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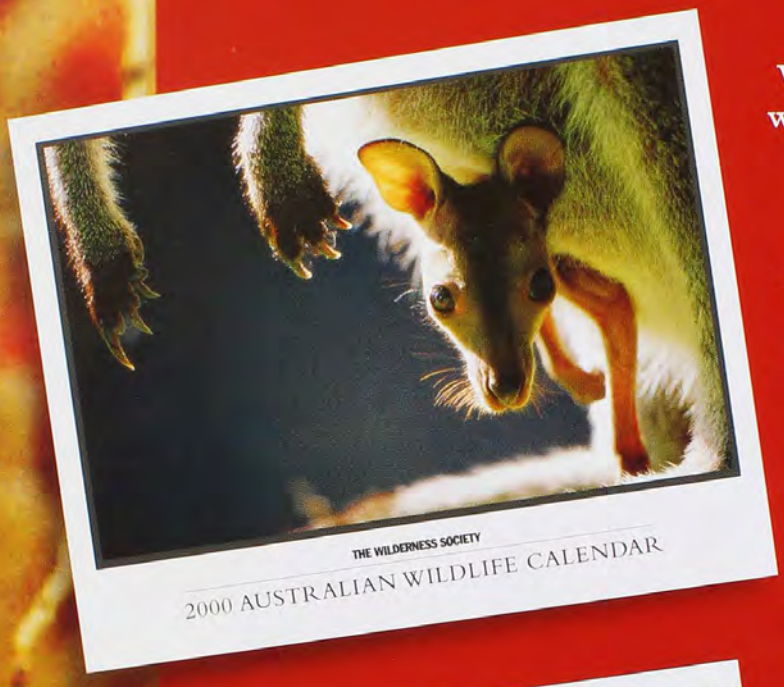

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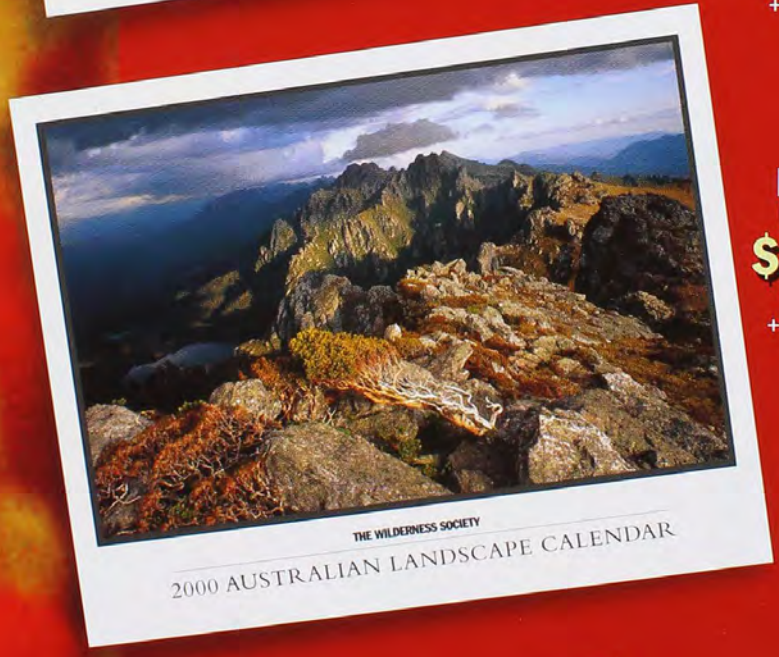

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Up Front

One misty morning, while camped near a billabong in Kakadu National Park, I was lucky enough to witness a White-bellied Sea-Eagle catching its first meal of the day. It was an amazing sight, as seemingly from out of nowhere a massive bird swooped down, thrust its talons into the water and pulled out a large silver fish. In the same fluid motion it then flew to a nearby perch and proceeded to tear its catch apart. After weeks of seeing these birds perched silently along the rivers of the far Northern Territory, it was thrilling to finally see one hunting. Penny Olsen has studied these magnificent birds for over 15 years so don't miss her article "Winged Pirates" as it provides a view into the world of the White-bellied Sea-Eagle—and includes her own first-hand experience of the power of those massive talons.

From Sea-Eagles to sea monsters, we go to Western Australia and join John Long as he describes the excitement of discovering Australia's largest and most complete skeleton of a mosasaur—a ten-metre-long marine reptile with a head full of vicious pointed teeth. Related to modern-day snakes, these reptiles propelled themselves through the water by powerful front and rear paddles, and used their teeth to crack open the hard-coiled shells of ammonites. John also describes the other types of marine reptiles that dominated our seas at the time of the dinosaurs.

PETER COOK/AUSCAPE

A shower of airborne droplets trail a White-bellied Sea-Eagle as it struggles to gain height, a fish firmly grasped in both feet.

DANIEL VERNER

One mosasaur attacks another.

Wade Sherbrooke's article on Thorny Devils and horned toads is a fascinating comparison between two of the world's weirdest-looking lizards. They share amazing similarities in appearance and behaviour, right down to their preferred food, yet one lives in Australia and the other thousands of miles away in America. So just why do these lizards look and act so alike?

Other stories in this issue include bettongs that have bounced back, perfectly preserved three-dimensional fossil insects from Queensland, venomous bandy-bandies that only eat blind snakes, and a pictorial look at the seasonal changes in Australia's alpine region.

—Jennifer Saunders

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Front Cover
Some scattered brown feathers among the white identify this as a subadult White-bellied Sea-Eagle (*Haliaeetus leucogaster*). The elongated feathers on its crown and nape are slightly raised in threat or curiosity. Photo by Nicholas Birks.

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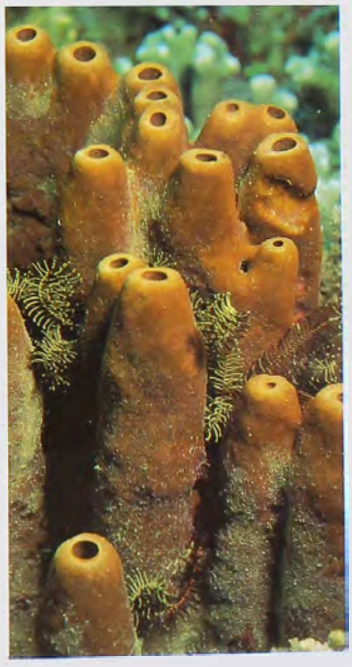

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LETTERS

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

Do Lions Purr?

I would like to question the assertion from the Autumn 1999 Quick Quiz that Lions don't purr. Joy Adamson stated several times that Elsa purred. Anyway, can one ever prove a negative claim?

—Anne Drover
Wollstonecraft, NSW

Do Lions purr? It really comes down to our description of the sounds animals make. In my reply to a reader's question on this topic (Q&A, Autumn 1998), I acknowledged that Lions make a sound that may well be described as a purr, but they do not produce the continuous involuntary purring that we associate with the smaller cats. Anatomical differences in the throat area of these two groups of animals are among the features that determine whether or not continuous purring is possible. These same anatomical differences also help explain why large cats can roar while smaller cats, in similar circumstances, scream.

—Linda Gibson
Australian Museum

Long Live Whale Strandings

In making the case for intervention in whale strandings, Joseph Geraci gives little consideration to the case for non-intervention (*Nature Aust.* Summer 1998–99). That case needs to be put, if for no other reason than scarce conservation dollars are spent on whale rescues. In New Zealand, sizeable sums are spent on whale rescues every year—more than is spent on all but a couple of our endangered species programs. Among the main whale species involved in New Zealand strandings are the pilot whales, which are comparatively common species.

Intervention is justified if it assists species suffering from the impacts of humans or from the alien pests we have introduced. For critically threatened species, intervention to rescue individual animals from natural events, such as fire or flood, can also be soundly justified. But the case of intervention to 'save' reasonably common species from natural events runs counter to ecologically based conservation management. Whale strandings repeatedly occur in some areas and, from what is known, these strandings have been part of the ecological processes at these sites for millennia.

Almost certainly the nutrient inflows from decaying and scavenged whale carcasses play a role in shaping the natural ecology of the local area. The stench from the rotting carcasses may be obnoxious to humans but it is surely wrong to want to sanitise nature to fit a largely urbanised society's sensibilities.

It can be argued, as Geraci does, that providing assistance to stranded whales represents a genuine humanitarian response by helping another species in distress. Yet human perceptions of animal welfare provide a poor ethical basis for intervention in natural events. We do not ask Tanzanian wildlife rangers to run animal ambulances around the Serengeti Plain, patching up or ending the suffering of victims of predation by Lions. We know such maimed victims help support a second tier of predators and scavengers, adding to the richness of African biodiversity. Equally, whale strandings are an inherent feature of coastal ecology in a number of areas.

BRIAN CHUDLEIGH/NATURE FOCUS

A reclining female Lion.

TOM & PAM GARDNER/NATURE FOCUS

A Little Raven (*Corvus mellori*) feeds on a Rabbit carcass.

Long may they continue to occur.

—Kevin Smith
Wellington, NZ

Australian Elephants?

After reading the bloaters-and-floaters article by Michael Archer (*Nature Aust.* Summer 1998–99) I came across the information that Strzelecki the explorer had discovered an elephant's tusk in a cave "beyond the Wellington Valley". In 1971, while working as a guide at Jenolan Caves, I became great friends with John Norris, the discoverer of 'Deep Pass' on the Newnes Plateau, who at that time was the Reserve Overseer at Jenolan. John had been doing a lot of work in McEwan's Valley at the caves where he was establishing a breeding colony of Brush-tailed Rock-wallabies and, during the course of his work, had picked up a small elephant's tusk in the dry bed of Harry's River. He showed me the tusk and it was about 20 to 25 centimetres long and, as far as I can remember, not very discoloured. Neither of us thought much about it, as at one time there had been a small house and a vegetable garden higher up the valley. We just assumed that the tusk had been lost from the house when it was eventually deserted.

John has been dead now for some years so I don't know what happened to the tusk. It may have dated back to the bush-ranging days when poor old McEwan lived there.

—Keith Watson
Bowenfels, NSW

Cockroaches and Disease

The piece by Steve Van Dyck on cockroaches (*Nature Aust.* Summer 1998–99) was very interesting, particularly in view of studies quoted in a 1993 article in *British Medical Journal* (vol. 306, p.591). Marc Klowden and Bernhard Greenberg (University of Illinois) apparently reported that cockroaches rapidly detoxified salmonella, and a group of French microbiologists questioned the ability of the German Cockroach to carry pathogens. Is the matter settled yet?

—Harvey Marrable
Wamberal, NSW

The studies quoted in the British Medical Journal *are interesting but selective.*

The habits of cockroaches mean they have the potential to be vectors of disease. A number of species live in sewers from which they can escape (cockroaches are even able to pass through the water in the S-bends of plumbing fixtures) and they may feed on bacteria-laden garbage, and then transfer these to human food.

Cockroaches certainly harbour pathogenic (disease-carrying) organisms, which have been isolated from their legs, gut and droppings, but whether they act as vectors of these organisms remains contentious. Studies have shown that Salmonella enteritidis *rarely multiplies in the gut of German Cockroaches, but cockroach faeces may contain the organism for 3–20 days and so are certainly capable of giving an inoculative dose to food (*J. Med. Entomol. *17: 417–423; 1980). In an earlier study the incidence of infectious hepatitis in Californian apartment blocks dropped when cockroaches were controlled but remained high in blocks not receiving treatment (*Am. J. Trop. M. *11: 705–711; 1962). And an epidemic of food poisoning in a hospital in Brussels only subsided after the severe infestation of German Cockroaches was controlled using DDT (*Ann. Inst. Pasteur *79: 654–660; 1950).*

Medical doctors often seem keen to show that cockroaches cannot spread disease and I wonder if this is because of the frequent appearance of cockroaches in hospitals.

Cockroaches are not vectors of disease in the same way as mosquitoes (no human pathogen is particularly associated with cockroaches). However, I feel that, because of the areas they inhabit and their ability to pick up pathogenic organisms on their body or in their food, we should regard them as potential disease vectors. Certainly in some instances there is evidence that they can spread disease.

—Peter Miller
University of Technology Sydney

Former Expats

Observing a group of ravens on the University of Queensland campus while eating my lunch, I reflected that these birds, more than any human institution or achievement I can think of, are a legitimate source of national pride.

The superfamily Corvoidea originated in Australia, where it includes such prominent local identities as the Australian Magpie, butcherbirds and bowerbirds. Then some tens of millions of years ago a branch of the family emigrated, giving rise to the family Corvidae, a group of birds currently more successful on the world stage than the Spice Girls, and certainly with brighter prospects (and possibly better singing voices, although this is clearly not the forte of either group). A split within the Corvidae led to the formation of a new group, the crows and ravens (genus *Corvus*), which are mostly quite large and dress almost entirely in black (like Phillip Adams). There are 20-something species of *Corvus* worldwide, five of them in Australia, where they are our only resident corvids.

What all this means is that our crows and ravens represent that rarest class of birds, most worthy of our admiration: Australian expatriates that made it big overseas, then came back to live here while still remaining active and successful on the world circuit. And all that without picking up a trace of a foreign accent.

—John D. Scanlon
University of Queensland

Possums in the Spotlight

The possum names in two of the captions in "Possums in the Spotlight" (*Nature Aust.* Autumn 1999) were inadvertently transposed. The possum at the bottom of page 37 is a Lemuroid Ringtail, while the one on page 38 is a Herbert River Ringtail. We apologise for any confusion.

—G.H.

NATURE AUSTRALIA **welcomes letters for publication and requests that they be limited to 250 words and typed if possible. Please supply a daytime telephone number and type or print your name and address clearly on the letter. The best letter in this issue will receive a copy of *Australia's world heritage* from the Museum Shop. The winner this issue is John D. Scanlon.**

Nature Strips

COMPILED BY
GEORGINA HICKEY

A Tale of Two Tigers

Once widespread on mainland Asia and the Indonesian islands, the Tiger (*Panthera tigris*) is facing extinction throughout its range as a result of extensive habitat loss and hunting. Now a molecular study has challenged the traditional view that Tigers are a single species with five subspecies, and raised questions about current Tiger conservation problems.

Joel Cracraft of the American Museum of Natural History and colleagues have shown that the Sumatran Tiger (*P. t. sumatrae*) is genetically distinct from the four mainland subspecies, and probably warrants recognition as a distinct species. The researchers argue that the Sumatran Tiger diverged from mainland populations after rising sea levels isolated the island of Sumatra about 6,000–12,000 years ago. In contrast mainland subspecies continued to interbreed until recent times, when populations became isolated as a result of widespread habitat destruction.

The results of this study have serious implications for captive-breeding programs, which until now have focused largely on Bengal and Siberian Tigers. Captive-breeding stocks of Sumatran Tigers need to be increased to ensure that this genetically distinct species is adequately represented in breeding programs. At the same time interbreeding of captive Sumatran Tigers with animals from mainland populations must be avoided to maintain their genetic integrity.

Recognition that the Sumatran Tiger is distinct from mainland populations also adds a great deal of urgency to conservation programs for the few individuals that survive in the forests of Sumatra. Maintenance of viable populations in the wild will require increased political support for the protection of this species and its remaining habitat. By increasing public awareness about this discovery, the Sumatran Tiger will hopefully become a flagship for increased conservation efforts in Indonesia.

—S.R.

Termites and Moth Balls

We use moth balls (made from naphthalene) to keep clothes moths and carpet beetles at bay. Scientists have now identified an insect, the Formosan Subterranean Termite (*Coptotermes formosanus*), that uses naphthalene in a similar way.

Jian Chen from Louisiana State University and colleagues discovered that the termites incorporate naphthalene in their underground

KLEIN-HUBERT-BIOS/AUSCAPE

The Sumatran Tiger is genetically distinct from the other Tiger subspecies.

A Harbour Seal's whiskers aren't just decoration; they help the seal to find its food.

JEFF FOOTT/AUSCAPE

nests, which they build by cementing together soil and masticated wood with their saliva and excrement. In every kilogram of nest material, there was between 50 and 200 micrograms of naphthalene.

At these concentrations, the researchers demonstrated that Red Fire Ants (*Solenopsis invicta*), one of the termite's main predators, become paralysed, and that fungal growth is inhibited. As a fumigant naphthalene is ideal for termite nests, vaporising easily to permeate the complex system of tunnels. But naphthalene may not be limited to defence. The researchers also showed that soldier termites follow trails of dilute naphthalene, indicating a possible use in the coordination of colony behaviour.

The presence of naphthalene in *C. formosanus* nests is quite remarkable. Tar, coal, petroleum, and the products of partial combustion of organic matter, were once thought to be the only sources of naphthalene in nature. These termite nests now join magnolia flowers and the forehead of male White-tailed Deer (*Odocoileus virginianus*) as unusual places for naphthalene to be found. Exactly how the termites obtain naphthalene, or whether they manufacture it themselves, is unknown.

—P.R.

Riddle of the Red Nectar

High among steep inaccessible cliffs, under a cascading waterfall on the island of Mauritius, grows a rare and unusual flower. This is the only location in the world where the blue-flowering *Nesocodon mauritianus* is found. Scientists have been risking scaling the cliffs to study this tiny population of bird-pollinated flowers—not because of its beauty or endangered status, but because it does something most remarkable: it secretes scarlet-red nectar.

Only two other plants are known to produce coloured nectar and they also occur on Mauritius. These are the red-flowering *Trochetia blackburniana* and *T. boutoniana*. The function of the red nectar, however, remains a mystery.

A team of Danish researchers led by Jens Olesen (Aarhus University) has been studying these Mauritian flowers to determine why red nectar evolved. They point out that, since red nectar is extremely rare, it is unlikely to provide any pollinating advantage, otherwise it would occur more commonly. Does the red substance act as a signal or warning? During observations, the researchers witnessed birds stealing nectar and tearing flowers to pieces and concluded that 'seeing red' doesn't deter nectar thieves or protect flowers.

Olesen and colleagues instead suggest that red nectar may have coevolved with a pollinating bird species that is now extinct. Since the 16th century, the island of Mauritius has been steadily losing native species due to habitat destruction and over-hunting. By 1680, 28 bird species had disappeared. Today there are just 11 native bird species, eight of which are endangered. Perhaps the riddle of red nectar may be answered by a ghost from the past. In the hope of pinning down this ghost, the researchers are currently searching among recently extinct Mauritian birds for likely candidates.

—K.H.

Seals 'See' with Whiskers

Disabled animals rarely survive for long in the wild. An exception to this seems to be blind seals, which are often observed looking healthy and well fed. Indeed, most seals feed at night or in deep or murky waters, so even able seals are essentially swimming blind. How do seals, without the benefit of sight or an active sonar system, locate their prey?

Guido Dehnhardt and colleagues from the University of Bonn in Germany found that the whiskers of Harbour Seals (*Phoca vitulina*) can detect minute water movements generated by fish and other aquatic animals. The whiskers are supplied with a mass of nerve fibres, making them highly sensitive. This allows the seal to gain information not only by direct touch (as in rats), but also more indirectly from water movements.

To demonstrate that the whiskers are the essential element in vibration detection, the researchers conducted an imaginative experiment in which they trained a seal fitted with eye caps and headphones to dive under water and place its head in a hoop. This allowed them to place a vibrating sphere at a specific distance from the seal's whiskers. As soon as the seal felt a vibration through the water it left the hoop and surfaced for a fish reward. The seal responded

JEFF FOOTT/AUSCAPE

Female Polar Bears with male-like genitalia indicate that all may not be well in the Arctic.

to extremely weak water movements (similar to those generated by fish), but never responded when wearing a muzzle of wire mesh that hindered whisker movement.

Remarkably, this is the first time that this type of sensory system has been confirmed in a marine mammal.

—P.R.

Polar Gender Benders

Hermaphrodites are organisms that display both male and female reproductive organs. The word derives from a character in Greek mythology, whose lady love prayed to be united with him forever. The gods acquiesced, and the two became one.

While the appearance of hermaphroditism in nature is quite common, especially among plants and invertebrates, it is rare among mammals—particularly wild, naturally reproducing populations. It was therefore with surprise that a group of researchers working on Svalbard Island in the Arctic Ocean came across two young female Polar Bears (*Ursus maritimus*) sporting small (two-centimetre-long) penises, in addition to normal vaginas. The team also previously recorded two 15-year-old breeding female Polar Bears with unusually large, penis-like clitorises, and another four cases have since been found.

What could be causing the abnormal development of male characters in these genetically female Polar Bears? Øystein Wiig (University of Oslo, Norway) and colleagues admit there may be a perfectly natural explanation, such as an ovarian tumour in the deformed bears' mothers. This can lead to an oversecretion of androgens by the mother, which in turn may cause unusual sexual development in foetuses. However, the researchers point out there may be a more sinister origin.

Polar Bears from this area have an unusually high accumulation of organochlorine pesticides in their fatty tissues. The pesticides are blown to the polar region, condense down in the cold air, and accumulate in the food chain. Certain organochlorines, such as PCBs (polychlorinated biphenyls) can have a gender-bending effect on mammal foetuses. PCBs are remarkably similar to some of the body's natural hormones, and can bind to receptor sites in developing organs in place of them.

The effects of environmental pollutants on Polar Bears are not well understood and research is currently underway to assess the impacts on their immune function and hormone regulation. However, if pollution is the cause of the genital abnormalities, they indicate that all is not well in the world of the Polar Bear.

—A.T.

Scrofulous Mummies?

The ancient Egyptians may have portrayed themselves as beautiful on the outside, but the inside story was not so pretty. Andreas Nerlich (University of Munich, Germany) and colleagues examined bone and lung tissues from a 3,000-year-old male mummy from Thebes-West, Upper Egypt. Their DNA analysis, coupled with X-ray and other findings, showed that ancient Egyptians suffered from tuberculosis (TB)—the oldest reported case of infection by TB (*Mycobacterium tuberculosis*).

Earlier DNA analysis of a 1,000-year-old female mummy from Peru, South America, also indicated infection by TB—a remarkable finding as it seemed to demonstrate that TB was not introduced to the Americas by Christopher Columbus in 1492, as previously thought. This does not deny the ruthless impact of introduced disease strains (notably smallpox, measles, influenza and typhus), which have decimated native American populations in the past. But could the TB bacterium really have evolved independently in two places? Some have argued that the DNA tests used to identify *Mycobacterium* in the Peruvian mummy have not distinguished human TB from another species (*M. bovis*) common in wild animals. Jared Diamond (University of California at Los Angeles) argues that TB is a 'crowd

disease', probably derived from cattle, and, like the other major infectious diseases of the Old World, has been an unforgiving companion since humans first started domesticating animals about 10,000 years ago in Eurasia. If the Peruvian mummy was indeed infected with human TB, then it indicates an earlier (pre-Columbian) period of human contact between south-west Asia and the New World.

Whatever the answers, study of past diseases certainly holds a key for understanding the present and future impacts of ancient bacteria, emerging viruses and other microbes.

—Richard Fullagar
Australian Museum

Birds' Navigational Nightmare

Harsh conditions and sporadic resources in the Arctic force many animals to migrate huge distances. Every year a multitude of Arctic birds on their way from Siberia to North America will make a 3,000-kilometre intercontinental journey across the pack-ice to Alaska. But do any birds take a short cut, by flying directly over the North Pole?

To find out, Gudmundur Gudmundsson and Thomas Alerstam from Lund University in Sweden crossed the Arctic Ocean in the icebreaker *Oden*. Between the summer months of July and September, they used radars mounted to the ship to detect any birds flying high above the clouds and fog. To their surprise, they found no trace of birds migrating across the central Arctic Ocean, which is in stark contrast to the many skuas, shorebirds, terns and waterfowl that have been recorded migrating at the same time of year along its edge.

BRIAN CHUDLEIGH

Why don't Pectoral Sandpipers (*Calidris melanotus*), in their annual migrations, take a short cut directly over the North Pole?

Why do birds avoid the shorter transpolar route? Birds may prefer to skirt the Arctic Ocean because the feeding grounds at the edges are richer. However, as some birds are known to make non-stop journeys of up to 5,000 kilometres, lack of resources may not be the primary reason.

