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WINTER 2002

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Lungfish

LAUGHING KILLERS

ISSN 1324-2598

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FRONT COVER
Despite the violent start to their lives, Laughing Kookaburras (*Dacelo novaeguineae*) grow up to be very sociable creatures. Photo by Kathie Atkinson.

up front

IT'S GREAT TO BE ABLE to announce that for the last year we have been printing *Nature Australia* magazine in Australia. The Australian-owned company that prints the magazine takes great care and pride in the publication's production. Along with a new printer, we also had to choose a new paper. After much deliberation, we chose a wood-free paper offering high gloss and whiteness produced using chlorine-free pulp, which is important if you want to choose a more environmentally friendly paper.

Our paper has also been awarded the Nordic Green Swan Label. The Nordic environmental label is a neutral, independent label that guarantees a certain environmental standard. Only products that satisfy strict environmental requirements on the basis of objective assessments are allowed to display this label. This helps consumers to identify the products that cause the least damage to the environment among those in the market place and hopefully, as a result, manufacturers are stimulated to develop products and production processes that are more environmentally aware. The criteria taken into account when awarding the label relate to the environmental factors through the paper's life cycle, from raw material, during production and distribution, during its use and as refuse.

NICHOLAS BIRKS/WILDLIGHT

The second great announcement for this issue is our new regular feature—The Secret Life of Plants. In response to your desire to see more articles on plants, we went on the hunt for someone who could take you into the life of plants. We found Dr Tim Entwisle, Director of Plant Sciences at the Royal Botanic Gardens Sydney, and each issue he will bring you a fascinating insight into the world of plants. Turn to page 76 for his first story on a harmless alga with a particularly nasty side.

We also expose the Laughing Kookaburra's darker side, introduce you to some amazing jumping spiders and examine the precarious future of the Queensland Lungfish.

—**JENNIFER SAUNDERS**
Managing Editor

SIMON D. POLLARD

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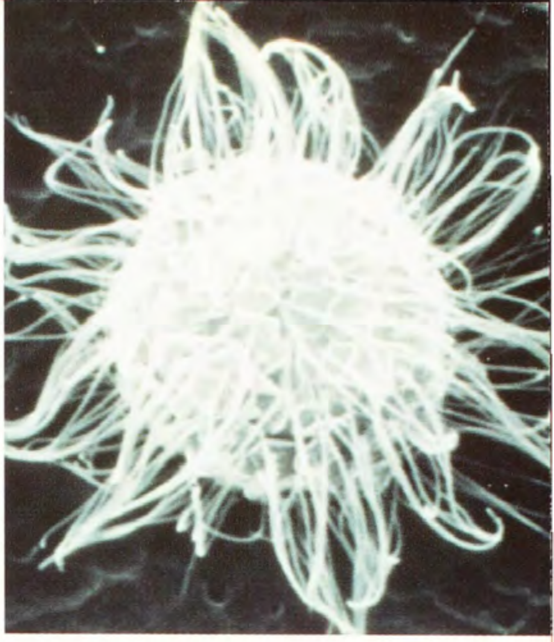


REGULAR FEATURES

COLUMNS

letters

Scaredy Stag

I have some reservations about the suggestion that in stormy weather big stags lose heat quickly and have to seek shelter, but the smaller females "see out the storm" (*Nature Aust.* Winter 2001). In his delightful essay "On being the right size", J.B.S. Haldane wrote over 60 years ago that "All warm-blooded animals at rest lose the same amount of heat from a unit area of skin, for which purpose they need a food-supply proportional to their surface and not to their weight". Cold climate mammals are large because their surface area is proportionally less than similarly shaped smaller mammals. They lose proportionally less heat and are more likely than their young, for example, to survive a cold snap. They also need proportionally less food to maintain their body heat. I think the 'weather-sensitivity hypothesis' described by Conradt *et al.* needs more work.

—Barrie Gillings
University of Sydney

Barrie Gillings is right to point out that large animals lose heat less rapidly relative to small animals. However, for the weather-sensitivity hypothesis, what is critical is the absolute (not relative) heat losses, and these are larger for large animals. In winter, animals of both sexes should choose the habitat in which they gain most energy: that is, the habitat in which energy gain from food intake, minus energy lost as heat, is maximised. Heat loss and food intake both increase with body weight, but for deer heat loss increases more steeply with body weight (to the power of 0.63) than does food intake (body weight to the power of 0.48). This means that energy loss increases more rapidly than energy gain as the animal's body size increases.

Winter habitats usually either offer good shelter or good forage, and therefore deer have to choose between these two factors. Because heat loss increases more steeply with body weight than does food intake, the larger males have, relative to the smaller females, less to gain in a good forage habitat but more to lose in a badly sheltered habitat. Therefore, males more often choose sheltered habitats with poor foraging conditions than do females, especially when weather conditions are bad.

—Larissa Conradt
University of Leeds, UK

Beautiful Hagfishes

I have always enjoyed reading your journal with its beautiful pictures. However, having studied hagfishes for four decades, I would like to disapprove of the tone in your editorial as well as in the article that describes these creatures as disgusting (*Nature Aust.* Spring 2001). Remarkable and fascinating are more appropriate words; even beautiful can be used for some hagfish species like the Japanese *Eptatretus burgeri* with its whitish dorsal line. Your editorial is illustrated with a neatly coiled hagfish that unfortunately is labelled *Myxine glutinosa*. But *M. glutinosa* never coils its body in this manner. That type of coiling is peculiar to the genera *Eptatretus* and *Paramyxine*. Most likely all the pictures in the article (and editorial) represent the Pacific Hagfish (*Eptatretus stouti*), which was studied by the author.

—Bo Fernholm
Swedish Museum of Natural History

True. All the pictures were of the Pacific Hagfish and Nature Australia *takes full blame for the error.*

—G.H.

Party Quotes

Many thanks for all the interesting articles and superb photos. However, I believe that articles from two recent issues lifted the standard to a new level!

I refer firstly to Steve Van Dyck's "What-a-rat!" (*Nature Aust.* Winter 2001). This article has the quote of the year: "...odour that is eclipsed only if a polecat in a nearby cage has died and gone unnoticed for two weeks." I must remember to try and work that into polite

YANN ARTHUS-BERTRAND/AUSCAPE

Are Red Deer stags (*Cervus elephus*) really the first to seek shelter in a storm?

dinner-party conversation!

The other is Doug Fudge's article on hagfishes (*Nature Aust.* Spring 2001), which has several 'quotable quotes', including the one about the hagfish's ability to tie itself in a sliding knot to rid itself of slime. But the one that really stands out is: "...endowed with two sets of opposing, horny, rasping teeth that they can extrude and retract, Alien-like, from their mouths." A bit like an uncle I used to have!

—Brian Ward
Douglas Park, NSW

Optimal Design

In "The Killer Rat-kangaroo's Tooth" (*Nature Aust.* Winter 2001), Stephen Wroe suggests that the configuration of *Ekaltadeta*'s adult dentition "undermines the notion of optimal design", based on the exceptional role of the second premolar (P2) acting as a buffer for the massive, possibly carnivorous third premolar (P3). Yet optimisation theory does not always predict the evolution of the "best" solution to a problem, such as buttressing the P3 with additional bone. It predicts the optimal evolution of form, given a specific, limiting developmental and historical context. The Killer Rat-kangaroo's dental pattern does not undermine optimal design theory. Rather, it begs the question: why might this have been a good solution for *Ekaltadeta*, given its particular developmental and ancestral constraints?

—Justine A. Salton
City University
of New York

The Needs of Natives

Why does Nick Mooney polarise the debate on native animals as pets (The Last Word, *Nature Aust.* Summer 2001–2002)? Some Australian species (like Budgies) make excellent pets, while others do not. The suitability of any animal (native or not) as a pet depends on both the needs of the animal and the ability of the pet-owner to provide for these needs.

Some of Mooney's arguments against native pets are equally applicable to domestic animals. Domestic species/breeds can be "cantankerous" and all are capable of passing on life-threatening illnesses to humans. We don't ban Cats because they pass on abortion-causing parasites, nor Dogs when they give us hydatids. We immunise them, wash our hands and advise pregnant women to avoid them. Knowledge, not negativity, is the answer.

The illegal trade in wild-caught animals is likewise a concern, but again no reason for blanket restrictions. Restrictions should apply to those species that need protection, and resources should not be wasted denying access to those species that breed well in captivity and whose needs can be met as successfully as those of domestic species.

Mooney doubts the educational merit of keeping native animals. Sadly, some people will never learn much from keeping pets, domestic or otherwise. But I would rather see my children learning about the needs of pet native mice or some other suitable Australian species than the pestilential introduced species currently forced upon us. Let's move this debate forward by discussing the needs of the different species (native or domestic) and helping people match their own needs with those of the animals they choose to either live with, or admire from afar.

—Danielle Clode
Smiths Gully, Vic.

DAVE WATTS/NATURE FOCUS

Some native species, such as Budgerigars, make excellent pets.

Nature Australia requests letters be limited to 250 words and typed if possible. Please supply a daytime phone number and type or print your name and address clearly. The best letter in this issue will receive a copy of _Past lives_. The winner this issue is Danielle Clode.

nature strips

COMPILED BY GEORGINA HICKEY

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

Grandmother Knows Best

A long-term study on the calls of African Elephants has revealed that, when it comes to telling friend from foe, grandmother knows best.

Karen McComb (University of Sussex) and colleagues discovered not only that older elephant matriarchs are better at discriminating between the calls of friendly elephants and those that might want to harm the family, but also groups with older (and presumably wiser) matriarchs at the helm produce more young.

Female African Elephants (*Loxodonta africana*) live in family groups led by the oldest female. As they range widely and feed, they make contact calls—deep, rumbling sounds that carry great distances—to advertise their presence to widely spaced social companions.

When the researchers played back contact-calls of other elephants in the area to their study groups, they found that, in response to rarely encountered calls, elephant families with older matriarchs were much more likely to bunch themselves together protectively than when they were played calls of more regular associates. In contrast, groups led by younger females failed to show this sharp discrimination between friend and foe. Although an earlier study had found that adult females are familiar with the contact-calls of around 100 others in the population, this research shows that older females are more adept at reading the auditory cues and signalling the appropriate response to their families.

Believing that superior discriminatory abilities should translate into reproductive benefits for the

Groups of African Elephants are more likely to bunch themselves protectively when an older female matriarch is at the helm.

FERRERO-LABAT/AUSCAPE

group by allowing younger females to concentrate on calf rearing, the researchers compared data on recent reproductive success rates with the age of each family's matriarch. They found that the older and more protective the leader, the more calves produced per female, and say that this is the first time a statistical link has been found between reproductive success and social knowledge.

The study has significant conservation implications, since older, larger elephants are more prized by hunters and poachers, and the deaths of these individuals could weaken the family unit for many years to come.

—R.S.


ANNE & JACQUES SIX/AUSCAPE

Some Honey Bees punish intruders by locking them up in makeshift prisons.

The Honey Bee Hilton

Everyone knows that Honey Bees (*Apis mellifera*) are into capital punishment, death by stinging being the common sentence for most hive intruders. But a recent study has shown they also use life imprisonment to punish some offenders.

Small Hive Beetles (*Aethina tumida*) are a major headache for beekeepers in the US, where they were accidentally introduced in the late 1990s. The beetles enter hives to feed on the developing young, pollen and honey. However, their tough exoskeletons, rounded bodies and habit of tucking in their heads like turtles make them virtually impervious to the bees' stings.

The beetles are native to South Africa, so Peter Neumann (Martin Luther University, Germany) and colleagues decided to study how South African Honey Bees deal with them. They found that when a beetle is detected, a group of worker bees surrounds it, herds it into a crack or corner, and then guards it continuously. Meanwhile, other bees gather a type of fast-setting tree resin known as propolis, normally used for sealing cracks in the nest cavity. The propolis is used to build a makeshift prison, within which the captured beetles eventually starve to death.

European Honey Bees, the subspecies kept in the US, also use tree resin as a sealant, but apparently they haven't learnt to imprison the beetles, probably because they didn't evolve with them. It's hoped that crossbreeding could introduce the tactic to the European bees.

—G.T.

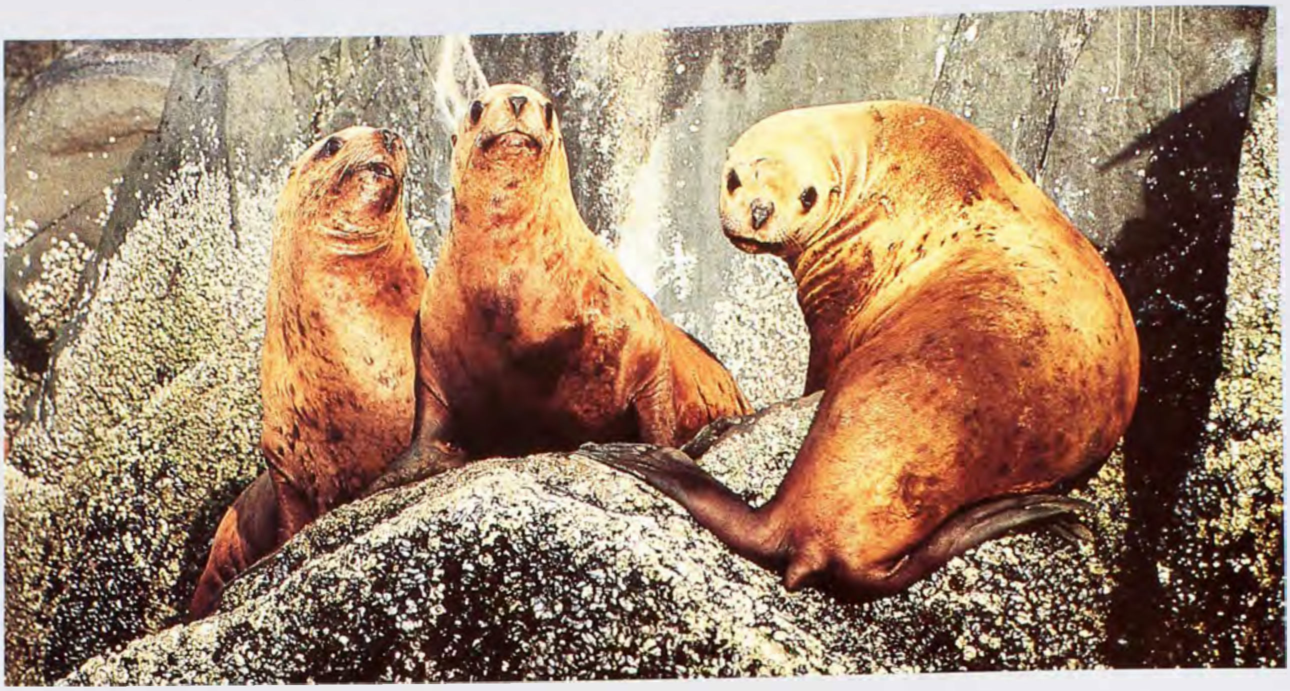
Mini Midwives

Amoebae, like many single-celled organisms, reproduce by splitting themselves in two. It's a sexless process that increases numbers rapidly, and researchers have always assumed individual cells do it without any contribution from another party. However, not all amoebae manage to go it alone, as David Biron and colleagues from the Weizmann Institute of Science in Israel have recently shown for *Entamoeba invadens*.

The researchers observed that these cells 'get stuck' during the final stage of division when they are linked by only a microscopic tubular tether. Most eventually manage to split successfully, and 10 to 20 per cent simply give up. But it's the other third that is of particular interest. These dividing cells are attended to by other amoebae which, like midwives cutting umbilical cords, rupture the ties that bind separating daughter cells.

Suspecting that some sort of chemical cue was involved, Biron and colleagues sucked up fluid from around dividing cells into a micropipette. When they released the fluid near other amoebae, most of the cells moved rapidly towards it. In fact, so intense was the attraction that the amoebae persistently followed the tip of the retracting pipette, even when its direction changed.

—K.McG.



D. PARER & E. PARER-COOK/AUSCAPE

Reducing commercial fish quotas should benefit Steller Sea Lions...but only if the right fish species is targeted.

A Steller Mistake

Like many marine mammals, the Steller Sea Lion (*Eumetopias jubatus*) is endangered. Its numbers worldwide have been dwindling since the 1970s so that only 40,000—just 20 per cent of the population three decades ago—now survive.

The most consistent explanation for the sea lion's decline is due to a reduction in the amount of fish available as food. As a result, substantial quota cuts have been made in recent years to restrict the commercial fishing of Walleye Pollock (*Theragra chalcogramma*) in Alaskan waters. But a recent study in Prince William Sound shows that, even though pollock numbers are now high, the sea lions have continued to decline, and the researchers suspect that the wrong fish species has been targeted.

Using the latest sonar and infrared tracking technology, Gary Thomas and Richard Thorne, from the Prince William Sound Science Center in Alaska, discovered that Steller Sea Lions selectively target schools of Pacific Herring (*Clupea pallasi*) during winter foraging despite the presence of large aggregations of Walleye Pollock. Night-time infrared surveillance revealed that the sea lions worked cooperatively to herd the herring into high-density schools at the surface. They then attacked them furiously and fed on the stunned fish at their leisure. In contrast, in the seven years of surveying, no sea lions were seen near pollock schools.

Why Steller Sea Lions ignore pollock as a source of winter food could be a simple matter of logistics. Sonar data showed that the pollock tended to remain at depths of 150–250 metres during the day and night, whereas herring moved to within 50 metres of the surface during the night, making them more accessible to the sea lions. The researchers point out that, by cutting back on pollock quotas, fisheries biologists may have actually further endangered the Steller Sea Lion. This is because the pollock compete for the same planktonic foods as the herring and, as adults, eat the herring as well.

—K.McG.

Oldest Human Ancestor

As humans we have an innate interest in our own family tree. We know our closest living relative is the Chimpanzee, and that we split from a common ancestor sometime between six and ten million years ago. But who (or what species) was our oldest human ancestor? Fossils recently found in the Middle Awash area of Ethiopia provide an answer.

Yohannes Haile-Selassie (University of California at Berkeley) discovered a 5.2–5.8-million-year-old jaw with teeth, plus several arm and foot bones, of a creature he named *Ardipithecus ramidus kadabba*. This is nearly a million years older than *Ardipithecus ramidus ramidus*, which was discovered in 1994 and, until now, thought to be the oldest hominid. The bones of the new subspecies are about the size of a modern Chimpanzee. The lower canines, in particular, show characters that are definitive of all later hominids, and the distinctively shaped toe bone indicates it walked on two legs. Clearly this animal was on the human line and Haile-Selassie concludes it was close to the last common ancestor of Chimpanzees and humans.

Another contender for the title of earliest hominid has been the six-million-year-old *Orrorin tugenensis* from Kenya. Discovered in the year 2000 by Brigitte Senut (Kenyan Palaeontology Expedition) and colleagues, it was quickly dubbed 'Millennium Man'. However, its teeth are more ape-like, and Haile-Selassie suggests it was either the last common ancestor of humans and Chimpanzees, or an early ape.

Perhaps the most significant finding comes from a detailed study of the geology and past environments of the Middle Awash area. Giday WoldeGabriel (Los Alamos National Laboratory, USA), Haile-Selassie and others point out that *Ardipithecus* (and also *Orrorin*) lived in wooded or forest habitats. Contrary to received wisdom, global climatic change and open habitats could not have been driving forces in this early period of human evolution. The new evidence suggests that early human ancestors may not have frequented open savanna environments until 4.4 million years ago. By this time, hominids had already evolved in fundamental ways that ultimately gave the human species an evolutionary edge.

—R.F.

> *Human female body odour could be our Chimp's bottom, metaphorically speaking.*

Revealed Ovulation

It's impossible to ignore a female Chimp when she is most fertile. Her rear end swells to such an extent that no potential mate could be in doubt she's ovulating. But women, according to conventional scientific wisdom, produce eggs without any such outward sign. This idea of 'concealed ovulation', however, may require a rethink following a study by Devandra Singh and Matthew Bronstad (University of Texas) that suggests female body odour could be our Chimp's bottom, metaphorically speaking.

The researchers 'collected' odours on plain cotton T-shirts worn by Caucasian women at different phases of their menstrual cycle. The volunteers had regular 28-day cycles and weren't using any hormonal form of contraception. They were also asked to refrain from using scented soaps and detergents, sleeping with pets or other people, and eating spicy food.

The women slept in one T-shirt on days 13, 14 and 15 of their cycle (the days they were ovulating) and another on days 20, 21 and 22 (after ovulation had finished). A group of Caucasian men, unaware of the study's purpose, were then asked to sniff the shirts and rate their odours according to intensity, pleasantness and sexiness. They found the smell of the 'ovulation T-shirts' to be far more pleasant and sexy than the smell of shirts worn later in the cycle, and did so even after the shirts were stored at room temperature for seven days.

It would make sense if men could detect when women are ovulating, because from an evolutionary perspective men could enhance their reproductive success by mating during women's most fertile times. But women need not worry about any unsolicited advances in the middle of the month. Modern society's predilection for perfumes and deodorants is likely to mask any aromatic clue to a female's fertility.

—K.McG.

Dolphins Stun Prey with Sound

For the past 20 or so years researchers have been bouncing around the idea that dolphins are capable of killing their prey with a blast of noise. Now Ken Marten (Earthtrust, USA) and colleagues have assembled acoustic and video data consistent with the theory that Atlantic Spotted Dolphins (*Stenella frontalis*), Killer Whales (*Orcinus orca*) and Bottlenose Dolphins (*Tursiops truncatus*) stun their prey with sound.

Using hydrophones and underwater video cameras, Marten and the team recorded the predatory behaviour of wild and captive populations of Killer Whales and dolphins. They found two distinct sonic predation strategies.

Wild Atlantic Spotted Dolphins emitted a continuous, medium-frequency buzzing sound lasting from two seconds to two minutes and ending with a final buzz as the dazed prey was retrieved from the sandy sea bed. Killer Whales and Bottlenose Dolphins, however, used a big bang—a high-amplitude, low-frequency sonic impulse lasting hundreds of milliseconds—or a series of bangs to possibly stun or disorient their prey.

In a separate experiment, the effects of simulated dolphin bangs (using a hydrogun) were tested on a captive school of Northern Anchovies (*Engraulis mordax*), and their behaviour recorded on camera. The researchers found that, after an extended period of exposure to the sonic impulses, the fish became disoriented or died.

The different strategies employed may reflect the Atlantic Spotted Dolphin's smaller size compared with Bottlenose Dolphins and Killer Whales. However, Marten and colleagues suspect it is more likely to reflect the differences in prey. Prey of the Atlantic Spotted Dolphin are smaller.

KEVIN AITKEN

Atlantic Spotted Dolphins make buzzing noises that apparently daze and facilitate capture of their seafloor prey.

Nostrils at the tip of the snout, as opposed to the top of the head, would have made *Tyrannosaurus rex*'s nose all the better to smell with.

Dino Nose Job

Have you ever wondered exactly where a dinosaur's nostrils should be? Until recently, few people had and it turns out they got it wrong anyway.

The tiny holes in our faces that children are so fond of exploring lead to a much larger hole in the skull (the naris). Chances are that dinosaurs (like all other vertebrates) had a similar arrangement. But when you have a dinosaur with a naris up to half a metre long, deciding where the external nostrils were located was anyone's guess.

