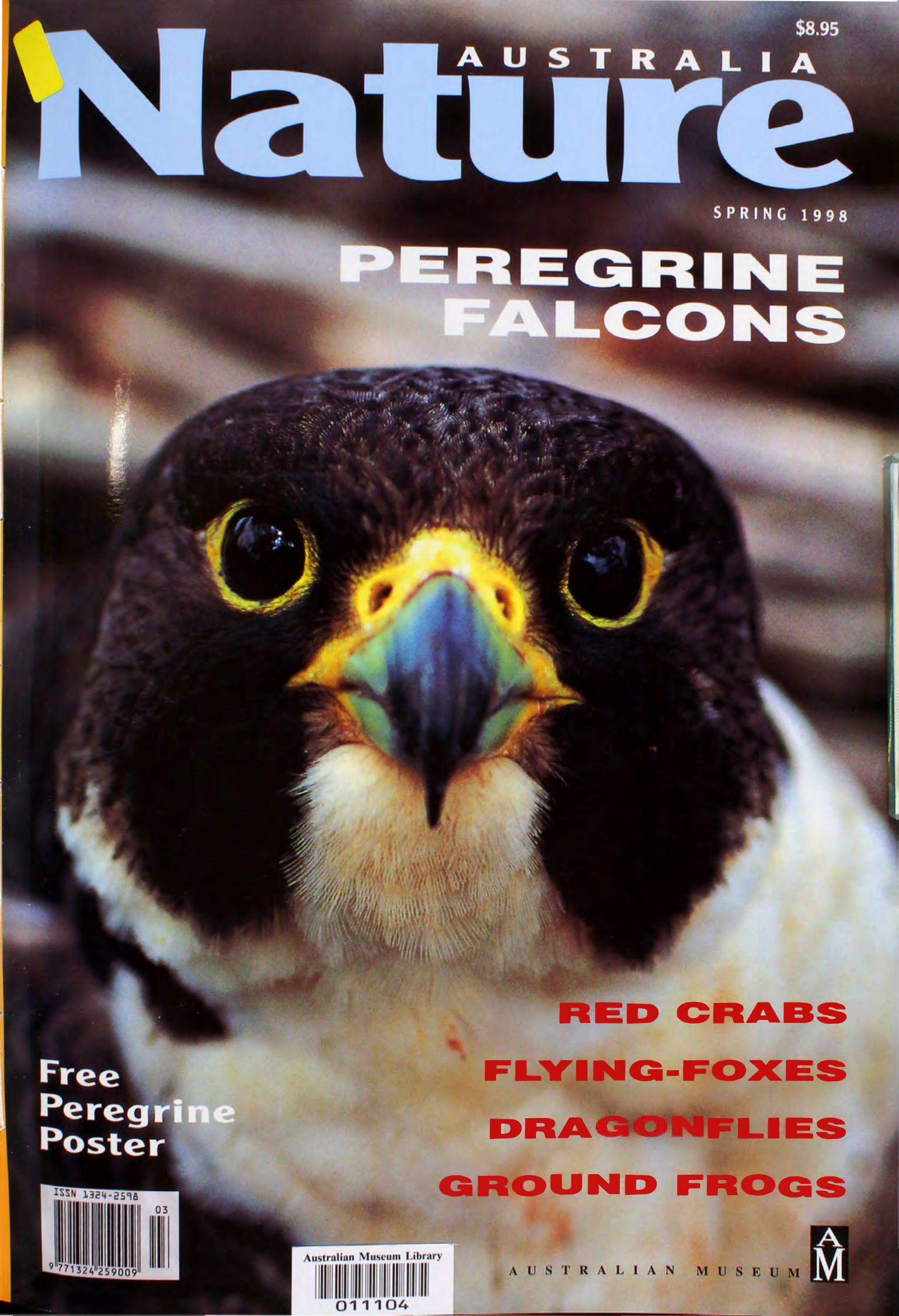

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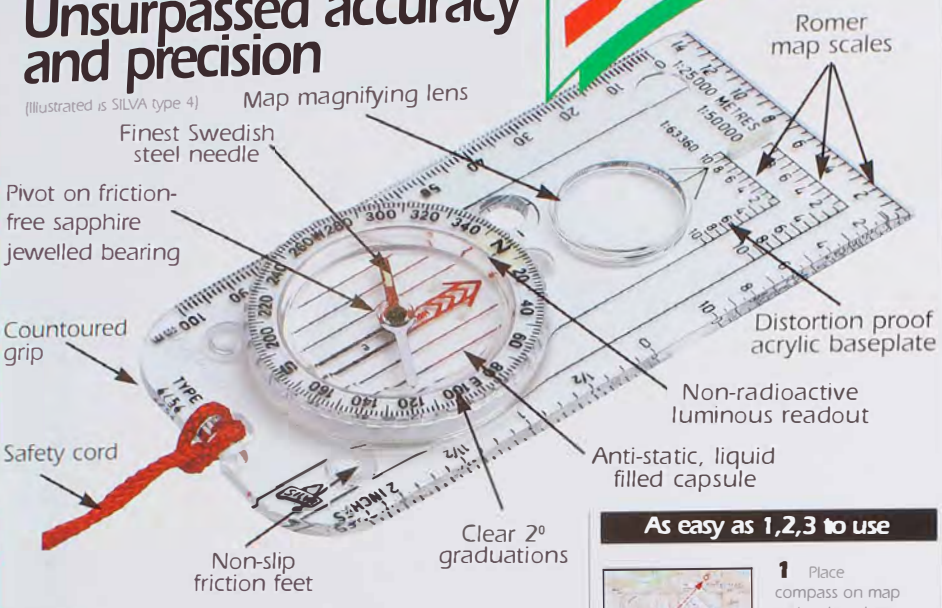

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Up Front

JEAN-PAUL FERRERO/AUSCAPE

On Christmas Island it's time to prepare for their emergence. They will appear on the forest floor in their millions and, like a red tide, wash over the island on their way to the sea. Nothing will stop them—it's all pretty impressive for a 500-gram land crab.

That's right, come November the Red Crabs of Christmas Island will head for the sea to breed and, like every year for the past five years, researchers Steve Morris and Agnieszka Adamczewska will be there to watch them. Halfway through their ten-year study, they already have some fascinating insights into what makes these crabs tick. See their story on page 44, plus some of the most beautiful photos of Red Crabs imaginable.

Penny Olsen has been studying Peregrine Falcons for over two decades and around eight years ago became intrigued with the idea of finding out what makes a Peregrine a good parent. After risking life and limb on too many occasions, she has discovered the gentle side of these awesome hunters. Her research not only provides a fascinating insight into these birds but may help in the management of other, more vulnerable, birds of prey.

Why do the peoples of our region keep and transport captive wild animals? What impact has this had on the environment? Why would a scientist spend ten years of his life trying to find the answers to these questions? Turn to page 36 and Tom Heinsohn will tell all.

They're intelligent, gregarious, very social and are finding that suburbia is a great place to rear kids. So what's all the fuss about? Seems that some people just don't appreciate having flying-foxes as neighbours. In our article "Urban Flying-foxes" we explore the problems associated with this difficult situation.

We also take a look at some well-grounded little frogs from Western Australia, find out why Indonesia's Yellow-crested Cockatoo is so endangered, explore the insane life of dragonflies, take a scenic tour of Tasmania's beautiful wilderness, and find out why Australian plants prefer to be evergreen.

—Jennifer Saunders

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Front Cover
The Peregrine Falcon's forward-facing eyes give them a wide field of binocular vision, much as humans have, and allows fine judgement of distance. Photo by Nicholas Birks/Wildflight Australia.

