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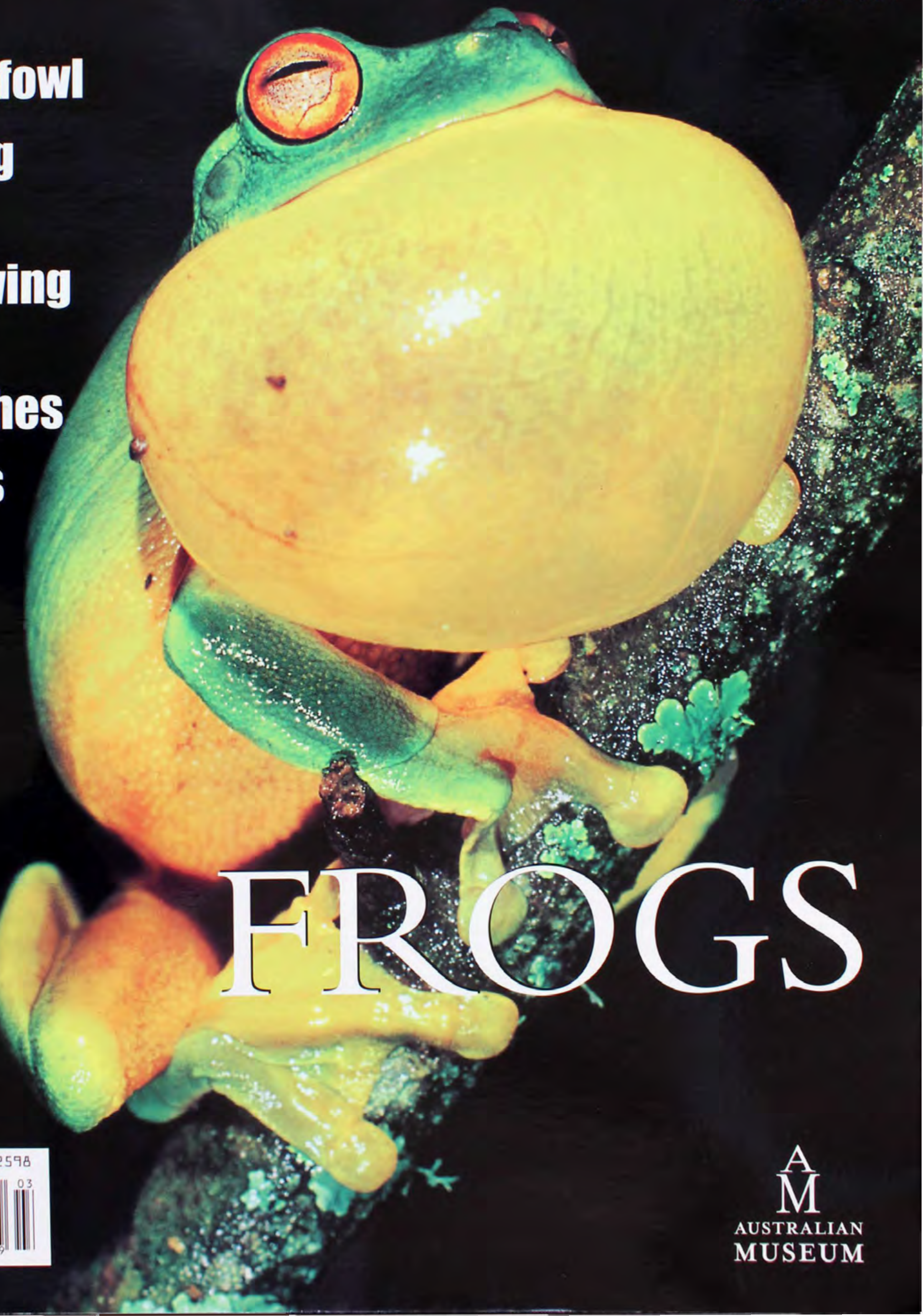

FROGS

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03

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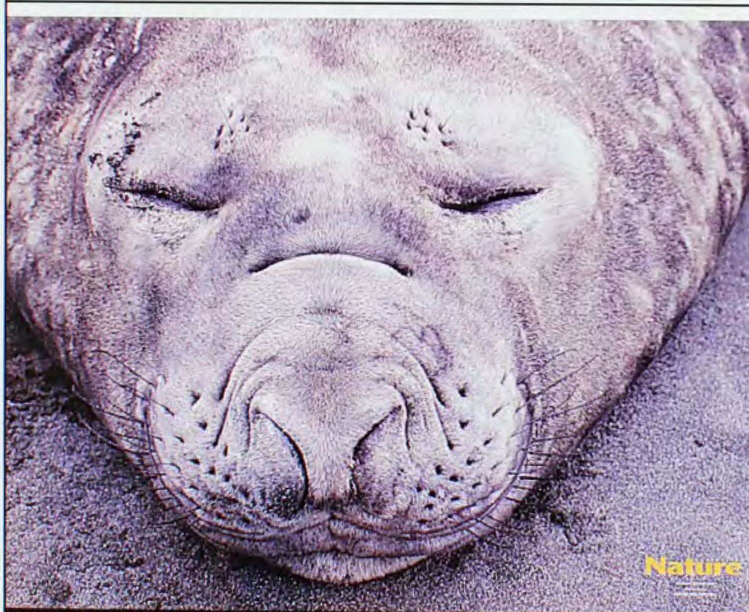

ELEPHANT SEAL

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FRONT COVER
A male Red-eyed Tree Frog (*Litoria chloris*) inflates his throat pouch. Photo by Ken Griffiths.

up front

When you graduate with your degree in hand and start working in scientific research you often end up doing all sorts of unsavoury jobs. One of mine was to dissect and weigh the poison glands from hundreds of formaldehyde-soaked Cane Toads. Unfortunately, even after years in preservative, the toads' glands were still full of their creamy-coloured, pus-like poison that often oozed out as I inserted the scalpel. Sometimes when I pushed too hard I'd end up wearing the offensive exudate. Not a pleasant experience let me assure you. However, after reading Douglas Fudge's article in this issue, I've decided it could have been worse—at least I wasn't put in charge of a hagatorium. A hagatorium is the laboratory home of what many people believe are the most disgusting species on the planet. It's where deep-sea hagfishes are kept, and these fishes and their slime glands are definitely not for the uninitiated or faint-hearted. So what is it about hagfishes that convinced Doug to spend his days pondering slime? In "Hagfishes: Champions of Slime", you'll find the answer and a lot more. It's a mix of the unusual, with more than just a touch of the grotesque.


CHRISTINE ORTLEPP

An Atlantic Hagfish (*Myxine glutinosa*).

Moving up the water column, we enter the intriguing world of Dugongs. Dugongs appear to be defenceless herbivores, yet they manage to survive in the shark-infested waters of Shark Bay, Western Australia. Geoff Taylor threw caution to the wind and entered these dangerous waters in a rubber dinghy in order to investigate one particular Dugong. What he discovered might not have been pretty but it gave an insight into how Dugongs manage to coexist with predators like the Tiger Shark.

Malleefowl are unusual birds even by megapode standards, not because they choose to incubate their eggs in enormous mounds of leaf litter but because they choose to do it in the arid interior of Australia. This choice of habitat means that, once the eggs are laid, the male Malleefowl must work tirelessly for over two months in order to keep his mound at just the right temperature for the chicks. The work, dedication and skill involved is quite amazing. Unfortunately, once the chicks manage to dig their way out of the mound, they are on their own, and since the introduction of Foxes they are not doing too well. Scientists are now faced with the challenge of saving these wonderful birds from extinction.

There's also plenty more for you in this issue as we meet the elusive Giant Burrowing Frog, take a look at how fire has shaped Australia, discover the perceptions of lizards and the secrets of slaters, and admire a cool gallery of reptiles and frogs.

—JENNIFER SAUNDERS

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REGULAR FEATURES

COLUMNS

letters

Once Exotic, Always Exotic

Letter-writer Paul De Barro (*Nature Aust.* 2000–2001) wonders what constitutes a native species and whether it matters anyway, especially if the non-native species is "innocuous".

My own view is that a species is non-native (exotic) if it reached the place where it now occurs as a result of human agency or influence. Hence, species like the wild dog (aka Dingo) brought from South-East Asia a few thousand years ago are non-native in Australia, as are Koalas on Kangaroo Island and Laughing Kookaburras in south-western Australia.

And what difference does it make? A lot, if your interest in nature is not only for the individual species themselves but also for the patterns of interactions between them that have arisen as a result of 3.2 billion years of evolution in the absence of human influence. Further, no exotic species is "innocuous". They all have a disruptive effect on the species interactions that developed in the pre-human environment, even though that effect may be below the level of human ken or concern.

The level of concern is the nub of this and all other conservation issues. If you don't subscribe to the view of no, or at worst only the most minimal, human impact on nature, then where exactly do you draw the line?

—Allen E. Greer
Australian Museum

Stressed Mole

No way will I inform Thompson, Withers and Seymour about sightings of marsupial moles (*Nature Aust.* Summer 2000–2001). I do not want to see more of them subjected to stress and starvation at the hands of people who know next to nothing about them and who plan to "experiment with a range of possible food items" next time around.

It is not good enough to use one's scientific collector's permit to pluck a specimen from its desert habitat, fly it to Perth, stick it in a sandbox, offer it various local foods and be sorry when it dies. Such treatment might be expected from a well-meaning but ignorant amateur, and legislation is designed to protect our wildlife from it. We should not accept it from a team of scientists.

What did they learn of normal marsupial-mole physiology and behaviour from a single specimen in a lab? That its faeces were "a very watery green paste" suggests not that it lacked the ability to conserve water, but that it had diarrhoea induced by stress and wrong diet, and probably died of dehydration. Aboriginal people familiar with these animals tell me that normal marsupial-mole faeces are small, solid, elongated pellets the colour of sand.

Thompson *et al.* might begin their studies of marsupial moles by asking desert people about them. Then they might observe them in the field—not as easy as flying one home with you, but more informative and much better for the animals themselves.

—Pat Lowe
Broome, WA

We would very much like to study marsupial moles in their natural environment but all our efforts to find a suitable study site have been in vain. We spent four days driving to a remote Aboriginal community to learn about marsupial-mole ecology and natural history. Our poster on marsupial moles brought us in contact with a number of people including Aborigines whom we spoke with to ensure we knew everything there was to know about these animals. We

DAVE WATTS/NATURE FOCUS

As far as Allen Greer is concerned, the Dingo (*Canis lupus dingo*) is non-native in Australia.

also made every effort to read all that had been written about marsupial moles before we caught one.

We don't think our captive animal's watery green faeces indicated diarrhoea. Our captive animal maintained, and at times increased, its body mass for over four weeks while producing this type of faeces. David Howe also reported that the apparently healthy Notoryctes typhlops *he held in captivity produced similar faeces (*Aust. Mammal. *1: 361–365; 1975). We are appreciative of your information on marsupial-mole faeces being solid, elongated, sand-coloured pellets and we would welcome the opportunity to follow this up with any Aborigines with first-hand knowledge about their habits.*

From our studies, we now know more about their basic physiology essential to husbandry (for example their inability to thermoregulate); that they are not true sand-swimmers, which affects the type of soil they require for husbandry; that, even without access to free water, they do not have a water-balance problem; and that the only practical method to census them might be to use geophones. A more detailed account of what we learnt is available in Withers et al. *(*Aust. J. Zool. *48: 241–258; 2000).*

—G.G. Thompson (Edith Cowan University),
P.C. Withers
(University of Western Australia)
& R. Seymour
(University of Adelaide)

True Hookers

Steve Van Dyck, in his article "The Happy Hooker?" (*Nature Aust.* Summer 2000–2001), tells us that butcherbirds got their name from their supposed practice of impaling their prey on a twig or thorn, like the true shrikes. However, he cites long-time butcherbird observer Dariel Larkins who has never witnessed this behaviour and who is therefore convinced that the trait is a myth.

Well, I have seen butcherbirds hooking prey. In November 2000, I handfed a male Grey Butcherbird from my sundeck at Bateau Bay. He immediately flew up to a bough above my head and impaled the meat on a thorn-like twig. He then proceeded to tear pieces from the meat and feed them to a baby in a nearby nest. A friend who also lives in Bateau Bay told me he had regularly seen the birds using the spikes on a barbed-wire fence for the same purpose.

—Ern Downes
Bateau Bay, NSW

An Eastern Blue-tongued Lizard (*Tiliqua scincoides*) with its young.

P. Roach/Nature Focus

Blue-tongue Egg?

In 1966 when I was in fifth class at Manly Vale Public School, it was the boys' weekly job to empty the bins and burn off the rubbish. In the undergrowth, resting on the ground under some bush near the incinerator I saw what I thought was a golf ball. Closer inspection showed it to be slightly smaller and flatter, and creamy-coloured and smooth-skinned. The underside had a darker tan dot a bit less than a centimetre wide where it had been resting. Like all unenvironmental boys of the time, I opened the egg up and inside was an unmistakable tiny blue-tongue, three or four centimetres long with a dark mask over its face, and a yolk sac and a fair amount of fluid. In your article on blue-tongues (*Nature Aust.* Summer 1998–99), Glenn Shea tells us that blue-tongues do not lay eggs but give birth to live young. If this wasn't a blue-tongue egg, what was it?

—Jim Williams
Eden, NSW

Blue-tongues definitely don't lay eggs! They've been bred innumerable times in captivity and always give birth to live young. I suspect what your reader found was a fetal blue-tongue, born a few hours before, which hadn't managed to free itself from its membranes (unlike the others in its litter, which would have already dispersed). The young are born encased in membranes, which form a rounded but flattened sac about golf-ball size. After a few hours, it's likely that these membranes would have dried out a bit and become more papery and opaque. Further enhancing the creaminess of the 'shell' would have been the pale yolk stuck to the inside of the membranes. The dark spot was probably the blue-tongue itself, pressed against the membranes on one side over a small area. The dark pigmentation seen on the fetus when the egg was opened indicates it was fully developed and ready to be born, as this pigmentation is about the last thing to be developed.

—Glenn Shea
University of Sydney

Nature Australia requests letters be limited to 250 words and typed if possible. Please supply a daytime telephone number and type or print your name and address clearly on the letter. The best letter in this issue will receive a copy of _Natural gain_. The winner this issue is Ern Downes.

nature strips

COMPILED BY GEORGINA HICKEY

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

To Row or to Flap?

Many aquatic and semi-aquatic vertebrates 'fly' through water by *flapping* their fins, limbs or wings up and down. Others move by *rowing* their appendages back and forth.

To investigate why some animals flap while others row, Jeffrey Walker and Mark Westneat from the Chicago Field Museum of Natural History used computer modelling to assess these two methods of aquatic locomotion.

They found flapping to be a more efficient way of moving at all speeds, suggesting it should be the preferred mode of travel for animals needing to conserve energy, such as migrating turtles and many fish. Rowing, on the other hand, was shown to provide more thrust at low speeds, indicating it should be a better option for animals needing to make tight manoeuvres through water such as repeated stops, starts and turns, and short, rapidly accelerating darts.

Walker and Westneat found support for their findings in real-world observations in the scientific literature. For example, Loggerhead (*Caretta caretta*) and Green Turtles (*Chelonia mydas*), which use their forelimbs to flap and their hind limbs to row, flap when travelling long distances and row over shorter distances. Fishes, though, either flap or row. Most row at slow speeds (and adopt an undulating gait for speed), whereas some fish that swim at 'cruising speeds', such as the parrotfishes and wrasses, flap their pectoral fins, as predicted by the model. And, among mammals, it seems that only those that make long ocean-going migrations, such as fur seals and sea lions, flap their flippers.

—K.McG.

Sex in the Sun?

What determines the colour of our skin? We know skin colour depends primarily on melanin, which blocks UV light and reduces the chances of skin cancer. But whether skin colour

DOUG PERRINE/AUSCAPE

Green Turtles flap their forelimbs when travelling over long distances.

evolved as an adaptation to environmental conditions (such as UV exposure in different areas of the world) is debated. Skin cancer, which normally develops later in life, hardly affects the ability to reproduce, and so cannot have any bearing on evolution.

Nina Jablonski and George Chaplin (California Academy of Sciences), however, have recently reviewed the evolution of human skin colour. They point out that melanin levels (and thus UV absorption) are linked to two important, but conflicting, processes that directly affect reproductive success. UV light, besides causing potentially lethal skin cancers, also breaks down folate, an important biochemical obtained through the diet and essential for normal embryonic development of the nervous system and adult sperm production. UV light, on the other hand, stimulates production of vitamin D3, which is necessary for skeletal development and healthy immune systems, especially during pregnancy and lactation. (This might also explain why females tend to have paler skin than their male counterparts.) Consequently, regulating melanin levels in response to different UV exposures is a critical process for successful reproduction. The skin must absorb just enough UV to generate adequate amounts of vitamin D3, but not too much that it destroys dietary folate. Skin colour can thus be thought of as a compromise solution to two conflicting physiological requirements.

The researchers propose that, when human ancestors lived around the tropics, dark skin was necessary to prevent the breakdown of folate by UV. But when they migrated into higher latitudes where UV levels were lower, their dark skin prohibited adequate production of vitamin D3 and evolution selected for lighter-skinned individuals.

So, we have a plausible evolutionary scenario for variation in skin colour. But is skin colour really linked to regional differences in UV radiation? For the first time, the researchers were able to compare the skin colours of hundreds of different indigenous groups with direct measurements of UV radiation from across the globe. The UV measurements came from 15 years of satellite data obtained from the NASA Total Ozone Mapping Spectrometer. The results were unambiguous. UV radiation is highly correlated with indigenous skin colour—areas receiving low UV levels have indigenous populations of light-skinned people, and *vice versa*.

Although skin colour is one of the obvious features that distinguish different racial groups, Jablonski and Chaplin's research has confirmed that skin-colour differences are simply an evolutionary adaptation to regional differences in UV levels and cannot be used to understand the deeper evolutionary relationships of human races. Skin colour, it seems, is only skin deep.

—R.F.

Ouch! The lacerating penis of the bean weavil *Callosobruchus maculatus*.

PHOTO LIBRARY.COM-SYDNEY ANDREW SYRED/SPL

Love Hurts

Armed with a penis resembling a medieval mace, males of the bean weevil *Callosobruchus maculatus* are taking the battle of the sexes to a new level.

Helen Crudgington and Mike Siva-Jothy from the University of Sheffield found that the head of the bean weevil's penis bears strongly sclerotised spines that inflate during copulation. By snap-freezing a copulating pair of weevils, the researchers showed these spines inflict severe damage to the genital tract of the female.

But evolution has not left the female completely defenceless against these males. The female is equipped with strong kicking legs that she

The Tawny Frogmouth shuts down when things get tough.

uses to actively discourage males from copulating longer than necessary and to save her from excessive damage.

Females that were able to shorten copulation time by kicking had significantly less damage to their genital tract and, it is suspected, also led a longer life. Certainly, female weevils that mated only once lived far longer than those that mated twice or more.

But why opt for genital wounding in the first place? How could this benefit the male? It takes a female bean weevil 16 hours to recover from the damage inflicted by the male's penis. This recovery time could work to the male's advantage by increasing the number of eggs fertilised by his sperm as opposed to a rival male that may later mate with the same female. Alternatively, the female may perceive the genital damage as a threat to her survival, which may induce her to lay her eggs immediately (being possibly the last chance she'll get).

—J.M.

Big Chill for Big Bird

To survive winter's big chill, many small mammals, unable to maintain high metabolic rates in the face of dwindling resources, enter a state of torpor, during which they lower their body temperature to conserve energy. A few small birds (weighing less than 80 grams) are also known to enter torpor, although it is widely thought that birds generally migrate when things get tough.

Now Gerhard Körtner and colleagues from the University of New England have discovered that the large (500-gram) Tawny Frogmouth (*Podargus strigoides*) also uses torpor to help survive seasonal prey fluctuations.

The researchers used temperature-sensitive transmitters to measure skin and core body temperatures of wild frogmouths every ten minutes from autumn through to summer. They found that in winter the seven birds they measured entered torpor for about seven hours after a brief period of activity each night, with core body temperatures falling to below 34°C from an active 38–40°C average.

On cold winter nights, core body temperature dropped to as low as 29°C. The birds warmed up at sunrise and, after flying to their day roost, often entered a second, albeit shorter (three-hour) bout of torpor.

Körtner *et al.* say that the use of torpor allows the Tawny Frogmouth to survive in a wide variety of habitats and remain sedentary all year, despite its dependence on seasonally fluctuating arthropod populations. They suggest that torpor among birds is probably much more widespread than previously thought—it's just that few researchers have really bothered to look for it in the wild.

—R.S.

Impalpable Passions

Imagine twisting off one of your testicles and eating it. Biologically, one reproductive organ is enough—at least for the tiny comb-footed spider *Tidarren cuneolatum* from Yemen. Barbara Knoflach (University of Innsbruck in Austria) and Antonius van Harten (General Department of Plant Protection in Yemen) found that the male spiders, just before they moult into adulthood, hook one pedipalp (the modified leg they use to insert sperm) onto the female's web, twist it off and eat it.

The female comb-footed spider *Tidarren cuneolatum* consumes her dwarf mate after sex.

COURTESY BARBARA KNOFLACH

All female comb-footed spiders have a pair of reproductive openings, each of which is inseminated separately. While the males have two pedipalps, they are usually inserted alternately. Among cannibalistic spider species, it is common for males to only manage one palpal insertion before either fleeing or being eaten. The *Tidarren cuneolatum* male is always eaten by his much larger mate after just a single insertion.

Like many close relatives, male *Tidarren cuneolatum* have little to do in life, other than wait for an opportunity to mate. Living as parasites on the female's web, males compete only in the speed with which they can mate with the female. Every non-reproductive part of their body has shrunk, leaving only their out-sized pedipalps to maximise their chances of insemination. But producing two of these large organs is a bit wasteful in a species that never has the opportunity to use the second palp. In the race to moult into sexual maturity and mate, the superfluous palp may be a critical extra meal for the spiders. They might seem to have an easy life, but male comb-footed spiders need all the energy they can get. So demanding is their coital interlude that many males die from sex-induced exhaustion even before the female eats them.

—D.C.

Foul Proof of Foul Play

No-one doubts that humans occasionally eat other humans, but the circumstances are widely

What's the secret to the Tokay Gecko's powerful grip?

debated, and abhorrence of cannibalism, like the practice itself, is rooted in cultural traditions.

Archaeological evidence of cannibalism is often indirect, through study of the bones (see, for example, "Neanderthal Cannibals", *Nature Aust.* Summer 2000–2001). However, Richard Marlar (University of Colorado School of Medicine) and colleagues have found the first direct evidence of cannibalism in an archaeological deposit—proof that human flesh was actually ingested.

The research team analysed 850-year-old fossils from an abandoned Pueblo village, along Cowboy Wash in south-western Colorado, USA. Like a few other archaeological crime scenes, human bones, scattered on a well-preserved pit-house floor, suggest they had been butchered and cooked. This is supported by study of the stone tools, which tested positive for human blood. But the big breakthrough came with the discovery of a broken cooking pot and—here comes the best part—a human coprolite (ancient human poo) that had been rudely parked in the cold ashes of the last fire.

Using a biochemical technique that enables recognition of distinctive proteins of particular species, the researchers showed that human myoglobin, a protein found in heart and skeletal muscle cells, had been absorbed inside the pottery wall during cooking. Most significantly, they found the same human protein in the coprolite. There were no traces of plant material; only meat. Myoglobin is found only in heart and skeletal muscle tissue, and its chemical composition differs between species. This rules out the possibility that the protein in the coprolite was sloughed off from the gut, or came from another prey animal.