To remove some of the guesswork, Lawrence Witmer from Ohio University studied the relationship between the location of the nostrils and the naris in a variety of vertebrates, including the dinosaurs' closest living relatives, birds and crocodiles. He painted a latex solution laced with radio-opaque barium sulfate around the nostrils of various dead animals, and then X-rayed their heads. Consistently Witmer found that the nostrils were located at the front of the naris, towards the tip of the snout. This conflicted with the popular depiction of dinosaurs where the nostrils had been located at the top of the naris. (They were originally put there by early palaeontologists studying the gigantic sauropods, which were once assumed to have led an aquatic existence and so nostrils at the top of the head made sense.)

Witmer then dissected the snouts of crocodiles and lizards, and noted that the bones at the front of the naris had small holes for blood vessels and nerves that supplied the fleshy tissue around the nostril. A search of dinosaur nares revealed the same vessels, again located at the front.

Such a location makes sense from a functional point of view. The forward nostril creates a continuous passage for air to flow through to the lungs. A more posteriorly located nostril would create a blind corner in the airway where 'dead air' could accumulate. Not only would this be inefficient, it would also hamper the animal's sense of smell, which appears to have been very important to dinosaurs.

—Paul Willis
Catalyst, ABC TV

TUI DE ROY/AUSCAPE

more stationary and live under the sand in an acoustically cluttered environment, and buzzing is the best way to 'fish' them out. For Killer Whales and Bottlenose Dolphins, a big bang may be the best strategy for stopping their larger, faster, free-swimming prey.

—R.S.

QUICK QUIZ (Answers on page 83)

1. *What colour are the irises of adult currawongs?*
2. *In which Australian State would you find the Naracoorte Caves?*
3. *What is the title of Stephen Hawking's latest book?*
4. *Which Humpback Whales sing: the males, the females, or both sexes?*
5. *Where in Australia do Bogong Moths migrate to each spring?*
6. *Does a Kea have fur, fins or feathers?*
7. *Which planet in our solar system boasts the greatest number of moons?*
8. *Are Platypuses mostly active during the day or night?*
9. *Where (in which country) is the impact-crater of the asteroid that is thought to have wiped out the dinosaurs?*
10. *What is the more common name for the Black-necked Stork?*

The Vesuvius Vapours

Some volcanoes have the power to instantly vapourise vital body organs.

There are many ways to die during a volcanic explosion. You can be hit by flying debris, choke on poisonous gases, combust in the flow of larva, or suffocate from the enveloping ash. Volcanologists and anthropologists, in collaboration with other researchers, have recently uncovered yet another way to succumb to volcanoes.

Just down the road from Pompeii, the town of Herculaneum is set amongst coastal cliffs where some people took refuge as Mount Vesuvius erupted in AD 79. A team of scientists led by Italian researchers Giuseppe Mastrolorenzo (Osservatorio Vesuviano) and Pier Petrone (Università di Napoli Federico II) studied the skeletons of 80 people found in these cliffs, and the conditions under which they were buried, to determine their cause of death. The remains are quite remarkable as their postures are relaxed and do not display any evidence of the contortions or usual defensive reactions seen in other victims of explosive volcanoes. The researchers suggest this is because these people died instantly from a hot ash and steam cloud that surged from the volcano.

The victims' vital activities were stopped in a fraction of a second—less than the conscious reaction time—a state known to forensic investigators as 'fulminant shock'. Their brains and other vital organs would have instantly vapourised. Also evident on the skeletal remains are blackened skullcaps and cracked tooth enamel, which are consistent with exposure to temperatures of around 500° C. Although these ancient folk avoided the slow and agonising deaths that commonly oocur in the pathway of an exploding volcano, they could not escape the melting moment when Vesuvius vapourised them in a blast of heat.

—K.H.

Study of the protein of ancient bone can tell us what foods an animal ate.

Fish and Fast Food

We are what we eat. So much so, that study of the protein (collagen) of ancient bone can tell us what foods an animal ate. The levels of carbon and nitrogen isotopes allow researchers to estimate the source of average dietary protein over the last few years of the animal's life.

Michael Richards (University of Bradford, UK) and colleagues have recently applied this method to the skeletons of nine early modern humans found in various European grave sites dated between 20,000 and 32,000 years old. The results indicate a diet with a significant proportion of aquatic freshwater animals, including fish, molluscs and waterfowl.

The researchers then compared their results with published isotopic values for five European Neanderthals, whose remains ranged from 28,000–130,000 years old (see "Neanderthal the Hunter", *Nature Aust.* Winter 2001). The Neanderthals ate far less aquatic foods than the early modern humans and instead obtained most of their protein from terrestrial herbivores. This, despite the fact that at least two of the Neanderthals lived close to large rivers.

The study indicates there was a major shift in early human diets by the mid Upper Palaeolithic (about 28,000 years ago). Whereas archaic humans hunted mostly large herbivores, early modern humans also trapped and snared fish and other fast-moving, smaller animals that are generally more difficult to catch. As populations increased and resources became scarce, hard-to-catch, fast food would have become an economic necessity. The increased dietary breadth is associated with elaborate burials and artefacts found in the European Upper Palaeolithic sites. The next question is whether the broader diet and sophisticated technologies of early modern humans gave them a competitive edge over their Neanderthal contemporaries. Could this have been critical in the disappearance of the Neanderthals?

—R.F.

Firefly Switches

Most bioluminescent animals glow almost continuously, but the fireflies' ability to control their bursts of light has allowed them to evolve elaborate courtship rituals based on synchronised flashing.

Scientists have long understood how the light is generated but couldn't work out how the beetles turn their tiny lanterns on and off. Now a team of researchers led by Barry Trimmer (Tufts University, Massachusetts) has illuminated the secret of the light shows: nitric oxide, contained in the cells that line the ends of the lanterns' air tubes, provides the switch.

JEAN-PAUL FERRERO / AUSCAPE

Scientists have now worked out how fireflies turn their lights on and off.

A firefly's light comes from a chemical reaction between the protein luciferin and the enzyme luciferase, which are found in the light cells (photocytes) in its abdomen. When oxygen enters the photocytes through tiny air tubes it causes luciferin and luciferase to react, producing light.

Nitric oxide (NO) is an important cell-signalling molecule in many animals. (In humans, it is responsible for dilating blood vessels and is one of the principle ingredients of Viagra.) To investigate whether NO might play a role in firefly flashes, the researchers placed fireflies (*Photuris* sp.) into tiny custom-designed chambers and exposed them to a stream of NO. Their lanterns glowed continually, stopping only when the NO was removed.

Closer investigation of the fireflies' lanterns revealed how the NO-switch might work. Where the air tubes enter the cells, densely packed mitochondria (energy-producing structures) consume the oxygen before it can light the lantern. When it's time to flash, the concentration of NO increases and causes these mitochondrial "gatekeepers" to temporarily shut down, allowing oxygen to enter the cell's interior and produce a flash. Because

Bacterial Reawakenings?

We've all heard the occasional story about miners smashing solid boulders and finding entombed toads that are very much alive. For a brief moment, it seemed that such science fiction might enter the realm of science fact. Russell Vreeland (West Chester University) and colleagues recently claimed to have successfully regrown bacteria from dormant spores older than the oldest dinosaurs.

The viable spores were suspended in droplets of brine inside salt crystals from an ancient underground saltpan in New Mexico. The structure of the crystals suggested they had never dissolved and recrystallised since their original formation in the saltpan 250 million years ago. When the salt crystals were dissolved and the spores placed in nutrient-rich broth, three new forms of bacteria emerged under the eyes of excited scientists. Laborious sterilisation techniques minimised the chances of contamination from present-day bacteria during the process. One of these ancient bacteria (dubbed 2-9-3) even had part of its DNA sequence determined, and it was found to be most closely related to the salt-loving bacterium now known as *Salibacillus marismortui* from the Dead Sea, but with a one per cent difference.

However, doubts have been raised over whether the droplets (and included bacteria) were truly original, or later inclusions. Dan Graur and Tal Pupko (Tel Aviv University) noted that, if 2-9-3 was really frozen in suspended animation 250 million years ago, one would expect its nearest living relative, which must have undergone an extra 250 million years of evolution, to be much more dissimilar. Rather, the meagre difference translates to something between 13,000 and 65,000 years of evolutionary divergence, according to most 'molecular clocks'. This suggests that 2-9-3 is nowhere near as old as originally claimed by Vreeland and colleagues, and instead represents either a much more recent inclusion in the salt crystal, or even a dreaded modern-day contaminant. In addition, Robert Hazen (Carnegie Institute of Washington) and Edwin Roedder have argued that the permeability of the salt crystals is not beyond doubt, consistent with the molecular arguments for contamination. The initial report should therefore be taken with a grain of salt.

—M.L.

JEFF FOOTT/AUSCAPE

Aboriginal overfishing of Sea Otters (*Enhydra lutris*) thousands of years ago had drastic effects on Northern Pacific kelp forests due to the increase in the Sea Otter's prey.

NO is inhibited by light, the light itself appears to enable the mitochondria to start working again, thus turning the light off.

The researchers say that the flash patterns of fireflies are species-specific, and that the ability to control flash timing is the key to successful courtship.

—R.S.

The overfishing of marine megafauna probably underpins many of the modern extinctions we're now witnessing.

Marine Megafaunal Overkill

Watch the six o'clock news any night of the week and you're likely to catch an item from somewhere in the world that shows humans wreaking environmental havoc on the planet's coastlines. Think of seabirds floundering in oil spills. Smoke stacks spewing out greenhouse gases that will ultimately nudge sea levels to rise. Noxious industrial effluent winding its way down creeks towards oceans. Backhoes filling in estuarine wetlands.

But all that pales in significance, according to a group of 19 internationally esteemed marine scientists, compared to the impact that overfishing by our ancestors has had on coastal ecosystems.

Their view stems from a two-year retrospective study initiated by marine ecologists Jeremy Jackson of Scripps Institution of Oceanography, in San Diego, that delved into three lines of reference in the scientific literature.

The researchers explored the palaeontological record from about 125,000 years ago to the present, coinciding with the rise of modern humans. They looked at the archaeological record after about 10,000 years ago, when sea levels had reached the same as today's. And they probed into more recent historical data recorded over the past several hundred years.

What they came up with was a picture of human impact that led to both localised and worldwide extinctions of various large marine vertebrates—ranging from whales, Dugongs and turtles to giant rays and codfishes—long before recent generations took over stewardship of the planet. Furthermore, the researchers believe, the overfishing of such marine megafauna probably underpins many of the modern extinctions we're now witnessing in coastal ecosystems to a

A male Rock Ptarmigan shows off his whites.

Dirty Birds

Those people whose partners have gradually gone to seed may take comfort from this story. The male of one bird species looks good only until he's got his girl, and then he goes out of his way to spoil his looks.

The male Rock Ptarmigan (*Lagopus mutus*) is a dazzling white during the Arctic winter. But come June, after the snow has melted and he's found a mate, he deliberately goes about soiling his plumage with mud. In a 17-year Canadian study, Bob Montgomerie (Queen's University, Ontario) and colleagues found that the male ptarmigan begins to pull on the avian equivalent of scungy tracksuit pants within one to two days of his mate laying her first egg. He goes from a white so bright he can be spotted two kilometres away, to a dirty brown visible less than a few metres away.

The female ptarmigan begins to moult in June, as soon as the snow starts to melt. Within three weeks she becomes a mottled brown that blends in perfectly with the barren rocky tundra. Males on the other hand delay their moult until July when the tundra is virtually snow-free. Why?

According to the researchers, the boys hang onto their conspicuous whites for as long as possible to attract a mate. The snowy plumage of males is thought to be a big drawcard for females (if he can survive the attention of hawks and falcons, then he must be a good catch!). Once they've got their mate, they deliberately get down and dirty to make themselves cryptic and less easily spotted by predators. Only when all mating opportunities are over do the males begin the slower process of moulting.

Not only does soiling enable male birds to become cryptic quickly, it's reversible. Two males whose mates' eggs were eaten by predators immediately cleaned themselves up, transforming back to their snowy, chick-pulling plumage.

—A.T.

greater extent than pollution, human-induced climate change and other modern environmental ills.

This doesn't let current or future generations off the hook and it's certainly not a unilaterally accepted theory. But it does provide us, if we're smart enough, with lessons from the past that may prove to be important in modern conservation plans.

—K.McG.

The Power of Purring

When I was ten, 'Kitty', the family's beloved Burmese, accidentally got her head slammed in the car door. My mother banished my sisters and me from the crime scene while she nursed Kitty through her final moments. After a brief (but meaningful) burial, Mum told us that Kitty purred on her way out. Of course we all thought she was lying, to prevent us from any long-term psychological problems associated with the guilt of killing Kitty. Only now, a full 33 years after the event, is it clear to me that she was probably telling the truth. Kitty's final purrs, rather than being a sign that she was ready for any afterlife, were her last-ditch attempts to save herself.

The function of purring has always been a little hazy. Most vets would tell you that cats purr to indicate contentment. For example, kittens are able to purr and suckle at the same time, so a kitten's purrs would tell its mother that all is well. However, cats also purr when they are injured. Some people have suggested that purring in these situations is a cat's way of reassuring and calming itself. Liz von Muggenthaler from the Fauna Communications Research Institute in North Carolina finds it hard to believe how a feature that indicates contentment would evolve. Natural selection acts on characteristics that affect survival, and indicating emotional states (especially to oneself) just doesn't seem to fall into this category.

Instead, von Muggenthaler believes purring functions like an internal exercise and massage machine. Clinical studies have shown that low-frequency vibrations (between 20 and 120 Hertz or cycles per second) help in the strengthening and repair of human bones, muscles and tendons, in wound healing, and in the relief of pain and shortness of breath. Most recently Clinton Rubin (State University of New York) demonstrated that Sheep that stood on a wobble board for 20 minutes a day for a year had a 34 per cent increase in thigh-bone density compared with an unshaken control group. Vibration therapy mimics exercise and appears to fool the bone into thinking it is working hard. The bone responds to this stress by growing new bone cells.

Von Muggenthaler

Kitty's final purrs were her last-ditch attempts to save herself.

The secret to a Domestic Cat's 'nine lives' may be in the purring.

COLIN MILKINS/OSF/AUSCAPE

analysed the dominant purring frequencies of several cat species (Cheetah, Puma, Serval, Ocelot and the Domestic Cat) and found that they all lay within the range of therapeutic frequencies. She pointed out that, in the wild when food is plentiful, most cats are sedentary, lounging about in the trees or on the ground. Purring would enable these cats to maintain their strength and condition while at rest, and also to repair bone and soft-tissue damage without the risk of further injury through exercise.

If purring really is a natural healing mechanism, it would help explain the extraordinary ability of Domestic Cats to survive

COURTESY ROBERT M. TIMM

Horns of the Spiral-horned Ox: fair dinkum or a load of bull?

falls from multi-storey buildings, and the myth that they have nine lives.

—G.H.

Cow-a-Bungle

The discovery of a new mammal species, let alone genus, is extremely rare in this day and age. And so it was with much excitement that *Pseudonovibos spiralis* was named in 1994, based on several curiously twisted, corrugated, lyre-shaped horns found in markets in Vietnam and Cambodia. Scientists believed the horns belonged to some sort of bovid (cattle, goats etc.), yet its taxonomic status has remained controversial as no living specimens have ever been found. Local hunters claim the creature lives deep in the forest and feeds on venomous snakes, which explains why Vietnamese attribute magical powers to the creature they call 'Khting Vor'. Taxonomists decided the only way to get a handle on this mythical beast was to take the bull by the horns.

Alexandre Hassanin (Pierre and Marie Curie University, Paris) and colleagues conducted genetic and morphological tests on the horns in order to determine whether their owners were related to goats or cattle. Instead, they found that these *Pseudonovibos spiralis* were imposters—proving to be nothing more than Domestic Cattle (*Bos taurus*). Rather than being a deliberate hoax, however, the researchers say the horns are a product of the folk industry, as morphological examination shows the horns have been heated and twisted into shape. The rings of keratin have been clearly cut, indicating the corrugations were carved by human hand. This tradition of sculpting horns has been practised in Indochina for many hundreds of years.

However, while the French are dismissing the species as mere fiction, scientists in America have also been examining horns from this enigmatic animal and claim the 'Spiral-horned Ox' to be fact. Robert Timm (University of Kansas) and John Brandt (Denver Museum of Natural History) assert that two sets of horns found in the University of Kansas Natural History Museum (and also others) were wrongly identified as Koupreys (*Bos sauveli*) and in fact belong to *Pseudonovibos spiralis*. The horns were collected in 1929 by a father-and-son team who apparently killed the animals while on a hunting trip. Curiously, the two groups of scientists published their papers independently and within two weeks of each other. Timm and Brandt believe that, while fakes may have been produced, they were based on the real thing. But until this snake-eating, curly-horned phantom steps forth from the forest, we'll be left guessing whether it's fair dinkum or a load of bull.

—K.H.

Arctic Pioneers

It is generally believed that humans did not colonise the northernmost parts of Europe and Asia until about 14,000 years ago, but archaeological discoveries from Russia indicate a human foothold in the European Arctic Circle at least 20,000 years earlier.

Pavel Pavlov (Russian Academy of Science) and Norwegian colleagues came across an exposed sequence of geological deposits in a bend on the Usa River. The oldest levels of the site, known as Mamontovaya Kurya, yielded bones (mammoth, horse, reindeer, wolf) and stone artefacts that were radiocarbon-dated to between 34,000 and 37,000 years old.

The plant remains suggest a treeless grassland with some willows along the riverbanks. The climate was probably much colder and even more continental (summer/winter extremes) than today. Humans were most likely preying on large herbivorous animals like mammoths. One mammoth tusk found at the site even appears to have marks incised by a stone tool, perhaps reflecting symbolic meaning.

So who made the artefacts? It is difficult to say, as they are not diagnostic of distinct cultural phases, nor are they indicative of any specialised tasks. Neanderthals, who survived until at least 30,000 years ago, could have made them, but to live in such a challenging environment would require a high degree of adaptability generally not credited to them. Pavlov *et al.* think it is more likely that modern humans were responsible. This would mean the newcomers must have hightailed their way up north only a few thousand years after arriving in Europe some 40,000 years ago.

Why were humans such successful colonisers at this time? John Gowlett (University of Liverpool, UK) points out that fluctuations in climate from 60,000 to 40,000 years ago were greater than previously thought, and these conditions may have prompted population movements and cultural change. Furthermore, recent geological investigations indicate there were no large icesheets in Eurasia between 30,000 and 40,000 years ago, and the continent was ice-free all the way up the Arctic coast.

—R.F.

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www.amonline.net.au/natureaustraliamagazine

CLAY BRYCE LOCHMAN TRANSPARENCIES

Could coral bleaching be a risky survival strategy?

Out with the Old

One of the most disturbing environmental phenomena of recent times has been the widespread bleaching and subsequent death of coral reefs around the world. However, recent research by Andrew Baker of the Wildlife Conservation Society in New York suggests that coral bleaching may not be the disaster it appears to be.

Bleaching occurs when the individual polyps expel the colourful algae that live inside them, turning the coral white. This often leads to the death of the colony, which relies on nutrients provided by the photosynthetic algae. Bleaching results from environmental stress such as high water temperatures, and many scientists expect it to become more common as global warming gathers pace.

Working off the coast of Panama, Baker swapped coral colonies between deep and shallow water, and monitored their progress. He found that most of the corals he moved upwards bleached, but over time they recruited new algae, and many colonies survived. In contrast, those he transplanted to deeper waters retained their algae, even though they weren't suited to the greater depth, and ultimately perished.

Baker believes that bleaching is a risky strategy that may allow some corals to rapidly swap their algae for types that are better suited to the new conditions, thus avoiding large-scale extinction. This idea is highly controversial, however, with experts pointing out that many reefs have still not recovered from the last major bleaching episode associated with the 1997–98 El Niño event. —G.T.

Flying in the face of guilt

Defenders of flying-foxes are seen as advocates of a degenerate lifestyle too alarmingly like the human condition to be sanctioned.

BY STEVE VAN DYCK

When I was in kindergarten we lived a few blocks up from an orchard in outer Sydney, and my summer nights were forever punctuated by the bangs of guns and carbide cannons. Most of them were trained toward flying-foxes stealing ripening peaches, but a good few of the blasts would have been aimed toward our place. That would have been the direction our Dog was heading those dark mornings when she arrived home carrying semi-conscious chooks the same colour as the ones the orchardist bred.

Early one day the massive, gumbooted farmer turned up in our backyard with something that nearly made my eyes pop. While my mother was off locking the Dog in the toilet, he told me it was a flying-fox he'd shot during the night and, after mumbling something about the similarity of our hens to his, he asked me if I'd like to keep the big bat. I couldn't believe my ears. Would an Aussie boy like to keep the Ashes?

After he'd gone my mum and I hung the dead flying-fox up by the hooks of its toes from the clothesline. In this way we could unfold its arms and the full one-and-half-metre spread of its cold, black, rubbery wingspan was on display. It was beyond me that anything so heavy and Dog-like could really fly. And if it could do the impossible, why shoot it? Peaches weren't *that* delicious.

Later that morning I proudly strutted up the road with my Grey-headed Flying-fox (*Pteropus poliocephalus*) hoping to impress anyone with the windfall, but by the end of the day both Mariner and Albatross had been thrown out of most houses. Who could have predicted the violent reactions of my friends' mothers? It was soon clear. I should feel very bad about loving this sort of animal.

Around that time it was standard mitigation practice for frustrated fruitgrowers to go into daytime flying-fox roosts ('camps') with 44-gallon drums filled with scrap metal, welding-rod ends, nuts, bolts and broken glass. Then, much like pushing a cinnamon stick into a Sri Lankan curry, a charge of gelignite would be added and the drum hoisted by ropes high into the trees. After the flying-foxes had resettled into their familiar roosts, the explosive would be detonated and the drum of shrapnel blown to pieces. Descriptions of the aftermath of such events make for disturbing reading, mostly because the number of 'clean' kills was far outweighed by the bulk of wounded animals writhing around on the ground with shredded wings and shattered bones.

Years later, after I'd moved to Brisbane, flying-foxes helped me hit on a perfect study-displacement activity that would not only firm up my lifelong interest in bats, but set in concrete my terminal ignorance of high-school chemistry. I discovered that by nailing an old-fashioned wire soap holder three metres up a tree in our suburban backyard, and filling it with chopped pawpaw or pears, I could take well-earned study 'breaks' on the back porch with a pair of binoculars, watching the flying-foxes visiting the feeding station and squabbling over the fruit. (Depending on how much fruit was available, refilling the soap holder throughout the night could then account for much of the time *between* the chemistry study breaks.)

But getting the local greengrocers to see the point in handing over spotty seconds, gratis, for my evening callers rekindled the old memory that flying-foxes were fertile grounds for growing guilt. In the end, the volumes of lies I could spin about why I wanted free bruised fruit was matched only by the vacuum in my brain where the Periodic Table should have been.

A new millennium and not much has changed. Most people still expect some sort of apology from flying-fox defenders. Why? Probably it's a matter of lifestyle. Flying-foxes go out at night and gorge on whatever is sweet and free for the taking, and then by day they join in a salacious bacchanal that rages on throughout the sultry summer months. Perhaps subconsciously, defenders of flying-foxes are seen as advocates of a degenerate lifestyle too alarmingly like the human condition to

Grey-headed Flying-fox

Peteropus poliocephalus

Classification
Family Pteropodidae.

Identification
Black wings, grey head, orange collar, silver to dark grey back, hair down to toes. Head–body length 250 mm, weight up to 1 kg, wingspan 1.5 m. No tail.

Distribution
Coastal eastern Aust., from Bundaberg to western Vic.