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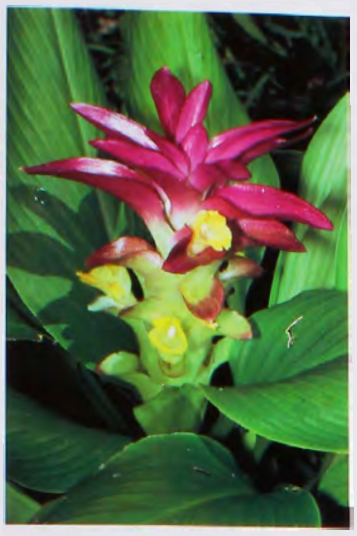

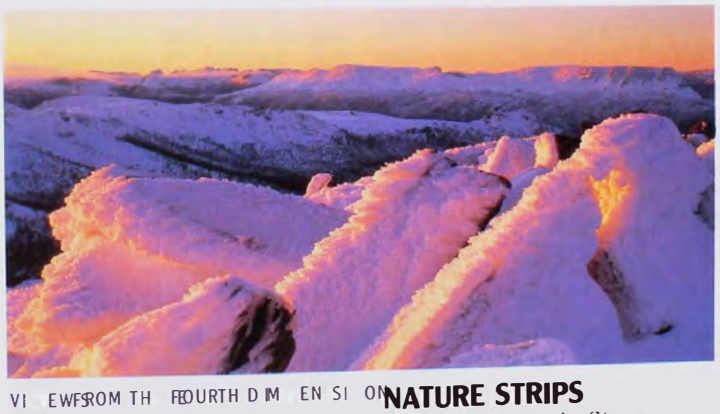

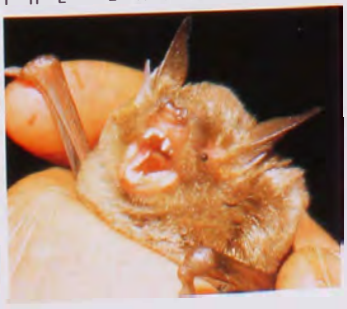

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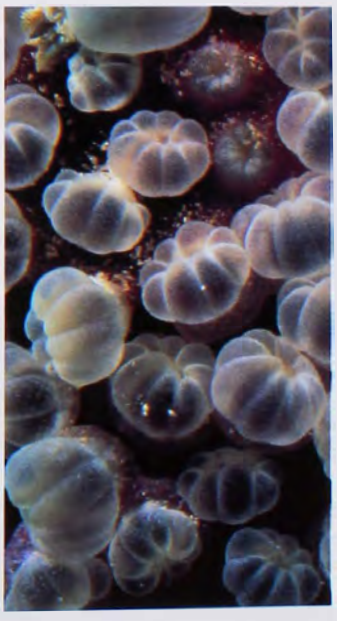
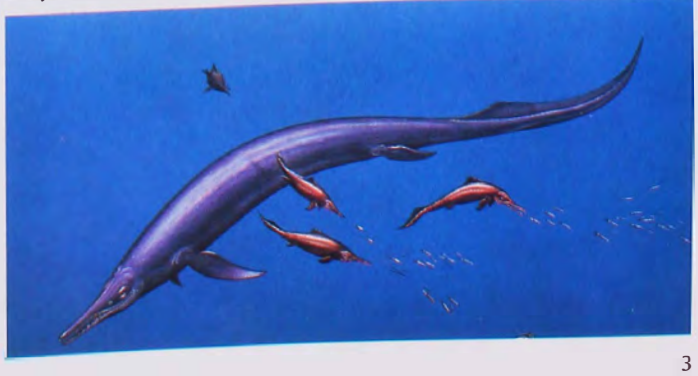




LETTERS

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

Bountiful Foxes

Everyone recognises the damage Foxes are doing to our native Australian environment (including spreading the dreaded Bitou Bush), however it seems little effort is being made to control these vermin. I would advocate introducing a healthy bounty on these pests. We saw, tragically, what effect a bounty system had on the Thylacine; imagine what it could do for the Fox.

According to a previous article on tortoises (*Nature Aust.* Autumn 1993) there was a major decline in Fox populations during the 1950s, due I presume to trapping for furs. Could we not again impose these pressures on the Fox?

It may even help unemployment figures with a new occupation—that of Fox-trapper! If it works, we could then try a bounty for, say, Cane Toads. What a way for kids to make pocket money! Ecotourism would flourish!

As we introduced the Fox to Australia, I feel we owe it to our furry, feathered and scaly neighbours to try and undo some of the damage before Australia's wildlife becomes a balance of Foxes and Rabbits.

—E. Williams
Grandchester, Qld

Blue Blood and Aristocrats

The piece in Nature Strips (*Nature Aust.* Autumn 1998), explaining why blood in our veins may appear blue, does not mention whether there is any historical basis for the association of blue blood with 'gentle birth'.

Could it be that the veins of 'plebs' were hidden by tanned and weathered skin caused by toiling outside, while the skin of aristocrats remained clear and translucent so that the veins were more visible? My own veins are blue on the inside of the wrist but not on the weathered back of the hand.

—Bill McKenzie
Melbourne, Vic.

Creation 'Scientist' Bashing

I have been prompted to write this letter by the recent series of somewhat inflammatory articles by Michael Archer printed in your magazine. While I fully appreciate Archer's desire to defend his hypotheses against those which he perceives to be erroneous, I find his method of doing so disturbing.

First, Archer appears to have fallen into the age-old trap of ridiculing the 'opposition' instead of demonstrating the infallibility of his own theories, or the fallibility of theirs. This sort of rhetorical device belongs more to the realm of propaganda than to the objective discourse of science. For example, claiming that the politicians of the Wombat Party are stupid provides voters with no reason to vote for the Kangaroo Party, only with a reason not to choose the W.P.

Second, Archer seems to regard the mere existence of Creation 'scientists', or indeed religion as a whole, as a personal insult and his articles are becoming increasingly personal and insulting. It is clear that Creation 'scientist' bashing is a personal hobbyhorse of his (*Nature Australia* being one of his forums), yet he would be the first person to argue that personal belief or faith is no foundation upon which to base scientific conclusions.

Finally, it is beyond contention that Archer is an intelligent and highly qualified expert in his field. This renders even more puzzling the lack of professional restraint in his approach. Would his desire to educate not be better served by clearly written articles wholly devoted to his research findings, than by devoting at least half of his space in an otherwise interesting article about the fossil history of koalas or wombats to barbed witticisms about "this religion" (by which I assume he means Judaism and Christianity)? He does himself and his colleagues no credit when he crams the results of his research into the final few paragraphs of each article.

—Julia Petzl
Dulong, Qld

You certainly have a spectacular magazine and I admire your scientific information on all the magnificent creatures alive today, but in Michael Archer's article "Koalas: apostles vs fossils" (*Nature Aust.* Summer 1997–98) you have shown yourselves to be name-calling, 'pretend' scientists. Deliberate snide remarks get nowhere with the average, thinking person wanting to learn and read about science. By making fun of someone

T. & P. GARDNER/NATURE FOCUS

Would a bounty system help control feral Foxes in Australia?

else's view, Archer presents himself as nothing more than a 'scaredy-cat', retaliating because someone has challenged his own closed-minded fairy story.

Do what you do best; provide us with accurate information that is documented with science. Your magazine is amazing, but please keep your opinionated 'views' on opposing theories (which to date are currently unproven) scientific and unbiased. At the moment, your readers 'on the borderline' (that is, on the brink of accepting evolution) are laughing at articles such as this one. When you disagree with something, don't just call names and try to ostracise someone else; prove to us with science why you disagree.

—Heidi Eldridge
Seaford, SA

Will the Real Easter Bilby Please Stand Up?

Tim Flannery's sympathetic piece on the Easter Bilby (*Nature Aust.* Autumn 1998) is appreciated, but his statement, that it owes its origin to "some confectioner", is only part of the story.

The Easter Bilby was created by the Anti-Rabbit Research Foundation of Australia (ARRFA) in 1991, and registered as our trademark in 1993, the first year in which the confectionary appeared.

It was the focus of a campaign with three aims: to raise awareness of the environmental and economic damage that Rabbits do; to make Australians more aware of native wildlife threatened by Rabbits; and, through royalties, fund our research, conservation and education projects.

Since ARRFA's headquarters are in Adelaide, we initially approached Adelaide confectioners to market our product. Two of the original three manufacturers (Haighs's and Melbas) still do so; the other no longer exists.

The Easter Bilby was such an instant success that other manufacturers, perhaps unaware of its origins, began to produce competing products. Some contested ARRFA's trademark but, in 1997, ARRFA's rights to its creation were recognised and all opposition withdrawn. From Easter 1998, all 'Easter Bilbies' must be licensed by ARRFA.

There is strong competition, however; there are now at least 14 other chocolate bilbies being sold at Easter under a variety of names.

Does it matter? Yes, it does. Most competing products contribute nothing to conservation work; certainly nothing to ARRFA, so it matters to us. And it matters to the original confectioners who took the initial commercial risks to support us. If the Easter Bilby has caught on, it is they who helped it do so, paving a surer way for other, often much bigger, manufacturers who now displace them.

We appreciate the warm reception given to the Easter Bilby. It has done great work in making Australians much more aware of native Bilbies and the urgent need for their conservation. All we ask is that people make sure that the chocolate bilbies they buy are trademarked 'Easter Bilby'. They will then know that their royalties are funding the conservation work for which this new symbol of Easter was devised.

—Robert G.B. Morrison
Chairman Anti-Rabbit
Research Foundation of Australia,
Adelaide, SA

Pebble Mystery Solved

Your article on pebble-mound mice (*Nature Aust.* Spring 1997) stopped me wondering about what lived in this home (photo enclosed), which is on a road where I walk nearly every day. I had thought the stones too big for ants to move about.

