meal. Baby birds, however, have taken the art of begging for food to its screeching zenith. Nestlings of many bird species jostle vigorously against each other and plead—with necks stretched and mouths agape—loudly and strongly. The advantages are obvious. But such conspicuous behaviour must also run the risk of revealing nest locations to potential predators.

Perhaps, speculated James Briskie (University of

Dusky Woodswallow chicks (*Artamus cyanopterus*) beg for their supper. How much noise they make depends on the level of predation.

Oxford) and colleagues, some species have evolved begging calls with certain acoustic qualities that reduce the risk of predation.

Working in a pine forest in central Arizona, the researchers first established general predation risks for nests in the area. They did this by measuring predation levels on nests for 24 different bird species. They found some species lost all but a few eggs to predators, some lost almost none, while others fell somewhere in between.

Briskie and colleagues then recorded the calls made by the begging chicks and, using computer analyses, determined the frequency (pitch), amplitude (loudness) and frequency range for each species.

As expected, species with the highest risk of predation had calls with the lowest amplitudes and highest frequencies (that is, soft and squeaky). These are acoustic characteristics that, for a predator, would make the source of the calls hardest to locate. In contrast, chicks that faced the lowest predation levels had no need to be inconspicuous and begged as loudly and deeply as they could.

—K.McG.

Some American species, like Red-sided Gartersnakes, engage in mass matings involving hundreds of writhing snakes.

Snakes' Tell-Tails

Much has been made of the urban myth that men with big feet, hands or noses are similarly well-endowed elsewhere. I don't know how true this is in humans, but apparently a similar association, with tail length, occurs in snakes.

Rick Shine (University of Sydney) and colleagues wondered why the males of most snake species have longer tails than their females. Differences between males and females often reflect sexual selection, but snakes are secretive about their sex lives and difficult to study. Fortunately some American species, like Red-sided Gartersnakes (*Thamnophis sirtalis parietalis*), are less introverted and engage in mass matings involving hundreds of writhing snakes, shortly after emerging from their communal winter dens.

When the researchers compared the tail length of male gartersnakes with the size of their two hemipenes (reproductive organs), they found that the longer the tail, the longer the hemipenes. Hemipenes are sheathed inside the base of the tail except when mating. Both long tails and long hemipenes may be advantageous to Red-sided Gartersnakes, since a long, strong tail enables males to wrestle opponents away from females, while long hemipenes may increase attachment during copulation. Certainly, males with long tails were more likely to be found mating than males with shorter tails. Males with tails reduced by

accidents or predation were particularly unlucky in the copulatory stakes.

Competition between male Red-sided Gartersnakes is likely to be stronger than in less promiscuous species. Even so, this study suggests that mating competition may be why the males of many snake species have proportionally longer tails than their females. Perhaps it also suggests that, if we had kept our tails, we would be less obsessed with the size of our feet, hands and noses, even our cars and chequebooks!

—D.C.

Sticky Fingers Save Lives

Many people who have visited Taronga Zoo in Sydney watch with amazement at the way the tiny Feathertail Glider (*Acrobates pygmaeus*) can cling to smooth, vertical, glass surfaces. Herb Rosenberg and Robert Rose from the University of Calgary examined the foot pads of Feathertail Gliders to see how they perform their Spiderman-like tricks. They also wondered how the feet resist the forces that a gliding animal must experience when it comes to land abruptly on a hard surface, such as a tree trunk.

When pressed onto a microscope slide, Feathertail Glider pads leave a kind of fingerprint. Close examination of the pads with a scanning electron microscope reveals that the surface is covered with skin ridges. These are perforated by numerous sweat gland ducts running up from deep within the tissue. Moisture from these ducts spreads along the skin ridges, creating minute adhesive strips with enough capillary force to help the glider stick fast to smooth surfaces.

Feathertail Glider pads also have a unique arrangement of skin cells that protects the feet from the forces of shear and compression. Normally, mammalian skin responds to impact and shearing by thickening up and forming an outer layer of dead cells. Just look what happens when you wear tight or new shoes. But the glider pad grows in such a way that the skin surface never forms a thick layer of dead cells. Instead, a layer of tiny liquid-filled chambers in the skin forms a kind of sponge that absorbs compression and gives the glider a soft, safe landing.

—A.T.

Pleistocene Park?

Spurred on by a best-selling novel and later a blockbuster film, attempts to extract DNA from ancient organisms have intensified in recent years.

Most DNA that is extracted comes from the mitochondrial genes, which exist in thousands of copies in each cell and contain instructions for making the energy-producing mitochondria, among other things. But there are other genes, the nuclear genes, which only exist in two copies in each cell, and are responsible for what the animal looks like. Clearly, for an understanding of the

P. GERMAN

Smooth operator: the feet of Feathertail Gliders are adapted to clinging to smooth surfaces.

RON TESTA/THE FIELD MUSEUM, CHICAGO, IL., NEG#CK50T

A recent study has shown that mammoths were almost identical, genetically, to Asian Elephants.

genetics of extinct animals, we require information from both types. Because of their relative rarity, nuclear genes are much harder to extract and isolate, and until now good results have not been obtained for samples older than about 10,000 years. However, Alex Greenwood and colleagues from the University of Munich have recently managed to obtain partial sequences from four of these elusive nuclear genes, using Alaskan and Siberian mammoths (*Mammuthus primigenius*) that had been frozen in permafrost for around 14,000 years.

The results are intriguing for another reason. Apart from their hairiness, mammoths are very similar anatomically to Asian Elephants. The new study reveals that the two forms are almost identical genetically as well—in fact, mammoths are more similar genetically to Asian Elephants than are African

MARC S. DANTZKER

The side-on courtship display by the male Sage Grouse.

Elephants. However, before scientists (and entrepreneurs) start dreaming of extracting sperm from frozen mammoths and artificially impregnating Asian Elephants—an idea sensationalised quite recently in the popular press—some caveats are in order. The nuclear sequences the researchers managed to isolate were extremely short, and lab trials showed that, like all ancient DNA, even cryogenically preserved mammoth DNA is extremely degraded and distorted and, therefore, likely to be useless biologically.

—M.L.

Sound Shift for Sage Grouse

In the realm of bird courtship a male will do just about anything to get noticed by nearby females. But the North American Sage Grouse (*Centrocercus urophasianus*) plays it cool. Sure he's got the dramatic display—with wings held out to the side, he inflates a pair of dark neck sacs that pulsate through the bird's contrasting white feathers, and produces a series of loud accompanying calls—but he directs his display away from the females whose attentions he is trying to attract.

Intrigued by the birds' seeming nonchalance, a team led by Marc Dantzker (University of California, San Diego) investigated the directionality of the acoustic signal. Placing eight microphones in a circle around the male's display territory, they found that the birds' acoustic radiation patterns are unlike those of any other vertebrate. Usually a call is loudest in front of the animal, tapering off along its body, however Sage Grouse are able to broadcast components of their songs in varying directions around their bodies. The 'whistling' component, for example, is most intense to the sides and behind the caller.

In order to attract a mate over the cacophony of other males, callers try to hit females with the loudest 'whistles' they can. Since these are loudest just behind the shoulders, males face away from the objects of their desire and rely on their sound to put their best face forward. This makes it look like the males are ignoring the very females they most want to attract.

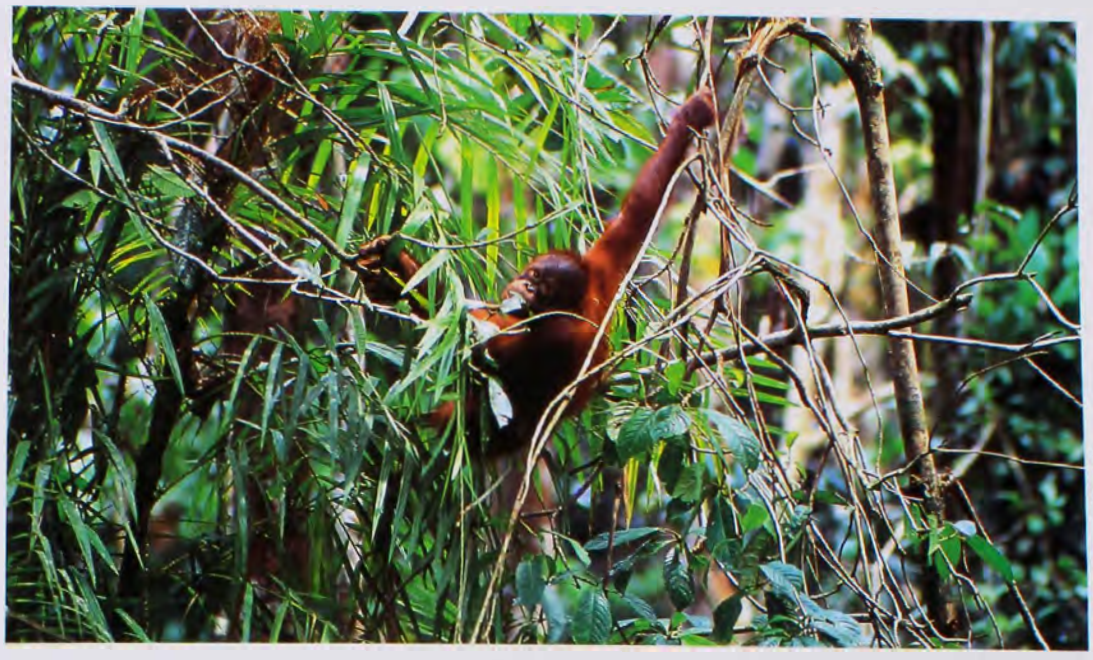
The females get their suitors' messages, though, turning with the males to maintain an oblique angle between them and ensuring they're always hit with the loudest part of the song. As to the adaptive value of this unusual acoustic pattern, the researchers suggest that perhaps it evolved to improve the effectiveness of a side-on display that evolved first for other reasons, or maybe it is simply a 'side-effect' of selection for loud and impulsive sounds that the birds make to attract females from a distance.

—R.S.

Neanderthal Cannibals

For nearly a century we have debated whether Neanderthals were cannibals. Previous archaeological evidence could not rule out the possibility that markings on Neanderthal bones were caused by gnawing animals, or by the Neanderthals themselves in preparation for burial. But new evidence, unearthed from a 100,000-year-old cave deposit at Moula-Guercy, south-eastern France, provides the best proof yet that Neanderthals ate their own kind.

Alban Defleur (University of the Mediterranean at Marseilles, France) and colleagues compared 78 Neanderthal bone fragments (representing at least six individuals) with the fragmented bone remains of deer and other animals found in the same stratigraphic level of the cave. The types of bones that were broken, and the patterns of cut marks, were



JEAN-PAUL FERRERO/AUSCAPE

The Orang-utan (*Pongo pygmaeus*) is just one of the many animals that rely on the mass fruiting events of Borneo's dipterocarp forests.

the same for both the Neanderthal and animal remains. The skulls and long bones had been defleshed with a stone tool, and then smashed with a hammer, presumably to remove brain tissue or marrow. Only the hand and foot bones, which have no marrow, remained in tact. The researchers argue that, if the non-human bones were the result of food preparation, then the human bones, which were processed in the same way, must also have been on the menu.

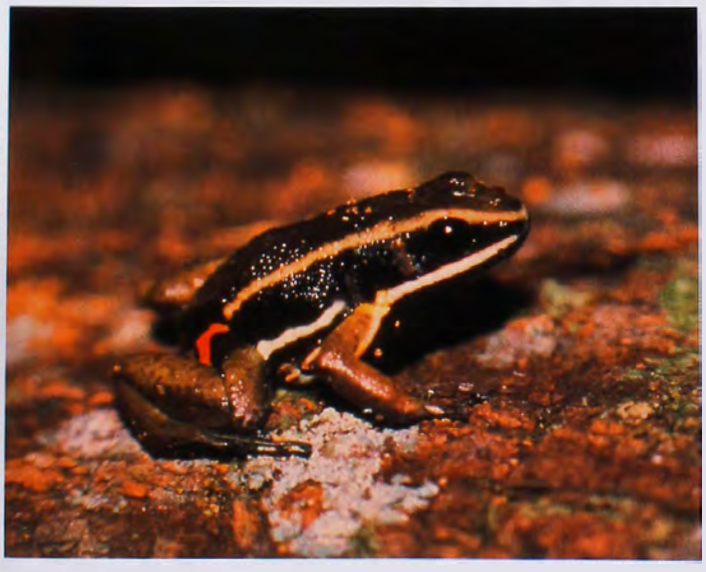
Although Neanderthals shared Europe with more modern-looking hominids for several thousand years, we tend not to think of them as sharing the same bed, or even the same table. Yet cannibalism is another piece of evidence for similarity (see "Neanderthal Cocktail", *Nature Aust.* Spring 2000). Cannibalism (whether for food or, more often, for ritual purposes) is of course documented in several modern societies. Cannibalism may be the dark side of human nature but, given what we also know about their stone tools and burial rites, Neander-thals appear to share a full range of human behaviour, certainly as complex as that of our more modern-looking ancestors.

—R.E

Borneo Fruit Falls

Every few years, the forests of Borneo yield a feast of flowers and fruit that requires an exquisitely coordinated effort by some 50 different tree species. Now, after a 14-year investigation, a team of US and Indonesian researchers led by Lisa Curran (University of Michigan in Ann Arbor) has uncovered the secret to the synchronicity of these extraordinary events.

Borneo's remarkable botanical bounty is produced by members of the tree family that dominates the canopies of most South-East Asian tropical forests—the Dipterocarpaceae (or dipterocarps). Their sporadic reproduction is known as 'mast-fruiting' and they have negligible seed production during intervening years. Such a strategy has probably evolved at least partly in response to pressure from



COURTESY CLAUDE GASCON, CONSERVATION INTERNATIONAL

The poison dart frog *Epipedobates femoralis* reveals the Amazon's buried secrets.

seed predators. Each masting is intended to produce so much food that the many animals plundering the booty are quickly sated, leaving behind enough seeds that will survive to germinate.

Curran's research team started looking in 1986 for the trigger that prompts so many different tree species over such a wide-ranging area to set fruit within weeks of each other. The team conducted field trials in Gunung Palung National Park and compared their observations with climatic data. They found a pattern that clearly correlated mast events with El Niño-Southern Oscillation cycles. These occurred at irregular intervals every three or more years, with the start of each cycle marked, in particular, by a huge decrease in the June-to-September rainfall.

Unfortunately, however, the researchers uncovered another notable trend. During the last three of the four mast events they witnessed, the animals weren't leaving as many seeds behind, resulting in a decline in the establishment of viable seedlings. One of the main reasons, the research revealed, was due to loss of trees by logging.

The long-term future of Borneo's forests looks bleak, it seems, unless there are some dramatic changes in land-use practices on the island.

—K.McG.

Ridges or Rivers?

The Amazon Basin has the greatest diversity of species on the planet. It has long been thought that the river itself is responsible for this diversity, as the meandering Amazon and its labyrinth of tributaries cut off pockets of land where animals become isolated and genetically distinct. However, a new study on the poison dart frog *Epipedobates*

femoralis has revealed that other hidden forces may be more important in shaping life in Amazonia.

Stephen Lougheed of Queen's University, Ontario, and colleagues have been mapping DNA sequences from different populations of this predominantly terrestrial frog. If the river is the driving force of diversification, it follows that frogs on opposite sides of the river bank should be genetically distinct, and differences should become exaggerated as the river widens. Yet the frog DNA shows both riverbank populations to be similar. Instead, the greatest genetic difference occurs between the headwater and all other populations, about 800 kilometres upstream from the mouth. This area coincides with an ancient ridge, known as the Iquitos Arch, that once extended hundreds of kilometres in a direction at right angles to today's river. A similar pattern of divergence has also been reported in rodents.

Five to 15 million years ago the ridges dominated the landscape, crisscrossing the region and impeding gene flow.

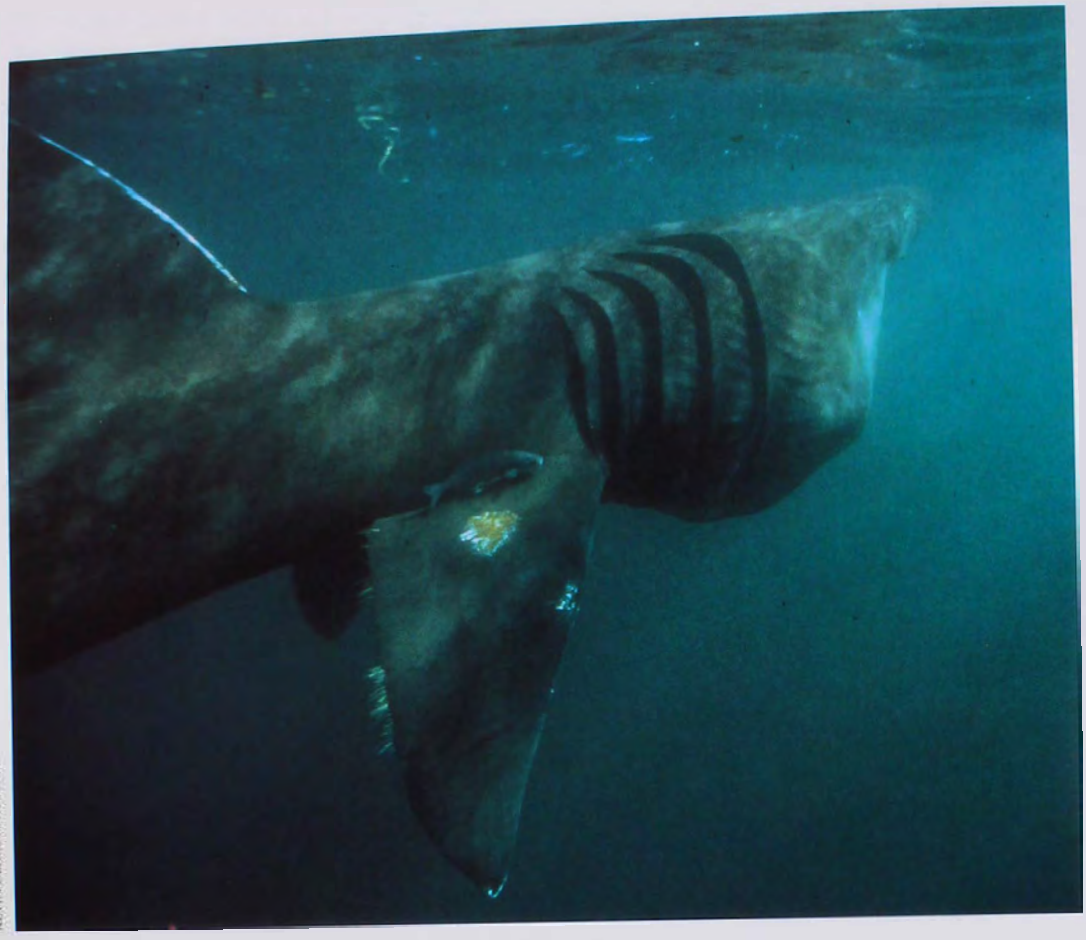
It is little wonder that scientists missed the importance of Amazonian ridge lines, for these massive formations are now buried in sediments. Five to 15 million years ago, however, the ridges dominated the landscape, crisscrossing the region and impeding gene flow. Although now hidden, the invisible force of these ancient boundaries has shaped the patterns of species distribution and created the richest assemblage of animals in the world today.

—K.H.

The Cost of a Big Open Mouth

Feeding for a Basking Shark (*Cetorhinus maximus*), the world's second largest fish after the Whale Shark, is a drag...quite literally. It forages by swimming forward with its huge mouth agape, collecting and filtering out tiny animals (zooplankton) from the world's temperate coastal waters. Because the open mouth increases resistance against the water, eating like this requires more energy than normal swimming.