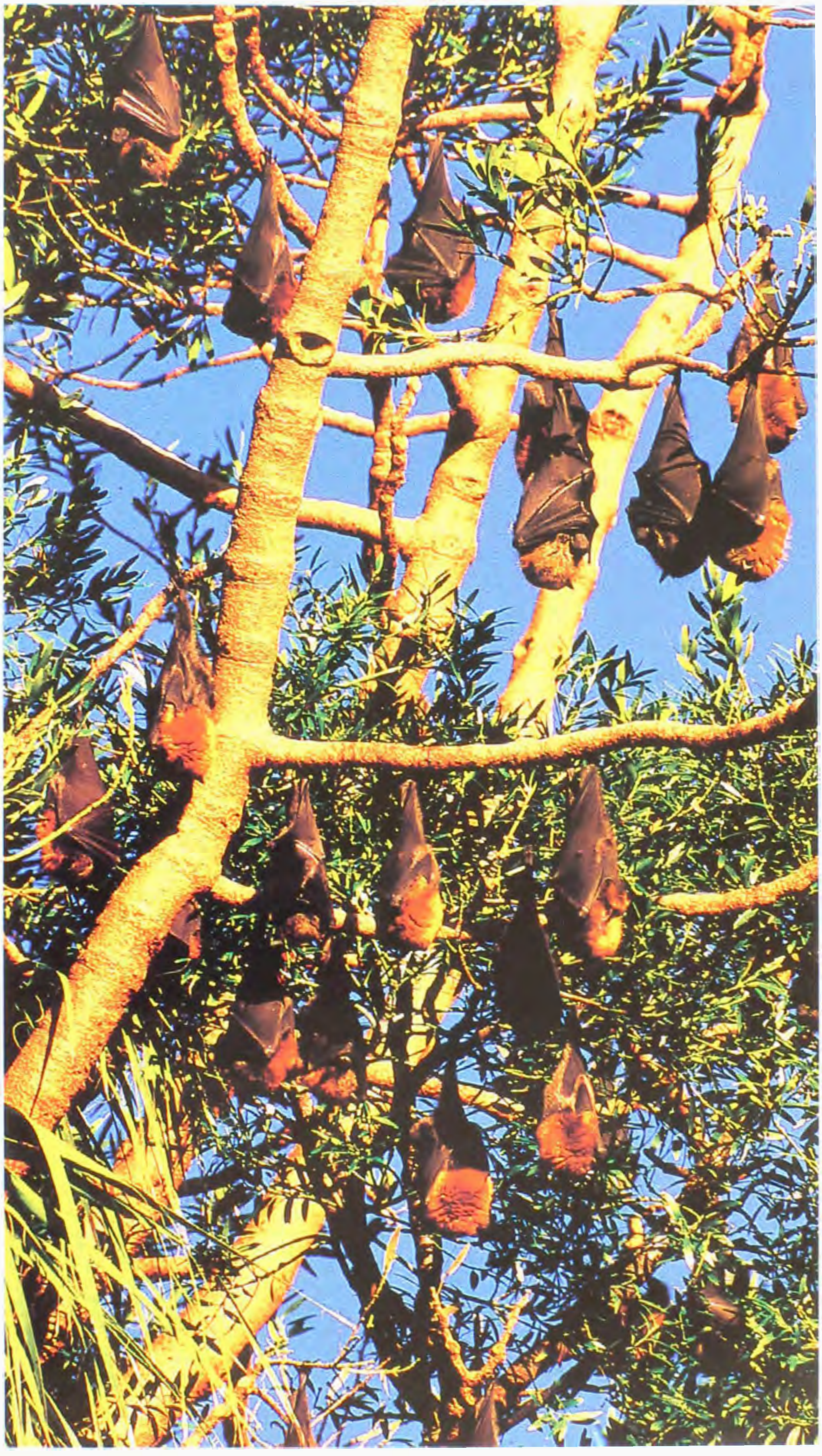
Biology
Forms spring–summer camps of up to 200,000 individuals. Forages up to 50 km from camp each night. Eats fruit (mostly native figs) and blossoms (mostly eucalypts). Single young born Sept.–Oct. and carried by mother for first 3 weeks. Mates March–May. Adults disperse in winter.

be sanctioned. Humans, like flying-foxes, are also at their very worst when they get together in big aggregations. Football crowds, market places, refugee camps, houses of parliament…whenever humanity trips over itself the scene gets grubby.

Fish certainly do it, and plenty of birds come together in thousands to reproduce (penguins, terns), but usually in isolated refuges. Very few Australian mammals seek out the big-group procreation scene, but those that do share the capacity to cover enormous distances in the course of their daily or seasonal activities (seals, bats). Most of the aggregating insectivorous bats do it privately inside dark caves or mine tunnels where there is more climatic stability. Big, strong flying-foxes, however, are the conspicuous terrestrial exception. When they join forces in traditional summer breeding grounds, their numbers can reach thousands (commonly hundreds of thousands in the old days). The incessant flapping, the splashings of excrement, the squabbling and shrieking, the smell, and the shredding of the treetops make for an intoxicating site for biological study, but the scene might come as a surprise if you happened to have purchased your dream block next door in August just before the neighbours returned in September!

Some things are dawning in this new millennium however. One is the evidence that flying-foxes are important pollinators and seed dispersers. Another is that a camp of flying-foxes is just as precious as any rookery of penguins, seals, albatrosses or turtles. Another is that it is no longer acceptable to shoot or electrocute them just because they eat your fruit, splat on your BMW, or choose to roost in your city's botanic garden.

In spite of all that's fantastic about them, flying-foxes will continue to polarise public opinion until we know them better and manage them more effectively. Lifting the guilt that accompanies them might even allow some of us to move on and patch up unfinished business (of a Periodic-Table nature) elsewhere. □



Grey-headed Flying-foxes roost in Sydney's Royal Botanic Gardens.

JEAN PAUL FERRERO/AUSCAPE

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

Yellow-footed Rock-wallaby

Over the four-year study period, wallaby numbers within the baited area increased by over 600 per cent.

NICHOLAS BIRKS/WILDLIGHT AUSTRALIA

YELLOW-FOOTED ROCK-WALLABIES (*Petrogale xanthopus*) are arguably Australia's most charismatic macropod. These wallabies are characterised by distinctive white stripes on the hips, cheeks and flanks and by a uniquely banded tail that alternates with rings of brown and gold. Inhabiting areas of semi-arid Australia, the wallabies are dependent on rocky mountainous habitat, which provides them with shelter from the extremes of climate and protection from natural predators. The wallabies, despite weighing seven to ten kilograms, can negotiate the steep escarpments of their habitat with consummate ease and speed.

Although the total Australian population of Yellow-footed Rock-wallabies is considered to have a low risk of extinction, the species is listed as Endangered within New South Wales and Vulnerable to extinction in South Australia. In Queensland, where the wallabies are relatively abundant and the population stable, the species is classified as Common.

In New South Wales, extensive surveys of the north-west of the State have revealed that the wallabies once enjoyed a wider distribution in historical times. Today, the New South Wales population is confined to a single location within Mutawintji National Park and portions of adjacent pastoral properties, approximately 120 kilometres north-east of Broken Hill. Annual helicopter surveys, conducted between 1980 and 1995, indicated that this population had declined in size by 73 per cent and possibly numbered as few as 80 wallabies.

BY ANDY SHARP

In 1995 the New South Wales National Parks and Wildlife Service began a recovery program to uncover and arrest the possible causes of decline of the State's population. These included competition with feral Goats and Rabbits for food, and predation by Wedge-tailed Eagles and Foxes. Taking a cue from research conducted in Western Australia, which showed that the removal of Foxes resulted in large increases in populations of Black-footed Rock-wallabies (*Petrogale lateralis*), Melinda Norton, Adam Marks and I decided to focus on Fox predation. We established an intensive Fox-bating program around half of the remnant wallaby colonies, and left the others as an unbaited experimental control. Over the four-year study period, wallaby numbers within the baited area increased by over 600 per cent, while those within the unbaited area remained low.

Examination of the age structures of the colonies indicated a virtual absence of juveniles within the unbaited area, but an increasing number of young in the baited area. This, combined with a noted high survival rate of adult wallabies within the unbaited colonies, confirmed our suspicions that Fox predation was focused on young wallabies. The Foxes appear to capitalise on the fact that juvenile rock-wallabies, rather than follow their mothers around while foraging, are left unattended on the rock outcrops, making them vulnerable to predation.

So what was so different between predation by Foxes and that of the natural predators with which the wallabies have coexisted for millennia? In another study, we found that the wallabies made up only a minor fraction of the diet of Wedge-tailed Eagles, which was probably due to their ability to evade aerial predators by hiding in their rocky shelters. Similarly, the wallabies' refuge sites provided considerable protection from Dingoes because, unlike Foxes, Dingoes are poor climbers and their

larger size limits their ability to penetrate the wallabies' hiding spots.

On the basis of our studies, Fox-baiting activities were expanded in 1999 to include all New South Wales colonies. Helicopter surveys conducted over the past couple of years revealed further substantial rises in wallaby numbers and the total New South Wales population is now estimated to be in the order of 450 to 550 individuals. The future of Yellow-footed Rock-wallabies now seems assured in New South Wales. □

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ANDY SHARP HAS SPENT THE LAST TEN YEARS STUDYING THE ECOLOGY AND POPULATION BIOLOGY OF YELLOW-FOOTED ROCK-WALLABIES AND IS CURRENTLY COMPLETING HIS PH.D. IN THE DEPARTMENT OF ZOOLOGY, UNIVERSITY OF QUEENSLAND.

Amazing Murnong

The critical event in Murnong's evolution took place in a North American meadow.

ACROSS MUCH OF VICTORIA LIFE was made easy for Aborigines by a dainty little plant called Murnong, or Yam Daisy (*Microseris lanceolata*). Murnong grew prolifically in grasslands and woodlands, and beneath each plant lay a tasty tuber.

One early settler saw "millions of murnong or yam, all over the plain". Edward Curr recalled how "the wheels of our dray used to turn them up by the bushel", observing that near Echuca, Murnong was "so abundant and so easily procured, that one might have procured in an hour, with a pointed stick, as many as would have served a family for the day."

Around Melbourne the pale tubers were baked in earthen ovens, in which they would "half melt down into a sweet, dark-coloured juice", wrote A.F. Mollison in 1837. Murnong's range extends into South Australia, inland New South Wales and coastal Western Australia, and the tubers were probably important foods in all these regions, although little evidence for this survives. Frederick Manson Bailey, who grew up in Adelaide in the 1840s, recalled white settlers there harvesting Murnong roots, following the example of the Aborigines. "I was fond of it as a boy", he wrote.

Murnong sustained more people in Victoria than any other wild food. But this dandelion-like plant has attracted international attention for a very different reason. It belongs to a genus, *Microseris*, with a quirky distribution. Southern Australia has two species, the other one, *M. scapigera*, growing in New Zealand as well. A third *Microseris* grows in Chile and the other 13 species are found in western North America.

Genetic work on the group provides a remarkable explanation for this far-flung distribution. The cluster of species in North America, and occurrence there of related plants, imply that *Microseris* evolved there. The two Australian species are closely related to each other, and their presence here suggests that a seed or two floated all the way from North America to Australia or New Zealand, a distance of around 7,000 kilometres or more, before the progeny evolved into two species, one of which crossed the Tasman. Another seed floated from North America to Chile and gave rise to *M. pygmaea*. (Murnong, like the related dandelion *Taraxacum officinale*, has wind-borne seeds.)

This is a fantastic story, but there is more. The genetic work shows that the Australian and New Zealand species, unlike American *Microseris*, are of hybrid origin. Their ancestor arose, probably in Oregon or California, when an annual *Microseris* received pollen from another species, a perennial related to *M. borealis*, which grows today in boggy meadows in Oregon and up to Alaska. Their hybrid descendants bore double the usual number of chromosomes, and they sent a seed or two out to sea before they all died, leaving no trace whatsoever in North America. The critical event in Murnong's evolution thus took place in a North American meadow. That event had no consequences for America, but influenced the lifestyles of millions of people in southern Australia. It also made a difference to the Long-billed Corella (*Cacatua tenuirostris*), a parrot that once fed largely on Murnong tubers, digging them up with its pointy bill.

PHOTOS: TIM LOW

Murnong tubers, although small, are easily gathered in large numbers. One hundred grams of the tubers yield 264 kilojoules of nutritional energy.

BY TIM LOW

Murnong, sometimes known as 'Native Dandelion', is closely related to 'true' dandelions, which it resembles.

Because the one or few seeds that came our way were of hybrid origin, they carried a wealth of genetic material, allowing the founder plants to diversify upon arrival. There are now *Microseris* populations in Australia or New Zealand adapted to seashores, alpine meadows and semi-arid woodlands. Only the woodland form of *M. lanceolata* produces plump tubers, and the name 'Murnong', strictly speaking, applies just to it. Australia's *Microseris* are acknowledged around the world as an outstanding example of adaptive radiation following long-distance dispersal.

The sad part of this story is that Murnong today is a scarce plant. Hundreds of thousands of Sheep that were turned onto the plains ate it up. Curr noted "several thousand sheep not only learnt to root up these vegetables with their noses, but they for the most part lived on them for the first year, after which the root began gradually to get scarce". The Aborigines suffered greatly from Murnong's decline. So did Long-billed Corellas, whose numbers plummeted until they learnt to eat crops and weeds instead. Now these birds are notorious pests and many thousands are culled each year. Murnong today grows mainly in national parks and other places where Sheep don't feed. □

Murnong sustained more people in Victoria than any other wild food.

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TIM LOW IS A NATURE WRITER AND ENVIRONMENTAL CONSULTANT BASED IN BRISBANE. HIS MOST RECENT BOOK IS *THE NEW NATURE* (PENGUIN).

When resources are limiting it's every kookaburra for itself.

TO KILL A KOOKABURRA

BY SARAH LEGGE

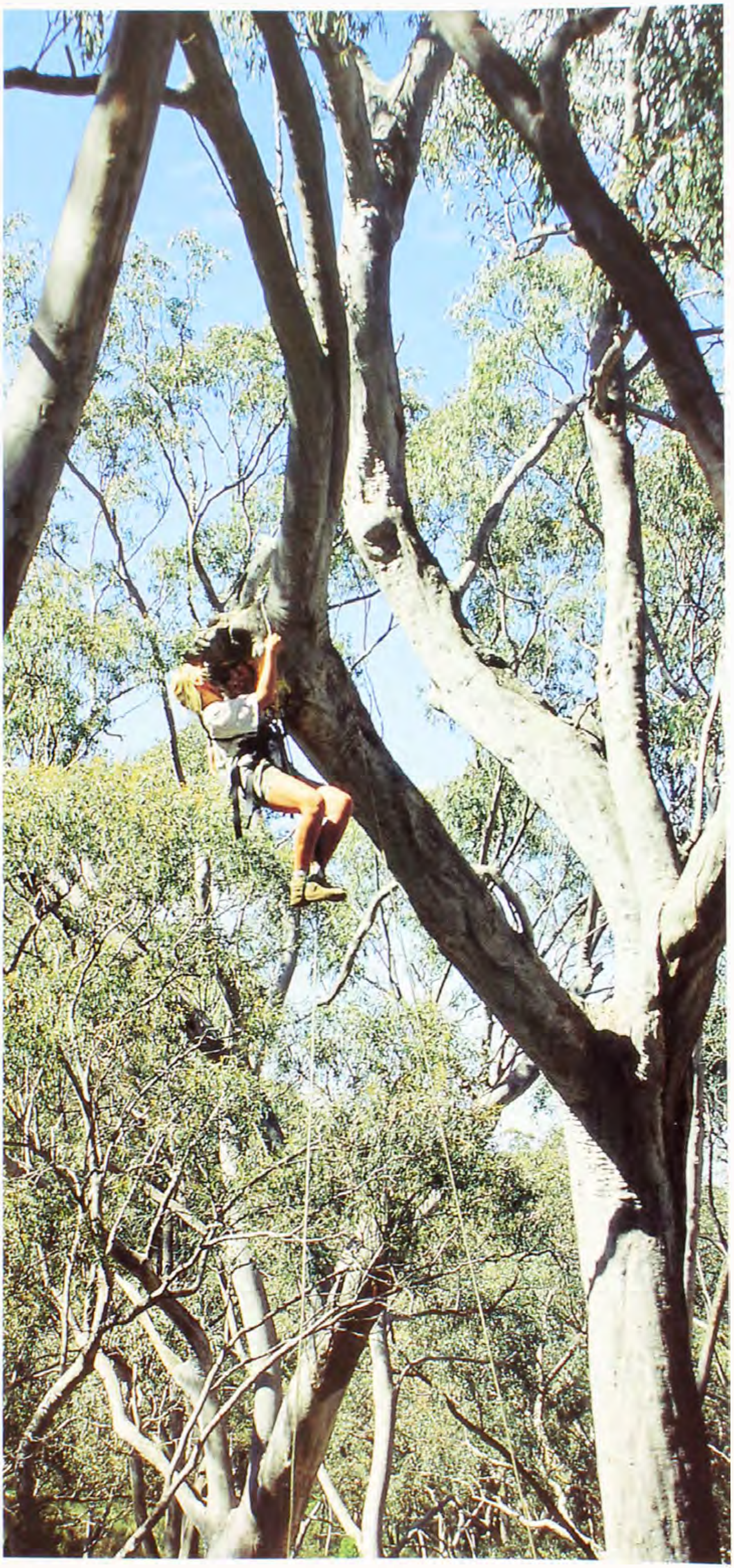
The Laughing Kookaburra's debut on the stage of Western science was made in a flurry of ambition-driven deceit. In 1776 Pierre Sonnerat, a French scientist with a proven predilection for telling the odd porky, provided a description and illustration of the "*Grand martin-pêcheur de la nouvelle Guinée*" (Big Kingfisher of New Guinea), and claimed to have observed two of them there. In retrospect, this was a rather astonishing feat, considering that he barely ventured east of the Moluccas, let alone reached the mainland, and anyway, Laughing Kookaburras don't occur in New Guinea. So where did the scoundrel 'acquire' the specimen? One likely explanation is that Joseph Banks, who had been sailing up the east coast of Australia on the *Endeavour* around the same time that Sonnerat was in Indonesian waters, gave the skin to Sonnerat when they met at the Cape of Good Hope. If so, Sonnerat was a plagiarist as well as a fibber. This intriguing story is immortalised in the inappropriate scientific name for the Laughing Kookaburra, *Dacelo novaeguineae*.

This confusing beginning seems to have set the tone for European knowledge about the bird because, despite their widespread familiarity and appeal, Laughing Kookaburras are saddled with a surprising level of erroneous information. For example, many people will tell you that Laughing Kookaburras are voracious predators of other birds' nestlings. Perhaps the startling sight of a kookaburra bashing a helpless young

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

Laughing Kookaburras are often seen on exposed perches, keeping a watchful eye out for unsuspecting prey passing by.

(Left) Laughing Kookaburras lay their eggs in tree hollows, which the researchers had to reach by climbing.



creature to a pulp on a branch before swallowing it sticks in one's mind, but the fact is that Laughing Kookaburras rarely raid the nests of their winged neighbours. To put things into perspective, I have found that nestlings make up a diminutive 0.3 per cent of the diet of Laughing Kookaburras around Canberra. Staying on the culinary theme, these kookaburras also have an enviable but overstated reputation as snake-killers. This idea was fostered and perpetuated by many famous Australian naturalists at the beginning of the last century, and was partly responsible for the zealous introduction of Laughing Kookaburras by acclimatisation societies to various places where they are not naturally found, including Western Australia and Tasmania. They were even (unsuccessfully) introduced to Fiji. Kookaburras do eat snakes, but relatively rarely compared with small lizards and invertebrates.

I HAD GOOD REASON TO PONDER THE myth and misinformation that seems to dog these birds early on in my Ph.D. studies on the social and mating systems of Laughing Kookaburras. One fine day, whilst dangling in my climbing harness at the entrance of a nest hollow containing newly hatched young, I saw the most extraordinary spectacle. Like most hatchling birds, young kookaburra nestlings are tiny, blind and wobbly, and exhausted from the effort of struggling out of their respective eggs. Despite their pathetic appearance and superficial clumsiness, these pink blobs were staggering around the nest with considerable agility, lunging with biting pecks towards their siblings. If one chick was lucky enough to grab hold of a wing or, even better, the neck of one of their nearest and dearests, they bit down hard and shook the poor victim with surprisingly well-coordinated fury.

I didn't need to watch this fighting bout for very long to realise that it wasn't just a mild spat between siblings—these nestlings were going for

(Right) Before they fledge, Laughing Kookaburras go through some fairly comical stages. This chick is about three weeks old.

NICHOLAS BIRKS/WILDLIGHT

the full knockout. I was watching siblicide in action! Chicks in the vast majority of my nests were fighting, and in one-third of them the youngest was killed within a few days of hatching. Before their disappearance they were wounded and bruised; sometimes I found their lifeless, pulverised little body on the nest floor. Young chicks even have a menacing downward-pointing hook at the end of their top beak, which they use like a grisly gaff. In other words, these pink blobs have the technology as well as the inclination to be killing machines.

This was a far cry from the cute, overstuffed toys in the shops, or the harmless jokers that cackle loudly in the treetops. Why hadn't anyone described this incredible behaviour in the 'merry, merry king of the bush' before? After all, Laughing Kookaburras are common, amenable to suburbanisation, and they've enjoyed more formal scrutiny than most Australian birds. In the early 1960s they were the subject of a pioneering Master's thesis by Veronica Parry (Monash University). She established unequivocally that Laughing Kookaburras breed in cooperative groups, and showed that the helpers

> **THESE PINK BLOBS HAVE** *the technology as well as the inclination to be killing machines. This was a far cry from the harmless jokers in the treetops.*

were probably the young from earlier breeding attempts. Parry peered into the nesting hollows regularly to check the chicks, so why hadn't she seen this fatal aggression?

In fact, if you read the small print of Parry's thesis, it's clear that she did 'see' siblicide, but just didn't interpret it that way. In several of her nests the youngest chick disappeared soon after hatching. Their weights were normal before the disappearance, and Parry even noticed

(Above and right) Within hours of hatching, bedlam breaks loose as the chicks try to inflict serious damage on each other.

that one chick had small dark scabs on its head the day before it went missing. Earlier observations by Keith Hindwood in the 1940s tell the same story: "I noticed a young bird, one day old, attempt to nibble or bite the neck of a fellow nestling; no doubt this was an instinctive reaction when its bill came into contact with the other bird's body." No doubt.

It may seem strange that people could watch the same behaviour yet come to different conclusions about what was happening. I think it's a good example of how our social and intellectual environment dictates how we interpret what we see. For example, Parry studied Laughing Kookaburras during the dying gasps of a biological paradigm—group selectionism—which has not stood the test of time. She believed that individuals behaved in ways that benefited the population or species. It may well have seemed ridiculous to her that a chick would lower the nest's productivity by murdering one of its siblings. However, under the current paradigm of individual selectionism, we expect individuals to do whatever it takes to increase the proportion of their own 'selfish' genes in the next generation. Pushing a sibling over the edge seems drastic and even counterproductive, since the sibling takes some of the other bird's genes with it. But, of course, although the minute murderers would ideally prefer their siblings to survive and propagate their shared genes, when resources are limiting it's every kookaburra for itself.