Sometimes the stones get messed up after a car wheel passes over them, but the next day they are all back in order. On other days the entrance may be blocked up with stones, but then open again the next. The mouse (mice) must have gone visiting!

I enjoy reading your magazine and have been able to identify some of the trees and bushes in my area from the articles and photographs.

—Bronwyn Bews
Biggenden, Qld

COURTESY BRONWYN BEWS

The work of mice, not ants.

Octopuses and Screwtop Jars

Thankyou for your immensely enjoyable article on octopuses (*Nature Aust.* Summer 1997–98). In regard to the intelligence of octopuses as revealed by their opening of screwtop jars, I have a notion that this is merely an extension of normal hunting methods.

If a jar lid is screwed on very tightly (such as in pressure-sealed jars), it frequently takes a man all his strength and considerable discomfort to his hands to open it. He only knows in which direction to persevere because of a lifetime of unscrewing threaded objects; there is no movement of the lid to give him any clue about which direction to twist or even whether the lid is the actual access point. Thus it is not the application of intelligence, even by a human being, that effects the opening of the jar.

Presumably the lids of jars given to octopuses open reasonably easily.

Consider an octopus hunting in a rock pool. Usually pools containing octopuses have a bottom covered with rocks and pebbles of various sizes. These pebbles are jammed or wedged together, the spaces between often being filled with smaller particles, the whole comprising a tightly packed body.

These pebbly bottoms are, of course, the hiding places of much of the octopus's prey, such as crabs and shrimp. If an octopus had only a slight grip on his prey in such a situation, just enough to hold the prey in place but not to extract if from its crevice, the octopus might then investigate the pebbles around the prey to see if any could be moved to afford it better access. Sensing movement in any pebble, the octopus would pursue that movement, wiggling the pebble back and forth until it came free, thus loosening the prey and allowing the octopus to get at it.

Such behaviour could readily translate to jar opening. The octopus would test the whole assemblage to see if any part of it was moveable. Once the lid moved in a particular direction, the octopus would quickly sense that the lid was becoming looser (most lids have to be turned much less than 360°, or even 180°, before coming off) and pursue that avenue, to achieve success.

Just a thought.

—Alan Crowe
Woonona, NSW

NATURE AUSTRALIA **welcomes letters for publication and requests that they be limited to 250 words and typed if possible. Please supply a daytime telephone number and type or print your name and address clearly on the letter. The best letter in this issue will receive a Foldable Magnifier from the Museum Shop. The winner this issue is Alan Crowe.**

Nature Strips

COMPILED BY
GEORGINA HICKEY

Tragedy Written in Stone

For more than 70 years, the rocky alps at Monte San Giorgio, near the Swiss–Italian border, have been offering up stories of an ancient world—one that existed during the mid-Triassic, some 240 million years ago. It is the fossils of mainly marine vertebrates, including many complete and near-complete skeletons of fish and reptiles, that this area has been yielding.

One exciting find, made in 1957, features the skeleton of an adult *Mixosaurus*, a genus of an extinct reptilian ichthyosaur. Around and within it are many smaller bones belonging to the same genus. Long-preserved evidence of some nasty act of cannibalism? Definitely not, according to University of Zürich palaeontologist Winand Brinkmann. For one thing, none of the smaller bones is found within the area where the adult's stomach would have been. For another, the small vertebral columns found within the adult are arranged parallel to each other—too neat, surely, to represent a meal.

Brinkmann believes this instead is the final scene of a birthing event that went terribly wrong. The larger skeleton, just over a metre long, is pregnant. The smaller skeletons with her are her unborn offspring. There are the bones of at least three embryos, each about 40 centimetres in length and at a stage of development suitable for birth.

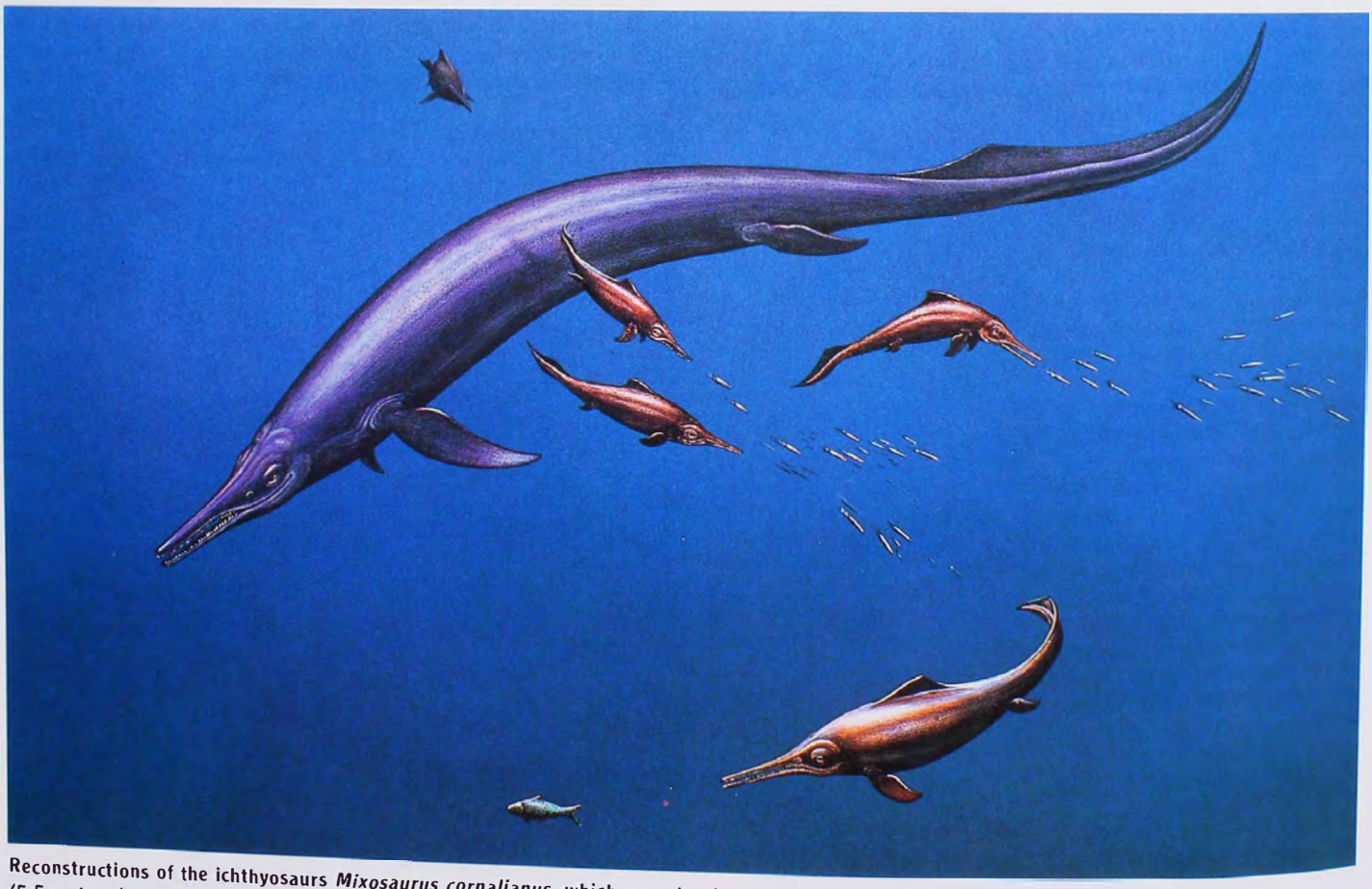
It appears that the embryos, with their heads positioned towards the posterior of their mother, were oriented in the wrong direction for birth. Brinkmann believes that the natural way for young ichthyosaurs to emerge from their mothers would have been, like whales and dolphins of today, tail first.

—K.McG.

Paint-pilfering Bees

It seems that anything that isn't nailed down can get knocked off, even a coat of wet paint. The small stingless bee *Trigona hockingsi* has been observed stealing wet paint on many occasions in northern Queensland. The paint is used as a substitute for resin in nest construction and doesn't appear to do any harm to the little thieves. While the quantities of paint a single bee can remove are extremely small, there are some local stories of their paint-stripping prowess that test credibility. In one yarn reported recently in *Aussie Bee* (the publication of the Australian Native Bee Research Centre, North Richmond, NSW) a fishing trawler was being repainted and, by the time the second side was finished, the first side had been nearly stripped!

We recently came across one hive whose workers had been busy pinching white paint to repair their resinous structural work. It looked just like a lump of Toblerone chocolate. Sometimes bees



COURTESY WINAND BRINKMANN

Reconstructions of the ichthyosaurs *Mixosaurus cornalianus*, which grew to about 1.5 metres, and the larger *Cymbospondylus buchseri* (5.5 metres long).