The researchers suggest that birds may be giving the pole a wide berth because it is a navigational nightmare. Birds navigate with the help of an internal magnetic compass, and by using the Sun and stars as directional cues. The polar region is unusual in having an extremely weak horizontal geomagnetic field intensity. It may be that this, combined with the absence of stars all summer, throws the birds' compass out, forcing them to choose more easily navigable areas.

—A.T.

Sunfish Flaps and Female Choice

Sexual ornaments are widely used by males to attract mates, and females often choose sexual partners with the most extravagant ornamental structures. However structures that act as sexual ornamentation are extremely uncommon in fish, probably because they hinder efficient movement through water. Kaye Goddard and Alicia Mathis from Southwest Missouri State University recently discovered that the Longear Sunfish (*Lepomis megalotis*) is a rare exception to this rule.

Longear Sunfish are unusual among fish in having soft, scaleless extensions of the protective flap covering their gills (the opercula). Goddard and Mathis noticed that, although the size and shape of the flaps were variable among individuals, males generally had longer flaps than females. They wondered whether the flaps may be a sexual ornament used to attract females, and tested this theory by observing the responses of female sunfish exposed to males with opercular flaps of different sizes.

Offered a choice of males with normal or shortened (clipped) flaps in a laboratory experiment, females spent more time near, and displayed more often to, males with normal flaps. And in another experiment, females showed a stronger preference for males with artificially extended flaps over those with normal flaps.

Exaggerated opercular flaps are clearly sexually attractive to female Longear Sunfish, so why is there so much natural variation in the size and shape of flaps in this species? It is likely that these ornaments are energetically expensive to produce, and possibly make the male more vulnerable to predation. Large flaps may therefore be an accurate reflection of male condition, developed only by the fittest individuals. Whether females that choose these males derive a direct benefit in terms of their own reproductive success remains to be determined.

—S.R.

Beetlemania

The world is crawling with beetles (order Coleoptera)—330,000 species of them in fact. Indeed when the renowned biologist J.B.S. Haldane was asked his conclusions about Creation, he reportedly quipped that the Creator had an "inordinate fondness for beetles". Likewise, evolutionary entomologist Brian Farrell (Harvard University) believes that the beetles' diversity is a result of their inordinate fondness for a leafy diet.

Although the idea of coevolution of plants and insects is not new, it recently took a hit when it was shown that the appearance rate of insect families did not increase with the flowering plant (angiosperm) radiation during the Cretaceous, some 100 million years ago. But Farrell believes beetles were a different story.

Analysing DNA sequences from 115 species of herbivorous beetle subfamilies, he created a phylogenetic tree showing the evolutionary relationships of today's beetles and when they diverged from common ancestors. To this he added details about species' dietary habits, information from fossils and biogeography of extant species,

PAVEL GERMAN

A longicorn beetle (*Batocera* sp.). Why are there so many different kinds of beetle?

to identify which ancestors ate what plants on which continent and when.

His work showed a tight relationship between plant and beetle diversity, with cycad- and conifer-eating species forming the trunk of the family tree and angiosperm-eaters the top branches. Two superfamilies in particular, Chrysomeloidea (including potato beetles) and Curculionoidea (including weevils) flourished in response to the rise in angiosperms. Their known 135,000 species comprise about 80 per cent of all herbivorous beetles and almost half of all herbivorous insects.

It just goes to show what can happen if you eat your greens.

—R.S.

Basking Cases

With its massive mouth agape, gills flared and 11-metre-long body barely creating a ripple as it cruises just below the ocean's surface, an adult Basking Shark (*Cetorhinus maximus*) can be a formidable sight.

No need, however, to flee this leviathan. The world's second largest fish species, it might be. But it's a gentle giant that eats only plankton. In an hour, it can cover about four kilometres of ocean and filter 2,000 tonnes of water across its gills.

Basking Sharks were once thought to feed indiscriminately by simply swimming, in the world's temperate coastal waters, with their huge mouths open. But a new study by David Sims and Victoria Quayle (now at the Universities of Aberdeen and Southampton, respectively) has found they are actually very selective foragers.

For two years, the researchers tracked the movements of Basking Sharks off the south-west coast of England, measuring water temperature and zooplankton densities wherever the sharks fed. The sharks spent the longest time foraging in areas with the highest densities of large zooplankton. They fed only along thermal fronts—areas of high-plankton productivity where cold and warm waters meet. And they followed plankton patches as they moved on tidal currents.

TONY CRABTREE/AUSCAPE

A formidable sight, but Basking Sharks are gentle giants and only eat plankton.

Sims and Quayle speculate the huge fish may have electroreceptors that sense muscle activity in some of the tiny animals that comprise zooplankton. Like some seabirds, they may also detect dimethyl sulphide, which is released by phytoplankton when grazed by zooplankton (see *Nature Aust.* Winter 1997).

Because all marine food chains are based on plankton, its distribution is a useful measure of ocean productivity: where there's a lot of plankton there are also lots of fish. Presently, sophisticated satellite imagery can give us detailed information on phytoplankton abundance, but not zooplankton abundance. Because Basking Sharks forage selectively on zooplankton, they could be used as biological plankton recorders, providing us with information not available from satellites.

—K.McG.

No Head-butts About It

Dome-headed dinosaurs (or pachycephalosaurs) had massive bulbous craniums. Just what they did with them has been a matter of intrigue for decades.

According to one popular theory, first published in the 1950s, dome-headed dinosaurs used their thickened skulls in head-butting contests with rival males, much like male Bighorn Sheep (*Ovis canadensis*) do today.

COURTESY KENNETH CARPENTER

Did dome-headed dinosaurs, like these horned *Stygimoloch* individuals, butt the heads of their rivals, or their flanks (as shown here)?

The heads of sparring rams meet with great speed and force, but their brains are protected because the stress of impact is dissipated across the heavy horns and forehead and down through the neck and back. Similarly, supporters of the dinosaur head-butting theory believe the thickened front and sides of pachycephalosaur skulls would have received the full force of collisions, while residual stress was passed down through the neck to the rest of the body.

After a re-examination of the fossils, however, Kenneth Carpenter, from the Denver Museum of Natural History, has reached a different conclusion. He points out that pachycephalosaurs didn't have the horizontally straight neck configuration required for transferring stress during head-to-head collisions. Furthermore, head-butting would have been difficult because of the small surface areas available for contact on the opposing domes. Instead he believes pachycephalosaurs used their heads like modern-day African antelopes, to butt the flanks (not heads) of competitors.

According to Carpenter, the thickening of the dinosaurs' skulls served to increase the mass behind blows to the flank and not, as the previous theory advocated, to help absorb the force of collisions between heads. In some pachycephalosaurs, small horns had even developed in the skin along the back of the dome, which Carpenter believes would have helped to inflict more pain (but not serious injury) with each blow.

—K.McG.

Against the Flow

Most carnivorous freshwater trout hunt from downstream. In this way their chemical odours don't give them away to their upstream prey. But shrimp-like amphipods (*Gammarus pulex*), which are only 10–16 millimetres long, have been found to avoid trout downstream. How do they do this? It appears they can whip up a backcurrent that alerts them in advance of their downstream predators.

Drifting with the current provides a means of foraging and finding mates, and amphipods do this irrespective of predatory risks. Their crescent-shaped body and movement of their numerous legs create the backcurrents that bring to them, against the stream's flow, the chemical cues or smell of any trout lying in wait. Once detected the amphipods can actively avoid becoming hors d'oeuvres.

To discover this Jonas Dahl and colleagues from Lund University in Sweden set up mesh enclosures in a stream. Half the enclosures contained Brown Trout (*Salmo trutta*), the other half contained none. When they released amphipods upstream, they found they steered clear of the enclosures with trout. In the laboratory they found the amphipods only responded to a trout's scent. Visual cues failed to elicit an avoidance response.

Video recordings suggest the amphipods leave little room for error, retreating just one centimetre from a predator. A trout's hunting prowess, however, is diminished in poor light, and the amphipods drift mainly at night. Even one centimetre, it seems, is sufficient to detect and manoeuvre around a predator.

—J.M.

Tadpole Schools

Social behaviour is uncommon among tadpoles, largely because this stage of the frog's life cycle is devoted exclusively to feeding and growth. So why do tadpoles sometimes form large schools?

Schools may form simply because tadpoles aggregate in patches of water that are warm or have high concentrations of food, but it is increasingly clear that they may also serve a number of

Tadpoles from an undescribed Irian Jayan tree frog: a new reason for going to school?

S. RICHARDS

social functions. For example some tadpoles actively form schools to avoid predators. In these schools there is a constant movement of tadpoles from the edges to the centre of the school, where the risk from predators is lowest.

Recently, while surveying in the remote mountains of Irian Jaya, I came across an unusual schooling behaviour by tadpoles of a small, undescribed tree frog in the genus *Litoria*. The tadpoles were in a large, shallow rainforest pool where they formed a compact school of several thousand individuals. The surface of the water looked like it was boiling, as a central plume of tadpoles rose from the school to gulp air before returning to the safety of the throng.

As the school moved slowly around the pool, large amounts of detritus and algae were brought up from the bottom and the tadpoles

ROB WALLS/AUSCAPE

Spices, such as garlic, do more for food than enhance its flavour.

rapidly consumed this. So it appears that schooling behaviour in this species provides nutrition for the individual tadpoles. As far as I am aware, this type of group foraging by tadpoles has never been reported.

—S.R.

Why Spice?

Why do people use spices? The obvious answer is that it enhances the flavour of foods. But why did people evolve to savour these tastes? Is it because spices disguise the taste of spoiled food, increase perspiration and thus help cooling, provide nutrients, or do they have antimicrobial properties?

All except the latter can be discarded, according to Jennifer Billing and her colleague Paul Sherman from Cornell University, New York.

Billing and Sherman assessed 43 spices used in meat-based cuisines of 36 countries. What they discovered suggests there is more to a good curry than the flavour and fire. All the spices studied exhibited some degree of antibacterial function. Over half the spices inhibited or killed more than 75 per cent of bacteria in the dishes. And four spices—garlic, onion, allspice and oregano—inhibited every bacterium tested.

In addition, the researchers found the hotter the country's climate, the more spices appeared in the cooking, especially those with the highest antibacterial potency.

If we came to use spices for their antibacterial properties, how did we learn which ones to use? Billing and Sherman propose that those who added spice to their food, especially in hot climates, may have been able to store food for longer before spoilage, enabling them to better survive times of scarcity. They would also be less likely to suffer food poisoning. Such evolutionary beneficial habits then get passed on to succeeding generations.

So remember, if you are planning overseas travel to one of the hotter climes and are wary of the 'Delhi Belly', go the vindaloo—extra spicy.

—J.M.

Overkill or Underkill?

No-one knows for sure why the Australian marsupial megafauna died out towards the end of the Pleistocene (sometime between 10,000 and 100,000 years ago). They may have succumbed to a drying out of the climate, vegetation change, overhunting, or a combination of these factors.

The overhunting or 'human blitzkrieg' theory has received revived interest of late with the publication of Tim Flannery's *Future eaters* (1994). However, without knowing exactly when the megafauna became extinct or even when humans first reached Australia, archaeological and fossil evidence may never fully resolve the issue.

Taking a different approach, David Choquenot (now with Manaaki Whenua Landcare Research, New Zealand) and David Bowman (now at Northern Territory University) have created a mathematical model to determine just how efficient Pleistocene hunters would have needed to be to cause such large-scale destruction.

Basing their model on contemporary population densities and hunting efficiencies of Aboriginal populations in Arnhem Land, the simple predator-prey model was run

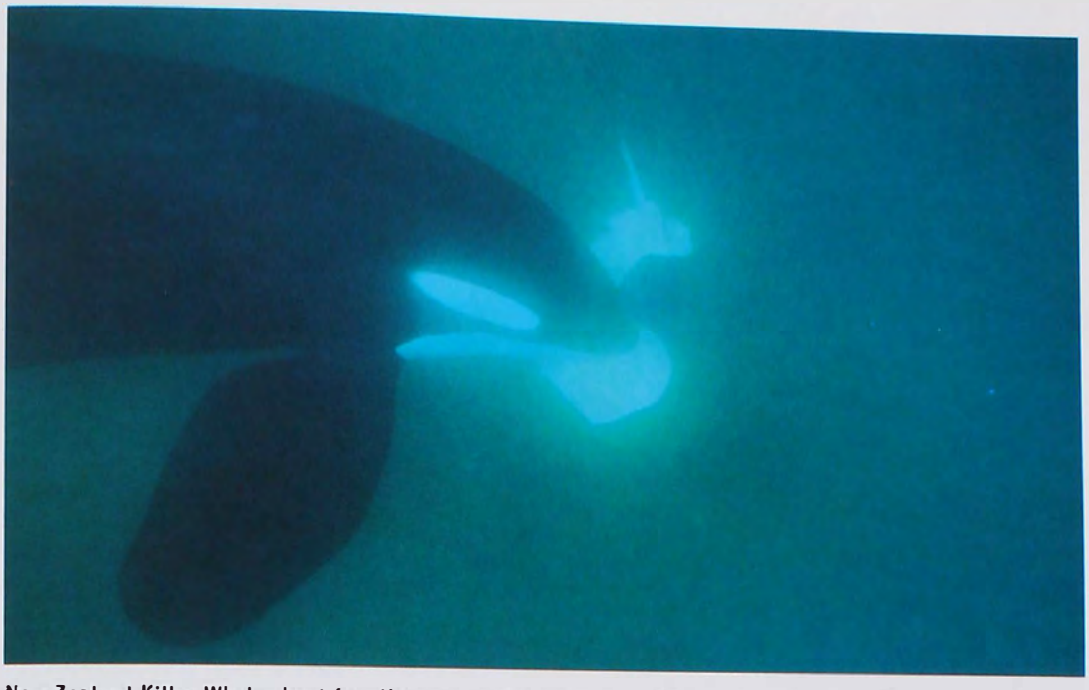
to explore the response of different prey species (with 250-, 500- and 1,000-kilogram body masses) to different hunting rates.

Interestingly they found that the species most vulnerable to overhunting were the smallest. Their model also showed that, at population densities less than 0.1 persons per square kilometre (the pre-European population estimate for Arnhem land), each hunter would have needed to search 100 hectares per day. (By comparison, an experienced Buffalo shooter working from a helicopter can only cover 600 hectares per day.)

Choquenot and Bowman suggest that such high hunting efficiencies would be unreasonable, given the limits of normal human ability, and the unlikelihood that every member of the population, irrespective of age and gender, would hunt.

The researchers therefore conclude that overkill alone cannot be held responsible for the demise of the megafauna.

—R.S.



INGRID N. VISSER

New Zealand Killer Whales hunt for stingrays on the sea floor and have adopted extraordinary ways of dealing with their tricky food.

Kiwi Killers Play Frisbee

In David Attenborough's documentary "Wolves of the Sea", we watched in amazement as Killer Whales (*Orcinus orca*) carelessly tossed seals around before eating them. Killer Whales have also been known to toy with penguins and dolphins, and even a Beluga Whale. But in New Zealand, Killer Whales have a new food to play with—stingrays.

In the first recorded instance of benthic (bottom) feeding by Killer Whales, Ingrid Visser from the University of Auckland found that whales living between Auckland and the Bay of Islands forage for stingrays, often up to two metres across, by standing on their heads in shallow water and

QUICK QUIZ

1. Name the comet responsible for the Leonid meteor shower last November (1998).
2. Who was named Young Australian of the Year (1999)?
3. What do most frogs have that toads do not?
4. In the field of organ transplants, what is xeno-transplantation?
5. Do Lumpsuckers have fur, fins or feathers?
6. What does ENSO stand for?
7. How many arms and tentacles do giant squids have?
8. Do echidnas have a pouch?
9. In which country do Lesser Short-tailed Bats live?
10. What type of organisms produce stromatolites?

(Answers in Q&A)

digging into the substrate. On several occasions, she saw whales emerge from the bottom with mud covering their noses right up to the blowhole. Once a ray was located, whales would often work cooperatively. In one instance, for example, a whale pinned a ray to the bottom with its nose, while another whale grabbed it by its tail.

Visser describes how Killer Whales would often throw a ray out of the water before tossing it around, frisbee-style, with other whales. But this 'game' may be more of a life-saving device, enabling the whale to reposition the ray in its mouth without being stung by the venomous tail spine.

There have been very few accounts of Killer Whales eating elasmobranchs (rays and sharks), but for this New Zealand population, rays appear to be an important part of their diet. To put it in perspective, Visser saw Killer Whales eat more rays on one day in New Zealand than has been reported worldwide for the previous 40 years! This may have important implications for fisheries management of rays and their habitat in this area of New Zealand.

—A.T.

Sex Shells

Most land snails, like people, are right-handed. But rather than describing hand preference, which is meaningless in limbless animals, handedness or 'chirality' in snails refers to the direction in which the shell coils. Interestingly, the internal arrangement of organs in left- and right-handed snails is also reversed.

About a decade ago, it was noted that more left-handed species evolved in groups of snails with tall slender shells, compared to those with low globular shells. Biologist Takahiro Asami, from the Tokyo Metropolitan College, and colleagues now offer a reason why. Their research indicates that it's all to do with the way snails get around the cumbersome problem of sex in a shell.

Snails, as a group, display two copulatory positions. Partners either mate face-to-face, with their shells behind them. Or one snail can mount the shell of the other so that sperm transfer takes place while the snails are in parallel alignment. Asami and his team of researchers found that the overwhelming majority of species with low shells opt for face-to-face copulation, while species with tall slender shells favour the mounting approach.

Right-handed snails have their genital apparatus opening on the right side of their bodies; and *vice versa* for left-handers. Thus, mating between individuals with reversed handedness is physically difficult, resulting in a mating disadvantage for whichever handedness is least represented in the population. The researchers predicted that mating between left- and right-handers would be easier in the mounting position than face-to-face and, if so, selection against the coil of minority would be more relaxed in tall slender

COURTESY TAKAHIRO ASAMI

Why do shells coil in both directions for tall-spired snail species, but usually only in one direction for low-spired species? It's all to do with their choice of mating position.

KATHIE ATKINSON

Could tunnels found in billion-year-old rocks have been made by complex animals such as this polychaete worm (*Eonice aphroditois*)?

(mounting) species. This means that genes for reversed handedness would persist longer in populations of tall species, providing more opportunity for left-handed species to evolve.

—K.McG.

Wormholes in Deep Time?

A piece of sandstone from India has recently excited and divided biologists. Why? Because it apparently contains worm burrows, yet it's been radiometrically dated at over a billion years old—nearly twice as old as the oldest known fossil animals. A team of scientists led by Adolf Seilacher (University of Tübingen, Germany) announced the unexpected find late last year.

Fossil evidence indicates that complex animal life arose less than 600 million years ago, shortly before the famous Cambrian explosion. Before then, only tiny single-celled organisms and relatively simple multicellular seaweeds were thought to have existed. Thus, the 1,100-million-year-old burrows, which appear to have been produced by large, complex animals, pose a huge dilemma, implying that such animals flourished for over 500 million years before leaving their first body fossils (or, for that matter, any other convincing trace fossils).

Obviously, such an extraordinary claim was bound to provoke scepticism. Almost immediately, it was challenged by R.J. Azmi (Wadia Institute of Himalayan Geology, India) who claimed to have found "small shelly fossils" adjacent to the rocks bearing the worm burrows. These tiny, highly distinctive fossils are common worldwide in rocks that are only about 540 million years old. Thus Azmi's fossils implied that the Seilacher team's radiometric (and biostratigraphic) dating was wrong, and that their rock was only half as old as they claimed. In which case the presence of worm burrows would be nothing special. The claim for unknown worm-like animals existing in 'deep time' appeared to be refuted.

However, a new twist occurred when Simon Conway Morris and colleagues from Cambridge University re-examined Azmi's "small shelly fossils" and concluded that they weren't fossil organisms at all, but mineral deposits. But they also challenged the idea that the branching tunnels were made by worms, suspecting they too may have an inorganic origin.

With the evidence so ambiguous and the claims so startling, arguments on both sides are likely to get as tortuous as the putative burrows themselves.

—Michael Lee
University of Queensland

Hornbills Feast and Fly

Hornbills, instantly recognised by their large horny beaks, have recently gained recognition for a much more significant ecological feature—their important role in rainforest regeneration.

Thanks to the work of Kenneth Whitney (from both the San Francisco State University and University of California at Davis) and colleagues, who studied the Black-casqued, White-thighed and Piping Hornbills (*Ceratogymna atrata, C. cylindricus* and *C. fistulata*) in the rainforest canopy of the Dja Reserve, Cameroon, the birds have been found to act as seed dispersers for a significant proportion of the forest flora.

The birds' dietary habits were determined through direct observation and by collecting the seed that accumulates beneath the nest cavities when the male delivers food to the female and chicks, which are sealed within the cavity for the duration of the nesting period (four to six months). They found that collectively the hornbills consumed fruits from at least 50 species of trees, and dispersed the seeds for about 22 per cent of the trees in the study area. They also found that their relatively slow digestion is gentle on the ingested seeds. Out of 24 tree species tested, 23 germinated after being eaten.

In a separate study, Whitney and Thomas Smith (from the same two universities) showed that the Black-casqued and White-thighed

KATHIE ATKINSON

Mayflies mistake asphalt roads for water, with disastrous consequences.

Hornbills, previously thought to be sedentary, actually track seasonally variable fruit resources. Exactly how far the birds travel is at present unknown, but preliminary radio-tracking studies by Kimberly Holbrook (San Francisco State University) indicates they may travel as much as 290 kilometres.

The researchers say these results show that *Ceratogymna* hornbills rank among the most important seed dispersers in Afrotropical forests and will become increasingly important in forest regeneration as populations of larger mammalian seed dispersers, such as elephants and primates, are diminished through hunting.

—R.S.

Auto-Erotica

Asphalt roads are proving to be a fatal attraction for mayflies in the throes of passion. As thick clouds of these water-seeking insects gather for their mating dance, they are being lured towards the reflected light of roadways, and females, instead of laying their eggs in water, are tricked into laying them on the asphalt surface where they are doomed to desiccation.

György Kriska (Eötvös University, Hungary) and colleagues have been studying these entomological road fatalities. By offering mayflies various surfaces on which to lay their eggs, the researchers have established that mayfly navigation is guided by horizontally polarised light. They discovered that polarised light bounces off asphalt in the same manner that light reflects off water. The darker and smoother the asphalt, the higher the degree of polarisation and the more enticing the road is to mayflies. The detour of the open road is irresistible to mayflies as they prefer habitat free of dense vegetation for their sex swarms, and the warmer temperatures of the tarmac prolong copulatory activity.

Mayfly species have undergone severe declines in recent years due to habitat destruction and pollution, and asphalt road traps near riparian (water) habitats may further threaten the survival of many future generations. The road toll may also affect stream ecosystems, as mayflies are an important food source for fish. The researchers are currently testing lighter-coloured asphalt with a rougher surface, to see if they can curb the mayflies' fatal fetish for hot tar and gravel.

—K.H.

Light-fingered Sponges

Plants need light to produce food, and in the murky depths beneath the Antarctic seas, a sponge and an alga have come to an ingenious arrangement that enables the plant to photosynthesise in almost complete darkness.

In the chilly depths of the Ross Sea, tiny unicellular algae (diatoms) flourish deep inside living sea sponges. These sponges are supported by a network of silica spines, called spicules, around the base of which the algae grow. Now Italian researchers have discovered these spicules may be acting as optical fibres to mop up what little light penetrates to 120 metres, where the sponges grow.

Riccardo Cattaneo-Vietti, from the University of Genova, and colleagues extracted long spicules from the demosponge *Rosella racovitzae* and shone beams of laser light through them. They found that the spicules were excellent conductors of light, even when bent at various angles. In one experiment, the amount of light carried a centimetre beyond a 90°-bend in the spicule was still 65 per cent of the original beam intensity. Each spicule looks a little like a palm tree, with a cross-shaped structure at the top. The researchers showed that this serves to increase the spicule's light-collecting capacity. In fact, spicules deprived of their apex con-

Karina Holden, Jason Major, Karen McGhee, Stephen Richards, Philippa Rowlands, Rachel Sullivan and Abbie Thomas are regular contributors to Nature Strips.

ducted 70 per cent less light. It seems that the spicules collect and concentrate light down to the garden of diatoms at their base. In return for this service, the sponge also benefits, because a flourishing and photosynthesising population of algae provides it with nutrients and oxygen.