It is said that the proof of the pudding is in the eating, but in this case it seems that the proof of the eating is in the pudding!

—R.F.

Grip of the Gecko

The Tokay Gecko (*Gekko gecko*) seemingly defies gravity as it scuttles up, down and across smooth vertical and overhead surfaces. It can even hang from a ceiling with just one toe.

The secret to its acrobatic abilities lie, like that of other climbing gecko species, in the microscopic structure of its enlarged toe pads. Each foot typically bears nearly 500,000 hairs or setae about a tenth the diameter of a human hair. Each seta, in turn, supports hundreds more projections that are flattened at their ends like spatulas.

Kellar Autumn (Lewis and Clark College, Oregon) and colleagues from Stanford University and University of California at Berkeley have recently taken the first measurements ever of the force exerted by a single gecko-seta. They found that a single seta is ten times more effective at hanging on than previous estimates based on whole geckos. One seta is capable of lifting an ant. And the combined adhesive power in the feet of one gecko could theoretically support a weight of over 40 kilograms, which is the equivalent of two small children.

The combined adhesive power in the feet of one gecko could theoretically support a weight of two small children.

The researchers' work confirms the view that the cumulative action of weak powers of attraction between molecules, known as van der Waals forces, makes the actions of gecko setae so effective. The one billion or so microscopic 'spatulas' covering a gecko's feet would provide enough surface area for van der Waals forces to contribute significantly to adherence. The unusual way that geckos peel and uncurl their toes during movement also probably assists in the formation and breaking of these forces.

If the structure of the gecko footpads can one day be copied, we will have a super adhesive that will work in a vacuum, under water, and on perfectly smooth surfaces—in other words, one that would far outrival any commercial fastener currently available.

—K.McG.

Vegetarian Crocs

The few living species of crocodilians (crocodiles and alligators) are all semi-aquatic ambush predators, but these reptiles were far more diverse in the past. Fossil relatives include giant ocean-going forms with flippers, and long-limbed terrestrial forms that ran down prey and perhaps even climbed trees. Recent finds now reveal that crocodilians once exploited yet another niche.

Several years ago, a small crocodile from the Cretaceous of China was named *Chimaerasuchus* on account of its bizarre teeth, consisting of blunt, chunky, mammal-like molars rather than the usual crocodilian array of sharp fangs. This grinding dentition, and a short heavy snout, suggested a diet of tough land plants. At the time, it appeared to be a small, although intriguing, side branch of crocodilian evolution. Subsequent studies, however, have revealed that there was actually a large and diverse radiation of herbivorous terrestrial crocodilians, the most recent discovery coming from rocks of similar age but on the other side of the world (Madagascar).

Gregory Buckley (Roosevelt University) and colleagues named it *Simosuchus* (from the Greek *simo* meaning pug-nosed and *souchus* crocodile) because of its short, square snout. Its teeth are semicircular, with scalloped edges, very much like those in plant-eating dinosaurs and lizards (iguanas). Given the abundance of large meat-eating reptiles during the Cretaceous, it is not

COURTESY GREGORY BUCKLEY

The pug-nosed crocodile *Simosuchus* had a taste for greens.

surprising that this small vegetarian croc had strategies to avoid being devoured by dinosaurs or even its carnivorous cousins. The shovel-like snout and large insertion areas for neck muscles suggest that *Simosuchus* could burrow headfirst. It was also heavily armoured, with thick plates over its back and belly, and even bony nodules around its eyelids.

—M.L.

When Less Means More

Sexual selection often leads to elaborate traits, such as the Peacock's train and the excessive feathered coronets of some of the birds of paradise. But can sexual selection also lead to the *reduction* of a trait? Yes, according to a study on Australian Golden-headed Cisticolas (*Cisticola exilis*).

In field studies based in Queensland, a team of researchers led by Andrew Balmford (University of Cambridge) and Milton Lewis (while at James Cook University) artificially lengthened and shortened the tail feathers of 36 adult males. Males with the shortest tails were by far the most successful breeders, attracting the greatest number of females. Short-tails had twice as many fledgling chicks as the control group, and six times as many chicks as the long-tails.

Why do females prefer short tails? The researchers suggest that shorter tails create less drag and facilitate greater flight speed. This allows short-tailed males to spend more time performing aerial displays to impress females. Short-tailed males are also better at fighting off rivals in high-speed chases and so can offer females better territory.

Although a shorter tail increases speed, this proves to be a problem during the birds' slow-speed foraging flight. In an experiment in which birds with manipulated tail lengths had to negotiate their way through a maze of vertical strings (simulating dense vegetation), short-tailed males hit significantly more strings than long-tailed males. In this way the cisticola's short tail is still a classic example of sexual selection. The desirable trait is energetically costly, thereby indicating the male's ability to invest in future offspring *despite* his sexy impediment.

In 1874 Charles Darwin proposed that sexual selection could potentially cause trait reduction. This is the first time his theory has been experimentally proven, and it just goes to show that it's not always the largest and loudest that gets the girl.

—K.H.

ROGER BROWN/AUSCAPE

Short tails are *de rigueur* for male Golden-headed Cisticolas.

Opossums Grip and Grope

There is a common myth about American opossums: they have 'nasal sex' (that is, up the nose) and the females 'sneeze' the babies into their pouch. This fanciful tale probably derives from the fact that males have a forked penis and, shortly before birth, mother opossums poke their snout into their pouch to clean it out.

But for some of the South American mouse opossums, sex is not so much due to a nose job as to a flick of the wrist. The discovery was made by Darrin Lunde and William Schutt while curating opossum specimens in the American Museum of Natural History. They found that, in some species of these tiny marsupials, the adult males have a bony protuberance that extends from the wrist, almost like a sixth finger.

Giant Pandas of both sexes also have a bony wrist extension, the so-called Panda's 'thumb', which enables them to grapple with bamboo (see *Nature Aust.* Winter 2001). However, the researchers suggest that, because only male opossums have the bony extension, it might be there to grasp the female during copulation. This precarious act involves the male clinging to the female's front and back limbs from behind, while both animals are suspended from a branch only by the male's tail. The bony wrist extensions of the male fit snugly into the female's elbows and might thus secure the male's grip (and grope).

Only one other mammal may have had a similar adaptation: an extinct whale found in 42-million-year-old Egyptian deposits (see *Nature Aust.* Spring 1991). *Basilosaurus* had small hind limbs, possibly to help position the animal during copulation, although it is not known if these limbs occurred only in males.

Ancient whales getting their leg over aside, the mouse opossums are the only known mammals where the males have an extra digit likely to have evolved exclusively for sex.

—A.T.

Malaria in a Warmer World

Among the many disturbing predictions linked to global climate change are those that forecast an increase in the distribution of insect-borne diseases. It's often prophesied, for example, that rises in global temperatures are likely to lead to the penetration of malaria into places where presently it's not encountered, including large sections of North America and central and northern Europe.

Now work by David Rogers and Sarah Randolph, from the University of Oxford, casts doubt on the dire warnings about malaria in a warmer world. They believe previous models on the

A. PASIEKA-PETER ARNOLD/AUSCAPE

Will the distribution of malarial mosquitoes (*Anopheles* sp.) change in a warmer world?

ANNE & JACQUES SIX/AUSCAPE

When the hive gets sick, the temperature rises.

future spread of the disease have been too simplistic, focusing on anticipated rises in temperature ranges. However, outbreaks of malaria occur only when a range of factors (from environmental and climatic to biological) come into play. Temperatures might be right, for example, for the development of the malarial parasites in mosquitoes, but there might not be enough rainfall to create mass-breeding conditions for the mosquitoes, which are necessary for the disease to spread.

Rogers and Randolph have devised what they believe to be a more accurate computer model for the future distribution of the most deadly form of malaria, caused by the parasite *Plasmodium falciparum*. As well as temperature, their predictions take into account anticipated changes in rainfall patterns and humidity.

After crunching all the relevant data, Rogers and Randolph's predicted global distribution map of malaria for 2050 is surprisingly similar to the current global map of the disease. But although the disease will remain more or less restricted to zones equivalent to the present-day tropics, the distribution within those zones will shift.

—K.McG.

A Social Fever

Most people have suffered from a fever at some stage of their lives—confined to bed with a flaming temperature, often lying in a swamp of sweat. It's a normal bodily response when the immune system fights infection (see *Nature Aust.* Spring 1991). But Cornell University biologists have now discovered that Honey Bees (*Apis mellifera*) can produce a collective fever when their hives get sick.

Hives are susceptible to 'chalk brood', a disease caused by the fungus *Ascosphaera apis*, which infests the brood and mummifies the larvae so that they dry into white chalky lumps. In response to this infection, the bees band together to produce a fever. Philip Starks and colleagues measured the temperature shifts inside beehives and recorded rises of up to 20 per cent in infected hives. The Honey Bees increase the temperature by huddling together and shivering (see *Nature Aust.* Autumn 1995). The increase in temperature appears to be enough to kill the temperature-sensitive fungus and protect the brood from the mouldy invader.

Interestingly, fever occurs before any larval mortality. The researchers suggest that larvae may set the worker bees into action by communicating an alert when they first ingest fungal spores that have penetrated the colony. Alternatively, worker bees may be the first to recognise the fungus. Either way, fever appears to be a preventative response to the illness before symptoms take hold of the hive.

—K.H.

Oiling Up Against Skin Cancer

Many Australians can remember coating themselves in oil and spending long hot summer days lying in the sun. They are paying the price now in the form of skin cancers but, ironically, a team of Japanese dermatologists has found that liberal application of oil after sun exposure actually reduces the formation of skin cancers—at least if you're a mouse and the oil is extra virgin.

A range of antioxidants has been found to prevent skin cancers, including green tea polyphenol which is effective both as an ointment and when consumed. Olive oil is known to have similar dietary antioxidant effects, and to test whether it could also be effective against sun damage, Masamitsu Ichihashi (Kobe University School of Medicine) and colleagues subjected specially bred hairless mice to UV radiation three times per week.

Five minutes before or straight after the radiation treatment, the mice were painted with either regular or extra virgin olive oil. Oil-free control mice developed tumours after 18 weeks and those treated with regular olive oil fared little better. But mice painted with extra virgin oil immediately after their sun-baking session not only had smaller, less potent tumours, but the tumours

Slip, slop, slap. Extra virgin olive oil after sun exposure reduces skin cancers in mice.

ANDREW HENLEY LARUS

took an extra six weeks to appear.

The researchers speculate that the oil inhibits the formation of UV-induced free radicals, which are responsible for gene mutation and triggering abnormal cell growth. However, they caution that olive oil is not a sunscreen and that, while rubbing extra virgin olive oil on after sun exposure might protect skin from UV damage, for now it's safer to cover up if you're in the sun.

—R.S.

Ancient Nit-Pickers

Every few months a note comes home from school warning parents about another outbreak of Head

Lice (*Pediculus humanus capitis*)—those pesky insects that lay their eggs (nits) at the base of human hair. The lice hatch within a week or so to feed on our blood, and it is little consolation to parents or children that they prefer clean hair. The problem does not seem to go away and indeed has been around for thousands of years, as suggested by Karl Reinhard (University of Nebraska–Lincoln) and colleagues who have recently discovered the world's oldest known human–louse association—a nit on a human hair from a 10,000-year-old archaeological site in Brazil.

Head Lice have been reported before from various archaeological sites around the world. Previously the oldest nits had been found on an Egyptian mummy, dating to 3,000 BC, but the age reported for the Brazilian nit will hopefully allow an assessment of louse evolution, through DNA studies of different *Pediculus* species.

Some societies actually put live lice back into hair so they have a reason to pick nits out at a later date.

Most people in the world have dealt with the nit problem by doing each other's hair, or grooming. Nits were (and still are) picked with a special tool and crushed. Some people even ate them to prevent them finding another host, as evidenced by nits found in ancient American coprolites (desiccated human faeces). While I personally don't recommend eating them, the act of removing them (grooming) is socially important—so important that some societies, as reported by David Trigger from the University of Western Australia, actually put live lice back into hair so they have a reason to pick nits out at a later date. In this social context, therefore, nits can be good for you. Tell that to your parents and teachers next time the newsletter comes around!

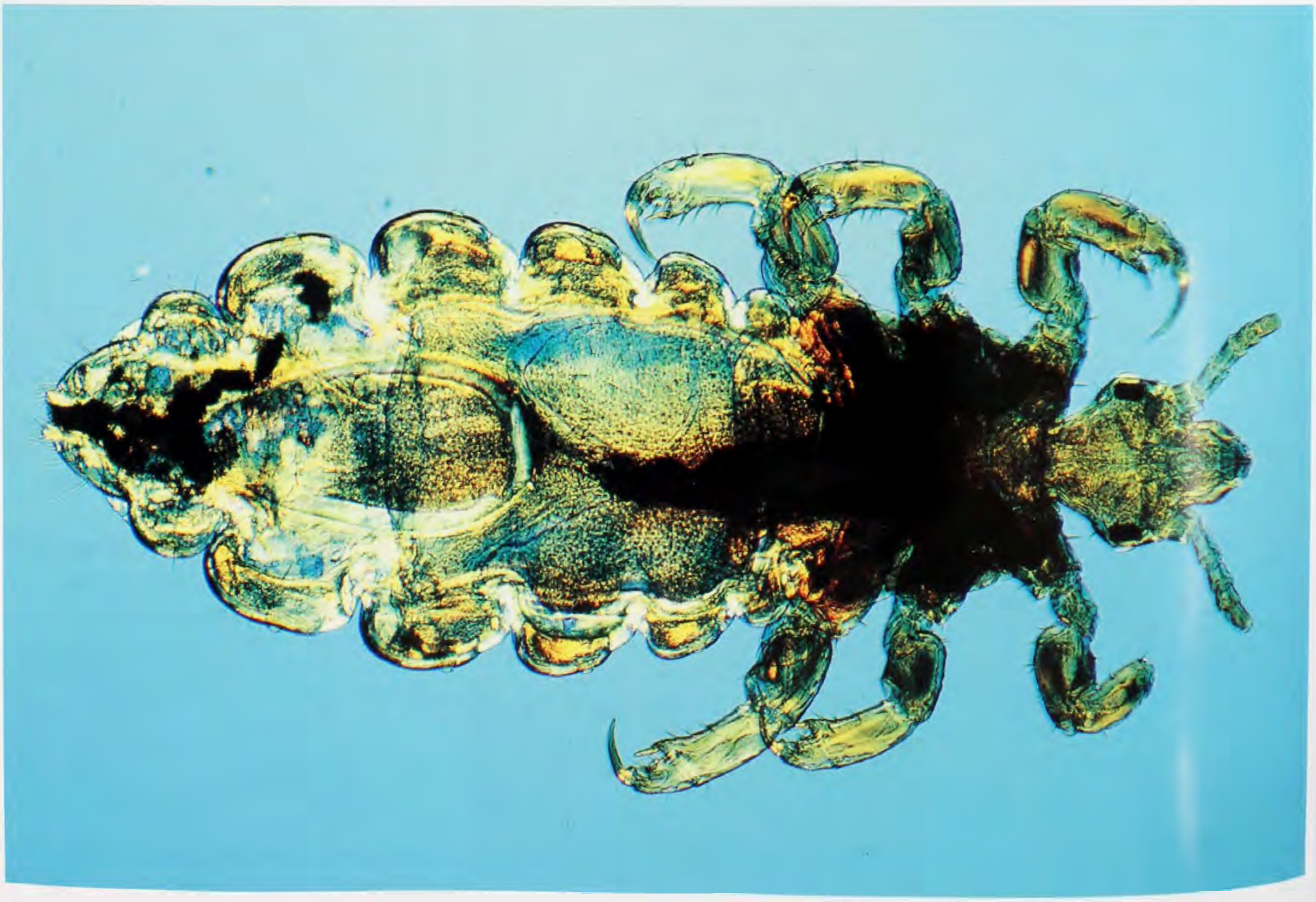
—R.F.

Toxic Birds

In 1992, scientists working deep in the wet cloud forests of Papua New Guinea discovered three species of songbirds (*Pitohui*) equipped with a barrage of toxic chemicals in their skin and feathers—the first birds known to be equipped with such a defence mechanism (see *Nature Aust.* Autumn 1994). But now, just when you thought it safe to go back in the forest, the same scientists have found another three toxic bird species—two more pitohuis and the smaller, unrelated Blue-capped Ifrita (*Ifrita kowaldi*).

Each species carries a cocktail of batrachotoxins, which are among the most powerful neurotoxins known. Just handling the birds may cause sneezing and upper respiratory irritation. Previously these toxins were known only from neotropical poison dart frogs from Colombia.

The levels of batrachotoxins vary greatly between



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Head Lice have had a long association with humans, and picking them (and their eggs) out is a socially important pastime.

different populations of the birds, which suggests that the birds, rather than producing the toxins themselves, obtain them from some as yet unknown component of their diet.

And what use is this chemical arsenal? Well, it certainly deters the local villagers from eating them. They claim that eating the Blue-capped Ifrita, which they know as the 'bitter bird', makes hot chilli pale in comparison. The effect could act as a similar deterrent to other potential predators. However, the researchers showed that the breast and belly feathers had the highest concentration of toxins. The birds might rub these feathers against their eggs to provide protection from snakes and rodents. The batrachotoxins may also act to ward off lice and other parasites.

—J.M.

The taste of Blue-capped Ifrita makes hot chilli pale in comparison.

JOHN DUMBACHER

Decoy Bee Cells

The solitary bee *Chelostoma florisomne* lays her eggs in brood chambers inside hollow plant stems. She then packs in some pollen and seals up the chambers. But often she goes to considerable effort to seal up empty chambers between those containing eggs. Mikael Münster-Swendsen and Isabel Calabuig from the University of Copenhagen wondered if the empty chambers act as a decoy

COURTESY LON WILKENS

This Paddlefish takes a strike at a pair of silver wires delivering an electric current similar to that produced by their zooplankton prey.

against the parasitic wasp *Sapyga clavicornis*.

The researchers studied solitary bees (and their wasp parasites) that had built their nests in the thatched roofs of two Danish buildings. They found that each brood chamber is separated from other chambers by a thin wall made of saliva mixed with nectar and loam. While a bee was away gathering pollen, a wasp would use the opportunity to sneak in and lay eggs in the brood cell. The bee combated this by vigorously cleaning out the wasp eggs when she returned. But the wasp had another strategy—she could also penetrate a newly sealed wall with the tip of her abdomen and lay an egg inside the adjacent chamber where the bee couldn't reach.

But in a case of double one-upmanship, the presence of the empty decoy cells meant that the wasp would often lay her eggs in an empty cell, where they would hatch and then die of starvation.

The researchers calculated that, if the bee did not create empty brood cells, 26 per cent of the eggs would have been parasitised. But with empty decoy cells present, only about a third of this (9.5 per cent) was actually lost to the wasp.

—A.T.

Paddlefish have weird flattened snouts that detect the faint electrical fields emitted by their food.

Paddlefish Shun Metal

Paddlefish (*Polyodon spathula*) have weird flattened electrosensitive snouts that detect the faint electrical fields emitted by their zooplankton food. They are the only fish known to use their passive electric sense to detect plankton. Craig Gurgens and colleagues from the University of Missouri-St. Louis wondered whether such heightened sensitivity might also be used in navigation.

They tested the responses of 30 juvenile Paddlefish to aluminium, plastic and plastic-coated aluminium rods suspended in a pool lit only by infra-red light (invisible to fish). Using a computerised tracking system to record the movements of each animal, the researchers found that, while the fish collided frequently with the plastic and plastic-coated rods, they not only detected, but violently avoided (to the point of jumping out of the pool) the aluminium rods from up to 30 centimetres away.

Encountering the natural electric fields of plankton induces a feeding response in Paddlefish, so why the startled reaction to the aluminium poles, which emit a signal 100 times stronger?

The researchers explain that the weak localised electric fields of plankton activate the electrosensors sequentially as the Paddlefish swims, but the powerful electric source of the poles activates all receptors simultaneously, much like running into an electric fence would. The unfamiliarity of the object, and the fact that a metal pole's electrical signature may resemble a large fish, turtle or other predator's signature, would explain such dramatic avoidance behaviour.

These results have important implications for Paddlefish migration. Endemic to the Mississippi River and its tributaries, the fish once travelled long distances to spawn. Now they congregate in large numbers below the steel gates of locks and dams, refusing to pass through the electrosensory barrier unless the gates are lifted free of the water. One way to minimise this barrier to migration may be to coat the gates in plastic.

—R.S.

Spinning to Order

Many parasites, not content with 'sucking the sap' out of their hosts, force them into doing things they would not normally do. Often these involve subtle changes to the host's behaviour, such as eating more, sleeping less, or moving to a new habitat (see *Nature Aust.* Spring 1995), but others involve Herculean feats just before their final death knoll. William Eberhard (Smithsonian Tropical Research Institute and Universidad de Costa Rica) recently described one such case for the tropical ichneumonid wasp (*Hymenoepimecis* sp.) and its orb-weaving-spider host (*Plesiometa argyra*).

When a female wasp locates a spider, she paralyses it with her sting, and lays an egg on the surface of its abdomen. The spider soon recovers and, apparently unaware of the violation, continues with its normal activities, spinning webs day and night and catching food. But over the next week or two, the larva grows fat as it feeds on the spider's blood, which it sucks through tiny holes it makes in the abdomen.

When the larva is ready, it somehow induces the spider to spin a special web, radically different from its normal orb pattern, and consisting of only a few non-sticky radial lines and central hub. As soon as the web is complete, the larva kills and consumes the architect, and then makes a cocoon to fit the custom-made house. The 'cocoon web' is much stronger than a normal orb web and provides better protection for the cocoon in heavy rains.

Eberhard believes that the signal for the spider to spin the special web is chemical, rather than physical, because even when the larva was removed shortly before web construction, the spider sometimes went ahead and spun it anyway.

—K.H.

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QUICK QUIZ

1. *What is the name of the potato-shaped asteroid on which the NEAR Shoemaker spacecraft landed in February 2001?*
2. *Which animals are responsible for producing ambergris, a substance used primarily in the perfume industry?*
3. *What does AD, as in AD 2001, stand for?*
4. *Where does the largest possum in the world live?*
5. *What do ophiologists study?*
6. *Which Australian area was listed as a World Heritage site in November last year?*
7. *What is the predominant colour of a male Eclectus Parrot?*
8. *Which are the only reptiles that don't have a penis?*
9. *What is the name of the icebreaker used by Australian Antarctic researchers?*
10. *Where was the world climate conference held in November 2000?*

(Answers on page 83)

Slater peccadillos

If you aren't in South America, slaters are as close to armadillos as you can get.

DENNIS SARSON/LOCHMAN TRANSPARENCIES

BY STEVE VAN DYCK

WE HAVE A 95-YEAR-OLD relative who persists in asking our 16-year-old what she was doing at the time President Kennedy was assassinated. As I was about 12 then, and her mother eight, our daughter's answer "I can't remember" seems tactful enough. While that question was once a great ice-breaker, I've come up with a new, more contemporary question for the old man to ask that will again embrace every living individual on the planet: "When did the face of David Attenborough first appear on your TV screen?" My answer: "About the same time President Kennedy was shot".

Attenborough then was not the hoary, puffing omniscient luminary he is now. I remember revering him at a time when he was a wiry, pipe-smoking animal-wrestler, sailing to every corner of the world to put every known type of animal in a wooden crate to send back to a British zoo. These were the Zoo Quest days, when wildlife shows were still a novelty and animal ethics committees mere bureaucratic eye-twitches. For me, the episode that deified him forever was where he was in Argentina thrashing around in the dust with a Giant Armadillo, trying, as he always did with everything, to get it into a bag.