COURTESY CHRIS SIMON

Not a common sight: periodical cicadas (*Magicicada* spp.) only emerge every 13 or 17 years.

steal paint from a variety of sources resulting in hives dotted with many different colours. Like other social native bee species, *T. hockingsi* constructs grape-like clusters of pots for storing honey and pollen instead of the honeycomb arrangement employed by Honey Bees.

So residents of northern Australia be warned: the paint thieves are out there just waiting for your next stint of decorating. But it's relatively easy to foil these paint-purloining insects. They are inactive at cooler temperatures, particularly below about 17° C. So it's best to restrict your painting activities to cooler times (unless you don't mind sharing your Dulux with the bees).

—Paul Willis (ABC Science Unit, Sydney) & Anne Dollin (Australian Native Bee Research Centre)

Cicadas Primed for Survival

The yearly summer buzz of adult cicadas is a familiar sound on balmy nights, but in North America you might hear them just five or six times in your life; periodical cicadas (*Magicicada* spp.) only emerge every 13 years in the south of their distributions or 17 years in the north. These cicadas display an extraordinary trait called synchronised emergence: cicada nymphs remain underground for exactly 13 or 17 years (both prime numbers) and then the fully matured adults emerge together, almost to the day.

Jin Yoshimura, while at Imperial College in the UK, has proposed a new theory that explains both the periodic nature of the cicada's emergence and the prime-number phenomenon. He believes they are a permanent evolutionary response to periods of dramatic climatic cooling over the last two million years.

According to Yoshimura, now at Shizuoka University in Japan, the ancestors of *Magicicada* were non-periodical, with individuals emerging every year and with a seven-to-nine-year life cycle. He believes cold climatic conditions triggered a growth delay in cicada nymphs (in their burrows), elongating their life cycles to 14–18 years in the north and 12–15 in the south. The cold conditions would also have killed a large number of individuals. With severely depleted numbers, strict timing would have become essential to the survival of cicada populations. Individuals that emerged together (in time and space) would be more likely to find a mate and produce offspring.

To efficiently maintain the purity of each cicada population, and to ensure the synchronised nature of their emergence, the prime-number life cycles of 13 and 17 years would have developed in the south and north respectively. Adults from adjacent populations with non-prime-number life cycles would have often emerged in phase with one another, resulting in offspring with random emergence. Populations with prime-number cycles, however, would only rarely have had the chance to mix with adjacent populations. Yoshimura believes this would restrict interbreeding between groups that could result in cicadas emerging in the 'wrong' years when they would be unlikely to find a mate.

Over time, a long regular cycle with prime-number synchronised emergence would have been established.

—P.R.

Stiff Wrap for Armadillo

On the highways of Florida, motorists often see a strange sight. If an armadillo should wander across the road, the noise of the approaching engine makes it leap into the air with fright. Consequently, the animal usually ends up flattened against the vehicle's grill.

But what is bad for armadillos has been a windfall for biologists. Diane Kelly, while at Duke University in North Carolina, took advantage of

JOHN CANCALOSI/AUSCAPE

The Nine-banded Armadillo's *appareil d'amour* may have more relevance to us than you might think.

the available carcasses to study one outstanding feature. The erect penis of the Nine-banded Armadillo (*Dasypus novemcinctus*) is extraordinarily large, about one-third the length of the body. Penises are hydrostatic structures, meaning they hold their shape through fluid exerting pressure on a resistant fibrous sheath. In most hydrostats, such as earthworms, elephant trunks and tongues, these fibres are arranged in overlapping spirals, allowing for bending. But Kelly found that armadillo penises have fibres running both along and around the organ. She proposes that this previously unknown arrangement provides vital support to prevent bending, particularly in such a long organ. It makes evolutionary sense that an armadillo with a rigid penis has more chance of passing on his genes than one whose penis bends when the pressure is on.

Since Kelly's armadillo study, she has observed the same arrangement of fibres in the penises of a variety of other mammals. Rather than being just a quirky interest, her findings may have important implications for developing lighter, stronger condoms and even improved penile implants.

—A.T.

To Hatch or Not to Hatch?

Many eggs are like time bombs, ticking until the alarm goes off and new life emerges. This clock is usually set by the mother, who chooses when to lay and incubate eggs. Ducks, for example, only incubate after every egg has been laid, ensuring that all their ducklings hatch at once.

Eggs of many species may lie dormant and hatch when environmental conditions are right. Some eggs even seem to time hatching in response to predation. While a certain frog's eggs hatch prematurely when they sense a snake trying to eat them (see *Nature Aust.* Spring 1996), recent experiments suggest that the eggs of some freshwater crustaceans may delay hatching in response to predators.

Water fleas, clam shrimps and copepods are all eaten by the tadpoles of the Israeli Fire Salamander (*Salamandra infraimmaculata*). Fire Salamanders are born as tadpoles and spend two to three months in the water before becoming land creatures. Leon Blaustein from the University of Haifa, Israel, noticed that pools with salamander tadpoles had far fewer crustaceans than pools without. But this reduction was not all due to predation. Blaustein demonstrated that the numbers of crustaceans remained low regardless of whether the tadpoles were free-swimming or restrained in a mesh cage. It appears that the crustacean eggs were simply not hatching—but why not?

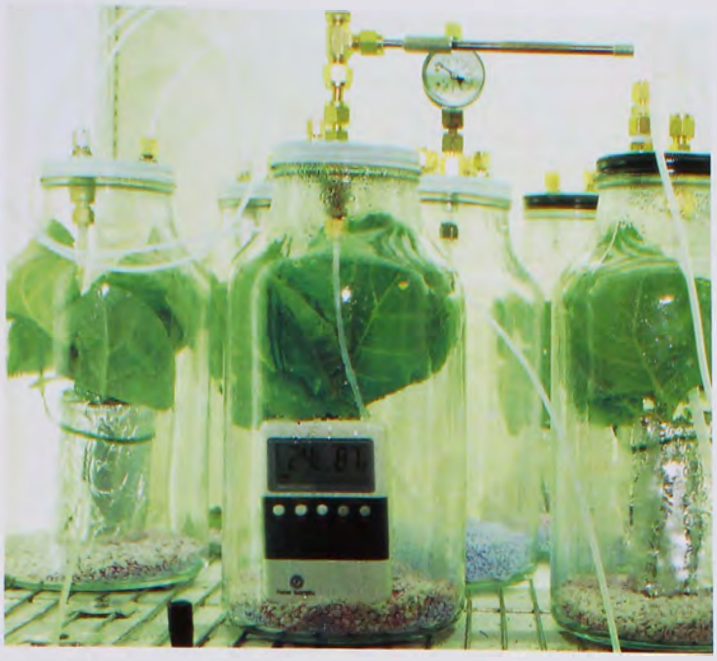
The crustacean eggs were somehow able to detect predators and delay hatching, perhaps waiting for the salamanders to mature and leave the pool.

Blaustein believes the crustacean eggs were somehow able to detect predators by an as yet unidentified chemical cue and delay hatching in response, perhaps waiting for the salamanders to mature and leave the pool.

—D.C.

Plants Talk

Many gardeners swear that communicating with plants makes them strong and healthy. Well, this may not be far off the mark.



COURTESY VLADIMIR SHULAEV

Air fed from the chamber of an infected tobacco plant causes healthy plants to marshall their defences.

Communicating, it has been found, does help plants to live longer . . . at least when they talk among themselves.

Vladimir Shulaev and colleagues from Rutgers University in New Jersey discovered that, when under attack by disease-causing organisms, tobacco plants (*Nicotiana tabacum*) produce an airborne signal that warns other plants to marshall their defences against a possible onslaught.

They found that plants infected with the tobacco mosaic virus produce considerable quantities of the gaseous form of salicylic acid, otherwise known as methyl salicylate or oil of wintergreen. They already knew that, when in sufficient quantities, the acid helps the plants fight disease by inducing the expression of antimicrobial proteins in the infected areas. Salicylic acid also travels to healthy parts of the plants, building up their systemic immunity to disease.

But when the researchers pumped the air from a chamber containing infected plants to another containing healthy specimens, the healthy ones also began producing antimicrobial proteins under the influence of methyl salicylate from the diseased plants. This is the first time that a plant has been shown to activate a defence response in another plant.

—R.S.

Whale Records Track Ice Edge

Why would one-quarter of the Antarctic sea ice suddenly disappear? This question has puzzled scientists since late last year when William de la Mare, from the Australian Antarctic Division in Hobart, published his startling discovery: between 1957 and 1973 the sea ice retreated by 5.65 million square kilometres.

De la Mare was using old records from the Bureau of International Whaling Statistics in Sandefjord, Norway, to model whale populations, when he realised they revealed crucial information about the icesheet during the harvesting period.