IN SOME SPECIES OF SIBLICIDAL BIRDS, nestling aggression is positively related to the hunger of the brood, so it's easy to see the link between limiting resources and siblicide. But in other species, including the Laughing Kookaburra, siblicide occurs when the chicks are so tiny that parents are still able to provide enough food for them all. In other words, the siblicide is pre-emptive—it occurs well before the resource shortage. In my study population, the broods that experienced siblicide belonged to parents without helpers, precisely those that were most likely to have trouble raising the full complement of three young.

Pre-emptive siblicide probably saves these poor-quality parents a lot of wasted effort feeding a chick that will eventually die when the resource crunch really does bite. It also allows all the available resources to be channelled into the surviving offspring from an early stage. This could increase their quality, albeit at the expense of the quantity of young. I have supporting evidence for this, because Laughing Kookaburra chicks that killed a sibling grew faster and achieved heavier weights at fledging than their less agro counterparts in broods where siblicide did not occur. Fledging as a fatso is an ill-gained but valuable reward for a bully, because heavy fledglings were more likely to survive the critical period after fledging when they were learning to hunt for themselves. On top of that, heavy fledglings were more likely to find a breeding vacancy when mature.

Although the parents of siblicidal broods were fledging fewer young, at least those young were of 'high quality', and the parents hadn't flogged themselves out in the breeding attempt. However, as I delved more deeply into the events surrounding siblicide, I found that the parents weren't exactly innocent bystanders. They were implicated in the murder of their offspring

NICHOLAS BIRKS/WILDLIGHT

right up to their eyeballs. As well as monitoring nests very closely in the first few days after hatching, I was joined in my final field season by Anjeli Nathan (Australian National University), who cleverly installed tiny surveillance cameras inside the nest hollows so that she could watch the behaviour of chicks and adults in frame-by-frame detail. Here's what we found.

Parents usually laid three eggs, which hatched up to two days apart. This created an age and size hierarchy in the brood. Contest theory predicts that chicks should fight less if these compet-

Laughing Kookaburra

Dacelo novaeguineae

Classification

Family Halcyonidae ('terrestrial' kingfishers).

Identification

Brown upper parts, off-white underneath, sometimes with light barring. Sexes hard to distinguish but females larger and males more likely to have a blue tinge on upper rump. Immatures darker underneath, often with more barring, and may have noticeably shorter beaks.

Distribution and Habitat

Endemic to eastern Aust. from Cape York in Qld to Eyre Peninsula in SA. Introduced to Tas., Flinders and Kangaroo Iss, the south-west of WA, and NZ. Prefers open schlerophyll forests and woodlands, but also found wherever tree hollows are available for nesting.

Biology

Hunts invertebrates, small reptiles and, less frequently, birds, small mammals and larger reptiles. Forms long-term pair bonds. Mates monogamously. Usually lays 3 eggs. Young fledge after about 35 days and remain dependent on adults for food for another 2 months. Offspring often recruited into breeding group to help incubate eggs, brood and feed nestlings.

itive differences are more pronounced: there's no point wasting time and energy in fighting an opponent if the outcome is a foregone conclusion. Conversely, fighting should escalate in more evenly matched opponents. This is exactly what we saw. In broods that experienced siblicide, the competitive asymmetry between the older two chicks was reduced. They fought at every opportunity, and the oldest chick in particular lashed out at anything that came within striking distance. The second-hatched chick was fairly adept at getting out of the way, but the third-hatched chick, which was younger and relatively uncoordinated, got caught in the crossfire between its elder siblings and died.

Parents themselves 'engineered' the hyper-competitive environment in siblicidal nests, and they did so in several ways. First, the hatch interval between the first and second chicks in siblicidal nests was very short. Hatch intervals are determined by the female's behaviour when she lays her eggs, one or two days apart. If the female begins incubating as soon as she's laid the first egg, it has a head start in terms of development and will hatch well before later eggs. If, instead, she delays incubation until she's laid the second egg, the first and second eggs will begin developing around the same time and hatch together. The mothers of siblicidal broods were using the latter strategy. Of course they probably were not deliberately modifying their incubation behaviours—remember that siblicide happens in broods belonging to poor-quality parents. Females in poor condition are unlikely to begin incubating with the first egg because they need to continue foraging in order to complete their clutch. So foraging constraints in poor-quality females may dictate incubation patterns, resulting in a hatching pattern that promotes nestling aggression.

Another spin-off from delaying incubation and continuing to forage after laying the first egg is that the female's second egg is likely to be larger than it otherwise might have been because she's still shovelling fuel into the egg-

The cacophony of Laughing Kookaburras is one of the characteristic sounds of the Australian bush.

S LEGGE

The eggs in a clutch usually hatch at intervals, which can result in a clear size and developmental hierarchy.

making furnace. Normally, the size of eggs in a Laughing Kookaburra's clutch decreases with their laying and hatching order. But in siblicidal nests, the first two eggs are very similar in size, whereas the third egg is much smaller. This is significant because the size of a chick just after hatching is tightly correlated with the size of the egg it hatched from. Thus the second tactic used by mothers of siblicidal broods was to produce two older hatchlings that were evenly matched in size as well as age, with a smaller and vulnerable runt to follow up.

The final ploy used by parents to encourage aggression in their brood is also the most remarkable. Female Laughing Kookaburras have the amazing ability to control the sex of their offspring. Mothers of siblicidal broods nearly always hatched a male first and a female second. Adult females are about 15 per cent larger than males, and female nestlings begin outstripping their brothers within days of hatching. This sequence of sexes is therefore a sure-fire way to destabilise dominance between the oldest chicks, because second-hatched females will be able to challenge the dominance of their slightly older, but slower-growing brothers. A first-hatched brother may also try to beat the living daylights out of little sis immediately after hatching. By cowing her into early submission he may forestall the incipient threat to his first-hatched advantage.

But the gory inside scoop on the Laughing Kookaburra's private life doesn't stop there. Not only did parents 'create' the conditions in their brood that led to aggression, they continued to foster a bickering environment after the chicks had hatched. Chicks can only fight when they are not being brooded, but if they are left uncovered for too long they stop fighting because they are too young to thermoregulate and low spring temperatures soon make them torpid. Parents of siblicidal young brooded their chicks in shorter but more frequent bouts than other parents. This brooding pattern has the effect of keeping the chicks warm but giving them plenty of opportunities for fighting.

It seems clear, then, that siblicide in Laughing Kookaburra broods is a well-orchestrated manoeuvre by parents, using the older chicks as accomplices, to reduce the brood from three to two soon after hatching. This begs the question: why bother laying the third egg in the first place? The likely explanation is

After the chicks have fledged, the adults in their group continue to feed them for another couple of months until the youngsters have honed their hunting skills.

that it's an insurance policy. Over 16 per cent of Laughing Kookaburra eggs fail to hatch, either because they're infertile, the embryo experiences developmental failure, or a clumsy adult sits down on them a little too hard. Siblicide is the kookaburra's efficient, dependable and cost-effective way of cancelling that insurance policy. How quirky that a bird that spends the beginning of its life in mortal combat with its siblings should spend much of its adult life cooperating with a relative it failed to dispatch. If Joseph Banks had had an inkling of the Laughing Kookaburra's fascinating social biology, as well as its destiny of becoming one of our national icons, I wonder if he would have handed over his "Big Kingfisher" specimen to Sonnerat so readily. □

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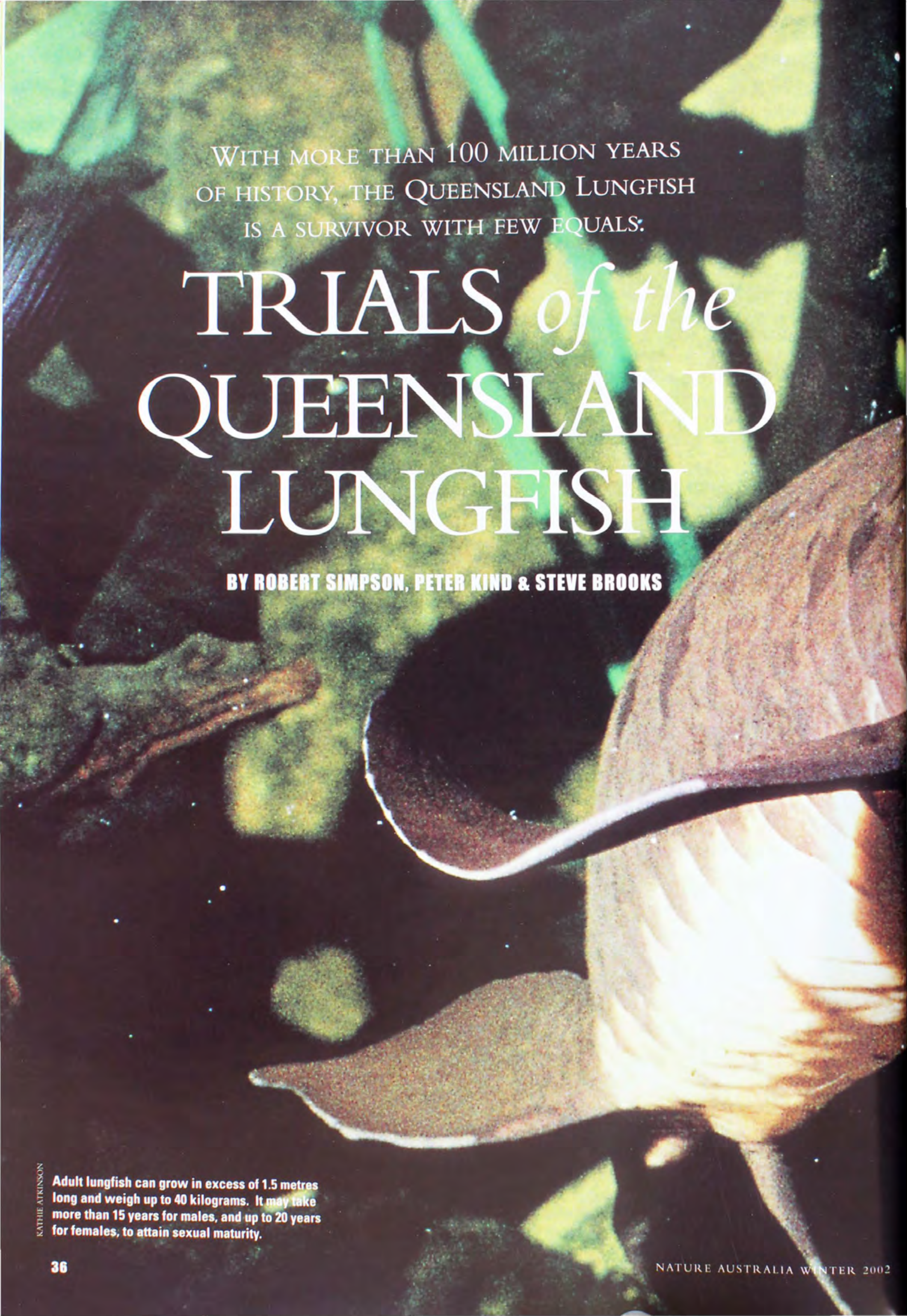
Nicholas Birks/Wildlight



WITH MORE THAN 100 MILLION YEARS OF HISTORY, THE QUEENSLAND LUNGFISH IS A SURVIVOR WITH FEW EQUALS.

TRIALS *of the* QUEENSLAND LUNGFISH

BY ROBERT SIMPSON, PETER KIND & STEVE BROOKS

KATHIE ATKINSON

Adult lungfish can grow in excess of 1.5 metres long and weigh up to 40 kilograms. It may take more than 15 years for males, and up to 20 years for females, to attain sexual maturity.

THE YEAR IS 100 MILLION BC and the morning sun is shining on Gondwana. A small carnivorous dinosaur crouches to drink from the cool waters of a shallow swamp. Beneath the surface, a metre-long lungfish fins along the edge, probing the sparse weed growth for mussels and snails. Its tail momentarily breaks the surface of the water. The dinosaur, alerted by the spreading rings across the water's surface, crouches lower as the familiar outline of a lungfish comes into view. The peaceful foraging of the fish is shattered in a shower of spray, as sharp talons pierce deeply into its flesh. With the writhing fish firmly in its grasp, the dinosaur stands upright to check for challengers to its morning meal. Seeing none, it lopes over to a dense stand of cycads to feast on its catch.

The year is now 2002 AD, and the scene is very different. Gondwana is no more, having been broken up by years of geological upheavals and continental plate movements. A few cycads can still be found here and there, but not the dominant forest giants of Cretaceous times. And, of course, the dinosaurs are all gone. But some things never seem to change. The very same species of lungfish, now known as the Queensland Lungfish (*Neoceratodus forsteri*), is still foraging for mussels and snails in freshwater streams of south-eastern Queensland.

The fossilised remains of more than 100 species of lungfish, dating back to the Devonian Period (395–345 million years ago), have been collected from around the world. At least 18 species are known to have lived in Australia. Fossil remains of the sole surviving Australian species, *Neoceratodus forsteri*, have been found in early Cretaceous deposits (more than 100 million years old) in New South Wales. However, the species was confined to the Burnett and Mary Rivers in south-eastern Queensland when European settlers arrived in the early 1800s. Worldwide, only two other genera of lungfish survive today—*Protopterus* (with up to four

JEAN-PAUL FERRERO/AUSCAPE

This young lungfish has assumed the adult body shape, but retains some of the mottling that is typical of juveniles.

species) from tropical central Africa, and *Lepidosiren* (represented by a single species) from South America.

LUNGFISHES ARE NAMED AND NOTED for their ability to breathe air via a 'lung'. The Queensland Lungfish uses its single lung relatively rarely, relying mainly on a set of well-developed gills to meet its oxygen requirements. The lung comes into play if oxygen levels in the water become depleted, or during periods of high activity. At these times it is not unusual to hear the trademark 'gasp' of a lungfish as it surfaces to refill its lung, a process that may be repeated every half an hour to an hour, or as an occasional one-off event to supplement gill respiration.

Despite occasional reports to the contrary, and unlike its African counterparts, the Queensland Lungfish cannot survive in a dry creek-bed by enveloping itself in a burrow of mud and mucus. The species can, however, survive for long periods out of water if kept moist. In 1898, several lungfish were transported to London by wrapping them in aquatic weeds and occasionally sprinkling the fish with water. After a trip lasting eight weeks, the lungfish reportedly arrived at their destination in good condition.

Although some aspects of the biology of the Queensland Lungfish have been well studied, particularly the anatomy, physiology and embryology of the species, surprisingly little is known of lungfish ecology. This gap in our understanding of the Queensland Lungfish was highlighted in 1995 during planning for a major new irrigation weir to service the sugar industry in the Bundaberg area. At 12 metres high, and located slap-bang in the middle of one of the main strongholds of the lungfish, Walla Weir would back up the waters of the Burnett some 34 kilometres. When asked to comment on the potential impacts on lungfish populations of this major restructuring of the Burnett River, biologists and engineers alike scratched their heads and shrugged their shoulders.

Electrofishing is an efficient method of catching adult lungfish. Lungfish that have been affected by the electric current often roll at the surface and are easily netted, then recover within seconds of the current being switched off.

With the sudden political interest in lungfish populations in the Burnett River, the Queensland Lungfish research team was formed, with funding from the Department of Natural Resources and Mines. Our aim was to study the lungfish's ecology and thus the likely effects that river regulation might have on the species. The study, which was conducted over a three-year period, involved electrofishing and netting surveys, a tagging study, radio-tracking, collection of gonad samples, and an investigation of lungfish spawning behaviour.

MORE THAN 2,200 LUNGFISH HAVE now been tagged in the Burnett River. We implanted 11-millimetre-long Passive Integrated Transponder (PIT) tags into the shoulder muscle of each lungfish, allowing us to recognise

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SOUTHERN FISHERIES RESEARCH CENTRE

A 15-millimetre-long lungfish just emerged from the egg. Eggs are often attached to the strap-like fronds of *Vallisneria gigantea*, among which juvenile lungfish may shelter for several months after hatching.

individuals so that specific data on growth and movements could be collected. Of the tagged fish, 120 have so far been recaptured.

From examination of the recaptured fish we now know that adult lungfish grow very slowly, often less than five millimetres per year. By extrapolation, this means that very large lungfish are likely to be very old, and lungfish longer than one metre are probably more than 50 years old. One important effect of this, from a management point of view, is that any decline in the success of spawning or recruitment may not become evident in the adult population for many years after the event. This means we need to be particularly vigilant in monitoring the status of lungfish populations, and look to the younger year classes as indicators of any decline in breeding success.

Movements of PIT-tagged lungfish were quite variable. While more than

The skull and jawbone of an adult Queensland Lungfish. The large, molariform tooth plates are used to crush a range of food items, including fish, crustaceans, molluscs, insect larvae, worms and aquatic plant matter.

half of the recaptured individuals moved only a short distance or not at all, approximately ten per cent were found more than ten kilometres from where they had been tagged, and one fish had moved almost 40 kilometres. In order to investigate the timing, frequency and triggers for these longer movements, we undertook a radio-tracking study to accurately track the progress of individual lungfish.

Small, battery-powered radio-transmitters were surgically implanted into 30 lungfish. The simple surgical procedures were carried out on a makeshift operating table on the river bank, often in the cool of night. Once a fish was knocked out by the anaesthetic, a small incision was made through the body wall and the transmitter slotted into the body cavity. Medical sutures were used to close the incision before the fish was revived and released. The entire operation took five to ten minutes, and each fish usually needed only a couple of minutes to get its bearings and swim off.

Radio-tracking has revealed much about the behaviour of adult lungfish. While daily movements are generally localised and predictable, movements in excess of 40 kilometres within seven days are not uncommon. This is particularly so in the still, or impounded, waters of weirs and dams where lungfish movements follow a cyclic pattern related to spawning.

Prior to the spring spawning season, large numbers of lungfish leave the impoundments and enter shallow, heavily vegetated sections of the river or tributary streams. Most of these spawning movements proceed upstream. However, upstream movements in the Burnett River may mean a fish will find itself at the foot of the next barrier rather than in a suitable spawning site. We tracked a number of lungfish as they moved from the Ben Anderson tidal barrage upstream to the base of Walla Weir, whereupon they turned and drifted back downstream. Presumably, lungfish confronted with this situation will spawn in the most suitable habitat available, but this is likely to lead to lowered success of spawning and recruitment. After spawning, individuals leave these areas on a staggered basis, often timing their return to the impoundment with a period of increased water level. Some fish have returned to the exact position that they originally left.

Lungfish in more natural riverine areas moved long distances much less often than those in impounded waters. Some riverine fish moved less than two kilometres over two years of observation. We believe that lungfish in these relatively undisturbed areas have little need to move, as suitable feeding and spawning areas are always close at hand. Lungfish in impoundments, on the other hand, must move longer distances to find spawning habitats that meet their requirements.

Movements are an important part of the lungfish life cycle, providing access to suitable breeding and feeding habitats, and escape from localised adverse conditions. It is therefore essential that passage for lungfish past weirs and dams is maintained. This is particularly so if, as appears to be the case, these structures are in fact contributing to the wandering behaviour of individuals in some areas. One possible solution to this problem is to ensure that fish-passage devices, or fishways, are fitted to all weirs and dams within the natural range

KATHIE ATKINSON

Lungfish have poor eyesight and appear to rely largely on electroreception to detect prey that is hidden among aquatic vegetation and debris on the stream bed. The tiny pores concentrated on the snout are the external receptors for the electrosensory system.

Queensland Lungfish

Neoceratodus forsteri

Classification
Order Dipnoi (lungfishes), family Neoceratodontidae. The only living species in this family.

Identification
Elongate, heavy-bodied, freshwater fish with large overlapping scales, five pairs of gills, broad flat head and small eyes. Back and sides olive-brown to dark brown with irregular black blotches; belly pink to orange. Pelvic and pectoral fins resemble flippers. Length to 1.5 m, and commonly seen up to 1 m.

Distribution and Habitat
Confined to Burnett and Mary Rivers, south-east Qld, at time of European settlement. Since introduced into streams and impoundments throughout south-east Qld.

of the lungfish. Fishways come in a variety of designs, but all provide a connection between the impounded waters in a dam or weir and the river downstream, through which migrating fish can move. Current fishway designs show promise for lungfish, but large individuals often have difficulty accessing the relatively narrow passageways provided. More research is needed to look at this problem.

Lungfish spawning occurs from August to December, and involves a mating 'dance' between the expectant female and up to five males. The dance, which often occurs at night, is a series of ritualised chasing manoeuvres that can go on for hours. During this time, the female may deposit several hundred spherical, ten-millimetre-diameter eggs within clumps of aquatic vegetation (macrophytes). The males follow her around, fertilising eggs as their chance arises. During these displays, the mating lungfish can become totally oblivious to just about everything else around them, often bumping into the legs of human observers standing in the shallows.

Larval lungfish emerge from the egg about three weeks after spawning. They are strange, leaf-like creatures that bear little resemblance to adults, and spend a considerable amount of time lying on their sides on the stream bed. At about six weeks of age, the larvae have absorbed their yolk reserves and start feeding on small invertebrates. They gradually develop into the adult form over the following four or five months.

An important part of our research is to determine just what constitutes a suitable spawning site for lungfish, and whether the basic requirements for spawning will be met in the increasingly regulated Burnett River. After inspecting and measuring numerous spawning sites, some trends have emerged. Depth is a critical factor, with the majority of sites located in less than one metre of water. Some are so shallow that the backs of spawning fish break the water's surface. Most sites comprise dense macrophyte beds, particularly the ribbonweed *Vallisneria gigantea*, but other structures like submerged tree roots are sometimes used. Lungfish

Small juvenile lungfish have a proportionately more slender body, rounder head and smaller fins than adults. It is not until about six months of age that they become true replicas of the adult form.

REG MORRISON/AUSCAPE

appear to choose their spawning sites carefully, and may swim a considerable distance to find the right conditions. The macrophyte beds they use are usually well oxygenated, and provide good cover for the larvae when they hatch.

The Burnett River impoundments we surveyed (Walla Weir, Jones Weir and Ben Anderson tidal barrage) provide relatively little habitat with the appropriate combination of water depth, macrophyte growth and water quality required for successful spawning and recruitment of lungfish. We believe that this finding is typical of impoundments in general. The continued wellbeing of lungfish populations therefore relies heavily on the maintenance of sufficient undisturbed riverine areas to provide spawning sites, and the maintenance of access to these areas by adult lungfish.

One issue this raises is how much of the riverine habitat of the Burnett River can be inundated by impoundments before the resultant loss of spawning habitat will lead to a decline in lungfish populations. This is an obvious question for resource managers and politicians to ask, but one that is not easily answered. Even with the large amount of data collected during this project, we are still

not confident that we can estimate either the overall size of the Burnett River lungfish population, or the total amount of suitable lungfish spawning habitat in the river. We feel it is unrealistic and unwise to think in terms of minimum areas of spawning habitat required by lungfish.

What we can say with certainty is that lungfish spawning habitats are a finite resource, and that with each new impoundment constructed, this resource is diminished. While we will continue to work on the problem, politicians and resource managers must decide whether the economic gains of building more impoundments are worth the potential risk to lungfish populations.

With more than 100 million years of history as a species, the Queensland Lungfish is a survivor with few equals. It has witnessed the rise of flowering plants and the fall of the dinosaurs, it has seen ice ages come and go, and has so far survived humanity's rise to power and the changes this has brought. But significant changes to the natural habitats of the lungfish continue to occur at an unprecedented rate, while advances in our understanding of this species lag behind. It is somewhat ironic that, whereas the lungfish is protected by law, its habitats are not. Already in the Burnett River, approximately 40 per cent of lungfish habitats in the main channel have been inundated by dams and weirs, and more structures are planned in the near future. Our study has identified some clear risks to lungfish populations if this trend continues, but there is currently no suitable means to quantify the likely long-term impacts.