—A.T.

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Getting Australians to raise their glass to such an environmentally friendly, low-fat godsend involves a quantum leap of Looking Glass proportions.

GREYS HOT IN THE LONG-JUMP STEAKS

BY STEVE VAN DYCK

THE FIRST NEXT-DOOR NEIGHBOUR I can remember with genuine affection was an old lady whose hair was as silver as her thumb was green as her thighs were purple. To be minded by her for a morning was not so much a squeeze through the paling fence as a step through the Looking Glass. Her vegetable garden hummed with harvest-festival anticipation, her kitchen with the promise of hot shortbread. Although between the stove and the compost heap there were always good things to eat and do, these delights would be later eclipsed in her more sombre lounge room.

There, around noon, the unnerving vapour of neat spirit would announce that she, not alcoholic but diabetic, was preparing to shoot up, a spectacle to surpass all the morning's pumpkins and pastry.

With nonchalance belied by her poor bruised thighs she would swab her leg with alcohol, then inject herself with a needle better suited to pumping yabbies than insulin. And to help me recover my five-years worth of wits, she would produce a small jar whose contents would absorb my attention until it was time to go home.

Bobbing around in metho was a newly born Eastern Grey Kangaroo (*Macropus giganteus*), no bigger than a jellybean, with a little bit of cut-off nipple hanging from its mouth. The injection was one thing, but a kangaroo in a Vegemite jar made my head spin more and called for a lot of hard questions that my neighbour was never really able to answer.

It was perfectly normal as far as newborn kangaroos went; it had no eyes, no ears, and mere buds for hind legs, yet it had ironman arms and pig-like nostrils . . . a shapeless mite more maggot than macropod, more miscarried than delivered.

Mine wasn't the first head to be scratched over a kangaroo neonate. For centuries intellectual battles raged over whether birth took place inside the pouch, whether the joey just budded out from the end of the teat, or whether the female manipulated it into the pouch or licked a path for it to follow.

Today we know at least that the newborn beats its own track from the birth canal up to the pouch, totally unassisted by its mother and totally dependent on its Herculean forearms to effect the passage. But we also know that it is guided to the nipple in the pouch by complex and highly developed sensory responses involving scent and touch.

A joey still in its mother's pouch.

JEAN-PAUL FERRERO/AUSCAPE

EASTERN GREY KANGAROO

Macropus giganteus

Classification
Family Macropodidae (wallabies, kangaroos and tree-kangaroos).

Identification
Silver-grey above, lighter on belly, woolly fur, hairs between the top lip and the nostrils. Sexes similarly coloured, but males (head–body 150 cm, tail 95 cm, weight 50 kg) almost twice as big and heavy as females. Probably just smaller than Red Kangaroo. Speed recorded at 64 km/h, long-jump reported at 13.5 m, can high-jump to around 3 m.

Distribution and Habitat
Eastern half of Qld, most of NSW and Vic., south-eastern tip of SA, and north-eastern Tas. Found where annual rainfall exceeds 250 mm, in open forests and scrubs, woodlands, freshwater swamps and mangrove edges, heaths, shrublands, tussock grasslands and pastures.

Behaviour
Mostly nocturnal, but active from late afternoon through to early morning. Lives in groups of up to a dozen, but may aggregate in much larger numbers at favoured feeding grounds. Vocal communication by coughs, grunts and cluckings. Mating usually occurs in early summer, gestation 33 days, usually one young produced but twins have been recorded. Pouch with four teats.

Status
Abundant on the mainland, but vulnerable in Tasmania.

Once fastened onto a teat that swells inside the mouth and firmly anchors the joey, it grows in the pouch for about nine months, gets its eviction notice at 11 months, and loses all rights to the nose-bag at 18 months.

Most remarkable in this process is the double-dipping that can occur when conditions are right. Any time after the joey is four months old its mother may mate and become pregnant again. However, to avoid straining the hip pocket, the developing hopper in the uterus is put on the backburner until Number One gets its marching orders.

As soon as Joey One is evicted, the dormant foetus resumes growth to be born a month later. It develops in the pouch alongside the long teat that Joey One feeds from when it pokes its head in for a drink. Both have different nutritional needs, and each is supplied a different brew. When weaned, a fairly specific range of grasses and forbs (pasture plants other than grasses) will be just about all the Eastern Grey Kangaroo feeds on for its six to eight years. Unlike its chief competitor the Sheep, however, it doesn't grind its food so fine as to destroy most of the seeds that would pass out in its dung. Protected inside the dung ball, such seeds can lie in wait until germination can take place.

The upkeep of feeding machinery in this kangaroo (and all its congeners for that matter) is also quite astonishing. Grass is a notoriously abrasive substance to process . . . mower blades don't wear down to bootstraps just because we keep hitting the footpath. A long way behind a kangaroo's snipping incisors, in both the upper and lower jaws, is a set of grinding molars that look like end-to-end dice with the middles gouged out. A kangaroo gets five of these to an innings. One is a milk tooth that gets pushed out relatively early, but the other four erupt slowly from the back of the jaw and move like Processionary Caterpillars toward the front. One by one, worn down and useless, they suicide off the Gap at the front of the molar row. A very old kangaroo might have only one molar left on each side of its jaws, so its death might come from starvation while standing hip-deep in lucern.

Since the time of European settlement in Australia, the Eastern Grey Kangaroo has borne the brunt of the sporting man's fancy. In 1907, naturalist Thomas Ward provided the following comments on the subject. "The requirements of the sport are a swift-running dog of powerful jaw . . . dogs are frequently ripped open, or cut nearly in two; and the first hunters to come up to a kangaroo at bay spring from their horses, and, seizing its tail, hold it up. This prevents the animal from lifting its legs to strike . . . thus assisted, the dogs pin it by the throat, and soon have it down."

KEN GRIFFITHS

This joey still relies on its mother for a feed and will suckle from the long teat that can be seen in her pouch.

Fortunately we no longer dignify such behaviour as 'sport', yet we still procrastinate, shuffling the Eastern Grey between the status of a pest, a harvestable resource, and a species to be conserved. Unlike many small wallabies and kangaroo-like marsupials, this species has benefited profoundly from agricultural practice. And despite unique and novel arguments to the contrary, with something like one-and-a-half million harvested annually (nationally), prospects for the species' survival are still good.

Getting Australians to raise their glass to such an environmentally friendly, low-fat godsend however, involves a quantum leap of Looking Glass proportions. Attitudes have to be gently massaged by example. If a joey in a jar of metho can produce a headspin and a long-lasting impression, so too can a kangaroo steak with a tumbler full of red. The ingredients are essentially the same, the only difference is that, in the meal, at least some of the hard kangaroo questions are being addressed. ■

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The discovery caused quite a stir as Northern Bettongs are one of the country's rarest marsupials.

NORTHERN BETTONG

BY ALLEN McILWEE

LISA POPE

IN NOVEMBER 1997, WHILE DRIVING through the Coane Range, not far from the rainforest township of Paluma (northern Queensland), I spotted what appeared to be a Northern Bettong bounding across the road. If the animal was indeed a Northern Bettong, it sure had quite a distance to cover. The nearest recorded 'home' for this species was more than 300 kilometres away to the north.

Uncertain of what tricks the animal may have played on my eyes, Alastair Freeman of the Queensland Department of Environment and I organised an expedition to uncover the identity of this mysterious animal. To our delight, it turned out to be no lonesome stranger that had strayed from foreign lands, but rather a member of a new Northern Bettong population that had somehow managed to evade the probing eyes of researchers. The discovery caused quite a stir as Northern Bettongs are one of the country's rarest marsupials.

Northern Bettongs (*Bettongia tropica*) are found only in upland areas of north-eastern Queensland, and live within narrow strips of wet eucalypt forest that hug the western edge of rainforests. They are small 1.2-kilogram marsupials in the family Potoroidae. This group includes the shy and elusive bettongs, potoroos and the rainforest-dwelling Musky Rat-kangaroo (*Hypsiprymnodon moschatus*). Although Northern Bettongs can sometimes be heard rummaging about on the forest floor, they are seldom seen, but when they are, they are easily recognised by their soft grey coat and the dark crest of fur at the end of their tail. They are similar in appearance and genetics to Brush-tailed Bettongs (*Bettongia penicillata*) from Western Australia. However, the two species are separated by such a large distance that their status is regarded separately.

Like their potoroid relatives, Northern Bettongs have undergone a dramatic range contraction over the past two centuries. They have vanished from two known locations—the Dawson Valley near Rockhampton and the greater Ravenshoe area south of the Atherton Tableland. Currently only three populations are known to exist—one on the Mt Carbine Tablelands (north of Cairns), where only three animals have been caught since the early '90s; the recently discovered Coane Range population, from which we trapped eight individuals; and another on the Lamb Range (west of Cairns). In contrast to other populations, Northern Bettongs on Lamb Range occur at relatively high densities, however they are restricted to a strip of just 25 x 5 kilometres.

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The modest size and isolated nature of Northern Bettong populations make these animals extremely vulnerable to stochastic events, such as disease and predation from Foxes and feral Cats. In addition, sclerophyll forests at the wetter end of their range are currently undergoing dramatic changes caused by a lack of fire and the subsequent invasion of rainforest. Scientists at CSIRO in Atherton have shown that around 30 per cent of potential Northern Bettong habitat on the Lamb Range has been lost due to invasion of rainforest species.

Northern Bettongs, like their southern relatives, are highly reliant on truffles as their main source of food. The availability of truffles, which are the fruiting bodies of underground fungi, are believed to be the most important

factor limiting the extension of the species into dry types of forests and woodlands. Truffles are eaten year round and comprise between 30 and 70 per cent of the diet. Some 40 species of truffles are known to be consumed, although this is probably an underestimate. Roots, tubers and the succulent underground stem bases of grasses and lilies are also important food items.

In 1990 a Recovery Team was established to monitor and direct research on the species. The team is currently coordinating efforts to search for additional populations. Through the use of fine-scale distribution and habitat models, scientists from the Queensland Department of Environment and CSIRO are working towards identifying key areas of potential habitat. These locations could provide suitable reintroduction sites for the species. A study using mitochondrial DNA and other genetic markers is also in progress by Lisa Pope at the University of Queensland. Lisa hopes to reveal the age of populations. This will show whether Northern Bettongs have suffered a long history of isolation, or whether a decline in their status has occurred during recent times.

While Northern Bettong populations will continue to face a variety of potential threats, discovery of the Coane Range population gives hope that, amidst the constant battle to save our endangered animals, some species may be a little more resourceful and resilient than we currently suspect. ■

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Allen McIlwee has completed an honours degree on the feeding ecology of Northern Bettongs. He is currently a PhD student at James Cook University, looking at the nutritional ecology of leaf-eating possums and gliders in eucalypt forests.

Many of the shrubs store their seeds in woody, fireproof fruits that only open after a fire has been through.

FIRE, SEEDS & PARROTS

BY TIM LOW

FIRE IS THE GREAT LEVELLER. Every few years it rages through Australia's heathlands, wasting leaf and limb, laying bare the land. Yet despite the death and destruction, no lasting harm is done. Rains fall and flushes of seedlings rise from the ash to refurbish the land.

Seedlings sprout prolifically after fire in heathland because many of the shrubs store their seeds in woody, fireproof fruits that only open after a fire has been through. Storage of seed in the canopy is called 'serotiny'. Serotinous plants do not shed seed each year, but build up an accumulating store, awaiting the inevitable inferno. The wet season after a fire is the best time to germinate because competing plants have been singed away, the ash is nutrient-rich, and the opportunity before the next fire will never be greater. Some species of *Banksia* can store their seed for 17 years, the Broad-leaved Paperbark (*Melaleuca quinquenervia*) for ten years. In banksias, the fire melts the resin that holds the follicles closed, while the dried flower heads act as convenient torches.

Many of Australia's best-known shrubs and trees are serotinous, including vast numbers of eucalypts (*Eucalyptus* species), banksias, sheoaks (*Allocasuarina* species), hakeas (*Hakea* species) and bottlebrushes (*Callistemon* and *Beaufortia* species). The eucalypt and banksia families (Myrtaceae and Proteaceae) are especially rich in serotinous plants, and this habit has undoubtedly contributed to their success in a fire-prone land. Within many genera there are strongly serotinous species, non-serotinous species and others that store some seed and shed the rest seasonally.

Serotiny is best developed in dry heathlands with a Mediterranean climate, where the dry summers ensure regular fires, and the vegetation is so low it cannot escape the flames. Around Perth, the degree of serotiny increases the farther north you go, even among the same banksia species, as the climate becomes drier and the banksias more stunted. Some serotinous species (shrubs without an underground reserve system of dormant buds) are readily killed by fire, and the seeds falling from their dying limbs afford their only hope of reproduction. Others resprout from underground lignotu-

PHOTOS: TIM LOW

The characteristic appearance of bottlebrushes such as the Lesser Bottlebrush (*Callistemon phoeniceus*) owes partly to their habit of retaining their seeds in intact capsules along the upper stems.

The serotinous seeds of Baxter's Banksia (*Banksia baxteri*) are protected from fire and birds by thick woody follicles which are bright red in colour. Few seeds are produced but these are well guarded.

bers, while others, including many eucalypts, easily survive fires but take advantage of the flames to cast their seeds into the mineral-rich ash bed. Seeds of most eucalypts are so tiny that, without a fire to clear away grass and litter, their seedlings have little hope of surviving.

Serotiny is rare in most parts of the world, although common in the South African fynbos heathlands and among fire-tolerant pines (*Pinus* species) in North America. Australia has more serotinous plants than any other land, reflecting the pivotal role played by fire on this most ancient continent. Indeed, serotiny in Australia probably dates back at least 50 million years to *Banksia archaeocarpa*, a fossil species from Western Australia with thick woody follicles. Australia's serotinous fruits are so distinctive they have won a place in craft and folklore. In *The complete adventures of Snugglepot and Cuddlepie*, May Gibbs' cherubs snuggle inside bloodwood (*Corymbia*) gumnuts, while the banksia men speak evil through serotinous lips.

Serotiny goes a long way towards explaining why Australia is so well endowed with parrots. Serotinous seeds are permanently available to any animal able to breach the woody wall. Parrots are masters at this task, and serotinous seeds appear on the menus of many species, especially the black-cockatoos with their massive beaks. In south-western Australia, where serotiny reaches its highest development, Short-billed Black-Cockatoos (*Calyptorhynchus latirostris*) are a feature of the heathlands, where they crack apart the woody fruits of hakeas and dryandras (*Dryandra* species) with plier-like beaks. In nearby woodlands, Long-billed Black-Cockatoos (*C. baudinii*) and Red-capped Parrots (*Purpureicephalus spurius*) use their slender bills to extract seeds from the huge gumnuts of Marri (*Corymbia calophylla*), their staple food. Seed capsules in the south-west are sometimes remarkably woody, not because fires there are exceptionally hot, but because specialised parrots and seed-eating insects are a major force.

The Glossy Black-Cockatoo (*C. lathami*) in eastern Australia is another by-product of serotiny, with a diet made up almost entirely of sheoak seeds. Serotinous seeds are obviously a reliable food, these parrots having some of the narrowest diets of any birds in Australia. Remarkably, black-cockatoos all over the country have learnt to harvest serotinous seeds of exotic pines (*Pinus radiata* and *P. pinaster*). The Short-billed Black-Cockatoo is even a nuisance in some pine plantations.

Serotiny also helps explain why Australian shrubs and trees do so well as weeds overseas. Hakeas in South Africa, and the Broad-leaved Paperbark in Florida, when poisoned, uprooted, ring-barked or bulldozed, shed huge loads of seed, irrespective of the season in which they are killed. Release of seed is triggered by death of the branch, even if no fire has passed through. A single paperbark in Florida can shed 20 million seeds, accumulated over a decade, a statistic that makes American land managers queasy. In South Africa, biologists have introduced Australian moths and weevils to attack the serotinous seeds of hakeas. Maybe they should introduce cockatoos as well! ■

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Tim Low is a biologist and writer who lives among serotinous trees in Brisbane. His latest book is Feral future *(1999), published by Penguin.*

A FIRST FOR NORFOLK

BY PETER WHITE & ATHOLL ANDERSON

Why the early Norfolk Islanders disappeared remains a puzzle.

WHEN CAPTAIN COOK LANDED briefly on the north coast of Norfolk Island in 1774, there was no-one there to greet him. Captain Philip Gidley King couldn't find anyone there either when, 14 years later with a band of soldiers and convicts, he established the first European settlement on the Pacific island, at Kingston on the south coast. But King did find bananas (he called them "plantains") and noted a "diminutive" rat (probably the Pacific Rat, *Rattus exulans*). Both of these could only have reached this very isolated island with human help. But which humans? When? And where was the firm evidence?

Over the next 200 years, at least 30 Polynesian-style adzes (axe-like tools) were collected. Made from Norfolk Island basalt, the tools were found from all parts of the island, but mostly from the Kingston area. These finds led Australian Museum curators Fred McCarthy and Jim Specht to suggest that Cemetery, Emily and Slaughter Bays were the most likely locations for early human settlement. These bays, which are all in the Kingston area, front the island's only large area of flat land near the sea. Emily and Slaughter Bays are also protected by the only coral reef on Norfolk Island, providing a good harbour for small boats. This is why King established his settlement there, and the same reasoning is likely to have been applied by prehistoric settlers.

With funding from the Australian Heritage Commission, the Norfolk Island Prehistory Project was set up in 1995 to search for the elusive early-settlement sites. The first season's work began in Cemetery Bay where previous researchers and local enthusiasts had noted a brown layer in the quarried sand dunes and where Pacific Rat bones had been dated to about AD 1100. However no definitive cultural material was found.

Attention then switched to adjacent Emily Bay. A series of augur holes and small pits was dug along the dunes behind the beach, with the idea that, while the beach may have been important for canoes, people would probably have lived a little back from it, sheltered from the regular south-easterly trade winds. The reward came at the western end of the bay, in a patch of Norfolk Island Pines (*Araucaria heterophylla*) planted in the 1920s. Here was a horizon of grey sand with a patch of burnt basalt cobbles, charcoal and fish spines—evidence of an oceanic type of cooking area. This discovery prompted local resident Bevan Nicolai to show us bones, including the jaw of a Dog, that were collected some years earlier from holes dug about 100 metres away for pit toilets. Large-scale excavations in 1996 and 1997, with additional funding by the Australian Research Council, Australia and Pacific Science Foundation and the Norfolk Island Government, have now given us a much fuller picture of the nature, contents and date of this settlement.

So far we have excavated about 80 square metres of the site, working between the pine trees. Lying about 50 metres back from Emily Bay, the occupation was on a gently sloping sandy surface, which human use turned grey with

ROBIN SMITH

AUSTRALIAN MUSEUM/NATURE FOCUS

Above: These kinds of rowing boat are still used on Norfolk Island. In the background is Philip Island, denuded of vegetation by people, Pigs and Rabbits in the 19th century. Right: A basalt adze from Norfolk Island now in the Australian Museum. Many of these have been found by islanders over the years and are clear proof that Polynesians once lived there.

charcoal and other organic refuse. Radiocarbon dates show it was in use between 800 and 400 years ago (AD 1200–1600), but this form of dating is not precise enough to determine how long the site was occupied.

The range and nature of the excavated structures and artefacts show three important things. First, the site was occupied by East Polynesians; second, it was quite substantial—clearly more than castaways resting and re-grouping before trying to get back home; and third, the inhabitants may not have been totally isolated on Norfolk Island.

A. ANDERSON

A bone awl, a bone fishhook and the pointed part of a two-piece fishhook were among the finds at the Polynesian settlement at Emily Bay.

A. ANDERSON

The stone pavement being excavated at Emily Bay. Built from slabs of local calcarenite, it may have been the platform of a *marae* (ceremonial platform), or just a patio in front of a house.

The Polynesian source of the occupation was already implied by previous discoveries of basalt adzes. We confirmed this by finding more of them, along with bone fishhooks and the head of a jabbing harpoon made of turtle bone, all with shapes like those made at about the same time on other Polynesian islands, including New Zealand.

The substantial nature of the occupation is evidenced by our excavation of two large building structures. Three sides of one of these was outlined by the actual bases of wooden posts and post holes, starting in the grey occupation zone and extending down into the white sand. This structure was at least 3 x 2 metres. The other was a 5 x 4-metre area paved with calcarenite slabs (a form of limestone locally available and commonly used in European period buildings). This may have been used as an outdoor patio area for daily use, or it could have been part of a ceremonial platform, similar to a Polynesian *marae*.

We know that the islanders had links with a wider world from the discovery of more than 20 small flakes of obsidian, a black volcanic glass that does not occur on Norfolk Island. Analysis using a method called Proton Induced X-ray Emission (PIXE) has sourced the obsidian to Raoul Island, 1,300 kilometres away to the east. Also, the flakes were concentrated near the pavement, suggesting that their use was restricted and maybe even ceremonial. This lends support to the idea that the pavement was used as a *marae*.

These hints of an on-going settlement are reinforced by environmental evidence suggesting people lived on the island for several generations. As well as the 900-year-old rat bones from Cemetery Bay, a pollen core of about the same

A. ANDERSON

The base of a Polynesian house post still in place. Made of Norfolk Island pine, the in-ground end was sharpened and then driven into the sand rather than being set into a post hole dug for it.

age, taken in 1995 from the Kingston swamp, showed a concentration of charcoal and of cordyline (*Cordyline objecta*), the root of which was commonly eaten by Polynesians.

A well-established settlement at AD 1200–1600 makes it particularly curious that there were no people living on Norfolk Island when Captain Cook arrived in 1774. The settlement we excavated, along with the adzes collected from all parts of the island, show that this was not a short-term or very small-scale occupation.

Why the early Norfolk Islanders disappeared remains a puzzle. Perhaps isolation was to blame? They might not have been able to obtain enough desired products such as obsidian, or enough suitable marriage partners, or even just enough social contact. Isolation may have induced the Emily Bay community to sail back to their original homelands in the east. Another possibility is that the island's resources were insufficient. Norfolk has very limited reserves of shellfish, only a small area for sheltered fishing, and fragile populations of nesting seabirds. These could have been easily depleted, as happened when Europeans first settled. If the Polynesians had only the banana and cordyline as food crops, their subsistence base would have been quite vulnerable. Although they don't appear to have suffered a disaster like a tsunami or cyclone, when living became difficult, they may have simply headed home. They might even have gone farther west, seeking another island, in which case they would have arrived in Australia. ■

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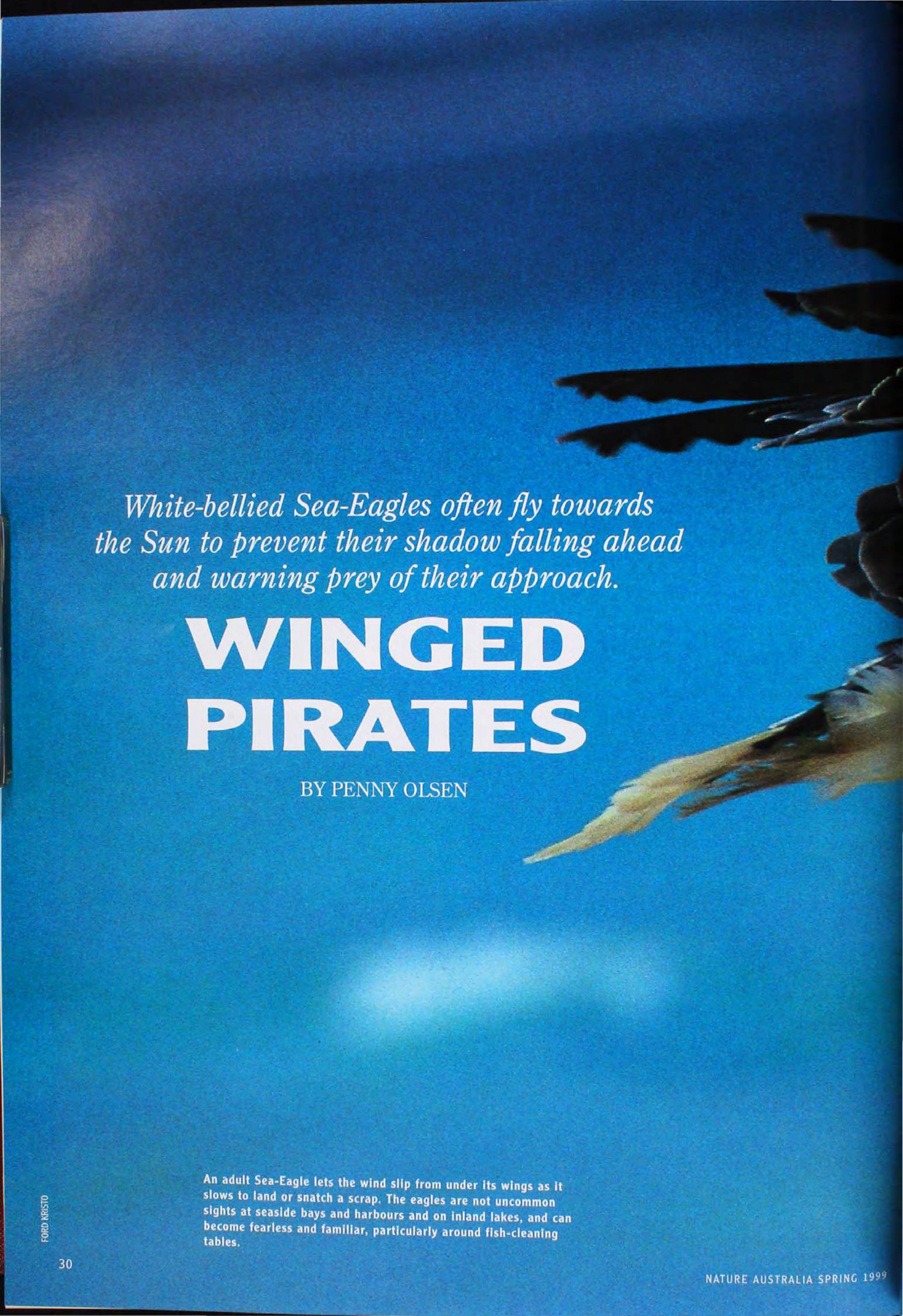
ROBIN SMITH

Part of the European cemetery at Slaughter Bay. There is environmental evidence of Polynesian settlement here, in the form of changes in landsnails and pollen, but the main settlement was at the more protected Emily Bay behind the pine trees on the right.