Whalers operated their factory ships close to the edge of the summer icefloes, where the Blue, Fin, Humpback and Minke Whales congregated to feed on krill. According to their logs, the sea ice edge extended to 61.5° south between 1931 and 1957. However from 1973 onwards it was stable at 64.3° south. (Satellite data, available from 1973, confirm that the icesheet has been stable since then.)

Nobody noticed this change take place: the whalers were busy harvest-

ing Sei Whales farther north between 1957 and 1972, and widespread satellite observations only started in 1973.

What does this rapid polar retreat mean? Scientists do not know but it may have happened too early to be caused by global warming. One possible explanation is changes in ocean currents. Nevertheless this discovery adds to the growing evidence that rapid changes in the Earth's climate systems can occur. Clearly, important processes that contribute to the Earth's climate are poorly understood. This has obvious implications for our ability to predict future climate change from the greenhouse effect.

—L.A.

Perfume or Poison?

Nicotine, one of the chemicals found in cigarette tobacco, is not just harmful to humans; it is also an effective natural pesticide used by some plants to deter predatory insects. But plants that produce nicotine to deter predators also repel potential pollinators. How do they get around this problem?

Michael Euler and Ian T. Baldwin, from the State University of New York in Buffalo, identified a delicate balancing act between the production of nicotine and a powerful perfume called benzyl acetone, in the tobacco relative *Nicotiana attenuata*. The researchers found that nicotine production is high during the day when predatory insects are about but drops rapidly in the evening when pollinating moths become active. At night-time benzyl acetone production in the flowers is stepped up to attract moths. As long as the flowers and leaves of *Nicotiana attenuata* are not damaged, this process continues in a daily rhythm. However, if the plant is attacked, nicotine levels rise regardless of the time of day. Protection of the plant, it seems, is more important than the potential loss of a few insect pollinators.

The perfume–poison seesaw, and the specific roles these chemicals play in the plant, produce an elegant and effective resolution to the problem of how to reduce predatory damage to the plant while increasing successful pollination.

—P.R.

In humans, boys are more likely to die during childhood than their sisters, and young men are more likely to meet an untimely demise than young women.

The Price of Manhood

Are males really the weaker sex? In humans, boys are more likely to die during childhood than their sisters, and young men are more likely to meet an untimely demise than young women. Having survived these early obstacles, elderly men are still more likely to leave their wives as widows. Why such a bias towards male mortality? It's thought that male sex hormones are

STEFANO NICOLIN/AUSCAPE

Whaling records indicate a rapid and dramatic retreat of the Antarctic sea ice. Is this natural or human-induced?

to blame.

Antechinuses present an extreme example, where males die after a single mating season from testosterone-induced stress. However, male hormones may also have a less direct effect. Whereas female hormones such as oestrogen are thought to stimulate the immune system, male hormones like testosterone may depress the immune system. To test this idea, Gina Schalk and Mark Forbes from Carlton University in Canada reviewed 38 published studies of parasitism in mammals. Given that parasitism is highest in animals with weakened immune systems, the researchers predicted that males would have higher levels of parasitism than females.

Schalk and Forbes found that males generally do have more parasites (particularly arthropods like fleas and ticks) than females of the same species. This sex difference could be due to many factors. After all, some males travel farther and have different diets than females, thus exposing themselves to more parasites. However, in studies of animals kept in laboratories (where the sexes were housed and fed similarly), the sex difference was still, if not more pronounced. And, most significantly, Schalk and Forbes found no sex difference between juveniles. Since juveniles have much lower hormonal levels than adults, Schalk and Forbes suspect that a male mammal's parasite load is increased by his hormones rather than his lifestyle. The price of being macho seems great indeed.

—D.C.

Turtles Chill out in the Sun

Freshwater turtles are often seen out of the water basking on logs and along the banks of rivers. It has always been assumed these reptiles soak up the sun to raise their body temperature. Yet during a study of the Brisbane River Turtle (*Emydura signata*), Ben Manning and Gordon Grigg from the University of Queensland were hard pressed to find turtles that supported this assumption.

C. ANDREW HENLEY/NATURE FOCUS

Testosterone certainly takes its toll on male mammals, especially antechinuses such as this Dusky Antechinus (*Antechinus swainsonii*).

Manning and Grigg recorded the body temperatures of eight free-ranging turtles that had been implanted with temperature-sensitive radio-transmitters. To their surprise, body temperatures were almost always the same as the water, despite the turtles' basking habits.

Only ten of the 1,402 temperature records showed turtles to be hotter than the water. So rarely were the turtles 'warm' that the researchers suggested these individuals may have been undergoing a "behavioural fever" rather than a routine increase in body temperature. Presumably, basking events are normally too short for the animals to warm up, although they certainly do emerge for long enough to dry out.

If there is no thermoregulatory reason for basking, can there by any other benefit from lazing around in the sun? Manning and Grigg suggest turtles may sunbake to inhibit algal or fungal skin infections, and/or to synthesise vitamin D. While these hypotheses wait to be tested, Brisbane River Turtles will continue to chill out in the sun.

—K.H.

Leaf with Teeth

Picture an elm, a maple, or an alder. Their leaves, like those of many deciduous trees, are serrated (toothed) or lobed. By contrast, evergreen leaves of tropical forests tend to have smooth edges. What adaptive advantage could leaf teeth and lobes be giving deciduous trees?

Recent research by Kathleen Baker-Brosh and Robert Peet (University of North Carolina at Chapel Hill) has produced evidence that leaf teeth and lobes may be crucial sites of early-season photosynthesis. Immature leaves of 18 species were dosed with radioactive carbon dioxide and autoradiography was used to locate the photosynthetically active sites (those areas of the leaves that had absorbed the carbon dioxide). The researchers found that, in over half of the 14 species with toothed or lobed leaves, a significant concentration of early-spring photosynthesis occurred in the leaf margins. In contrast, immature smooth-edged leaves showed no effective photosynthesis at all.

BRIAN CHUDLEIGH

Toothed leaves enable maples and other deciduous plants to get an early-season start to photosynthesis.

Clearly, in some deciduous species the leaf teeth and lobe tips mature early and carry out photosynthesis while the leaves are still expanding. However, as the leaves get larger, the precociously mature teeth and lobes become proportionally smaller and the distance between them increases. Baker-Brosh and Peet postulate that this feature of deciduous leaf morphology represents an important adaptation to short growing seasons, allowing plants to make the most of the short period of intense light at the beginning of the spring flush.

—L.A.

Earwax: Food for Thought?

The diet of oxpeckers, small birds of sub-Saharan Africa, appears to be even more curious than previously thought. Oxpeckers only feed on what they can collect from the skin of large mammals such as the Giraffe, buffaloes and rhinoceroses. Their main food item is thought to be blood-sucking ticks, although they are also known to eat blood, dead skin and mucus. While studying Red-billed Oxpeckers (*Buphagus erythrorhynchus*) in southern Zimbabwe, however, I discovered that oxpeckers also have an inordinate fondness for earwax.

As part of my PhD research into the effects of oxpeckers on domestic cattle, I ran an exclusion experiment in which oxpeckers were kept off a herd. I was expecting to see a dramatic and sudden increase in the number of ticks on the cattle, thereby confirming the theory that oxpeckers are good for their hosts. Instead, I found no significant change in tick loads, but a rapid build-up of earwax. Oxpeckers spend between 10 and 20 per cent of their time feeding deep inside mammalian ears, and it was thought that they were eating Brown Ear Ticks (*Rhipicephalus appendiculatus*), a species that only attaches to this part of the animal. It now seems that they are actually more interested in cerumen, the scientific term for earwax.

Oxpeckers are not alone in finding earwax a tasty snack. Tom Arny (University of Massachusetts at Amherst) reported that cats greatly enjoy the bitter taste of

HANS & JUDY BESTE/NATURE FOCUS

Do 'basking' turtles, like this Brisbane River Turtle, really bask?

human earwax but he could not suggest a plausible explanation. I am also unsure of what the appeal of earwax might be. Earwax is made up of long-chain fatty acids, the same substances that make up fat. These presumably give earwax a high energy content, but they may also make it difficult to digest. Alternatively, the birds could be after carotenoids—the chemicals that many species need to maintain their yellow, orange or red colouration. The oxpeckers in my study have bright red bills but most of their diet is completely lacking in carotenoids; earwax, on the other hand, is apparently rich in them. Whatever the reason for eating earwax, neither the flavour nor any indigestion associated with eating it, is enough to put the oxpeckers off.

—Paul Weeks
University of Cambridge, UK

PAUL WEEKS

Red-billed Oxpeckers have a taste for earwax.

Hot Blue Bellies?