Given half a chance, the Queensland Lungfish will carry on foraging in the quiet waters of south-eastern Queensland for millennia to come. But the long-term survival of this ancient species now depends as much on a conservative approach from the human population as it does on the adaptations that have served it so well over the last 100 million years or so. Biologists and engineers must collaborate closely to develop lungfish-friendly solutions, governments must be prepared to fund the necessary research, and the general community may have to accept that some economic potential will go unrealised in order to preserve Australia's unique character(s). Through it all, we would do well to consider the ancient heritage of Australia and its fauna. As one of the oldest living Australians, the Queensland Lungfish deserves the best efforts we newcomers can muster. □

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SIMON D. POLLARD

TUSKS, HORNS

JUMPING SPIDERS ARE SO BIZZARE THEY MIGHT AS WELL HAVE COME FROM MARS.

The ant-mimicking jumping spider *Myrmarachne plataleoides*. Here two males wrestle with locked fangs.

and HAIRY PENISES

BY SIMOND D. POLLARD & ROBERT R. JACKSON

IN A SCENE RE-ENACTED countless times, two males prepare to fight one another. Like knights from the Arthurian legend, they each raise two long swords and approach each other with fixed stares. After a brief clash of weapons, the contest of strength is over and the losing male runs from the victor's arena. The knights are tiny jumping spiders, the swords their mouthparts, and the battlefield, a rainforest leaf in the Philippines.

On another leaf, this time in Singapore, two male jumping spiders act out a scene played out by their relatives in the Philippines, but with a different set of armaments. Instead of mouthparts, these males use horns to settle disputes. And in Australia, in a much more deadly contest, a male jumping spider disguised as a piece of debris creeps up on another species of jumping spider. Suddenly, the stalked victim sees that the camouflaged predator has flamboyant genitalia and flees.

Similar male traits can be found in numerous species throughout the animal kingdom. Like the fan of the Peacock or the antlers of the giant, but now extinct, Irish Elk, these traits are called secondary sexual characters (primary sexual characters are the actual reproductive organs) and are usually exaggerated forms of structures also found on females of the same species. Through sexual selection, males have evolved these characters for competing with rival males and impressing females (see "Dressed to Impress", *Nature Aust.* Summer 1994–1995 and "The Struggle for Sexual Success", *Nature Aust.* Winter 1996). Apparently they have evolved, despite reducing individual survivability,

(Right) This male *Myrmarachne plataleoides* has been 'tarred and feathered' by a moth. Because the male cannot inject venom into its prey, the moth looses scales as it is stabbed by the clumsy predator.

because they increase the reproductive success of males. Study of these bizarre structures, which are so incongruous from a survival perspective, is important for understanding how sexual selection influences the evolution of male characteristics. Through experimentation and observation we have begun to understand these characteristics in the family Salticidae, commonly known as jumping spiders, which we will illustrate here with three examples.

There are over 5,000 described species of jumping spiders, making

A male *Mopsus morman* uses a palp to wipe the lens of one of its two large eyes.

PHOTOS SIMON D POLLARD

them the largest family of spiders. It's unlikely David Bowie was thinking of this group when he wrote about extraterrestrial arachnids, but jumping spiders are so bizarre they might as well have come from Mars. These spiders have excellent eyesight that is unparalleled in any other animal of similar size. Stare into the face of a jumping spider and two large eyes, with the lustre and convexity of our own, and capable of assessing size, colour and shape, stare back. Six other smaller eyes are mainly movement detectors.

Because jumping spiders are visual animals, it is not surprising that many species have moustache-like tufts, punk-style 'haircuts' and jewel-coloured scales. Males court females and threaten rival males in complex species-specific sequences of visual displays involving, for instance, special waving of legs, body posturing and dancing to and fro. And because of these face-to-face interactions, it is also not surprising that the male's secondary sexual characters are often associated with his mouthparts, face and palps. The male's palps, a short pair of leg-like appendages either side of the face, are used to transfer sperm to the female. They are considerably enlarged compared to the female's palps, and often have conspicuous hairs and markings.

MYRMARACHNE PLATALEOIDES, from the Philippines, is a special jumping spider in more ways than one. Not only is it one of the most extreme examples of sexual dimorphism (differences between the sexes) known for any animals but also males and females of this species convincingly mimic Green Weaver Ants (*Oecophylla smaragdina*) both in colour and shape. Spiders have a two-segmented body, but *M. plataleoides* creates the illusion of the three-segmented body of an ant by having an extra constriction. Also, ants, unlike spiders, have antennae, but the two front legs of *M. plataleoides* are slender and angled forward, and are waved up and

Male *Epeus* sp. from the Philippines. With his large eyes, white moustache, punk-style hair cut and colourful markings, he looks more like a diminutive primate than a spider.

plataleoides. Weaver ants, because they can bite and mount a communal defence, are formidable prey for many predators that might readily eat a jumping spider. Resembling a weaver ant appears to protect *M. plataleoides* against these predators.

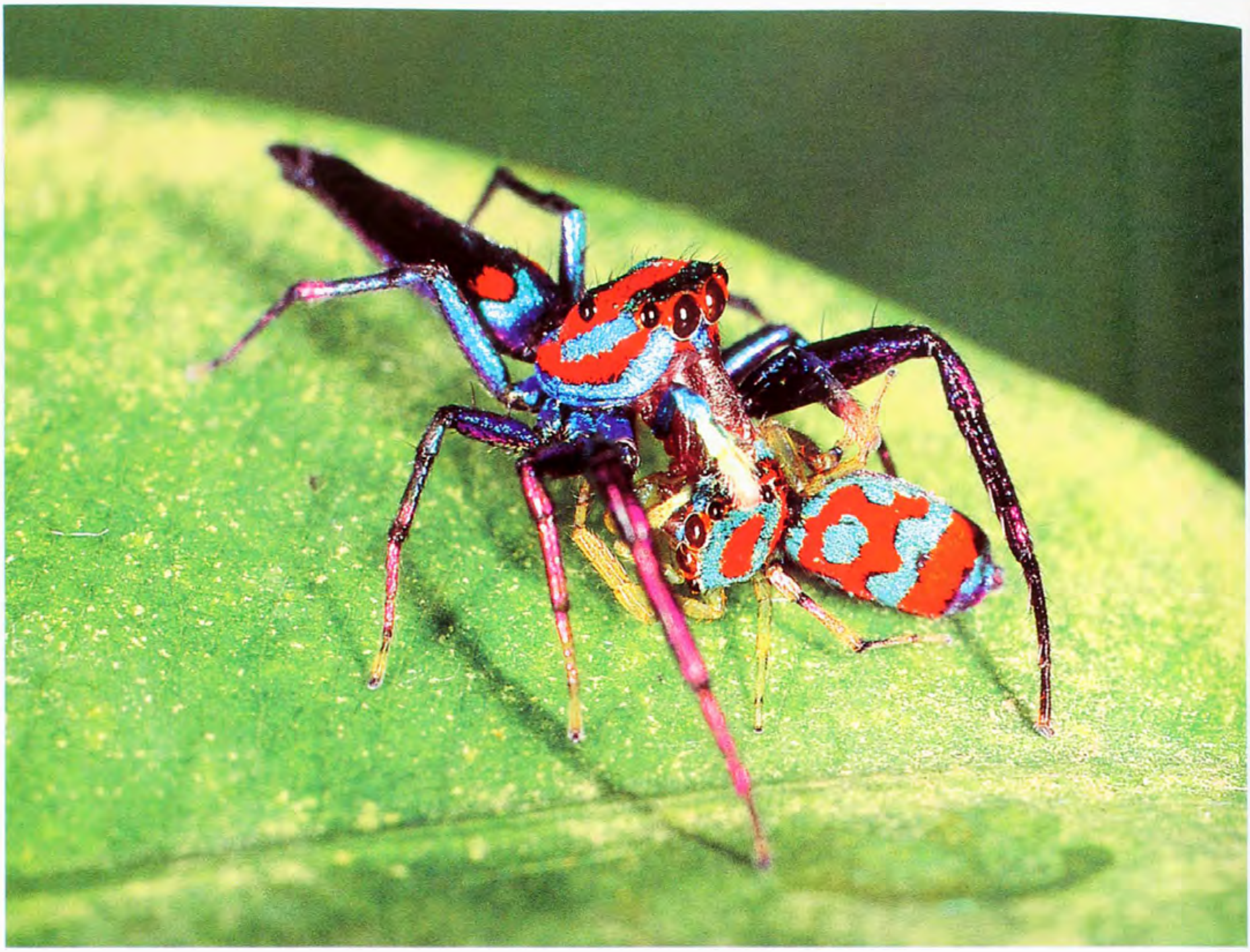
In *Myrmarachne plataleoides* males, the chelicerae (mouthparts) have been exaggerated for sexual display—males use their 'swords' in contests with rival males. In contrast to the female's chelicerae, which point downwards, those of the male have been raised 90 degrees during development and are five times as long. In fact, the male's tusk-like chelicerae may be 50–70 per cent as long as his entire body. This dramatic metamorphosis occurs during the male's final moult and resembles a special effect in a horror film. Yet, prior to this last moult, it is difficult to tell immature males and females apart.

What effect does growing large chelicerae have on ant mimicry? Does a male *Myrmarachne plataleoides* look less ant-like to a potential predator? Our own experiences as collectors suggest an interesting answer. Reaching into a sea of ants, what we think is an *M. plataleoides* sometimes turns out to be a large weaver-ant worker carrying a

PHOTOS SIMON D POLLARD

Female *Myrmarachne plataleoides* (top) are convincing mimics of the Green Weaver Ant, (*Oecophylla smaragdina*). However, it is the chelicerae (mouthparts) of the male (bottom) that have been exaggerated for contests with rival males. Interestingly this doesn't seem to affect the disguise.

down to simulate an ant's antennae. Even *Oecophylla*'s large, laterally positioned compound eyes are simulated: *M. plataleoides* has two pigment spots that serve as fake ant eyes, whereas its real eyes are at the front. Usually it is the spider's behaviour, rather than its appearance, that betrays it as an arachnid in ant's clothing. When we go collecting, we look for an anti-social ant facing away from the general flow of ant traffic, as this 'ant' often turns out to be *M.*



Sexual cannibalism in a kaleidoscope of colour as a male jumping spider (*Siler* sp.) from Sri Lanka eats a sexually immature female.

smaller worker in its mandibles. Weaver-ant workers come in two sizes—larger ones that forage for food and smaller ones that care for eggs and larvae inside the nest. The larger workers commonly carry their smaller nest mates from one sub-nest to another. *Myrmarachne plataleoides* males may be able to maintain the illusion of being ants by mimicking weaver ants ferrying nest mates.

Support for this hypothesis comes from an unexpected source—the behaviour of other jumping-spider species. Most jumping spiders avoid ants, as ants are more likely to prey on the spider than *vice versa*. However, there are some that routinely eat ants. These ant-eating jumping spiders prefer to attack ants that are carrying something in their mandibles, presumably because these ants are more or less disarmed. Ant-eating jumping spiders also commonly stalk *Myrmarachne plataleoides*, as though they were ants. Furthermore, they prefer to stalk *M. plataleoides* males rather than females, suggesting they mistake *M. plataleoides* males for ants with occupied mandibles. Incidentally, stalking of either sex is usually in vain. Both sexes of *M. plataleoides* usually escape unharmed because they see, then display at, the ant-eater, communicating their true identity as jumping spiders and unsuitability as prey. Although looking like an ant-eating salticid's favourite prey is probably not much of a problem for *M. plataleoides* males, there is an apparent price that males pay for their enlarged chelicerae.

MALES FORFEIT THE USE

of venom and instead must sit on their prey and stab it to death with their fangs.

The process of cheliceral elongation appears to preclude males from having a functional duct running from the venom glands in the head to the tips of the fangs; ducts that would have to be about five times longer than those in females. The problem for males is analogous to having a small syringe with a long needle. It just seems impracticable to produce sufficient pressure to squeeze the venom out into prey, given the distance between the glands and the fang tips. Consequently, when they mature, males forfeit the use of venom they enjoyed as juveniles to immobilise their prey, and instead must sit on their prey and stab it to death with their fangs. Not surprisingly, larger prey often escape beneath the male's body. A male that repeatedly attempts to stab a butterfly, for example, may end up looking like he's been tarred and feathered with nothing to show for his efforts except butterfly scales.

And the problem doesn't stop with the kill. Feeding on prey once it's been killed is also a problem for male *Myrmarachne plataleoides*. Spiders feed by dissolving prey with digestive fluid and sucking up the partially digested liquid nutrients. A female sucks nutrients from holes made by her fangs in the prey's body, rather like a person sucking from the top of a pierced fruit-juice carton. However, because of the male's long fangs, he has to push them through both sides of the prey's body, until the tips point back into the spider's mouth. The male can then suck nutrients from holes in the prey where the fangs have poked through, but this is rather like having to push a straw through the bottom of a fruit-juice carton, until it pokes out the top, before being able to drink. The price that *M. plataleoides* males appear to pay for their cheliceral weaponry is taking longer to feed compared to females and, because the prey is full of holes, getting less food for their efforts. Also, because males' fangs often resemble grisly skewers after feeding, males must devote more time to cleaning mouthparts, during which they might be more susceptible to predation.

THE MALE *THORELLIOLA ENSIFERA* is a tiny Asian 'rhino' with two upward-curving horns protruding from below the jumping spider's front eyes. The female of *T. ensifera* has a triad of small hairs or setae below her front eyes and the male's horns are stiff enlargements of the lower two of these hairs. The chelicerae or feeding appendages of *T. ensifera* are also sexually dimorphic. Spider chelicerae are positioned in front of the mouth and consist of two stout basal segments, each with a movable fang at its tip. The basal segments of the chelicerae of female *T. ensifera* are shaped like barrels, but those of the male are flat and have ridges on their lateral borders resembling rose prickles.

Conflicts between males of greatly disparate size are usually settled by both spiders briefly waving their legs at one another. The smaller male assesses the

Female *Thorelliola ensifera* (below top) have a triad of small hairs below their large front eyes. It is the lower of these two hairs that are enlarged in males (below bottom) to form horns.

PHOTOS: SIMON D. POLLARD

size of his opponent, recognises his likely defeat should there be a contest of strength, and then behaves as many people do in the same situation—he runs away.

When *Thorelliola ensifera* males are similar in size they tend to engage in the spider equivalent of wrestling. After waving their legs at one another, they come face to face and interlock horns. The outside of each horn has a band of grooves that probably helps to keep the horns in a locked position during conflicts. This may be an important safety measure. If the horns were smooth, instead of grooved, they might slide forward and damage the eyes. After pushing backwards, forwards and sideways with their horns for two to three seconds, they move apart and one spider, evidently having judged his rival to be stronger, flees.

Although disputes are usually settled after a brief tangle of horns, conflicts sometimes escalate into lengthy (one-minute) battles in which the males charge at each other with their fangs spread. They lock their horns together, push against the ridges of each other's chelicerae, and kick at each other with their legs. These conflicts are not only energetically costly but may also end in injury or death of a combatant. It seems likely that the function of the male's horns is partly to defend its owner, in most cases enabling rivals to settle disputes short of a violent outcome. But horns do come at a cost. When it comes to feeding, the male's forward-facing horns get in the way when they try to bring their face in close enough to bite all but the smallest of prey.

ALTHOUGH DISPUTES ARE *usually settled after a brief tangle of horns, conflicts sometimes escalate into lengthy battles.*

Compared with a male *Portia fimbriata*, the palps of a female are smaller and more slender and, when retracted, tend to blur into the contours of the body.

FOR *PORTIA FIMBRIATA* IN Queensland, rather than 'horns' or 'tusks' it is the male's decorated genitalia that impair foraging. *Portia fimbriata* is an unusual jumping spider because its preferred prey is other species of jumping spiders. It captures these by using a special type of trickery called 'cryptic stalking', which capitalises on *Portia*'s extraordinary appearance. Owing to unusual markings, tufts of hairs on its body, and long spindly legs, *P. fimbriata* looks more like a piece of debris than a spider. When cryptically stalking another jumping spider, *P. fimbriata* moves very slowly, often going undetected by its keen-sighted victim. However, if the other jumping spider does detect something moving up from behind, it swivels around to have a look. When this happens, *P. fimbriata* freezes in its tracks and remains frozen until the other jumping spider turns away. Cryptic stalking becomes interesting in relation to sexual selection because of another consistent part of *P. fimbriata*'s cryptic-stalking routine. When stalking another jumping spider, *P. fimbriata* pulls its palps back so the outlines blur into the contours of the body. Hiding the outlines of palps is important because these are cues by which the other jumping spider can recognise the piece of debris as a camouflaged predator.

However, the male *Portia fimbriata* has a problem. His palps are larger and more decorated with hairs than those of the female and, even when pulled back, are more conspicuous than her slender pair. Having the equivalent of two hairy penises dangling either side of the face, the male *P. fimbriata* often blows his cover as a piece of debris and reveals his identity as a predator to his visually competent prey. It's not surprising that female *P. fimbriata* are more successful at capturing jumping spiders than males.

A single dangling penis (palp) beside the face of a male *Portia fimbriata* can blow his cover as a piece of debris to another jumping spider.

This example differs from *Myrmarachne plataleoides* and *Thorelliola ensifera*, where it was the secondary sexual characters that impaired predation. For the male *Portia fimbriata*, it appears to be a combination of primary (that is, the copulatory organs) and secondary sexual characters (hairy decorations) that compromise predation.

From mites to Mandrills, males often have bizarre structures and garish behaviours, seemingly inexplicable in relation to survival but important when it comes to mating success. Sexual selection is what Darwin proposed to account for these puzzling characteristics of sexually reproducing animals, and they have been the subject of studies ever since. Of course, male jumping spiders couldn't care less about what we might learn from their antics. They will continue to strut and dance before females, jostle and wrestle with rival males, and hunt their prey despite ungainly sexual structures. □

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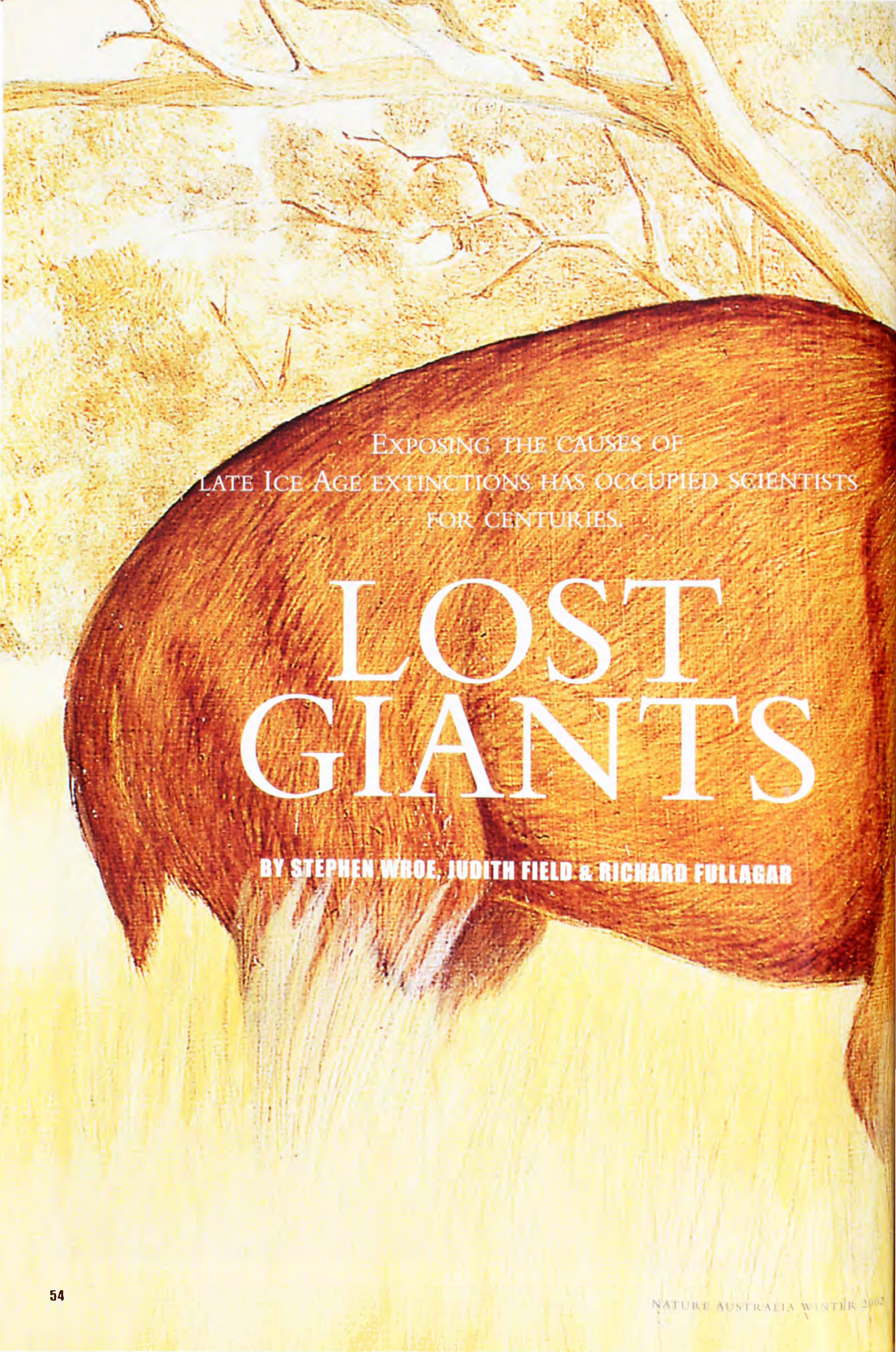


Exposing the causes of late Ice Age extinctions has occupied scientists for centuries.

LOST GIANTS

BY STEPHEN WROE, JUDITH FIELD & RICHARD FULLAGAR

Diprotodon optatum. Weighing in at close to three tonnes, this massive marsupial was megafauna by any definition. Unfortunately, at present, most estimates of body mass for Australia's fossil species are the product of guesswork only.

ANNE MUSSER, AUSTRALIAN MUSEUM

MAKE NO MISTAKE, the protestations of a vocal minority aside, size matters. Big is good. Big animals get first access at the local watering hole and can monopolise food resources. They also have fewer predators and live longer. Consequently, it surprises many to learn that large animals are rare. The vast majority of species, both in the past and present, are small.

Superficially, this seems counterintuitive, but scrutiny reveals there is an extensive downside to large size. Big animals need more food, more water and they need more time to grow and reproduce. Thus, their populations are typically small and, when the going gets tough, they are the first to bite the dust. It remains cruelly ironic that the Lion is far more vulnerable to extinction than the louse.

Still, for all their evolutionary fragility, there can be no doubt that large animals have charisma and when big animals go extinct people demand an explanation. Such issues become even more vexatious when many species go extinct within short periods (mass extinctions). Of course, most species

WHEN BIG *animals go extinct people demand an explanation.*

that have ever lived are extinct and most of these weren't extinguished in mass events. These unsung extinctions remain largely unexplained. But mass extinctions always attract comment and, for some at least, consensus has been reached. Sixty-five million years ago a very large wayward rock took out the dinosaurs. With big names, big body counts and a bona fide extraterrestrial, this theory has always had real Hollywood-appeal and, not surprisingly, it's had wide coverage. Everyone knows an asteroid killed the dinosaurs.