White-bellied Sea-Eagles often fly towards the Sun to prevent their shadow falling ahead and warning prey of their approach.

WINGED PIRATES

BY PENNY OLSEN



An adult Sea-Eagle lets the wind slip from under its wings as it slows to land or snatch a scrap. The eagles are not uncommon sights at seaside bays and harbours and on inland lakes, and can become fearless and familiar, particularly around fish-cleaning tables.

FORD KRISTO

WHILE I WAS LUNCHING IN the restaurant of the National Gallery of Australia, something at the edge of my vision snapped me to attention. I turned just in time to catch nature in action. A White-bellied Sea-Eagle (*Haliaeetus leucogaster*) cruised nonchalantly across the panorama framed by the long plate-glass wall, scooping a fish from the choppy waters almost in passing. It was all so casual and I thought how wonderful it was to share our city with such an awesome creature. Typically, large predators are unwelcome around human habitation. Yet, here was one of Australia's largest and most powerful birds patrolling the artificial waters of the nation's capital.

Sea-Eagles haunt a variety of aquatic habitats, from the bays and inlets of coasts and islands, to freshwater lakes, rivers and wetlands. They need quiet woodlands for nesting and, in general, avoid built-up areas, although they are not above visiting fish-cleaning tables, rubbish tips and other sites of human activity to scrounge a meal. In the Canberra district, as elsewhere, they have probably benefited from the damming of rivers and proliferation of introduced European Carp (*Cyprinus carpio*).

ONE OF THE MOST IMPOSING OF BIRDS, with a two-metre wingspan, long, broad wings held in a distinctive shallow 'V', and short, pale-ended tail, Sea-Eagles in flight have a silhouette reminiscent of a giant butterfly. Adults are mostly white with a grey back and dark grey flight feathers and tail base, while young birds are dark brown, mottled and scalloped with fawn. The birds take about five years to attain adult plumage and, like most birds of prey, females are larger and heavier than males.

Sea-Eagles soar conspicuously in the updraughts that form where air currents hit hillsides and cliffs, and perch promin-ently in tall trees overlooking water. Their far-carrying honks and yelps echo across the water. In flight the dark wings contrast with the great snowy white of their body; perched, the pristine white and grey of the adult, broad shoulders, and stumpy tail hidden by the cape of its wings, are unmistakable. Not surprisingly, the Sea-Eagle features prominently in Aboriginal mythology and was one of the first Australian land birds to be described, spotted by the naturalist accompanying James Cook on his first visit in 1770.

As noted by early naturalists, the White-bellied Sea-Eagle is the only Aus-

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

The mottled brown of a young Sea-Eagle readily distinguishes it from the pristine grey and white of an adult. Each year, until the eagles are about five or six years old, more and more of the cream and brown feathers are replaced with white and grey.

IRI LOCHMANN LOCHMAN TRANSPARENCIES

A breeding pair of White-bellied Sea-Eagles meets at the nest, which both have helped to build or renovate. The male and female are identical in plumage but the female is noticeably larger.

tralian representative of a nearly cosmopolitan group. Indeed, the genus *Haliaeetus* contains some of the largest and most handsome birds of prey, including the Bald Eagle (*H. leucocephalus*), America's national bird emblem, the African Fish-Eagle (*H. vociferoides*), often called the voice of Africa, and Steller's Sea-Eagle (*H. pelagicus*) of Japan and Korea, with the most massive beak of any raptor. In Australia, the Sea-Eagle's closest relatives are the much smaller, typical kites: the Brahminy Kite (*Haliastur indus*), Whistling Kite (*H. sphenurus*) and Black Kite (*Milvus migrans*). The Sea-Eagle and the kites are only distantly related to the true eagles, which differ in having fully feathered legs, among other distinguishing characteristics.

White-bellied Sea-Eagles are less specialised in behaviour and anatomy than that other notable fish-eating raptor, the Osprey (*Pandion haliaetus*). Unlike the Osprey, they are not adapted to plunge headlong into water, and rarely do they fully submerge. (They are able to lift themselves from the water, but for them it is a laborious and dangerous process.) Nevertheless, their sturdy, heavily scaled legs and powerful, short-toed feet, soled with sharp spicules, equip them well for catching large, slippery prey. A deep, laterally compressed bill, much stronger than the Osprey's, allows them to tear open beached seals and other tough food.

Unlike falcons, which kill with their beak, the eagles use their powerful grip. A male Sea-Eagle once grabbed me by the forearm. He drove his hind talon through to the bone and sent me, a veteran raptor handler, into a state of shock. I was grateful he just gave me a quick squeeze and chose not to lock on as he would to prey. The sheer force of his grip was something that had to be experienced to be believed.

Much of a Sea-Eagle's day is spent at favoured perches, watching for prey. Typically, after sighting a fish or other prey item, the eagle swoops down low, levels out and, on nearing the target, thrusts its feet forward to strike. With

NICHOLAS BIRKS/WILDFLIGHT AUSTRALIA

An incoming adult Sea-Eagle returns to its nest wedged among the boulders high on a cliff overlooking the Southern Ocean. Nests are refurbished annually and, judging from its size, this nest must be decades old.

WHITE-BELLIED SEA-EAGLE

Haliaeetus leucogaster

Classification
Order Falconiformes (largely diurnal birds of prey), family Accipitridae (hawks, kites, eagles and allies).

Identification
Large, imposing, grey-and-white eagle found near aquatic habitats. Immatures are mottled brown. Length 75–85 cm, wingspan 1.8–2.2 m, weight 2.5–4.2 kg; females larger and heavier than males.

Distribution
Occurs from Aust. and NG through south and south-east Asia to western India and southern China. In Aust., frequents tropical and temperate coasts and wetlands.

Habitat
Typically occurs along coasts and on offshore islands and inland near larger freshwater rivers and lakes. Found in woodlands but more often in open freshwater areas fringed with forest or woodland, sometimes far inland.

Reproduction
Eggs laid May–Sept., earlier in the north than south; fairly matt white eggs, sometimes with pale splotches, laid in huge nest of large sticks, lined with seaweed, grass or green eucalypt sprays, built in prominent position near water in a tall tree, on a cliff or, on remote islands, on the ground; clutch size usually 2 (1–3); incubation about 7 weeks; fledging after about 9 weeks in nest; about 5 years to reach maturity.

Status
Secure nationally, but listed as threatened (rare) in Vic. and proposed for listing in Tas., mainly because of population declines associated with disturbance from human activities and habitat destruction.

the prey clasped in one foot, a powerful sweep of the wings lifts it from the water, to be carried back to a perch or the shore.

If you look beneath their regular feeding perches, you will often find a thick layer of prey remains. Depending on the area and what prey is available, the debris may contain anything from the remains of mullet, eels, Magpie Geese (*Anseranas semipalmata*), Water-rats (*Hydromys chrysogaster*), Canefield Rats (*Rattus sordidus*), penguins, turtles, sea-snakes—virtually anything that's edible. The eagles often scavenge dead seals, fish offal and other floating or beach-washed animal remains. Young birds may also congregate at rubbish tips in search of organic matter.

Apart from scavenging, and catching surface-feeding aquatic animals, Sea-Eagles hunt terrestrial prey, including Rabbits, young wombats, wallabies and large skinks. They steal chicks from heronries and seabird colonies and, sometimes in pairs, harass waterbirds, such as grebes, forcing them to dive until exhausted and easily snatched from the water. They attend foraging dolphins and seals, and trail cane-harvesters, in the hope of picking up prey they flush, and pluck flying-foxes as they hang at the roost. Altogether, the White-bellied Sea-Eagle is one of the most gastronomically versatile of avian hunters.

When attacking, Sea-Eagles often fly towards the Sun, or at right angles to it, to prevent their shadow falling ahead and warning prey of their approach. Surprise is an effective hunting tactic but the eagles don't always need to be so cryptic. Kleptoparasitism—stealing food from another individual—is yet another of their feeding strategies. Apparently compulsive pirates, Sea-Eagles frequently chase and scream at other birds until they drop or disgorge their prey. Anything that carries largish prey—be it another Sea-Eagle, raptor, waterbird or seabird—is fair game. This same behaviour in the closely related Bald Eagle led Benjamin Franklin to decry it as "a bird of bad moral character".

Piracy may be a lazy way to get a free meal but it does have risks. Studies of the Bald Eagle suggest that, when pirating from other Bald Eagles, they adhere to the rules of 'game theory', a mathematical concept that has been applied to decision-making by interacting individuals with conflicting interests. Sticking to the rules means that injuries during these robberies are rare. Size and experience

DAVE WATTS/NATURE FOCUS

A massive chest, relatively small head, and wings cloaking a short tail, are characteristic of the impressive White-bellied Sea-Eagle.

matter, so that females prevail over males and adults over youngsters. The degree of hunger also counts. The pursuer is thought to assess its own hunger and that of its victim from the size of the crop (the pouch-like enlargement in the throat where food is partially digested). Thus, the pirate usually only pursues disadvantaged, smaller, younger or less hungry possessors of food. Young Sea-Eagles spend many of their immature years in areas where there are few breeding adults, and I suspect the reasoning behind this is their vulnerability to piracy by older birds.

ADULT SEA-EAGLES HAVE TERRITORIES that they defend vigorously from other Sea-Eagles, especially during the breeding season. In the month or so before they lay eggs, breeding pairs court conspicuously. Particularly in the morning, they duet from perches, with their heads thrown back, the male's metallic 'ank, ank, ank' higher-pitched and slightly faster than the female's. They also call as they chase each other, and make mock attacks-and-parries. Soaring together, they circle upwards, possibly to advertise to neighbours that the territory is occupied. In one of their more spectacular displays, one bird, usually the male, dives at the other. As the male approaches he stretches his talons forward in mock attack and the female rolls and presents her talons in mock defence. Occasionally, the pair even locks feet and spirals downwards. This is a ritualised version of real conflict behaviour seen when an intruding Sea-Eagle enters an occupied territory. Often it is difficult to interpret which behaviour is occurring—courting or fighting.

Sea-Eagles construct a large nest in a tall gum tree or on a cliff, always in a commanding position. On predator-free islands they may build on the ground or in low scrub. Both members of the pair collect large dry sticks from the ground or break them, in flight, from a tree, and finish the nest by lining it with seaweed or fresh eucalypt sprigs. Although few studies have been done, apparently pairs often remain in the same territory but do not necessarily breed every year. If they do breed, they often reuse their old nest which, over the years, may grow as big as five cubic metres in volume. Occasionally, they also occupy a deserted nest of their major competitor the Wedge-tailed Eagle (*Aquila audax*), or extend the more modest nest of a Whistling Kite.

The nest sites of neighbouring pairs may be as close as four kilometres but are usually much farther apart. Breeding density depends to some extent on prey availability. For example, on a lake near Canberra, normally only one or two pairs nest, but in one year when the lake was low and European Carp were abundant in the shallows, at least four pairs nested. This suggests that, although some pairs are resident and hold stable territories, others must wander to find food.

Each year we check a nest that has been occupied on and off for more than 15 years. From the boat we usually spot the heavy-shouldered white shape of the female perched near the nest and, closer, glimpse the heads of the active white chicks as they peer out from their stick platform. As at all the nests I have visited, the female takes to the air and disappears, although I have been told that a few pairs defend the nest from humans by swooping at the intruders. We tie the boat to the base of the partly submerged nest tree and Tony Ross, an indispensable companion in the field, easily climbs the three metres to the large stick nest. I look forward to his return to the boat, where we weigh and measure the chicks. Removed from the sack used to ferry them down, the one or two gawky piles of tufty white down, with their enormous legs, feet and talons, lie limp in the bottom of the boat. With their head and neck lowered, they clearly hope that if they remain inert we will pass them by, not at all like the feisty chicks of a Peregrine Falcon (*Falco peregrinus*) or Nankeen Kestrel (*F. cenchroides*), which hiss and strike at

PETER COOK/AUSCAPE

White-bellied Sea-Eagles often carry prey back to a favourite feeding spot. This one holds a file snake in its feet, and tears and slices with its sharply hooked beak, eating the soft parts and some bone. The remains are left to be taken by other scavengers or litter the ground around the perch.

FRANK WOERLE/AUSCAPE

An adult Sea-Eagle attends her two mottled brown nestlings in a lofty gum tree overlooking water. The chicks grow fast, reaching full weight before their first flight at just ten or so weeks of age.

you with their talons.

The Sea-Eagles usually lay two eggs and both may hatch, but most often only one young survives to fledge. This is because the second-hatched chick may be killed by its older sibling in what is often called the 'Cain and Abel struggle', after the biblical brothers. In some eagles siblicide is obligatory, but in Sea-Eagles the second chick may survive. The outcome may well depend on the size difference between the two, but this has not been studied.

Despite their siblicidal tendencies, the chicks are quite incapable of looking after themselves and are brooded by the female almost continuously for the first few days. She then broods less and less until they are about 30 days of age, when she perches near the nest during the day and only broods at night. During this time, the male does almost all the hunting and delivers prey to the female, which tears it up and feeds it to the chicks. Later, both parents hunt and drop food at the nest for the chicks to eat unaided. At about eight weeks of age the chicks practise wing-flapping and at nine weeks they take short flights but return to sleep at the nest. A week later they leave the nest for good, but stay with their parents for a few months until they learn to hunt for themselves.

STUDIES IN VICTORIA, TASMANIA AND South Australia have shown that there is cause for concern for the Sea-Eagles in those States. Adults tend to desert eggs if disturbed, causing reproductive failure, and young Sea-Eagles in particular are prone to poisoning, shooting and electrocution. In Tasmania, many juveniles become fatally oiled while scavenging in offal pits at fish-farm processing factories. Nevertheless, destruction and disturbance of habitat are by far the biggest threats, causing loss of territories and also reduced breeding success. In Victoria, Roger Bilney (then at the Arthur Rylah Institute) and colleagues found that Sea-Eagles living in pasture with isolated trees produced fewer young (0.2 chicks per pair) than those in more natural, tall open forest (1.2 chicks per pair).

Only about 100 breeding pairs are estimated to occur in Victoria, concentrated in the Gippsland Lakes and Corner Inlet regions. As a result they are listed as rare, threatened by various human activities especially habitat destruction. Similarly, in Tasmania, they are being proposed for threatened status, mainly due to disturbance and loss of much of their preferred habitat to coastal development.

Despite these problems, the Sea-Eagle is secure nationally. This impressive raptor still commonly patrols the waters and shores of bays, inlets and islands around the entire Australian coast, and graces many larger inland lakes and rivers. Occasionally it can even be seen in settled areas such as Sydney Harbour and Lake Burley Griffin, as evidenced by my unexpected experience at the National Gallery. ■

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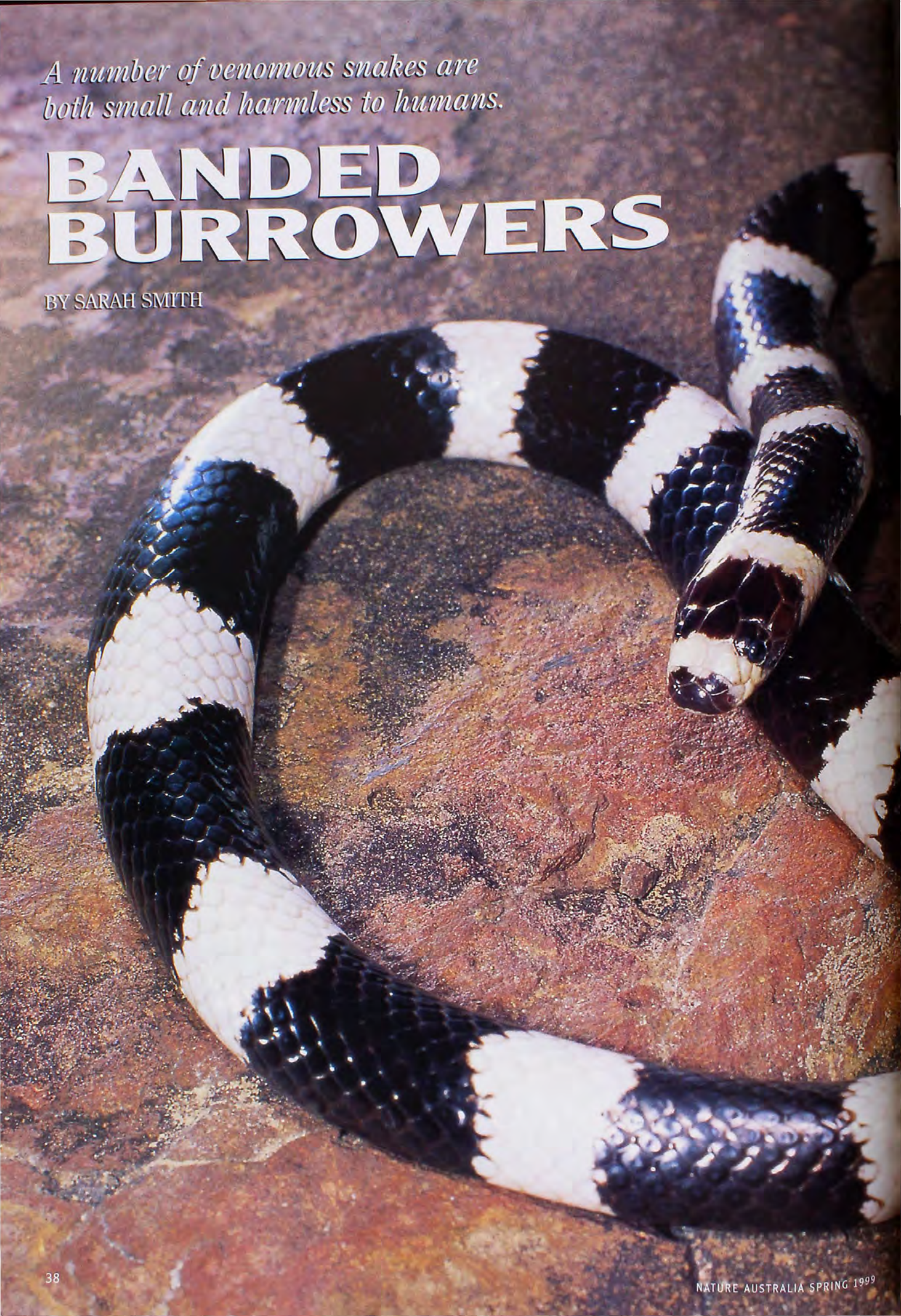
A number of venomous snakes are both small and harmless to humans.

BANDED BURROWERS

BY SARAH SMITH



Bandy-bandies, like *Vermicella annulata*, are not what most people think of when you talk about Australia's venomous snakes. Bandy-bandies are small, burrowing and nocturnal, and are extremely shy and secretive.

PAVEL GERMAN

AUSTRALIA'S SNAKES HAVE A reputation for being large, venomous and aggressive. While most aren't actually aggressive, many of the elapid snakes are large and venomous, and bushwalkers know all too well the adrenalin rush that comes from an unexpected encounter with one. But not all of Australia's venomous snakes fit this scary stereotype. A number of venomous snakes are both small (many less than 40 centimetres) and harmless to humans. To avoid predators, virtually all of these small species have taken on a nocturnal and fossorial (burrowing) existence, usually feeding on other small reptiles or even just their eggs.

Among the most striking of the small snakes are the bandy-bandies (genus *Vermicella*). Their catchy common name comes from the distinctive pattern of black and white bands around their body and head. This black-and-white colouration is probably used to warn off predators. Contrasting bands are also known to cause an optical illusion known as flicker-fusion. When a series of contrasting bands moves quickly, it is difficult for an observer to determine in which direction the object is moving. This illusion is particularly effective in dim lighting. So, at dusk or by moonlight, when bandy-bandies are most often active, the moving bands may confuse a predator long enough to allow the bandy-bandy to escape.

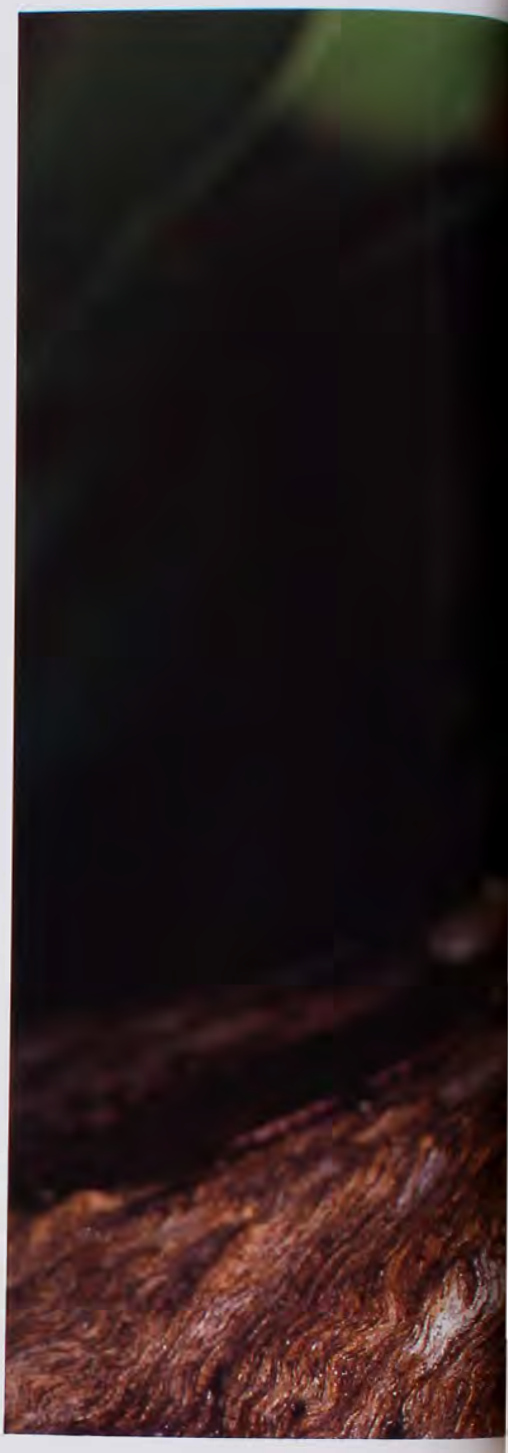
Black-and-white colouration is probably used to warn off predators. Contrasting bands are also known to cause an optical illusion known as flicker-fusion.