There is no doubt I wanted to be like him. I wanted to wrestle with armadillos. But in spite of all the aspiration, the closest I ever came to emulating that Argentinean effort was grappling with the armadillos under our garbage bin by the back door. Well, the grappling was more poking them with a stick and, not to stretch the point, they were not so much armadillos as...slaters.

Porcellio scaber **is an introduced slater commonly found in Australian backyards. The back half of this individual has recently moulted, while the front half is yet to moult, which is why it is darker in colour.**

If you aren't in South America, slaters are as close to armadillos as you can get. Everybody has seen slaters. Under a doormat, among decaying grass clippings, in crevices among rock walls. Unmistakably dry-looking and grey, jelly-bean-sized, hardish-shelled, banded into lots of segments, with seven pairs of scratchy legs underneath a body that may fold up when prodded. A three-way cross between one of those impossible-to-remove limpets on a seashore rock, a trilobite in a fossil book, and an armadillo on a small TV.

There are two things I find most fascinating about slaters (sometimes called 'sowbugs' or 'woodlice'). One is that most of us really don't know too much about them, and the second is that for some strange reason they don't elicit the immediate 'squash' response demanded by, say, a cockroach.

On the topic of what we squash, we humans are innately discerning crushers. Just a split second before we squash we usually make a taxonomic judgment. Sometimes we have to go on a gut feeling. In the case of slaters, squashing them just doesn't seem right. And why? Because slaters are crustaceans. We might boil crustaceans alive, dismember their arms and legs, then eat them; but we don't go around squashing them!

Many of the world's 55,000 species of crustaceans live in the sea and include things like barnacles attached to rocks, microscopic water fleas and krill that whales swallow by the tonne, to the more celebrated and identifiable things like crabs, lobsters and crays. Within the Crustacea, slaters belong to the order Isopoda (about 12,000 species), and many of the world's isopods also live in water. There they might be found as free-swimming scavenging 'sea lice' that sometimes bite surfers, or parasitic 'fish lice' living inside mouths and gill covers, or they might be sand skaters or sea centipedes.

Some isopods bravely took to the land somewhere around 70 million years ago, living in the moist leaf litter of ferns and horsetails. For an aquatic animal already flattened from top to bottom and with lots of legs underneath for support, the transition from water to land must have been a piece of Darwinian cake for them. But the survival of the world's 4,100 species of terrestrial isopods ('slaters' and 'pillbugs') is credited to five magnificent evolutionary innovations: a tough calcium-impregnated skin (cuticle) that resisted drying out, a moist pouch (marsupium) for their small litter of babies to grow and feed in, gills that became lungs-of-sorts (pseudotracheae), the wherewithal to absorb water vapour through their body, and the trick of excreting toxic ammonia as a gas (without losing water with it). Excreting ammonia *en masse* comes with a price, however, and the Dutch word for slaters, *pissebeden*, might allude to the bouquet that hovers over a huddle of slaters all powdering their noses at the same time. However, an alternative interpretation links *pissebeden* with the disconcerting consequence of drinking a nightcap of diuretic tea made from steeped slaters.

WE MIGHT BOIL *crustaceans alive, dismember and then eat them but we don't go around squashing them!*

For all this biotechnology most slaters are just as content to graze on decaying vegetation or a dead mouse's head as they are to nibble on one another's faecal pellets or those of the family Dog. But it is the astonishingly *delicate* way they dine that endears them to many museum researchers around the world. Australian bat taxonomist and conservationist Harry Parnaby has more time for slaters than he has for many humans. In preparing a bat for identification, Harry will only entrust the precious raw material to the discerning jaws of his esteemed slaters. Within a few days a bat's head can be reduced to a skull tenderly picked down to elements literally as fine as a hair's breadth.

The only thing that goes against their record as champion bone-exposers is their slow reproductive rate. Harry's attempts to speed up the recruitment process in his skeleton-picking slaters foundered even after feeding his adults an old copy of *Playboy* magazine. Harry put this failure down to the fact that his colony was composed entirely of Sydney slaters, which presumably had seen and eaten it all before!

But slaters, by nature, are fairly short-lived (less than five years) and conservative breeders. The ubiquitous Garden or Delicate Slater (*Porcellionides pruinosis*), introduced to Australia via shipping from Europe, produces more broods than most other slaters, but even its reproductive turnover is only three to six broods (each of 25–30 eggs) per year.

Unfortunately for me, looking down on a handful of slaters will always be like melancholic inspiration for a Leunig cartoon... "he remembered wanting to grapple with giant armadillos and look at him now!". It's fine to have heroes, but I think my chances of shooting to the top would have been substantially improved had wildlife movie-makers like Attenborough not kept me rooted to base camp and glued to the TV for the last 40 years! Better grappling with the remote control and slaters under the bin than nothing, I say!

Slaters, Pillbugs

Classification
Order Isopoda, suborder Oniscidea (terrestrial isopods = slaters, pillbugs), 4,100 species worldwide, 130 described from Aust.

Identification
Look like miniature armadillos or WWI tanks. Semi-flattened, oval body to 12 mm long, with overlapping armour plates; 7 pairs of legs; long, bent, forever-twitching antennae. Usually grey-brown, sometimes with dusty white 'bloom'.

Distribution
Worldwide, from deserts to seashore, tropics to cool temperate climates. In leaf litter, under logs, rocks. Must have humid hiding place during day.

Food
Detritus, fungi, living or dead plants and animals, paper, their own faecal pellets (prefer fresh faeces to dried or decayed). Occasionally cannibalistic. Rely on gut bacteria to digest decomposed leaves. Themselves eaten by centipedes, spiders, frogs etc.

Breeding
Varies according to species, but usually throughout the year with an increase in spring. Carry 10–200 eggs in brood pouch. Eggs hatch in 3–7 weeks. Young stay in pouch 6–8 weeks. On leaving pouch young known as 'mancas'.

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Brush-tailed Phascogale

Brush-tailed Phascogales may have diverged sufficiently over time to become different species.

ANYONE WHO HAS SEEN A Brush-tailed Phascogale (*Phascogale tapoatafa*) in the wild should consider themselves lucky. These small carnivorous marsupials (dasyurids) are notoriously difficult to see, let alone study. Phascogales are about 40 centimetres long with a dark dorsal surface, cream belly and a conspicuous black 'bottle-brush' tail. They are generally solitary, arboreal and very agile. Females occupy a large home range of up to 80 hectares, and males nearly twice this size. Like a number of other carnivorous marsupials, after the breeding season all males die, and the entire population is made up of females. They produce six to eight young and these are deposited in a nest (usually a hollow in a mature or dead tree) until they disperse during the summer.

This delightful dasyurid was first described from specimens collected in 1793 in New South Wales and is now known from three distinct areas. They occur in eastern Australia (from Victoria through into the northern regions of Queensland), in a pocket in south-western Western Australia, and in a 'band' across northern Australia. Two subspecies are generally recognised: *Phascogale tapoatafa tapoatafa* in the east and south-west, and *P. t. pirata* in the north. Many people think all Brush-tailed Phascogales look alike. However, the groups are completely separated from each other and are reproductively isolated, and may therefore have diverged sufficiently over time to become different species.

DNA analysis is becoming an increasingly important tool in work on our native fauna, because much of the past history (evolution) is recorded and contained in the genes. Together with colleagues from Murdoch and Macquarie Universities, we used mitochondrial DNA (mtDNA) to examine the Brush-tailed Phascogale's taxonomy. This particular portion of DNA is invaluable because it is only passed down from the maternal side of the family. Regardless of whether an animal is a male or female, only the mtDNA from the mother, and her mother (grandmother), great grandmother etc. will be retained throughout time. In theory, phascogales should still be carrying the mtDNA of the phascogale equivalent of 'Eve'. Fortunately, however, mtDNA changes at a relatively constant rate because of mutations, and this allows researchers to compare different populations and to estimate the time since their separation.

We compared the sequences of the mtDNA of the eastern, northern and western Australian populations of the Brush-tailed Phascogale with those of its closest relative, the Red-tailed Phascogale (*Phascogale calura*), and a completely different type of dasyurid, the Brown Antechinus (*Antechinus stuartii*).

The Brush-tailed Phascogales from the three regions showed more than ten per cent sequence divergence, which suggests they have been separated from one another for around five million years. This compares with differences of more than 12 and 16 per cent between the various Brush-tails and the Red-tailed Phascogale and Brown Antechinus, respectively. To give some idea of just how big this difference is, the Southern and Northern Hairy-nosed Wombats (*Lasiorhinus latifrons* and *L. krefftii*) show about four per cent sequence divergence—and no-one disputes they are different species.

Information based on our data and in combination with morphological analysis strongly suggests that the genus *Phascogale* comprises four (not two) highly divergent specicies: *P. calura* (Red-tailed Phascogale), *P. tapoatafa* (Brush-tailed Phascogale or Tuan) from south-eastern Australia, *P. pirata* ('northern' Phascogale) from nothern Australia, and *Phascogale* sp. nov. from south western Australia. The new species is currently being formally described and named by staff at the Western Australian Museum.

This work will have considerable conservation ramifications. The Brush-tailed Phascogale is currently listed as a lower risk/near threatened species but it will now need to be reassessed to determine whether it should be listed under another IUCN category, for example as threatened or endangered. This is likely for the northern and new western species, which are lower in numbers than the eastern species. The main threats to all phascogales continue to be Cats (both feral and pet), Foxes, and the further fragmentation of their habitat. Clearly, knowing how many species there are is important for working out their conservation.

BY PETER SPENCER

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To catch a lizard

I have often fooled lizards by approaching with one eye closed. Without the two dark spots they are slower to see me as dangerous.

Unusual among geckoes, Western Spiny-tails perch by day on exposed stems. If harassed, they squirt from their tails a fluid that is thought to deter their enemies.

PHOTOS: TIM LOW

TO CATCH A LIZARD, THINK LIKE one. They don't perceive things as we do. Stand stock-still and a lizard probably won't notice you. Move and it will flee. Movement stirs them. When their prey items (grasshoppers, moths and the like) sit still they seldom see them. To approach, avoid jerky motions. By offering a lizard's brain no sudden stimulus, you can often come close. Only when it tenses ready to sprint should you make a sudden dash or strike.

These suggestions I offer after 30 years of lizard catching. Doing fieldwork as a biologist, I've caught many hundreds of lizards in all shapes and sizes. Some were rare and some were new. I was the first naturalist ever to pounce on a Dwarf Litter-skink (*Menetia timlowi*), a cute little lizard I was fortunate to have named after me.

Lizard hunting has taught me about reptile perception, and it's not information I've encountered in books. The best data I've seen came from some studies conducted in Costa Rica on the Black Iguana (*Ctenosaura similis*), a large lizard often hunted by humans for food.

Joanna Burger of the State University of New Jersey found that you can get closer than usual to a Black Iguana if you drape a wig over your face. You can't get close at all if you wear a mask with over-sized eyes. Iguanas evidently recognise human faces, or at least eyes. I have often fooled lizards by approaching with one eye closed. Without the two dark spots they are slower to see me as dangerous.

Burger also found that approaching a lizard at an angle with averted gaze works better than a direct approach or a direct stare. A dragon perched on a log or rock may think it hasn't been seen if your actions are unsuspicious. It will lower its head as you pass, or retreat around the corner, to offer less of a visual cue. You can often get close by pretending you haven't seen it, by maintaining a trajectory that appears innocent.

During cold weather lizards remain sluggish and this should be the best time to catch them, but not necessarily. One study, also in Costa Rica, found that anoles (*Anolis lineatopus*) flee from a greater distance during cool weather, to compensate for their slower speed.

Lizards will habituate to regular human traffic. Alongside national park trails where people pose little threat, they often become blasé. In the Kalahari in Africa I once caught a Spotted Desert Lizard (*Meroles suborbitalis*) that was far too confident. It was excavating a burrow in the middle of a busy dirt road—a doomed enterprise. So indifferent was it to my driving that I was able to stop the car, open the door and grab it. Had I approached on foot it would have fled from far away.

Catching lizards teaches me about my own perceptions. Once in mountains near Mackay in Queensland, I was searching at night for leaftail geckoes (*Phyllurus nepthys*), but they were so well disguised I couldn't find any. But while returning along the track I finally spotted one on a mossy tree, then noticed a second leaftail right beside it. I retraced my steps and found many more leaftails on trees I had already searched. I needed to see one first to get a proper search or prey image to work from; then it was easy. I assume that many predators also work from prey images rather than just looking for the unexpected.

Biases can also get in the way. Western Spiny-tailed Geckoes (*Diplodactylus spinigerus*) in Western Australia

BY TIM LOW

offer a striking exception to the rule that geckoes hide by day. When I first found one perching in bright sunshine on exposed wood, I disregarded this as unusual and continued searching in more protected places, without success. Only when I shed my prejudices and refined my search—to low wattle stems exposed to full sunshine—could I find them easily. In most cases, however, prejudices and gut feelings work well.

By writing these words I'm not seriously advocating that readers go out after lizards. Reptiles can die from rough handling and you need permits to catch them. My aim is really to touch on the ways in which lizards and people see each other. Lizard behaviour is studied so rarely that insights gained during fieldwork can be useful. Once I was lifting logs on a cold winter's morning on the Atherton Tableland and found myself amazed by how quickly the lizards, mainly Prickly Forest Skinks (*Gnypetoscincus queenslandiae*), fled. Reptiles hiding under logs in cold weather are usually very slow. Could this reaction be a leftover response to some recently extinct, log-rolling predator? The wet fertile Atherton Tableland may well have been a last refuge for Pleistocene megafauna. Does lizard behaviour offer clues about the past? It's a thought that tantalises me as I scan the understorey for patterned prey.

I WAS THE FIRST *naturalist ever to pounce on a Dwarf Litter-skink*

A young frilled Lizard (*Chlamydosaurus kingii*) perched on a tree will freeze to avoid detection from humans and other predators.

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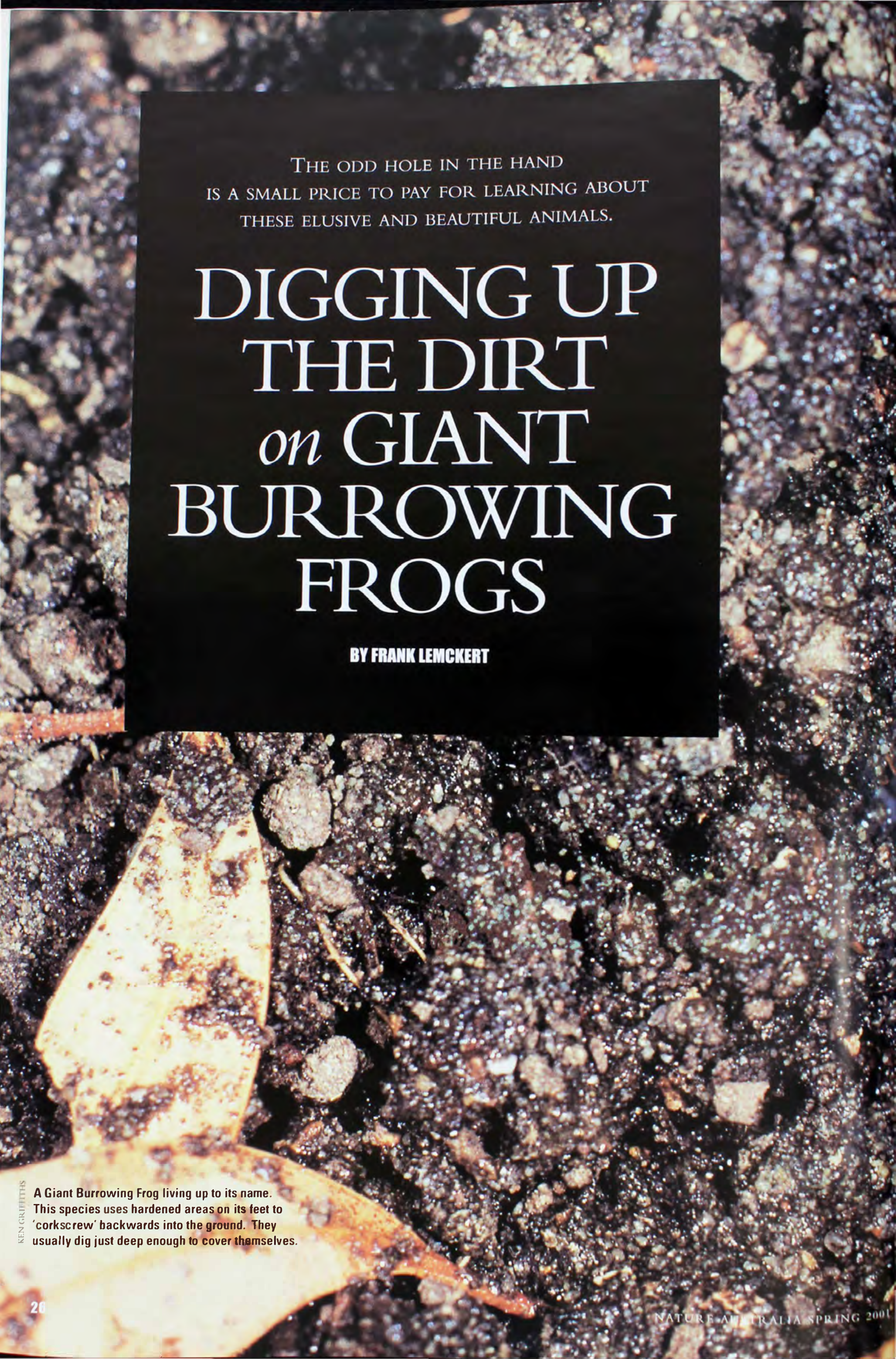
Tim Low is a Brisbane-based environmental consultant and naturalist, who has contributed to the discovery of several new geckoes and skinks.

The odd hole in the hand is a small price to pay for learning about these elusive and beautiful animals.

DIGGING UP THE DIRT *on* GIANT BURROWING FROGS

BY FRANK LEMCKERT



KEN GRIFFITHS

A Giant Burrowing Frog living up to its name. This species uses hardened areas on its feet to 'corkscrew' backwards into the ground. They usually dig just deep enough to cover themselves.

IT WAS A WARM, DRIZZLY NIGHT and I was driving along one of the dirt roads that cut through Eden's forests. There, sitting in the middle of the road, was a Giant Burrowing Frog (*Heleioporus australiacus*). I hopped out of the car, keeping the frog in the centre of my headlamp beam. It was only as I picked it up that I remembered the large, black spines males have on their thumbs. Too late! The frog thrust out its arms and I yelped in surprise. This time it only managed to scrape the skin of my thumb, but other male Giant Burrowing Frogs (and occasionally researchers) are not always so lucky. The odd hole in the hand, though, is a small price to pay for learning about these elusive and beautiful animals.

A fist-sized, blue-grey, warty-looking frog with yellow spots and jewel green eyes would seem to be the sort of frog that would be easily noticed; indeed, in 1795 the Giant Burrowing Frog became the second Australian frog to be officially described. Add the intriguing presence of the spines on the hands and a range of calls you don't quickly forget, and you'd think scientists would have spent more time finding out what this frog does for a living. However, this amphibian remains one of the least known of all the frogs in south-eastern Australia. The reason for this is simple. You just about never see or hear a Giant Burrowing Frog on your normal wanderings. Giant Burrowing Frogs are, however, found in forests subject to logging and I was curious to know whether this disturbance to their environment affects them—hence the reason for me driving along wet forest roads at night.

IF YOU HANDLE Giant Burrowing Frogs, one of the first things you will notice is their array of defensive strategies. Individuals first make themselves look bigger than they really are by drawing air into their lungs and puffing themselves up. They also turn themselves side-on to the threat and stand on tippy-toes to heighten this effect. Hopefully, the predator will think the frog too big to eat and leave it alone. If that doesn't work, individuals can produce a sticky, white secretion from the glands on their skin (which gives them their warty look). This substance has the texture of woodworking glue and is presumably toxic, although no tests have been done to confirm this. If the predator tries to bite the frog, it may be discouraged when it tastes this liquid. However, if that also fails, as a final option a Giant Burrowing Frog can produce the most amazing, almost electronic-sounding call like a whining Cat, although much louder. This call should convince most predators to leave the frog alone. Throw in the spines, and you have a frog that any predator should

FRANK LEMCKERT

When threatened, a Giant Burrowing Frog will usually stand on its tippy-toes and present the broadest side towards its attacker. This will hopefully make the predator think the frog is too big to eat and so leave it alone.

think twice about before trying to eat it.

Breeding is a potentially hazardous affair for the males. They arrive at their local breeding stream to find a site from which to call and attract a mate. This calling site can be amongst vegetation or debris by the water or, more usually, a burrow in the banks of the stream. Males may call at any time in response to rainfall, although summer and autumn appear to be the favoured seasons. The call is an owl-like hoo-hoo-hoo-hoo-hoo repeated on a regular basis (and is the reason why the species is also sometimes known as the Eastern Owl Frog). Females are drawn to the calling males and, if they like what they find, will lay their eggs in the burrow or in vegetation adjacent to the stream. This is all straightforward enough, but there appears to be a premium for good calling sites, and males are willing to fight to get the best ones.

Observations of male Giant Burrowing Frogs indicate that they follow similar rules to most other frogs when it comes to occupying territories. If a male wants to move into an already occupied site, he will call in response to the resident male's call. Larger males

The Giant Burrowing Frog has rather warty skin, which gives it a somewhat toad-like appearance. Indeed, people in western Sydney who are lucky enough to find one often mistake it for a Cane Toad.

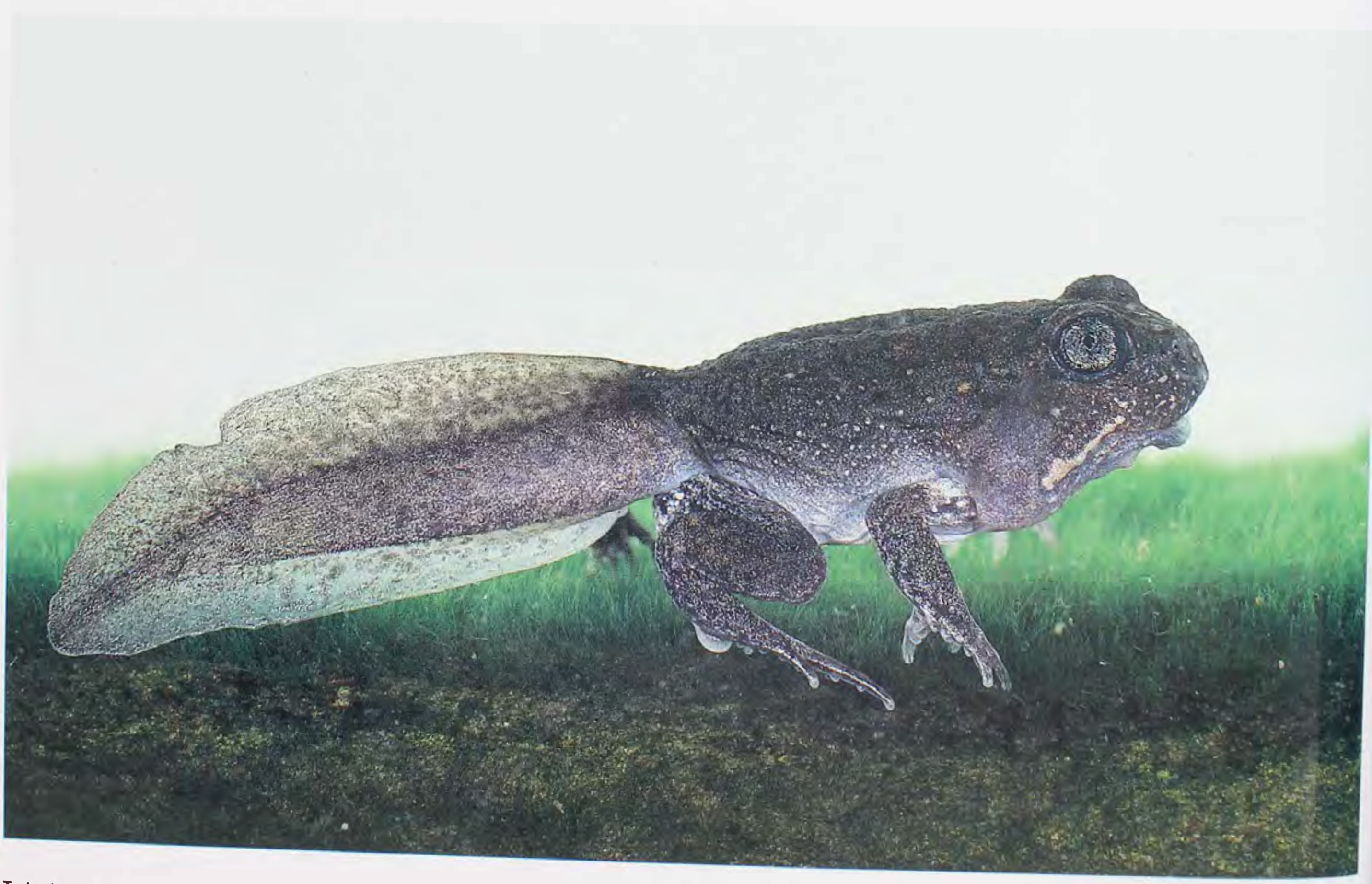
have deeper calls, and this should be enough for most males to decide who would win a physical encounter. If neither male is willing to back down, individuals might issue a territorial call, which is a drawn-out and rising whoooop. If this is still not enough to convince one male to leave, a fight can break out. Fights for calling sites occur in many species of frogs and they are almost always relatively harmless bouts of wrestling where the opponents try to tire each other out. However, fights between male Giant Burrowing Frogs appear to be much more serious. Those large spines can be used to good effect. The scars on the sides of captured frogs indicate that males rake the spines along their opponents and slice into the skin. The loser may possibly lose his life as well as the breeding site. Such a severe penalty for contesting a calling site is rare in frogs around the world and unknown in other Australian frogs.