With dinosaur extinctions wrapped up, in recent years another mass extinction has come to the fore—the late Ice Age extinction of the megafauna. Over the last 100,000 years around half the genera exceeding 44 kilograms or so have disappeared. Lost giants include everything from mammoths and sabre-toothed tigers to marsupial lions and the rhino-sized, wombat-like *Diprotodon*. Although most were not as massive as dinosaurs, a twist to these extinctions gives them special appeal: *Homo sapiens* was at the scene.

EXPOSING THE CAUSES OF LATE ICE Age extinctions has occupied scientists for centuries. Humans and climate change have both been strongly implicated, but neither model has gained clear ascendancy. That is until recently. Over the last few years a succession of articles and books has placed the blame squarely on humankind. Proposed mechanisms range from human-induced habitat modification to the introduction of disease, but a model involving human causation called 'blitzkrieg' has received particular attention.

Developed more than 30 years ago to explain late Ice Age extinctions across the planet by Paul Martin (University of Arizona), blitzkrieg is characterised by tantalising simplicity. Proponents of Martin's best-selling global model argue that, wherever late Ice Age humans invaded pristine environments, they violently and almost instantaneously eliminated most of the megafauna. Support centres largely on proposed dates for human arrivals and megafaunal extinctions, but two supposed behavioural phenomena are central. Foremost is the concept of naivety, that is, that the large animals of previously unoccupied lands were easy prey because they were ignorant of humans. The second principle is that, regardless of culture, if people can exploit a food source they will. Furthermore, such exploitation will only cease if the resource is squeezed into extinction or becomes uneconomical to obtain.

Today's blitzkrieg hit-list includes the


JANETTE MUIRHEAD

A Pleistocene Marsupial Lion (*Thylacoleo carnifex*) attacks a subadult of the rhino-sized *Diprotodon optatum*. Hard evidence shows that this formidably armed predator hunted even the largest of Australia's megafauna.

Americas, Australia, Madagascar, New Zealand and various smaller islands. Some reports have presented global blitzkrieg as fact.

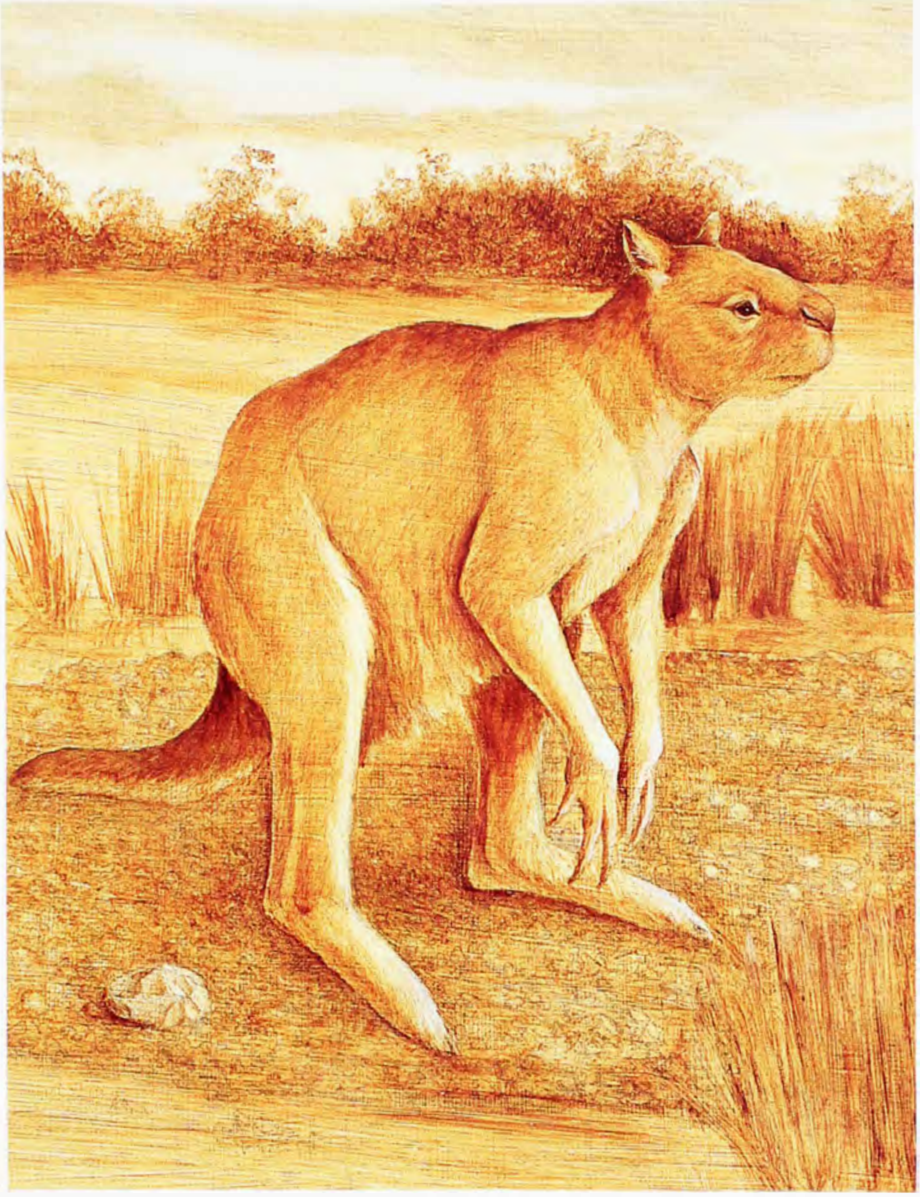
However, the issues here are important and of more than strictly scientific significance. Politicians and special-interest groups have misused and misrepresented interpretations of late Ice Age extinctions. In Australia some have argued that, because we now 'know' Aborigines wiped out the megafauna, farmers are in fact simply applying a replacement therapy by stocking our continent with large hard-hoofed animals. Others have used this 'fact' to attack the credibility of Aborigines as environmental custodians. Thus, it is especially important that scientists distinguish fact from hypothesis and that all sides of the debate are heard.

Here we give our case and, far from accepting that recent investigations have proven global blitzkrieg, we feel that some actually represent compelling evidence against it, especially with respect to Australia. Consequently, we will focus on Australia as the spanner in the works for those who advocate blitzkrieg as a worldwide phenomenon.

BUT FIRST WE WISH TO POINT OUT that, despite the high profile developed for universal blitzkrieg, there remains not a single landmass exceeding 150,000 square kilometres (South Island of New Zealand, where the Maoris wiped out the moas) for which human causation is generally accepted, and even here it is not clear that predation was the primary factor. Although many scientists clearly don't subscribe to global blitzkrieg, their protestations have largely fallen on deaf ears. But then perhaps this is not surprising. The mostly climate-based counter-hypotheses were always going to look shop-worn against the sensational imagery of spear-wielding hordes hacking their way through herds of startled megafauna. Yet while universal blitzkrieg has simplicity and pizzazz, it has obvious problems. Fundamental to these is the fact that each of the landmasses involved are so very different—different sizes, different biological histories, different climatic histories and different cultures, to list a few. These differences are often overlooked by advocates of blitzkrieg, who focus on the timing of extinctions and human migrations, together with the fact that more megafauna went extinct in places such as the Americas and Australia than in Africa, where humankind evolved.

This is too simple, but even at this level, one fact is often overlooked. In Europe there were also major megafaunal extinctions over the last 100,000 years. Yet these were clearly staggered over tens of millennia and there is no evidence for rapid mass extinction, despite both major climate change and human activity. Recent discoveries demonstrate that technologically sophisticated humans had extended their range to the European Arctic nearly 40,000 years ago (see "Arctic Pioneers" on page 18 in this issue) and at such high latitudes these people were almost certainly big-game hunters (in this extreme environment there was little else for humans to eat). Yet they had no immediate or obvious effect on the megafauna. This inconsistency will

The moas of New Zealand went extinct shortly after humans arrived. Widespread extinction on oceanic islands, subsequent to human colonisation, is commonly flagged in support of global blitzkrieg. But other factors besides human predation, such as introduced species and habitat modification, are also to blame.



ANNE MUSSER/AUSTRALIAN MUSEUM

Not all of Australia's so-called 'megafauna' were giants. A number of extinct kangaroos, such as this small *Sthenurus*, were comparable to living species. In fact, of around 55 species thought to have gone extinct in the Late Pleistocene, around 16 were smaller than 44 kilograms.

require some special pleading by proponents of blitzkrieg.

There are other elemental difficulties. Typically flagged as support for the linchpin of blitzkrieg—naivety—is humankind's ability to eliminate species from previously uninhabited islands. Examples include everything from Dodos to moas. But ignored are the facts that island species are uniquely vulnerable to extinction and that the animals in question had no prior experience with any large terrestrial predators, human or otherwise. It is misguided to transfer this model across to continents, orders of magnitude larger and dominated by ferocious carnivores the calibre of sabre-toothed tigers and marsupial lions.

Differences among continents themselves further eat into arguments for universal blitzkrieg. Australia is particularly conspicuous. Among the three continents for which blitzkrieg has been invoked, Australia is the smallest, the flattest, the driest and the most isolated. The history of human occupation in Australia is also unique and an intractable thorn in the side of global blitzkrieg theorists is the fact that no direct evidence exists for even a single Aboriginal kill. Even more importantly, the large stone spear-points typically associated with Ice Age big-mammal hunting elsewhere don't appear in Australia until 6,000 years ago, long after the megafauna perished. The significance of this absence is evidenced by investigations of more recent cultures. A study of 70 traditional American societies by Christopher Ellis (University of Western Ontario) demonstrated that stone points were used almost exclusively for hunting large game (over 40 kilograms). Large game was sometimes hunted with wooden-tipped projectiles, but never systematically. We don't argue here that a lack of big-game-specific hardware excludes the possibility that Australia's first humans killed megafauna. In fact we think that they almost certainly did, on occasion. But the lack of such a tool-kit strongly suggests that, where the megafauna was hunted, it was done so opportunistically. This does not sit well with blitzkrieg, which demands efficient, systematic and continent-wide persecution.

Technological differences are closely associated with another weakness in the argument—the assumption that all colonising cultures must treat all big game not just as food, but as the primary food source. The elimination of 20 megafaunal genera within 1,000 years from a landmass the size of Australia, by small bands of people that only *occasionally* ate big game, truly stretches credulity to the limit. Stone Age societies were not a homogeneous, culturally impoverished rabble, and not every society has systematically hunted megafauna, even when such fauna was abundant. Indeed, such societies have always been in the minority. Among many examples, the Early Stone Age Gravettian people of southern Europe relied heavily on small game, not because large prey or necessary hardware were absent, but because they had technology (such as nets) that made smaller prey easier to get. We know almost nothing about the culture of first Australians, but if they were anything like all known societies from low latitudes, then their diet comprised around 70 per cent vegetable matter and most meat eaten was in the form of small game.

The type of culture imported by colonising humans may have profoundly affected their approach to the big game they encountered. Debate still rages over whether the Clovis Indians of North America exterminated 'their' megafauna. But we *do* know they had a megafauna-specific tool-kit, they defimitely used it to kill at least some species and, importantly here, they hailed from a proud tradition of high-latitude, big-game hunting, honed on the vast Siberian tundra. However, for the first Australians, there is no smoking gun in the form of murdered megafauna, there are no specialised weapons, and their immediate ancestors were almost certainly not systematic hunters of big animals.

One last important factor distinguishes Australia. On other landmasses that were allegedly blitzkrieged, humans arrived in company. For example, when humans entered North America around 13,000 years ago, they were joined by a suite of essentially Eurasian megafauna, including Moose, Brown Bears and, quite possibly, the Grey Wolf—one of the most successful and efficient big-game hunters the world had ever seen. Demonstrable climatic upheaval aside, the devastation wrought on the endemic North American megafauna by these non-human assailants must have been significant. Singling out *Homo sapiens* as the sole culprit under such circumstances is indefensible. Most accept that the extinction of North America's megafauna happened quickly, but if humans played a role it was done with assistance. In Australia we don't know whether megafaunal extinction was rapid, but we do know that, if humans contributed, they had no help from other non-endemic megafauna.

NOT EVERY SOCIETY *has systematically hunted megafauna, even when such fauna was abundant.*

FOR THESE REASONS AND OTHERS, Australia has long been the weakest link in the case for global blitzkrieg. Indeed, the strongest argument for any human culpability in Australia has been evidence suggesting that a big bird (*Genyornis*) went extinct from three sites in arid-semiarid southern Australia around 50,000 years ago, without evidence for climatic catastrophe. The team that forwarded this data, headed by Gifford Miller (University of Colorado), further inferred that, if people did in *Genyornis*, then maybe they exterminated other megafauna. But younger dates for *Genyornis* at Cuddie Springs (New South Wales) indicate that *Genyornis* extinction wasn't continent-wide at 50,000 years and, even if it was, the great majority of extinctions can't be attributed to obvious calamity. So, a lack of major climate change at this time doesn't automatically implicate humans in the extinction of *Genyornis*, let alone the rest of the megafauna. Lastly, if less extreme climate change was responsible, then arid-semiarid Australia is the first place we'd expect megafauna to disappear.

Consequently, when a team led by Richard Roberts (University of Melbourne) recently claimed to have pin-

Unearthing the biggest mammal ever to wear a pouch-the 2.7—tonne *Diprotodon optatum*. The authors argue that 40 or more large to gigantic animal species could not have been hunted into extinction within 1,000 years given the absence of stone-tipped spear-points from the early Aboriginal arsenal.

pointed the last gasp of six genera of megafauna at 46,000 years ago, it was heralded as a shot in the arm by advocates of blitzkrieg and other models founded on human interference (Roberts's team included proponents of extinction through habitat disturbance, as well as blitzkrieg). This is because mass extinction is more likely to correlate with major catastrophe, and cataclysmic climatic change didn't peak until around 20,000 years ago. Again the inference, in the complete absence of direct evidence, is that if it wasn't climate then it must have been people. In this study Roberts *et al.* dated six sites with megafauna at significantly less than 46,000 years old, yet they dismissed them, based on the grounds that they were more likely to have been disturbed because they didn't contain skeletal material in neat, anatomically correct positions. But this is not standard practice, and serious doubts will remain until the ages of these six and at least ten other sites dated at less than 46,000 years are individually corroborated or disproved. Moreover, the sample of nine sites that ended up being included in the analysis is insufficient on which to draw confident conclusions. An additional problem is that the results actually reaffirmed previously determined dates of 27,000 to 36,000 years for one of the sites dismissed from their analysis, Cuddie Springs.

However, even if we suspend disbelief and accept that the megafauna hit a brick wall 46,000 years ago, one thing is clear—blitzkrieg wasn't the *modus operandi*. On the basis of previous studies by Roberts himself, his team argues for human arrival at 56,000 years ago. So a best guess for human–megafaunal coexistence based on their own data is 10,000 years. This is not blitzkrieg.

The authors have since stated that their results don't actually rule out blitzkrieg because, if we stretch the confidence limits on these numbers to their maxima, then the human–megafaunal coexistence of 1,000 years or less demanded by blitzkrieg is just possible. Strictly speaking this is true. Indeed very little can be completely ruled out. But in our view, conclusions should articulate what results show to be most likely, and the results tendered by Roberts *et al.* demonstrate that blitzkrieg most likely didn't happen in Australia.

TOGETHER WITH THE LACK OF KILL sites, specialised weaponry, or a big-game-hunting pedigree, this evidence for sustained coexistence leaves the argument for blitzkrieg in Australia all but dead. The implications are wide reaching. It is possible that extremely localised blitzkrieg happened in the relatively small islands of New Zealand and maybe even on other landmasses, but if blitzkrieg does not apply to Australia, then, regardless of wherever else it may have occurred, the global blitzkrieg paradigm is sunk. With it goes the notion that mass extinction is an inevitable consequence of human interaction with naive megafauna.

While blitzkrieg now looks untenable in Australia, this hardly solves the riddle of what happened to our megafauna. Various scenarios remain credible, although in our view the available data are most consistent with extinctions occurring over a long period and at varying rates and times according to location. Roberts *et al.* showed that many genera of late Ice Age megafauna may have been extinct before humans arrived. We believe that climate change probably drove the final round of extinctions, beginning at around 45,000 years ago in the now arid–semiarid zones. Extinctions accelerated on an expanding but irregular outward front from this point, as Australia careered through the tumultuous lead-up to the Last Glacial Maximum 22,000 years

MAURICIO ANTON

American Lions (*Panthera atrox*) and woolly mammoths (*Mammuthus primigenius*) in Late Pleistocene Alaska. The retreat of glaciers by 13,000 years ago, facilitated the invasion of southern North America by a swathe of essentially Eurasian megafauna from Alaska, as well as people. Most invaders survived, while most endemics went extinct. Even if climatic influence was ruled out, we cannot attribute these extinctions to humans until the impact of these other 'exotics' is known.

ago. Megafauna probably persisted longest in ever-shrinking wetter regions, especially toward the coast. This is a testable hypothesis and supported by the fact that, with one borderline exception, all younger sites dated by Roberts *et al.* fall outside the now arid-semiarid zone. Such a climate-driven model does not necessarily absolve humans of any responsibility, but against this backdrop of prolonged climatic change, precise apportioning of blame will be very difficult.

Humans are instinctively attracted to simple explanations, but extinction is generally anything but simple. Complicating factors include fluctuations in temperature and rainfall, habitat destruction by humans, reconfiguration of habitats, fire, introduced predators and competitors, disease, and cascading effects whereby the extinction of one or a few key species forces the extinction of others. Particularly pressing questions that need to be answered include—why did the extinction process in Australia almost exclusively target browsers, why did so many late Pleistocene species evidently disappear before humans even arrived here, and why did the few survivors shrink in size? The role of humans will be very difficult to assess against this intricate canvas and, although we feel that blitzkrieg in Australia can be all but discounted, remaining models, including our own, have yet to be comprehensively tested. The way forward in this debate is to find and date more sites, re-date old ones, and investigate changes in animal populations through time, both before and after the arrival of humans. As Richard Wright (University of Sydney) commented a decade ago, "megafaunal extinction is a topic that now requires rather more digging than talking". □

***Genyornis newtoni*—the last of an enigmatic lineage of gigantic birds called dromornithids. At only around 80–100 kilograms, *Genyornis* was a small member of the family, which may have included carnivorous representatives.**

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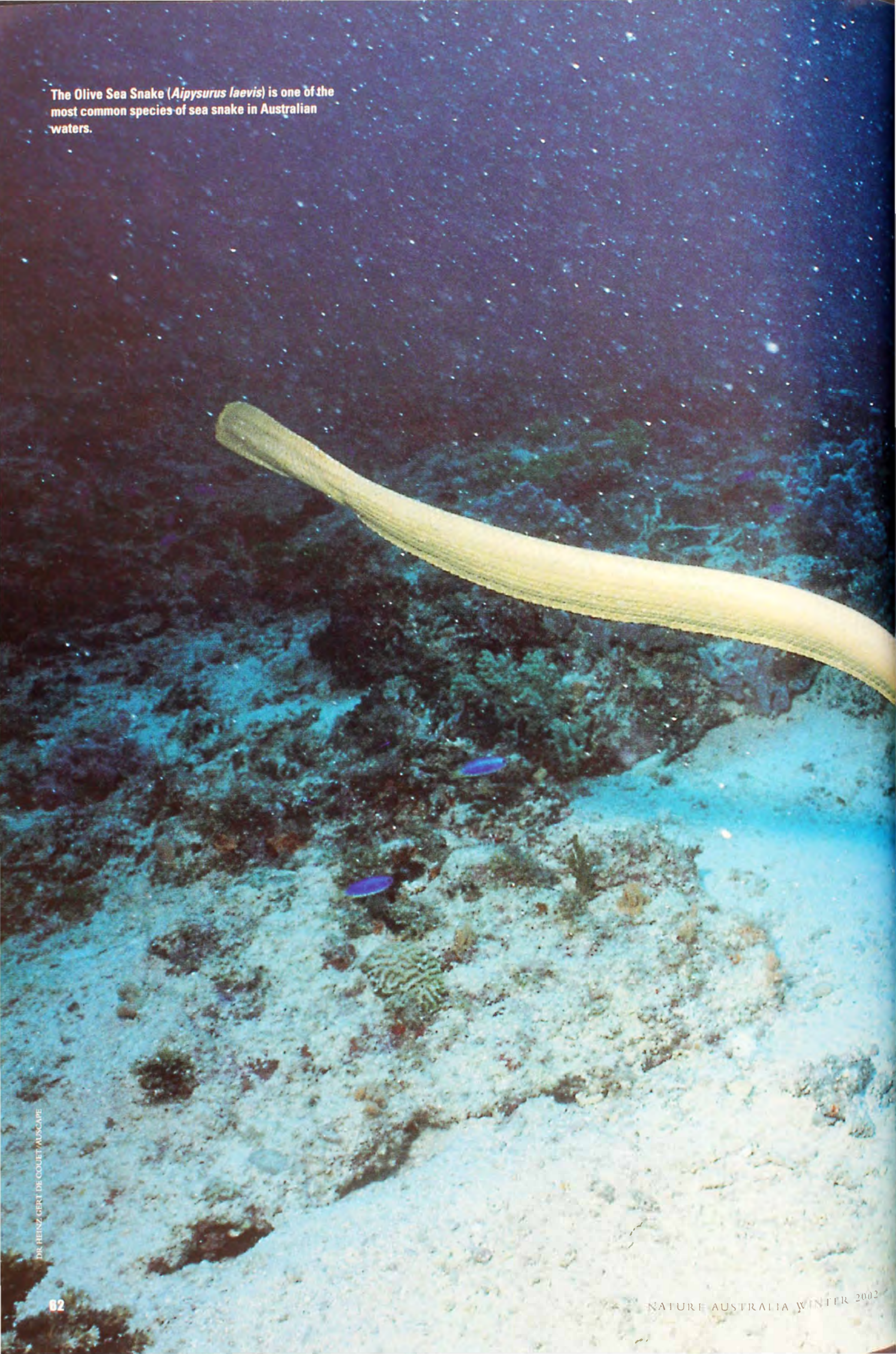


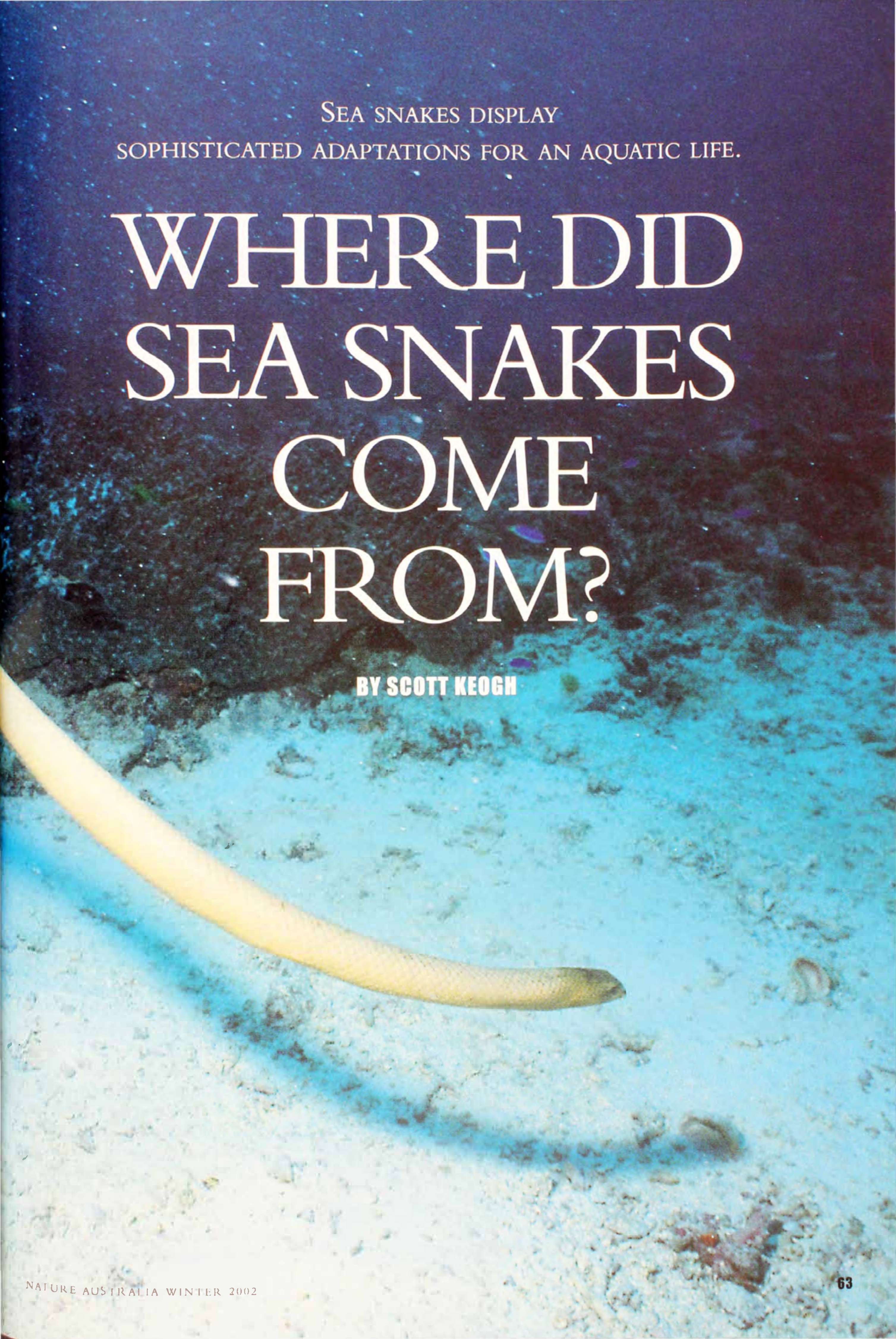
The Olive Sea Snake (*Aipysurus laevis*) is one of the most common species of sea snake in Australian waters.