The other notable characteristic of bandy-bandies is the behaviour they display when threatened or disturbed. Bandy-bandies raise the middle part of their body off the ground in a loop, creating an impression that was described by early naturalists as "incongruous" and "most strange". Young bandy-bandies start using the body-looping display within a week of hatching. Although it may look amusing, this posture serves several functions. Not only do the snakes display their black-and-white warning colouration more effectively and generally make themselves look bigger, but they draw attention away from the head (the least expendable part!), which lies flat on the ground away from the predator.

Early naturalists knew that bandy-bandies ate other burrowing snakes, called blind snakes (family Typhlopidae), and assumed that they also ate lizards, frogs and insects. In 1980 Rick Shine, now at the University of Sydney, examined the stomach contents of preserved museum specimens and found that blind snakes are actually the only food bandy-bandies eat. While other elapids are known to eat snakes, bandy-bandies are unique because they specialise on one particular type of snake (although probably many different species).

Like the bandy-bandies that eat them, blind snakes are not only fossorial but

P.G. HORNER



The bandy-bandy species *V. multifasciata* was thought to only occur on the northern end of the Northern Territory–Western Australia border. However, this individual was found on Melville Island, just north of Darwin.

KEN GRIFFITHS

A bandy-bandy meets its match in a Green Tree Frog (*Litoria caerulea*).

they are fussy eaters too. Blind snakes follow the chemical trails laid down by ants and, once inside the nests, eat the eggs and larvae. They rely on their thick smooth scales that cover their entire body (including their eyes) to protect them from the jaws of adult ants. It is possible that bandy-bandies also use the ants' scent trails to find blind snakes. Bandy-bandies often eat blind snakes that are the same size as or even larger than themselves. Only a few bandy-bandies preserved in museum collections have anything in their stomachs, suggesting that, since they eat such large meals, they don't need to eat very often.

ONE INTRIGUING ASPECT OF BANDY-bandies that hadn't been explored was the large geographic range of *Vermicella annulata* (commonly referred to as *the* Bandy-bandy). The widely accepted distribution map suggested that *V. annulata* occurred virtually throughout Australia except for the north of the Northern Territory and southern Western Australia. (The other generally recognised species, known as the Northern Bandy-bandy *V. multifasciata*, occurs on the northern end of the Northern Territory–Western Australian border.) If the distribution map for *V. annulata* were correct, the snake would be almost unique in having such a broad range of habitats. A more plausible explanation would be if the map was based on a series of separate populations. In this case, the question of the relationships of these populations is important. How closely are they related? Is there any genetic exchange between

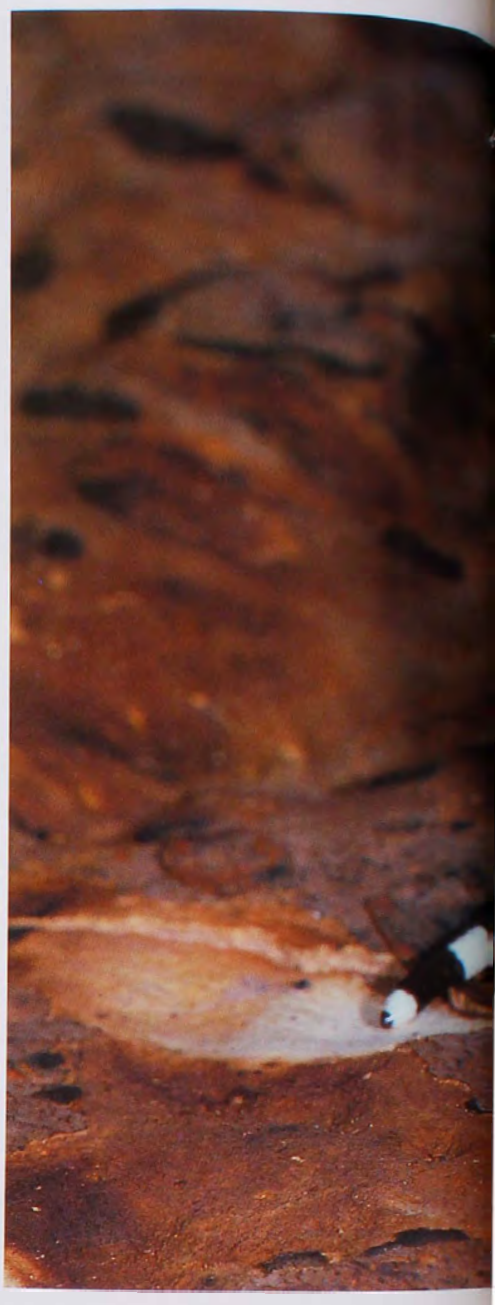
populations, or does '*Vermicella annulata*' actually represent a number of unrecognised species, each with a smaller geographic range? Ever since the genus was described 140 years ago, no thorough taxonomic study, using all the available specimens, had been carried out, so it was possible there were unrecognised species.

A number of techniques can be used to address the question of relationships. Morphological taxonomy classifies organisms based on their external, and sometimes also internal, appearance. By measuring and counting a number of characters on snakes from each population, the degree of difference between populations can be tested statistically. This is the way many new species of animals are discovered. Rather than the romantic notion of turning over a rock or opening a trap to find something new, most discoveries involve hours of work sorting through and examining the jars and drawers of museum collections.

Rather than turning over a rock to find something new, most discoveries involve hours of work sorting through museum collections.

Much of the information available about bandy-bandies is based on studies of museum specimens. Many people don't realise that, in addition to being a source of education and entertainment to the general public, natural history museums have a significant role in scientific research. One of the most important resources museums provide is their collections. The collections of preserved specimens include whole animals, skins, frozen tissues, skeletons and information about where and when they were collected. Each museum cooperates with the others by loaning and swapping specimens and information to be used by scientists. By studying these preserved animals (and plants) we can learn about their diet, reproductive habits, distribution and variation in size and shape, as well as how all of these characteristics change across time (both in yearly cycles and over long periods).

In 1994 Scott Keogh (now at the Australian National University) recognised the significance of the large distribution of *Vermicella annulata* while working on his PhD into the relationships of Australian elapids. At the time, I was in the second year of my science degree at the University of Sydney and, as a keen would-be biologist, was thrilled at the chance of working on a 'real' research project. Scott designed the project, decided what characters we needed to look at, organised loans of museum specimens, and showed me how to find and measure the important characters. Using material from the Australian Museum and also other natural history collections throughout Australia, we had a total of 425 intact specimens of *Vermicella* to study.



A bandy-bandy (*V. annulata*) displays the characteristic defence posture of these snakes, which involves throwing the middle part of its body off the ground and into a loop.

BANDY-BANDIES
Vermicella spp.

Classification
Order Squamata, family Elapidae, genus *Vermicella*. Currently 5 spp. recognised: *V. annulata, V. multifasciata, V. intermedia, V. snelli* and *V. vermiformis.*

Identification
The only black-and-white banded land snakes in Australia, distinguished from the black-and-white banded sea snakes (*Laticauda* spp.) by the absence of flattened tail. The 5 spp. are identified by geographic area, body length and number of bands. Females generally longer than males (av. female length 55 cm, av. male length 40 cm).

Distribution and Habitat
The genus occurs over most of the eastern and northern parts of Aust. *Vermicella annulata* makes up the largest continuous population along the east coast and north-west to north-eastern corner of the NT, *V. intermedia* occurs in Darwin and Humpty Doo area, *V. multifasciata* on the WA–NT border (with one specimen from Melville Island, just north of Darwin), *V. snelli* in the Pilbara, and *V. vermiformis* in Alice Springs area. Due to their nocturnal and burrowing habits, specific habitat preferences unknown.

Biology
Nocturnal and burrowing. Most often seen active on warm nights after rain. Diet consists entirely of blind snakes. Characteristic defence display involves raising middle part of body off ground, to show off warning colours, hide the head, and make snake look bigger.

Breeding
Lay 2–10 eggs between Nov. and Jan. Incubation period approx. 60 days.

Status
Unknown.

KEN GRIFFITHS

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

Bandy-bandies are fussy eaters and will only dine upon blind snakes (typhlopids).

PAUL HORNER

After much research and study it is now accepted that there are five distinct species of bandy-bandy instead of two. One of the newly recognised species is *V. intermedia*, which occurs in the Darwin and Humpty Doo area of the Northern Territory.

The two species that were recognised when we started, *Vermicella annulata* and *V. multifasciata*, were distinguished from each other by both their geographic distribution and the presence or absence of two scales between the internasals (the scales containing the nostrils). We examined specimens for this and several other characteristics, including the number and position of certain head scales, length of body and tail, head length and height, eye size, number of scales around the body, number of bands on the body and tail, thickness of the black and white bands, and the colour pattern on the belly (banded or mottled). We also looked for any stomach contents and counted the num-

G. HAROLD

Nocturnal and burrowing, bandy-bandies are most often seen active on warm nights after rain when they go in search of blind snakes to eat.

ber of eggs of pregnant females.

After several months of staring down a microscope, counting and re-counting scales, measuring tail and body lengths, and determining the sex of dead snakes, followed by several weeks entering all the data into a computer spreadsheet, we found there were five morphologically different groups of bandy-bandies. These can be distinguished from each other using easily measured characteristics, including body length and the number and width of the bands. Several of these morphological groups occur in geographically separate areas, while some overlap. This evidence suggests that the 'groups' we identified are actually five species of bandy-bandy (see box for distributions).

THE LONG PERIOD DURING WHICH THE taxonomy of bandy-bandies was not questioned is typical of the history of taxonomy for many Australian snakes and may be critically important for the planning of conservation strategies. Before this study, the Action Plan for Australian Reptiles, on which most conservation decisions about reptiles are based, listed *Vermicella annulata* as 'rare or insufficiently known'. The new species we have described are even less well known than *V. annulata* and need to be further studied before their conservation status can be assessed.

Although taxonomy is regarded by some scientists as an uninteresting and slow science practised by socially challenged biologists in museum basements, the importance of this field is increasingly being recognised. With the recent social and political focus on understanding, documenting and preserving biodiversity, a crucial role of taxonomy has been highlighted. Simply put, it is impossible to know where species occur or how common they are if we don't know they exist. Studies such as ours show the additional danger of relying on accepted taxonomy without questioning the methods used to arrive at these considerations.

The bright colour pattern, unusual defensive display and specialised diet of bandy-bandies make them an easily recognisable component of our fauna. Despite this, by using relatively simple techniques, we have found there to be actually five species of bandy-bandy, not just two as was previously thought. Nothing is known of the basic biology of most of these species and, until further studies are done, their conservation status will also remain unknown. These small inoffensive snakes demonstrate that there is still much we don't know about even the most distinctive of Australian snakes. ■

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Sarah Smith is currently undertaking a PhD, on the evolution of live-bearing reproduction in lizards, at the South Australian Museum and University of Adelaide.

JOHN WOMBEY/AUSCAPE

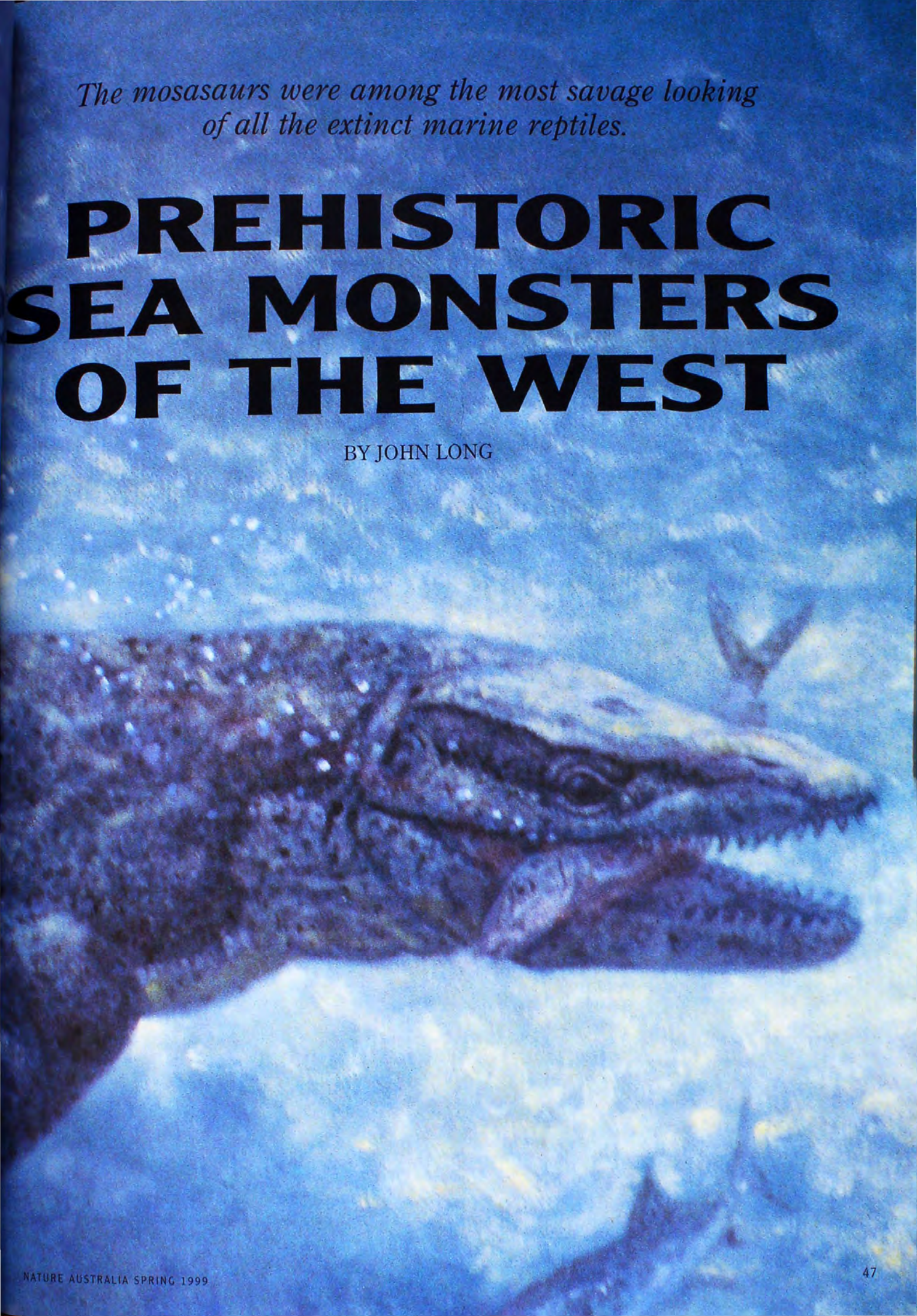
The distinctive stripes on a bandy-bandy may help it avoid predators by creating an optical illusion when the animal moves. Known as flicker-fusion, it results in the inability to tell whether the snake is moving forwards or backwards.

A mosasaur, *Plioplatecarpus* sp., feeds on a school of fish. Mosasaurs are only known in Australia from three sites on the western margin of the continent where Late Cretaceous marine rocks occur.

The mosasaurs were among the most savage looking of all the extinct marine reptiles.

PREHISTORIC SEA MONSTERS OF THE WEST

BY JOHN LONG



WE DUG DEEPLY INTO THE soft crumbly sediments, and bones started to fall out from everywhere. Within a few hours we had excavated nearly 50 bones, and then found about a dozen more from sieving the soft scree downslope of the fossil site. I was ecstatic. This was the first time ever that an articulated skeleton of a sea-going reptile from the 'Age of Dinosaurs' had been found in Western Australia. The site near Kalbarri, 600 kilometres north of Perth, was discovered a year earlier in 1991 when fourth-year geology students, during the course of their mapping project, stumbled upon some bones in an eroding gully. When they brought the bones to me at the Western Australian Museum, I could see from their good preservation and close position on the skeleton that they had probably come from a single animal. I was immediately hooked and decided to visit the site myself to look for more of the skeleton.

Until these finds, only isolated bones of reptiles from the Mesozoic Era (230–65 million years ago) had turned up in Western Australia. How to extract these articulated skeletons from their remote location therefore posed a new challenge for me. We spent a whole day excavating and securing our booty by covering the skeletons with strips of wet hessian dipped in plaster of Paris. On hardening, these plaster jackets would protect and retain the position of the bones until they could reach the laboratory. However, after completing the job we quickly realised they were far too heavy to carry down the rocky cliffs to our campsite, some three kilometres away. Alex Ritchie, from the Australian Museum, was present on the dig and it was he who suggested we use a helicopter. That evening we drove into town and I rang up Paddy Berry, the Head of Natural Sciences at the Western Australian Museum. I explained that we had probably made one of the biggest discoveries ever for the State and that we had no other option but to hire a helicopter to get the specimens back safely. He gave us the OK and the next morning a bright yellow chopper landed near our camp and flew us to the site. Within half an hour we had loaded all the specimens, including two more partial skeletons and a dinosaur bone, into the helicopter and were on our way back to Kalbarri with our precious cargo.

I was ecstatic. This was the first time ever that an articulated skeleton of a sea-going reptile from the 'Age of Dinosaurs' had been found in Western Australia.

ONE HUNDRED AND TWENTY MILLION years ago, while dinosaurs were roaming around on land, the seas abounded with swimming reptiles that occupied similar niches to those of marine mammals today. The three main groups living in the Cretaceous Period were the long-snouted ichthyosaurs, the plesiosaurs, and the giant marine lizards, the mosasaurs. Ichthyosaurs had a fish-like body with a triangular dorsal fin and upright tail flukes, and they probably shared similar lifestyles to today's dolphins. The plesiosaurs 'flew' through the water using their front and

PHOTOS: JOHN LONG

When dinosaurs roamed the land, the seas were full of marine reptiles. Excavations near Kalbarri have led to the discovery of a number of fossilised skeletons of these swimming reptiles.

Above: Alex Ritchie and John Long load precious plaster-jacketed specimens from the second site at Kalbarri into a helicopter. Right: The upper arm bone (humerus) of the short-necked pliosauroid discovered near Kalbarri, Western Australia.

rear flippers. One group had long necks and small heads (plesiosauroids) and the other had short necks and generally longer snouts (pliosauroids). The gracile long-necked plesiosauroids may have used their long necks for extending their heads into shoals of fishes; today they have no modern equivalent. The small, short-necked pliosauroids were the sea-lions of their day, whereas larger pliosauroids, such as the ten-metre-long *Kronosaurus queenslandicus* from Queensland, could be likened to our modern Killer Whales. Mosasaurs had large heads with many teeth and lizard-like bodies with powerful front and rear paddles. They propelled themselves through the water using their long tails. So what were the new specimens we had dug up from Kalbarri?

After a few months of painstaking preparation in the lab using a small vibrating chisel, the bones were identified as belonging to a small, short-necked pliosauroid in the genus *Leptocleidus*. The genus is also known from 120–100 million-year-old deposits in England, South Africa and Coober Pedy in South Australia. The Coober Pedy specimen is the famous opalised pliosauroid dubbed 'Eric', now housed in the Australian Museum (see *Nature Aust**. Summer 1990–91 and Spring 1993). It is currently being studied by Natalie Schroeder (Monash University) who has shown

**Previously ANH*

that it is distinctly different from the one found in Western Australia.

British palaeontologist Arthur Cruickshank and I have recently described and named the new Kalbarri species *Leptocleidus clemai*. We named the species in honour of Perth businessman John Clema who not only donated the funds to mount the expeditions, but also keenly participated in several of the field trips. The specimens collected from Kalbarri belong to three separate individuals all about 2.5–3 metres long, making the species the largest in its genus. When the upper arm bones (humeri) are compared to those of 'Eric', it is clear how much larger and more robustly built the Western Australian species was. Move over 'Eric', the West Coast *Leptocleidus* is coming through!

Marine reptile bones were first described from Western Australia back in 1944 when fossil wood and bones were found during the excavation of a phosphate test-pit near the town of Dandaragan, about 150 kilometres north of Perth. The handful of bones consisted of both ichthyosaur and plesiosaur vertebrae, and some isolated plesiosaur teeth, of Late Cretaceous age (90 million years old). In the late 1950s a creek gully near Gingin, 90 kilometres north of Perth, yielded three small, insignificant-looking bones from a marine reptile. These were identified and described as belonging to a mosasaur, the first record of that group from Australia. The 90-million-year-old bones came from the front paddle, representing the ulna and two of the finger bones (phalanges), and the animal would have been about 2.5 metres long. In July 1991, Peter Bindon, an anthropol-

COURTESY JOHN LONG

The author, John Long, in the field cleaning a vertebra.

ogist at the Western Australian Museum, and I found another three mosasaur bones during a field trip to the Giralia Range just south of Exmouth Gulf. These three large vertebrae were excavated from 65–70-million-year-old sedimentary rock, representing the final stage of the Mesozoic Era. The bones came from the tail region of an animal

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Mosasaurs like these once swam the seas of Western Australia. Here, the ten-metre-long mosasaur *Tylosaurus proriger* is depicted attacking its much smaller relative, *Platecarpus* sp. This reconstruction is based on complete skeletons found in North America.

whose length was close to eight metres, a good size for a mosasaur.

The most recent discovery of a mosasaur in Australia came in late May 1998 when a field party from the Western Australian Museum found an associated series of vertebrae in an eroding creek gully near Dandaragan. A large vertebra of a long-necked plesiosaur had been uncovered two years earlier in a nearby paddock, so we were keen to get back to the region and investigate further.

We started the day at an outcrop of the Molecap Greensand, a green sedimentary rock, coloured by the mineral glauconite. It had been raining the night before, so we all spread out and began

clambering over the slippery, muddy creek gullies. Minutes later our technical assistant Danielle West came over to me with a large fossil bone in one hand and asked me if it was anything of interest. I yelled out to everyone that she had found a mosasaur bone. Then, as my gaze fell back to the gully, I was dumbstruck at seeing a row of bones just poking out of the top of the exposed creek bank. An hour or so later, we had excavated about ten large vertebrae, some very well preserved with the neural arch on top and wings for rib attachment on each side. The animal would probably have been at least ten metres long, making this Australia's largest and most complete associated skeleton of a mosasaur, although still not enough to allocate the beast to a genus.

The mosasaurs were among the most savage looking of all the extinct marine reptiles. They reached lengths of up to 15 metres, and had skulls with hinged lower jaws armed with many stout, pointed teeth. For many years, it was thought that their closest living relatives were the varanid lizards like our goannas. Recent work, however, by Monash University palaeontologist Michael Lee has shown that they were more closely related to snakes. In 1996 he and Mike Caldwell (Natural History Museum in Ottawa) described a 100-million-year-old primitive fossil snake (*Pachyrhachis problematicus*) from Israel that had small remnant legs. They noted close similarities with mosasaur skeletons and suggested that snakes evolved in the sea as swimming reptiles, and that both snakes and mosasaurs probably evolved from the same common ancestral group of reptiles.

Mosasaurs have an excellent fossil record from New Zealand, where several complete skulls have been recovered from Late Cretaceous marine rocks in the northern half of the South Island (Waipara River, Haumuri Bluff), and from a single site in the middle of the North Island (the Mangahouanga Stream). The New Zealand mosasaurs indicate that large forms like *Mosasaurus* and *Prognathodon* were widespread in the seas of the world. We know that mosasaurs ate ammonites, squid-like creatures that lived in buoyant coiled shells. Fossil ammonite shells have been identified with mosasaur bite marks that precisely match the outer tooth row and inner palatal teeth patterns of certain mosasaurs. The mosasaurs probably grabbed the ammonite and gently squeezed it between its hinged jaws until the shell cracked open, and then the juicy animal could be easily extracted. Some plesiosaurs also ate ammonites. The fossilised skeleton of a small pliosauroid from Japan had many ammonite 'beaks' (their hard mouthparts) preserved where its stomach would have been. Some mosasaurs, like *Globidens*, had rounded compressed teeth, forming nutcracker-like dentitions more specifically adapted for cracking harder shells. Australia has a good record of fossil ammonites (see *Nature Aust**. Summer 1987–88) but very few mosasaurs. Why is this so? The answer lies in the rarity of good Late Cretaceous exposures of sedimentary rock. These are only found in a few small areas in Western Australia, and coincide with Australia's only known finds of mosasaurs.