> **THE SCARS** *on the sides of captured frogs indicate that males rake the spines along their opponents and slice into the skin.*

The tadpoles too are quite spectacular. I call them big blue bombs. They grow to about the size of a man's thumb with a thick tail, and are coloured grey to grey-blue. The eggs might be laid into a burrow, but the tadpoles are washed into the stream when rainfall raises the water level and they end up in whatever pools remain. These tadpoles grow slowly on a diet of algae, and the pools need to be nearly permanent as the tadpoles take between three and 11 months to grow from the egg stage to the point where they metamorphose into a fully fledged froglet. They then head off into the forest and grow up on a diet of just about any invertebrate they can catch, including spiders, centipedes and bulldog ants.

Morphological and genetic work on individuals from various parts of the Giant Burrowing Frog's range indicates there are distinct northern and southern populations that are probably two different species. The northern form is associated with sandy soils from the forests near Gosford, north of Sydney, to the Narooma area, while the southern form extends down into Victoria on soils derived from metamorphic rocks. More importantly, while the northern form has a number of populations in national parks and nature reserves, the southern frog has rarely been recorded in any sort of conservation reserve. Rather, the majority of southern Giant Burrowing Frog records are from lands subject to human disturbances, particularly forestry operations.

My work on the southern frogs commenced in 1998 and has involved surgically implanting radio-transmitters into some of the frogs we find in the forests near Eden, in southern New South



Tadpoles of the Giant Burrowing Frog grow slowly. This metamorphosing froglet has probably taken a year to reach this stage.

KEN GRIFFITHS

When searching for Giant Burrowing Frogs on the road, the best feature to look out for is their white tummy.

Wales. Tracking individuals with a telemetry receiver through the forest after they have been released has provided me with information to assess how forestry-related activities might affect this frog and to decide what protective measures might be implemented to reduce any possible negative effects.

CONTRARY TO the commonly perceived image of frogs, Giant Burrowing Frogs do not spend much time near water. In fact, except when breeding, just about none at all. Previously, these frogs had been found hundreds of metres from obvious water sources, but this was always when it was raining and there was no indication that they did not head back to a stream when it started to dry out. I have now followed southern Giant Burrowing Frogs through long dry spells and they have shown no inclination to return to the moist streamside areas. They are equally as likely to be found on the driest-looking ridge-top as anywhere else. Frogs I have tracked for several months all exhibit a similar pattern of activity. For many weeks they wander around in an area of only a few hundred square metres, then over about one week they move several hundred metres, in a relatively straight line, to a new patch of forest where they again settle down. Hence, any given area appears to be used as a residence for only a limited period of time, although it is possible that individuals might eventually return to a previously used site as the seasons pass.

Males may use deep burrows in the banks of streams during the breeding season, but at any other time individuals will just corkscrew straight down into loose soil where they sit and hide only one or two centimetres below the surface, ready to emerge for the next night's hunting. They can be seen sitting at the entrance of these temporary burrows at the start of the evening. If conditions become too dry to emerge, they burrow deeper and deeper to get away from the dry top layers of soil. So far we have found them to a depth of

Giant Burrowing Frog

Heleioporus australiacus

Classification

Family Myobatrachidae. One of 6 species. of *Heleioporus*. Also known as Eastern Owl Frog.

Identification

Adults grow to 100 mm, with males, on average, being slightly larger than females. Stocky body and warty skin, with warts capped by tiny black spines. Males have enlarged forearms with spines on fingers and 1 very large spine at base of each thumb. Blue-grey to brown on top and white or cream underneath, with varying degrees of yellow spotting on sides and back of legs. Tadpoles reach 80 mm and are grey or blue-grey in colour. Tadpoles take 3–11 months to reach metamorphosis.

Distribution

Found along coast and adjacent ranges from Gosford area of NSW down to eastern Vic.

Habitiat

Native vegetation including heathland, dry open woodlands and dry sclerophyll forests. Also found in wetter forests in southern NSW and Vic. Found in areas with loose soils suitable for burrowing.

Reproduction

Main breeding season Sept.–Apr. but males may call year-round. Males call from burrows (usually) to attract females. Clutch size 750–1,200 eggs. Calling and breeding usually occur around ephemeral streams, but ponds and permanent streams also used. Eggs laid into burrows or vegetation adjacent to water.

Status

Listed as 'Vulnerable' in both Vic. and NSW. If southern population declared as separate species, status may be reviewed.

H. EHMANN

25–30 centimetres, but it seems likely they will go deeper if there is a prolonged dry spell.

When I started radio-tracking, I wasn't sure how frogs would use the landscape after logging operations had taken place. Around Eden, about 30–50 per cent of any logged area is left undisturbed. This may be in the form of retained streamside corridors to protect water quality, as occasional between-catchment connection corridors, or as patches specifically for wildlife to use. Tracked frogs might have remained almost exclusively within the retained vegetated areas. However, it turns out that Giant Burrowing Frogs often move into the logged areas, even very recently logged forest patches where regeneration of the vegetation has barely started. Maybe these frogs can stay in logged habitat because they can just burrow down into the ground when they need shelter. Other species of frogs that hide in vegetation will probably not venture far, or often, into the disturbed areas until more advanced regeneration provides them with shelter sites. How long these other frogs wait before they move into logged patches is another subject ripe for research.

GIANT BURROWING FROGS *often move into logged areas, even very recently logged forest patches.*

The information gained so far has posed interesting questions in regard to the conservation of Giant Burrowing Frogs in the forestry environment. Traditionally, conservation of frogs is achieved by leaving the breeding streams and ponds, and their bordering vegetation, undisturbed. Retaining such 'buffer zones' to protect breeding habitat remains very important for the conservation of all frog species, but just how effective it would be for Giant Burrowing Frogs, which spend most of their life away from water, is unknown. Currently 200-hectare undisturbed protection zones are set in place around any sightings of this frog, but again the effectiveness of this conservation measure for this particular species remains to be tested. Also unknown is whether retaining large undisturbed patches of forest is essential for the survival of the Giant Burrowing Frog in forestry areas. Individuals are willing to move into the logged forest patches and this suggests that maybe they can survive well enough in a mosaic of logged areas interspersed with smaller unlogged patches connected by unlogged corridors.

The male Giant Burrowing Frog (left) can be distinguished from the female by its relatively larger forearms and the obvious black spines.

Giant Burrowing Frogs need to be followed for even longer periods in logged areas to see just how well they fare compared to frogs living in undisturbed forest patches. Other frog species also need to be investigated to see how they cope with forestry disturbances. After all, protection measures must be adequate for all species in the area. Planning for these studies is already under way. In the meantime, we're delighted that this elusive frog can still be stumbled upon in the forests around Eden, and the aim for biologists like myself is to keep it that way.

FRANK LEMCKERT IS A RESEARCH OFFICER AT THE FOREST RESEARCH AND DEVELOPMENT DIVISION, STATE FORESTS OF NEW SOUTH WALES. HE HAS BEEN STUDYING THE BIOLOGY OF FROGS SINCE 1986 AND IN 1995 STARTED RESEARCH INTO THE IMPACTS OF FORESTRY ACTIVITIES ON FROGS.

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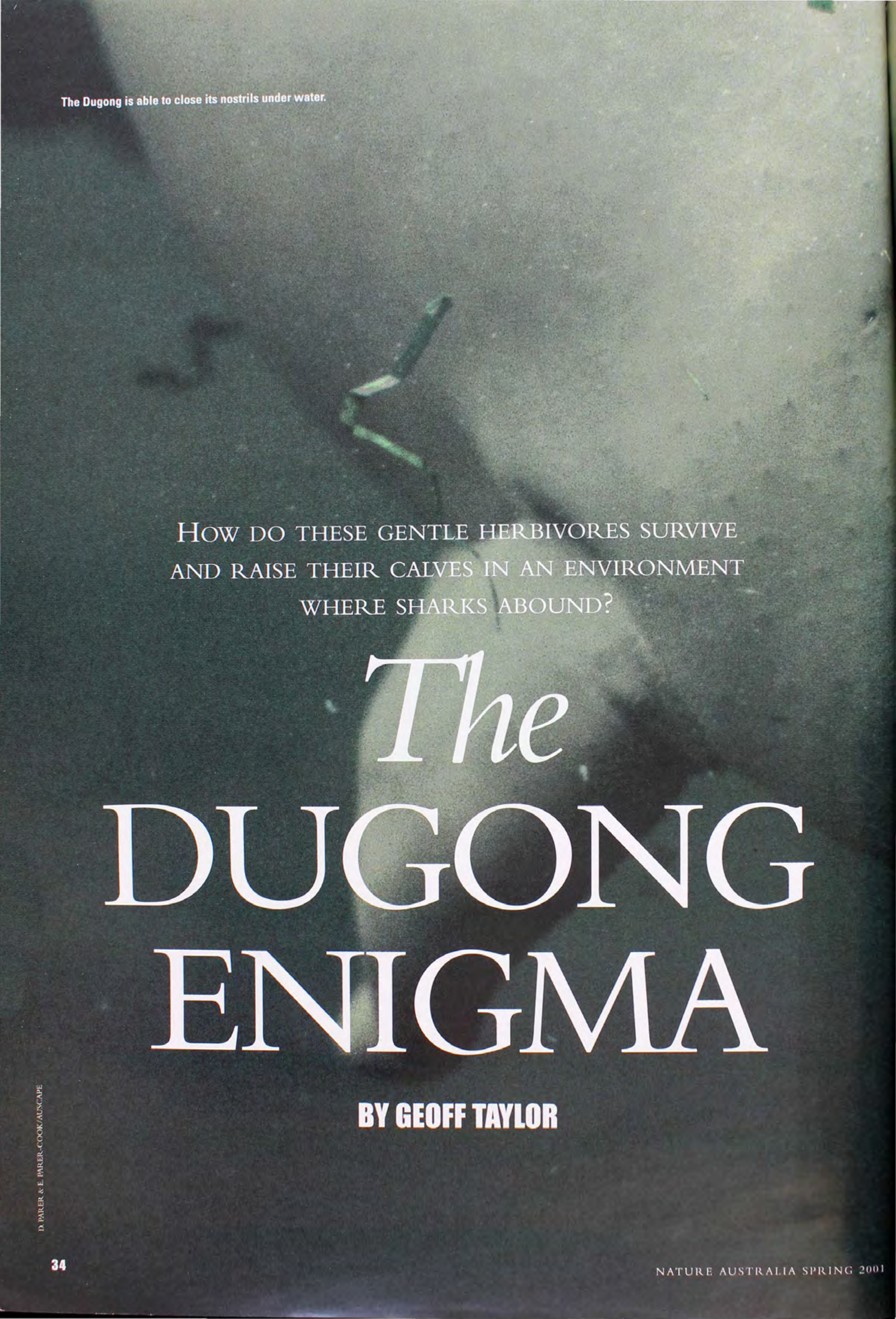
A rare sight! A male Giant Burrowing Frog in the water. This usually happens only when males are looking for or defending a calling site.

KEN GRIFFITHS

KEN GRIFFITHS

Giant Burrowing Frogs have beautiful jewel-green eyes that can only be fully appreciated when they are seen up close.



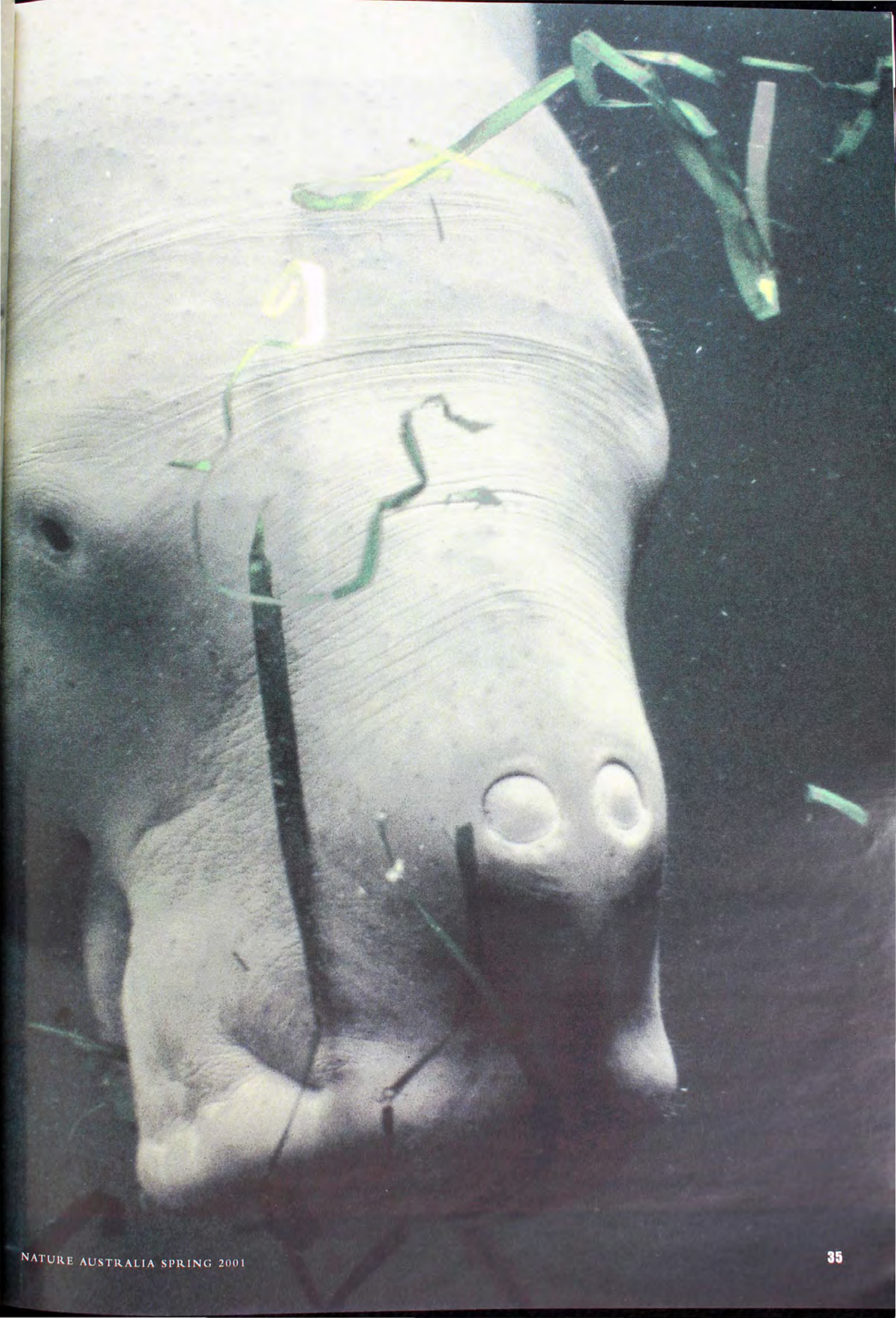
The Dugong is able to close its nostrils under water.

D. PARER & E. PARER-COOK/AUSCAPE

How do these gentle herbivores survive and raise their calves in an environment where sharks abound?

The Dugong Enigma

BY GEOFF TAYLOR



IT WAS GETTING LATE IN THE afternoon, and we were somewhat frustrated because we hadn't been able to film our quarry under water. I was with a Japanese film crew on a 12-metre catamaran, searching for the elusive Dugong (*Dugong dugon*). We had motored and sailed up the east coast of Dirk Hartog Island on the west side of Shark Bay, off Western Australia, and had come across a herd of 12 Dugongs. We managed to photograph them from the crow's nest, looking down into the water, but underwater visibility was only a couple of metres and filming was impossible.

The herd was moving north in the deeper water on the edge of a seagrass bank, some 300 metres offshore from the island. Suddenly our eagle-eyed skipper spotted an unusual 'hump' in the shallow water, close to the island, several hundred metres away. Was it a turtle or perhaps a dead Dugong? As we watched, we saw that every now and again there was some splashing. Could it be Dugongs mating? What an opportunity—high-quality footage of wild Dugongs mating had never been obtained.

The draught of our vessel prevented us from approaching closer than 200 metres, so five of us clambered into the small inflatable dinghy, clutching our camera equipment. We motored a short distance to place ourselves upwind of the disturbance, and then slowly drifted and rowed towards the 'hump'. Our excitement increased as we realised it was a Dugong, and very much alive. Every so often it would lift its tail clear of the water. The wind was pushing us closer and we were no more than ten metres from the Dugong when a huge black shape launched itself clear of the water, sinking its teeth into the flesh of the animal. In no time at all more huge black shapes were investigating our dinghy. "Sharks, sharks!" the cry went up, and there was panic aboard our pint-sized vessel as the fin of a four-metre Tiger Shark (*Galeocerdo cuvier*) scythed its way towards us and under

BEN & LYNN CROPP/AUSCAPE

The Tiger Shark is a formidable predator and feeds on a wide variety of items, including crabs, gastropods, jelly fishes, bony fishes, turtles, rays, other sharks and, of course, marine mammals.

(Top Right) A Tiger Shark attacks the Dugong in the shallows of Shark Bay. (Middle Right) The Tiger Shark rolls belly up as it feeds on the Dugong carcass. (Bottom Right) Caught in the light of the setting sun, the Tiger Shark carves another feed from the Dugong carcass.

GEOFF TAYLOR/LOCHMAN TRANSPARENCIES

the dinghy. This was too close for comfort—especially since the water we were in was only a metre deep.

However, the sharks circled back to their prey, and again launched themselves at the poor Dugong. Witnessing this frightening spectacle only a few metres away, I was overcome with a sense of awe. As we contemplated the danger of our own situation, I wondered if my companions could really appreciate their incredible good fortune.

THE NAME SHARK BAY is attributed to the English explorer William Dampier who, having arrived here in 1688, wrote "The Sea-fish that we saw here are chiefly sharks. There are abundance of them in this particular Sound, that I therefore give it the name of *Shark's Bay*." His crew caught and ate many of the sharks. About one particular shark he noted "Its Maw [stomach] was like a leather sack in which we found the Head and Bones of a Hippopotamus; the hairy lips of which were still sound and not putrefied, and the jaw was also firm out of which we pluckt a great many teeth, 2 of them 8 inches long." What he was describing of course was the head of a Dugong, with its distinctive tusks. And the shark would have been a Tiger Shark, as these are really the only sharks found in the shallow waters of the north-west that would be big enough to consume a Dugong. So Dampier and his crew were the first European explorers to document the eating of a Dugong by a Tiger Shark in Shark Bay.

It seems quite extraordinary that this huge embayment, full of shoals, named because of its huge numbers of sharks, should also be home to a large population of seemingly defenceless Dugongs. How do these gentle herbivores survive and raise their calves in an environment where sharks abound?

The Dugong is indeed an enigma, the subject of myth and legend. It is best known to many as the animal that gave

DURING THE SUMMER MONTHS,

Dugongs congregate in eastern Shark Bay to feast on the lush growth of seagrasses. This is the only area that mating behaviour has been observed.

rise to the mermaid myth. One can only surmise that the vision of mariners in days of old was distorted by scurvy, dehydration, or the demon drink, for them to have conceived the Dugong as a maiden in disguise. Granted, the naked hide of the Dugong is virtually hairless, giving it a certain human quality. But as we were soon to discover, their skin is far tougher than human flesh.

Shark Bay lies in a transition zone between temperate and tropical waters. It is at the northern limit of the common wire weed *Amphibolis antarctica*, a cold-water species that grows prolifically throughout much of the bay and provides winter grazing for the Dugong. On the eastern coast of the bay is the massive Wooramel seagrass bank, covering an area of 1,000 square kilometres. The bank supports tropical seagrasses including the Dugong's favourite salad item—*Halodule uninervis*. Dugongs don't just eat the leaves of these seagrasses; they tear out the whole plant from the seabed, consuming the nutritious roots and rhizomes as well. When feeding in this way, the Dugongs leave a trail of silt drifting away on the tide, which gives away their presence.

During the summer months, Dugongs congregate in eastern Shark Bay to feast on the lush growth of seagrasses. This is the only area that mating behaviour has been observed. As autumn approaches, the seawater temperature falls dramatically in the bay, and the Dugongs move in search of warmer water. By mid-winter, large numbers of Dugongs graze on the *Amphibolis* seagrass beds to the east of Dirk Hartog Island. This western side of Shark Bay is warmed by the influx of oceanic warm water brought south by the tropical Leeuwin current.

My early experiences with Dugongs all occurred 320 kilometres to the north of Shark Bay, in the waters around North-West Cape and the town of Exmouth. My first encounter was a memorable one. Late one winter after-

Dugong

Dugong dugon

Classification
Order Sirenia, family Dugongidae.

Identification
Rotund grey mammal with horizontal tail fluke, growing to 2.4–3 m in length. Large hairy muzzle, with nostrils on top of head. Sizeable tusks (up to 15–20 cm long), which erupt in adult males but only occasionally in females. Paddle-like pectoral fins. Female's mammary glands located in the 'armpits' and large teats protrude.

Distribution
Indian Ocean (east and west coasts, including Arabian Gulf, Red Sea and East Africa) and Western Pacific Ocean. Found throughout northern Aust. waters from Shark Bay in the west, to the waters of the Great Barrier Reef, and as far south as Moreton Bay in the east.

Biology
Underwater herbivore that feeds primarily on seagrasses. Produces one calf about every 3 years or so. Thought to give birth mainly in second half of year. Life span up to 70 years.

Status
Reduced to small populations throughout much of its range. Listed as 'Vulnerable' by IUCN. Northern Aust. is its stronghold.