Calculations published in the scientific literature in 1954 estimated that Basking Sharks need to forage in waters with zooplankton concentrations of at least 1.36 grams per cubic metre, just to meet the energy costs of feeding. This threshold led to the idea that Basking Sharks live on an "energetic knife-edge" and has been used to explain annual disappearances of these fish from coastal waters. The theory goes that, unable to cope with the energy deficit incurred by feeding on the low zooplankton concentrations present throughout the coldest months, Basking Sharks migrate to deep waters and hibernate during



KEVIN DEACON/AUSCAPE

Why do Basking Sharks disappear from coastal waters during winter?

winter to conserve energy.

Now David Sims (University of Aberdeen, UK) is challenging this 50-year-old theory and the figures behind it. According to Sims' own theoretical calculations and field observations of Basking Sharks feeding in the English Channel, the foraging threshold for these fish is considerably lower than previously accepted—about 0.62 grams per cubic metre. Zooplankton concentrations above this lowest limit are often found during the coldest months in coastal waters frequented by Basking Sharks.

This means that an energy-saving, overwintering hibernation is not necessary for Basking Sharks. Sims speculates that the reason the sharks disappear from coastal waters during winter may be to court and mate in as-yet-to-be-discovered deep-water breeding grounds (although recent sightings of Basking Sharks mating in British surface coastal waters in summer make this doubtful). Perhaps they disappear to feed on zooplankton that overwinter in deep water.

—K.McG.

Burying Burrowing Origin for Snakes

The present is not the key to the past. At least this is the message that comes from some recent studies on the evolution of snakes.

It has long been assumed that snakes got their 'snakiness' (lack of limbs and long cylindrical body) through adaptation to a burrowing lifestyle. After all, the most primitive living snakes (such as the small worm-like blind snakes) are burrowing, and it all seems to make sense: if you make a living sliding through narrow burrows, legs become an impediment and so they eventually get lost, while an elongate slender body is distinctly advantageous.

But it just ain't so, according to John Scanlon and Michael Lee from the University of Queensland, who have taken a closer look at an extinct group of boa-like snakes known as the madtsoiids. They looked at 234 features of these snakes and all their slithery kin to work out their relationships. It turns out that none of the early, primitive snakes was a burrower. Instead they either swam in oceans or hunted above ground. So it's time to rethink the burrowing origins for snakes.

Why has it taken so long to analyse these primitive snakes? It's a bony question. Fossil snakes, including most of the madtsoiids, are usually known only from vertebrae, yet it's the skull that has all the really useful bits that help work out relationships. Fossils of skull elements from the huge madtsoiid *Wonambi* (Aboriginal for 'dream serpent') have only just come to light in Riversleigh (Queensland) and Naracoorte (South Australia), allowing the snake people to put the puzzle together.

But wait—there's more! Perhaps it's the marine connection that holds the clue to snake origins. In another paper, Lee and colleagues took a deep look into the mouths of mosasaurs—those enormous turtle-chomping lizards of the Cretaceous seas. They concluded that mosasaurs were the oral intermediate between lizards and snakes, for they found the perfect precursors to the rather complicated dislocating gob of the modern snake.

With the link between lizards and snakes via mosasaurs now established, perhaps some more thought will be given to just how a bulky marine ancestor bequeathed so many snaky features to their descendants. Stay tuned.

—Paul Willis
Quantum, ABC TV

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ILLUSTRATION BY PETER SCHOUTEN / HAND COLOURED BY LORRAINE FOSTER

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QUICK QUIZ

1. *What is the name given to floating volcanic rocks?*
2. *Which species of albatross is the only one to breed entirely within Australia?*
3. *What is the name of the massive underground water supply discovered in the Western Australian goldfields in May 2000?*
4. *In which year did the last Thylacine in captivity die?*
5. *What are angiosperms more commonly known as?*
6. *Name the second largest planet orbiting the Sun.*
7. *What do the larvae of mud-dauber wasps eat?*
8. *Which species of Australian snake is the longest?*
9. *What are CFCs?*
10. *On which island in Sydney Harbour is Fort Denison located?*

(Answers on page 83)

The happy hooker?

To some people the sound of the Grey Butcherbird means the prospect of a cheeky visit from a familiar friend…to others it sends a cold shiver up their spine.

NICHOLAS BIRKS/WILDLIGHT

A Grey Butcherbird has wedged its prey into the fork of these branches and is proceeding to tear it apart.

AN ESCAPED CANARY ONCE flew into our backyard and my cleric father, who must have had closet aspirations for the fire brigade, braced himself behind the garden hose and baptised the poor Canary under such pressure that the christening almost ended with the last rites. So we got another little cage, another four-inch nail, and the new Canary and our old miserable Budgie spent sunny days back to back on one of the tree trunks in our yard.

Despite its rude welcome, the Canary was everything the Budgie wasn't. It jumped happily around its cage while the Budgie moped; it sang a full-throated chorus while the other regurgitated over its own reflection; it bubbled with the *joie de vivre* while the Budgie smouldered with unrequited love. Then, in mid-warble, disaster struck. A Grey Butcherbird flew down and dragged half the Canary out through the bars of its cage. I suppose that said something for the butcherbird's power of discrimination, but we were left with a pile of yellow feathers and the tough old Budgie that lasted for another year until my father slept through its terminal epileptic fit.

Since that day I've watched Grey Butcherbirds (*Cracticus torquatus*) fly off with all sorts of things…day-old Bantam chicks, the children's pet white House Mice, young Bearded Dragons, Dog biscuits, T-bones, apricots, as well as their staple diet of insects, small birds, bats, and pieces of cheese or salami snapped from slow sandwiches.

In these days of black polystyrene meat trays and refrigerated use-by dates, goodness knows how the present generation of city slickers is expected to twig to the derivation of the word 'butcherbird'. Does this bird bind up its food in Glad Wrap? The time-honoured explanation is this—being food hoarders, butcherbirds kill their prey, fly off with it to snag it on an appropriate hook or twig, then perhaps fly back for more of the same while the prey species abounds. It was this practice of hooking and hanging their meat and dismembering it later (albeit by tugging and tearing) that gave butcherbirds their common name. But who has ever seen them actually hooking up food? Every time I think I'm onto that bit of behaviour, all I see is the bird dragging the prey along a rough branch or between twigs, and finally wedging it in such a way that it can be tugged at and dismembered.

Long-time butcherbird observer Dariel Larkins, who has recorded Grey Butcherbirds with all sorts of prey items from apple cores to yellow nylon socks, is convinced these birds are not, in fact, hookers at all, that myth being perpetuated from the earliest days when it was assumed they were closely related to the true Afro/European shrikes (family Laniidae), which do use hooks and thorns to secure their meals.

My wife has observed that butchers behind the counter have a certain way with women, not overtly sexual, but definitely suss. I think it's got something to do with their macho provision of a commodity the customers' husbands just can't deliver themselves. Whatever it is, men are not fooled by knife-flashing butchers and, relieved to avoid their competitive presence, we embrace the anonymity of the Woolworths meatorama.

BY STEVE VAN DYCK

To be honest, the Grey Butcherbird is a species I just cannot come to reasonable terms with either. All the bravado, muscle flexing, clacking of blades, and tender offerings of meat to the opposite sex is a bit of a turn-off. No wonder some people see them as over-equipped brutes when it comes to their dealings with the smaller birds on their patch. Often a butcherbird's territory contains nothing much more than themselves, Noisy Miners, and one or two other equally aggressive species.

There is not much point whingeing about it, doing the Australian 'tall poppy' thing and knocking the clever and successful. Life in the 'leafy' suburbs is no bed of roses. It's still all about Dogs, Cats, slingshots, toughness, brains, hunger...Canaries. To adaptable butcherbirds, a suburb is just a chunk of disembowelled woodland full of short grass, open views, occasional tall trees and cheek-by-jowl Jennings brick caves from which fly all sorts of tempting treats like cheese, chopped meat and barbecue scraps. There they wait and watch, patiently scanning the scenery from a midstorey twig, then drop down and attack. Snipers. In areas of thick ground cover where wrens, finches and small honeyeaters occur, Grey Butcherbirds find it more difficult to operate because the small birds either escape into the undergrowth or they conceal their nests and contents within it.

The frustration associated with butcherbirds in the suburbs is this. Although you might plant your garden with all the recommended small-bird attractants (low twiggy shrubs, seeding grasses, nectar-producing flowers), the butcherbirds knock off the small birds on their way to your place, and their conspirators, the Noisy Miners, move in and harvest the nectar! The combined bullying effect of butcherbirds and Noisy Miners is so formidable that nature lovers busily birdscaping their gardens often throw in the towel and resign themselves to a garden where all feathers are grey!

Like their more conspicuous black-and-white relatives of the open woodlands and suburbs (Pied Butcherbirds, Magpies), Grey Butcherbirds have deliciously melodious calls that define territories, attract mates, service bonds and raise alarms. Some calls are choreographed so that unique phrases are sung only by the male, but they receive an immediate answer with an equally unique response by his mate. This soft, smooth interchange stands in stark contrast to the abrasive, gurgling chatter the birds engage in when mobbing and beak-snapping at a snake or an owl trying to look inconspicuous in a tree. Their most commonly recognised call, however, is rich and tuneful, and sung with force and apparent defiance. This call must set small feathery knees a-trembling.

To some people the sound of the Grey Butcherbird means the prospect of a cheeky visit from a familiar friend bold enough to come into the house and take food from human fingers. To others though, that voice sends a cold shiver up their spine, because with it comes cool killing efficiency guaranteed to reduce the number of small birds in your yard, or at least limit their reproductive efforts. But butcherbirds pursue life with as much natural efficiency as a pelican catching fish or a cockatoo cracking corn, so it's pointless to describe them as 'heartless' or 'cruel' birds. You give them the habitat that they were selected for and they'll occupy it. Hookers they might not be, but a vacant street corner and a good view are just about all this bird needs to make an honest living.

Grey Butcherbird

Cracticus torquatus

Classification

Family Artamidae (butcherbirds, magpies, currawongs, woodswallows), 4 butcherbird spp. in Aust., 4 in PNG (2 of these also in Aust.).

Identification

Half-magpie size. Black-capped head, grey-white throat and belly, slate-grey back, broken white collar. Strong blue-grey beak heavily hooked at black tip (beak bigger in male). Juvenile dirty brown-grey. Length 280 mm.

Distribution

Aust. south of around 20° but absent from NT/Qld/SA border area. Throughout most leafy cities and suburbs and in open woodlands to milder deserts.

Food

Omnivorous but mainly insects, small birds, mammals and reptiles, fruit. Connoisseurs of Blue Castello and Kameruka cut in cubes and stylishly arranged on verandah handrail.

Reproduction

Breeds mid-winter to early summer. Territory size around 5 ha, depending on habitat. Nest is a harsh cup of twigs but lined with a soft centre of bark and grass. Only female incubates 3–5 brown-blotched olive eggs (30 mm long) for 25 days. Male feeds female during incubation and brooding. Young leave nest at about 26 days old. Pairs usually manage to raise only 1 brood per year. Before attaining adult colour in their 2nd year, young may help raise subsequent brood.

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Dr Steve Van Dyck is a Senior Curator of Vertebrates at the Queensland Museum.

Peach Myrtle

Peach Myrtle was restricted prior to European settlement and so may be 'naturally' rare.

PEACH MYRTLE (*UROMYRTUS AUSTRALIS*) is an attractive rainforest tree confined to a small area in far north-eastern New South Wales. It is the most southerly member of an ancient genus and appears to be highly specialised, being found only in low numbers within a limited area of upland rainforest.

The landscape of far north-eastern New South Wales is dominated by the remains of the great eruptions that formed the Tweed Shield Volcano more than 20 million years ago. The lava flows varied in composition, and their overlay and subsequent weathering have shaped the land into a ring of elevated mountains and plateaus encircling the central Mt Warning volcanic plug, and rising above rich valleys of basalt-derived soils. Remnant basalt caps remain on some high areas, but the peaks and ranges of the southern and eastern Nightcap Range are dominated by rhyolite—a more erosion-resistant acid volcanic rock similar to granite. It is only on these rhyolite uplands, in a small area on the Nightcap Range, and nearby Mt Jerusalem and Koonyum Range, that Peach Myrtle may be found.

Rhyolite-derived soils are relatively infertile compared with basalt-derived soils, and this has a profound effect on the vegetation. The basalt soils support complex subtropical rainforest, while the rhyolite soils tend to support simpler warm temperate rainforest dominated by Coachwood (*Ceratopetalum apetalum*) and its relatives. Peach Myrtle is scattered within the dense mid-storey of this misty upland rainforest, in an area where the rainfall is the highest recorded in New South Wales.

Peach Myrtle grows to about 15 metres, and is superficially similar to some other members of the Myrtaceae family, but distinct in several ways. Most prominent are the flowers, which are at first white, then pink and finally magenta when mature, and hang on pendent stalks. They have a characteristic appendage on the anthers from which the genus name *Uromyrtus* (= tailed myrtle) is derived. There are four Australian members of *Uromyrtus*, all of which have very limited distributions. Two are in northern Queensland, while the other (as yet unnamed) is confined to the eastern McPherson Range on the New South Wales–Queensland border.

Probably less than 1,000 Peach Myrtles exist in the wild, although the plants are often multi-stemmed and so can appear more numerous than they really are. Many individuals appear to be very old, growing slowly and sprouting more than once from the base. Peach Myrtle's requirements seem more specific than those of the broader rainforest habitat, as its distribution is patchy and the species is absent from areas of superficially suitable habitat.

Peach Myrtle is formally listed as endangered, reflecting its small range and low numbers. However, reasons for the low numbers and ongoing threats are not immediately obvious. Processes such as wholesale clearing have been limited, and forest cover and possible pollinators (insects) and seed dispersers (small birds) remain over most of its range. The principal land use has been forestry of varying intensity, although its full impact on Peach Myrtle is unknown. The species can tolerate some mechanical damage (by suckering from the roots), but the effects of fire, often used in forestry operations, is much less clear.

Even so, it appears that Peach Myrtle was restricted prior to European settlement and so may be 'naturally' rare. The apparently specialised habitat needs, plus the distribution and ancient origin of *Uromyrtus* (which arose on Gondwana and is now centred on New Caledonia), suggest Peach Myrtle is a relict species. It seems to have adopted a 'hermit' strategy of retreat to a mountain stronghold over long periods of climatic and geological change.

What this means for the protection of Peach Myrtle is not entirely clear. 'Natural' rarity can arise for a number of reasons, and rare species are not always threatened with imminent extinction, especially if limited habitat and/or small numbers do not compromise essential activities such as reproduction. On the other hand, a species must become rare before going extinct.

Understanding the particular nature of Peach Myrtle's rarity is vital in determining conservation strategies. Studies on population dynamics are especially important and have already commenced. If numbers are currently declining, urgent measures may be required. Even if this is not so, the hermit strategy of low numbers and limited range means an elevated risk from such threats as occasional catastrophic wildfire and climate change.

The good news is that most of the Peach Myrtle's habitat is now contained within the national park system, and a recovery plan is being prepared. With sympathetic conservation management, there is every hope Peach Myrtle will continue to survive, if never really thrive, in the mountains of the Nightcap.

BY NICK WILSON

NICK WILSON IS A BIOLOGIST WHO WORKED AS A CONSULTANT TO THE NSW NATIONAL PARKS AND WILDLIFE SERVICE ON THE *UROMYRTUS AUSTRALIS* SPECIES RECOVERY PLAN.

NICK WILSON

City of frogs

On hot steamy nights they chorus from garden ponds in almost every street.

PHOTOS: TIM LOW

Brown-striped Frogs are the 'weeds' of the frog world, thriving in highly disturbed situations, including inner-city gardens.

IN THE SPRING OF 1981 MARTIN and Hillary Boscott, a Brisbane brother and sister, found a pair of Green Tree Frogs (*Litoria caerulea*) mating in their swimming pool, at a time when the chlorine level was low. They scooped out the eggs and reared the young. In 1982 the frogs returned and more eggs were laid. The next spring was different—instead of a pair of frogs, dozens of young adults came to breed, presumably the offspring from 1981, and the Boscotts had 2,000 tadpoles to raise. But this was only the beginning. By 1984 the Boscotts had 300,000 tadpoles to cope with, and they began giving them away.

A journalist learned about their giveaways, and the Boscotts found themselves on radio and television. Suddenly they were celebrities. Hundreds of people were clamouring for their tadpoles. Many older folk remembered a time when Green Tree Frogs lurked in their toilets and laundries, and the Boscotts' vision of a frog-loving city struck a resonant chord.

The Boscotts had to organise their giveaways. "From the mid 1980s to the early 1990s the number of people who wanted tadpoles was overwhelming", Martin told me. "It was extraordinary. We had organised sessions to give them away. Up to 200 people would come in a single afternoon. We put a limit of one parent and one child per collection. We'd give a 15-minute talk, quickly give them the tadpoles, get rid of the people who wanted to ask the extra questions, pause to have a quick cold drink, then another crowd would arrive." Notes provided with the tadpoles explained the basics of pond design, and hundreds of people had frog ponds installed.

Brisbane now abounds in frogs. On hot steamy nights they chorus from garden ponds in almost every street. Brisbane wasn't like that 15 years ago. The Boscotts ignited a remarkable ecological and social phenomenon, one with few parallels in Australia.

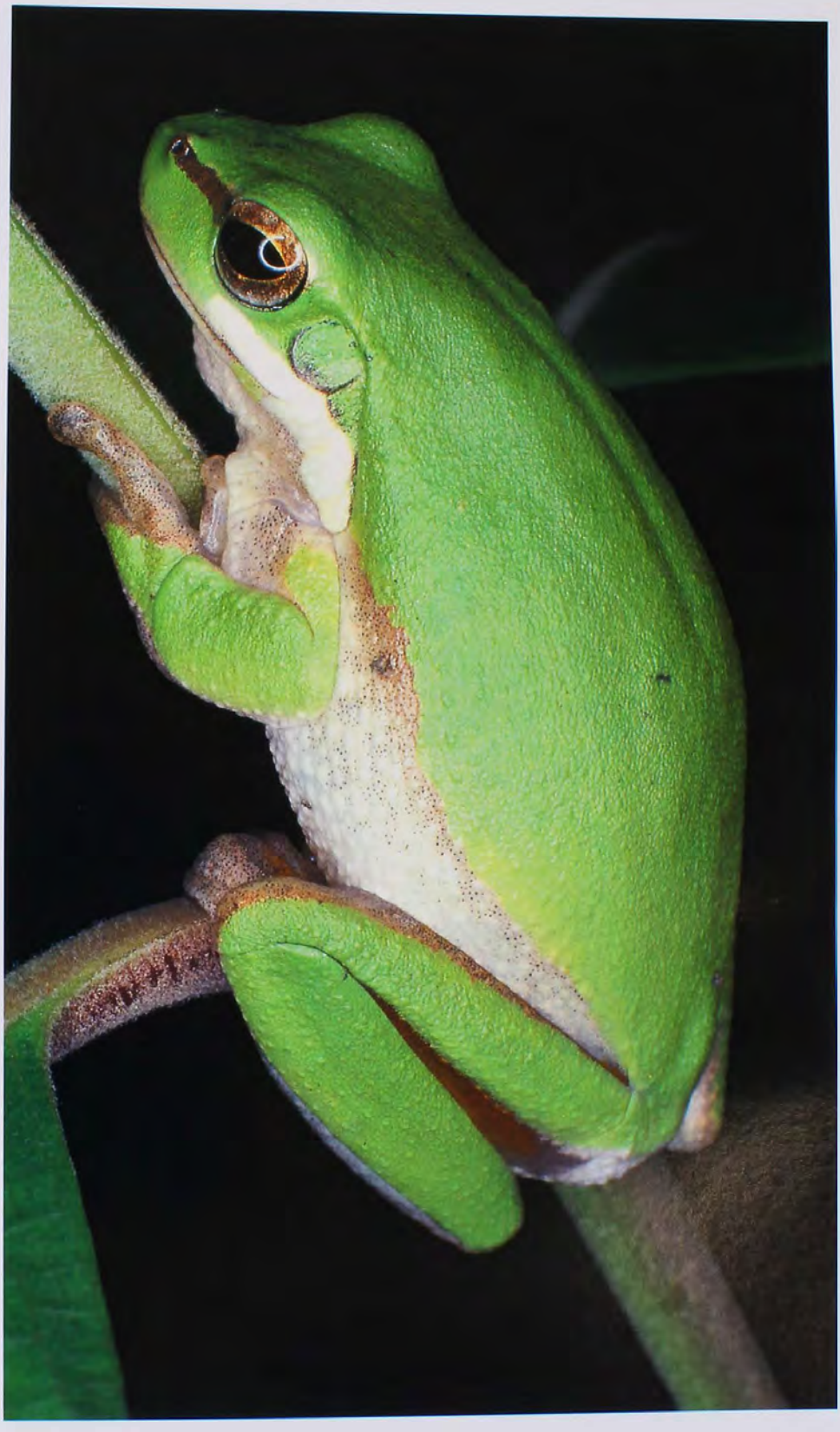
But the main beneficiaries have not been Green Tree Frogs. In 1984 Dainty Green Tree Frogs (*Litoria gracilenta*) visited the Boscotts' pool, followed by Brown-striped Frogs (*Limnodynastes peronii*) two years later, and the Boscotts distributed tadpoles of these as well. Green Tree Frogs are more popular because they are big and 'friendly' and enter houses, but many people took the other tadpoles as well. The dispersal of so many tadpoles, and creation of so many ponds, has allowed Brown-striped Frogs to explode in numbers. Their incessant 'pok pok pok' choruses now keep residents awake and trigger neighbourhood arguments. Some pond-owners regret introducing them, and now remove their spawn; others even kill the adult frogs. One proud pond-owner, Steve Rhodes, told me he scoops out hundreds of thousands of their eggs each year, to give other species a better chance.