COURTESY JOHN LONG

The author, John Long, at a site near Dandaragan, Western Australia, where Australia's largest and most complete specimen of a mosasaur was found. The animal would have been at least ten metres long when alive.

The ichthyosaur *Platypterygius* sp., reaching seven metres in length, is shown here as a reconstruction based on nearly complete skeletons found in Queensland. Its remains have also recently been discovered from Western Australia.

BY THE END OF THE MESOZOIC ERA, 65 million years ago, all the great sea-going reptiles (the ichthyosaurs, plesiosaurs and mosasaurs), as well as the dinosaurs and flying pterosaurs and

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COURTESY BRIAN CHOO

many other groups of animals and plants, had become extinct. It is hard to come up with a simple scenario that explains the observed pattern of extinctions of dinosaurs, pterosaurs and marine reptiles, unless one regards it as a more complex set of events involving many minor changes to the environment, changes that were steadily building up during the last tens of millions of years before the extinctions themselves. There is geological evidence that a massive meteorite struck the Earth at the end of the Cretaceous, but many palaeontologists tend to regard this event more as the straw that broke the camel's back rather than the primary cause of the extinctions.

If we consider the major changes to the plant communities throughout the Cretaceous Period, the huge variations in sea levels, the changes in oxygen content of the atmosphere and so on, a bigger picture of large-scale environmental chaos emerges. Maybe the impact event triggered off the final series of environmental catastrophes, such as acid rains, long periods of darkness and volcanic eruptions, all of which no doubt contributed towards sounding the final death knell for many groups of Cretaceous organisms. The great marine reptiles, and also the pterosaurs, probably succumbed to changes in the composition of the marine fauna, as these creatures seemed dependent upon fishes and marine invertebrates as their prime sources of food. ■

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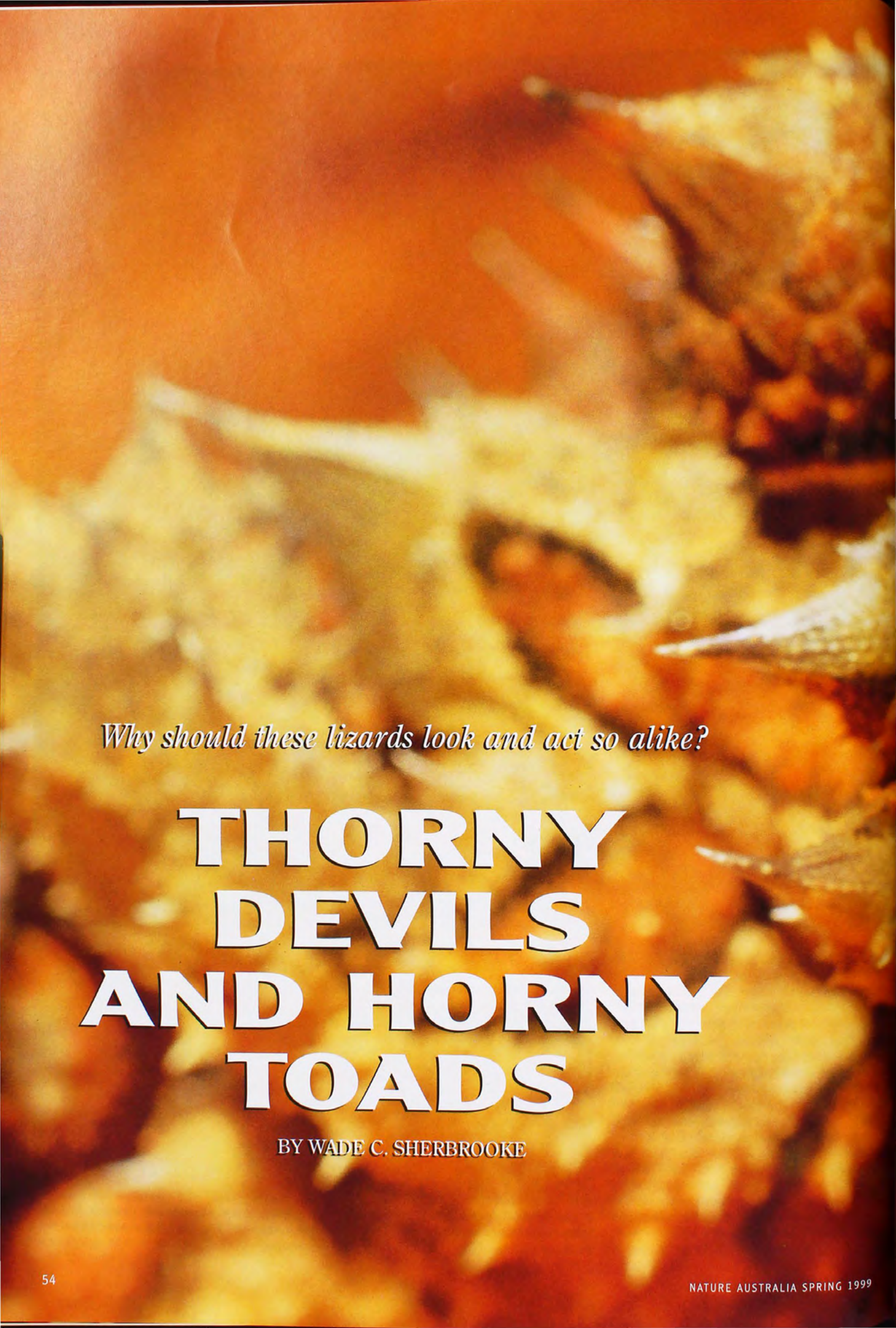
Dr John Long is Curator of Vertebrate Palaeontology at the Western Australian Museum, and the author of several popular science books. His research focuses mainly on fossil fishes and Mesozoic reptiles.



Why should these lizards look and act so alike?

THORNY DEVILS AND HORNY TOADS

BY WADE C. SHERBROOKE

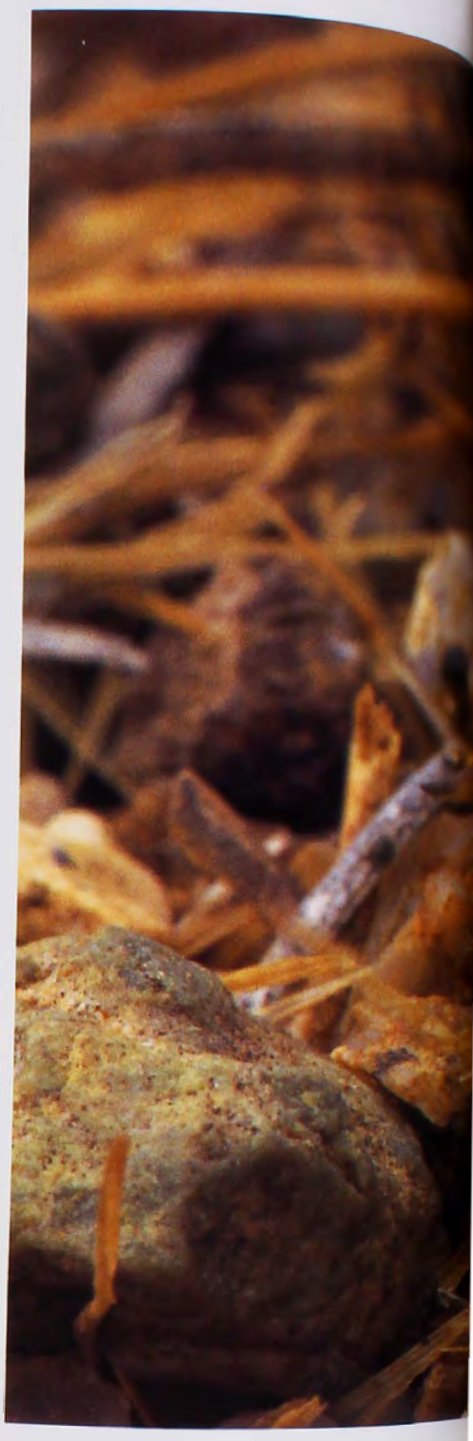
Australia's Thorny Devil is certainly a distinctive-looking reptile with some very unusual behaviours, but it is not alone—the horned lizards of North America appear to share many of the same bizarre characteristics.

KATHIE ATKINSON

AUSTRALIA'S THORNY DEVIL would have to be one of the most distinct and bizarre-looking lizards in the world. Living in the deserts of central and western Australia, its spectacular spiny armament, coupled with its habit of freezing in the face of the enemy, have made it one of the best photographed lizards around. And, from study of the portraits alone, one may be forgiven for assuming its formidable armoury is matched by size. Not so. Thorny Imp might be a better name, for this amazing creature will sit gently in the palm of my hand.

But the Thorny Devil (*Moloch horridus*) is not alone in its bizarre appearance. A band of 13 look-alikes occurs on the other side of the world—on the North American continent, in arid and montane habitats from Canada down through the western United States to southern Mexico. These are the horned lizards or 'horny toads' (genus *Phrynosoma*), and not only do many of the species bear an uncanny resemblance to Australia's Thorny Devil, but they also share many of its weird behaviours.

Why should these lizards look and act so alike? They are not close relatives. Thorny Devils belong in the dragon family (Agamidae) and horned lizards in the family that contains the iguanas (Iguanidae, although some people now place them in their own family, Phrynosomatidae). Could these thorny, horny lizards, on two widely separated continents, have independently evolved their extraordinary features to cope with similar environmental pressures? Such 'convergent evolution' is known to have occurred between many non-Australian eutherian (placental) mammals and Australian marsupials, the classic example being wolves and the now-extinct Thylacine. Have Thorny Devils and horny toads similarly converged? To answer this we need to look closely at each of these two lizard groups to see just how similar their features really are.



BOTH THE THORNY DEVIL AND HORNED lizards have spiny body scales or horns, particularly around the head and extending above the eye. This is usually the end that is attacked and swallowed first by a predator, especially those eating their prey whole, like snakes. The horned lizards have a crown of horns arranged along the back of the head and directed up and backwards over the neck. The neck of the Devil has an enlarged knob with a thorny spine point-

Both Thorny Devils and horned lizards sport spiny armaments around their heads as a means of defence. When threatened, they bend their head forward to expose their horns. Top: When touched on the head, a Thorny Devil responds by lowering its head and exposing its thorny knob, which acts as a pseudo-head. Bottom: A Regal Horned Lizard (*Phrynosoma solare*) raises its crown of thorns as a defensive reaction to the same stimulus.

WADE C. SHERBROOKE

JOHN CANCALOSI/AUSCAPE

A Regal Horned Lizard emerges from its overnight retreat below the sand and pebbles.

ing to either side. If this armament has convergently evolved for protection from predators in both types of lizard, then we might expect to see them use it in a similar fashion.

Indeed, both Thorny Devils and horned lizards react to threats by puffing themselves up with air, thus increasing their size and causing their body scales to become more erect and rigid. In both lizard types, I have found groups of microscopic structures on the scales surrounding the base of each enlarged spine. When examined under an electron microscope, these structures proved to be specialised nerve endings for touch, suggesting a tactile function, possibly during defence, for the spines.

If a Thorny Devil is touched on the head or a bird swoops at it, the lizard lowers its head between its front legs so that its neck knob is extended forward. This otherwise non-functional structure is now converted into a pseudo-head with spines, potentially expendable if bitten off, and difficult to bite or chew. Better to lose your hump than your head! Horned lizards similarly bend their head forward when threatened. This action puts the horns on the back of their head into an upright position, making a vertical bite by a potential predator dangerous to its fleshy mouth lining and enlarging the girth of the lizard's head to thwart swallowing. So spiny armament around the head in both types of lizard is associated with similar behavioural responses that help avoid predation, supporting the idea of their convergence.

Of course the best defence of all is to avoid being seen in the first place. Both Thorny Devils and horned lizards are noted for their ability to freeze in place for long periods of time if they see a potential predator. The visual cover of the stationary lizards is further enhanced by camouflage. By having skin with colours that match the surrounding environment and patterns that disrupt the typical lizard form, Thorny Devils and horned lizards are masters of cryptic design. Some scientists have suggested that the Devils may even be mistaken for dead spiny plants, and the smallest horned lizard species, the Round-tailed Horned Lizard (*P. modestum*), mimics the form, colour and shadow pattern of rocks in its stony habitat. It even hunches up its back to appear more stone-like. Other horned lizards have a row or two of elongated fringe scales around the sides of their flattened bodies. These eliminate tell-tale shadows on the soil, enabling them to visually blend into the background surface.

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

A Thorny Devil attempts to run across a dry salt lake. An aversion to running, which would attract the attention of predators, is something else that Thorny Devils and horned lizards have in common.

THORNY DEVIL
Moloch horridus

Classification
Family Agamidae, genus *Moloch* (only 1 described species). (Moloch was the tribal god of the Ammonites, who required sacrifice of human children by fire.)

Identification
Conical spines and modified scales on head, back, tail and legs distinguish it from any other Australian reptile. Fat, rotund and slightly depressed body. Snout–vent length 9 cm.

Habitat
Sand plains, spinifex desert and arid scrub of central and western Aust.

Distribution
Occurs from extreme western Qld across lower portion of the NT and southward throughout much of western SA into WA, where it occupies all but the extreme southern and northern portions of the State.

Breeding
Lays 3–10 eggs at the bottom of a tunnel excavated by female. After the eggs hatch, the young may eat the egg shells, before tunnelling out to the surface.

Behaviour
Remains motionless for long periods of time to avoid detection by predators. Moves by a distinctive forward-and-backward jerky locomotion pattern.

Diet
Restricted to ants, mostly of the genera *Iridomyrmex* and *Crematogaster*.

This feature is not present in the heavier-bodied Thorny Devils, although their pronounced spines may serve a similar form-disrupting function. So in this first line of defence (avoiding visual detection), many details seem convergent, while others are not.

Both Thorny Devils and horned lizards are capable of rapid colour changes, occurring within several minutes. From my studies on several horned lizard species it is clear that colour change is regulated by hormones from the brain, and that it plays a role in maintaining body temperature, through darkening and lightening, when the animals are thermoregulating in the sun. Changing colour may also play a role in camouflage, as shadows change throughout the day. Thorny Devils change colour by physiological means as well, but the mechanisms remain unstudied. Whether or not the colour changes are for similar purposes also remains unstudied, although Devils do seem to darken when entering shaded areas. A comparative assessment would certainly shed light on another aspect of possible convergence between the two lizard types.

If detected, most prey animals try to

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make a run for it (the second line of defence) and, only if cornered or outrun, do they actively defend themselves. As far as running for it is concerned, Thorny Devils and horned lizards again have something in common—they are both bad at it. The Devils resort to a slow-motion, jerky, forward progression of movements seemingly designed to maintain the first line of defence (no motion) while really moving away. Horned lizards can be induced to flee, but only for a short distance, at which point they freeze to re-establish their protective visual camouflage. In these behaviours we see two distinctly different forms of locomotion for escaping a potential predator.

And what about the third line of defence, that of resistance? How do these lizards compare when they are cornered? There is very little information on how Thorny Devils react to natural predators, which might include Wedge-tailed Eagles and other raptors, Australian Magpies, cuckoo-shrikes, butcherbirds, crows, Dingoes, goannas and snakes. Essentially all the recorded defensive responses have been towards humans and these have involved the head-down–spines-up approach. In contrast I have worked rather extensively with the Texas Horned Lizard (*P. cornutum*) and monitored its responses to a variety of predators. The resistance strategies employed by these lizards are very different depending on the capabilities of the attacker. They vary from flattening their back and using it as a defensive shield against carnivorous Grasshopper Mice, Roadrunners, Leopard Lizards and whip snakes, to running from rattlesnakes, and to squirting a stream of blood droplets from a sinus around their eye into the mouth of an attacking Dog or Kit Fox (see *Nature Aust.** Winter 1993). The blood-squirting response has never been reported being used towards other predators. The blood appears to have a repulsive taste to Kit Foxes and probably other canids but, as I discovered when I first tried it (the things we do for science!), it was not particularly offensive to my taste buds. In fact, had I been blind-folded, I would have assumed it was my own blood. Nothing like this blood-squirting defence has ever been reported for the Thorny Devil, nor any other reptile or animal for that matter.

Nothing like this blood-squirting defence has ever been reported for the Thorny Devil, nor any other reptile or animal for that matter.

Apart from the head-tilting motions and inflation of their spiny bodies, in the third line of defence there seems to be no convergence between Thorny Devils and horned lizards. But then we don't know much about interactions between Thorny Devils and their natural predators. Interestingly, horned lizards seem to have lost the tail-shedding, predator-escape ability common in their rapidly running iguanid relatives. Thorny Devils also lack this ability, but in their case tail retention during attack is the general, inherited condition in dragons (agamids). Since we do not know why horned lizards lost tail-shedding as an escape mechanism, it is difficult to envi-

JOHN CANCALOSI/AUSCAPE

Thorny Devils and horned lizards are both masters of cryptic design. This Regal Horned Lizard from the Sonoran Desert in Arizona blends perfectly with its rocky background and so avoids detection by predators.

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

sion this loss as a convergent adaptation. Not all similar features are necessarily convergent adaptations.

IN A BOOK PUBLISHED IN 1897, NATURALIST W. Saville-Kent reported on several aspects of the 'York Devil' or 'Mountain Devil' as it was known in Western Australia at the time. He noted that its diet consisted of minute ants, "small black evil-odoured". He also noted that the living lizard species that bear the strongest resemblance to these Devils are the North American "Horned Toad[s]". So struck was he with the physical resemblance, and not knowing what the diet of horned lizards was, he predicted that "*Phrynosoma*, in common with *Moloch*, is an anteater". He was right, and perhaps lucky, as not all ant-eating lizards are cryptic and spiny. Most importantly, though, Saville-Kent opened our minds to comparing features of these unusual lizards.

More recently, Eric Pianka (University of Texas, Austin) and colleagues have looked in detail at potentially convergent aspects of the lives of one horned lizard, the Desert Horned Lizard (*P. platyrhinos*), and the Thorny Devil. They related the need for camouflage, body armour and a broad ample body to their diet of ants, with one of the predictions being that the diet, poor in nutritional value, requires eating large numbers of ants, which would expose them for long periods of time to predation. Among several predicted considerations if convergent evolution is a major force here, is that both the Desert Horned Lizard and the Thorny Devil should have relatively large stomachs. Their investigation showed large stomach size to be true for the horned lizard, but not the Devil. Ants in the diet, it seems, are not good predictors of body form.

Pianka's examination of the feeding behaviour in Thorny Devils and a number of horned lizard species showed that ants make up 100 per cent of the diet of Thorny Devils, while horned lizards vary considerably in the percentage of their prey consisting of ants (47–97 per cent). On both continents these lizards eat ants by protruding the tongue, picking each ant up individually in the mucous covering, and returning the tongue and ant to the lizard's mouth. This method of feeding is more like that of toads and frogs than of most iguanid and agamid lizards, and seems, in these lizards, to be a convergent adaptation for feeding on small mobile prey.

North American ants are different from those in Australia, and biologists have found one group of large seed-eating ants, of the genus *Pogonomyrmex*, to occur frequently in the stomach of horned lizards. These ants are noted for their venomous, wasp-like sting and, as demonstrated by Pat and Justin Schmidt (Southwestern Biological Institute in Tucson) and me, horned lizards show biochemical resistance to the venom. Nothing comparable has been studied in the Thorny Devil.

Heavy infestations of thin, white nematodes are found in the stomachs of many

JOHN CANCALOSI/AUSCAPE

Above: Like the North American horned lizards, Australia's Thorny Devil loves to eat ants. Above right: A Flat-tailed Horned Lizard (*Phrynosoma mcallii*) in its daytime retreat.

horned lizards. In the 1950s, Sheridan Lee (University of Minnesota) discovered that these nematodes have a very 'tight' life cycle involving infection of both the horned lizards and their *Pogonomyrmex* prey. Every time a lizard eats ants, it exposes itself to reinfection by larval nematodes potentially harboured in the ants. Female nematodes drop out of the digestive tract of the lizard, desiccate on the ground, and are subsequently found by foraging ants and carried back to the colony to be fed to the developing larvae. Thus adult ants infect the next generation of ants with eggs carried in the body of the dried female nematode. And when members of this next generation of ants mature and leave the nest to forage, they may be eaten by a horned lizard . . . and the cycle continues. Lee might have predicted that

HORNED LIZARDS

Phrynosoma spp.

Classification

Originally placed in family Iguanidae, which has since been split into several families, including Phrynosomatidae (sand lizards of North America and horned lizards). Horned lizards in the genus *Phrynosoma* (13 or 14 spp. currently recognised). (*Phyrnosoma* from the Greek *phryne*, a toad, and *soma*, body.)

Identification

Bony, skin-covered horns along back of skull and a wide, depressed body form distinguish them from other North American lizards. Size, colour pattern, and number and length of horns vary between spp.

Habitat

Arid and semi-arid habitats, including sandy areas of western North America to southern Mexico, but also found in montane habitats such as open areas in coniferous forests and pine-oak woodlands. The different spp. may be restricted to very different habitats within one geographic area or, where their distributions overlap, several species may occupy the same landscape.

Distribution

From extreme south-western Canada southward throughout western United States, west of Mississippi river, into northern Mexico, where they occur widely in the desert and dry plateau lands southward to the warmer dry climates of northern Central America, near the border with Guatamala.

Breeding

Both egg-laying and live-bearing spp. are found in the genus. Live birth tends to occur in spp. with northern or high-elevation distributions. Brood size varies from 3 to 48.

Behaviour

Remain motionless when approached, only running when about to be stepped on. From tissues around the eye, some species squirt blood, which exits the tear duct and provides an effective defence against Kit Foxes and other canids.

Diet

All spp. eat ants, some almost exclusively. One group of ants commonly eaten are the seed-harvester ants of the genus *Pogonomyrmex*, large ants with a forceful bite and a wallop of a sting. Various other insects and arthropods eaten as well.

WADE C. SHERBROOKE

A Texas Horned Lizard adopts a characteristic rain-harvesting stance in a rainstorm—its back is arched and flattened and its mouth is opened and closed rhythmically. Although the Thorny Devil doesn't favour any particular rain-harvesting position, both lizards drink the rainwater that is drawn to their mouth via narrow channels between the individual body scales.

Thorny Devils, and other ant-eating lizards, would harbour a parasite with a similar two-host life cycle. However, recent studies by Hugh Jones (University of Western Australia) in the Great Victoria Desert failed to identify any parasite with a life cycle closely linked to Thorny Devils and their ant prey.

AS EARLY AS 1923, NATURALISTS IN Australia were claiming that Thorny Devils absorb water through their skin, as amphibians are known to do. Amazingly, if a Thorny Devil was placed in a saucer of water, the water moved up the skin to the top of the animal's head. But in 1962 Peter Bentley and William Blumer (University of Western Australia) reported that the water moving up the skin surface was not absorbed by the skin, but transported to the corners of the lizard's mouth, which was opened and closed slowly, and then ingested (they demonstrated this by using blue-dyed water). Later it was shown that the water flows in narrow channels between individual scales, utilising the physical forces associated with capillary action.

Native Americans were impressed by their strange horned lizards, attributing to them great healing powers for coping with the hidden forces of the natural world.

In 1976, I had begun studies on Texas Horned Lizards in Tucson, Arizona, and had several in an outdoor enclosure near my kitchen window. Early in September there was a typical monsoonal afternoon shower. As I looked out the window through the falling rain I could see that two lizards had raised and arched their backs, spread their legs, and were slowly opening and closing their mouths. Flat out like a lizard drinking? It sure looked like it. Was this another example of convergence with the Thorny Devil? Years later (1990), with the results of dyed-water experiments, scanning electron micrographs of skin scales and further observations, I was ready to say yes (see *Nature Aust.** Winter 1992). And it is convergent too with an agamid lizard from Asia (*Phrynocephalus helioscopus*) in which a similar water-collection system was found.