DR HEINZ GERT DE COUET/AUSCAPE

Sea snakes display sophisticated adaptations for an aquatic life.

WHERE DID SEA SNAKES COME FROM?

BY SCOTT KEOGH



MANY SNAKES AROUND the world live in water or are closely associated with it. This affinity for water has evolved many times independently in a variety of distantly related snake groups—for some reason snakes seem to have a propensity for evolving forms that can exploit aquatic habitats. But of the various groups that live in or near water, the sea snakes display the most sophisticated adaptations for an aquatic life, and they are highly venomous!

TRUE SEA SNAKES *are completely marine—they never, willingly, come on land.*

Sea snakes are members of one of the two major groups of venomous snakes—the family Elapidae. Apart from sea snakes, elapids include virtually all the venomous land snakes in Australia such as the death adders, tiger snakes, taipans, brown snakes, and also the African mambas, the African and Asian cobras, the Asian kraits, and the Asian and American coral snakes. Elapids have a type of venom-delivery system known as 'proteroglyphous', which simply means that they have front fangs that are permanently erect. The other major group of venomous snakes, the non-Australian vipers and pit vipers (family Viperidae), have hinged front fangs that can fold back in the mouth. This venom-delivery system, known as 'solenoglyphous', allows the fangs of viperids to be much longer than those of elapids. (If elapids had long erect fangs, they would stab themselves in the lower jaw!)

Elapid snakes are a large and diverse component of the modern snake fauna. With some 61 genera and more than 300 species, they represent approximately ten per cent of the world's living snake species and more than 50 per cent of the world's species of venomous snakes. The 17

COURTESY SCOTT KEOGH

The author examining a Yellow-bellied Sea Snake (*Pelamis platurus*).

genera of sea snakes are a significant part of this diversity.

We cannot simply refer to all the sea snakes under the one banner, though. The sea snakes most Australians would be familiar with are the 'true' sea snakes. True sea snakes are abundant on coral reefs in the warm waters around northern Australia, and also New Guinea, Indonesia, the Philippines and all of South-East Asia. A few species occur as far west as the Persian Gulf and as far east as French Polynesia. There is only one species that extends beyond these borders—the Yellow-bellied Sea Snake (*Pelamis platurus*)—and it is the

This is a Blue-banded Sea Krait (*Laticauda laticaudata*) from Ambon, Indonesia hunting for its prey in a coral reef. Sea kraits are very good at pulling eels out of their dens.

only open-water or pelagic species. It is found in warmer waters from the east coast of Africa to the west coast of North and Central America in the Pacific and Indian Oceans. No sea snakes are known to occur in the Atlantic Ocean.

The true sea snakes are a morphologically diverse group with 16 genera and almost 60 species, although the number of genera recognised varies among authorities. True sea snakes are completely marine—they never, willingly, come on land. They are born in the ocean (they give birth to live young) and they die in the ocean. However, the other major group of sea snakes, while still superbly adapted to marine life, is not so fully committed. The sea kraits comprise only five formally described species in the one genus *Laticauda*. Sea kraits spend most of their time at sea, but they come on land to lay eggs and to rest. One species even lives in a brackish lake.

SEA SNAKES, LIKE ALL SNAKES, ARE carnivores. Most spend their time hunting for fish, eels, crabs and squids around coral reefs, although some species venture into more open waters, even into brackish-water mangrove

areas. Their potent venom makes it easier to subdue their fast and slippery prey. Some species are highly specialised in what they eat. For example many species specialise on eels or small goby-type fishes that they seize from crevices in the coral. Three species have even gone so far as to specialise on a diet of only fish eggs, and since their prey can't escape or bite, they have lost virtually all of their now-unnecessary teeth in the process.

Sea snakes have evolved many adaptations for their marine existence. For example all sea snakes have valves on their nostrils, and can form a tight seal around their mouths when they dive to keep out water. Many also have special salt-secreting glands in their lower jaw to deal with the excess salt in their environment. They have a very large lung (most snakes have just one) to help with diving and buoyancy control, but they can also absorb oxygen through their skin. They are also able to control how much blood goes to the lungs or skin to fine-tune their oxygen balance. This allows some species to dive to more than 50 metres below the water surface, and they can stay under water for more than an hour. Sea snakes move sinusoidally like land snakes, but instead of having wide belly scales to grab onto the ground surface, their belly scales are virtually the same size as the other body scales, and they propel themselves through the water with their paddle-shaped tail.

True sea snakes, like these Olive Sea Snakes (*Aipysurus laevis*), even do their elaborate courtship rituals in the sea.

SOME SPECIES *dive to more than 50 metres and they can stay under water for more than an hour.*

The long list of morphological adaptations to life in the sea has made it difficult to understand where exactly the sea snakes came from. Which snakes, for example, are their closest relatives? And which part of the world did they first evolve?

It's been known for well over 100 years that the sea snakes share the 'proteroglyphous' venom-delivery system with the land-based elapids. Despite the fact that the close relationship between land and marine elapids was identified long ago, evolutionary relationships

The Black-ringed Mangrove Snake (*Hydrelaps darwiniensis*) is one of the only 'true' sea snakes that spends most of its time in very shallow waters and mud flats like this.

among the major elapid lineages have been the subject of much debate. Prior to the late 1960s, all classification schemes simply broke elapids up into land forms versus marine forms. All of the sea snakes were placed in their own family Hydrophiidae, and given equivalent taxonomic rank to the land elapids, which were placed in the family Elapidae. Some workers even put the five species of sea kraits in their own family Laticaudidae. But these classification schemes did not accurately reflect the evolutionary relationships of sea snakes. It did not emphasise to which other group of snakes the sea snakes were related.

Work began in earnest in the 1960s to try to sort out the relationships of sea snakes, and thus their origins. Based largely on anatomical studies by Sam McDowell (Rutgers University, USA), sea kraits and the true sea snakes were shown to be most closely related to the Australian land elapids. McDowell recognised a major subdivision in elapid snakes. He broke elapids up into the now well-known groups called 'palatine erectors' and 'palatine draggers'. (Although not particularly descriptive, the terms refer to the direction of movement of the palatine bone in the upper jaw.) The 'palatine erector' group includes all land elapids in the New World, Africa, Asia and South-East Asia, plus the sea kraits. The 'palatine dragger' group includes all the Australian and Melanesian land elapids and true sea snakes. McDowell considered the sea kraits to share a closer relationship with Asian and American coral snakes than with true sea snakes, which he thought were more closely related to Australian land elapids.

With the exception of the evolutionary relationships of the sea kraits, McDowell's proposed split into these two major elapid lineages has been confirmed by diverse data sets including venom protein sequences and mitochondrial DNA sequences. We also now know that the true sea snakes and the sea kraits form two very distinct groups of sea snakes and, while they share many adaptations for marine life, the two groups are not each other's closest relatives. Instead they have evolved independently from land snakes.

SO WHERE DID THE TRUE SEA SNAKES and sea kraits come from? For the

KEVIN DEACON/OCEAN EARTH IMAGES

A Turtle-headed Sea Snake (*Emydocephalus annulatus*) hunts for fish among the coral reefs.

EVA BOERGAARD/LOCHMAN TRANSPARENCIES

true sea snakes, the evidence points to the diverse radiation of Australian and New Guinean elapids. About half of the land snakes in our Australo-Papuan 'palatine dragger' radiation lay eggs, but the other half give birth to live young (viviparous). We now know that the true sea snakes are closely related to the live-bearing elapid snakes of Australia and New Guinea, and there has been much work to try and discover which specific land snake represents their closest living relative. For a long time various workers have pointed to the water-loving tiger snakes as a possible candidate, but mitochondrial DNA data have shown that, while the tiger snakes are relatively closely related to true sea snakes, there is another, lesser-known group that appears to be closer. The small snakes of the genus *Hemiaspis* live in swamps and other wet areas in eastern Australia, feeding mostly on frogs. McDowell first pointed out the close relationship of these 'swamp snakes' to true sea snakes in the 1960s, but this is still an area of active research. If *Hemiaspis* species do prove to be the real long-lost land relatives to true sea snakes, at least it will be satisfying to know that the closest relative does spend a lot of time in or near water.

TRUE SEA SNAKES *are closely related to the live-bearing elapid snakes of Australia and New Guinea.*

But things are not so simple for the sea kraits. While we do know that the closest relatives of sea kraits are not the true sea snakes, sorting out which land snakes are the closest relatives has been difficult. As with true sea snakes, adaptations for a marine life have made it difficult to use anatomy as the basis to evaluate relationships. Because of this, the sea kraits have been the subject of continual taxonomic debate, and their affinities are still not fully sorted out. However, my recent mitochondrial DNA data have shown convincingly that McDowell, who lumped sea kraits with the non-Australian cobras and coral snakes, was wrong, and we now at least know that the sea kraits are most closely related to egg-laying land elapids in the Australo-Papuan region. The sea kraits can be thought of as 'intermediate' or 'transitional' between the Asian and Australian land elapids. They have now been placed, for the moment at

This Stoke's Sea Snake (*Astrotia stokesii*) has a large lump in its belly from its most recent meal.

The venomous Australian Black-bellied Swamp Snake (*Hemiaspsis signata*) may be the closest living terrestrial relative to the true sea snakes.

least, in the subfamily Hydrophiinae, which includes all the Australo-Papuan land elapids and the true sea snakes.

What does all this mean? Well for one thing, it means that 'sea-snakiness' has evolved twice independently in the Australo-Papuan region and in the elapid group. We can look at the origin of sea snakes in another way too—from a biogeographical sense. Despite the great morphological diversity evident in the Australo-Papuan land elapids and sea snakes, my DNA data show that this group (the subfamily Hydrophiinae) represents a comparatively recent radiation derived from Asian ancestors, following the collision of the Australian and Asian tectonic plates about 20 million years ago. The evolutionary trees generated from these DNA data show what can be called a 'stepping-stone' pattern of invasion from these Asian ancestors. This simply means that, as new species moved into the area, they left descendants on islands (the Solomons, Fiji, New Guinea) as they continued their colonisation. The 'stepping-stone' biogeographical pattern matches nicely with what is known of the geological history of the region.

Australia is thought to have broken off from the southern supercontinent Gondwana approximately 60 million years ago. Australia, New Guinea and other associated islands then drifted toward Asia in relative isolation from other continents until they reached South-East Asian islands approximately 15 million years ago. However, the colonisation of the Australo-Papuan region may have happened earlier. The Australo-Papuan landmass was preceded by a series of islands that have since joined the New Guinean or Asian landmasses. This may have allowed early colonisation by ancestors of Australo-Papuan elapids from Asia. It is worth mentioning here the intermediate nature of the sea kraits in terms of their degree of 'sea-snakiness'. Molecular data clearly unite the genus *Laticauda* with the Australo-Papuan land elapids and sea snakes (although an early offshoot of this radiation), while the anatomical studies of McDowell suggest the sea kraits 'sit' somewhere between their Asiatic ancestors and the Australo-Papuan elapids. If the sea kraits really are intermediate (which is also supported by the 'stepping-stone' pattern of invasion), then this lends support to an amazing idea proposed in the 1950s by Garth Underwood at the British Museum (Natural History).

Underwood postulated that perhaps the Australo-Papuan elapids (and thus true sea snakes as well) were derived from an ancestor that swam to our region from Asia! McDowell also considered this possibility in his comparisons of sea kraits with land-based Melanesian elapids. If true, then the evolutionary scenario might go something like this. An early sea-krait-like snake swam to the Australian region from South-East Asian islands, hit land, and then proceeded to evolve into the wide variety of venomous elapid land snakes we have today—a return from the sea! My own data, while not providing proof for this scenario, certainly don't discount it. Indeed, this scenario offers a relatively simple, albeit highly controversial, explanation for how Asiatic elapids might have crossed Wallace's Line—the deep trench between Bali and Lombok, which has acted as a strong barrier to exchange between some Asiatic and Australo-Papuan faunas.

Clearly, the evolutionary and biogeo-

graphic history of elapid snakes, and sea snakes in particular, is complicated. While the data available today support the major division between the Australo-Papuan land elapids—true sea snakes and sea kraits on the one hand, and cobras and coral snakes on the other—there is still a tremendous amount of work to be done to fully understand the origins of our venomous snakes.

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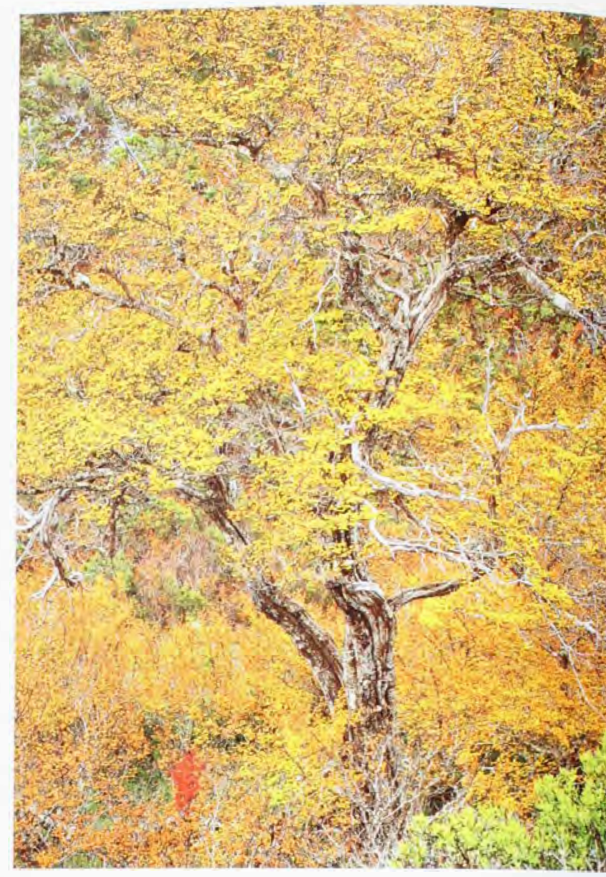
beech seasons

BY ROBERT BLAKERS

Nature Focus

Autumn:
Deciduous Beech (*Nothofagus gunnii*), Tasmania.



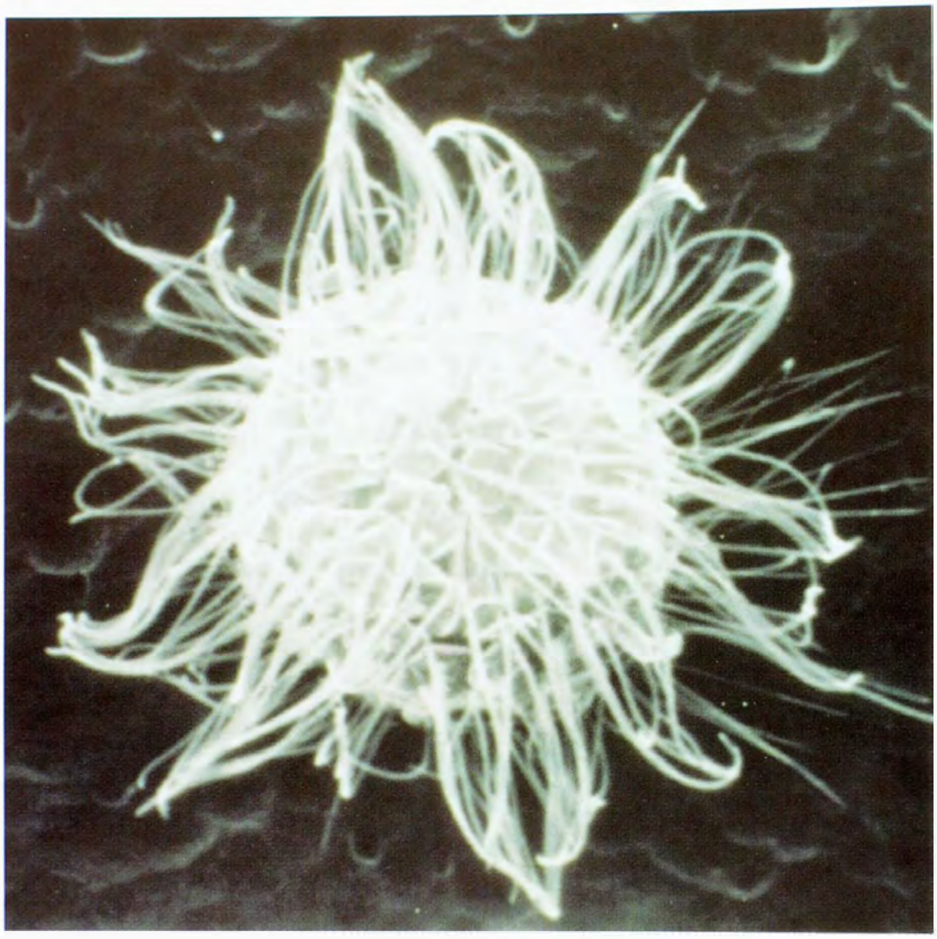
Winter:
Deciduous Beech (*Nothofagus gunnii*), Tasmania.

Spring/Summer:
Deciduous Beech (Nothofagus gunnii), Tasmania.

Forest scene, Tasmania.

Flesh-eating Algae

Pfiesteria is a benign predator, but once it comes into contact with living fish, it turns nasty.



CENTER FOR APPLIED AQUATIC ECOLOGY (CAAE), NORTH CAROLINA STATE UNIVERSITY

A scanning electron micrograph of a *Pfiesteria piscicida* cyst with scales and bracts (hair-like extensions). The maximum diameter with the bracts is nine micrometres.

WHICHEVER WAY YOU LOOK at it, this is a gruesome tale. With over 20 different guises and a craving for live flesh, you are excused for picturing a serial homoeopath rather than a microscopic marine alga. Research on *Pfiesteria* (pronounced feas-TEER-ee-uh) has revolutionised our view of the algal world, and shocked scientists across the globe.

The two known *Pfiesteria* species (*P. piscicida* and *P. shumwayae*) are members of a shady group of creatures called dinoflagellates. This diverse group of unicellular algae is responsible for 'red tides'—a menace to mankind since perhaps the time of Moses who, to prove the power of his god, reputedly turned the water in the River Nile to blood. A more secular explanation for this colouration and the resulting fish deaths and stench is toxic poisoning caused by a surge in the dinoflagellate populations. One notorious example that has come to light in recent years is paralytic shellfish poisoning, which occurs when dinoflagellate toxins build up inside shellfish to levels that can kill humans. Dinoflagellate blooms are increasing in frequency, intensity and distribution around the world, and *Pfiesteria* is but the latest manifestation of this intriguing but dangerous band of algae.

The *Pfiesteria* story begins in Pamlico Estuary, North Carolina. Since the mid 1980s, local fishermen had accused industry of polluting the estuary, and poisoning millions of finned fish and shellfish every summer and autumn—the 'fish kill season' as it is called. Then in 1991 *Pfiesteria* was discovered, and it seemed industry was off the hook. At a Christmas party that year hosted by the State's Department of Environment, Health and Natural Resources, industry officials were toasted and Mother Nature took the rap.

But the celebrations were short-lived. A team of scientists at North Carolina State University found *Pfiesteria* thrived in waters rich in agricultural run-off, human sewage and other animal wastes. The Department, unnerved, demanded ten years of data before the link between *Pfiesteria* and fish deaths, and between pollution and *Pfiesteria*, would be accepted.

The scientists continued their research, despite attacks on their credibility and with key funding withdrawn. Eventually the facts won out, but there is still an undercurrent of distrust and scepticism. *Pfiesteria* is no longer just a local issue on the Atlantic coast of North America. As is the pattern with marine pests, this alga has 'spread' to northern Europe, New Zealand, and most recently Tasmania. In August 2001, *Pfiesteria* was detected in the Huon Estuary near Hobart, and soon after at Triabunna on the State's east coast.

Whether it was transported inside shellfish, in ballast water, or already a native of our estuaries, is unknown. Of concern is that *Pfiesteria* appears to have been resident in the Pamlico area for thousands of years as a non-toxic predator or, at most, a killer of small numbers of fish. A group of specialists from CSIRO, university, government and the shellfish industry, are currently working to determine whether *Pfiesteria* is native or was introduced to Tasmania, and how widespread it is in Australian waters.

A major challenge for researchers has been to unravel the life history of *Pfies-*

BY TIM ENTWISLE

teria. This super-chameleon has the ability to morph into a diverse array of free-swimming flagellated cells, sluggish amoeboid forms, as well as resistant cysts. In size, this organism can range from smaller than a blood cell to almost the thickness of a human hair. Regarding its nutrition, it's a whole new and complicated story.

Mostly *Pfiesteria* is a benign predator, capturing other microscopic algae. But once it comes into contact with living fish, it turns nasty. Typically, excreta from a school of fish will trigger the production of toxins by amoeboid and flagellated forms, and rouse new recruits from the cysts. The toxins make the fish lethargic, causing the school to linger. This allows time for the algal exudates to puncture the skin of the fish, destroying their ability to maintain an internal salt balance. The wounds bleed openly and often haemorrhage.