Brisbane now has two frog groups, boasting more than 700 members between them, and one of them, RANA (Restoring Australian Native Amphibians), has taken over from the Boscotts as the focus for tadpole distribution, although it refuses to deal in Brown-striped Frogs. Frog-breeding is nowhere near as popular in Sydney and Melbourne, where State laws forbid movement of wild tadpoles, and the climates and gardens suit frogs less.

BY TIM LOW

Brisbane's frog resurgence is an extraordinary, heart-warming phenomenon, but one that raises a number of questions. First, should tadpoles be moved from place to place? Some of the Boscotts' frog progeny have found their way down to Sydney and up to Cairns, mixing up the gene pools of local populations. Some zealous frog fans are taking tadpoles outside their original range. In 1999, while weeding my garden, I uncovered something that made me gasp. Crouched under a tuft of grass was a Fletcher's Frog (*Lechriodus fletcheri*), a rare species of high-altitude rainforests. Someone had probably taken tadpoles from a mountain reserve to rear in a Brisbane pond. Not only were they depleting native stocks, they were possibly creating a new feral population—Fletcher's Frogs don't belong in Brisbane and shouldn't be allowed to establish. I've also heard of local ponds and streams carrying Red-eyed Tree Frogs (*Litoria chloris*), another montane rainforest species. Also of concern is that huge numbers of pond-reared Brown-striped Frogs will descend upon natural wetlands and displace dwindling colonies of other frogs. Because of such concerns, and the very real risk of spreading disease—notably the chytrid fungus (*Batrachochytrium dendrobatidis*), which is prevalent in Brisbane ponds—the Queensland Frog Society is opposed to the redistribution of tadpoles. Build a pond, they say, but let the frogs move in. RANA's policy is only to move tadpoles locally.

Frog breeders are motivated to help frogs, but only a few Brisbane species have benefited—the three I have mentioned, plus Eastern Dwarf Tree Frogs (*Litoria fallax*), and the occasional Tusked Frog (*Adelotus brevis*) and Ornate Burrowing Frog (*Limnodynastes ornatus*). RANA members are dabbling with others. At Steve Rhodes' pond I heard the chuckle of a Peron's Tree Frog (*Litoria peronii*), the progeny of a tadpole he obtained, but this species is fussy and it rarely spawns in city ponds. Martin Boscott says that all frogs benefit from the popularity of breeding, and I can see his point. Children who rear frogs are likely to grow up concerned about the plight of all species, including declining rainforest frogs. I only hope that all frog breeders resolve to act responsibly, by limiting the spread of tadpoles, otherwise they run the risk of doing more harm than good.



Eastern Dwarf Tree Frogs will live around garden ponds and dams, provided there are plants to cling to.

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TIM LOW IS A CONSULTANT AND WRITER LIVING IN BRISBANE. HE IS THE AUTHOR OF FIVE BOOKS, THE MOST RECENT OF WHICH IS *FERAL FUTURE*.

BLIND DIGGERS IN THE DESERT

BY GRAHAM THOMPSON, PHILIP WITHERS & ROGER SEYMOUR

The capture of a single live marsupial mole provided us with a rare opportunity to study these unique and little-known marsupials.

MARSUPIAL MOLES (*NOTORYCTES*) are the most unusual of all Australian marsupials, as they are the only marsupials that live almost entirely under ground. They seem to be restricted to the sandy desert regions of central and western Australia, and to survive there, they need to be highly adapted desert dwellers. Early researchers provided us with considerable detail about their morphological adaptations to a burrowing (fossorial) lifestyle, but we know little about their physiological adaptations, not even their body temperature. The capture of a single live marsupial mole from Western Australia provided us with a rare opportunity to study the physiological adaptations of these unique and little-known marsupials.

Two very similar species of marsupial mole have been described: *Notoryctes typhlops* from central Australia, and *N. caurinus* from the north-west. Little is known of *N. caurinus*; even its taxonomic status is uncertain, with many researchers treating it as synonymous with *N. typhlops*.

Notoryctes typhlops was first described in 1888 by E.C. Stirling. He noted its striking similarity with the placental golden moles (family Chrysochloridae) from southern Africa, but speculated it might be a monotreme because he could find no trace of a separate urogenital orifice in the poorly preserved specimen. This feature was found in later specimens and the marsupial nature of the mole was soon undoubted. However, the exact systematic position of marsupial moles within marsupials is still not clear, although it is apparent that they are sufficiently different from other marsupial groups to warrant separate familial status.

In 1920, the second species of marsupial mole, *Notoryctes caurinus*, was described by Oldfield Thomas from a single female caught in August 1910 at Eighty Mile Beach, on the north-west coast of Western Australia. This new species was described as being generally smaller than *N. typhlops*, having a smaller skull, a shorter and narrower muzzle, a nasal opening of lesser height, larger tympanic bullae (bone coverings of the middle ear), and smaller and fewer

MIKE GILLAM/AUSCAPE

(Above) *Notoryctes typhlops* was reported to eat centipedes but the smaller *N. caurinus* would only eat beetle larvae.

(Right) This is the site west of Kiwirrkurra where local Aborigines reported catching marsupial moles.

WITHERS THOMPSON

teeth. But this specimen was probably not the first *N. caurinus* to have been collected by non-Aborigines. In 1907, a government surveyor by the name of Trotman caught a marsupial mole in the north-west of Western Australia; but when he asked the local Aborigines about its habits, he did not learn much. This may have been more a result of his inability to effectively communicate with the local Aborigines. Since the first descriptions of *N. caurinus* from

PHIL WITHERS THOMPSON

In soft sand *Notoryctes caurinus* leaves a very characteristic track. The furrow caused by the tail and the lateral marks left by the hind feet are most noticeable.

Western Australia, relatively few specimens have been collected. To our knowledge, nobody had ever maintained a live *N. caurinus* in captivity for any time. Practically nothing is known about its natural history, behaviour and physiology, as is also true for its sister species.

BOTH MARSUPIAL MOLE SPECIES have a compact body and short limbs, and are covered with a rich cream to golden fur. The rostrum (nose) bears a pad of thickened skin and the tail is short and cylindrical. There are no external eyes or ears, although ear openings are present beneath the thick fur. The degenerate eyes are only hollow balls of pigmented cells lying underneath the skin; there is no lens, retina or optic nerve, so it is unlikely that marsupial moles can detect light. Their forelimbs have two well-developed flattened claws for digging. They generally do not leave a recognisable burrow since the loose sand often fills the opening as the mole moves forward. They thus appear to 'swim' through the sand. On the surface, marsupial moles move at a slow pace, often dragging their rear feet and tail, and leaving an easy-to-identify track.

With nothing at all known about the physiology of marsupial moles, we were intrigued by the possibility that their metabolism and pattern of thermoregulation might be as specialised as their morphology, and be more like the physiology of the placental African golden moles, than other marsupials. We had studied the unusual physiology of the Namib Desert Golden Mole (*Eremitalpa granti namibensis*), and so had a good physiological basis for comparison (see *Nature Aust.* Autumn 1998). Namib Desert Golden Moles have a lower and more variable body temperature, and a lower metabolic rate, than typical mammals. Therefore, in 1997 we decided to search for a live marsupial mole to study. We widely circulated a poster that offered a reward for information leading to the capture of a live marsupial mole. A number of people contacted us with details of recent sightings—from Uluru National Park in the Northern Territory, Lake Gregory in the north of the Great Sandy Desert, Kiwirrkurra toward the western edge of the Western Australian section of the Gibson Desert, and Nifty and Telfer mine sites to the west of Rudall River National Park. We went to both Kiwirrkurra and the Nifty mine site to search for moles, but with no success.

WE DON'T KNOW

if marsupial moles will drink, either from water droplets at the surface after rain, or by sucking water out of moist sand.

Eventually, in August 1998, a live marsupial mole was found at Punmu, a remote Aboriginal community near the Rudall River National Park. Phil Withers flew to Punmu the next day, to collect and bring the mole to Perth for study. We found that this marsupial mole, positively identified as *N. caurinus* by Ken Aplin of the Western Australian

A 35-gram marsupial mole (*Notoryctes caurinus*) comfortably fits in a human hand.

WITHERS THOMPSON

Museum, resembles the Namib mole and other specialised fossorial mammals in having a low and unstable body temperature, ranging from 15–30° C. Unlike the Namib Desert Golden Mole, *N. caurinus* does not have an unusually low basal (resting) metabolic rate. The metabolic cost of 'swimming' through sand is similar for both the marsupial mole and the golden mole, and is about 60 times higher than the metabolic cost of walking or running on the surface. However, the cost of sand-swimming is much lower than the cost of excavating a burrow in compacted soil. So, marsupial moles have some physiological specialisations for their sand-burrowing existence. But are they adapted to living in a desert?

Maybe not! Their small size and fossorial existence allow marsupial moles to avoid the extreme high temperatures and low humidities characteristic of daytime conditions in deserts. Even a few centimetres under the sand surface, the temperature is considerably lower than the daytime air temperature, and the humidity is much higher. Marsupial moles gain water through their food and metabolism. Our captive mole only consumed the moist abdominal contents from large, soft-bodied insect larvae, leaving the harder head and thorax regions. Being small, the mole would also produce a significant amount of water from its metabolism, despite having a relatively low metabolic rate for a mammal. We don't know if marsupial moles will drink, either from water droplets at the surface after rain, or by sucking water out of moist sand. But, given the infrequent occurrence of rainfall, it is unlikely that they would rely on drinking.

If water intake is limiting for marsupial moles, then we would expect adaptations for conserving water, although living under ground at high humidity would reduce respiratory and skin evaporation. Recently we studied the structure of a marsupial mole's kidney and did not find it to be particularly specialised. It lacked the enlarged central medulla region and long medullary papilla that are characteristic features of

Marsupial Moles

Notoryctes spp.

Classification

Family Notoryctidae. Two recognised spp.: *N. typhlops* and *N. caurinus*.

Identification

Cannot be confused with any other marsupials. Both spp. have large nose pad, short hairless tail, strong heavily clawed fore- and hind limbs, no eyes, and creamy-gold short thick fur. *Notoryctes typhlops* up to 19 cm long, whereas *N. caurinus* smaller (up to 14 cm long) with smaller and fewer teeth.

Distribution

Sandy deserts of central WA, southern NT and northern SA. Exact distribution of the 2 spp. unknown, although *N. typhlops* has been found in eastern and southern sections of sandy inland deserts of Aust. and *N. caurinus* in the north-west of the Great Sandy Desert.

Behaviour

Fossorial (burrowing), only coming to the surface occasionally; little else known of their behaviour.

Diet

Poorly known. Stomach contents of *N. typhlops* contain mostly eggs and adults of ants and termites. In captivity *N. typhlops* will eat beetle larvae, centipedes and lizards; *N. caurinus* only ate beetle larvae.

Reproduction

Little known. Like other marsupials the female suckles young in a pouch. Pouch faces towards rear to avoid filling with sand.

KYLE ARMSTRONG

The large rostrum and claws of marsupial moles (in this case *Notoryctes caurinus*) are an obvious adaptation for digging in the sand.

many desert dasyurid marsupials and rodents. Its faeces, which we might also expect to be relatively dry to conserve water, were instead a very watery green paste. So, contrary to expectations, marsupial moles do not seem to be physiologically adapted to desert life—rather, their underground habitat and diet insulate them from their desert surroundings.

The extreme morphological adaptation of *Notoryctes* but lack of physiological adaptation to desert life is consistent with the discovery of 20-million-year-old marsupial mole fossils from the rainforest deposits of Riversleigh, north-western Queensland (see *Nature Aust.* Spring 1989). It appears that the moles' more obvious desert adaptations (body shape and spade-like limbs used to burrow through desert sands) evolved well before Australian deserts did. These morphological features may have originally been for burrowing through thick mosses on the rainforest floor, and were put to other uses (sand-swimming) in sandy desert environments.

WHERE TO FROM HERE? Our preliminary physiological study of a single specimen of *N. caurinus* needs to be supplemented with more data from other marsupial moles of both species, especially in the field. We need to learn more about the ecology, biogeography, reproduction, social organisation and the phylogenetic status of these unique marsupials. Ultimately, we also need to learn how to keep and breed marsupial moles in captivity. Our first *N. caurinus* ate only insect larvae and rejected adult insects and small vertebrate prey, and unfortunately died after five weeks in captivity when it suddenly stopped eating. To avoid this problem in future we will experiment by supplementing the diet with a range of other possible food items, including ant eggs and larvae.

If you know of a recent sighting or can provide us with any information on marsupial mole ecology, natural history or a suitable field study site, we would be interested in hearing from you. We can be contacted on 08 9400 5427 (Graham Thompson), 08 9380 2235 (Philip Withers), or 08 8303 5596 (Roger Seymour).

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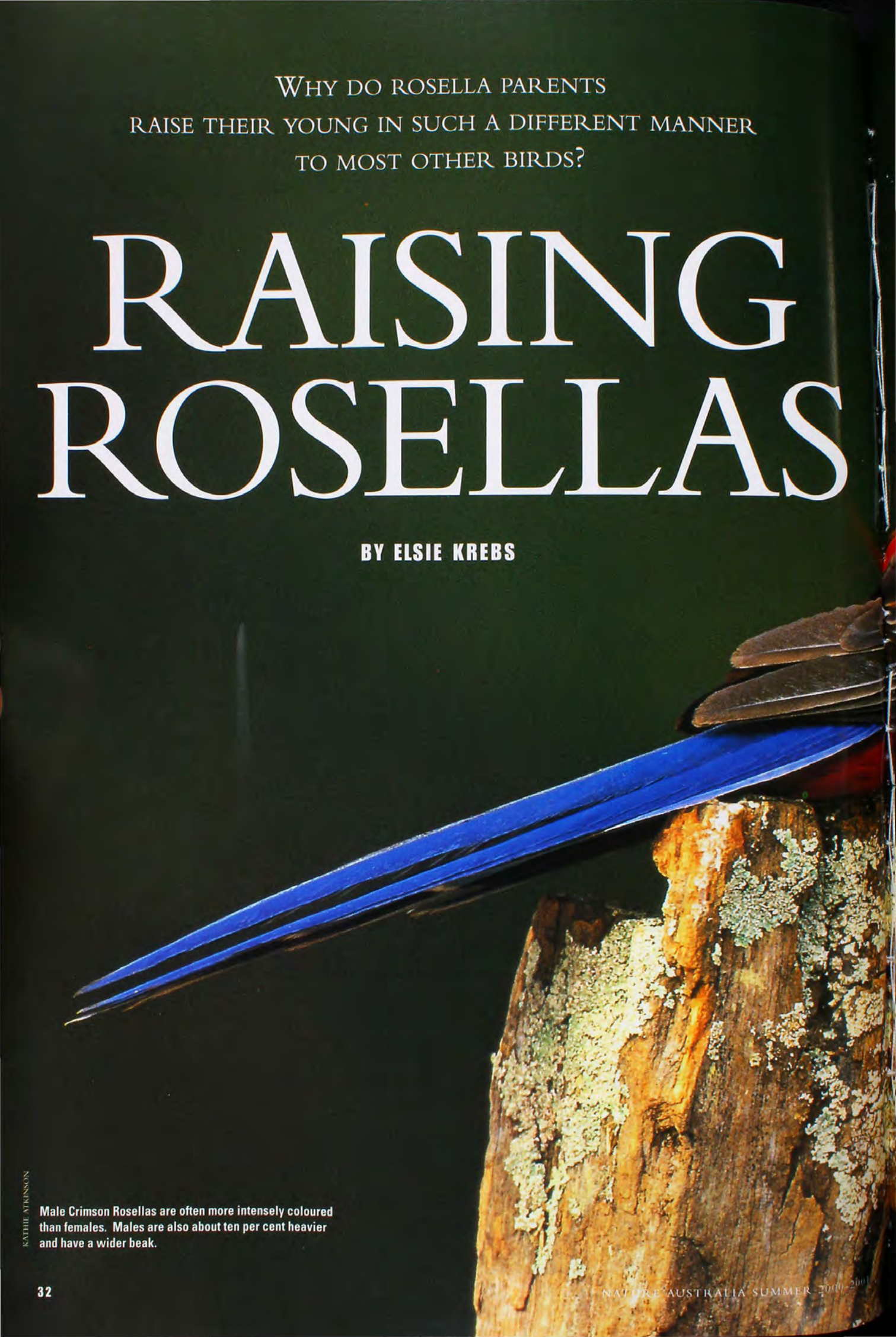
KYLE ARMSTRONG

When placed on the sand, our captive *Notoryctes caurinus* would immediately begin to burrow.

WHY DO ROSELLA PARENTS RAISE THEIR YOUNG IN SUCH A DIFFERENT MANNER TO MOST OTHER BIRDS?

RAISING ROSELLAS

BY ELSIE KREBS



KATHIE ATKINSON

Male Crimson Rosellas are often more intensely coloured than females. Males are also about ten per cent heavier and have a wider beak.

WHEN I FIRST SET foot in Australia, I was absolutely astonished to see a group of parrots (Sulphur-crested Cockatoos) feeding on a roadside verge near the airport. To me, parrots have always been the ultimate in exotic bird species—bright, big, noisy and unmistakable. So a place where such creatures were common had to be extraordinary indeed. Australia is home to one-sixth of the world's parrot species and has the greatest diversity of forms. Parrots were once considered to characterise the southern continent, so much so that early explorers referred to Australia as *Terra Psittacorum*—land of parrots.

Among parrots, rosellas (*Platycercus* spp.) have long been in Australia's national psyche. Every tomato-sauce-loving child knows the colourful figure of the Eastern Rosella (*P. eximius*). Rosellas are a large and highly successful genus that can be found in almost every corner of Australia and nowhere else. How they came to be known as rosellas is not entirely clear, but Archibald Campbell, writing in 1900, claimed that their name was a corruption of 'Rose Hill Parakeet'—a regional name for the Eastern Rosella. The colours and markings of rosellas vary around Australia and regional variants often interbreed where they meet. This has led to considerable debate about precisely how many different species and subspecies exist. Classification debates aside, there are eight major races that divide into three groups: one with white cheek patches (Eastern, Pale-headed and Northern Rosellas), one with blue cheek patches (Crimson, Adelaide, Yellow and Green Rosellas) and one species with yellow cheek patches (Western Rosella).