Male Tree Lizards (*Urosaurus ornatus*) are nick-named 'Blue Bellies' because, when they display on tree trunks during the day, their belly skin is an intense (iridescent) azure blue. At night or before emerging into the sun however, these same lizards have bellies coloured rusty cream or faded turquoise. Colour change in animals can vary depending on sex, age, season, temperature and mood, and is normally under the control of hormones or the nervous system. But Blue Bellies exhibit a previously unrecorded situation in animal colour change. With my colleagues Randall Morrison (Hood College, Maryland) and Sally Frost-Mason (University of Kansas), we have shown that the rapid change to intense blue is achieved simply by raising the temperature of the cells while the lizard basks in the sun.

The pigment cells responsible for the Tree Lizard's change in belly colour are called iridophores. Within each iridophore, tiny crystals are carefully arranged in layers, like bricks in a wall. Cytoplasm is the matrix or 'mortar' that separates the layers. And, like water and air, the crystals and cytoplasm have different optical densities (and thicknesses), which affect the transmission of wavelengths of light. As sunlight enters from the skin surface, it is broken up (diffracted) and only certain wavelengths, or colours, are reflected back out through the skin surface, the others being absorbed deeper in the skin tissues.

When the skin temperature increases, male Tree Lizards are somehow able to increase the thickness of the cytoplasmic layer flowing between the fixed layers of crystals in the iridophores of their belly

JEAN-PAUL FERRERO/AUSCAPE

COURTESY WADE SHERBROOKE

Male Tree Lizards, restrained (belly up) in a double glass-walled 'lizard press', change from pale blue (top) at 25° C to bright blue (bottom) at 37° C.

skin. This has the effect of shortening the wavelength of the reflected light, thus making the skin on the belly appear bright blue.

Male Tree Lizards flash their 'hot' blue bellies at other lizards by raising their bodies, flattening their sides (exposing more of the belly) and rapidly executing multiple push-ups. For a male audience, this would be like putting on war paint before battle; for a female audience, it is more the equivalent of a male's fancy suit.

—Wade Sherbrooke
American Museum of Natural History

Keeping Testicles Cool

Why do most mammals have external testicles? In a recent report it was proposed that keeping the testes outside the body cavity prevents leakage of sperm produced by rises in abdominal pressure during exercise (see *Nature Aust.* Spring 1997). However, Roger Short from Melbourne University has put forward a rather different explanation.

His central thesis is based on two important differences in germ cell production in the two sexes. Germ cells are the precursors for sperm in the male and for eggs in the female (the gametes). In the male, once he has reached puberty, his testes begin producing sperm at a steady rate, a rate that is maintained more or less continuously for the rest of his life. In his lifetime, he therefore produces enormous numbers of sperm.

The situation is very different in the female. The number of eggs she is destined to produce is already laid down while she is still in her mother's womb. And the number of cells involved, a few hundred thousand, is a tiny fraction of that produced by the male. The foetal germ cells then enter an arrested stage of development, during which their metabolism is kept low. Only after their owner reaches puberty do small numbers leave the dormant pool at regular intervals to continue their development.

The numbers of gametes produced is just one important difference between the sexes. Another is the incidence of errors in the duplication of chromosomes during germ cell production. In mammals the male has the sex chromosomes XY, the female XX. The male Y chromosome is particularly prone to errors of duplication because it does not have an identical partner with which to exchange pieces to repair any mistakes. The female X chromosome has an identical partner and so is less prone to errors of duplication.

Finally, it is known that mutations are triggered spontaneously by a variety of factors, including atmospheric UV radiation and radioactivity. However we now know that some products of cell metabolism also trigger mutation. In the male, mutations of the germ cells can occur throughout adult life as the testes remain metabolically active and constantly manufacture sperm. In the female the germ cells are protected from these mutagens because they are metabolically dormant.

All of this means that male sperm are genetically a much more diverse bunch of cells than female ova. The diversity we see in the population is therefore largely the result of influences arising in the male. And that, finally, brings us

JEAN-PAUL FERRERO/AUSCAPE

Red Kangaroos (*Macropus rufus*) need to keep their testicles cool.

back to testicles. Too much variation is not a good thing. In order to dampen metabolic activity and keep mutation within manageable levels, testicles are externalised and kept cool (via countercurrent heat exchange between the spermatic artery and vein).

Why don't all mammals have externalised testes? We don't know. In dolphins, even though the testes are inside the body cavity, specific mechanisms are available to keep them cool. But that is not so for elephants. Here Short postulates that, because elephants have a long generation time (bulls will not normally breed before they are 40–50 years old), the amount of variability injected (so to speak) into the next generation must be maximised.

So the strategy of externalising the testes, rather than providing protection from the rigours of an active life, is designed to put a damper on the drive for diversity.

—Uwe Proske
Monash University

COURTESY PAUL V. SWITZER

Do American Crows rely on cars to crack open their nuts?

The Nutcracker Street?

Birds aren't, in general, renowned for their abilities as intelligent thinkers. A small brain is, after all, one of the evolutionary concessions that comes with the capability for flight. Some bird-brains, however, aren't thought to be as limited as others.

Take, for instance, the corvids—crows and their close relatives. Numerous anecdotal reports of these birds carrying out supposedly intelligent acts have led to them being popularly regarded as veritable Einsteins in comparison to the rest of the avian world.

Crows making use of moving cars to crack open nuts strategically dropped onto roadways is one of the most often quoted behaviours used to support this. However, according to Daniel Cristol and colleagues from the University of California at Davis, the scientific literature contains only three first-hand reports of such an act and those are based on uncontrolled observational studies.

To put these anecdotes to the test, the researchers carried out extensive observations of the methods used by American Crows (*Corvus brachyrhynchos hesperis*) to open walnuts at two locations in Davis. They witnessed hundreds of cases of crows dropping walnuts onto roads, but saw no evidence of cars being used deliberately as nutcrackers. Crows were no more likely to place nuts in front of cars than elsewhere.

The University of California team concluded that crows, like a lot of other birds, simply drop nuts onto any available hard surface in an attempt to break them open. There is simply not enough evidence, they say, to use the exploitation of moving cars by crows as an example of avian intelligence.

—K.McG.

QUICK QUIZ

1. What colour is Leichhardt's Grasshopper?
2. In which direction do cyclones usually rotate in the southern hemisphere?
3. What is a patagium?
4. What did Alan Hale and Thomas Bopp independently discover on the night of 23 July 1995?
5. In orb-weaving spiders, which is usually the bigger sex: the male or the female?
6. What do piscivores eat?
7. In which city and country was the December 1997 conference on world climate change held?
8. What is the term given to the widespread computer failures that are predicted to occur on 1 January 2000?
9. How many genes are there in the human genome: 1,000, 10,000 or 100,000?
10. Off which State of Australia is Franklin Island situated?

(Answers in Q&A)

Lynne Adcock, Danielle Clode, Karina Holden, Karen McGhee, Philippa Rowlands, Rachel Sullivan and Abbie Thomas are regular contributors to Nature Strips.

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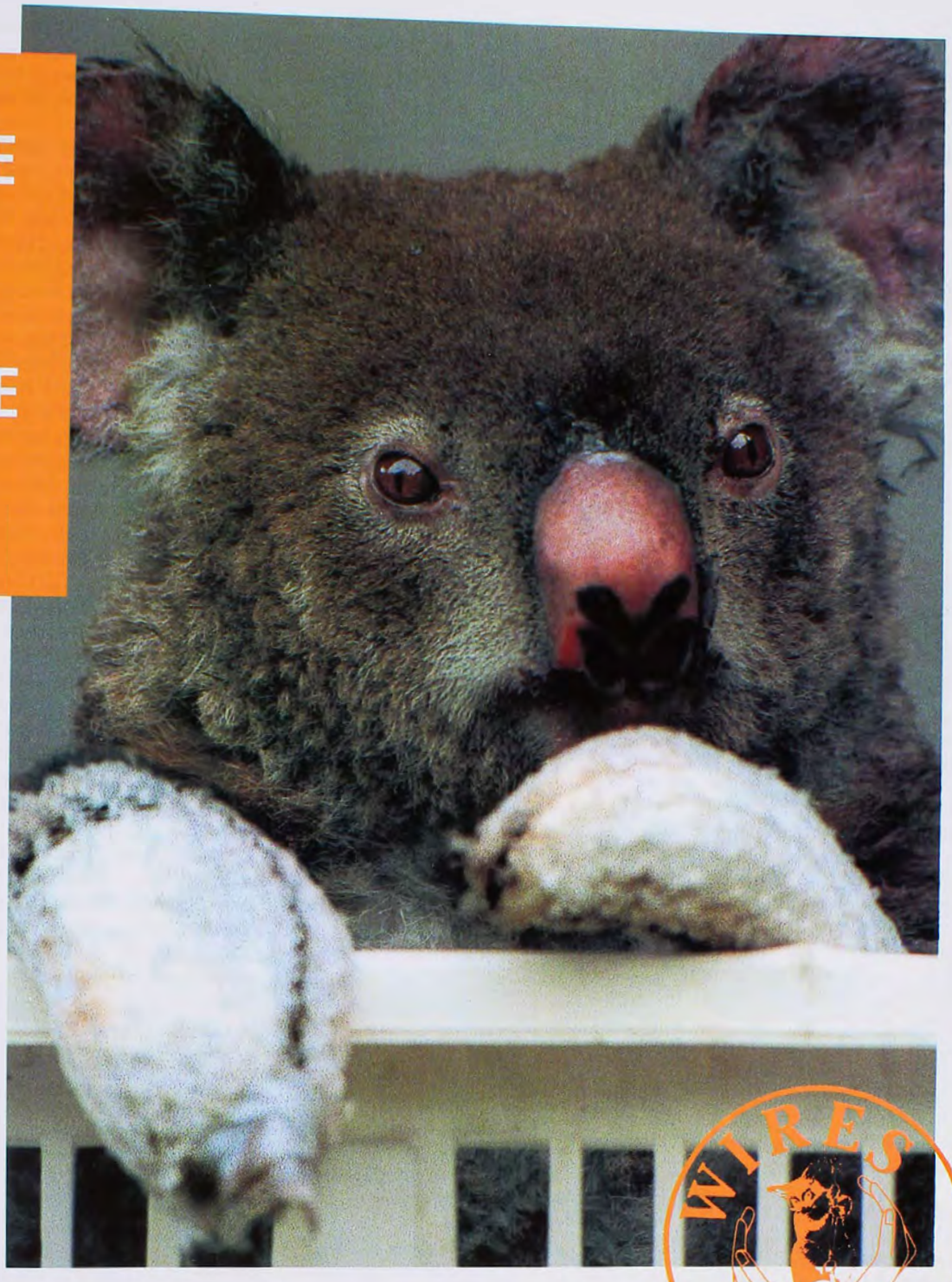