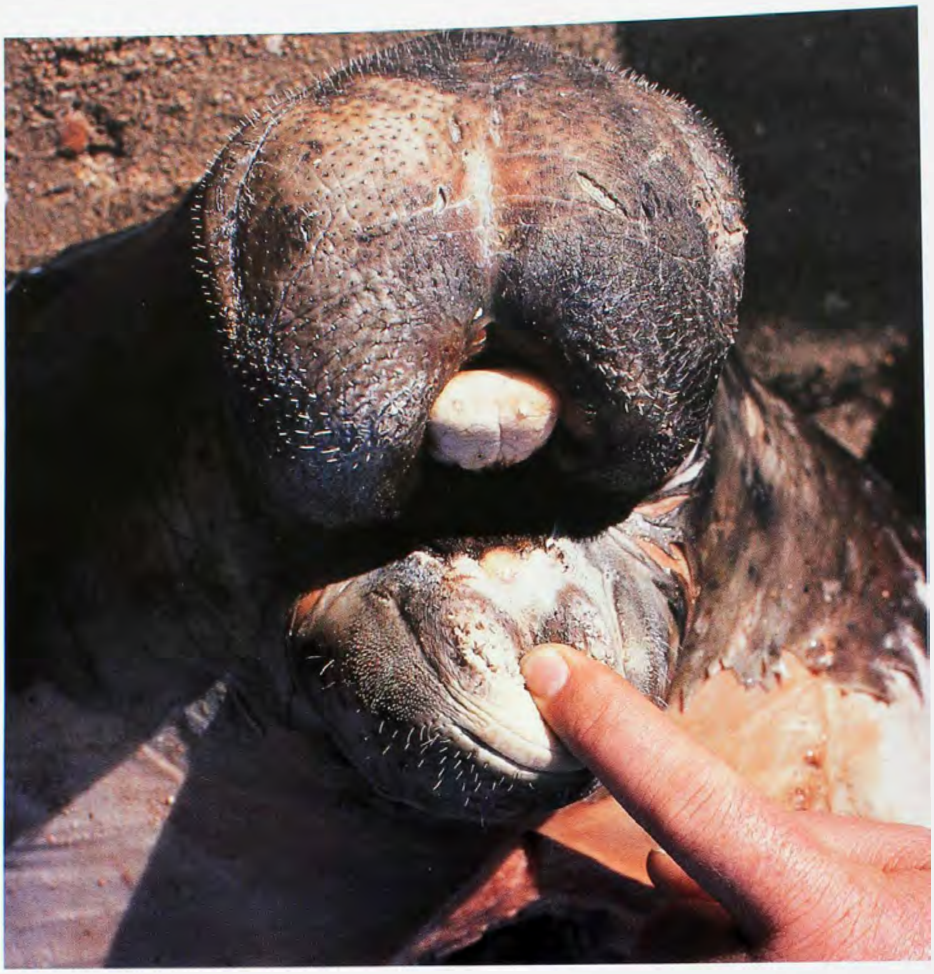
GEOFF TAYLOR/LOCHMAN TRANSPARENCIES

noon, I had returned from a fishing trip in Exmouth Gulf. Friends on the beach informed me that a Dugong was tangled in a mooring line, and had been there for several hours. It was in danger of drowning. They had decided that since I was a diver, I might be able to free the animal. Clutching a knife, I ventured out to inspect it and see what could be done.

There to my surprise was a tiny newborn baby Dugong, the smallest I have ever seen, cuddled up beside its captive mother. In the fading light, the baby appeared alabaster white. It swam from one side of its mother to the other, playing hide and seek with me. The mother had a mass of thick mooring rope twisted around the base of her tail. My initial attempts to cut the rope were unsuccessful, and with the powerful thrashing of the tail I only succeeded in cutting my own hand. However, eventually I succeeded, and it was a relief to see the mother head out into the waters of the gulf accompanied by her calf.

In spite of several expeditions to search for them, it was some years before I encountered Dugongs again. It was not until I swapped my noisy powerboat for a sleek sailing trimaran that I found there were plenty of Dugongs, often within just a few hundred metres of the boat ramp. I spent many hours observing and attempting to film them. Visibility in the waters of

A photographer's dream: this mother and calf Dugong swam right up to the author in the crystal clear waters of Ningaloo Reef. Dugongs give birth only about once every three years and the calf stays with the mother until it is almost her size.



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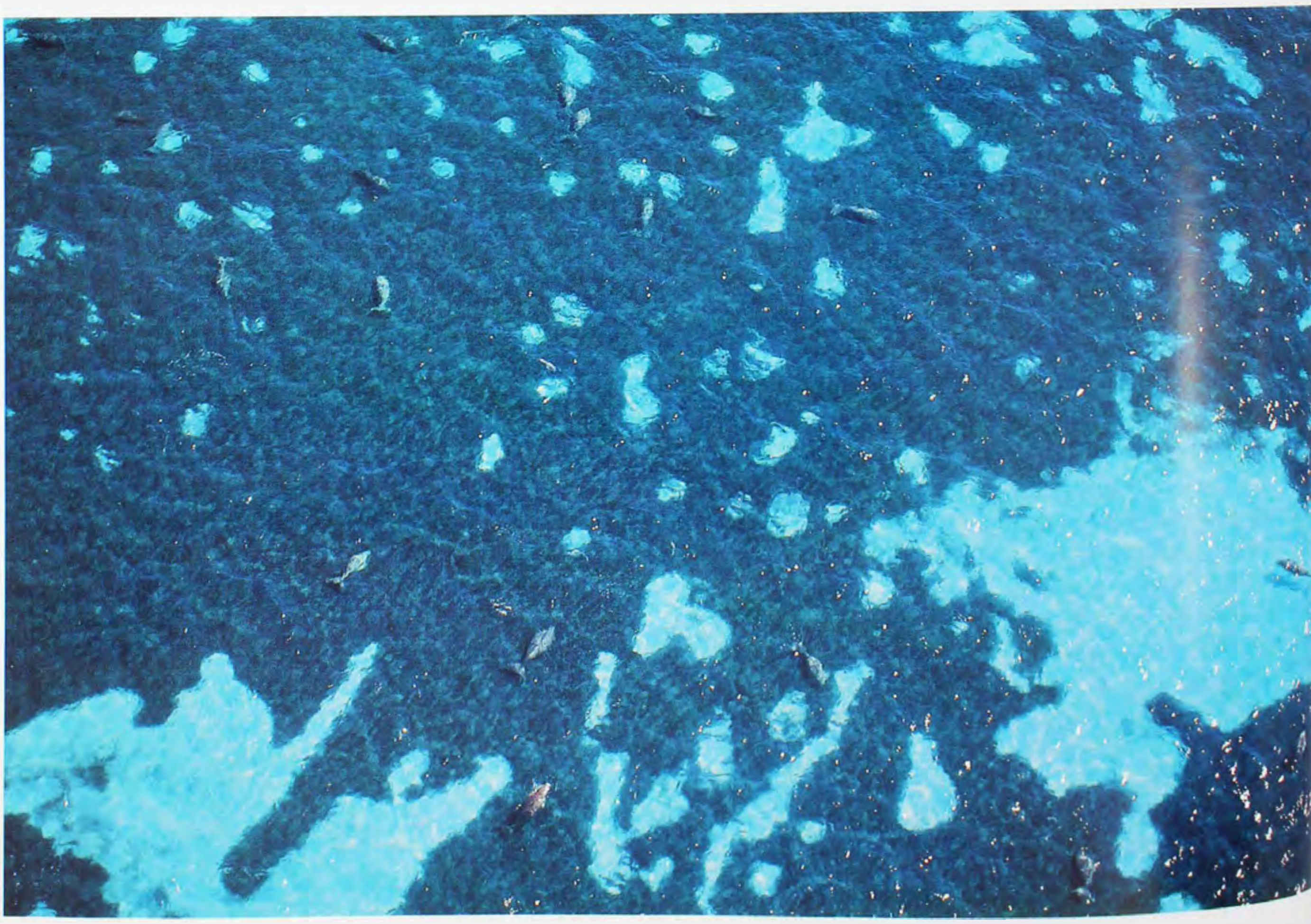
The Dugong uses its bristly upper lip to find, select and dig up seagrasses in the muddy beds.

Exmouth Gulf was often a problem, but I soon found Dugongs in the most unexpected places, such as outside the reef on the west coast of North-West Cape in crystal clear water over the coral. There are no seagrasses here and it is truly the home of large predatory sharks. It was here that I succeeded eventually in photographing a mother and calf at close quarters.

The importance of the west-coast Dugong population becomes ever more apparent. Throughout most of its range from east Africa to Vanuatu, the Dugong is now rare. The problem with the Dugong is its low fecundity, giving birth only once every three years on average. The Dugong calf swims with its mother until it is almost as large as she is, when it is finally weaned and replaced by another newborn. The species struggles to maintain its numbers even in the best circumstances, and cannot cope with pressures such as overkill or habitat loss.

Even though Dugongs are protected,



D. PARER & E. PARER-COOK/AUSCAPE

From the air, Dugongs in Shark Bay can easily be spotted feeding on seagrasses.

Once the tail was removed by the Tiger Shark, the Dugong was an easy target and was soon decapitated.

GEOFF TAYLOR

there has been a dramatic decline in their numbers on the urban coast of Queensland. This has been attributed to a range of factors including overkill from Indigenous hunting, animals being accidentally drowned in commercial gill nets and shark nets, and habitat loss. The combination of torrential cyclonic rains and excessive land clearance for agriculture has resulted in increased siltation of the seagrass beds. In areas like Hervey Bay, emaciated carcasses of starved animals have washed up on shore. There is the potential for the same disasters to occur in Shark Bay. The waters of the Wooramel seagrass bank are in the estuary of the Wooramel River, which flows through station country that has been degraded by cyclical drought and overgrazing. Thankfully, cyclonic rains are infrequent. Farther north in Exmouth Gulf, when Cyclone Vance (the most powerful Australian cyclone on record) hit in 1999, heavily silted waters caused massive coral destruction and it is likely that seagrasses were also destroyed.

So WHAT BECAME of our shark-attack victim off Dirk Hartog Island? The sharks continued their assaults for several minutes but then our proximity seemed to frighten them away. The presence of nipples below the pectoral fins revealed that this was a female and a very sick one. She had a bloated gut, which was possibly caused by a bowel obstruction. The Dugong headed for deeper water, but all attempts to dive were hopeless, as her balloon-like gut kept bringing her straight back to the surface. Studies by Mike Heithaus (Canada's Simon Fraser University) on the behaviour of sharks and dolphins in Shark Bay have shown that the shallow waters are the main hunting grounds for Tiger Sharks and the main feeding grounds for the dolphins and turtles on which they regularly prey. Perhaps the Dugong thought there might be safety in deeper water.

Our observations gave us an insight into how the Dugong defends itself. The initial shark attack was directed at the tail of the animal in an attempt to immobilise it. In response, the Dugong lifted its tail high out of the water. The shark could then only attack the torso of the animal, but it found it difficult to get its mouth around such a bulky object. The Dugong then did 'barrel rolls', spinning its body around using its pectoral fins, so the shark lost its grip. We had no idea how long the attacks had been going on for, but remarkably the body of the Dugong was still intact and, although covered in deep scratches, the skin had not been penetrated to any depth, a testimony to the toughness of its hide.

As the sun sank towards the horizon, it was not long before the sharks returned. They continued their attacks on the Dugong's tail and eventually succeeded in removing it. Once it was immoblised they went in for the kill, attacking the throat. The feeding frenzy continued, but the large sharks still had trouble getting a purchase with their teeth on the rotund torso of the Dugong. Thrusting their heads from side to side, they slowly carved up the remaining carcass.

What we had witnessed was euthanasia in action. In the wild, there is no place for the infirm. If an animal does not recover quickly from illness, it will be destroyed. This ensures the survival of the fittest, the young and the strong. As we motored south that night to seek a safe anchorage, we reflected on what a remarkable day it had been, and how privileged we had been to witness such an extraordinary event; an event that had also given us some answers to the enigma of the Dugong.

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We have been studying Malleefowl in an attempt to find a way of saving them from extinction.

MALLEEFOWL: MOUNDS *of* DIFFERENCE

BY DAVID PRIDDEL & ROBERT WHEELER

When it comes to breeding, birds are a pretty predictable bunch—they lay eggs (often in simple nests), brood these until they hatch, and nurture the young through to fledging. One group, however, dares to be different.

The megapodes (family Megapodiidae) use sources of heat other than body warmth to incubate their eggs. Some bury their eggs in sands warmed by the sun (as do turtles) or by underground geothermal activity; others build large compost heaps and lay their eggs into these (*à la* crocodiles). Most megapodes inhabit the rainforests

KATHIE ATKINSON/AUSCAPE

A male Malleefowl removing soil from the mound early one spring morning to permit excessive heat, emanating from the decomposition of the leaf litter, to escape. If this is not done, the mound will overheat and the eggs will die.

or tropical mangrove forests of Australasia and the South Pacific, where copious amounts of moisture and leaf litter favour the use of incubation mounds. The Malleefowl (*Leipoa ocellata*), however, inhabits the arid interior of Australia. The use of incubation mounds in such a dry environment requires this species to play a far more active role in the maintenance of its complex and intricate nest—a dome-shaped structure usually about three metres wide and a metre high.

The Malleefowl has undergone a substantial decline since European settlement and the species is now seriously threatened. Land clearance has been the main cause of the Malleefowl's demise, but other contributing threats include competition from stock and feral herbivores for food, altered fire regimes, and predation by Foxes (*Vulpes vulpes*). We have been studying Malleefowl in an attempt to find a way of saving them from extinction. One very disconcerting finding of our research is that Foxes kill most Malleefowl chicks within their first few weeks of life.

THE MALLEEFOWL IS a chicken-sized bird weighing about two kilograms. Pair bonds form at about two years of age and are maintained for life, often over 12 years. During this time, a pair may produce more than 150 chicks.

Much of what we know about Malleefowl nesting habits comes from landmark studies undertaken during the 1950s by Harry Frith (while at the CSIRO). More recent studies, particularly those undertaken by Roger Seymour (University of Adelaide) and his co-workers, have revealed the physiological intricacies that allow the Malleefowl to achieve its remarkable feats.

DAVID PRIDDEL

Malleefowl, both young and adults, roost in the outer foliage of tall shrubs and trees. Males often roost in trees within ten metres of their mound.

The nesting season begins in autumn when the male digs out the centre of an old mound to form a crater about one metre deep. He, or another pair, may have used this mound the previous season, or it may not have been used for decades. Only rarely will a male forgo renovating an existing mound in favour of constructing a new one.

Over the next few months the male

and his partner scrape leaves, twigs and small fallen branches, from within a 50-metre radius of the mound, into windrows. This material, totalling approximately one cubic metre in volume, is laboriously raked into the crater, providing the fuel needed to heat the interior of the mound.

Rainfall throughout winter is critical for the incubation mound to operate successfully. After each reasonable shower the male turns over the litter, aerating it and distributing moisture through it. This repeated turning accelerates the process of decomposition, and aids compaction.

The next stage in nest construction is the formation of an egg chamber. In spring, the male hollows out a pit in the centre of the compacted litter. He then fills this hole with a mixture of earth and litter, and covers the whole structure with soil.

Egg laying usually begins in spring, and continues until late December or, with good rains, even February. In these wetter years, a female may produce over 25 large-yolked eggs (35 eggs is the most laid by a female in one season). This prolific production of eggs is remarkable given that the size of the egg is eight to ten per cent of the

The male Malleefowl has shaped the mound into a dome to insulate the eggs from the intense solar heat of a summer's day. The eggs were located in an egg chamber about 70 centimetres below the summit. Leaf litter around the mound is scarce as much of it was raked into the mound during its construction in the winter months.

KATHIE ATKINSON/AUSCAPE

A pair of Malleefowl opening the mound in preparation for egg laying.

Malleefowl

Leipoa ocellata

Classification
Order Galliformes, family Megapodiidae.

Identification
Adults 2 kg, stand 440 cm high on robust, powerful legs. Sexes similar. Back, tail and wings a mottled brown, black, grey and white; cream body; grey head, neck and breast; rufous chin. Dark head crest, raised when alarmed.

Distribution and Habitat
Broken distribution across southern mainland Aust. from coastal WA through SA and north-western Vic. to central NSW. Semi-arid and arid shrublands dominated by mallee eucalypts; also *Eucalyptus* and *Callitris* woodland and, in WA, coastal heaths.

Breeding
Mates for life. Builds and maintains an incubation mound. Eggs laid in spring and summer at intervals of 4–17 days. Clutch size dependent on rainfall. Typically, females lay 9–21 eggs per season. Eggs weigh 170–210 g. Incubation about 62 days, 50–80% of eggs hatch. Chicks highly precocial and live completely independently of their parents. Life span may exceed 15 yrs.

Diet
Generalist feeder, eating seeds, shoots, flowers, buds, invertebrates, lerps and fungi.

Status
Vulnerable nationally and also in Vic., SA and WA. Endangered in NSW. Near extinct in NT. Estimated population size in NSW < 300 pairs.

Threats
Clearing for cropping or pastoralism; grazing by stock, Goats and Rabbits; frequent burning; predation by Foxes.

female's body weight. Within a four-month period, a Malleefowl may produce more than twice her body weight in eggs—an astonishing feat, considering the harshness and aridity of the environment in which she lives. To sustain this level of egg production, the female spends much of her day either searching for food or resting to conserve energy.

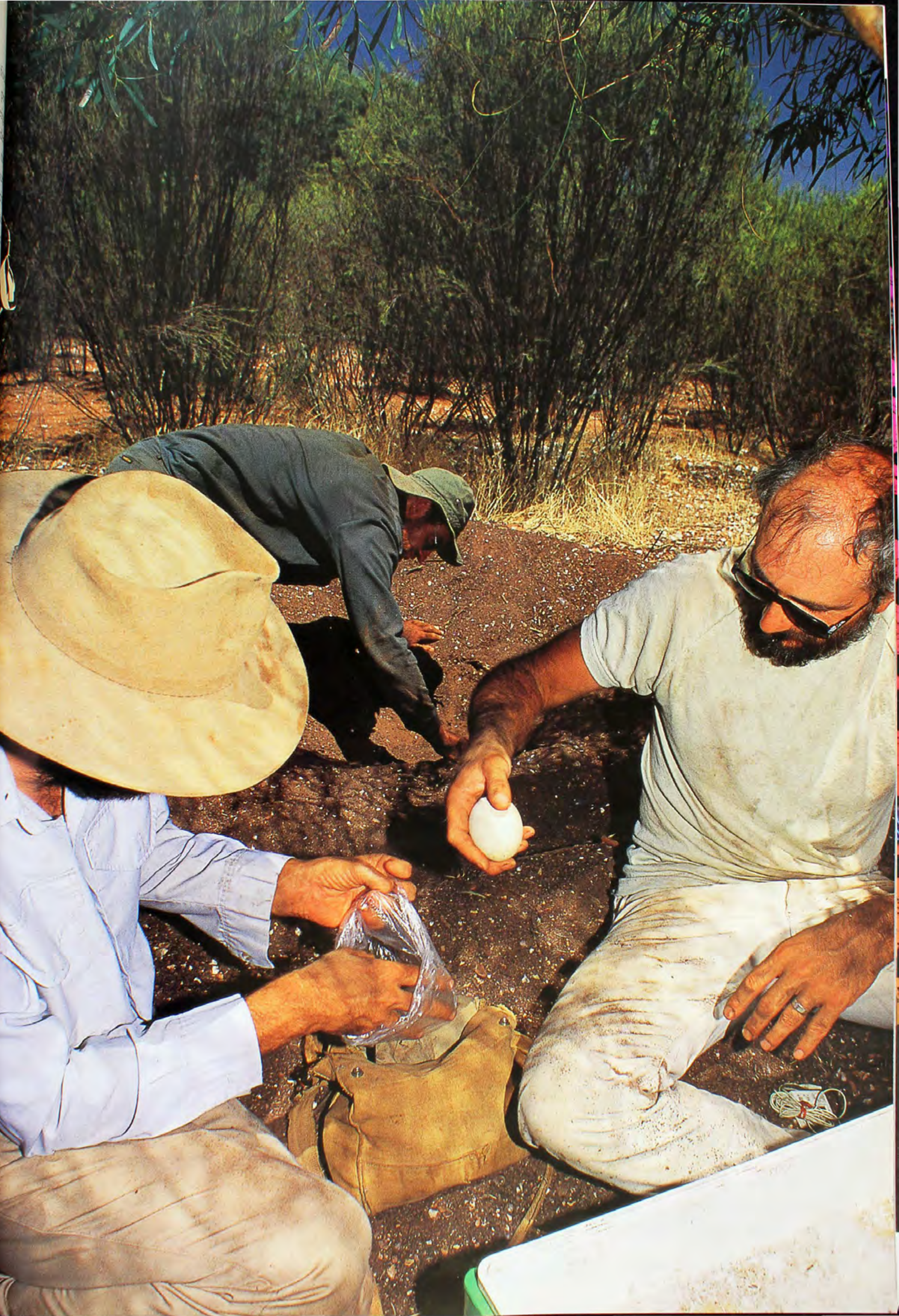
The male, on the other hand, devotes a large proportion of his energy to working the mound, for he has chief responsibility for maintaining the egg chamber at the optimal temperature of 34° C. During spring, heat from the decomposing organic matter is excessive and eggs left unattended in the chamber would overheat and die. On most fine mornings in spring and early summer, however, the male lets excess heat escape by digging out the mound almost down to the level of the nest chamber. He then quickly reforms the structure before too much heat is lost.

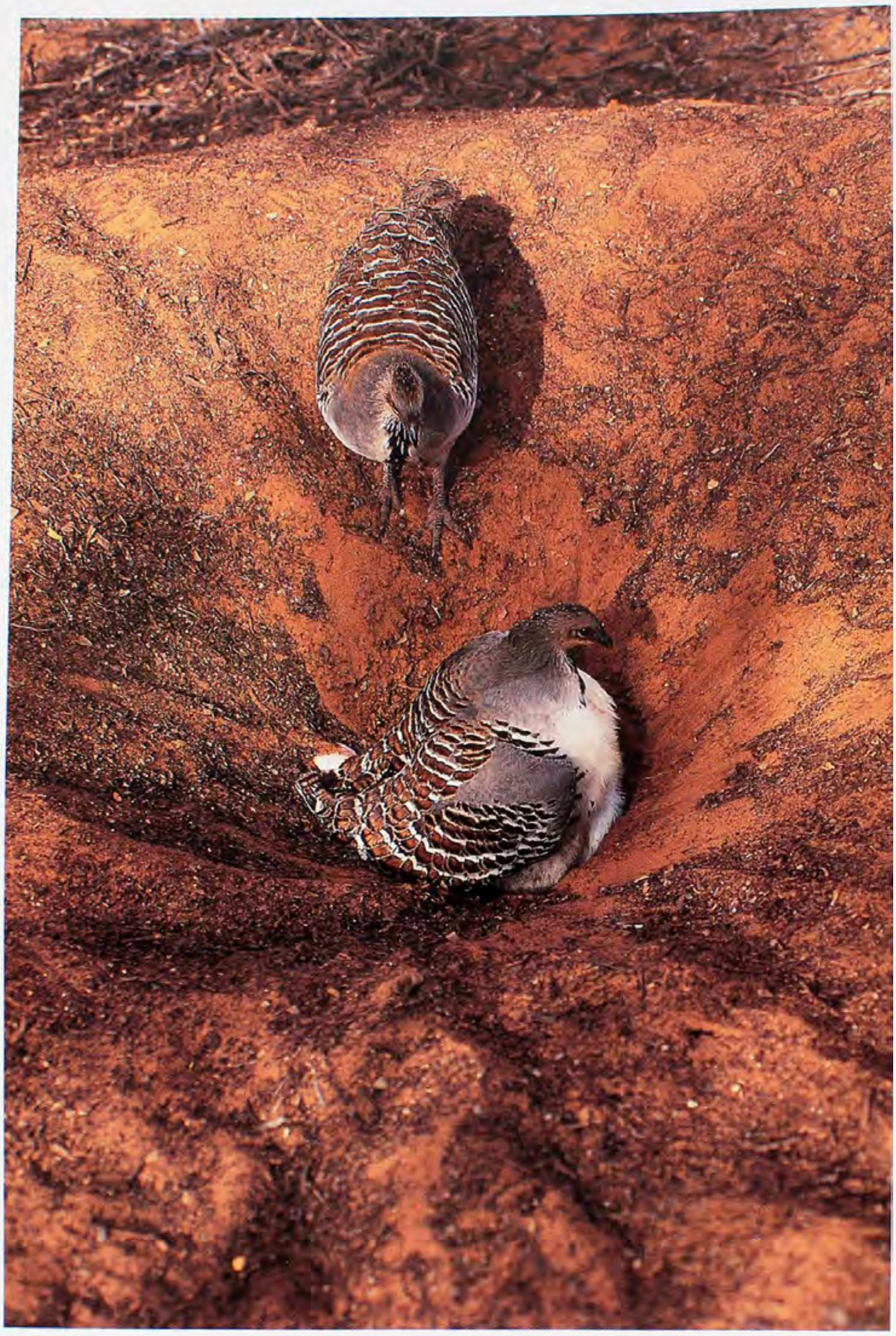
In late summer and autumn, the male adopts a completely different approach. With little or no heat generated from within the mound, the bird must now use the sun to warm the eggs. In the morning, the male flattens out the mound, increasing its surface area and exposing much of it to the sun's rays. Periodically throughout the day, he scrapes the warmed surface layer of soil back into the centre of the nest, so that by late afternoon the eggs are once again blanketed by a mound of warm soil.