Once the fish are incapacitated, *Pfiesteria* attacks the sloughed tissue, blood and other substances leaking from the wounds. When the fish are dead, flagellated stages convert to amoeboid forms and feed on the fish remains. Or, if interrupted by a storm for example, the flagellated cells form protective shells and sink to the bottom as dormant cyst stages. This can all take place within hours of first contact.

However the biggest shock, and one that led to an immediate upgrading of safety protocols, was the effect of the toxins on university staff. Twelve researchers developed sores, headaches, nausea, stomach cramps, burning eyes and, in several cases, acute short-term memory loss and kidney and liver dysfunction. Those infected became extremely lethargic, and were unable to perform arithmetic as simple as two plus two. While most of the acute symptoms were reversible over time, the victims continue to suffer lingering effects on their nervous system.

Part of the surprise was that *Pfiesteria* produces toxins that are carried in minute droplets of aerosol—unusual, but now reported for a few other toxic algae. The key neurotoxin produced by *Pfiesteria* has only recently been purified and characterised, and it will soon be possible to diagnose the presence of the toxins, in humans or fish.

So where does *Pfiesteria* fit in the food chain? Various microscopic organisms such as ciliates, rotifers and microcrustaceans will eat *Pfiesteria*. This micrograzing has a big impact on benign populations, keeping them in check, but apparently less of an impact on toxic ones. The role of shellfish is unclear, although some species seem to concentrate toxic *Pfiesteria*—a potential risk to one of the major shellfish predators, us.

The science of *Pfiesteria* is little more than a decade old, and already it has some familiar refrains. High nutrient levels, specifically nitrogen and phosphorus, stimulate production of potentially toxic strains. However, keep the water clean and flowing, and you reduce the risk of a *Pfiesteria* attack (and also help deter 50 or so other toxic dinoflagellates and harmful algae!).

Pfiesteria, while cause for concern, is not yet cause for alarm in Australia. There have been no reports of fish kills or human illness associated with the alga, and at this stage it appears to be quite benign. The decisive response of scientists and managers to Australia's first contact with this awesome alga augers well for our future. With adequate protection of water quality and continuing support for research and monitoring, Australia should be able to prevent *Pfiesteria* from turning into a flesh-eating monster and, if it does, will be in a good position to fight it.

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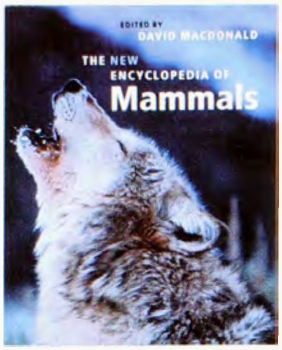
A scanning electron micrograph of a toxic zoospore of *Pfiesteria piscicida* in feeding mode (peduncle or feeding organelle is extended for suctioning the contents from fish tissue). This zoospore is about ten micrometres in diameter.

reviews



The New Encyclopedia of Mammals

Ed. by David Macdonald. Oxford University Press, Vic., 2001, 930pp. $135.00rrp.

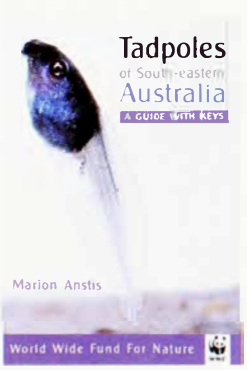
THIS BOOK IS NOTHING SHORT OF BRILLIANT! I have been a long-term user of Macdonald's two-volume 1984 edition of *Encyclopedia of mammals*. However, the passing of nearly 20 years has seen many new mammal discoveries and changes to classification, thanks mainly to advances in molecular techniques. The *new* and totally revised edition brings us up to date with the latest ideas on mammal systematics, evolution, and conservation status, and of course interesting research.

What attracted me to both editions is the entertaining delivery of hard-core facts. All the entries are written by the researchers themselves, so they are bursting with the sense of discovery and accurate to boot. The illustrations and particularly the photographs are exquisite. Indeed, the book is worth getting just for the photographs!

For presentation reasons, the various mammal orders are grouped according to their similar ecological and morphological characteristics. Where this does not reflect evolutionary relationships, we are told. Each section has a general discussion that outlines the similarities and differences in biology, ecology and evolution, followed by more detailed accounts of individual species or groups of similar species. Sprinkled throughout are boxes of specialised information that often highlight the section author's own research. Another attractive feature of the book is the use of 'photo stories'—pictorial sequences of interesting events, such as the birth of a dolphin.

I use this book all the time when researching stories for *Nature Australia*. But since I've had access to this latest version, I have found myself just flicking through the pages, pausing to read any one of the numerous entertaining special features, or to goggle at the fantastic photography.

—G.H.



Tadpoles of South-eastern Australia

By Marion Anstis. Reed New Holland, NSW, 2002, 281pp. $59.95rrp.

AS HUMANS CONTINUE TO DESTROY NATURE, frogs are useful bio-indicators of the general stage of degradation that freshwater and terrestrial habitats have reached. This is because frogs have very permeable skins and in their complex life histories most species are exposed to both water and air.

One of the difficulties of studying frogs is a general inability to identify the freshwater phase of most species' life cycles, the tadpole. However, this book now provides the first and by far most comprehensive attempt to produce a guide to the tadpoles of south-eastern Australia, the region where most of the human population resides. The guide includes both identification keys (to the eggs and embryos, as well as the tadpoles) and detailed accounts of each of the 84 species (out of 89) for which information was available. But in setting the stage for the enthusiastic but non-specialist user, the book also provides a huge amount of basic information on tadpole and frog biology and morphology.

The organisation and design of the book are superb. The information is clear, concise and extensive; the organisation both rigorous and aesthetic; the many illustrations and photographs (virtually all by the author) of high quality, and the style light and infectiously enthusiastic.

How the book will actually road-test remains for frog workers at the pond-face to determine. Because tadpoles are works in progress, that is, they are constantly changing as they develop, there is an extra level of variation to plague their precise description and identification in addition to the normal variation expected within and between populations. Hence it remains for the intended users to say ultimately how successful the book is in dealing with all this variation.

One final point. Over the last decade it has become a bitter joke in herpetology, about how much of the taxpayer's money has been given to professional (and largely male) researchers to develop regional guides to tadpoles and how little there is to show for it. Now, the author of this book, an amateur in the strict but in this case largely meaningless definition of the word (she actually earns her living as a highschool music teacher), has come along with only a pittance of taxpayer money for her research, and done what many who would wrongly consider themselves her 'betters' have so spectacularly failed to do.

—ALLEN E. GREER
AUSTRALIAN MUSEUM

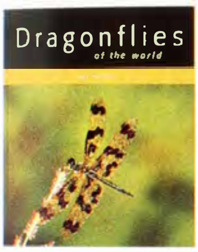
A Field Guide to the Mammals of Australia

By Peter Menkhorst. Oxford University Press, Vic., 2001, 269pp. $39.95rrp.

At last—a comprehensive, well-illustrated and ruggedly constructed field guide that covers all 379 Australian mammal species, including 55 marine mammals and all introduced species. An Addendum had to be added to include three recently named species, which just goes to show that we still have much to learn about the mammal fauna of this continent. This is by far the best field guide on Australian mammals. There are two well-illustrated keys (one to all genera, the other to all marine species), so the book will appeal to whale-watchers and land-lubbers alike. Species accounts describe diagnostic features, status and biology, and all species are illustrated with a distribution map and the breathtaking paintings by Frank Knight. Text margins contain numerous clear line drawings of diagnostic features, from snouts and feet, to skulls and teeth—and penises. The comprehensive text, fine illustrations and durable construction of the book, with its plastic-coated cover, compact size and high-quality paper, combine to make this a mammalian masterpiece.

—Harry Parnaby
Australian Museum

Dragonflies of the World



By Jill Silsby. CSIRO Publishing, Vic., 2001, 224pp. $59.95rrp.

Dragonflies (order Odonata) are among the most easily observed insects and are often seen patrolling water bodies in search of mates or looking for prey that is captured on the wing. The Odonata comprises the more robust 'true' dragonflies, which rest with their wings outspread, and the delicate damselflies, which tend to flit among vegetation and fold their wings back. Their aquatic larvae are predacious and have an extensible arm-like 'mask' that they use to capture aquatic insects and even small fish.

This beautifully illustrated book is the first to present dragonflies from a world perspective. All aspects are covered, including life cycles, habitats, behaviour, evolution, classification and biogeography. For example, you can discover the South American 'forest giants' (Pseudostigmatidae), whose larvae develop within wet tree holes and epiphytic bromeliads. With wingspans up to 13 centimetres, these are the largest living members of the Odonata, but they are small compared with the fossil Permian dragonflies that had wingspans up to 72 centimetres!

This book has just the right mixture of scientific information and visual appeal. If nothing else, you will be surprised by the beautiful colouration shown in many of the world's species.

—Daniel Bickel
Australian Museum

The Flight of the Emu

By Libby Robin. Melbourne University Press, Vic., 2001, 492pp. $69.95rrp.

The Flight of the Emu is a history of ornithology in Australia, principally from the 1901 genesis of the Australasian Ornithologists Union (later Royal Australasian Ornithologists Union, now Birds Australia).

to the Centenary of Federation, 2001. The RAOU was not intended to be a main player in this account, but it emerges in that role, and in a clever allusion to the RAOU journal *Emu*, Robin says "For a flightless bird, the Emu has travelled far."

Robin has methodically condensed a mass of archival material into 12 nearly chronological chapters, introducing many aspects of ornithology, professional and amateur, including a reminder that "the bird is an indicator of a healthy ecosystem". As well as potted biographies of ornithologists past and present, appendices, notes and bibliography, the book is generously illustrated with colour plates and black-and-white photographs. I particularly liked the Barnards' Central Queensland Coomooboolaroo Homestead, 1903, and the images of campers of long ago dressed in the garb of the early 20th century.

Printed on high-quality paper, *The flight of the Emu* is compelling reading, a valuable addition to a natural-history library, and certainly not overpriced.

—Dariel Larkins

The Science Book

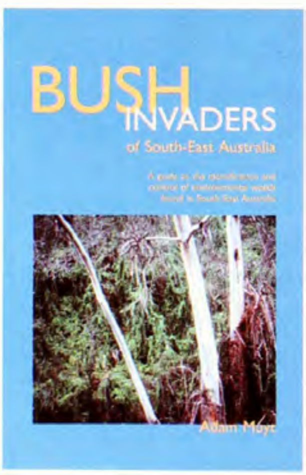
Ed. By Peter Tallack. Allen & Unwin, NSW, 2001, 528pp. $79.95rrp.

THE SCIENCE BOOK IS A BEAUTIFULLY PRESENTED and information-rich text that covers discoveries in science from the origins of counting more than 35,000 years ago through to the sequencing of the human genome in 2000. Chronologically organised, the book has easily accessible information that is detailed enough to allow a general understanding of some of the complex discoveries made by humans over this time.

Each achievement in science has a page of text and an image that attractively depicts the discovery. At the bottom of the page is a link to other relevant scientific events so that you can choose to follow an interest in a particular area, or simply flick through and allow yourself to be enthralled by centuries of scientific accomplishment.

The book is suitable for age groups ranging from upper primary to adults. Even those without an interest in science would be attracted by the images and easy-to-read text. Whether you are looking for a general introduction to science over the ages, or a deeper discussion of where science is heading now, this book should provide hours of enlightened entertainment.

—Emma Beacham & Lisa Miller
Australian Museum



Bush Invaders of South-East Australia: A Guide to the Identification and Control of Environmental Weeds Found in South-east Australia

By Adam Muyt. R.G. & F.J. Richardson, Vic., 2001, 304 pp. $59.00rrp.

Environmental Weeds: A Field Guide for SE Australia

By Kate Blood. C.H. Jerram, Vic., 2001, 228pp. $35.00rrp.

UNTIL RECENTLY THE NATURAL-HISTORY COMMUNITY, with few exceptions, paid little heed to the growing problem of environmental weeds. Those with an interest in plants immersed themselves in wild flowers. Most bushland weeds went unnoticed, naturalists lacking the skills and interest to identify them.

All that has now changed. In the past 15 years awareness about environmental weeds has surged. It's a sign of the times that two important books on the topic have suddenly appeared. These are excellent guides that for the first time make easy the identification of bushland weeds in south-eastern Australia. Their authors are Adam Muyt, an expert in bushland regeneration, and Kate Blood, of The Cooperative Research Centre for Weed Management Systems near Melbourne.

Muyt's is the more comprehensive book, and this is reflected in its higher price. He includes highly detailed information about weed control in general, and for each weed in particular. His is the book for the bushland regenerator. Blood does not cover eradication, but includes lots of entertaining snippets, noting for example that Sycamore Maple (*Acer pseudoplatanus*) was a favoured hanging tree in ancient Scotland. She has a nice colloquial style, describing Soft Rush (*Juncus effusus*) as "One of many GRTs (green rushy things) invading natural areas". A sense of humour helps when your topic is so bleak. Both books boast clear colour photographs and user-friendly descriptions.

Muyt explains that English Ivy (*Hedera helix*), a major weed in southern Australia, can live 400 years. That's a scary thought. So is the fact that these two books, despite their broad coverage, omit large numbers of minor bushland weeds. I say that not as any kind of criticism, but to make the point that Australia's weed flora is frighteningly diverse, and growing more diverse each year.

—Tim Low

SOCIETY PAGE

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

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Western Sydney Amateur Astronomy Group
PO Box 400
KINGSWOOD NSW 2747
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Membership: $30.00

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Web: *www.vicnet.net.au/~vicento/*
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Membership: $20.00 Metro, $16.00 Country, $12.00 Student

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Web: *www.marsupialsociety.org.au*
Contact: Tim Keynes
Membership: $25.00

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Contact: Karen Dobson

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Contact: Jenny Holdway
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q&a

Beached Mystery

Q: *While walking along the beach near my home, I came across this unusual looking marine mammal (photo enclosed). Could you please identify it for me and tell me a bit about it. Is it likely that the animal beached itself or would it have died at sea and been washed up onto the beach? It had no obvious external wounds or damage.*

—STEPHEN SAUNDERS
WHITEBRIDGE, NSW

A: The photo is of a Pygmy Sperm Whale (*Kogia breviceps*), a species that strands fairly regularly along the New South Wales coast. Pygmy Sperm Whales grow to around 3.5 metres long and are readily identified by their square-shaped head and small underslung jaw, which has a row of 12–16 sharp, backwardly curved teeth on each side. They are placed in the same family as the much larger Sperm Whale (*Physeter catodon*) and another small and much rarer species, the Dwarf Sperm Whale (*Kogia simus*). Little is known about the biology of Pygmy Sperm Whales, although they are known to feed on fish, squid and crustaceans and to occur in tropical and temperate waters around the world.

The Australian Museum generally adds two to three Pygmy Sperm Whale specimens to its collection each year and these are largely from animals that have stranded on the New South Wales coast, generally during rough seas. This species often strands while still alive, although it is possible that some die at sea and are washed up. Most autopsies carried out on this species by the Veterinary Quarantine Centre at Taronga Zoo or by ORCCA have not been able to detect the cause of death. In some cases, however, it appears they may have died from infections caused by the bites of cookie-cutter sharks.

—SANDY INGLEBY
AUSTRALIAN MUSEUM

Spider Twig

Q: *I live in Noosa, south-eastern Queensland. Over the past few weeks at night, I have noticed an orb-like web slung between one of the verandah posts and a nearby shrub. By morning the web disappears only to return again the next night. One day I decided to look for the spider and found an odd-looking dead twig in the shrub. When I touched it to my surprise it sprouted legs and became a spider! It was a mottled grey-brown colour and looked just like the end of the dead twig it was sitting on. Can you tell me what kind of spider this is?*

—DAMON HARDMAN
NOOSA, QLD

A: There are several genera of spiders that camouflage themselves by mimicking bits of plants during the day. From your description and the fact that it was on a dead twig, it is likely to be a species of *Poltys* or *Heurodes*—neither of which has a common name. *Poltys* is usually the more common of the two near the coast.

These spiders are quite common, especially in eastern Australia, but they are usually so well disguised that they go unnoticed. They build a finely meshed web (only at night) that is particularly effective at catching moths. The front eyes of *Poltys* species are on a tubercle that protrudes forwards while

COURTESY STEPHEN SAUNDERS

The underslung jaw with its 12–16 teeth clearly identifies this stranded animal as a Pygmy Sperm Whale.

A well-camouflaged *Poltys* spider.

HELEN SMITH/AUSTRALIAN MUSEUM

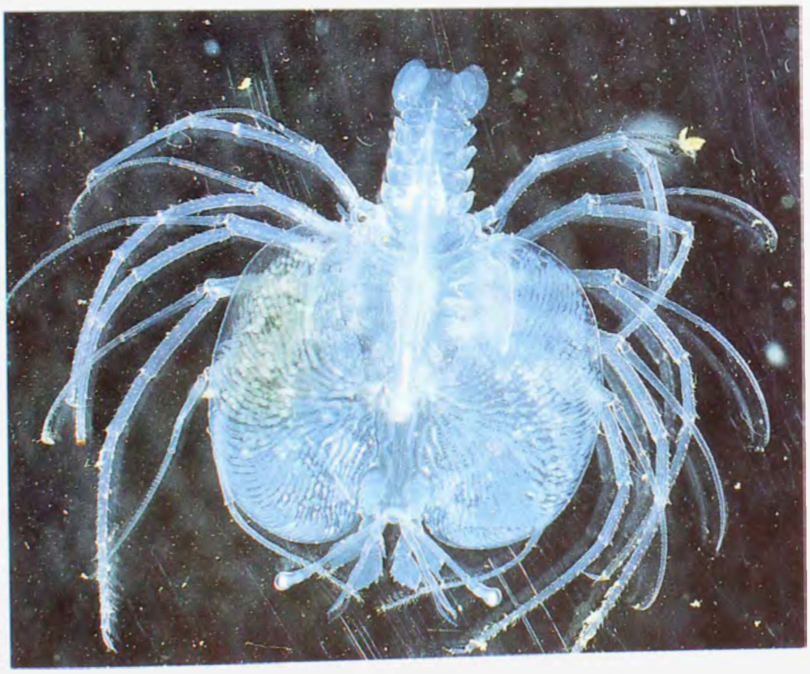
the spider hides with its legs drawn in close. Often the camouflage is so good it is difficult to work out which end is which. Some species have rows of false eyes on their abdomens, which presumably scare away some smaller predators. Others have bright yellow leg stripes that they expose by raising the front legs.

There are about 11 species of *Poltys* in Australia, over half of which are found only in tropical areas. In your area of Queensland there are three species, including two that look like dead twigs. One of these is common inland, the other on the coast. The third has a somewhat rounded abdomen and is the more frequently noticed species as it can grow quite large. This species often mimics dead buds or galls. All three are variable in shape and colour—true masters of disguise!

—Helen Smith
Australian Museum

Answers to Quiz in Nature Strips (page 12)

1. *Yellow* **2.** *South Australia* **3.** The universe in a nutshell **4.** *Males only* **5.** *South-eastern highlands* **6.** *Feathers* **7.** *Jupiter* **8.** *Night* **9.** *Mexico* **10.** *Jabiru*



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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 *Birds: their habitats and skills*. Autumn's Pic Teaser was a nudibranch (*Rostanga bifurcata*) with its egg mass (for more information on nudibranchs go to *www.seaslugforum.net)*.

Ecological triage

Money for threatened species should be applied to species where we get the biggest bang for our buck.

THERE IS GENERAL CONSENSUS that the world is in the midst of a mass extinction event. This extinction event is probably similar in size to the six other mass extinctions that we observe in the fossil record, but different in that it is caused by just one species—humans. Given the crisis, how should we respond? I believe that Australia's policy about how we allocate funding to threatened species is sentimentalist and muddle-headed. Too much is devoted to species on the brink of extinction and not enough to looking after species that are in decline but are still viable and recoverable with much smaller investments of time and money. It is time we took a more hard-nosed, business-like approach to the conservation of our flora and fauna.

It would be nice to think that we can save every species in Australia. With increased public awareness of the importance of conservation, especially endangered species, most of the public may believe that extinction is a thing of the past. Increases in the size of our protected areas, a focus on feral predator control and advances in captive-breeding methods are all sources for optimism; but recent data on nationwide declines of generally 'common' bird species present a gloomier picture.

Ecological theory shows that there is a long timelag between irreversible actions that affect biodiversity (like vegetation clearance and weed invasion) and their ultimate impact (species extinction). On mainland Australia only one bird species (the Paradise Parrot, *Psephotus pulcherrimus*) is almost certainly extinct, however over 200 are listed as threatened. Very rare species, like the Helmeted Honeyeater (*Lichenostomus melanops cassidix*) and Orange-bellied Parrot (*Neophema chrysogaster*), have been carefully managed and/or monitored for a long time, but we have only just begun to focus on the large number of more common species that is in rapid decline in the heavily fragmented woodlands of southern Australia—species like the Scarlet Robin (*Petroica multicolor*), Hooded Robin (*Melanodryas cucullata*), Grey-crowned Babbler (*Pomatostomus temporalis*) and Black-chinned Honeyeater (*Melithreptus gularis*). If we accept the theory and the trends, there can be little doubt that the rate of extinction in Australia has not slowed; indeed the next 200 years of European occupation could see as many, if not more, extinctions. How should we face up to the extinction flood? With small barricades and levies around species doomed in the long run? Or should we take a triage approach and retreat to a defendable position on higher ground?

I believe that Australia's policy about how we allocate funding to threatened species is sentimentalist and muddle-headed.

Given the huge costs of conserving species with very small population sizes—those that are 'ecologically dead' and unlikely to persist in the long term—triage conservationists advocate investing less effort on the critically endangered species and more on the uncommon and declining. However it is not just about how endangered a species is; it is also about the cost effectiveness of actions to save a species. Money for threatened species should be applied to species where we get the biggest bang for our buck; that is, where our actions decrease extinction probabilities at the greatest rate per unit dollar (or time) invested. In some cases this will be the most endangered species; in other cases it will not.

To date Australian conservation policy across all States and the Commonwealth has been to place the greatest investment in those species that are most likely to disappear—the critically endangered and endangered. I advocate a more sophisticated triage-like approach—one that involves spending time and money where our return on investment is greatest. In this way we adopt a longer-term view of species conservation that will maximise species diversity for future generations. Maybe if the environmental movement can show government and the public that it knows how to run its business efficiently and effectively for maximum long-term community benefit, it may gain more respect and more resources. □

FURTHER READING

Possingham, H.P., 2001. The business of biodiversity: applying decision theory principles to nature conservation. *Tela Series No. 9. The Australian Conservation Foundation: Fitzroy, Victoria. www.acfonline.org.au/docs/publications/tp009.pdf*

PROFESSOR HUGH POSSINGHAM IS A MATHEMATICAL ECOLOGIST IN THE DEPARTMENTS OF MATHEMATICS, AND OF ZOOLOGY AND ENTOMOLOGY, AT THE UNIVERSITY OF QUEENSLAND. HE IS ALSO DIRECTOR OF THE UNIVERSITY'S ECOLOGY CENTRE. HE CURRENTLY CHAIRS THE FEDERAL BIOLOGICAL DIVERSITY ADVISORY COMMITTEE.

BY HUGH POSSINGHAM

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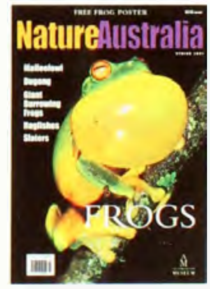

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