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Adult dragonflies normally live only a few months, but compared to larvadom it is a life twice as cutthroat, ten times as frenetic, and all set in a spectrum of psychedelic technicolour.

RAPT IN CELLOPHANE DRAGONS

BY STEVE VAN DYCK

CHAMPAGNE CORKS WOULD have popped at our place if a pet goldfish had ever notched up a life span exceeding that of its original packet of fish food. Over the years a parade of fish and their terminal illnesses came and went, and despite a million scrubbings of the tank, the grim reaper was well rewarded for his aquarium-side vigil.

Any fish with half a brain would jump out of the tank at night and kamikaze onto the floor to avoid meeting a more horrible protracted death. In summer, slime could overtake the tank within about three weeks. In that thick green lentil soup it was so difficult to tell when the inevitable capitulation to fungus or fin-rot took place that I could still be feeding them for weeks after all the fish had liquified on the bottom.

Then, unexpectedly, came the gift of an air pump, a box filter and some algae killer, all items of technology as foreign to us then as sewered pipes and Toilet Duck. And, as an ultimate expression of confidence in the apparatus, the present-giver threw in an additional item in the more familiar form of a fat goldfish, a Celestial, with eyes goggling appropriately toward heaven.

With us, a fat fish had a fighting chance of living a week or two longer than a skinny starter, but it all went too well. The fish stayed plump and healthy, the water stayed clear, and alas, the success went to my head. With an empty tin I ran down to the creek and stocked up with free-for-alls. There were small fish, snails, tadpoles, a crayfish with creepy leech-like parasites on it, and a curious little four-centimetre aquatic insect that looked like a cross between a cicada nymph and the Creature from the Black Lagoon.

...and under a bank he saw a very ugly dirty creature sitting, about half as big as himself; which had six legs, and a big stomach, and a most ridiculous head with two great eyes, and a face just like a donkey's. "Oh!", said Tom, "You are an ugly fellow to be sure!" (Charles Kingsley 1863, *The water babies*).

This innocuous-looking thing crawled around peaceably enough until, presumably, it got peckish. Then, instead of eating water weeds or the fish food, it lined up the goldfish's fat paunch, shot out an appallingly hooked lower lip, and tore the poor fish's belly inside out.

The alien pipsqueak was a dragonfly larva with a pirate's appetite for blood and gore, and a subaquatic life expectancy that might have reached a few years had it not been scooped out of the tank. There it could have worked its way through just about everything else before crawling out to 'hatch' into one of those fantastic cellophane Red Barons that cruise above the reed beds and along streams.

Once out of the stiff Cartesian diving outfit and up in the air, adult dragonflies normally live only a few months, but compared to larvadom it is a life twice as cutthroat, ten times as frenetic, lousy with ambush and pillage, and all set in a spectrum of psychedelic technicolour. Doomed insects such as gnats, mosquitoes, blow flies and mayflies are all intercepted in midair, grabbed by the dragonfly's spiny feet, and then devoured on the wing or nibbled back at the perch (dragonflies are grouped into 'fliers' or 'perchers' depending on how they spend most of their time). A few species pluck ('glean') sedentary insects from plant stems and some are cannibalistic. In 1917 entomologist Robin John Tillyard watched a dragonfly "... flying round and round a small bush about 7 p.m., when the mosquitoes were particularly troublesome. After ten minutes it was captured. I found its mouth so full of mosquitoes that it was unable to shut it. There must have been over a hundred mosquitoes all tightly packed into a black mass."

Of the world's 5,000 dragonfly species, Australia has at least 300, the largest of which (*Petalura ingentissima* from tropical Queensland) has a wingspan of 16 centimetres, qualifying it as one of the world's biggest. But the

DRAGONFLIES
(including damselflies)

Classification
Order Odonata, 3 suborders: Zygoptera (damselflies) with 11 families in Australia, Anisoptera (dragonflies) with 6 families in Australia, and Anisozygoptera (2 spp. only from Japan and Himalayas). About 5,000 described spp. worldwide, over 300 spp. in Australia.

Identification
Dragonflies: Stout with fore- and hind wings dissimilarly shaped, eyes close together. Wings generally held out flat while resting. Larvae with internal rectal gills. Damselflies: Slender with fore- and hind wings similar and paddle-shaped, eyes more widely separated. Wings of most spp. brought together over the back when resting. Larvae with external gills that resemble three tail paddles. Size range: wingspan 18 mm (for the damselfly *Agriocnemis rubricauda*) to 160 mm (for the dragonfly *Petalura ingentissima*).

Distribution
Worldwide, some genera circumpolar. Australia-wide near permanent and semi-permanent water (fresh, sometimes brackish or muddy, never marine), but most species coastal and tropical.

Food
Adults eat mainly flying but occasionally sedentary insects. Aquatic larvae eat small crustaceans, worms, the larvae of midges, mosquitoes, mayflies, tadpoles, small fish.

Reproduction
Eggs laid in fresh water, larvae go through 10–12 larval stages. Larvae of a few spp. known from leaf litter, all others aquatic. After a few months to a few years larvae emerge from water, split along back and adults emerge. Adults breed repeatedly during a life span of a few months (excludes those that overwinter in dormant state).

JOHN KLECZKOWSKI/LOCHMAN TRANSPARENCIES

Spectacular in colour and behaviour, dragonflies are much sought after by collectors.

real jumbo-jet that cruised the Permian forests 300 million years ago was *Meganeura monyi*. Its wingspan of 70 centimetres glorified dragonflies as the largest insects ever to exist on Earth.

So spectacular in colour and behaviour are dragonflies that they have always been a prized, yet challenging target for collectors. I recently heard of someone whose passion for the dragonflies he loved catching and keeping prevented him from ever actually killing them. Instead he carefully filed them according to species in transparent paper envelopes, inside illuminated card drawers, taking them out regularly to feed up on flies then putting them back until they died 'naturally'.

At close quarters dragonfly eyes, which take up all the head space not already taken by the mouth, are impossible to fathom. Scrutinising them produces the same frustration generated by those ridgy-textured plastic 3D images we sometimes get on children's rulers, pencil sharpeners and tacky greeting cards. In theory, the eyes look the way they do because they are a composite of many long telescope-like units called ommatidia packed together side by side like the wax cells of a beehive. Whereas some ants see the world through a single ommatidium, dragonflies geared for sky-high grappling can have over 10,000.

But it is this insect's derrière that takes the cake for cunning stunts. In the vicious little aquatic dragonfly larva, the gills are found inside its expanded rectum. Instead of using its mouth like a fish to suck in water, extract the oxygen and puff the stale current out again, dragonfly larvae accomplish the huff-and-blow at the tail end. It might be a bummer for halitosis, but for the enterprising nymph preoccupied with stalking and gaffing tadpoles, it was only a matter of time before it discovered that some heavy breathing at the eleventh hour could blast it from its rock straight to the dinner table where it could gobble sashimi without pausing for a breath.