Usually by mid autumn, when it has become too cold for the male to maintain the mound at the appropriate temperature, he abandons it, often digging out the decomposed litter and discarding any remaining eggs.

So determined is the male to properly regulate the mound's temperature that he will not open it on cold or rainy days, even if the female wishes to lay. Sometimes he even has to chase his partner from the mound. Much of our research has involved excavating Malleefowl mounds to monitor the

NPWS officers collecting Malleefowl eggs from an island of mallee vegetation isolated in a sea of agricultural land. The eggs were later artificially incubated and the young formed the basis of a captive-breeding colony.





KATHIE ATKINSON

The female lays an egg deep inside the mound while the male looks on. After laying, the female will leave the mound silently, in contrast to the frequent calling she made during the lead-up to laying. The male will then cover the egg and reform the mound.

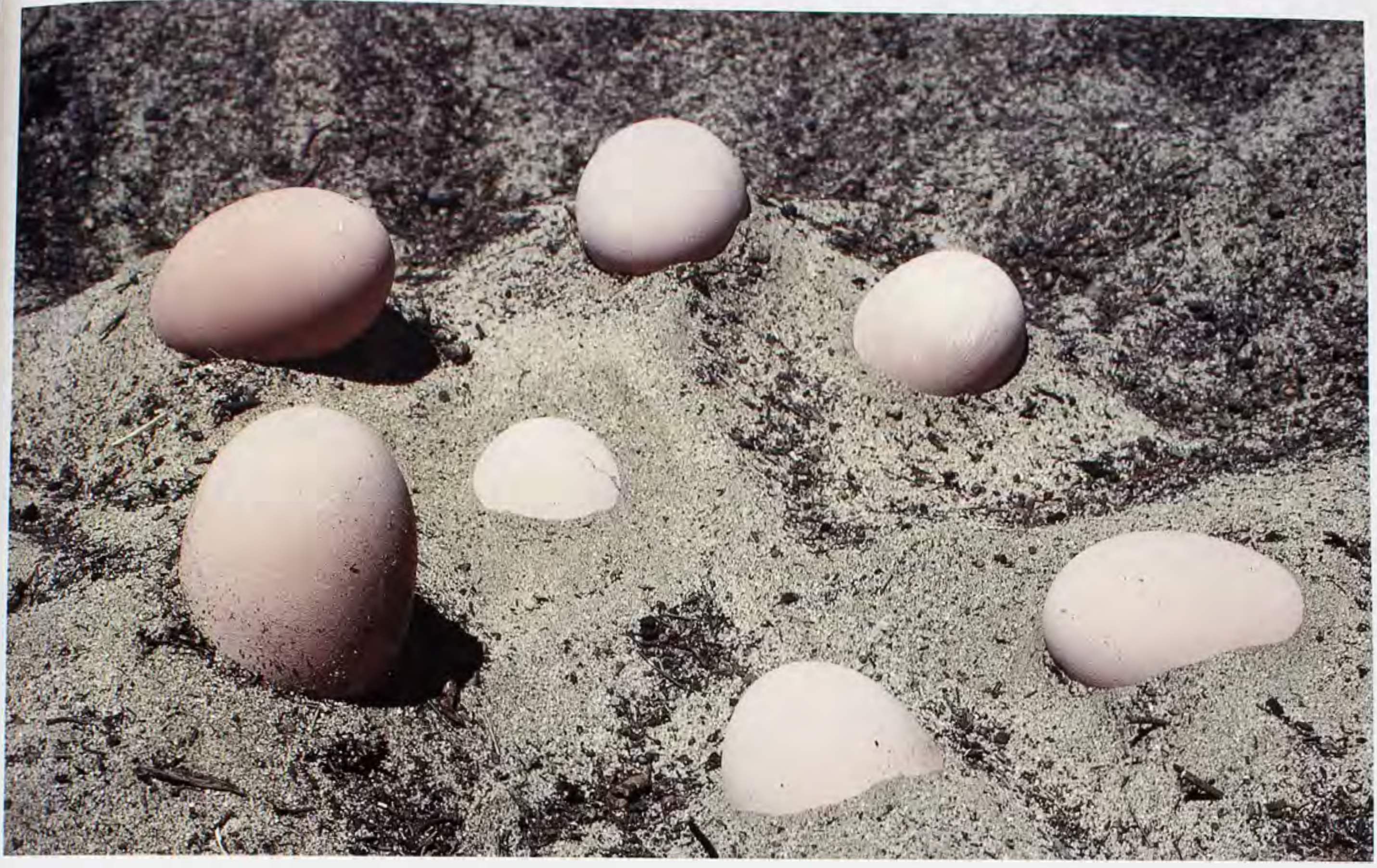
progress of the eggs inside. On many occasions we have had to endure sand being kicked into our faces by a Malleefowl intent on covering the eggs as fast as we attempt to uncover them.

Both sexes have temperature sensors located in their mouth, enabling them to gauge the temperature of the mound by taking a mouthful of soil from its core. The birds also appear to have some kind of in-built barometer. During winter, on days immediately before and after the onset of rain, many captive birds will embark on a flurry of activity, raking leaf litter into their mounds. Keepers at Western Plains Zoo failed to elicit the same response when they added copious amounts of water to the birds' leaf litter, indicating it is not water as such that stimulates the birds into action but something else—perhaps a change in air pressure.

As different as the Malleefowl nest is to that of conventional birds, so too is the Malleefowl egg. The typical avian egg has a shell perforated by cylindrical pores that allow the exchange of gases between the embryo and the outside atmosphere. This typical egg also has an air sac. When the embryo is ready to hatch, it punctures the air sac (internal pipping) and begins to breathe through its lungs for the first time. The chorioallantois, a network of blood vessels and membranes lining the inner surface of the shell and up until now the only means of gaseous exchange, begins to shut down. The changeover from chorioallantoic to pulmonary (lung) respiration usually takes about one day. The chick then chisels its way through the shell with its egg tooth (external pipping), flexes its body, and eventually frees itself from the shell.

For buried eggs, like those of the Malleefowl, adequate gas exchange is potentially more difficult. Although the nest chamber is exposed to fresh air when the adults dig into it, the decomposing leaf litter usually means that the air around the eggs is high in carbon dioxide and low in oxygen. The structure of the Malleefowl egg has evolved to cope with the difficulties associated with gas exchange below ground.

Pores within the shell of an egg facilitate the flow of carbon dioxide and oxygen, but also allow moisture to escape from the egg. Pores need to be narrow to conserve water but this can impede the flow of carbon dioxide and oxygen. Roger Seymour and colleagues discovered that pores in the shell of the Malleefowl egg are conical, not cylindrical as in most eggs, with the apex (pointy end) of each cone on the inside of the shell. In the early stages of development, the amount of gaseous exchange needed to sustain the embryo is low, so small pores are adequate. As the Malleefowl embryo grows, its need for oxygen increases, as does its need to excrete carbon dioxide. However the original pore size is too small to cater for this increase in metabolic activity. The Malleefowl embryo resolves this problem by absorbing calcium from the eggshell as it develops, causing the shell to thin



HANS & JUDY BESTE/LOCHMAN TRANSPARENCIES

Malleefowl eggs are buried deep in the sand and leaf litter of the nest chamber. Eggs are laid at regular intervals through spring and summer. The first eggs are laid at the base of the chamber with later eggs being progressively deposited towards the top. Although the Malleefowl is about the same size as a domestic chicken, its eggs are approximately three times the size of chicken eggs.

(and the bones to strengthen). As this thinning proceeds, the conical-shaped pores of the shell are continually truncated, thereby enlarging the internal opening of each and increasing the rate of gaseous exchange. Although the larger-diameter pores have the potential to increase the rate of water lost from the egg, this loss is limited by the high relative humidity (often over 75 per cent) within the egg chamber.

Malleefowl also differ from typical birds in their mode of hatching. Malleefowl eggs do not contain an air sac, so there is no internal pipping. Nor is there any external pipping. Consequently, the Malleefowl chick must switch from chorioallantoic to pulmonary respiration as soon as it breaks the shell. The Malleefowl embryo develops within the egg with its back arched, its head resting on its chest, and its feet tucked up under its body. To rupture the shell, the embryo stretches violently by simultaneously straightening its back and extending its legs. The eggshell shatters and the chick's head

TO RUPTURE THE SHELL, *the embryo stretches violently by simultaneously straightening its back and extending its legs.*

rears up to take its first breath. This is a critical time for the embryo. If the lungs are not functioning sufficiently, the chick dies.

Once free of the egg, the chick must dig its way out of the mound through soil up to a metre deep. This can take from two hours to as long as two days. The chick pops its head out of the mound and opens its eyes for the first time. It may rest here a while before it extricates itself in a puff of dust to wobble off the mound, often stopping to rest under a nearby bush. Within minutes, the chick is able to walk properly and peck at seeds and passing invertebrates. A few hours later it can flutter, and within a day it will be flying strongly. Malleefowl chicks live completely independently of their parents.

Crocodiles share a similar incubation strategy with Malleefowl (for example, use of incubation mounds, large-yolked eggs, precocial young) but the resemblance is superficial and coincidental, and is not an indication of a close evolutionary link between reptiles and the megapodes. Indeed, evolutionary biologists believe that the megapodes are a modern family of birds of relatively recent origin, and that the methods they use to incubate their eggs evolved from the typical strategy of using body heat.

THERE IS NOTHING EASY in the life of a Malleefowl. The adults endure a long and laborious breeding season in some of the harshest environments in Australia. Young Malleefowl have it

ROBERT BROWN

A Malleefowl treats itself to a dust bath while resting during the heat of the day. The bird's plumage mimicks the colours and patterns of its mallee habitat.

tough from the moment they hatch. Having dug their way up through the mound, the chicks must find food and avoid predators totally unaided by their parents. Regardless of these hardships, Malleefowl have survived for millions of years, evolving an elaborate and unique nesting procedure to cope with the interior of this country as it changed from luxuriant forest to semi-arid shrublands dominated by mallee eucalypts.

Despite their past resilience, Malleefowl have declined appreciably in number since European settlement of Australia. Their camouflage and habit of remaining motionless when threatened helps against aerial predators, but is not so effective against introduced mammalian predators such as the Fox, which can easily sniff them out.

Intensive ground-baiting of Foxes has met with limited success in protecting Malleefowl. However, baiting from the air in addition to ground-baiting has significantly improved the survival rate of Malleefowl in parts of New South Wales. This type of baiting needs to be extended, as does the control of Rabbits and feral Goats. Preventing the clearance of what is left of Malleefowl habitat is also crucial if this truly unique Australian is not to be lost forever.

The extinction of the prehistoric giant megapode *Progura gallinacea* appears to have coincided with the first wave of people arriving in this country. There is some debate as to whether this extinction was caused by humans or by climate change. Whatever the case, we should do everything that is necessary to ensure that its cousin, the Malleefowl, does not disappear as a result of the latest arrival of humanity.

ESTHER BEATON

A Malleefowl chick emerges from the mound after digging through a metre or so of soil. Its journey from the nest chamber has taken up to two days to complete.

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AUSTRALIAN MUSEUM RESEARCH LIBRARY COLLECTION

THE PRE-EUROPEAN AUSTRALIAN ENVIRONMENT WAS A NATURAL CONSTRUCT OF A LONG HISTORY AND THE THINGS WE ARE LOSING NOW WILL NOT BE RECOVERED.

PURE STATE *of* NATURE

BY DAVID HORTON

JAMES COOK, REFLECTING ON HIS FIRST IMPRESSIONS OF THE AUSTRALIAN CONTINENT and the relationship between Aborigines and the environment, wrote, "we see this country in the pure state of nature, the Industry of man has had nothing to do with any part of it." He had no scientific evidence for this of course, no archaeology, no ethnography, no ecology; it was just a gut feeling. After 230 years of accumulating scientific evidence of all kinds, and a debate raging backwards and forwards, it is clear to me that Cook's gut feeling was correct.

FRANK WOERLE/AUSCAPE

(Above) An Aboriginal campfire on the New South Wales coast. Such fires, seen from afar by explorers, were sometimes interpreted as evidence of 'fire-stick farming'. (Right) A tree burning after being set alight by lightning strike—the cause of large numbers of bushfires in the past and today.

What Cook was seeing was a landscape in which the forests and woodlands and heaths and grasslands and marshes and sand-dune vegetation all occurred pretty much where he expected to see them. His keen eye instinctively analysed mountains and hills and flats, and their exposure to winds, and the kind of geology, and the distance from water, and he didn't see anything in the vegetation that seemed out of place. Nothing anomalous that might be the result of human activity.

He couldn't have known anything about the animals and their habitats, but would probably have assumed that, if the vegetation was predictably in place, the animals living in that vegetation would be too. It was also impossible for him to know that the Australian fauna and flora had changed over time, with the country being at times wetter, and at other times drier, than it was when he cruised past, but I doubt this would have changed his opinion. Nor should it have. Finally, he could not have known that in the distant past (perhaps up to 20,000 years ago) there had been a range of giant animals (megafauna) that were now extinct. I don't know how he would have viewed this information, but when others discovered it, much later, their opinions were divided as to whether the loss of these animals had been due to excessive hunting by humans or to climatic change.

FIRE IN THE EUROPEAN *mind meant people, and they recorded not only the simple presence of smoke, but also the number of fires.*

Two centuries after Cook there is a popular belief that he was wrong—that Australia was not in a "pure state of nature"; that Aborigines caused the extinction of the megafauna, and that the vegetation Cook observed was not 'natural' but had been extensively modified by Aboriginal use of fire. Both beliefs, in my opinion, are wrong.

When the first Europeans sailed along Australian coasts, they were making observations with potential colonies in mind. A critical factor of course was whether there were already people living here. They couldn't see any obvious signs of habitation or other results of human activity, so they fell back onto one of the most fundamental signs of all—fire. Fire in the European mind meant people, and they recorded not only the simple presence of smoke, but also the number of fires. Every campfire meant a group of people, and the more campfires the bigger the population.

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

Aboriginal use of fire to hunt or clear vegetation in central Australia.

Many of our ideas about the past depend on interpreting the observations of people who saw Australia in the 18th century (or earlier) and early 19th century. When we look at their records we have to take into account what they knew about the world and about Australia. Some present-day scientists have thought that every time fire is mentioned in these early records it means bushfire, and, moreover, bushfires caused by Aboriginal burning. In fact, most records (for example by Cook) are simply of campfires.

Other early records that have been used in highlighting the role of fire in moulding the Australian landscape are those describing the vegetation as colonists and explorers pushed out from Sydney Cove. Some scientists have claimed that these early observations of occasional relatively clear areas of bush are evidence that Aborigines deliberately used fire to clear the land. But such records must

WAYNE LAWLER/AUSCAPE

JOHN McCAMMON/AUSCAPE

(Top) Logging is one of the many activities that are continuing to damage the Australian environment, almost to the point of no return.

(Above) 'Control burning' is the deliberate starting of fires in order to prevent fires later—a useful safety measure but environmentally damaging.

be used very cautiously. The explorers were expecting to see 'wilderness', by which they meant thick vegetation, and they were anxious to find relatively open areas that would be suitable for agriculture and put considerable emphasis on it when they did find such an area. They didn't understand (as James Cook seems to instinctively have done in a time long before the scientific study of ecology) that there could be considerable variation in the density of vegetation as a result of differences in soil, topography, rainfall etc. Nor did they realise that fire was a natural part of the ecology of Australia (and had been for millions of years). Some scientists have thought that the observations of clear areas suggest that Aborigines modified the environment extensively by use of fire, to the extent of clearing vast areas and leaving far fewer trees than there are today. I believe this is simply wrong, and that such interpretations can only come from a selective view of the evidence and a misunderstanding of the nature of the observations. In fact, of course, today there is only a tiny fraction of the trees remaining that were present 200 years ago, and one of the great conservation challenges of the 21st century is to halt and reverse the destruction of forest and woodland habitats.

I think there has also been a considerable misinterpretation of the use of fire by Aborigines in the context of the general extent of fire in the Australian environment. Undoubtedly Aborigines were much more relaxed about fire than we are. Fires were a frequent occurrence anyway because,

almost every time there was an electrical storm, lightning would strike trees and start bushfires. There were no permanent structures that could be damaged, no houses that couldn't be quickly rebuilt, no livestock, no commercial operations. The people themselves were so mobile that fires could be readily avoided. And areas that had been burnt in the recent past tended to be easier to move through and later still might provide some food sources. They would eventually grow back to what they had been before. With these observations in mind, Aborigines would have felt perfectly at ease casually using fire to flush out game, or to clean up some impenetrable forest, or even if the wind blew sparks from their campfires into nearby bush.

But how many fires could occur in a particular area in a decade would depend on the kind of vegetation that was there, what the topography was like, the climate, soils and so on. That is, fire (caused by both Aborigines and lightning) in Australia's past was a function of vegetation patterns, not the reverse. It doesn't much matter whether fires were caused by lightning or fire sticks, the frequency, and the effect, were the same. After all, you can only have fires to the extent that the vegetation in a particular region will permit. On average then, over 50,000 years, the fire regime would have been the same whether there were human beings here or not. We should keep this in mind when considering the vexed issue of control burning.

In Australia today there are houses and livestock and infrastructure and commercial operations and human life to be protected. Burning the bush in a controlled way in order to prevent more serious fires later is probably a necessity where houses and other structures have been allowed close to or within wooded areas. But while it might be a necessity, it is no more desirable than using a bulldozer to clear a firebreak, and it should only be done very sparingly. It is not desirable to regularly burn every part of the bush in the mistaken belief that this was done by Aborigines in the past. It wasn't, and if control burning is done extensively, it will result in considerable ecological damage. We need to live within the Australian ecology, not try to totally dominate it.

LUDWIG LEICHHARDT WAS one of the rare explorers who tried to adapt to the Australian ecology rather than dominate or ignore it. In 1844, at about the time Leichhardt was preparing for his expeditions, fossils were found of giant herbivores unlike any so far observed. Leichhardt's view was that this megafauna no longer lived in eastern Australia because of climatic change in the past, but that he would probably find them living in more tropical inland areas as he headed north and west. They weren't bad guesses, but he was a few thousand, perhaps quite a few thousand, years too late to see the giant wombat-like *Diprotodon* wandering the inland plains. But his first guess, like Cook's, was right, although opinions about this matter

Massive floods are one of the consequences of the combined effects of increased greenhouse gases and land clearing.

JEAN-MARC LA ROQUE/AUSCAPE

have also fluctuated in the 160 or so years since the fossils were found.

They have fluctuated for a number of reasons to do with both the nature of the evidence (and lack of it), and with the scientific and political environment at different times. The debate has a long and complicated history, but essentially has centred on the relative dates of human arrival and faunal extinction; what mechanisms there could be for either human-induced or environmentally induced extinctions; and the nature of the archaeological evidence for the dates and for the mechanisms of extinction.

After many excavations of sites with megafauna, and considering all the facts before me, I believe that Aborigines had nothing to do with the extinction of these giants. Extinctions were not caused by excessive hunting (nor could they have been over a whole continent by hunter–gatherers with spears), nor by the use of fire (which, given the way in which fire patterns are determined by vegetation patterns, was probably little changed after human occupation). Instead, the extinctions of the late Pleistocene were the result of a change in climate, just as climatic change caused all the extinctions that had occurred in the millions of years before human arrival. The climate in the late Pleistocene had become extremely dry—bad news for large animals that need a lot of water. The last of the megafaunal extinctions occurred not when humans arrived, but many thousands or perhaps tens of thousands of years later, as research at sites like Lancefield (Victoria) and Cuddie Springs (New South Wales) has shown. This coincides with about the time that climate deteriorated.

Does it really matter what caused the extinction of the megafauna? Well, yes—although it happened long ago, it has many implications for present-day attitudes to the Australian environment and approaches to conservation.

The extinction of the Australian megafauna, the result of climate change, was a very loud early-wake-up-call. Now it is high noon, have we heard the call? In the late Pleistocene the biodiversity of Australia was high and the environment in very good shape, thanks to the light touch of Aboriginal activities. Even so, that change to a drier climate caused a large number of extinctions, and it will happen again. The way Aborigines maintained the environment (by avoiding activities that would damage it), with the retention of trees and biodiversity, is a greenprint for the future. If the effects of Greenhouse arrive when the environment is not equipped as a result of our lack of maintenance, then the effects will be greatly multiplied.

Some people believe that, for the last 50,000 years, humans have been constantly manipulating the Australian environment, causing vegetation change and extinctions, and that it therefore needs to be constantly interfered with by us through activities such as logging and burning. But the pre-European Australian environment was not an artificial construct of human making; it was a natural construct of a long history and the things we are losing now will not be recovered.

As in many areas of political life, and life generally, perception is more

ANNE MUSSER, AUSTRALIAN MUSEUM

Reconstruction of *Diprotodon*, one of the giant marsupials that became extinct at the end of the Pleistocene Period.

Archaeological excavation at Cuddie Springs, New South Wales, a site where there is evidence that humans and giant marsupials overlapped in time.

important than substance. Some people argue that, if Aborigines caused extinctions, then we needn't look at the present Australian environment as a natural system to be conserved. A landscape dramatically altered once can be altered again and again. A similar argument can be seen in the idea that if a forest has been logged, it is no longer 'natural' and therefore not worth saving—the woodchips are on their way before the echoes of the word regrowth have faded. But Aborigines *didn't* cause extinctions, and the environment in 1788 AD, or 1788 BC, or 17,880 BP, or 37,880 BP, is the result of the environmental history to that point, and we need to maintain Australia in that evolutionary state. What we have is the way it was meant to be and there are no excuses.