Arriving in Canberra in 1993 from Canada to begin my graduate work, my eye was instantly drawn to the Crimson Rosellas (*Platycercus elegans*)—who could resist parrots the colour of Christmas decorations? Much to my surprise, I could find relatively little research published about their habits, in stark contrast to the literature on common European or North American birds. Why these birds, and indeed all parrots, should be so overlooked is not clear to me. Some have suggested that familiarity with parrots as pets bred contempt in early researchers. Of course, the considerable challenges of tackling birds that nest in small hollows high in brittle gum trees, and equipped with a beak that can be either bone-crushing or razor sharp, may also have had some influence! Nevertheless, naive and keen to tackle something new, the challenge of pursuing Crimson Rosellas was irresistible.

TO CONVINCE PAIRS to breed in something a little more amenable for research than a hollow with a five-centimetre-wide entrance, I decided to put up nest boxes. Armed with wire and ladder, my partner David and I erected the boxes in the dry sclerophyll woods of Black Mountain. Rosellas are so tuned into nesting hollows that, to our delight, we could see curious birds trailing behind us to investigate. Over

Crimson Rosellas love to eat grass seeds and can frequently be seen feeding on grassy roadside verges.

JEAN-PAUL FERRERO/AUSCAPE

NICHOLAS BIRKS

Male Crimson Rosellas guard nesting hollows early in the breeding season. They feed the sitting female during incubation and while the chicks are hatching.

the six years that I have monitored these nest boxes, around 80 per cent have been occupied by Crimson Rosellas each year.

Rosellas (and most parrots) do not build nests like many other birds. Rather than bringing in new material, they renovate a hollow by cleaning it out, removing old debris (trust me, much of this is pretty disgusting) and by chewing a thin layer of soft bark on which to lay eggs. When I put up a new nest box, I place a layer of wood chips inside, so that often the first sign of interest is when the female begins tossing the chips out!

Rosellas seem to be very selective about the hollows they choose to breed in. Even though a pair can use the same hollow over several years, they still spend about two months a year investigating a variety of possible nesting sites. So, despite the fact that pairs of rosellas were visiting my boxes, I had no idea if they would actually breed in them. Fussy tenants indeed! Once the choice has been narrowed a bit, a pair stakes out a breeding territory and attempts to keep other prospecting pairs at bay. This can be serious business, and anyone who has walked in forests in New South Wales during spring will have noted the conspicuous vocal interactions between Crimson Rosellas: aggressive chattering, tail wagging and occasional all-out fights.

ARRIVING IN CANBERRA

from Canada, my eye was instantly drawn to the Crimson Rosellas—who could resist parrots the colour of Christmas decorations?

E.A. KREBS

(Left) Crimson Rosellas have a keen eye for nesting hollows and they quickly occupied empty nest boxes within the study area.

(Right) The vibrant red, blue and black plumage of Crimson Rosellas is an unmistakable feature of Australia's fauna.

Crimson Rosella

Platycercus elegans

Classification

Order Psittaciformes (parrots), family Psittacidae.

Identification

Medium-sized broad-tailed parrot. Adults red with blue cheek patches and black patterning on wings. Immatures mottled green and red to almost purely red in some individuals. Weight 110–170 g. Adult males have wider bills and are generally heavier than females.

Distribution and Habitat

South-eastern NSW and Vic. with an isolated population in southern Qld. Introduced to NZ and Norfolk Is. where they are considered a pest. Prefers forested habitat, but is found in a wide range of forest types ranging from tropical rainforest to dry sclerophyll, and at elevations ranging from sea level up to subalpine.

Reproduction

Eggs laid from late Sept. to Dec. Occasionally produce 2 broods per season. Clutch size 3–8 eggs. Incubation 21 days. Chicks remain in nest for around 35 days.

Status

Not endangered, but like all hole-nesting species, vulnerable to loss of nesting habitat due to clearing, forestry, habitat degradation and competition with introduced hollow-dwelling spp.

Egg-laying in Crimson Rosellas typically starts in early October but varies over about one month, early in wet years and later in dry years. In the ACT, the earliest egg I have recorded was during the third week of September. Once a female is close to laying, she spends more and more time just sitting in the hollow or nest box, and a couple of days later, on one of my regular checks, I am usually rewarded with the sight of one or two round white eggs.

Female rosellas, I find, have varying responses to being disturbed by a lumbering biped with a ladder. Some females sense your arrival 50 metres from the nest box and are long gone by the time you arrive. Other females sit tightly in the box, covering their eggs and just daring you to stick your hand in the box. One particularly tenacious female never allowed me to see how many eggs or small chicks she had until she had finished brooding!

Rosellas normally lay an egg every other day, so the typical clutch of six eggs takes just under two weeks to lay. Not surprisingly, the female does not remain in the hollow continuously during this egg-laying period. Serious incubation usually begins when the third egg is laid, so early-laid eggs are especially vulnerable to interference—an all too common occurrence in my study.

Mammals that use hollows as roosts during the day are a particular threat to rosella eggs. In my study area, Sugar Gliders (*Petaurus breviceps*) and Common Ringtail Possums (*Pseudocheirus peregrinus*) commonly take up residence in nest boxes. Although Common Ringtails are mainly folivorous, I have found many eggs broken and eaten in a distinctive pattern, some with Ringtail hairs still stuck to them. Easy protein, it seems, is hard to refuse!

Introduced Common Starlings (*Sturnus vulgaris*) and Common Mynas (*Acridotheres tristis*) are serious

TOM & PAM GARDNER/NATURE FOCUS

(Left) By the time Crimson Rosella chicks approach fledging, the hollow can be quite crowded. Unlike many other birds, each chick can leave the hollow when it is ready, freeing up room for younger siblings. The youngest chick has visibly less feather development and can be seen on the left.

(Below) Here is a brood of six Crimson Rosella chicks ranging in age from 15 to 20 days old. Rosella broods are often large, and can take up to one week to hatch. Although there are large initial size differences between chicks, parents feed all chicks ensuring that even the smallest chick in the brood will survive.

competitors for hollows in areas such as urban neighbourhoods with degraded or non-native vegetation. Although I suspect a Crimson Rosella could win a one-on-one battle with either of these birds, both these species start breeding earlier in the season than rosellas and, once incubating, are impossible to displace. A more diffuse threat to all hole-nesting creatures is the European Honey Bee (*Apis mellifera*), which takes over as many as 20 per cent of nest

PHOTOS: E.A. KREBS

boxes in my study area, and about half of these colonies survive over winter.

Not all threats to rosella eggs come from other species. In some years, other Crimson Rosellas are the most common cause of egg loss, and can destroy more than half of all newly laid eggs. Egg destruction by other rosellas is not simply due to competition for nesting hollows, for if eggs are destroyed in a nest box, the box remains unused for at least a month and is never reoccupied by the original pair. Rather, egg destruction is more likely to be a strategy by dominant, residential pairs to prevent new breeding pairs from settling in an area. Why Crimson Rosellas should expend so much energy keeping neighbours at a distance is perplexing. It is unlikely that close neighbours reduce the food available for a breeding pair, since rosellas do not feed exclusively in their own territory, and fledged young never return to the hollow. If female rosellas opportunistically engage in extra-pair copulations, close neighbours might increase the possibility that a resident male is cuckolded. However, cuckoldry is uncommon in this species. Perhaps resident pairs are evicting non-kin that try to settle in the area, in an attempt to reserve places for any male offspring that remain close to their natal hollow. Knowing the sex primarily responsible for egg destruction would help us understand which birds might be benefiting from the behaviour—but this will have to wait for another study.

Having negotiated the perils of egg laying, females get down to the serious work of incubating. This job gets easier as the season progresses, since the length of incubation decreases with rising ambient temperatures, taking about 23 days at the beginning of the breeding season, and only 17 at the end. Incubation is a far less risky time for both the eggs and the incubating female, although occasionally both are eaten in the hollow, probably by mammalian predators.

In rosellas, because incubation begins before egg laying has finished, hatching of chicks is staggered. Asynchronous hatching is common among birds and produces broods with chicks of different sizes and ages. This means that there will be large, behaviourally dominant chicks alongside small, competitively inferior chicks. Generally, parents feed chicks that are most successful in competing for food, a pattern that clearly favours larger, older chicks. This strategy allows parents to raise at least some healthy chicks when food is scarce and insufficient for the whole brood, but it also may mean that younger chicks die even when food is abundant. Surprisingly, bird parents rarely show any discretion over how food is distributed, and in most species even relatively small differences in size at hatching reduce the survival prospects

JOHN COOPER

Female Crimson Rosellas are often seen breeding while still in juvenile plumage. Here, a young mother feeds her close-to-fledging chicks, which are queuing up for dinner at the hollow entrance.

© ANDREW HENLEY / LARUS

Two recently fledged Crimson Rosellas foraging in a gum tree. Although their body colour can vary between green and red, their characteristic red cap distinguishes them from older juveniles. Juvenile plumage is much more cryptic than adult red plumage, however even adults can be difficult to spot when foraging high in gum trees!

of younger, smaller nestlings.

Parrot broods are characterised by very long hatching intervals, suggesting that the competitive differences between chicks should be especially large. Crimson Rosella broods can take as little as two days to hatch, or as much as seven days. At its most dramatic, this results in a 40-gram chick sharing a nest with a five-gram hatchling. Surprisingly, even though there were large size differences within broods, I found that small nestlings grew equally as well as their larger siblings. How, then, does feeding within rosella broods differ from other species? How are parents able to distribute food to all their nestlings? I predicted that equal growth rates in a species with relatively extreme size differences could only occur if parents somehow intervened on behalf of the smaller chicks in the brood, preventing larger chicks from dominating feeds.

To tackle the problem of how rosella parents distribute food to chicks within a nest box, I was forced to take a high-tech approach. Both rosella parents feed their young by regurgitating a 'porridge' of seeds, buds and insects. I needed to do two things: first, film feeding visits to determine how food was divided up; and second, find out how much food mothers and fathers delivered. I did this by placing a small video camera inside the lid of the box, and a computerised digital balance under the nest-box floor that registered all changes in weight.

As the growth rates suggested, I found that all rosella chicks are fed equitably, regardless of their size. Since early-hatched chicks are much larger than later-hatched chicks, this means that parents must selectively feed smaller chicks within the brood. Indeed, this is what my videotapes showed. Parents went to great lengths to prevent any chick from receiving more than its fair share of food—they pulled their beaks away and refused to feed begging chicks, and they moved around the box, both to escape demanding chicks and to feed any that had missed out. Rosella parents, in contrast to most bird species, appear to use active measures to keep their offspring under control. As you would expect if parents are ruling the roost, rosella chicks beg rather weakly compared to other species, and in fact do not beg at all when they are very young.

Although all chicks are fed, rosellas achieve this balance by parents engaging in different feeding patterns. Mother rosellas seem to take the major role in determining the distribution of food within the brood. Whereas mothers feed selectively by refusing to feed large chicks, fathers feed older, more competitive chicks more than young chicks. Mothers are also sensitive

PARENTS WENT TO GREAT LENGTHS TO PREVENT ANY CHICK

from receiving more than its fair share of food—they pulled their beaks away and refused to feed begging chicks, and they moved around the box, both to escape demanding chicks and to feed any that had missed out.

to the overall needs of the brood and, if food becomes scarce, they reduce food allocated to small chicks and increase the food allocated to large chicks, a strategy that should allow the brood size to be reduced if food supplies remain poor. In contrast, fathers seem to respond more to the immediate demands of the chicks.

Why do rosella parents raise their young in such a different manner to most other birds? Rosellas may be more discriminating in how they distribute food because the extra time required to selectively feed young is small compared to the time they spend gathering food. Rosellas feed their young very infrequently, about once every two hours, deliver large loads (up to 25 per cent of their body weight in a single visit) and spend around three minutes in the nest, feeding each nestling several times. Songbirds, in contrast, typically spend just a few seconds stuffing an insect into the closest mouth before heading off to collect more food. Infrequent feeds and large loads allow parents to spend a relatively long time distributing food without reducing their overall feeding rate.

A second reason that younger rosella chicks are more likely to survive than in other species is because broods hatch and fledge asynchronously. Last-hatched rosellas can remain in the nest and be fed for several days after their older siblings have left, giving them time to complete their growth. In most songbirds, the brood fledges together. Synchronous fledging makes surviving even more difficult for later-hatched chicks because they require relatively more food to complete their growth at the same time as the rest of the brood, but are less competitive at obtaining it. Since younger chicks in rosella broods have the same chance of surviving as their older siblings, parents will have more to gain by ensuring that resources are shared equally between the chicks.

Studying Crimson Rosellas in the wild has revealed many unexpected aspects of their behaviour and society. Rosella parents are clearly capable of responding to the needs of their young in subtle, yet differing ways. Perhaps complex parental care within pairs, coupled with conflict between pairs, is typical of parrots with long-term pair bonds and a sedentary lifestyle. Certainly, it seems paradoxical that such quarrelsome extroverts could have such a calm and equitable home life.

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DR ELSIE KREBS WORKED ON THE BREEDING BIOLOGY AND PARENTAL CARE OF CRIMSON ROSELLAS FOR HER PHD AT THE AUSTRALIAN NATIONAL UNIVERSITY IN CANBERRA. SHE IS CONTINUING HER RESEARCH ON PARENT–OFFSPRING INTERACTIONS AS A POSTDOC AT THE UNIVERSITY OF QUEENSLAND.

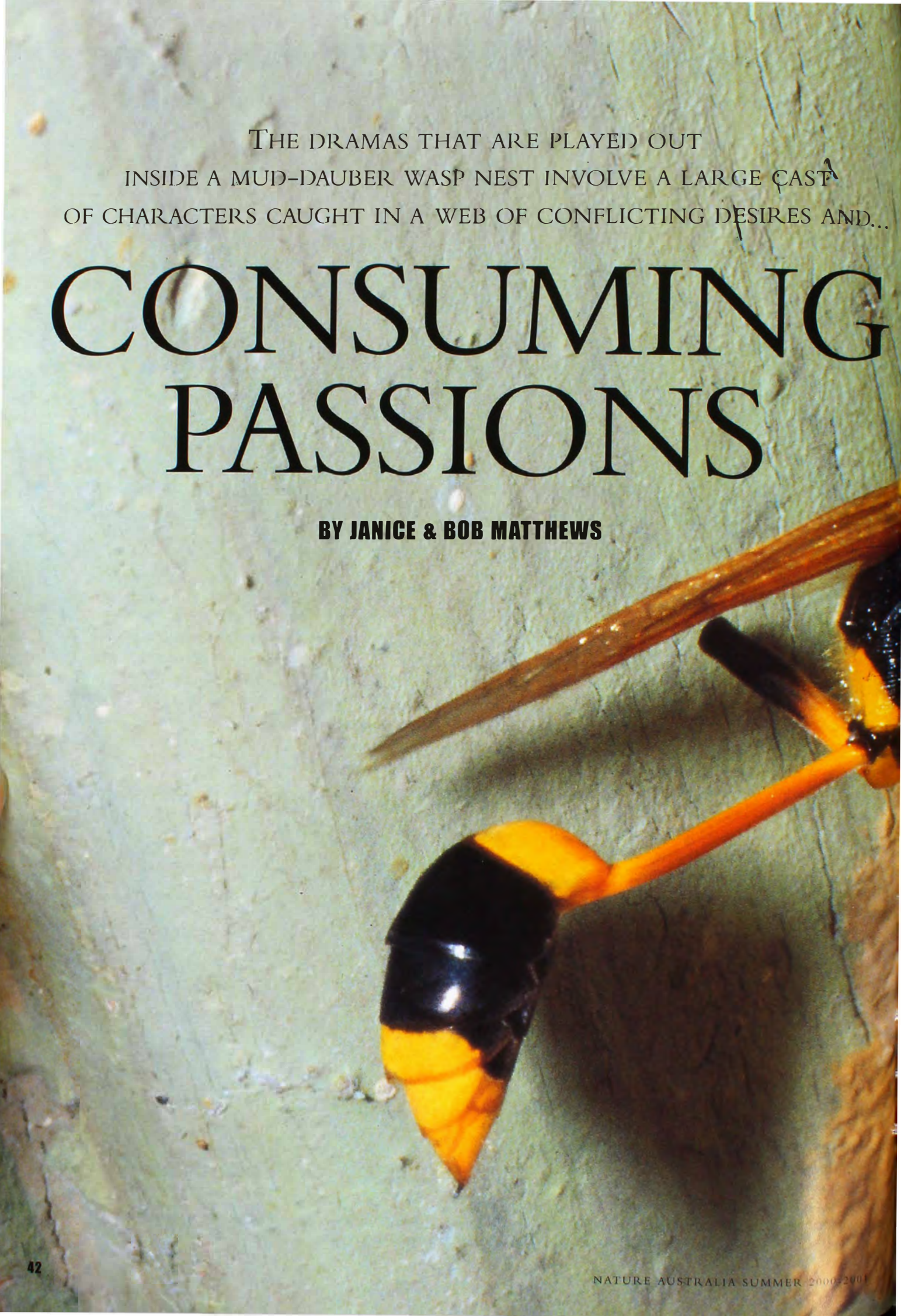
JEAN-PAUL FERRERO/AUSCAPE

Mottled green juveniles are commonly observed. Crimson Rosellas take two years to obtain their adult colouration. Here a juvenile enjoys a bath.

THE DRAMAS THAT ARE PLAYED OUT INSIDE A MUD-DAUBER WASP NEST INVOLVE A LARGE CAST OF CHARACTERS CAUGHT IN A WEB OF CONFLICTING DESIRES AND...

CONSUMING PASSIONS

BY JANICE & BOB MATTHEWS



The female mud-dauber stuffs each cell with paralysed spiders—a constant supply of 'fresh meat' for her voracious young.

DENSEY CLYNE/AUSCAPE

MOST OF US, AT ONE TIME or another, have seen the nest of a mud-dauber wasp. It may have taken the form of a wrinkled brain-like mound, a series of neat clay cylinders, or a little mud jug with a curious spout. Judging that it marred the neatness of our eaves or exterior walls, we may have destroyed it without much thought. But what would have happened if we had left it undisturbed?

Over the past 20 years, in both Australia and North America, we have been studying the dramas that are played out inside these little mud structures. They involve a surprisingly large cast of characters, caught in a web of conflicting desires and consuming passions.

The stars of the show are, of course, the mud-dauber wasps themselves. They belong to a large family of solitary wasps, the Sphecidae. In Australia, the most common species is the Black-and-yellow Mud-dauber (*Sceliphron laetum*). In North America, the most common is the Organ Pipe Mud-dauber (*Trypoxylon politum*). Like all mud-daubers, the females of these species labour alone to make nests, and leave soon after laying their eggs. They never directly guard their offspring as a social wasp would, but trust instead in the stout mud walls to protect their young.

Nearly any setting will do for this story, for mud-daubers are supreme opportunists, taking advantage of any place that is protected from the rain and sun and has a ready supply of prey and mud. In nature, mud-daubers are generally limited to rock overhangs, but they are quick to recognise new possibilities when houses, bridges and other man-made structures appear. A few years ago when we built a log cabin on an isolated 1.5-hectare block, mud-daubers began making numerous nests before construction had even finished. One of the nests was made of a grey mud, which proved to be so hard we could hardly break it open. The wasp had apparently obtained her mud from a puddle under a cement mixer, and when her nest hardened it was literally concrete!

Mud-dauber nests are the cumulative effort of a great many trips during which the female collects mud with her jaws and gathers it into a pellet, sometimes as large as her head. Hoisting the pellet in her mouth and using her head and front legs to brace the load, she flies back to her nest. While applying the pellets onto the nest, she makes a distinctive buzzing sound. We've often wondered if this facilitates mixing or settling of the mud, much the way a mason may finish concrete by vibrating the surface.