But there was still one aspect of the lizards' drinking behaviour I was unsure about. Both the Texas Horned Lizard and the Asian *Phrynocephalus* adopt stereotyped rain-harvesting stances, in which they position their bodies to maximise the surface area exposed to the falling rain. None of the published records on Thorny Devils had addressed this question. So off I went to the Northern Territory (Alice Springs and Uluru National Park) and Western

**Previously ANH*

Australia (Bungalbin, north of Southern Cross) in search of Thorny Devils standing in the rain. Luck was with me, for I found Devils and rain at all three places. But the ones I saw had no particular way of standing in the rain, suggesting this aspect of their behaviour is not convergent with the other two types of lizard.

Unexpectedly, another discovery was made during my visit to Bungalbin. Philip Withers (University of Western Australia) had been tracking Thorny Devils (for metabolic studies) by attaching thread bobbins to the lizards' tails. Accompanying him on one of his thread-following expeditions, immediately after a light shower of rain, I found several Thorny Devils that had been rubbing their bellies in the upper wetted crust of sand (see *Nature Aust.** Autumn 1995). Presumably they were using the capillary sucking-forces generated between their scales to pull water out of the sand into the interscalar channels on their skin for drinking. Earlier I had noticed a similar behaviour in Texas Horned Lizards, but at the time had no idea of its purpose. Withers, a physiologist, subsequently demonstrated in laboratory studies that Thorny Devils have the ability to remove water from damp sand in this fashion. However, it is yet to be confirmed for horned lizards.

So, are Thorny Devils and horned lizards examples of convergent evolution? Certainly there are some features in these lizards that appear to have evolved to meet the same purposes—avoiding detection by predators, thwarting biting attacks, catching ants and harvesting raindrops—yet there are others that do not. Larger convergent patterns may be strikingly similar, but in detail they may differ. Whether or not we choose to say these lizards have converged (in some ways they may have diverged as well) is somewhat subjective. But my subjective, overall evaluation is that Thorny Devils and horned lizards have remarkable and unusual resemblances that are largely due to natural selection having caused them to evolve similar solutions to similar problems of survival.

Other people have looked at these lizards in different ways. Aborigines from central Australia have seen Thorny Devils as food and have referred to them in the Dreamtime story of Miniri, in which they are reminders of how the small creatures acquired their colour markings. In North America too, Native Americans were impressed by their strange horned lizards, attributing to them great healing powers for coping with the hidden forces of the natural world. These strange beasts appear able to impress us all. ■

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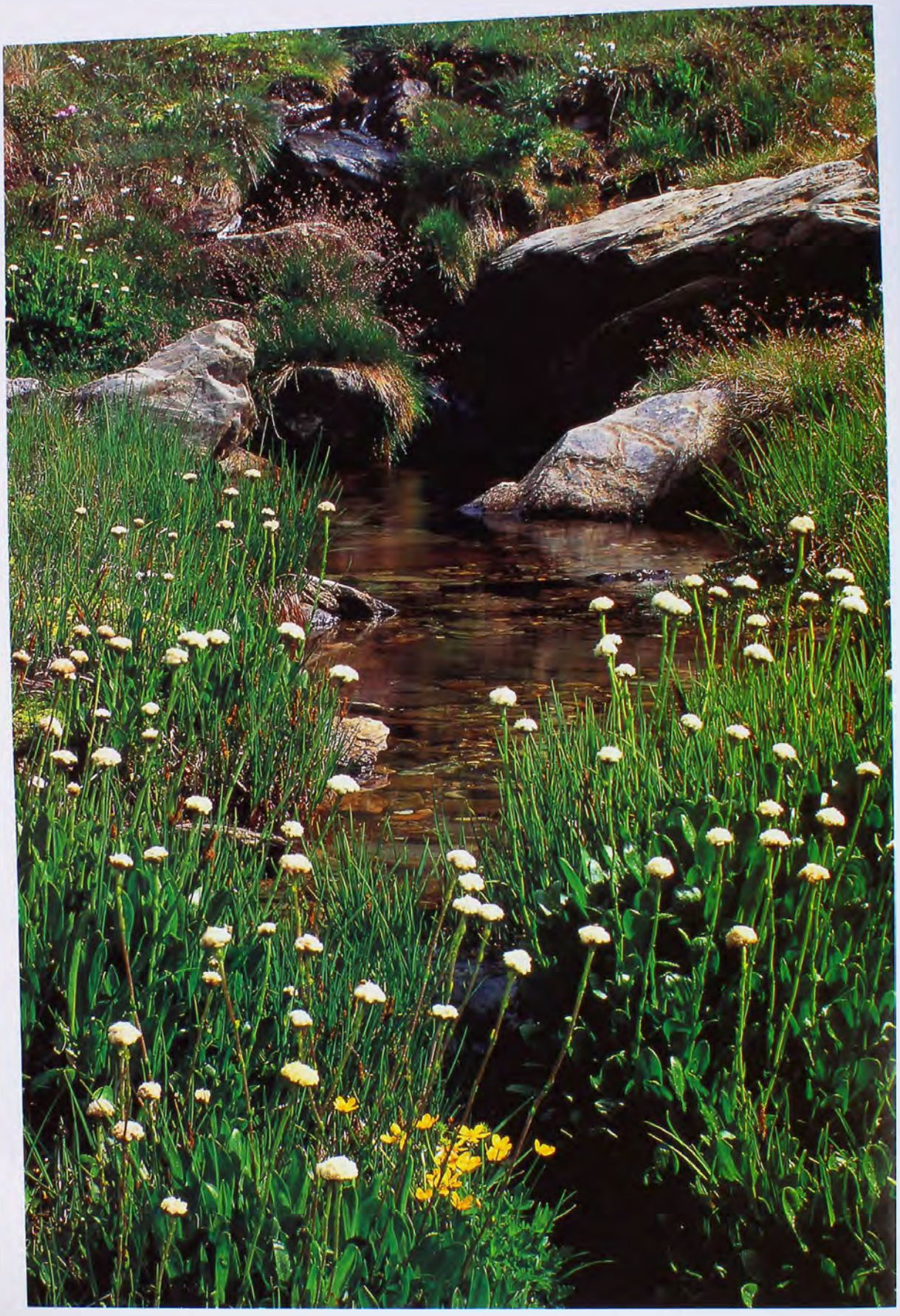
JOHN CANCALOSI/AUSCAPE

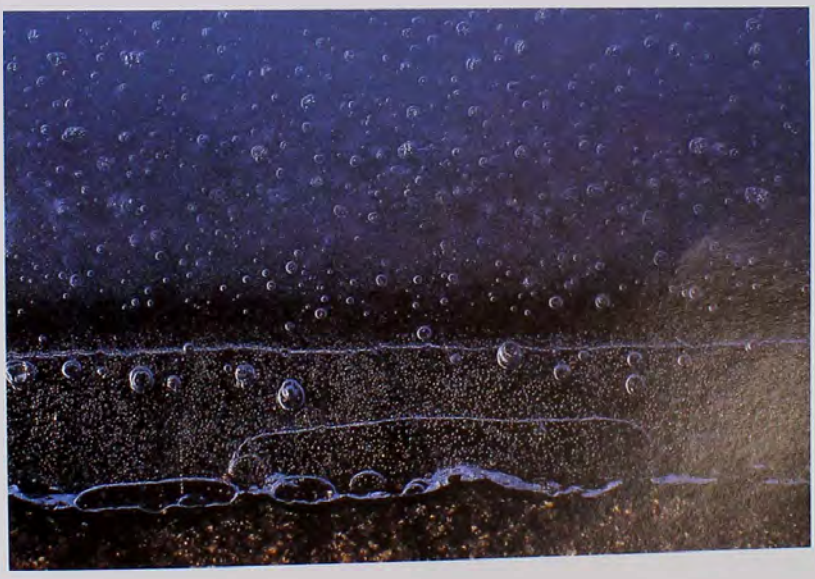
A Regal Horned Lizard from the Sonoran Desert in Arizona.

P H O T O A R T

ALPINE SEASONS

BY ROSS DUNSTAN
RAD EXPOSURES





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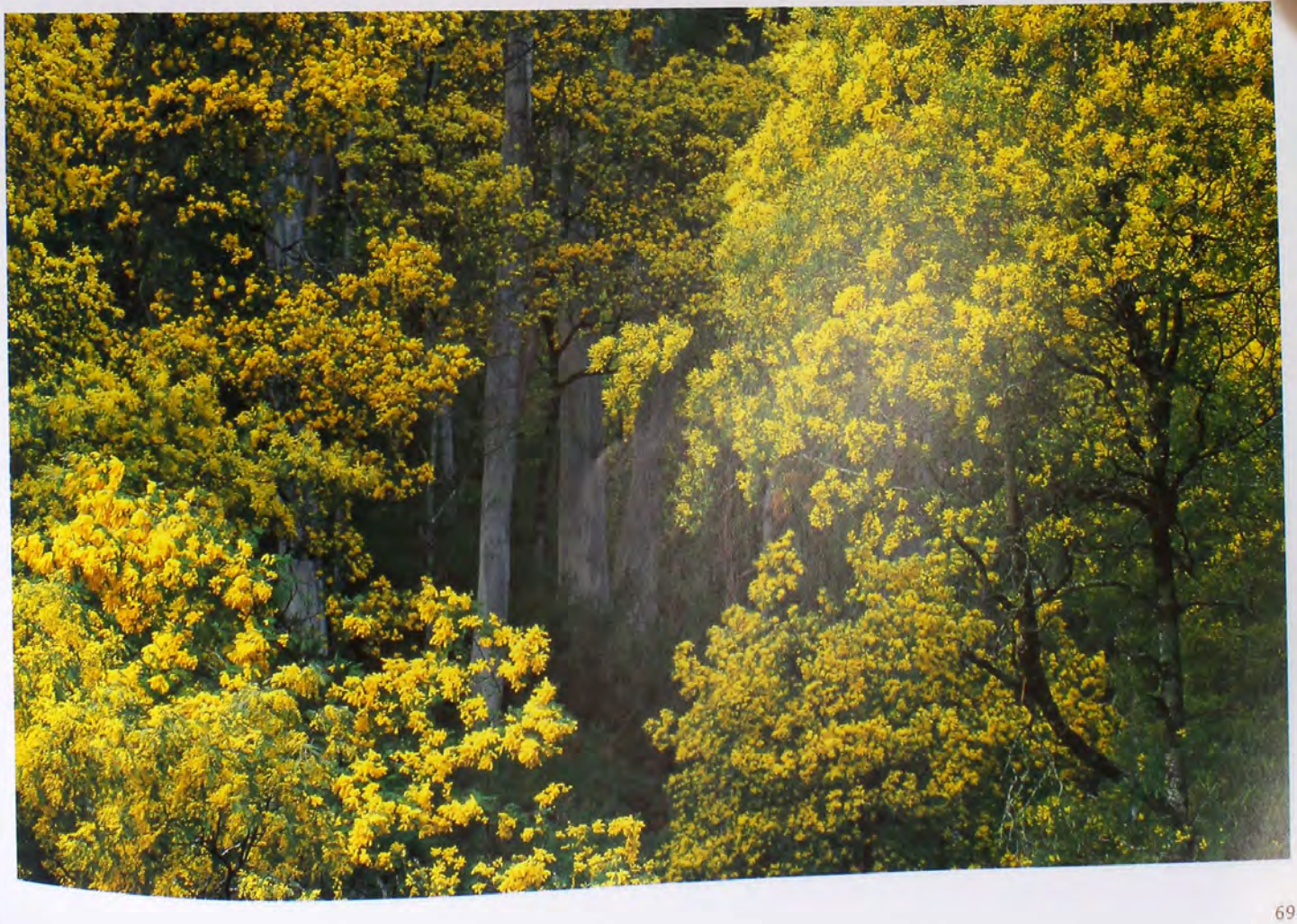


The next morning, an amazed, bug-eyed me shot out of my office for the lab to search for more!

BUGS AND BONES IN ANCIENT STONES

BY MICHAEL ARCHER

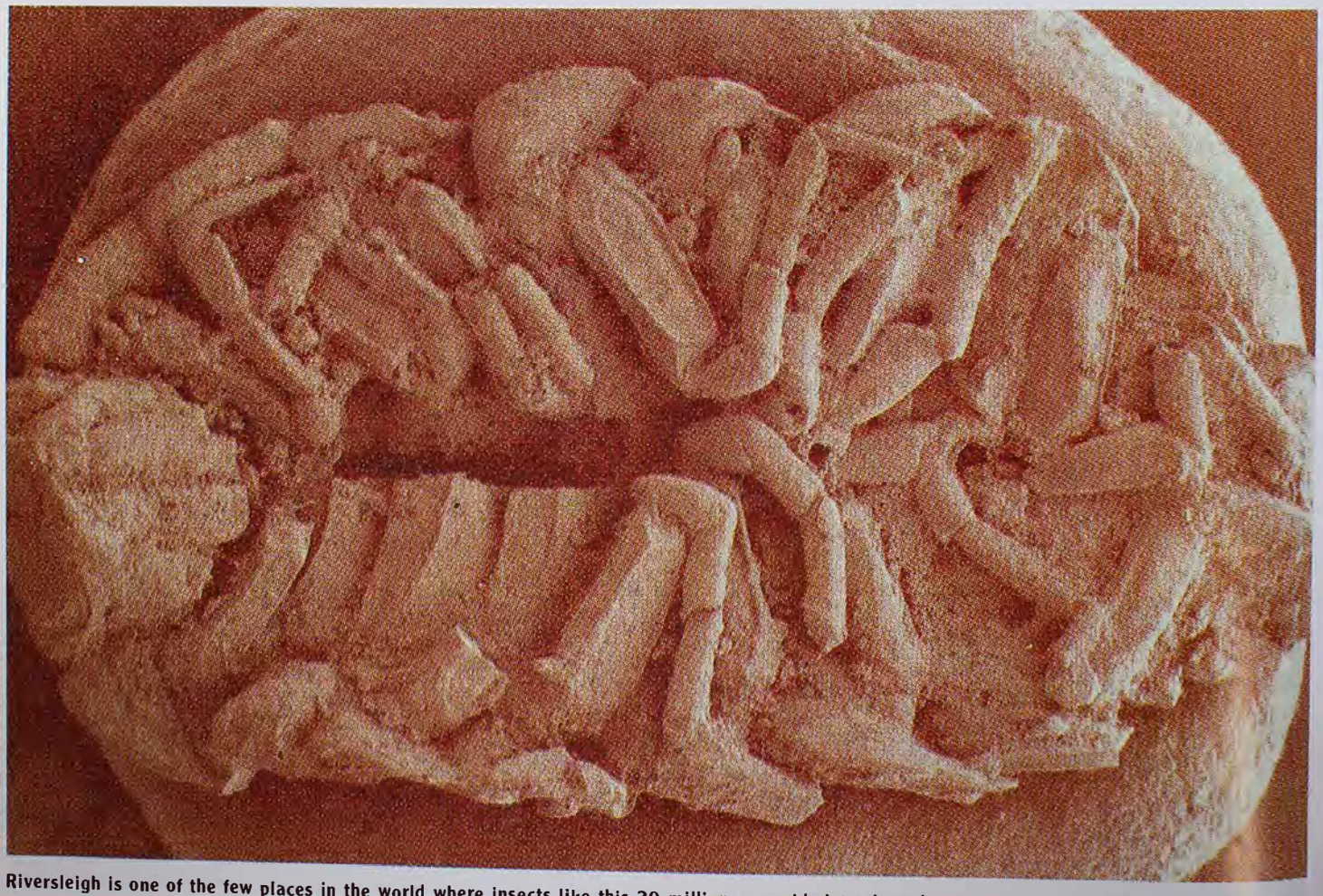
IN "INDIANA JONES AND THE TEMPLE of Doom", Steven Spielberg knew just how to tickle us with terror as the leading lady crept through the dimly lit labyrinthine passages of the Temple. Thinking she'd broken a finger nail, she lit a lamp to reveal an army of the biggest and most extraordinary tropical insects crawling up her arm. Her shriek alone was enough to make the hair stand up on viewers' arms!

Disquieting they may be to urbanised humans, but insects by the billions, flying, crawling, swimming, hunting, munching, mating, pollinating or becoming someone else's dinner, are among the most important components of all natural ecosystems. Without them, the world we now depend on would collapse from the bottom up. And this has probably been the way of things since the first insects wandered out on land at least 400 million years ago.

Yet when the World Heritage limestone deposits of Riversleigh (Queensland) began to tip out their treasures of spectacular skulls and skeletons, we hardly gave a thought to the insects that must have vastly outnumbered the vertebrates in those ancient forests. After all, while bones and teeth are made of hard substances that readily preserve in limestone, insects are squishy and mushy, poor candidates for fossilisation unless in amber or as wafer-thin organic traces on the flat surfaces of shales—certainly not full-bodied, three-dimensional fossils in limestone.

So it came as no surprise to Steph Williams (University of New South Wales) that I snorted in disbelief when he told me over the phone that he had just found what looked like an uncrushed fossil insect in the acid-insoluble concentrate from Riversleigh's Upper Site. I suggested it must have been some insect that had dropped into the acid vat when he opened the lid. Rather than argue with me, he simply mounted the impossible object on a pin under my microscope, and went home for the night. The next morning, apologising profusely to Steph along the way, an amazed, bug-eyed me shot out of my office for the lab to search for more!

And more there were! Once we retrained our eyes to look for bits of bugs instead of mammal teeth, fossil arthropods of all sorts suddenly became visible. There were insect larvae with pairs of cone-shaped bumps that we dubbed 'Venus de Riversleigh', weevils (curculionids), ommatid and possible histerid beetles, caddis-flies (trichopterans) and even slaters (isopods), all about 20 million years old. Most had either lived in or near a freshwater pool that had also trapped the bones of hundreds of vertebrates including more than 64 different



COURTESY REED BOOKS 'RIVERSLEIGH'

Riversleigh is one of the few places in the world where insects like this 20-million-year-old slater have been preserved uncrushed.

kinds of mammals.

Among the largest of the fossilised arthropod bits were dozens of sections of millipedes. Rolling them over in my hand brought back nostalgic memories of wet afternoons in the lowland rainforests of Borneo. Here we were always surrounded by a spectacular array of millipedes; from elongate black giants over 20 centimetres long to others that, when disturbed, coiled themselves into impenetrable, perfectly spherical balls the size of a 20-cent piece.

But the most amazing aspect of the Riversleigh fossils was not the fact that they represented a new and rare look at the evolutionary history of Australia's terrestrial arthropods; it was their incredible condition. They were uncrushed, three-dimensional ambassadors of prehistory, so exquisitely preserved that fossilisation had even led to replacement of muscles inside their body cavities!

How did this happen? Some of the researchers investigating the Riversleigh fossils (Ian Duncan and Derek Briggs of the University of Bristol, and Rick Arena of the University of New South Wales) have concluded that the key to this extraordinary process was the humblest of beasts—bacteria. The dark sediments of Upper Site indicate that the base of the ancient forest pool in which the arthropods accumulated had been starved of oxygen, a condition that inhibited the normal processes of decay. Instead, bacteria interacted with high phosphate levels in the water, rapidly replacing the arthropods' soft tissues with carbonate fluorapatite, a hard mineral that took on the form, at a microscopic level, of the tissues it replaced. The same process also resulted in fossilisation of the bacteria themselves, their tiny round bodies being present in the thousands within the uncrushed bodies of the fossilised arthropods. Even the microscopically fine filaments of fungi, the first ever found in the bodies of fossilised terrestrial animals, have been preserved in these fossils.

What most amazed the palaeontologists who examined this material were the eyes. Their multifaceted surfaces were as detailed as those of any living invertebrate. While some eyes revealed structures common to a wide range of insects, others were extremely rare. The eyes of one of the beetle larvae, for example, most resembled those of trilobites, marine arthropods that went extinct before the dawn of dinosaurs.

One of the only other places in the world where similar three-dimensional preservation of insects in phosphate has occurred is the Quercy phosphates of France. These French fossils, however, have all been recrystallised or encrusted and are no match in terms of preservational detail for the Riversleigh material. It is interesting that some of the distinctive types of fossil bats known from the Riversleigh deposits are also found in the Quercy phosphates, perhaps a reflection of similar prehistoric environments that may in turn have contributed to the way in which the arthropods were fossilised by phosphatisation.

Since Steph's discovery of arthropods at Riversleigh, we have found other sites from the same region that preserve

They were uncrushed, three-dimensional ambassadors of prehistory.

equally unexpected things. One of the most delightful was Dunsinane Site, now the research focus of Rick Arena. Although the age of this site is still uncertain, inside fist-size nodules Rick has been finding plant material (the only such deposit at Riversleigh), including well-preserved leaves with each layer of cells still intact, aerial roots, twigs and wood, and even perfectly preserved fruits. And caught among these antiquarian leftovers of an arthropods' banquet are some of the guests who stayed behind, including possible jewel beetles (buprestids), weevils, termites and even scales that once decorated the elegant wings of butterflies. With hundreds of nodules yet to be cracked open, there's no chance that Dunsinane has revealed all of its secrets.

Steph's chance discovery opened our eyes to the fossil arthropods that were under our noses all along. We hadn't seen them because we didn't expect to see them. Like so much of the biological world that surrounds us, living as well as extinct, it is often invisible to us until someone else shows us how to look. ■

Further Reading

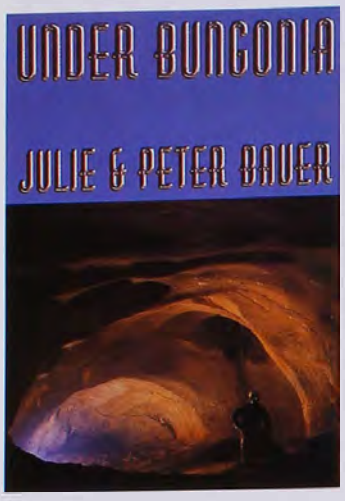
Arena, D.A., 1997. The palaeontology and geology of Dunsinane Site, Riversleigh. *Mem. Qld Mus.* 41: 171–179.

Duncan, I.J. & Briggs, D.E.G., 1996. Three-dimensionally preserved insects. *Nature* 381: 30–31.

Duncan, I.J., Briggs, D.E.G. & Archer, M., 1998. Three-dimensionally mineralized insects and millipedes from the Tertiary of Riversleigh, Queensland, Australia. *Palaeontology* 41: 835–851.

Michael Archer is the Director of the Australian Museum and Professor of Biological Science at the University of New South Wales. His major research interests are the fossil faunas of Riversleigh, north-western Queensland.

REVIEWS



Under Bungonia

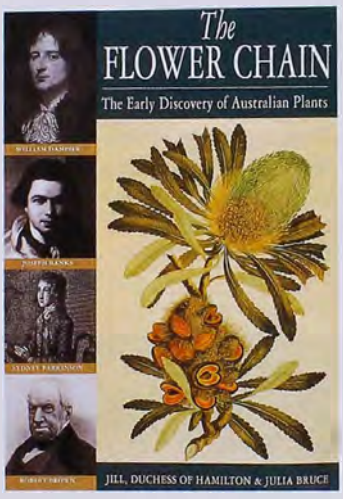
By Julie and Peter Bauer. JB Books, NSW, 1998, 284pp. plus maps. $45.00rrp.

Under Bungonia is a second, much-updated cavers' guidebook and compilation of scientific information on the caves of the Bungonia State Recreation Area, located near Goulburn in the Southern Highlands of New South Wales. Bungonia contains some of the deepest and most extensive caves in the country, in addition to remarkable surface scenery including the famous limestone gorge.

In general scope the book follows *Bungonia Caves* (Sydney Speleological Society, 1972), published to document a natural heritage threatened by limestone mining. *Under Bungonia* contains ten chapters on scientific studies by the nine supporting authors, covering knowledge of geology, regional geomorphological evolution, 'foul air', speleobiology and hydrology. The other major component of the book, resulting from a complete resurvey of the area, is an inventory of all 190 known caves that includes maps, passage descriptions and equipment requirements. Smaller-scale A1-size maps of ten frequently visited caves come with a surface map marking cave entrances in a separate pocket.

The clear and detailed cave maps alone make *Under Bungonia* indispensible to those with a recreational or research interest in the Bungonia Caves. These are complemented by a thorough evaluation of scientific knowledge of the caves with an appropriate geological bias towards ideas on cave evolution, making it a valuable educational resource. It is well illustrated with numerous colour photographs and diagrams.