Furthermore, if climate change can get rid of such a large chunk of Australia's mammal fauna in the past, then it can do so again in the future, and this time we would be starting from a much lower base. The 1997 Kyoto conference reporting on greenhouse effects seems to have largely focused on sea-level change, increases in natural disasters, and the impact on agriculture. But if, as seems likely, Greenhouse can interact with El Niño to produce much more drastic and longer-lasting El Niño events, then we are likely to also be in for other dramatic extinction events. This time round, with all the damage and massive habitat loss that has been caused in the last 200 years, there will be massive extinctions of the smaller herbivores and consequently carnivores, and the impact on biodiversity much greater and the chance of maintaining our fragile environment much less.

In a famous phrase, which caught the world's imagination, chaos theory was summarised in the happy thought that a butterfly flapping its wings in China could ultimately cause a tornado in America. In many ways the world is as tough as old boots. All kinds of changes have occurred over billions of years, but it has just kept rolling along, that old man Earth. The strength of the system is in its complexity, and its capacity for adjustment and repair. Australian Aborigines are crucial to the debate about conservation and the environment. Of all the Indigenous peoples of the world they are seen as those most closely attuned to nature, with every aspect of their society and culture and religion intimately bound into the rest of the natural world. Aborigines seem to have realised that environmental strength and sustainability come from biodiversity, and maintained that biodiversity by recognising that every element in an ecosystem is important.

If you push any system too far (and that is what we are doing), it loses its elasticity, its capacity to bounce back. The degraded systems we have been creating are vulnerable both to catastrophic events and to the slow attrition that rising temperatures will cause, and, in the well-known phrase, extinction is forever.

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DR DAVID HORTON IS AN ARCHAEOLOGICAL WRITER AND CONSULTANT WHOSE WORKS INCLUDE *RECOVERING THE TRACKS* (1991), *THE ENCYCLOPAEDIA OF ABORIGINAL AUSTRALIA* (1994), *ABORIGINAL AUSTRALIA* (1996) AND *THE PURE STATE OF NATURE* (2000).

If a contest were held for the most disgusting species ever to live on this Earth, the hagfishes would surely be top contenders. Hagfishes are eel-shaped primitive animals that occur in deep, cool ocean waters all over the world. They are so-named because of the less-than-handsome appearance of their anterior end, which would do equally well as the posterior end of a more elegant species, save for the six chemosensory barbels that surround its puckered mouth and single nostril. To add to the charm, hagfishes are endowed with two sets of opposing, horny, rasping teeth that they can extrude and retract, Alien-like, from their mouths.

Hagfishes lead relatively sedentary lives, and spend much of their time either curled up on the bottom or in their burrows, depending on the species.

HAGFISHES: CHAMPIONS *of* SLIME

BY DOUGLAS S. FUDGE

CHRISTINE ORTLEPP

Offensive anatomy aside, hagfishes possess a suite of behavioural traits that put most aspiring disgusting species to shame, and their feeding behaviour is no exception. Their long and slender shape and rasping jaws allow them to burrow headfirst into carcasses, eating from the inside out whatever expired soul comes their way. While their horny 'teeth' are well suited for biting off chunks of soft tissue or slurping up worms (many hagfishes are known to rely on annelid worms as a major food source), they have trouble penetrating through the tough skin of a fish or whale carcass. In these cases, hagfishes have few reservations about entering through a ready-made hole such as the mouth, gills, or anus of these fortuitous food-falls.

Burrowing into and eating rotten things may seem disgusting, but it is not nearly as alarming as the ability of hagfishes to produce slime. Many fishes can be quite slimy, and slugs certainly have their slimy side, but hagfishes are in a league of their own when it comes to slime production. When provoked, hagfishes let loose with all 150 or so of their slime glands, which line both sides of their body, and eject a concentrated slime solution into the water around them. When this concentrate hits seawater, it swells to several hundred times its initial volume. In this way, an annoyed hagfish can produce a cocoon of slime that is several times larger than its own body. The final trick in the hagfish's repertoire of repulsive behaviours is that they often void their digestive systems when they slime, which can result in a mass of slime that is streaked with the half-digested remains of something only a hagfish would eat.

CHRISTINE ORTLEPP

Hagfishes lay 20 to 30 large, yolky eggs that tend to aggregate due to the presence of Velcro-like tufts at either end.

YOU MIGHT SAY I STUDY hagfishes *in spite of* their obnoxious qualities, but this wouldn't be entirely true, because what drew me to them as a study animal were their heroic sliming abilities. I first encountered hagfishes as a lab technician at the Shoals Marine Laboratory in Maine, USA, where one of my jobs was to maintain the dreaded 'hagatorium'—a damp, refrigerated room that housed about 200 Atlantic

CHRISTINE ORTLEPP

By enveloping itself in slime, a hagfish may make itself less appetising to predators. In this photo, the fine reinforcing fibres that run throughout the slime are just visible. The parallel white lines on the bottom of the aquarium are made up of slime gland exudate that did not hydrate following ejection from the slime gland.

Hagfish (*Myxine glutinosa*) for research carried out by hagfish ecologists Ric Martini and John Heiser. When I began my Ph.D. a few years ago at the University of British Columbia under the guidance of biomechanics guru John Gosline, who has made a career out of probing the secrets of spider silk, slug slime and other so-called 'biomaterials', hagfish slime was a natural choice for the biomaterial on which I would focus.

What interests us most about hagfish slime is that it is fibre-reinforced. No other slime secretion that we know of is reinforced with fibres in the way that hagfish slime is. Moreover, the fibres themselves are fascinating in their construction, deployment and material properties. In a freshly produced slime cocoon, these fibres are very thin and quite astoundingly long for a fibre that is produced within a single cell. In diameter, the fibres are about as fine as a spider silk (about two micrometres), and yet they are about 12 centimetres long when completely unravelled. To give you an idea of how long and skinny that is, if a piece of two-centimetre-diameter rope had the same relative dimensions as a hagfish slime fibre, it would be over a kilometre long. Yet when these coiled fibres leave the slime gland, they unravel in a split second to their full length without tangling. Much of this remarkable feat can be attributed to the clever packing of the fibre within the cell in which it is manufactured, in addition to the subtle forces exerted by the mucous molecules expanding around it.

If the kilometre-long rope described above had the same material properties as a wet hagfish fibre, it could be stretched to well over three kilometres before breaking, and it would be strong enough to resist a force of over 50,000 newtons, or about the weight of two cars. If a two-centimetre-diameter rope had the same properties as a dry slime fibre in air, it would not be quite as extensible, but it would be able to resist 160,000 newtons of force, or about the weight of a small locomotive, without breaking. Perhaps the most astounding property of these fibres is their ability to absorb energy. The dry rope described above would be able to absorb 100 megajoules of energy before breaking. This is enough energy to bring a 2,500-kilogram car travelling at 75 kilometres per hour to a complete stop.

WHAT COULD BE *more unappetising to a predator than a mouthful of stringy mucus?*

From a material-science perspective, the slime is interesting stuff. But what is the function of the slime? How is it useful to the hagfish? The most obvious function of the slime is to deter predators. What could be more unappetising to a predator than a mouthful of stringy mucus? But the slime may be more than just unappetising; it may be downright dangerous to certain predators, especially fishes. A fish that attacks a hagfish risks getting slime all over its gills and, with no way of removing the slime, the fish could eventually suffocate and die.

Sliming doesn't only occur when hagfishes are under attack. They are also known to slime when they are feeding on carcasses. This behaviour has been interpreted as a deterrent to potential competitors that may have designs on the same bit of food. In these cases, a little bit of slime may go a long way in warning others to stay away. Evidence for this 'competitor-exclusion' hypothesis has come mostly from remotely operated vehicle surveys in which baits are presented at great depths to see which species arrive, in what quantities, and in what order. Hagfishes are often one of the first scavengers on the scene, and their slime, or perhaps just the threat of their slime, seems to give them an advantage when it comes to dominating food-falls.

The last plausible function of the slime is that it plays a role in reproduc-

Slime gland exudate can be collected and stabilised for later study. Here a few milligrams of stabilised slime has been added to a beaker of seawater.

PHOTOS: CHRISTINE ORTLEPP

Hagfishes sometimes slime during feeding, which may act as a deterrent to competitors. Here, two hagfish in an aquarium wrangle over the same piece of squid. In the upper left is a small mass of slime that was produced when the two animals came face to face.


250 ml
PYREX
No. 1000

Hagfishes

Classification

Family Myxinidae, subfamily Eptatretinae. Currently about 64 spp. known worldwide, incl. the relatively well-known New Zealand Hagfish (*Eptatretus cirrhatus*), Pacific Hagfish (*E. stouti)* and Atlantic Hagfish (*Myxine glutinosa*). Along with lampreys, hagfishes are the only living representatives of the jawless fishes.

Identification

Long, eel-shaped body with paddle-like tail. Pink to blue-grey in colour, with black and white mottling, depending on species. Eyes vestigial or absent. No true fins or jaws. Six barbels around mouth.

Distribution and Habitat

Deep, cool ocean waters all over the world. NZ Hagfish found all over NZ coast, as well as off coast of NSW. *Eptatretus longipinnis* found off southern coast of Aust.

Behaviour

Relatively sedentary. Most likely nocturnal. Graceful, but weak swimmers relative to most fishes. Subsist on carrion as well as invertebrates such as polychaete worms. Their most remarkable behaviours are their ability to produce large volumes of defensive slime and to tie their body in a knot.

Reproduction

Very little known about hagfish reproduction. In some species, sex ratio can be as high as 100:1 in favour of females. In other species, hermaphrodites (possessing both ovaries and testes) not uncommon. Females typically lay 20–30 yolky eggs. Development direct, with no larval stage between egg and adult.

tion. Aubrey Gorbman at the University of Washington in Seattle has proposed that hagfish slime might be useful during the mating process for localising sperm and keeping fertilised eggs together in burrows where they can be guarded from predators. Of course, these three hypotheses regarding the utility of the slime (defence, competitor exclusion and reproduction) are not mutually exclusive, and it is likely that the slime functions in all three roles over the course of a hagfish's life.

HAGFISHES ARE GILL BREATHERS, so why doesn't a hagfish, which finds itself smack in the middle of its own slime, suffocate? There are several reasons why this doesn't happen. One is that hagfish gills are discretely tucked away in pouches and possess none of the rough edges that most fish gills have. Consequently, there is no danger of the slime catching on and coating a hagfish's gills. Physiologically, hagfishes are extremely tolerant of low-oxygen conditions. One reason for this is that the metabolic rate of hagfishes is very low, which means they can get by on very little oxygen. For hagfish species that rely on unpredictable food-falls for their sustenance, this kind of fuel economy could mean the difference between survival to the next food-fall and starvation. But even when oxygen is completely absent, many hagfishes are quite capable of switching over to anaerobic metabolism. This capacity has obvious relevance for an animal that must not only tolerate the nearly anoxic conditions inside rotting carcasses, but must also remain active if it is to get its share of the food.

So suffocation is probably the last thing on a hagfish's mind after it envelops itself in a ball of defensive slime. But after danger passes, the hagfish needs to extricate itself from the slime. Eventually it would suffocate in there and, even if it didn't, it couldn't lead the rest of its life shrouded in a thick layer of stringy mucus. So what is a self-slimed hagfish to do? A hagfish that is fed up with its own slime simply ties itself in a tight overhand knot, and passes the knot down the length of its body. The effect of such a bizarre manoeuvre is that the slime is wiped off the animal's skin. As you might imagine, hagfishes are the only animals known to be able to tie themselves in knots. Earthworms may find themselves in knots occasionally, but that has more to do with mischievous boys than the wonders of natural selection. An octopus could probably tie one of its arms in a knot if it really wanted to, but apparently it has better things to do with its time. Same with elephant trunks. They have all the right muscles and the physical dexterity, so it must be motivation that is lacking.

Knot-tying has other uses as well. Sometimes there's simply nothing like a knot for getting a purchase on a big, tough carcass. If you think about it, being long, slender and limbless is good for burrowing, but not so good for tearing chunks from large carcasses. Hagfish teeth are not that sharp, so *slicing* off a chunk is not usually an option. Moreover, without a leg or other limb to brace oneself against, you might think it would be impossible for a hagfish to *pull* with any significant force. But you'd be wrong. By tying itself in an overhand knot with its head just sticking through the loop, a hagfish can effectively brace itself without the benefit of a limb. Knot-tying can also be used as an escape manoeuvre by giving the animal something to push against as it squirms free from a predator's grasp. Such a behaviour can only be fully understood by grabbing an unsuspecting hagfish in its middle and watching (and feeling) in astonishment as it extricates itself in a matter of seconds. Whether knot-tying evolved first for feeding, predator escape, or slime extrication is anyone's guess, but it is quite possible that, along with sliming, knot-tying is the key to how these animals have survived virtually unchanged on this planet for well over 300 million years.

A HAGFISH

that is fed up with its own slime simply ties itself in a tight overhand knot, and passes the knot down the length of its body.

In spite of their formidable sliming defences, hagfishes do have natural predators, although we are still lacking a complete picture of which species rely on them as prey. Species that are currently known to prey upon adult hagfishes are the Harbour Porpoise (*Phocoena phocoena*), Southern Giant Octopus (*Enteroctopus magnificus*), Peale's Dolphin (*Lagenorhynchus australis*), South American Sea Lion (*Otaria byronia*), Blue-eyed Cormorant (*Phalacrocorax albiventer*), Harbour Seal (*Phoca vitulina*) and the Northern Elephant Seal (*Mirounga angustirostris*). The most striking thing about this list is the complete absence of fish predators. There is some evidence that bottom fishes such as cods, hakes and halibuts will eat hagfish eggs and juveniles, but there are no known stomach-content data that suggest any fish regularly feeds upon adult hagfishes. This finding supports the 'fish-suffocation' theory of slime function, but of course does not prove it.

So what is it about the species that do feed upon adult hagfishes? How do they deal with the slime? With the exception of the octopus, all of the known adult hagfish predators are air-breathers, which means that sucking a hagfish into one's mouth poses no risk of clogging up the respiratory apparatus. It is also possible that these species employ anti-slime measures that leave the hagfish defenceless. As remarkable as hagfishes are in their ability to produce vast quantities of slime, ultimately the slime glands can deliver only so much. If a dolphin or seal or penguin could provoke a hagfish until it were positively slimed out, it's possible that the hagfish could then be sucked out of the slime and eaten, relatively slime-free. Octopuses are gill-breathers, and

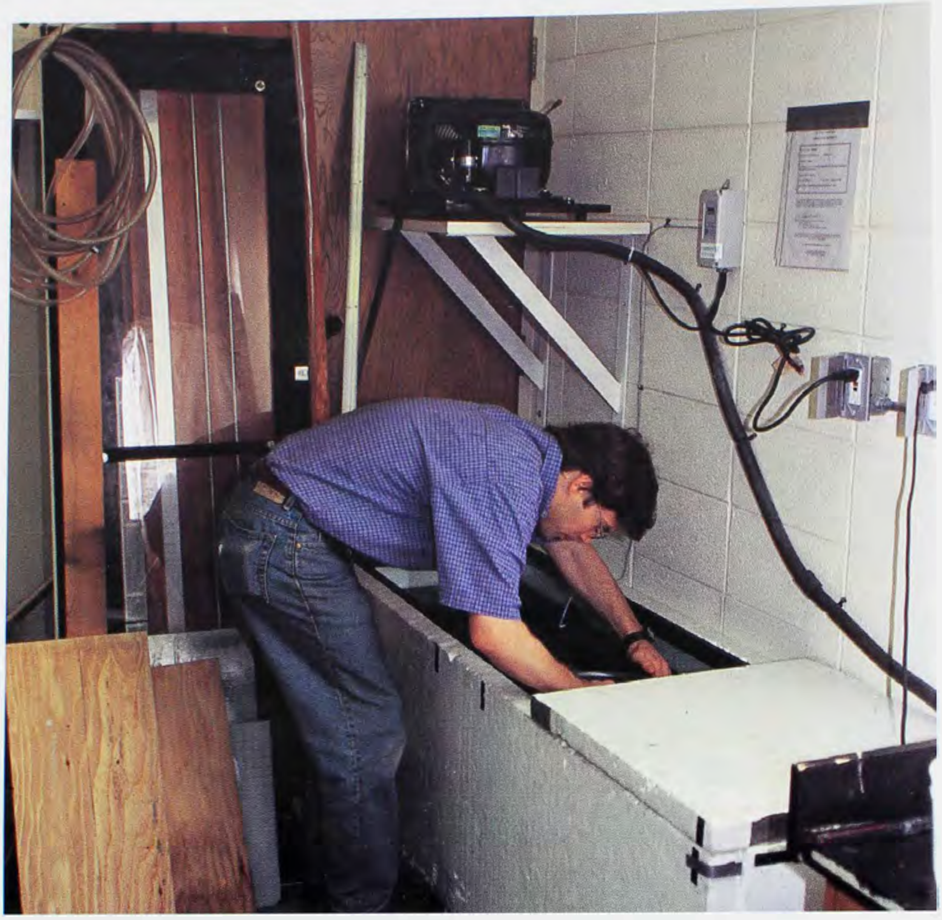
Hagfishes possess remarkable flexibility and manoeuvrability. Here, a hagfish begins a series of knot-like manoeuvres that will eventually free it from this mass of slime. About one second separates each photo in the series.

PHOTOS: CHRISTINE ORTLEPP

are therefore potentially at risk of suffocation if they are slimed by a hagfish. However, while a limbless fish that gets slime on its gills can do little about it, an octopus has eight highly flexible and manoeuvrable arms that it can use to de-slime itself if necessary. No-one has ever witnessed an octopus eat a hagfish, but my bet is that it's a slimy and topologically complex affair.

Unlike many marine animals, the hagfishes have been blessed with being found generally unfit for human consumption. There are, of course, exceptions. Certain regions in Korea and Japan have a history of eating hagfishes, and the Maori are known to have considered the 'Tuere' or New Zealand Hagfish (*Eptatretus cirrhatus*) a delicacy, placing them live into vats of fresh water to exhaust them of their slime before cooking them. Aside from these isolated instances, hagfishes and humans have enjoyed a long period of mutual indifference. In the last few hundred years, however, humans and hagfishes have begun to interact more and more. In some regions, they are considered pests by gill-net fishermen due to their habit of burrowing into their catch and sliming up their nets. Initially, the rise of commercial fishing was a boon for hagfishes, due to the discarded fish and bait that rained down upon them in heavily fished areas. In the 1960s, however, their luck ended and, for the first time, hagfishes were fished commercially for, strangely enough, the leather trade. In Japan and Korea, hagfish skin is tanned to make a light, high-quality leather (usually stamped with the misleading, yet marketable, "genuine eelskin"). In the last few decades, demand for eel-skin products such as wallets and purses has led to the exploitation of at least seven species of hagfishes around the world.

Due to the ease with which they can be caught, as well as their low reproductive rates, hagfish populations are exceptionally vulnerable to fishing pressure. Any container with holes drilled in it and baited with something rotten will quite effectively catch most of the hagfishes in a given area. And while



Although hagfishes will live happily in aquaria for many months at a time, and females will occasionally shed eggs, no-one has ever managed to breed them in captivity. Here the author checks on his own herd of hagfishes, which are kept in total darkness and provided with clean, cold seawater, and bimonthly meals of squid and herring.

PHOTOS: CHRISTINE ORTLEPP

A hagfish in a bucket of seawater can, if provoked, transform the water into a mass of gelatinous, stringy slime.

Here a hagfish contorts its body into a tight overhand knot—a manoeuvre that can be used during feeding, or as a way to free itself from a mass of slime.

very little is known about hagfish reproduction, we do know that hagfishes produce very few eggs compared to their bony-fish relatives. Investing lots of energy in relatively few offspring is a reproductive strategy that has obviously worked for hagfishes over the last few hundred million years, but as we know from commercial whaling and shark fisheries, these kinds of species are very slow to recover from overexploitation.

I usually cringe when someone wants to know what a species is 'good for', since the implication is that all species should have to prove their worth in terms of the human economy in order to be spared from extinction. Although I believe that hagfishes are worth saving for their intrinsic value, there are, for those who require such justifications, several practical reasons why we should value them. First, hagfishes play important roles in healthy marine communities by cleaning up carrion and turning over substrate with their burrowing. Second, hagfishes may be important food items for many marine mammals and birds. It's possible that very few or even no species rely heavily on hagfishes as prey, and that they only resort to taking hagfishes when their preferred prey are not available. If this is the case, then hagfish populations may represent an ecological safety valve that we would be foolish to tamper with. Lastly, hagfishes may teach us, via their slime, valuable lessons about how to engineer biodegradable materials with exceptional properties. So, although hagfishes may be the most disgusting animals ever to live on this planet, and while a hagfish plush toy is unlikely to hit the stores any time soon, the world's hagfishes are certainly deserving of our respect and protection.

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Green Tree Frog (*Litoria caerulea*).

Red-eyed Tree Frog (*Litoria chloris*).

croaks and daggers

BY KEN GRIFFITHS

Lace Monitor (*Varanus varius*).

Common Tree Snake (*Dendrelaphis punctulata*).

Peron's Tree Frog (*Litoria peronii*).

Blue Mountains Tree Frog (*Litoria citropa*).

Gree Tree Frog (*Litoria caerulea*).

reviews

Flying Foxes: Fruit and Blossom Bats of Australia

By Leslie Hall and Greg Richards. UNSW Press, NSW, 2001, 135pp. $32.95rrp.

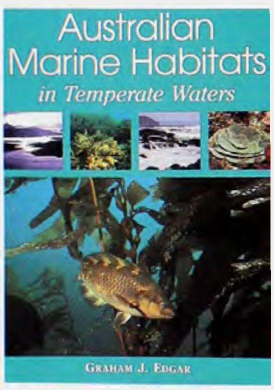
WITH THEIR NOCTURNAL HABITS and the folklore surrounding them, bats are often viewed as scary creatures. Recent bad press surrounding Australia's flying-foxes created further misconceptions about these important mammals. This timely book does much to dispel the myths.

The authors, respected bat researchers, have synthesised their own as well as a wide range of other biological, behavioural and ecological research to produce an easy-to-read account of the lives of Australia's 13 species of 'megabats'. It includes lovely colour photographs of these attractive animals and a selection of instructive illustrations.

Opening chapters explain what makes a bat a bat and introduce their classification and evolutionary history. All Australian species of fruit- and blossom-bats are described along with where, in Australia and beyond, they are found. The midsection deals with their body structures and systems, particularly the fascinating adaptations they have for their specialised life of flight and feeding on forest fruits and/or flowers. This leads onto the concluding chapters about their ecological importance, ways to ensure their conservation, and caring for injured or orphaned bats.

My one criticism is that the chapter on mortality and disease, with its well-balanced presentation of the facts surrounding flying-foxes and public health, seems illogically placed in the chapter sequence. Overall, however, *Flying foxes* is another excellent addition to this informative natural history series.

—TRISH MCDONALD

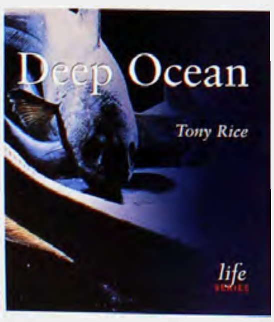


Australian Marine Habitats in Temperate Waters

By Graham J. Edgar. Reed New Holland, NSW, 2001, 224pp. $39.95rrp.

Deep Ocean

By Tony Rice. CSIRO Publishing, Vic., 2000, 96pp. $29.95rrp.