Because their young are meat-eaters, filling the pantry becomes a major life task for all mother mud-daubers. Prey paralysed by venom injected from a stinger are the wasp's solution to a lack of refrigeration. The meat stays fresh and nutritious, and the prey are unable to thrash around or escape from the nest.

DENSEY CLYNE/MANTIS WILDLIFE

DENSEY CLYNE/AUSCAPE

(Above) Bracing herself with her legs, the female mud-dauber wasp packs a mouthful of mud onto a new cell wall.

(Below) When she has finished, the mud-dauber seals her nest with a mud plug, then leaves.

KEN GRIFFITHS

A view of a mud-dauber nest from the back, showing larvae feeding on paralysed spiders in separate compartments.

Most mud-daubers catch spiders (although some, such as the potter wasps that make mud jugs, specialise on caterpillars). Each wasp species tends to choose prey belonging to only a small number of spider families or genera, a fact that probably reflects the relative local abundance of spiders. No-one knows how a solitary wasp judges that enough prey have been stockpiled to nourish a hungry larva through to maturity, but it's clear that a judgement is made (see *Nature Aust*. Winter 2000). A half-dozen mature spiders may be enough at the end of the summer, but earlier in the season when the available spiders are small, mud-daubers must (and do) collect many more of them.

A mud-dauber wasp cannot simply make a mud cave and stock it with a pile of spiders and eggs. Instead, each egg and its allotted prey must be placed in a different cell separated from the rest, for voracious mud-dauber larvae will eat each other just as willingly as they will eat spiders.

The labyrinth of separate cells made by some species creates an additional problem. When the newly matured mud-daubers are ready to leave the dark confines of the nest, how do they know which way to go? A typical nest of *Sceliphron laetum*, for example, will contain four to six cells, but there can be as many as 50. The new adults do not chew out of the nest randomly, for all the emergence holes in a nest are made on the same side. It turns out that when the mother wasp seals off the completed cell, she makes a plug with a flat or slightly convex inner surface. The rest of the interior walls are concave. Some ingenious experiments conducted many years ago showed that a mature larva detects this difference and turns toward it when making its cocoon. Thus, when the adult develops, it is facing in the correct direction for a successful escape.

When a nest is complete, the female mud-dauber leaves, never to return. She's done everything she can for her young, and now it is up to them. Inside the small mud fortress she has made, her eggs hatch into larvae. After consuming all the spiders in its cell, the full-grown larva makes a protective cocoon. It voids all the waste material accumulated during its entire larval life in one massive pellet, and then transforms into a limp, non-feeding prepupa and enters a period of arrested development called diapause. This stage is very important to survival in Australia's varied climates, for a prepupa in diapause can withstand extended periods of freezing or drought that would kill mud-daubers at other points in their life cycle. The length of time spent as a diapausing prepupa also determines how many generations of mud-daubers occur each year in different regions. In southern Australia, there is typically only one generation per year, whereas in tropical areas there are often several.

With the start of the wet season in the tropics or the coming of spring in temperate regions, prepupae transform into true pupae. Within the relative safety of the cocoon, each pupa continues to mature, and, depending on the temperature, becomes an adult in two to five weeks. Then each chews its way to freedom and seeks out flowers, where it feeds upon nectar and mates with others of its kind. Each female then sets about the business of choosing a new nest site. She may decide to nest somewhere close to the spot where she was born, but she never reuses the mud home that was her nursery.

THUS GOES THE BASIC plot line of our drama—a simple life cycle, with each egg, safe in its mud cell,

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The wingless female velvet ant doesn't look like the wasp that she really is.

giving rise to a new wasp in the next generation. In reality, however, intrigue and open warfare take a surprisingly large toll. Although the mud-dauber's fortress appears strong and impenetrable, studies of *Sceliphron* species around the world have discovered very high offspring mortality. Andrew Smith, while at Monash University in Melbourne, showed that nearly 40 per cent of the immatures of *S. laetum* perish.

A diverse cast of camp followers begins to converge on a mud nest the moment construction begins. Most are intent upon feeding upon the plump, defenceless mud-dauber larvae or pillaging the stores of paralysed spiders. Three wasps with strange names are major villains in our mud-wasp drama—wowbugs, cuckoo wasps and velvet ants. Andrew Smith discovered wowbugs (*Melittobia* spp.) at nearly every locality he sampled in New South Wales and South Australia; overall they accounted for more than 20 per cent of the mortality. He found that cuckoo wasps (*Chrysis* spp.) were responsible for another 20 per cent of mud-dauber mortality. Interestingly, Smith did not encounter any velvet ants (actually a type of wingless wasp in the family Mutillidae), although species of *Ephutomorpha* have been reported to attack other species of Australian mud wasps. In some US mud-dauber populations, velvet ants in the genus *Sphaeropthalma* are important mud-dauber parasites.

Wowbugs are diminutive black wasps. A single female wowbug sneaks into the nest, hides among the paralysed spiders, and waits until the young mud-dauber larva becomes a prepupa. (Alternatively, the female can chew through the mud wall to gain access to its host.) Entomologists still don't know whether the wowbug allows itself to be enclosed while the larva spins its cocoon, or chews in soon after the cocoon is finished. In either case, once inside the mud-dauber's cocoon, the prolific female lays dozens to hundreds of eggs on the prepupa's skin. These quickly hatch into hungry larvae that consume the mud-dauber larva entirely, pupate, and mature, often in less than three weeks. The new adults chew through the mud walls to enter other cells and repeat their life cycle, thereby building wowbug numbers to epidemic proportions.

Like the birds from which they get their name, cuckoo wasps rely on others to feed and house their young. The iridescent metallic green or blue female slips into an unattended mud-dauber nest under construction, and lays her own egg on one of the spiders inside. The rapidly developing cuckoo wasp larva either devours the mud-dauber larva along with the spiders, or

starves it to death by eating its food.

Female velvet ants are wingless, about ten millimetres long, and have a velvety covering of often brightly coloured hairs. But despite their ant-like bodies, these are not really ants but wasps, as a glimpse of the usually much larger winged males would show. When a female velvet ant finds a mud-dauber nest, she chews through the mud wall, nibbles a small hole in the side of the cocoon, and deposits a single egg on the mud-dauber pupa or prepupa inside. Then she closes up the telltale holes with little mud plugs. Inside the cocoon, her egg hatches almost immediately into a larva that quickly devours the developing mud-dauber and spins its own cocoon inside the now-empty mud-dauber cocoon. In this way, it is doubly protected from its own potential parasites and predators.

Curiously, in rearing several dozen velvet ants from a US species of mud-dauber, we obtained only males. We speculate that the mother velvet ant is somehow able to measure the size of the host. Above some threshold size, she deposits unfertilised eggs, which (as in all bees, ants and wasps) develop into the larger males. Fertilised eggs, destined to become females, probably are laid only in hosts smaller than mud-daubers.

While wasps practise sly deception in our drama, flies take the more straightforward approach: direct attack. Two kinds of flies almost invariably lay siege to a mud nest construction site—pirate flies and bee flies.

About the size of Bush Flies, pirate or satellite (miltogrammatine) flies are small and grey with alternating light and dark bands on their abdomens. They are well-known parasites of many species of solitary wasps. We have observed them apparently attracted by the buzzing sounds a female mud-dauber makes when adding mud to her nest. They hang around, just waiting for the golden moment when the mud-dauber leaves, and then dart in to lay their eggs.

Inside the nest, like a band of ruthless pirates, the maggot offspring kill the wasp egg or larva and take over the 'treasure'—the spiders in the cell. Having eaten all the booty in one cell, groups of 5–12 maggots sometimes tunnel from cell to cell as they grow, plundering the contents and killing the occupants. Finally they pupate, and the emerging adults exit through a single small hole chewed in the side of the nest.

Adult bee flies (*Anthrax* spp.) lay numerous eggs on surfaces in the immediate vicinity of a mud nest. Upon hatching, the tiny eel-like bee fly maggots storm the nest walls, seeking entry through small cracks in the masonry. In the dark interior, each is thought to remain in a quiet state of suspended development, unnoticed as the wasp larva eats its spiders and spins a cocoon. No-one knows how the maggot ultimately ends up inside the cocoon. Perhaps it attaches itself to the feeding larva. Alternatively, it may break into the completed cocoon. Once inside it grows rapidly as it attacks, kills and consumes the young mud-dauber, then completes its own development within the safety of its

G. HAROLD

ROBERT W. MATTHEWS

(Above) Like the birds from which they get their name, cuckoo wasps rely on others to feed and house their young.

(Below) Two female wowbugs lay eggs on a mud-dauber larva as three more prepare to attack. To the right, eggs laid earlier have already hatched into larvae and begun to feed.

victim's cocoon. At this point, its predacious days are over. Upon emergence as a large and conspicuous 'furry' fly, the new adult bee fly will feed only on pollen and nectar.

THE LINE BETWEEN parasites and predators is a blurry one in the mud-dauber world. Wowbugs, cuckoo wasps, velvet ants and bee flies are not predators in the sense of organisms such as a Lion or a preying mantis that capture and consume a series of living food items, each of which usually (but with notable exceptions) is smaller than itself. However, neither are they parasites in the sense of animals such as tapeworms or fleas, organisms that often live for an extended period on or in a larger host without substantially harming or killing it. Like most parasites, wowbugs, cuckoo wasps, velvet ants and bee flies are smaller than the larva but, like predators, they kill and devour it. In recognition of this unusual combination, scientists often call them 'parasitoids'.

Closer to true parasitism is one of the more bizarre organisms occasionally found with mud-daubers, a tiny mite belonging to the genus *Pyemotes*. (These are the so-called 'straw itch mites'; in barns where hay is stored, they attack other species of insects, but also readily crawl onto humans, where they inflict irritating bites.) In the mud-dauber's nest, straw itch mites attach themselves to the body of a developing larva and immediately begin to swell in size. When several mites attack at once, as usually happens, the mud-dauber larva becomes covered with little semi-transparent spheres in just three days. Each sphere is a pregnant female mite, and she immediately begins to produce dozens of offspring, tiny males only at first, followed by females. There seems to be some antagonism between mites and wowbugs, such that when mites invade a cell, wowbugs are unable to successfully attack. No-one yet knows why or how this works.

Do mud-daubers have any larger predators? Almost certainly. For example, during one winter's day in the US, University of Georgia colleague Stuart Coward observed a Tufted Titmouse (*Parus bicolor*) neatly pecking a hole through the side of a mud-dauber nest to extract a juicy yellow prepupa from within. Predation by various other birds on mud-dauber nests has also been reported. It seems likely that birds learn where to peck, and that they will eat any cell contents they find. The holes made by birds closely resemble the normal exit holes chewed by emerging mud-daubers, and so might not always be recognised for what they are. In Australia, Steve Van Dyck (Queensland Museum) observed a Black Rat (*Rattus rattus*) systematically cracking open mud-dauber nests in mid-winter and extracting their contents (see *Nature Aust.* Spring 1995).

AN ABANDONED *mud-dauber nest is like an empty building with a 'to let' sign out front, and the price is usually free.*

And then there are the scavengers. Oblivious to the outcome of the nest owners' battles, these little camp followers go about their daily routines, feasting upon whatever leftovers remain from the feeding habits of the other occupants. Two important scavengers are insects we also sometimes have in our own homes—carpet beetles and booklice.

Carpet beetles are small, plump, oval beetles in the family Dermestidae whose larvae feed on plant and animal products. They attack everything from wool, silk and feathers to waxes, meat and dried insect specimens. A mud-dauber nest collected at the end of the nesting season will almost always have evidence of carpet beetle infestation. Most commonly encountered are the bristle-covered skins that the beetle larvae discard as they grow.

Booklice, also called 'psocids', often resemble plant lice (aphids) in general appearance. They are so small and inconspicuous that most people never notice them. Their common name comes from a habit of feeding on the paste and paper of seldom-used books. Outdoors, most booklice feed on fungi, algae, dead plant tissues, and the feathers and other waste materials found in bird nests. However, if you look very closely, you may find booklice in older cells of mud-dauber nests.

WHEN THE DRAMA in the mud-dauber nursery is over, and the primary cast has left the scene, the stage seldom stands empty for long. An abandoned mud-dauber nest is like an empty building with a 'to let' sign out front, and the price is usually free. Not surprisingly, many other species of wasps and bees reuse old cells to raise their own young. Ian Naumann from the CSIRO documented some 43 different species of secondary nest renters in *Sceliphron* nests in Kakadu, Northern Territory.

In the process of subletting, some interesting renovations are made. Solitary bees may construct waxy walls, subdividing a cell into one to five rooms. Sometimes they use pieces of the discarded mud-dauber cocoon as parts of the walls. Smaller wasp species may line an old *Sceliphron* pupal case with fine mud and reuse it. Others clean house—they brush old rubbish, spider legs, and other debris into the corner, as far back in the cell as possible, and wall them up behind a partition of mud or silk.

One of the more intriguing of these wasps is the silk wasp *Arpactophilus mimi*. Upon finding a vacant mud nest, a group of 2–12 females and males sets up housekeeping. One might say that silk wasps are wiser to the world's ways than are mud-daubers, for silk wasps always post a guard at the nest entrance. Moreover, they do not leave their larvae unattended, but provide extended parental care. As the larvae

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

After mating, the female bee fly will lay eggs near a mud-dauber nest, and these will hatch into tiny eel-like maggots that invade the mud nest through small cracks.

grow, the adults repeatedly return with progressively more food (tiny plant-feeding psyllids). This strategy of high parental investment pays off—unlike *Sceliphron*, most of the silk wasp's offspring survive. Only one species of parasite has been found to successfully attack their offspring. This lone intruder (a wasp in the family Megalyridae) drills through the mud fortress from the outside with its long thread-like ovipositor, but it has a low success rate, inflicting less than five per cent mortality.

Does our mud-dauber drama have a moral? If so, perhaps it is this. As in other animals, wasp parenthood can be approached in many ways, and no one is more or less successful in the evolutionary sense. One tactic is to lay many eggs and leave them to fend for themselves. Wowbugs perhaps best exemplify this strategy. A single wowbug female can produce about 700 offspring on one mud-dauber host, but nearly all perish without reproducing. Another tactic is to raise relatively few young quite intensively, doing everything possible to ensure their survival. This is the silk wasp strategy.

Somewhere between these extremes is the mud-dauber. While a mud nest represents a large parental effort, it also presents an obvious target for potential enemies. Rather than staying and defending the nest, mud-daubers trust their luck and move on. There's an old jingle that says, "He who fights and runs away, lives to fight another day". By being quick to colonise newly available nest sites, mud-daubers often manage to stay one step ahead of their enemies, continually escaping them in time and space.

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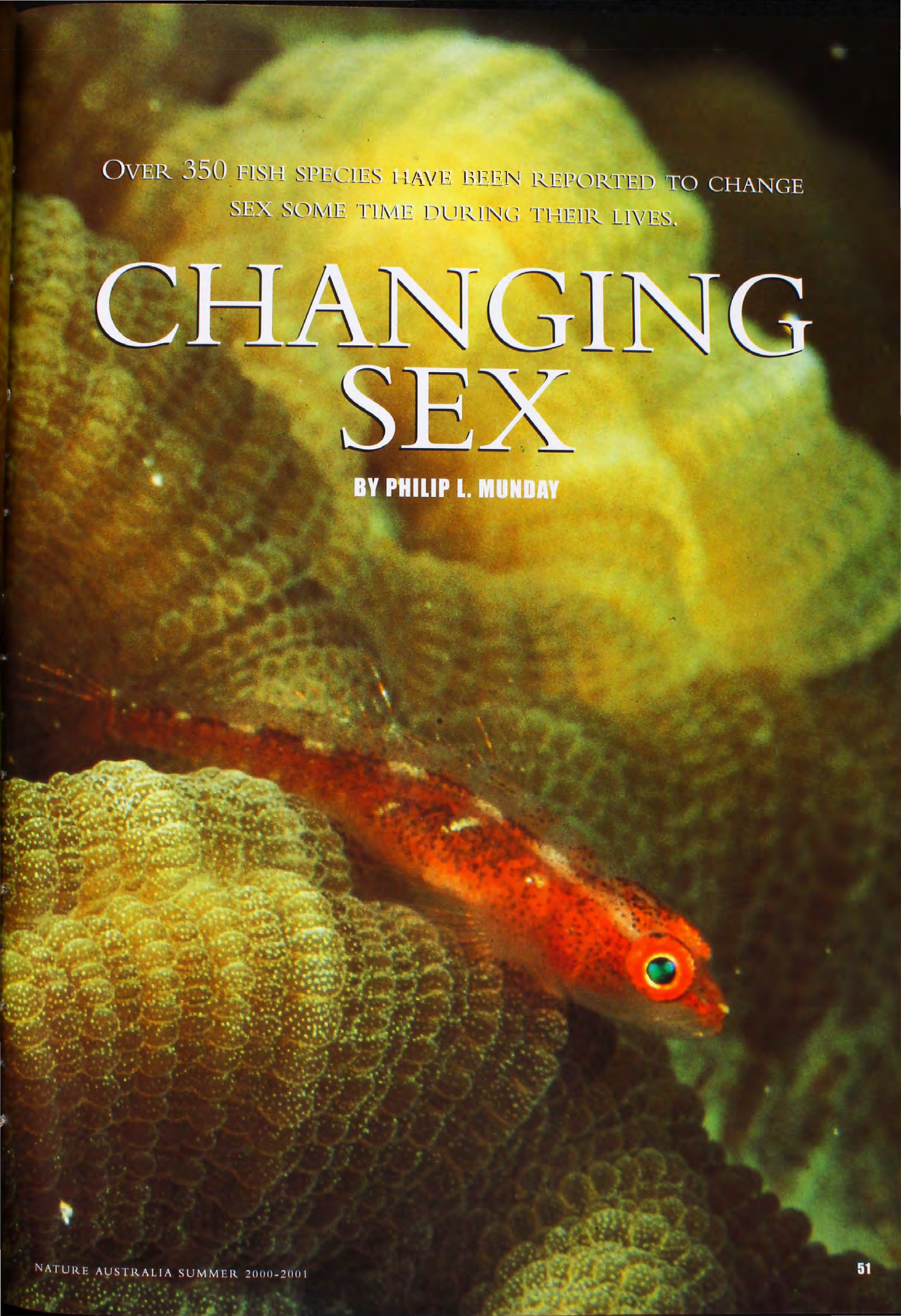
Gobies, including these Elongate Ghostgobies (*Pleurosicya elongata*), are the most diverse group of marine fishes and also have diverse sex-allocation strategies, ranging from species that don't change sex to species that can change sex in either direction.



OVER 350 FISH SPECIES HAVE BEEN REPORTED TO CHANGE SEX SOME TIME DURING THEIR LIVES.

CHANGING SEX

BY PHILIP L. MUNDAY

MOST ANIMALS ARE either male or female and remain that way for life. But things are not always so simple for coral-reef fishes. An individual may start life as one sex, then transform to the opposite sex at some stage during its life. Others can also function as both male and female at the same time. Although sex change in fishes has long been recognised, it was previously thought that individuals could change sex only once in a lifetime. Recent discoveries, however, have shown that some fish can change sex (or shift sexual function) more than once.

Over 350 fish species have been reported to function as both male and female at the same time (simultaneous hermaphrodites) or to change sex some time during their lives. Sex change can occur from female to male (called protogyny) or from male to female (protandry). Protogyny is the most common pattern of sex change among coral-reef fishes and is known from many groups, including the wrasses (Labridae), parrotfishes (Scaridae), groupers (Serranidae) and damselfishes (Pomacentridae). In these species, large males are able to monopolise breeding opportunities with numerous females, either by defending a harem or by defending breeding sites that females visit. By monopolising most of the breeding opportunities, these large males are reproductively very successful. In contrast, small males have few opportunities to mate and, consequently, have a much lower reproductive success. Females can always find a mate, and therefore will typically have higher reproductive success than small males. However, the reproductive success of large females is not as high as for large males. Therefore, an individual can increase its lifetime reproductive success by first being a female and then changing sex after it reaches a large size.