—Tony Allan
Consultant Geologist



The Flower Chain: The Early Discovery of Australian Plants

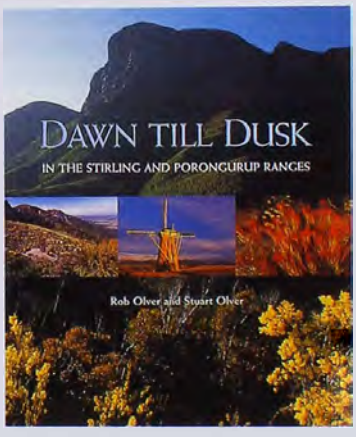
By Jill, Duchess of Hamilton and Julia Bruce. Simon & Schuster, NSW, 1998, 160pp. $39.95rrp.

The flower chain could simply be described as a chronology of early Australian botany beginning with the first recorded landings by the Dutch in 1606. It is, however, much more than a dry compilation of dates and facts; the authors have added a human dimension to many famous names associated with the discovery of Australia and our Australian flora.

Names of explorers such as Cook, Dampier, Hartog and Tasman, which I first learnt in third class, became people with ambitions and responsibilities, and the dangers that they and their crews faced, from storms to scurvy, became real. The difficulties that Banks and Solander and all the other botanists, horticulturalists and artists coped with while collecting, preserving, describing, illustrating and transporting the plants made me wonder at their ingenuity and dedication. The timeline of the discovery of our flora has given the authors the framework around which they have woven the personalities, politics and world events that were current at the time.

My only criticism is that there are a number of spelling mistakes in the Latin names. Despite this, it is a very readable book full of interesting information and with plenty of illustrations of both plants and people that help bring the history to life. I have greatly enjoyed reading it.

—Tracey Armstrong
Royal Botanic Gardens
Mount Annan, NSW



Dawn Till Dusk: In the Stirling and Porongurup Ranges

By Rob Olver and Stuart Olver. University of Western Australia Press, WA, 1998, 176pp. $34.95rrp. paperback, $45.00rrp. hardcover.

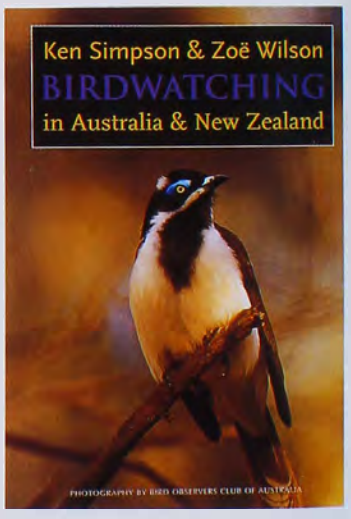
Rob and Stuart Olver's passion and enthusiasm for these remarkable ranges are articulately conveyed in this practical guide to the region.

The layout of the book is clear, covering the history, geology and climate, as well as the amazing biological diversity of both areas. The narrative is complemented by an array of superb photographs.

One of the main attractions for visitors to the Stirling and Porongurup Ranges, apart from the dramatic beauty of the mountains themselves, is the unique flora, which can be best appreciated by walking along one of the many tracks winding through both ranges. Bushwalking and rock-climbing opportunities in these mountains are comprehensively described from the easy to the more challenging. Average times for walks and climbs, as well as grade levels, make for quick assessment. Detailed but easy-to-read maps are a useful accompaniment.

Other attractions of the region such as the wineries, accommodation and recreational activities are outlined for the visitor to round off this useful publication, which I would like to have had when I visited the area last year. One final point is that an index would be a welcome inclusion in any future edition.

—Peter Sweedman
Royal Botanic Gardens
Mount Annan, NSW



Birdwatching in Australia and New Zealand

By Ken Simpson and Zoe Wilson. New Holland Publishers, NSW, 1998, 206pp. $29.95rrp.

There are a number of excellent field-identification guides currently available. However, getting a handle on those seemingly god-like skills of seasoned birdwatchers seems an almost unattainable goal to the beginner. These involve identifying birds based on characters such as behaviour, flight pattern and body shape, and require a greater understanding of the lifestyle of the bird.

Such skills generally come after years of practice, but fortunately for new birdwatchers, Ken Simpson and Zoe Wilson have decided to impart their years of accumulated skills and knowledge to the masses.

This book covers a broad range of topics such as birdwatching at home, breeding behaviour, record keeping and the effects of weather, as well as providing many helpful hints for identification. The reader is encouraged to take a more holistic approach to birdwatching, instead of simply identifying them based on their physical attributes. This view is supported throughout the book with many anecdotes and examples.

The conversational tone and logical setout of the book make it easy to read and the accompanying photographs make it an absolute pleasure. There is, however, a surprising lack of photographs of species endemic to New Zealand and this is my only disappointment. Although there are many examples in the text referring to such species, given the title of the book, I was surprised at their absence in the photographs. This is my only criticism.

Overall the book provides many interesting and useful facts, along with stunning presentation, and will be a great companion guide for new birdwatchers.

—Fiona Christie
Australian Museum

Wild and Free: Australia's Natural World Through the Lens of Nicholas Birks

By Nicholas Birks. New Holland Publishers, NSW, 1998, 178pp. $49.95rrp.

Farming and conservation don't have to be at odds. After a lifetime of working the land in South Australia, Nicholas Birks has successfully managed to combine the two. From the very beginning he only cleared part of his land and left a large area undisturbed, providing a sanctuary for wildlife.

The variety of animals portrayed in this book are amazing when you consider that this is the work of one photographer. Through patience and dedication Nicholas has taken candid photographs of animals within their landscape, unstressed and behaving naturally. Among the many wonderful photographs, we see Ghost Bats catching insects in mid flight, Malleefowl laying eggs, and the disastrous effects of feral animals on our native species.

Each photograph comes with an extended caption describing the animal or the situation when it was photographed and also a fact box containing the scientific name, habitat etc.

Nicholas Birks's understanding and interest in the wildlife around him has deeply enriched his life and, through his photography, others as well.

—K.L.

Wildflowers of the Snow Country: A Field Guide to the Australian Alps

By Ian Fraser and Margaret McJannett. Vertego Publications, ACT, 1998, 186pp. $24.00rrp.

This field guide will make a wonderful companion on summer rambles through the snow country of mainland Australia. The plants in the book are simply organised, first by flower colour and then by flower form (in other words, what colour is it and how many petals does it have?). This format makes it easy to use as you don't need to know anything about taxonomy, plant families or keys, all of which can confound and confuse the non-botanist. In addition, each species has its own colour illustration so you can easily discard options that don't match your unknown plant, helping you end up with the correct answer. (It is not uncommon with botanical keys to reach an outcome that is ludicrous, and to have to start again.) After you've identified your plant, the guide gives you general information on similar species in the area, which allows you to double check your choice, as well as a brief description of its habitat and distribution. This is a lightweight, practical and beautifully presented book that will be useful to people who want to find out more about the wildflowers they're seeing in the alpine country of Australia.

—Tracey Armstrong
Royal Botanic Gardens
Mount Annan, NSW

Australian Kangaroos: Magnificent Macropods

By Jill Morris and Lynne Muir. Greater Glider Productions, Qld, 1998, 48pp. $17.95rrp (softback).

Greater Glider Productions have published yet another aesthetically pleasing and scientifically accurate addition to their environmental art-book series. Author Jill Morris and illustrator Lynne Muir

have successfully collaborated to produce another gorgeous guide to add to previous editions, this time focusing on Australian kangaroos or, as they are rightly called in the title, magnificent macropods.

The book appears to have been written with older primary schoolchildren in mind. They are introduced to the topic of macropods by an interesting fact-filled four-page overview, which presents the subject matter in an accessible way. Any unfamiliar scientific words are explained in a glossary at the end of the book. Also included is a list of reference books that may be useful to the reader if he or she wishes to research a particular species in more depth.

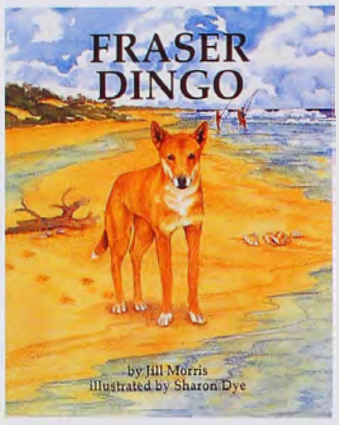
The bulk of the book consists of 17 double-page spreads each detailing, through text and illustrations, the appearance and habits of a variety of macropods. Every information report is written in a clear, interesting and lively way and is complemented by a scientifically accurate illustration of the macropod in question. Not only do the illustrations showcase each macropod to perfection, they also incorporate some of the flora and fauna typical of the macropod's home area. At the bottom of each illustration is an entertaining poem detailing some of the more unusual characteristics of the different species. Surrounding both the texts and illustrations are delightful borders that use an aspect of the habitat as their theme, such as wreaths of leaves. Embedded into the borders are small but clear maps showing the range of the macropod.

The illustrations showcase each macropod to perfection.

It is clear from the quality of both the text and illustrations that Morris and Muir have carefully researched their subject matter. They even go to the extent of including an addendum clarifying why they have included potoroos, bettongs, and Musky-rat Kangaroos in a book about macropods, when strictly speaking they belong to the family Potoroidae, a subgroup of the superfamily that contains kangaroos.

This book has been brilliantly illustrated and written in a simple, informative style that will encourage school librarians, teachers, parents and especially children to consider purchasing a copy. In fact, I have a sneaking suspicion that this book could form the basis of an environmental artbook collection if amassing has not already begun.

—Cheryl Hook
Australian Museum



Fraser Dingo

By Jill Morris and Sharon Dye. Greater Glider Productions, Qld, 1998, 24pp. $9.95rrp.

Author Jill Morris and illustrator Sharon Dye have collaborated to produce an attractive and instructive natural history book for children. Older primary schoolchildren shouldn't have any problems reading the text, but adult mediation would help emergent readers. The book introduces the reader to some fascinating snippets of information about Fraser Island Dingoes. For example, my nine-year-old was interested in the fact that Fraser Island Dingoes, due to their isolation, are perhaps the purest breed of Australian Dingo.

The book presents information about the Fraser Dingo using a variety of beautifully illustrated texts. There is an engaging narrative about the adventures that befall a young Dingo pup called 'Shortsocks', a short play about the problems associated with human visitors feeding Dingoes, an informative set of brief anecdotes about Dingo behaviour, four information reports and a basic map.

While I think it laudable that Morris has attempted to write a variety of 'user-friendly' text types for younger children, I do have a few pedantic quibbles about the structure of the reports and also the layout of the map. The three reports entitled "Finding Food", "Growing in Sand" and "Where Land Meets Sea" are really only partial reports. The information is not prefaced by an introductory paragraph identifying what the rest of the report is about and really only focuses on some of the descriptive aspects of information reports. The last report called "Fraser Island Dingoes" is a much better example of an information report. However, the final paragraph is written as an exposition, exhorting readers not to interact with Fraser Island Dingoes. Also, the map would greatly benefit by the inclusion of a key and linear scale, plus some information about where the island is located within an Australian context.

However, these are relatively minor criticisms. Overall the book is visually pleasing and contains many beautifully drawn images. It also includes useful snippets of information written in an easy-to-read format that is pitched at the right level for primary-aged children.

—Cheryl Hook
Australian Museum

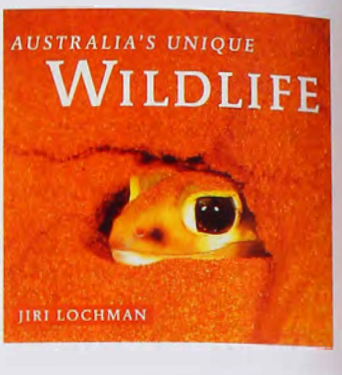
Australia's Unique Wildlife

By Jiri Lochman. New Holland Publishers, NSW, 1998, 128pp. $29.95rrp.

Wildflowers of Western Australia

By Jiri & Marie Lochman. New Holland Publishers, NSW, 1998, 112pp. $39.95rrp.

Jiri Lochman is a prolific and highly talented photographer, and I never cease to be amazed by the range of images in his collection. These books showcase both the wonderful photography of Jiri and Marie Lochman, and the rich diversity of Australia's fauna and flora.



Australia's unique wildlife can be enjoyed by people of all ages and backgrounds because the pictures tell the story. The introduction gives a brief description on the evolution of our animals and why Australia is unique. Each picture has a short caption, which includes the common and scientific name. This is an ideal book for getting a feel for the variety of animals and their locality.

Wildflowers of Western Australia

Wildflowers of Western Australia contains photography that is as good as it gets. This is much more than a picture book; it's a field guide and important reference specifically on the wildflowers of this region. The introduction contains things like the interaction of birds and animals with flowers, and a guide to understanding plant names. Each section is illustrated with a simple map, a description of the habitat, and how and where to look for certain flowers. It is beautifully designed and easy to read. I certainly wouldn't go to Western Australia without it.

—K.L.

SOCIETY PAGE

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

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NATURAL HISTORY

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Contact: Felicity Garde
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Perth, WA 6000
Ph: (08) 9427 2767
Contact: Kate Trinaistic
Membership fee: $12.00

Linnean Society of NSW
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Milsons Point, NSW 1565
Ph/Fax: (02) 9929 0253
Contact: Claudia Ford
Membership fee: $50.00 full members; $28.00 student or retired, $8.00 associate (no journal)

Field Naturalists' Association of Canberra
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Canberra, ACT 2601
Ph: (02) 9240 8152
Contact: Joyce Weeks
Membership fee: $20.00

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Marsupial Society of Victoria
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Kilsyth, Vic. 3137
Ph: (03) 9779 9418
Contact: Heather Niggendyker
Membership fee: $30.00 full; $35.00 family

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Contact: Carol Middleton
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Ph: (02) 9320 6225
Contact: Michelle Ball
Membership fees: $55.00 single; $70.00 household; $40.00 student/pensioner

REPTILES

SA Herpetology Group
C/- SA Museum
North Terrace
Adelaide, SA 5000
Ph: (08) 8204 8772
Contact: Helen Owens
Membership fee: $28.00

Herpetological Society of Qld Inc.
PO Box 5001
Kenmore East, Qld 4069
Ph: (07) 3202 9054
Contact: William McGrath
Membership fee: $25.00 single; $30.00 family; $20.00 student/pensioner

WILDLIFE PROTECTION

Australian Wildlife Protection Council
247 Flinders Lane
Melbourne, Vic. 3000
Ph: (03) 9650 8326
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Q&A

Black Blue-tongue

Q: *At a school display in Hobart we were handed a black blue-tongue that was really a Blotched Blue-tongue (*Tiliqua nigrolutea*), the only member of its genus found in Tasmania. Its appearance was quite extraordinary as the scales were all jet black, although the tongue was still blue and the mouth lining pink. How common is this colour variation in blue-tongues?*

—Bob Fletcher
Colebrook, Tas.

A: I am only aware of one other fully or near-fully melanistic blue-tongue, if melanism is treated as an occasional abnormality. Curiously, this was reported in a newborn Eastern Blue-tongue (*Tiliqua scincoides*) from Sydney, at about the same time that your letter arrived. Despite the apparent rarity of such melanistic blue-tongues, there is some precedent. In the Shingleback (*Tiliqua rugosa*), some populations in New South Wales (particularly those in highland areas) consist mostly or entirely of melanistic individuals, the melanism being normal in this case. Further, the Blotched Blue-tongue is a more heavily melanised species than other blue-tongues, with the melanin present in other species much more extensively spread over the body, reducing the pale markings to smaller blotches. Hence, it is probably not too difficult developmentally for the melanin to spread just a bit farther in your animal to obliterate the pale blotches.

—Glenn Shea
University of Sydney

Sponges

Q: *While walking along the beach, I came across a sponge that had been washed ashore. What exactly are sponges? Are they plants or animals, and do they float aimlessly or are they anchored somehow?*

—Angela Perry
East Hawthorn, Vic.

A: Sponges are animals that usually live attached to a hard surface in the sea, such as reefs or wharf pilings. They are found in many shapes and colours, although when washed up on beaches after storms they are usually dead and discoloured. Sponges are filter-feeders that draw water through small pores called ostia and expel it through large pores called oscules. This makes them very efficient pumps and a reef covered with sponges can pump thousands of litres of water in a day. The body of the sponge contains spicules, which are tiny rods of calcium carbonate or silica and give the sponge its shape. Some contain a matrix composed of an organic substance called spongin. More than 1,350 species of sponges have been found in Australian waters and in recent years the pharmaceutical industry has shown great interest in them as a source of biologically active chemicals.

—Penny Berents
Australian Museum

MICHAEL AW/NATURE FOCUS

A marine sponge (*Theonella cylindrica*).

COURTESY BOB FLETCHER

The unusual black blue-tongue from Tasmania.

The Eyes Have It

Q: *I have been reading a book on fossils in which some anapsid reptiles (*Procolophon *and* Elginia*) are shown as having a third eye. Was this actually an eye, a nerve centre, or what?*

—David Shera
Greenslopes, Qld

A: A number of fossil reptiles have a small hole in the middle of the top of the back part of the skull. Comparison with living reptiles, such as New Zealand's Tuatara, suggests that this hole was almost certainly for a third eye. Among Australian lizards this third eye, or parietal eye, is best seen in the larger skinks. If you look closely with a hand lens or a microscope you can see a little clear spot in the scales in

the middle of the back of the head. And if you look very closely you may be able to see what looks like a little eye staring back at you through this clear spot.

The parietal eye has some of the features of the eyes on the side of the head, the lateral eyes. For example, what you see as a dark circular area is the retina, the light-trapping part of the eye, and the clear area in the centre is the lens, the light-focusing part of the eye. The clear patch in the overlying scales is even similar to a small cornea, the protective outer part of the eye. In living species, and hence probably also in extinct species, the parietal eye is connected to the brain by a distinct nerve, just as the lateral eyes are connected to the brain by the optic nerve. However, unlike the lateral eyes, the parietal eye is probably not able to 'see' images, at least in living species. Instead it is probably a means for measuring the amount of solar radiation the animal has been exposed to. Knowing the amount of radiation received during the day may help regulate physiological processes such as thermoregulation and reproduction. Whether the parietal eye began its evolutionary history as an eye that could really see is not known.

Not all lizards retain the parietal eye. Many species that live in environments with little light or with more or less constant amounts of light lack a parietal eye. For example, many nocturnal species such as the geckos have lost it, and several tropical species such as some skinks in New Guinea and elsewhere have also lost it. Snakes, possibly because they went through a burrowing phase in their ancestry, also no longer have a parietal eye.

—Allen E. Greer
Australian Museum

T. & P. GARDENER/NATURE FOCUS

The mysterious eye of the Superb Fruit-Dove.

Split Iris

Q: *Why do fruit-doves have a split iris?*

—M. Barnett
Mackay, Qld

A: The pupil is actually not split at all. There is a dark spot on the iris of many fruit-doves, usually directly anterior to, and connecting with, the pupil. In species with light irises, this spot makes the pupil look much larger than it really is. The Superb Fruit-Dove (*Ptilinopus superbus*), with its yellow iris, has a particularly large and dark spot, which gives the impression of a greatly enlarged and elongated pupil.

—Walter E. Boles
Australian Museum

Answers to Quiz in Nature Strips (page 16)

1. Comet Tempel-Tuttle
2. Bryan Gaensler
3. Teeth
4. The transfer of an animal organ into a human.
5. Fins
6. El Nino Southern Oscillation
7. Eight arms, two tentacles
8. Yes
9. New Zealand
10. Cyanobacteria (blue-green algae)

P I C T E A S E R

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 *Australia's world heriatge* from the Australian Museum Shop. Winter's Pic Teaser was a close-up of bark.

It's a strange bed with unusual bed fellows.

SCIENCE AND THE MEDIA

BY RICHARD FULLAGAR & PAUL WILLIS

SCIENTISTS AND THE MEDIA are often at loggerheads. Scientists accuse journalists of sensationalism and misrepresenting the facts, while journalists accuse scientists of stuffiness and uncooperation. In the public eye, the media wields enormous power compared with any individual scientist or research institution. Such concentration of power leads to conflict. But the irony of this conflict is that both groups share a common goal: communicating ideas. Only with a greater understanding of the different forces and pressures that each group works under, will a solution to this conflict be found.

Australian people have been known for their heavy-handed criticism of the rich and famous, or of anyone who thinks differently; for cutting down tall poppies. Barry Humphries has already pointed out the irony of knocking the knockers; so we need to keep a sense of humour when looking at the interaction of science and the media. It is easy to imagine (if not recall) an episode of the TV program "Frontline" in which the similarly pretentious worlds of science and journalism are exposed. (Life rarely runs so smoothly as on ABC Radio's Science Show.)

In a recent article in *The Australian*, columnist Shelley Gare bemoans ". . . so many Australian journalists have the backbone, grace and generosity of a tapeworm . . ." and goes on to state that the "world of journalism . . . is an odd one. Jealousy, callousness and gracelessness abound." No need to dig out quotes from academic colleagues whose accusations of backstabbing, jobs-for-the-boys and political professorial expediency frequently fly. Professionals are good at putting down their colleagues, because they can. However, when the crossfire is interdisciplinary, as in between scientists and journalists, the gloves are off.

In June 1998 a debate was hosted by ABC's 'Science in the Pub' program at the Duke of Edinburgh Hotel, Sydney. Called 'Science and the Media: Friend or Foe?', scientists complained that journalists distort facts with sensational headlines, oversimplify complex arguments, and attack personalities by presenting scientific judgements as right or wrong. Journalists defended their practices by appealing to copy deadlines, the necessity of summarising and the need to reach a wide audience in an eye-catching, entertaining way. The objective communications of the scientist contrast violently with the personal stories needed for the general public. Attention-grabbing entertainment is crucial because the papers have to sell, but this also works against scientists who can get a bad reputation among scientific colleagues, sometimes jealous of media attention needed to raise the profile of poorly funded research divisions. Some research is dismissed by journalists as uninteresting or worthless, while some news reports are seen by scientists as fictional, defamatory or just plain wrong.

One effect of the media in general is that, with its small packages of second- and sometimes third-hand information, it tends to remove us from the real world. Ask any Australian to name a scientist, for example, and they're more likely to come up with Robyn Williams or Karl Kruszelnicki than Gustav Nossal or Peter Doherty. However, recent changes, particularly in the electronic media, are providing new opportunites for scientists themselves to write the news, and the scientist-as-communicator is becoming increasingly common. TV programs like the ABC's "Quantum" provide a venue for on-line discussion and debate between scientists, and between scientists and the public, and websites such as The Lab (*www.abc.net.au/science*) feature the communicating scientist in a variety of disciplines. The ABC also has a program called 'Science Fellows' where three working scientists get to spend six weeks with the media, learning science communication from the inside.

COURTESY LEIGH DEIGHTON

The things scientists do to sell science . . .

We live in a society where the intricacies and details of science have to be compressed into a five-minute package for general consumption.

Television, radio, websites, newspapers, magazines and other media are tremendously important not just for entertainment but for circulating and challenging ideas about science and society. Scientists, by the same token, should try more to add some fun or entertainment in their public communications. Many are doing it.

We live in a society where the intricacies and details of science have to be compressed into a five-minute package for general consumption. Can this be done without offending the scientists? It's a big ask but it can be done, provided both sides understand and respect the other. It's a strange bed with unusual bed fellows.

Dr Richard Fullagar is a Visiting Fellow in the Anthropology Division of the Australian Museum. Dr Paul Willis is a Trainee Science Broadcaster with the ABC.

The Last Word is an opinion piece and does not necessarily reflect the views of the Australian Museum.

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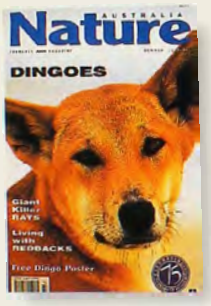

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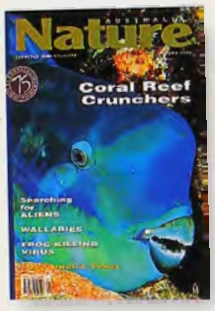

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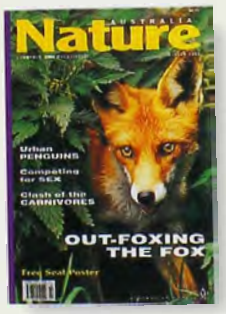

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