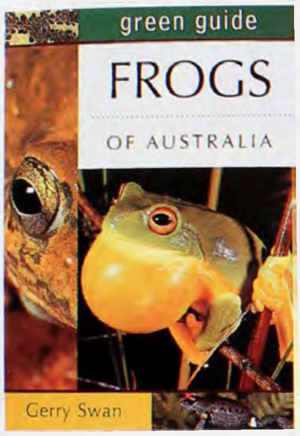


A GOOD BOOK CAN HAVE A PROFOUND IMPACT. I read C.P. Idyll's *Abyss* as a teenager, and was so fascinated by the strangeness of the ocean deeps that I became a marine biologist. Like the proverbial ancient fish that discovered walking, I left my 'first career' as a deep-sea biologist and now study, among other things, land-locked crustaceans. Nevertheless, my interest in the oceans is undiminished, so I gleefully jumped into Tony Rice's *Deep ocean* and Graham Edgar's *Australian marine habitats in temperate waters*. Both books are aimed at a general audience, rather than students or researchers. Many gorgeous colour photographs fill their pages—just flipping pages to look at the pictures was fun. I wondered whether these books had the ability to inspire readers, as Idyll's book did in my youth, so I dove in to see what they had to say.

At deep-sea biology conferences I've attended, Tony Rice earned a reputation as a superb raconteur. In *Deep ocean*, he skilfully portrays the arcane world of deep-sea oceanography as an exciting profession, using a mixture of diagrams, photographs and accessible explanations. The book starts with the physical and geological background necessary for understanding the deep sea, and touches on the history of oceanography and its tools. Readers are taken on a swim through the lighted surface waters, realm of plankton and micropredators and down past the strange denizens of the twilight midwaters. Then the reader is shown the vast plains and mountain ridges of the deep sea, where even stranger creatures like the Tripod Fish and hydrothermal vent worms dwell. Here, Rice teaches readers about biodiversity in the deep sea, discussing many odd adaptations and ecological associations. The book ends with concerns about how we humans may damage fragile abyssal ecosystems. Without going into detail, Rice manages to cover currently open questions in deep-sea ecology. In this book, the deep sea becomes a scientific frontier, as much as outer space. Some details got away from Rice: I grinned at a name for an isopod crustacean species that hasn't been used for over 30 years, and two fish in one figure (p. 85) aren't Orange Roughies. Nevertheless, *Deep ocean* is a fun and informative introduction to blue-water oceanography, especially for young minds. This book just might be another *Abyss*.

As a companion to his useful identification guide *Australian marine life*, Graham Edgar presents *Australian marine habitats in* *temperate waters*, concerning the ecology of temperate ocean waters in southern Australia. Similar to Rice's book, Edgar starts in the open ocean but then moves inshore, the deep sea skipped over probably because we know little about the abyss around Australia. He covers major habitats that 'the visitor' might encounter, from seagrass beds and mudflats to subtidal reefs and soft bottoms. Two-page "Environmental Issues" sections discuss serious human impacts on particular marine habitats. Unfortunately, the copious text reads like a rewrite of the notes from a marine ecology course, warts and all. Too many of his 'facts' are highly debatable, and each chapter has outdated food-web diagrams, which are based on assumptions and sketchy data. Because links between 'facts' and chapter bibliographies are not provided, I can't recommend the book as a teaching tool. The general reader will find it a tough slog too, since many technical terms do not appear in the short glossary. Given that Edgar's preface contains a desire to improve a visitor's appreciation for marine habitats and ecology, I can only reiterate W. Strunk & E.B. White's command: "Use fewer words!" Although this book has many attractive images, it doesn't meet my 'Idyll' criterion.

—G.D.F. 'Buz' Wilson
Australian Museum



Frogs of Australia

By Gerry Swan. New Holland Publishers, NSW, 2001, 96pp. $16.95rrp.

Frogs have been high on the animal popularity stakes for several years now. Coincident with the rise in popularity of frogs has been a rise in the production of frog field guides and reference texts. The range available is quite staggering; the methods of portraying frogs have also been quite varied.

With so many frog books about, the production of a new, small book about Australian frogs would seem very ambitious. However, this little book will give some of its more established rivals a lot of competition. The reason it will succeed is simple; it is very user-friendly and is aimed at a general audience. Many books that have preceded *Frogs of Australia* have been servicing the more advanced naturalists in the population and have tended to be technical, over-powering in their treatment of species and nomenclature, and cumbersome in format.

The author, Gerry Swan, is a well-known figure in frog and reptile circles in Australia. He has clearly twigged to the need to provide a gentler introduction to the world of frogs. *Frogs of Australia* treats various frog species as you would expect in a field guide but peppered throughout are question-and-answer segments about many aspects of frog biology, myths and facts, the future of frogs and how to look after frogs. The book is meant to be read in small doses, but once you have started reading you will definitely come back to sample more of the delights inside.

As if the arrangement of the book wasn't enticing enough, there are copious cute, enigmatic, diagnostic and humorous photographs from the pick of Australian wildlife photographers. The book oozes photos; there are even photo inserts inside other photos. I cannot imagine a better way to be introduced into the wonderful world of frogs, and to be inspired to learn more and to help frogs when they are in so much peril.

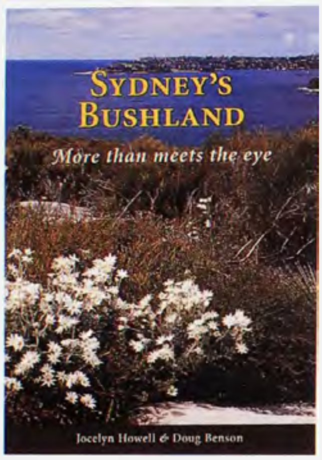
—Arthur White
Frog and Tadpole Study Group of NSW

Native Bees of the Sydney Region: A Field Guide

By Anne Dollin, Michael Batley, Martyn Robinson and Brian Faulkner. Australian Native Bee Research Centre, NSW, 2000, 70pp. $16.50rrp.

This small book is the first to be set up as a popular guide for the identification of some of Australia's native bees. Being able to find and identify an animal or plant yourself is the first step towards appreciating its beauty and whetting your appetite for more information. On the other hand, there is nothing more frustrating than finding something that catches your eye and that looks interesting but then not being able to find out anything about it. With a fauna of well over 1,500 species of native bees from which to choose, the authors have been wise to restrict their coverage to the Sydney area, from which bees are relatively well known, and to those species that are most likely to be seen by the novice bee hunter. The book is totally practical. The bulk of it is given over to describing and illustrating the most common 30 or so species, in colour as well as black and white. Next to each description is an actual-sized silhouette, which is a much more practical guide to size than giving a measurement in millimetres. There are interesting notes about feeding, nest-building, flight patterns and other bee behaviour, and there is a guide to which plants are most attractive to native bees. Using the book you will soon realise that there is still a lot to be learned about them and, with some keen, careful and accurate observations, you could even make your own contribution. It is a book for using, to help you enjoy and learn about the bees. There are not many books about these days as useful as this one for the price.

—COURTENAY SMITHERS
AUSTRALIAN MUSEUM



Sydney's Bushland: More than Meets the Eye

By Jocelyn Howell & Doug Benson. Royal Botanic Gardens, Sydney, 2000, 128pp. $27.95rrp.

WHEN THE WHITE SETTLERS ESTABLISHED SYDNEY IN 1788, little did they know that they were building on one of Australia's botanical hot spots. This latest book by Jocelyn Howell and Doug Benson brings together much of what we know of the Sydney Basin flora and highlights how easily accessible it is to the city's residents.

The book is broken into three colour-coded parts. The first part concentrates on the geology and climate and the main vegetation types found in the Sydney region. The vegetation types are nicely broken down into rainforest, open eucalypt forests, woodlands, heathlands etc. Each main community is illustrated and their general distribution noted.

The second part brings together all the ecological studies that have been carried out on the Sydney Basin flora over the last 50 years. This section covers the evolutionary forces that have shaped the flora; the various strategies that plants use to cope with, and survive, the Sydney environment and its harsh conditions; the effects of fire and how plants respond to it; common plant–animal interactions; and the invasive effects that weeds have on our bushland and how our remnants can be sustained.

The final section has suggestions for trips to get out and enjoy the beauty of Sydney's flora. The suggestions range from half-day through to full-day and potential overnight trips. Most are accessible by public transport, are ideal for people of all ages and are either free or have a low entrance fee.

The strength of this book lies in its easily digestible presentation. It would make a great reference book for school students between Years 6 and 10. It is also presented in such a way that it is informative without being condescending to people without science backgrounds. I really enjoyed this book and look forward to seeing many reprints in the ensuring years.

—PETER JOBSON
NATIONAL HERBARIUM OF NSW

Watching Wildlife Australia

By Lonely Planet Publications, Vic., 2000, 352pp. $28.97rrp.

THIS BOOK MAKES AN EXTREMELY VALUABLE CONTRIBUTION to wildlife-watching in Australia. It fills a niche left by the numerous specific field guides currently available. While these guides give detailed descriptions of every species, and some information about habitat, the Lonely Planet guide looks at the situation from a point of view of what each locality has to offer. This allows readers to choose a particular locality to visit, depending on their interests, available time, season etc. As is the case in most countries, birds are the easiest group to observe in Australia. The book is a little optimistic about the possibility of spotting mammals and most reptiles in the wild, which usually requires a fair amount of effort and good luck. This publication is an ideal size for the coat pocket or backpack and, as far as seeing fauna, you need carry little else except binoculars.

—LINDA GIBSON
AUSTRALIAN MUSEUM

SOCIETY PAGES

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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Wildlife Care Network Victoria
247–251 Flinders Lane
Melbourne VIC 3000
Ph: 03 9663 9211
Contact: Nadia Angeli

Wildlife Carers Network—Central West Inc.
PO Box 787
Mudgee NSW 2850
Ph: 02 6358 8277
Contact: Joan Hills
Membership: $20.00 (Joining Fee $5.00)

WRIN
Wildlife Rescue & Information Network Inc.
30 Collins Street
Kangaroo Flat VIC 3555
Ph: 03 5441 3211
Contact: Rob Schrieber
Membership: $15.00

ASTRONOMY

Western Sydney Amateur Astronomy Group
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Kingswood NSW 2747
Ph: 02 4739 1528
Contact: Tony Ellis
Membership: $30.00

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Birds Queensland
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St Lucia QLD 4067
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Birds SA
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Eden Hills SA 5050
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q&a

Mistletoe Munchers

Q: *I have enclosed two photographs that I took several weeks ago of these beautiful creatures living amongst and consuming mistletoe leaves. Having been told sometime earlier that "nothing eats Mistletoe", I found these large (about seven to eight centimetres long) caterpillars most interesting. Once they were fully fed, they pupated in the butt of the mistletoe where they still are. I wonder if you could tell me what kind of butterfly they will become and how long it may take them to hatch.*

—Jim Morse
Inverell, NSW

A: Despite what some people may think, many animals eat mistletoe, including Brushtail Possums, several butterflies and a variety of moths. The Mistletoebird also helps distribute the mistletoe seeds form tree to tree. The caterpillars in your tree are the larvae of the giant silk moth *Opodiphthera loranthi*, which belongs to the family Saturniidae. The adult is a large reddish brown moth with a spot on each wing that looks like an eye, similar to their relative the Emperor Gum Moth (*O. eucalypti*). The caterpillars are gregarious and can sometimes be so numerous that they can almost defoliate the mistletoe. They typically pupate in a cluster at the junction of the mistletoe and its host tree. Members of this family are similar in some respects to the silkworm moths (family Bombycidae) and were once collected in the wild for their silk. Interestingly some of the saturniid species in Africa are being tested for their suitability as commercial silk producers under captive conditions.

—Martyn Robinson
Australian Museum

COURTESY GARY WEBER

Giant silk moth larvae are mindless munchers of mistletoe.

A Ray's Prey

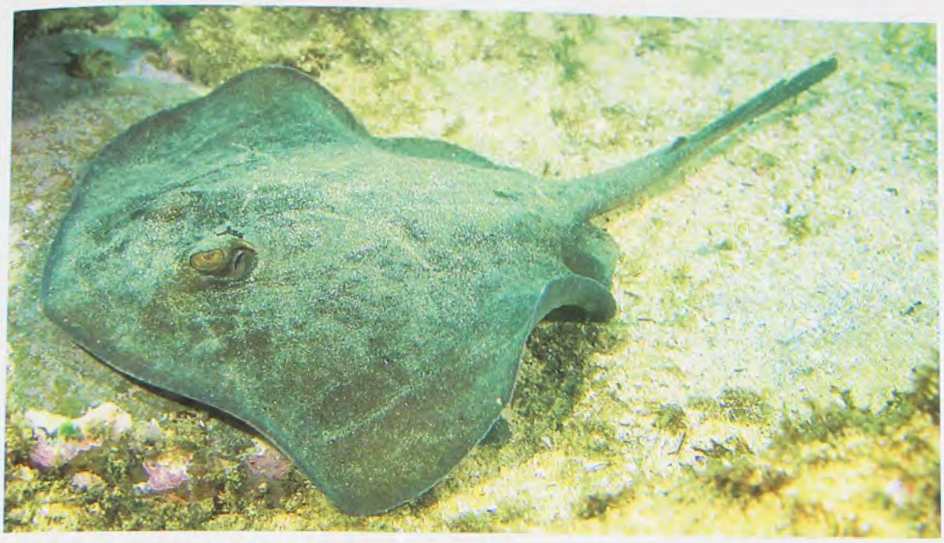
Q: *A few days ago while snorkelling in the netted pool within Bermagui Harbour I saw a stingray with a struggling mullet in its mouth. I watched for a few moments and then swam on. When I returned a short while later there was the mullet lying on the bottom with a lump taken out of its side, but still flapping its fins, and no sign of the stingray. I have often seen stingrays foraging on the bottom for food, so it came as a surprise to see one as an active predator on a free-swimming fish. Is this a normal hunting pattern for rays? Also, stingrays seem to come in a range of colours from near black to a light yellow-brown. Are they all the same species? Or maybe it's an age indicator?*

—John Crew
Bermagui, NSW

A: Most of the 117 species of Australian rays are specialist bottom-feeders. There are some rays that live near the surface and feed on plankton, with the Manta Ray probably the best known of these. The bottom-feeding species are generally not specialist feeders, but they do have a preference for the prey they will eat. Most of them feed on invertebrates such as crustaceans and marine worms, but they will also eat small fish. Many species are also scavengers.

Except for the plankton-feeding species, rays have a relatively small mouth. The luckless mullet that had become prey for the ray was obviously too large for the ray to swallow whole. Once the ray had latched onto the mullet, all it could do was take a bite. The mullet managed to swim away, minus some muscle tissue. Despite their bottom-living habit, rays are competent swimmers and are capable of rapid movements over short distances. This ray was obviously fast enough to capture the mullet. This sort of hunting behaviour is probably not typical of rays, but does demonstrate that they will eat most suitable prey items they can catch.

Colour in rays is one of their diagnostic features. Other characters include size, length and shape of the tail, horny ornamentation on the disk, and number and arrangement of fins and tail spines. There is some variation in colour with-



IAN SHAW

The Common Stringaree is often found in the shallow waters of Bermagui Harbour.

in a species that often reflects the habitat they are in or the geographic region they come from. But in general, different-coloured rays from the same area are probably different species. The ray you saw in Bermagui Harbour was probably a stingaree (family Urolophidae) with a tail that is about equal in length with the disk, or a stingray (family Dasyatididae) with a whip-like tail that is usually longer than the disk. The Common Stingaree (*Trygonoptera testacea*) is a species that is found in shallow waters in the area.

—Tom Trinski
Australian Museum

Answers to Quiz in Nature Strips (page 19)

1. *Eros*
2. *Sperm Whales*
3. Anno Domini *(in the year of our Lord)*
4. *Sulawesi*
5. *Snakes*
6. *Greater Blue Mountains*
7. *Green*
8. *Tuataras*
9. Aurora Australis
10. *The Hague*

Pic Teaser

Do you recognise this? If you think you know what it is, then send your answer to Pic Teaser, *Nature Australia* Magazine. Please don't forget to include your name and address. The first correct entry will win a copy of *National parks and other wild places of New Zealand*. Autumn's Pic Teaser was a sea spider, class Pycnogonida.

C ANDREW HENLEY NATURE FOCUS

Past sets limits for the future

To find out why land and water degradation is increasing, one has to appreciate that this ancient land has set the parameters within which sustainable use is possible.

AUSTRALIA TODAY FACES SERIOUS problems of soil and water degradation. Our current land-use and agricultural practices are largely unsustainable. The more visible problems of ever-increasing salinisation of soils and rivers in the two major food-bowl areas—the Western Australian Wheatbelt and the Murray Basin—are receiving increasing media attention. Less publicity is given to acidification of soils (resulting in loss of productivity), and to high levels of nutrients in rivers (leading to algal blooms and other imbalances) due to excessive use of fertilisers and the use of legumes in pastures and crop rotations. Loss of structure and microbiological content of soils, and the hazards posed by the profligate use of pesticides and herbicides, rarely get a mention. The adverse long-term effects of irrigation, the dams and water diversions that are profoundly affecting, and even killing, some rivers, are seldom acknowledged. The widespread degradation that results from heavy grazing pressures, in fragile arid and marginal lands in particular, is largely ignored.

To find out why land and water degradation is increasing inexorably, one has to appreciate that this ancient land, because of its geological and evolutionary history, has set the parameters within which sustainable use is possible.

Australia is the driest vegetated continent, and arid lands of the world have proved to be extremely fragile. (Similarly arid lands of the Middle East, for instance, are now man-made deserts.) It is also the flattest and most poorly drained, with vast regions, excluding the margins, inwardly draining. As a consequence of its flatness it has accumulated sediment and is a land of vast floodplains. Its rivers have the most variable flow patterns of any in the world, and most of those of the arid and semi-arid regions that comprise 85 per cent of the land surface are ephemeral. Floodplains are as much a part of the rivers as are the channels and banks, and failure to recognise this has led to widespread degradation. We now know that the health of the river ecosystems depends on the patterns of flood and restricted flow—the very features that our management and regulation have sought to eliminate.

Poor drainage of most of the continent has led to accumulation of salt, and saline watertables underlie much of the land. Upsetting the hydrology by removing perennial, deep-rooted vegetation, or by irrigating, causes rising saline watertables and salinisation.

Australia's soils are almost universally thin, poor and easily eroded, made from deeply weathered rocks that have had many nutrients leached out of them through the ages. Only six per cent of the land surface is regarded as arable. The continent's stable, mid-plate situation accounts for the absence of widespread volcanic activity and consequent soil enrichment. No renewal of soils by glaciation has occurred since the late Carboniferous ice age of nearly 300 million years ago. The Pleistocene ice age of the last 2.6 million years (in which we are living in an interglacial) brought extreme dryness and increased windiness in glacial stages. During the last glacial maximum 18,000 years ago, rainfall was half today's amount, and more than 80 per cent of the continent was affected by windblown sand. The major dune fields were established, as were the gibber plains and deserts. Recovery from that quite horrendous stage, when the Murray basin, for instance, was a salt desert, created the modern continent and its ecosystems to which Europeans came just over 200 hundred years ago.

The ice-age history of northern hemisphere lands from which the settlers came was completely different from that of Australia. Great icesheets had ground across the lands, creating fresh, new, nutrient-rich soils, and then modern climates stabilised with predictable seasons. In contrast, Australia has an unpredictable climate due to ENSO, the El Niño–Southern Oscillation, which creates additional and often devastating problems of drought and flood. The agricultural and land-use practices suited to those northern hemisphere conditions were imported into Australia, whose history and environments could not have been more different. The introduction of multi-millions of hard-hoofed grazers has had disastrous consequences for the grasslands, saltbush plains and the rangelands.

The incompatibility of inappropriate practices and foreign biota with our age-old, fragile land are now only too obvious. We currently feed the equivalent of 80 million people, and the run-down of our basic resources is reaching crisis proportions. Unless we change our ways and work within the limits set by the land, we will not have the viable resources to feed 20 million Australians in 2020.

DR MARY E. WHITE IS A PALAEO-ENVIRONMENTALIST AND AUTHOR. HER LATEST BOOK, ON WATER, IS CALLED *RUNNING DOWN* (2000).

BY MARY WHITE

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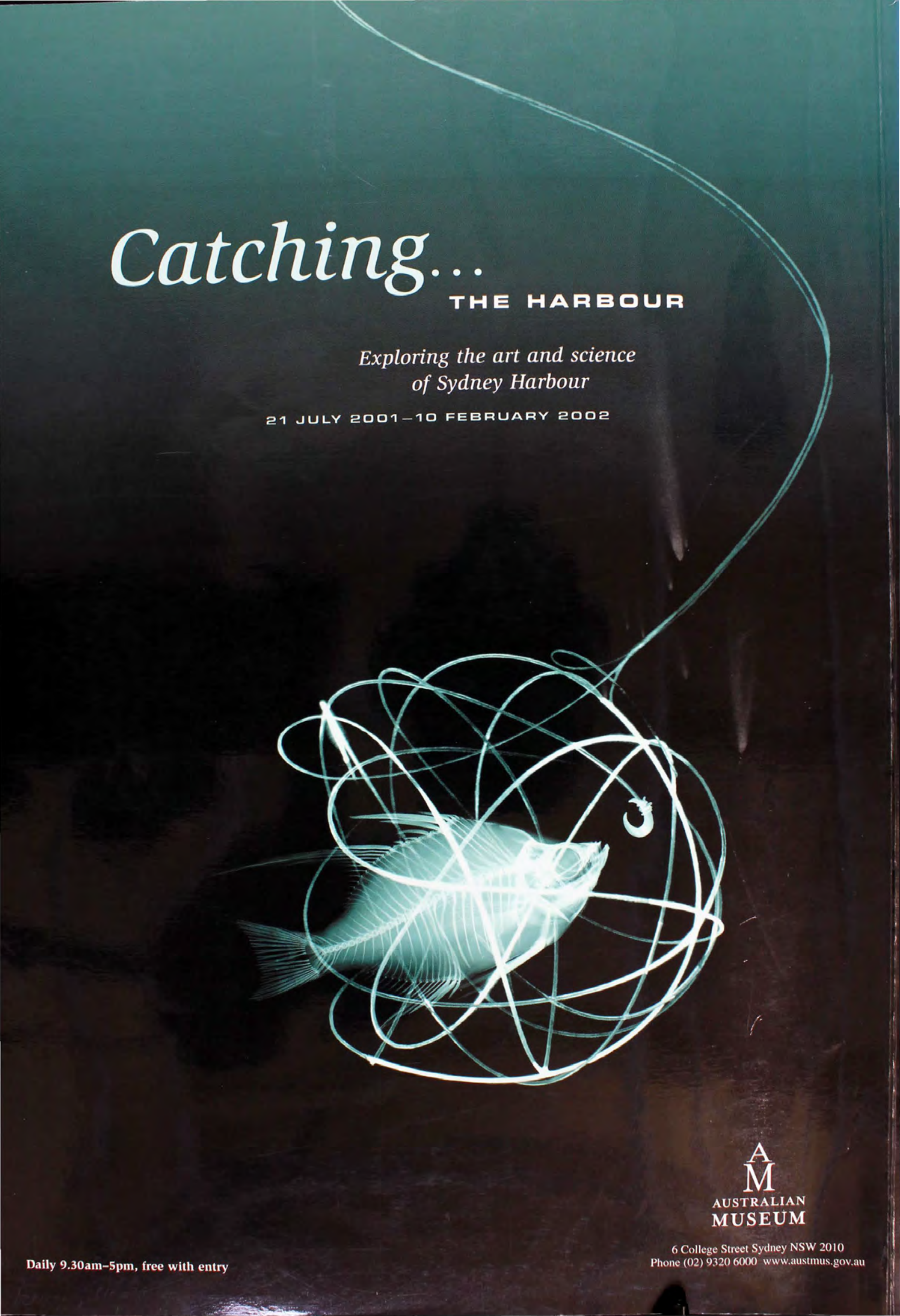
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