In many protogynous species, all juvenile fish are females, which first mature into adult females and may later turn into males. However, in certain groups, such as the wrasses and parrotfishes, some of the juveniles are males and these mature directly into adult males. These are called primary males and they are usually smaller than males that have changed sex from a female (secondary males). Primary males often have the general appearance and colour of females rather than of secondary males. In this disguise, they are able to mix with the females and may attempt to directly fertilise their eggs. Alternatively, they may 'cut in' on a large secondary male, racing up to the breeding pair at the moment of spawning and releasing a large batch of sperm. This behaviour is called 'streaking', for obvious reasons.

The proportion of primary males in a population is often related to the population's density. Robert Warner (University of California, Santa Barbara) and colleagues found that primary males of the Caribbean Bluehead Wrasse (*Thalassoma bifasciatum*) were more numerous when population density was high. At high densities the large secondary males could not adequately defend all the females and, therefore, primary males had a much higher chance of mating. In contrast, in areas where

RON & VALERIE TAYLOR-NATURE FOCUS

PETER & MARGY NICHOLAY-LOCHMAN TRANSPARENCIES

(Left) Male damselfishes, such as these Reticulated Dascyllus (*Dascyllus reticulatus*), often defend a harem of females. If the male is removed, the largest female changes sex to take his place.

(Right) In pairs of anemonefishes, like this Pink Anemonefish (*Amphiprion perideraion*), the larger individual is female. If she is removed, the male will change sex to female and a juvenile anemonefish will quickly mature to take the male's place.

population density was low, the large males were able to control the matings with most of the females and therefore limited the mating opportunities for primary males.

The opposite pattern of sex change, protandry (male to female), is best known among the anemonefishes (*Amphiprion* spp.). Small social groups of these fishes live in close association with sea anemones, from which they derive shelter. The largest individual in the group is a female and the next largest is a male. These two individuals form a breeding pair and any other individuals living in the anemone are immature males. If the breeding male dies, the largest immature fish rapidly matures to take his place. If the female dies or is removed, the breeding male changes sex to female and the largest immature fish matures into the new adult male. A female benefits from being large because she can produce more eggs. A small male, however, can fertilise all the eggs of a larger female, so there is no need for him to be large. Sex change is advantageous in anemonefishes because anemones are usually too sparsely distributed for an individual fish to find a new mate if its partner dies. Indeed, in areas where anemones occur in relatively high densities, some anemonefish species will move among anemones to search for a new partner, rather than changing sex.

IF THE MALE

is removed, or females are placed together in an aquarium, the largest female will quickly change sex to male.

Sex change appears to be socially controlled in most fishes. In protogynous (female to male) fishes such as the wrasses and many damselfishes, the presence of a large, dominant male maintains the sex of females. If the male is removed, or females are placed together in an aquarium, the largest female will quickly change sex to male. Changing from one sex to another can take a few weeks or even months, depending on the species and environmental conditions.

In some species, the number of males and females in the social group is strictly controlled. For example, schools of Scalefin Anthias (*Pseudanthias squamipinnis*), which feed on plankton above the reef, consist of a certain number of males and a much larger number of females. If one or more males is removed from the group, an equal number of females will change sex to

KEVIN DEACON/AUSCAPE

In the Scalefin Anthias (*Pseudoanthias squamipinnis*), sex change from female to male is accompanied by a change of colour from orange to purple.

male. Social structure also influences the early stages of sexual determination in some species. For example, in the freshwater Midas Cichlid (*Cichlasoma citrinellum*) the sex of an adult is determined by the social conditions experienced as a juvenile. All Midas Cichlids are born female, however early in life the largest individuals in each clutch become juvenile males. Richard Francis and George Barlow (University of California, Berkeley) showed that all individuals in the clutch had the potential to become males, but the smaller individuals stayed female because of the presence of larger fish in the clutch. Sex change before maturity has also been reported in some anemonefishes, wrasses and angelfishes (Pomacanthidae).

Sex change is thought to have evolved

a number of separate times and is now found in many different families of fish. In some families, all the species have the same pattern of sex allocation; in other families a wide range of sex-allocation patterns are found. For example, among the gobies, which make up the world's largest family of marine fishes (the Gobiidae), some species have fixed sexes, others are simultaneous hermaphrodites, others are protogynous (female to male) sex changers, and there are still others that can change sex in both directions (bi-directional sex changers). This ability to change sex in both directions has only recently been detected and it appears to have two basic forms. Some gobies, such as the tiny Orange-red Goby (*Trimma okinawae*), maintain both male and female tissue in their gonads (reproductive organs), but they function as only one sex at a time. Sex change can occur within a few days, simply by 'switching on' the inactive section of the gonad and 'turning off' the functioning section, thereby re-allocating sexual function. Coral-dwelling gobies from the genera *Gobiodon* and *Paragobiodon*, on the other hand, are complete sex changers. Sex change takes a few weeks in these fishes because the entire gonad changes from female to male, or *vice versa*.

SEX CHANGE CAN *occur within a few days, simply by 'switching on' the inactive section of the gonad and 'turning off' the functioning section.*

TWO-WAY SEX CHANGE in coral-dwelling gobies was first reported by researchers working on the Redhead Goby (*Paragobiodon echinocephalus*) in Japan. My research on the Broad-barred Goby (*Gobiodon histrio*) in the Great Barrier Reef has shown that bi-directional sex change also occurs in Australian waters and points to some of the advantages of two-way sex change in coral-dwelling gobies. I first became interested in the reproductive biology of these coral gobies while studying their habitat use. This small fish, with a maximum length of less than six centimetres, lives deep among the branches of coral colonies belonging to the genus *Acropora*. Usually only a single pair of gobies is found in each of these coral colonies and they rarely leave the safety of the coral. This pattern of habitat use and social structure is similar to the anemonefishes, therefore I expected the gobies to have the same pattern of sex change (male to female). However, when I examined the size range of males and females in a population at Lizard Island, it appeared that they were more likely to be protogynous (female to male sex changers). All the juveniles and small individuals were females, and males were only found in the larger size classes. This suggested that males were derived from individuals that were originally females. However, several features of the population structure did not con-

PHILIP L. MUNDAY

The coral-dwelling Broad-barred Goby has the ability to reallocate sexual function from female to male and *vice versa*, depending on the sex of a potential partner.

PETER & MARGY NICHOLAS/OCEANIC TRANSPARENCIES

In many coral-reef fishes, like this Cheeklined Maori Wrasse (*Cheilinus diagrammus*), the presence of a large male prevents sex change among females in the social group.

form to the general pattern for protogynous species. First, protogynous species usually have fewer adult males than adult females in the population, yet the Broad-barred Gobies had equal numbers of adult males and females in the population and they lived as apparently monogamous pairs. Second, in protogynous species, secondary males are usually larger than females. The Broad-barred Gobies, however, showed no difference in the average size of adult males and females, and individuals in each breeding pair were usually the same size. These social patterns, in conjunction with preliminary examination of the structure of their gonads, indicated that something unusual was occurring with the reproductive biology of these gobies.

The best way to determine the sex-change characteristics of a species is to manipulate the social structure and see if some individuals change sex. Luckily for goby researchers, it is possible to determine the functional sex of an individual from the size and shape of the genital papilla—an external extension of the reproductive tract, which for many goby species is long and conical in males and in females is short and broad, often with a feathery tip. (Apart from the genital papilla, males and females of this species look identical.) I collected adult pairs of Broad-barred Gobies, sexed them by the shape of their papillae, and then reassorted them into pairs of males and pairs of females. In order to individually identify each fish, I also injected them with a tiny wire tag (0.5 millimetre long), engraved with a code that could be read under a microscope. I then placed male–male pairs and female–female pairs on coral colonies that I had previously cleared of gobies, and returned to the reef one month later to collect all the fish that remained. By examining the structure of the gonads of the remaining fish, I was able to determine if they were changing sex and in which direction.

In most cases where a pair of females was placed on a coral, one of the females changed sex to male. In contrast, in most cases where two males were placed on a coral, one of the males left the coral and was replaced by a female from outside the study population. However, in two instances, one of the males changed sex to female, demonstrating that this goby species has the capability of changing sex in both directions and will do so in the wild. Overall, sex change from female to male occurred about twice as often as sex change from male to female. A similar pattern was described for the Redhead Goby in Japan. Therefore, coral-dwelling gobies can change sex in either direction, but they don't do it with equal frequency.

WHAT ADVANTAGE IS THERE to changing sex in both directions? The advantage of sex change in coral-reef fishes is usually explained in terms

JEAN-PAUL FERRERO/AUSCAPE

Most male parrotfishes are large and brightly coloured, like this male Highfin Parrotfish (*Scarus longipinnis*), but some are relatively small and drab so they can mingle with the females and avoid the attention of the dominant males.

of social structure and mating systems, as described above. However, patterns of habitat use may also be important in explaining sex change in fishes, such as anemonefishes and coral-dwelling gobies, that have unique habitat associations. Because only a single pair of Broad-barred Gobies inhabits a coral colony, an individual would need to move among coral colonies to reform a breeding pair in the event of mate loss or the host coral's death. Movement among corals is likely to involve considerable risk of predation for these small fish. Also, most coral colonies are already occupied by a pair of gobies that will defend their coral against intruders. The ability to change sex in either direction would enable an individual to pair up with the first 'unattached' individual it comes across regardless of its sex, thereby reducing the search distance and associated risks.

One puzzling aspect is why more female Broad-barred Gobies turn into males rather than *vice versa*. At this stage, it is not really clear, however sex change does incur costs in terms of the energy needed to reorganise gonadal tissue and lost mating opportunities during or after transition. Therefore, the frequency of sex change in each direction may be determined by the relative costs and benefits to each sex. Perhaps there are greater energetic or ecological costs to changing from male to female. Alternatively, the ability to change sex from male to female might be restricted to certain stages of development. These questions will be the focus of my future research.

The variation and complexity in patterns of sex change observed in fishes is unrivalled among other vertebrates. The recent discovery of bi-directional sex change adds to this complexity and highlights the flexible patterns of sex change that fish can possess. It also provides a unique opportunity to study the costs and benefits of different reproductive strategies. Usually, the costs and benefits of sex change from female to male versus male to female have to be studied in different species of fish. Using coral-dwelling gobies, it will now be possible to make direct comparisons of the different forms of sex change within the one species.

KEVIN DEACON/AUSCAPE

Schools of anthias, like these Scalefin Anthias, can have a fixed number of males living with a much larger number of females. If a male is removed, one of the females changes sex to male.

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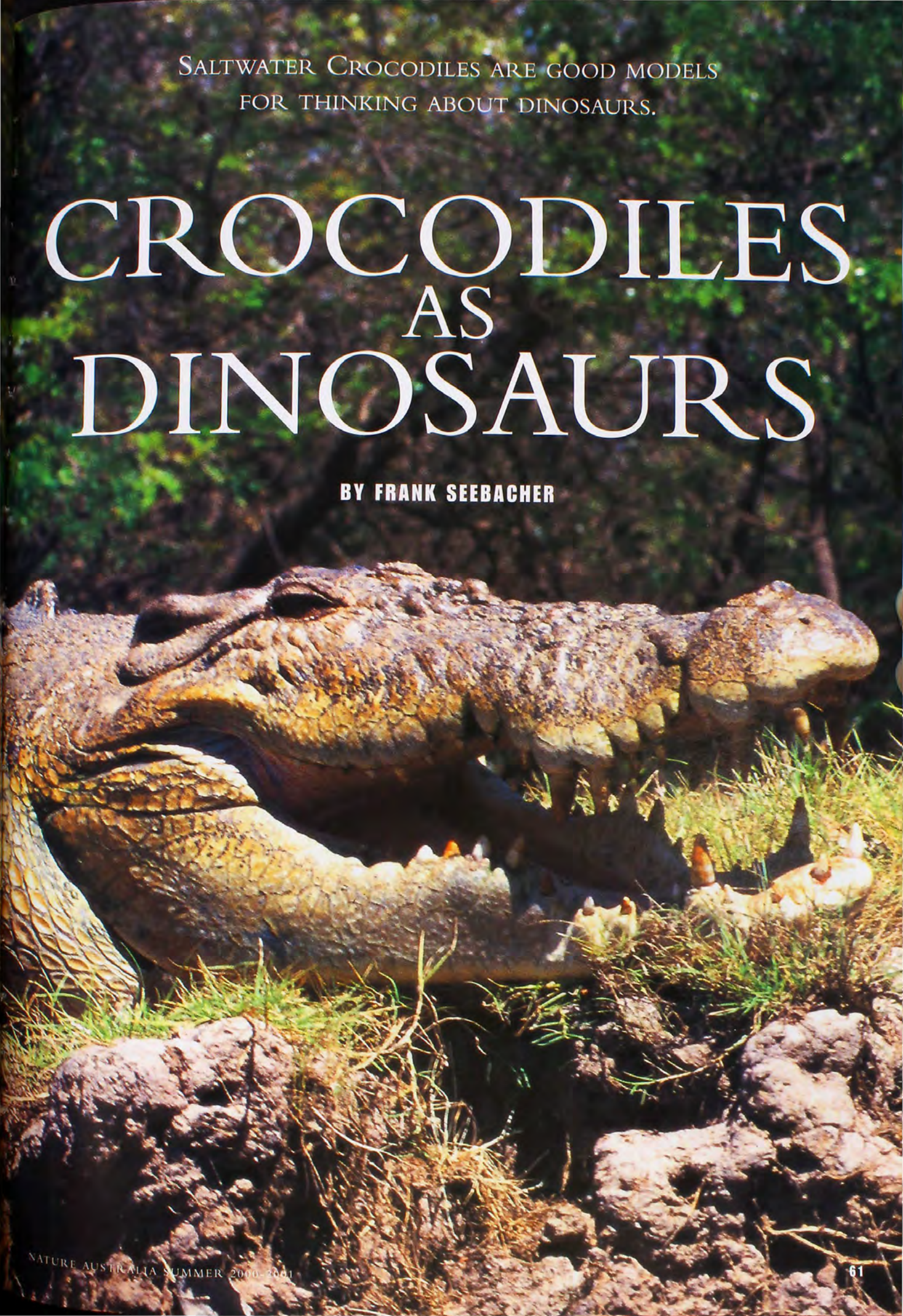
Crocodiles gain most of their heat from short-wave solar radiation. In a very typical behaviour, crocodiles of most species, including this Saltwater Crocodile, bask on land in the sun to raise their body temperature.

G. THRELFO

SALTWATER CROCODILES ARE GOOD MODELS FOR THINKING ABOUT DINOSAURS.

CROCODILES AS DINOSAURS

BY FRANK SEEBACHER



REPTILES ARE COLD-blooded, creepy creatures—or so some people think. Imagine what these same people think when they find out I'm interested in, and actually gain employment studying, the *enfants terrible* of the Reptilia—crocodiles. Many think that to have an interest in these animals beyond shooting them is sheer lunacy. But why is it that reptiles in general, and crocodiles in particular, elicit such a strong negative response in people? Apart from the obvious fear people have of crocodiles, I think that the perceived 'coldness' of reptiles, which goes hand in hand with 'sliminess', has a lot to do with it. Of course, anyone who has touched lizards, snakes, crocodiles and other reptiles knows they are often very warm and not at all slimy; indeed, if vertebrate life forms were to be judged by their 'warm-bloodedness', desert lizards would be at the top with body temperatures often well above 40° C.

It is clear then, that the body temperatures (or thermal physiology) of vertebrates have to be viewed within a conceptual framework that does not include the rather meaningless and anthropomorphic terms 'cold-' and 'warm-bloodedness'. In my opinion, it is useful to view the thermal physiology of animals in terms of energy exchange, or thermodynamics. The two main 'Laws of Thermodynamics' state that energy can neither be created nor destroyed, only exchanged; and that energy will dissipate unless an effort is made to keep it. So if we, and all other animals, are viewed as high-energy systems, we have to maintain this high-energy state by constantly gaining energy from the environment via food, for example, otherwise our bodies would spontaneously disintegrate into low-energy assemblages of atoms and life

FRANK WOERLE AUSCAPE

Crocodiles undergo an enormous developmental size range from 100 grams or less, like these hatchling Saltwater Crocodiles, to well over a tonne or two in the largest individuals. This, along with their archosaurian ancestry, makes them very good model animals to learn about the possible thermal physiology of dinosaurs.

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

A Freshwater Crocodile enters the water after basking. Its body temperature is now high enough to perform non-thermoregulatory behaviour such as feeding and socialising.

would cease.

Similar reasoning can be applied to the regulation of body temperature in animals. Most animals, including mammals and reptiles, try to maintain body temperature within a fairly narrow range (for humans this is within 1° C) despite much greater fluctuations in environmental temperatures. To do so requires work and exchange of energy.

There are two principle ways in which animals go about this: either by passive exchange of heat (energy) with their physical environment, for example by basking in the sun, or by the energetically costly metabolic breakdown of food. Animals that do it the first way are known as ectotherms and include reptiles and amphibians; those that do it the second way, such as mammals and

birds, are called endotherms. Note, however, that ectothermy and endothermy are not mutually exclusive, because all animals eat and digest food, and all animals live in a physical environment with which they exchange heat energy.

Crocodiles are particularly interesting in their thermoregulation, because of their extreme developmental size range, from a hatchling of 0.1 kilogram or less to a large adult of 1,000 kilograms or more. In my research, I am particularly concerned with the way body mass influences heat exchange between ectothermic animals and their environment. Large bodies can store more heat than small bodies, like a large bucket can hold more water than a small one. Also, because larger bodies have relatively less surface area than smaller bodies, large animals heat and cool more slowly than small ones. This could imply that very large ectotherms have stable body temperatures because they do not respond to short-term fluctuations in environmental temperature. As we shall see below, large Saltwater Crocodiles can indeed have high and stable body temperatures, which are more reminiscent of endothermic mammals than of small ectothermic lizards.

OVER THE PAST FEW YEARS I have been working with Gordon Grigg at the University of Queensland on the thermal relations of both Freshwater and Saltwater Crocodiles (*Crocodylus johnstoni* and *C. porosus*). Typically during these studies, I spend several weeks camping in the bush of Cape York Peninsula, monitoring the behaviour and body temperature of crocodiles, as well as environmental conditions. Body temperature is measured with temperature-sensitive radio-transmitters. These transmitters emit a radio signal whose pulse rate changes with the temperature of the transmitter, so that a transmitter located in a crocodile's body cavity tells me the body temperature of the animal. I studied the smaller Freshwater Crocodiles (ranging in body mass from 2.5 to 20 kilograms) in a permanent stream in the Gulf of Carpentaria country. But to get the transmitters into the animals, we first had to catch the crocodiles. We did this by setting nets in the water, and then jumping in ourselves and chasing the crocodiles into the nets with big sticks—'we' refers to friends always keen to lend a hand, particularly Andrew Dennis who rarely missed a field trip. After catching them, I surgically implanted the transmitters and

Large Saltwater Crocodiles are well within the size range of medium-sized dinosaurs. Even this relatively small female shown here guarding her eggs from predators would be about the same weight as a small dinosaur (100–200 kilograms).

BEN & LYNN CROPP/AUSCAPE

LIZ BRAGG

Catching Freshwater Crocodiles in northern Queensland. Nets are set to section off parts of the waterhole and crocodiles, which often sink to the bottom when disturbed, are chased into the nets with sticks. In the photo, Andrew Dennis is feeding the net out of the boat, while the author makes sure that the weighted bottom of the net sits snugly on the bottom of the waterhole.

marked the animals on their backs so that I could easily identify individuals. I then released them within 24 hours, waited a few days for the crocodiles to recover, and sat on top of a rocky outcrop bordering the river for several weeks, recording their behaviour and body temperatures every few minutes during daylight hours.

It turned out that the pattern of body temperatures for Freshwater Crocodiles was very much like that for small terrestrial lizards. Crocodiles moved, or shuttled, between sunbaking on land and cooling off in water, in a similar way that lizards have been reported to shuttle between sun and shade on land. Hence, on a typical day, basking in the morning caused body temperature to rise from water temperature (as low as 13–14° C) to between 29 and 32° C. With frequent shuttling between land and water, body temperature was then regulated within this preferred range until sunset, when crocodiles remained in the stream and their body temperature dropped to that of the surrounding water overnight. Interestingly, the number of times Freshwater Crocodiles shuttled between basking and the water during the day decreased with increasing body mass, so that a 2.5-kilogram crocodile basked four to five times a day, while a 20-kilogram crocodile would bask only twice. The reason for this, as mentioned above, is that the rate of heat transfer between the body interior and the environment decreases with body mass. One could therefore expect that, as crocodiles grow heavier, they would reach a point at which shuttling behaviour becomes ineffectual for thermoregulation, because body temperature would respond too slowly to changes in the thermal environment. With this question of how very large crocodiles regulate their body temperature in mind, Gordon Grigg initiated a study on Saltwater Crocodiles at Edward River Crocodile Farm, about half way up the west coast of Cape York Peninsula, to which he invited me as a collaborator.

I SPEND SEVERAL WEEKS *camping in the bush of Cape York Peninsula, monitoring the behaviour and body temperature of crocodiles.*

Our study site—a big natural lagoon (25 hectares) enclosed by a heavy wire fence—served as the main breeding

REG MORRISON/AUSCAPE

enclosure for the farm. The crocodiles are mainly left to their own devices within the lagoon, except for the once-yearly egg harvest. Here we studied 11 crocodiles ranging in mass from 32 to 1,010 kilograms. Again, we used temperature-sensitive transmitters but, rather than catching the crocodiles, Gordon suggested we insert transmitters into dead chickens and then feed these to the crocodiles. This worked reasonably well, as the transmitters resembled rocks, which crocodiles keep in their stomachs; these gastroliths, as they are known, are thought to aid in buoyancy or the breakdown of food. The crocodiles eventually regurgitated the transmitters, but we managed to obtain data from each crocodile for periods of 3–30 days in summer and winter. Working with Saltwater Crocodiles is quite different from working with the relatively harmless Freshies, and most of the data collection was done from the safety of my battered old Toyota Landcruiser, except on occasions when the large mass of some of the crocodiles reduced the range of the transmitter signals so that I, rather foolishly, had to approach the animals on foot to obtain a signal.

The results of this study, the first of its kind from very large free-ranging ectotherms, showed what we suspected from the Freshwater Crocodile data: in animals as small as 32 kilograms, body temperature fluctuated sinusoidally within a period of one day but, as body mass increased, daily body temperature became more stable. Hence, the largest of our study animals (1,010 kilograms) had a high and stable body temperature during the day. For the first time, we demonstrated what scientists had suspected for many years; namely, that very large ectotherms can be warm and have a stable body temperature—traditionally believed to be a characteristic of endotherms only—even in the absence

WORKING WITH SALTWATER CROCODILES IS DIFFERENT

from working with the relatively harmless Freshies, and most of the data collection was done from the safety of my battered Toyota Landcruiser.

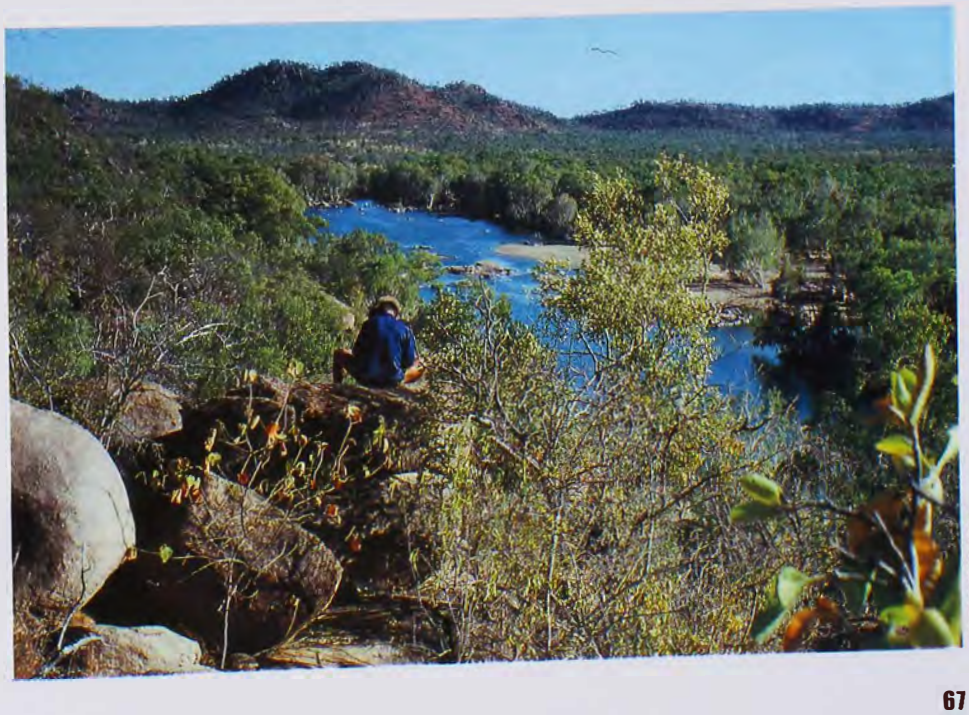
longer periods of time, between day and night and between seasons. In winter Saltwater Crocodiles would be partly submerged in water with most of their body exposed to sun during the day, but remain fully submerged at night; in summer they remained submerged in water during the day, but moved onto land at night.

NOW THAT WE KNEW the body temperature of the largest living ectotherms, we wondered about even larger possible ectotherms, the dinosaurs. The thermal physiology of dinosaurs has fascinated scientists for 100 years. The Dinosauria were a hugely successful group of animals, living from 220 to 65 million years ago and exhibiting an incredible diversity in form and size (0.5–50,000 kilograms). This success and diversity of dinosaurs has sparked many speculations and arguments about their thermal physiology, particularly in regard to whether they were 'warm blooded' or 'cold blooded', ectotherms or endotherms. These thermal considerations have, of course, a number of ecological connotations. 'Warm' animals, be they ectotherms or endotherms, have higher metabolic rates and are more active than 'cold' animals. Traditionally, northern hemisphere palaeontologists in the 19th century saw dinosaurs as sluggish, 'cold-blooded' creatures—much like a lizard in a London winter, I suspect. This view was challenged by, among others, Robert Bakker (now at the Glenrock Paleontological Museum in Wyoming) in the 1970s who made many impassioned pleas for dinosaurs being endothermic. Most scientists agree nowadays that dinosaurs must have been more athletic than imagined in the 19th century, moving large distances and actively foraging and hunting, but their thermal relations are as yet unresolved.

The author sits on the top of a rocky outcrop in order to collect body-temperature and behavioural data from Freshwater Crocodiles. The waterhole containing the study animals is to the right at the bottom of this 20–30-metre-high cliff, and the animals, which are paint-marked on their backs, could be observed easily from this vantage point.

The large size of Saltwater Crocodiles makes them difficult to catch for the surgical implantation of temperature-sensitive transmitters. Instead, we sewed the transmitters into dead chickens and fed these to the crocodiles. The transmitters resemble stomach stones (gastroliths), which crocodiles swallow to aid digestion. This trick worked well, and crocodiles retained the transmitters in their stomachs for up to several months.

of high, mammal-like metabolic rates. Also, the daily patterns of behaviour were quite different in Saltwater Crocodiles compared to Freshies. Although we no longer observed the lizard-like shuttling behaviour, large Salties did change their behavioural patterns over



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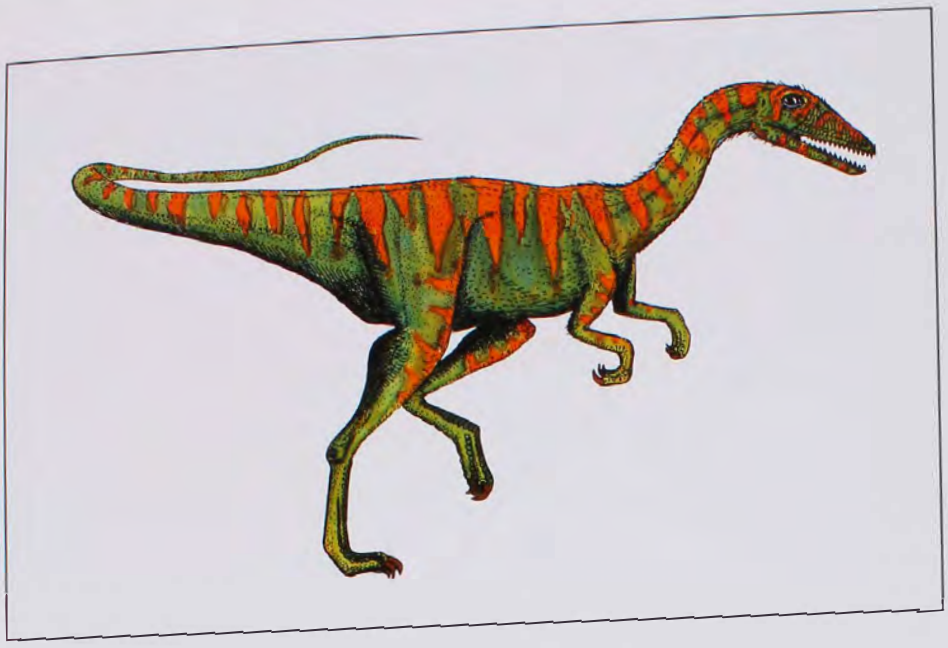

JOHN LONG

Dinosaurs were incredibly diverse. *Compsognathus* weighed only 3.5 kilograms and belonged to the phylogenetic group that ultimately gave rise to the birds.

CROCODILES AND DINOSAURS EVOLVED FROM A COMMON *ancestral group, the Archosauria, and they roamed the Earth together for millions of years.*

Saltwater Crocodiles are good model organisms for thinking about dinosaurs, not only because of their great maximum size and their great size range, but also because crocodiles and dinosaurs evolved from a common ancestral group, the Archosauria (which, incidentally, also includes the birds), and they roamed the Earth together for millions of years. In the past, researchers have compared the thermal physiology of the Leatherback Turtle (*Dermochelys coriacea*) to that of dinosaurs (see *Nature Aust.* Autumn 1992). Their data showed that these turtles may have slightly higher metabolic rates than those of other reptiles, and they surmised that the turtles' body temperatures may be considerably warmer than the surrounding water as a result of their large body size, and the use of peripheral tissues as insulation. The problem with turtles is that not only are they taxonomically quite different from dinosaurs, there are also barely any data documenting body temperatures of Leatherback Turtles, let alone temporal patterns of body temperature, in a large size range of free-ranging individuals.

In order to get an insight into the possible thermal relations of dinosaurs, I developed a mathematical model predicting body temperatures of large ectotherms, based on what we now knew of the temperature patterns of crocodiles. The model involved calculations of environmental conditions at the animal's surface, which are determined by climatic factors, animal mass, as well as by behavioural postures, particularly with respect to relative proportions of surface area exposed to sun and shade, in water and on land. Once I calculated surface conditions, I used mathematical equations to determine heat transfer between the surface and the centre of the animal, which made predictions of body temperature possible. I tested the validity of the mathematical calculations by looking at how well I was able to predict the data measured in crocodiles in the field, and I found that the model worked extremely well. Encouraged by this, I proceeded to tackle dinosaurs. The principle question I wanted to answer was: could dinosaurs have had high and stable body temperatures (warmer than 30° C and with daily fluctuations less that 4° C) had they been simple ectotherms relying on behavioural thermoregulation like crocodiles?

I started out by searching the literature and perusing descriptions of over 700 dinosaur fossils from over 320 genera ranging in size from 0.5 to 50,000 kilograms, for which I then predicted body temperatures. I also consulted the literature to learn about the climate during the time of the dinosaurs, and placed each fossil at its correct palaeolatitude and climate.

Quite to my surprise, I found that most dinosaurs (about 80 per cent of the fossils I looked at) could indeed have had body temperatures of 30° C or warmer, even at the coldest time of the year, had they been simple crocodile-like ectotherms. Of those 'warm' dinosaurs, about half would have had a 'stable' body temperature, while the other half would have fluctuated by more than 4° C daily. According to my calculations, it would only have been small dinosaurs (less than 200 kilograms) living at mid to high latitudes (over 45–50°) that would have been cold in winter (body temperature less than 20° C) by modern reptilian standards.

Pat Vickers-Rich (Monash University) and Tom Rich (Museum of Victoria) have described several small ornithopod dinosaurs and a medium-sized theropod that lived in high-latitude southern Victoria in the Early Cretaceous (135–95 million years ago). It is tempting to speculate that these dinosaurs evolved physiological adaptations, such as high metabolic heat production typical of modern endotherms, to avoid the potential disadvantages of low winter body temperatures. However, great care has to be taken when drawing conclusions about the physiology of extinct animals from fossils. Simply finding fossils in what may have been cool climates does not say much about their thermal physiology, because there are a number of strategies, such as winter dormancy and migration, that animals could have employed to escape winter cold and darkness. Besides, estimates of palaeoclimate vary considerably, and there are conflicting opinions about what the climate of southern Australia was like in the Early Creta-

ceous. It is intriguing, though, that fossils of crocodiles were found alongside these dinosaurs, which indicates that the climate was such that typical ectotherms were well able to survive in it.

Recent discoveries of feather-like structures on fossils from small dinosaurs that lived at mid to high palaeolatitudes indicate that at least some dinosaurs may have had the prerequisite thermal insulation for an endotherm-like physiological make-up. Incidentally, these 'feathered' dinosaurs were coelurosaurs, a phylogenetic branch that is assumed to have led to modern birds. In any case, most dinosaurs, particularly larger ones (over 1,000 kilograms) that lived at latitudes up to 45–50°, could have been warm ectotherms and, probably, even had stable body temperatures, so there is no need to invoke endothermy to explain high activity levels in those dinosaurs.

However, despite the good experimental data outlined above, I have already experienced how emotional some people are about the thermal relations of dinosaurs, and anonymous emails have informed me in no uncertain terms that my conclusions are all wrong. I suspect that the question of dinosaur thermal relations will only be laid to rest once cryptobiologists find an extant dinosaur population in central Africa, and until then it may be safer to stick to crocodiles.

Sauropods, like this 12-metre-long Australian *Rhoetosaurus*, were the largest of the dinosaurs. Some sauropods may have weighed 50 tonnes and grown up to 40 metres in length.

FURTHER READING

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Seebacher, F., Grigg, G.C. & Beard, L.A., 1999. Crocodiles as dinosaurs: behavioural thermoregulation in very large ectotherms leads to high and stable body temperatures. J. Exp. Biol. *202: 77–86.*

DR FRANK SEEBACHER IS A POST-DOCTORAL RESEARCHER IN THE DEPARTMENT OF ZOOLOGY AND ENTOMOLOGY, UNIVERSITY OF QUEENSLAND. HIS RESEARCH FOCUSES ON THE THERMAL RELATIONS OF VERTEBRATES, AND BIOPHYSICAL MODELLING OF HEAT TRANSFER IN ANIMALS.

BRIAN CHOO

Scarab beetle on a bottlebrush.

Gippsland Water Dragon (*Physignathus lesueurii howittii*).

caught in the ACT

BY MICHAEL MACONACHIE

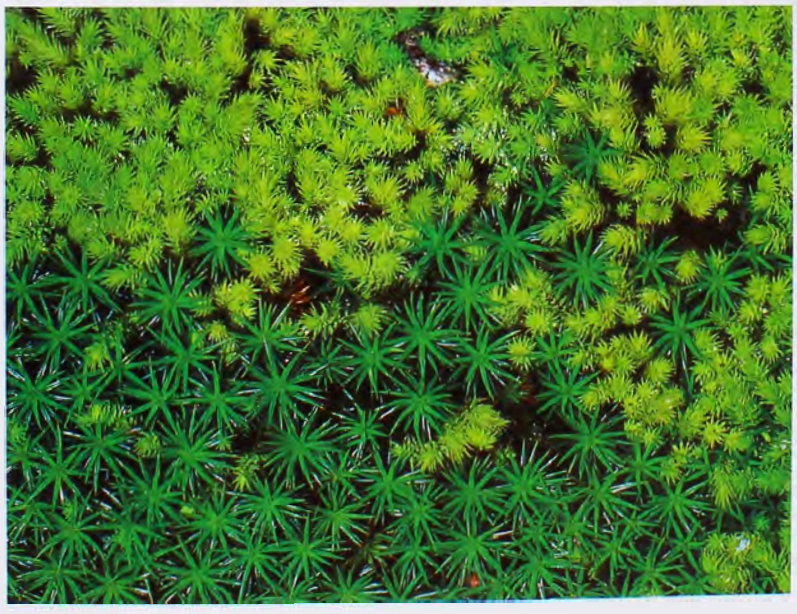
Frosted reeds.

Eastern Grey Kangaroo (*Macropus giganteus*).

Red-eyed Cicada (*Psattoda moerens*).

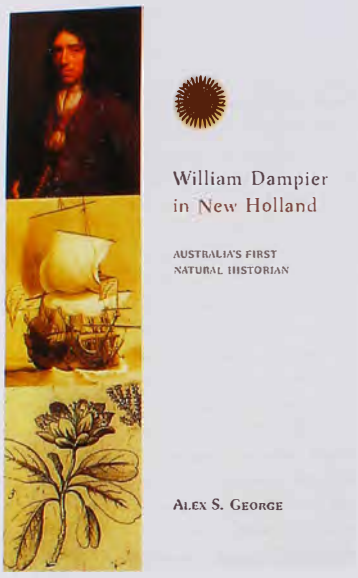
Sulphur-crested Cockatoo (*Cacatua galerita*).

Garden Wolf Spider (*Lycosa godeffroyi*).



Mosses.

reviews



William Dampier in New Holland: Australia's First Natural Historian

By Alex S. George. Bloomings Books, Vic., 1999, 192pp. $39.95rrp.

THIS DELIGHTFUL BOOK GIVES a brief biography of William Dampier and discusses the two voyages that took him to Western Australia. The book chiefly discusses the plants and animals he saw, collected or mentioned in his travels. There is a strong bias towards the flora he observed. This is probably due to the 24 extant collections housed at Fielding-Druce Herbarium at Oxford University, along with illustrations used to describe the first Australian plants by Pukenet (1705) and Ray (1704), and to the author's expertise in being one of Australia's prominent botanists. The collections are of a very high quality and are as scientifically informative as any contemporary collection. The animals and marine life that Dampier encountered are also discussed but their treatment is not nearly as exhaustive as the botany.

Accompanying the text are beautifully presented photos of Dampier's specimens, illustrations and contemporary photos of the places he visited in Australia, and most of the plants and animals.

Alex George completes the book by discussing geographical and scientific entities that commemorate Dampier. An appendix highlights, and often corrects, information surrounding Dampier, the places he visited and when. There are some problems associated with landing dates. This is because Dampier was using the Julian calendar during his voyages and 10 or 11 days need to be added to adjust to the Gregorian calendar, which is currently used. Alex George has obviously carried extensive and exhaustive research on all matters pertaining to Dampier.

I found this a delightful book, attractively presented and printed on high-quality paper. I recommend this book to all people interested in natural history and to those who thought that Cook's voyage in 1770 was the first to bring back Australian scientific material to Europe.

—PETER JOBSON
NATIONAL HERBARIUM OF NSW

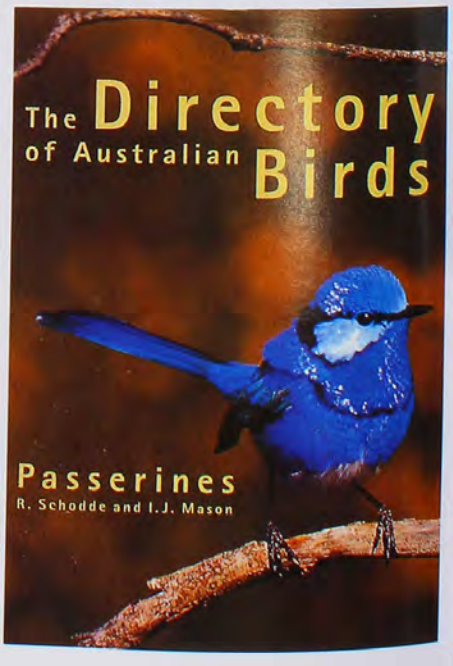
The Directory of Australian Birds: Passerines

By R. Schodde and I.J. Mason. CSIRO Publishing, Vic., 1999, 851pp. $180.00rrp.

THE SUBTITLE, *A TAXONOMIC AND ZOOGEOGRAPHIC ATLAS of the biodiversity of birds in Australia and its Territories* indicates the intended scope of this mammoth work. This volume, on passerines or songbirds, begins one of the most ambitious works in Australian avian taxonomy and distribution. The authors attempt to identify those regional populations that should be considered as basic units of biodiversity to be conserved.

Each species account presents the recognised regional populations and their defining characters, a map identifying their distributions and areas of intergradation, and more detailed discussion of geographic variation where appropriate. This re-evaluation has led to a number of name changes, with new or resurrected names being introduced, and several currently accepted species split or merged. By having only two authors making the taxonomic decisions, the volume promises to be more consistent throughout than previous lists that are amalgams of different workers' conclusions.

Because of its technical nature and price, the book will not appeal to many bird enthusiasts. For anyone interested in the distribution and taxonomy of Australian birds, however, access to it is a must. Although some decisions will be controversial, the authors have nonetheless presented a solid and extensive foundation for future work in these aspects of Australian ornithology and an invaluable basis for considerations about bird conservation in this country.



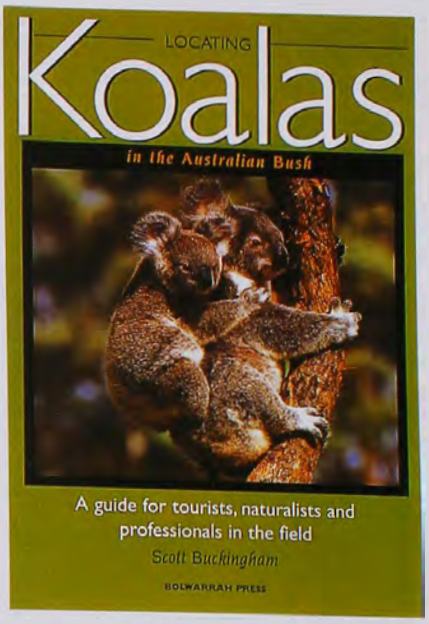
—WALTER E. BOLES
AUSTRALIAN MUSEUM

Locating Koalas in the Australian Bush

By Scott Buckingham. Bolwarrah Press, Vic., 1999, 85pp. $19.95rrp.

The Koala: Natural History, Conservation and Management

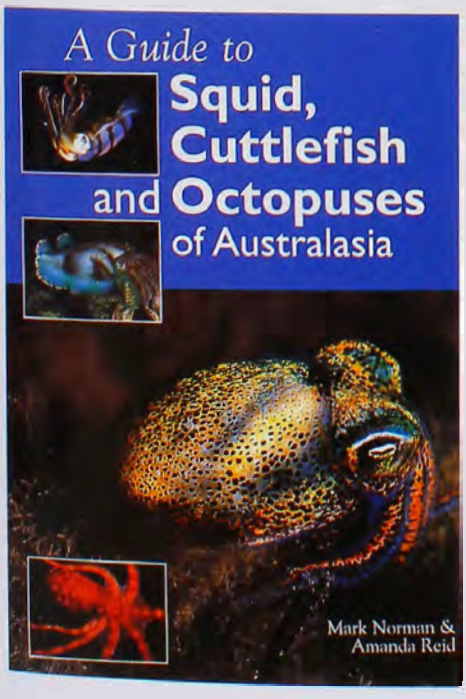
By Roger Martin and Kathrine Handasyde. UNSW Press, NSW, 1999, 132pp. $32.95rrp.



BOTH THESE BOOKS DEAL WITH KOALAS and both have been written from a slightly Victoriocentric point of view, as all authors make it clear that the majority of their experiences were gained in south-eastern Australia. But there the similarity ends. The first, *Locating Koalas* is written with a slightly folksy tone. Its target audience is said to be tourists, naturalists and professional biologists, and it contains some very practical advice about how to look for Koalas in the bush. Fortunately, Koalas are one of the few native animals whose presence in an area (scats and scratches on trees) can be quite easily detected. Seeing them is a different story. If anything, this book makes it sound a lot easier than it is. Nothing is left unsaid when offering advice about venturing into the Australian bush—don't stand on bull-ant nests, watch out for mine shafts, don't get lost. What to do in a variety of weather conditions is also covered, although why anyone would look for Koalas on a wet and cold day escapes me. The best you could hope for is a glimpse of a grey messy blob high up in a tree. However, if you can't find Koalas after consulting this book, you have chosen the wrong area. I would like to add one small piece of advice of my own: make sure you are in Victoria or Kangaroo Island, where your chances of seeing them are much higher than almost anywhere else in Australia, except a zoo.

The other publication is the second edition of this excellent book containing almost everything you need to know about Koalas. As the authors state in the introduction, there has been a mass of research carried out on this species since the first edition in 1988, and the results are reflected in the huge amount of information covered in the book. One of the really hard issues tackled by Martin and Handasyde is the variation in the conservation status of the Koala over its range, in particular the ongoing massive overpopulation in Victoria. What makes very sobering reading is not only their documentation of the enormous suffering that has occurred in Koala populations over the years, largely caused by the 'move-on-the-problem' philosophy exhibited by almost every government official faced with the situation, but they even nominate where it will occur again, and the likely consequences for Koalas and the doomed forests in which they live. The problem is that the animals eat themselves and other fauna out of house and home, and then slowly starve to death, in huge numbers. The solution, according to these authors, is not more of the same (that is, expensive sterilisation and translocation programs) but a plea to consider these animals, in their present circumstances, as a resource that could be harvested. A very brave suggestion, and one I fear will fall on deaf ears, given the very influential conservation 'industry' that surrounds this species.

—LINDA GIBSON
AUSTRALIAN MUSEUM



A Guide to Squid, Cuttlefish and Octopuses of Australia

By Mark Norman and Amanda Reid. Gould League of Australia, Vic., 2000, 96pp. $32.95rrp.

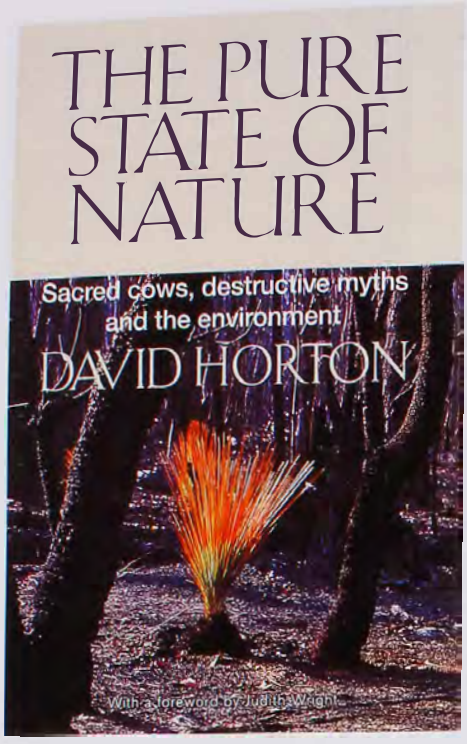
WE KNOW THAT BLUE-RINGED OCTOPUSES should be avoided, and calamari goes tough if cooked too long, but what do we know of cephalopods as living animals?

Mark Norman and Mandy Reid are two of a small group of research workers who have dramatically increased our knowledge of these animals in Australia over the last 20 years. This beautifully illustrated book, with introductory sections on the natural history and evolution of cephalopods, has descriptions of over 60 species, from the Chambered Nautilus and giant squids to an amazing variety of octopuses.

Usually I would say something derogatory about the use of invented 'common' names. However, when authors can come up with 'Wunderpus' for a spectacular brown and white striped octopus, who am I to deny them their triumph?

This book is the first illustrated summary of our cephalopod fauna. In this Olympic year it deserves a gold medal for opening our eyes to an amazing and hitherto hidden element of our marine fauna.

—BILL RUDMAN
AUSTRALIAN MUSEUM



The Pure State of Nature

By David Horton. Allen and Unwin, NSW, 2000, 192pp. $19.95rrp.

THE RELATIONSHIP BETWEEN ABORIGINES AND THE LAND, especially in a pre-European context, is a hot political topic. This is because it impinges heavily on issues such as Aboriginal land rights, and the contemporary management of the environment. This relationship is the core of David Horton's very readable book. And he brings an unusual perspective to the debate, being an expert in the identification of the fauna of archaeological sites. Briefly, Horton concludes that Aboriginal people did not cause the so-called megafaunal extinctions, which instead were probably brought about by climate change; that their attitude to and 'management' of the landscape derives from their spiritual (not rationalist economic) relationship with the environment of which they were just a part; and that this management was fairly light-on due to their beliefs and their low population densities. He also points out that the Aboriginal people's 'low-tech' way of life made adaptive sense considering Australia's unpredictable climate. As to the important question, at least to Western minds, of why Aborigines didn't develop agriculture, Horton argues convincingly that it may simply not have been appropriate under Australian conditions.

The book is written from a Western scientific point of view, but it is lightly infused with sentiment and whimsy, and, unusual among writings on the subject, a healthy dose of scepticism about inferences made about the past. As I thought about the book in the days after finishing it, I realised that most non-Aboriginal Australians, raised as they have been in traditions of Western thought, probably have no idea about how pre-European Aborigines really viewed their environment. That realisation itself is worth thinking about.

—ALLEN E. GREER
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SOCIETY PAGE

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Contact: Mrs E. McCulloch

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Web: www.science.adelaide.edu.au/sasta
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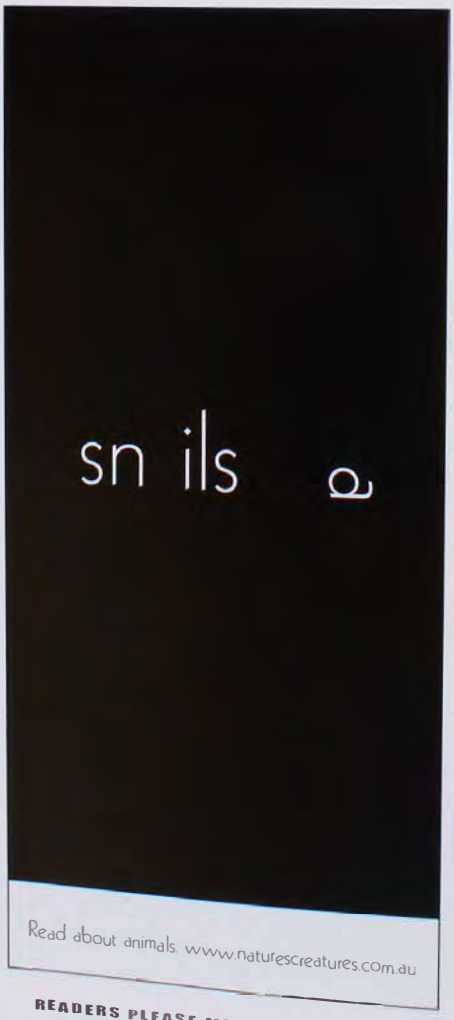

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—Kathryn Wells
Braddon, ACT

A: There are a number of myths about opals and this is one of them. Handling opals will not improve their appearance, although it might give the owner satisfaction. Opal is a softer material than quartz, so it needs to be handled with care otherwise it will easily scratch and chip. Opals contain water in their structure and, upon extraction from the earth, they dehydrate, then stabilise. Some craze at this point but those that don't are usually stable. However, any opal may crack with temperature or humidity extremes, or with rapid thermal changes. It is best to keep them out of conditions of high heat, such as direct sunshine, and low humidity, such as bank vaults. Perhaps the myth arose because people found that their opals responded better to a humid room environment, which included handling, than to storage.

Opal forms in a variety of geological environments, but Australian opal, which is the most stable opal, formed in a sedimentary environment. The withdrawal of a large inland sea in central Australia, about 100 million years ago (during the mid-Cretaceous) left sediments that later weathered, releasing silica into ground waters. These siliceous waters infiltrated cavities and fissures in the rocks, evaporating and concentrating, over a period of long geological stability. They formed an amorphous gel, rather than a crystalline mineral, composed of tiny, sub-microscopic spheres of silica. Often these spheres were arranged row upon row in orderly layers. These orderly layers break up (diffract) light into its spectrum colours, causing the play of rainbow colours in precious opal. Where the arrangement of spheres is not orderly, no diffraction occurs and common opal or potch is the result.

Current research also suggests a biological input to opal formation, with a possible link between bacteria and the original weathering process that formed the opal. Large bacterial populations may have excreted acids and enzymes that resulted in the biochemical weathering of clay minerals and feldspar.

—Gayle Webb
Australian Museum

COURTESY JIM FRAZIER

A thin layer of precious opal on ironstone. In adverse conditions, opals can crack, as shown here.

Wandering Wanderers

Q: *Where do Australian Wanderer Butterflies migrate to, assuming of course they are the same species as those in America (which migrate to a single location in Mexico)?*

—Roger Burgess
Tweed Heads, NSW

A: We know a lot about the migration patterns of Wanderer Butterflies in Australia, thanks to an Australian Museum research program from the 1960s to 1980s. Our species (*Danaus plexippus*) is the same as that in North America, where they call it the Monarch. The species was first seen in Australia in the late 1800s (in Queensland) having apparently arrived by a series of 'island hops' across the Pacific. In North America the species is widely dispersed over the continent during summer, as far north as southern Canada. In autumn the butterflies set off on a long flight southwards and congregate in vast numbers to spend the winter, hanging like bunches of dead leaves from the branches of trees. There are many such sites, the same sites being used year after year. The best known sites are in California, but others have been found as far south as Mexico. In spring the butterflies disperse northwards, the females laying eggs on milkweed plants as they go. The next generation moves farther north and, after another two or three generations, the species is again present in southern Canada, where it has time for just one generation to develop before the next southerly migration in autumn.

In Australia similar migrations occur, but generally the populations are smaller and the migrations are more complex. In summer the butterflies can be seen feeding at or flying around wherever milkweed plants occur. In the northern part of its range (north of the Richmond River), the butterflies move towards the coast in autumn and breeding is continuous throughout the year. Farther south there is also a general movement towards the coast but breeding ceases and overwintering congrega-

PAVEL GERMAN/NATURE FOCUS

tions gather in about April–May (depending on temperature) and remain until about August or September. The main, but not only, areas of concentrations are near Camden, in the Windsor area and in the Hunter Valley in New South Wales, near Adelaide in South Australia, and probably near Sale in Victoria. At dispersal time mating takes place and the females leave a little earlier than the males to seek out milkweed plants on which to lay eggs. By summer the butterflies have again colonised much of Australia, but more by random movements than direct flights.

—COURTENAY SMITHERS
AUSTRALIAN MUSEUM

The migrations of Australian Wanderer Butterflies are more complex than their northern hemishere relatives.

Answers to Quiz in Nature Strips (page 19)

1. *Pumice*
2. *Shy Albatross*
3. *Officer Basin*
4. *1936*
5. *Flowering plants*
6. *Saturn*
7. *Spiders*
8. *Amethystine Python*
9. *Chlorofluorocarbons*
10. *Pinchgut*

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 fungi diary for 2001* from the Australian Museum Shop. Spring's Pic Teaser was a Wanderer Butterfly egg.

GREG HAROLD

Putting the move on nature

How can it be that a major conservation effort actually destroys what it purports to save?

THERE ARE MANY WAYS HUMANS destroy the natural living world. The two best known are to kill off species and to destroy habitat. But there is also a third. It's translocation—when we move organisms from one place to another. The detrimental effect of the first two processes is well understood, but the problem with translocation is less widely appreciated. In fact, translocation figures prominently in many 'conservation' initiatives. How can it be that a major conservation effort actually destroys what it purports to save? To understand this, one has to think about how evolution works.

Almost all evolutionary change begins with a single mutation of a single gene in a single individual living at a single spot on the globe. Virtually all other evolutionary change is built on this basic process. Sometimes the mutations have no apparent relevance to the location in which they arose (although they become a place-specific characteristic of the population), while in other cases, they probably help the local population to live in that place. If enough different mutations accumulate in a population, usually due to its geographic isolation, individuals in that population may no longer be able to breed with individuals of other populations, and a new species emerges. If one could look at a map of the distribution of genes in a species throughout its range, there would be all sorts of complex patterns in addition to the areas where new species were forming. Some of this genetic variation reveals itself in easy-to-see morphology. For example, genetic variation is the basis of subspecies, geographic races, and gradual changes in size, shape and colour pattern over broad areas of environmental change. In fact, this geographic pattern of genetic variation is the very essence of what a species is, and evolution acting at the local level is the very process that has given us the distinct populations and species that we all work so hard to preserve.

When we move individuals around, we undermine the ongoing evolutionary process that produces and maintains this pattern. Even a single individual carried to a new place can disrupt the local genetic pattern. Unfortunately, many of those people who move organisms around in order to 'save' them either do not understand the destructive nature of this practice or, worse, do not care.

But what about the argument that individuals in nature are always moving themselves about, sometimes over vast distances? Isn't that the same as humans moving them about? Not at all; because when individuals move themselves, there is likely to be a genetic component to their movement—and one that may be important to the future of the continuing evolution of the lineage. Adventuresome individuals in other species may be as important to their species as they are to ours. When humans move individuals, they exert a form of artificial selection, whether the choice of individuals is random (but is any choice really random?) or conscious (the largest, strongest, most fecund, cutest, most helpless etc.). It would be highly unlikely that the individuals of a species humans chose to move were the same ones nature would have chosen, and even less likely that the new home chosen by humans was the same as nature would have found for them.

Does all this sound too academic? If a person just likes the look of plants and animals and doesn't care about their genes (which can't be seen anyway), what's the worry? Well fair enough, that's the majority attitude, even among professional conservationists. But think about the implications of this viewpoint. First, this attitude is content with the static wrappings of the package, and not its internal contents and structure, nor its continuity into the future. As long as there is something that looks like a Koala that is sitting in something that looks like a eucalypt that is growing in something that looks like a forest, there is no problem. And second, this attitude is apparently unconcerned if natural evolutionary change is replaced by some undefined degree of human-mediated, or artificial, change. But how far down this path are we willing to go? If, as a result of translocation and its accompanying artificial selection, the subsequent population of one's favourite organism has 0.1 per cent fewer spots, would that matter? How about one per cent smaller in body size? Or ten per cent paler?

The translocation mentality is now widespread. It is almost as if we feel it is our right to pick up organisms and carry them to a new place to make over our own little part of the world to our own specifications. But what is most remarkable is that translocation is a key management tool in many current conservation initiatives, programs often designed and delivered by biologists: animal rehabilitation, captive-breeding, revegetation, restocking, and 'troublesome' animal-relocation programs. With translocation, are we not trying to mend one end of the biodiversity tapestry by unravelling the other?

DR ALLEN E. GREER IS A PRINCIPAL RESEARCH SCIENTIST AT THE AUSTRALIAN MUSEUM.

BY ALLEN E. GREER

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