Biological tail-end and undercarriage technology reach their acme in the flying adult male where the fuselage is tipped with gaffs evolved to grab a female and keep her handcuffed before and during mating, and often even up until the time the eggs are laid. What is more, during mating, the 'penis' spends infinitely more time toiling as a dredge or pile-driver rather than a seed drill. Why this inordinate effort?

After emerging as adults, dragonflies spend anything from a few days to a couple of weeks feeding and acquiring their colour. They then move off on strong cellophane wings to watery breeding grounds, which may be either very close or great distances away. Males set up and patrol territories ('bailiwicks') along creeks, to which the females eventually come when they have a batch of eggs ready to be fertilised and laid. After some midair scuffling to determine if the female is receptive, the male grabs her by the back of the head (or prothorax in damselflies) using a pair of grappling hooks on the end of his tail. They fly off in this 'tandem' position until she eventually swings the tip of her abdomen forward to link against the second abdominal segment of the male (under the wing attachments) to where he has already deftly transferred some surprise packages of sperm. Although there is a spicy hint of the Kama sutra associated with this copulatory manoeuvre, it is officially known as the 'wheel' position in polite entomological circles. This act, however, marks the point at which the penile skulduggery officially begins.

In a typical slow mating procedure taking 16 minutes, 15 of these might be spent by the 'penis' shovelling and scraping *out* the sperm of previous matings from the female's reproductive tract. Only during the last precious minute might he deposit his own. In other quick-mating species, the penis may rapidly pack and sweep the sperm of prior donors into dark corners of the female's reproductive tract, making it less available for fertilisation than what he leaves behind.

In promiscuous dragonfly circles the last male that mates prior to egg laying gets to call 95 per cent of the dragonettes his own. So after copulation, instead of releasing the full nelson, he and his mate (if they're damselflies) may fly in tandem down to the creek where, like a Chinook helicopter, they dip the end of her tail in and out of the water while she lays the eggs. Alternatively (in most dragonflies), the male may fly above the inseminated female and guard her from other suitors while she lays her (and his) eggs.

Three hundred million years of evolution have left dragonflies unrivalled as iridescent hedgehoppers, and the cooperation between male and females while egg-laying is touching to watch. However, an aura of paranoia surrounds dragonflies. With a lot less trust than thrust and a lot more scraping than raping, an obsession with 'being the father' is almost palpable at every twist of the creek. But even knowing the pedantic lengths they go to to establish fatherhood, it is infinitely more satisfying to enjoy dragonflies as flashy sky-pirates out in their Al Grasby coats, rather than as what they probably really are . . . frustrated glitterati bogged down in their perennial paternity suits. ■

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RARE & ENDANGERED

The Yellow-crested Cockatoo has become one of Indonesia's most endangered parrots.

YELLOW-CRESTED COCKATOO

BY PAUL JEPSON

NOT LONG AGO FARMERS in Australia and East Indonesia would have found common ground in their frustrations over crop-raiding flocks of 'yellow-crested cockatoos'. Today, however, while the Sulphur-crested Cockatoo (*Cacatua galerita*) flourishes in Australia and parts of New Guinea, its smaller neighbour, the Yellow-crested Cockatoo (*Cacatua sulphurea*) of the Sulawesi and Nusa Tenggara regions, has become one of Indonesia's most endangered parrots.

Superficially the eight subspecies or races of the two species differ only in size—all are white cockatoos with sulphur-yellow crests. They are considered distinct species primarily because there is a break in the distribution of the four smaller *C. sulphurea* races and the nearest *C. galerita* populations in Irian Jaya. The gap is in the Moluccan Islands, which are occupied by three other species of white cockatoo. The most distinctive race of the *sulphurea–galerita* complex is *C. s. citrinocristata*. Endemic to Sumba, Indonesia's southernmost island, it has an exquisite orangey yellow crest and, because of this, some experts are suggesting it should be classed as a separate species, and the seven 'sulphur-crested' birds merged as one.

Although *C. s. citrinocristata* has been considered endangered for some time, it is only recently that the other three races of Yellow-crested Cockatoo have been added to the endangered list. Noticing that visiting birdwatchers were regularly failing to see cockatoos, BirdLife International and PHPA (the Indonesian Government's nature conservation agency) mounted a series of rapid status assessments between 1994 and 1996. The results were alarming: there had been massive declines everywhere. Yellow-crested Cockatoo populations are now extinct in Lombok (race *parvula*) and probably in North Sulawesi (race *sulphurea*), and the race *abbotti* from the tiny, isolated Masalembo Islands in the Java Sea totals just nine individuals!

Interviews with village leaders and farmers revealed that 20 years ago flocks of Yellow-crested Cockatoos were a familiar sight; the general view is that trapping has caused their decline. Trade data show that nearly 100,000 Yellow-crested Cockatoos were exported between 1980 and 1992. This is a significant number, yet the Tanimbar Corella (*Cacatua goffini*), which is endemic to the 5,000-square-kilometre Tanimbar Islands and which was traded to a similar extent, remains a common agricultural pest. Why has the Yellow-crested Cockatoo, with its massively larger range, suffered such a different fate?

"Baretta", a popular American TV detective show of the 1970s, featured a tame Sulphur-crested Cockatoo called Fred. This show stimulated demand for the species in the USA. But because trade in Australian parrots was forbidden and Sulphur-crested Cockatoos were protected in Indonesia, Yellow-crested Cockatoos were trapped and exported instead. Like their Sulphur-crested relatives in Australia, Yellow-crested Cockatoo flocks are loyal to a favoured roost tree and this appears to have been the reason for their downfall. Trappers wound horsehair (later nylon) snares in the branches along with a tame decoy bird. However, climbing tall forest trees is a dangerous occupation, so in Sulawesi a safer technique was developed, requiring only one climb. Palm mid-ribs smeared with a sticky tree resin were placed in the branches; cockatoos brushing against them stuck fast and, mid-rib and all, tumbled to the ground. The method was so effective that whole flocks were caught at once, and this may account for the Yellow-crested Cockatoo's extreme rarity in Sulawesi.

By the mid 1980s prices had risen, as had an awareness of the ready market for cockatoos. In Nusa Tenggara, farmers who traditionally go in search of forest products during the long dry season when there is little work in the fields, took to collecting cockatoo nestlings—further pressuring already decimated populations.

PHPA reacted promptly to the survey results by stopping exports in 1993, and an inter-agency recovery plan prepared together with BirdLife has recently been published. An urgent priority was to inform villagers of the species' plight and the trade ban. A simple visit to the Masalembo Islands was enough for community leaders to pledge to safeguard the last individuals of the beleaguered *abbotti* race. In East Sumba, discussions with the local government led to the Regent (District Officer) declaring the Yellow-crested Cockatoo the Regency's faunal mascot and issuing a decree giving it full protection. Copies of the decree are being circulated to all Regents in Sulawesi and Nusa Tenggara with the suggestion that they follow Sumba's lead. In remote islands and regions, community leaders are being mailed with an attractive awareness leaflet, and a program of regular press and radio articles seeks to generate wider public concern. The response so far is encouraging.

Ending trapping may not on its own lead to a strong population recovery, as the status assessment revealed additional threats. One is the loss and fragmentation of the cockatoo's favoured habitat, tropical dry forest, which is particularly vulnerable to shifting cultivation and rangeland burning. A 1995 study on Sumba indicated that Yellow-crested Cockatoos need forest blocks over 1,000 hectares and there are few dry forests in the region's reserve network. PHPA, BirdLife and World Wide Fund for Nature are now working together to rectify this. Another concern is the loss of nest sites. Studies in Sumbawa indicate that the mature trees favoured by cockatoos are also sought by villagers for timber. However, reports of Yellow-crested Cockatoos nesting in old Coconut and Lontar Palms, and even in sand banks, suggest that they might be quite catholic in nest-site choice, and the recovery plan includes proposals for trials with nest boxes, as well as focusing on training for local PHPA staff.

Sulphur-crested Cockatoos are wonderful habitat generalists and, with similar protection from persecution, the same might be the case for Yellow-crested Cockatoos. In March 1997 in Sumba's Langilluru reserve I saw four pairs of cockatoos in an area where five years earlier I had heard only one—hardly a scientific survey, but grounds for hope that this charismatic bird will one day again be a familiar sight in Indonesia.■

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COURTESY BIRDLIFE INTERNATIONAL

There was no autumn flush, no salute to the seasons, just that "tiresome, shadeless never-green", as traveller Godfrey Mundey put it.

WHY EVERGREEN?

BY TIM LOW

TO THE PIONEERS, Australia's forests seemed gloomy, monotonous and melancholic. Artist Ellis Rowan wrote in 1898 of "mile after mile of shadeless, grey, sombre-looking gum trees, poor and scantily clothed, stretching away in indefinite monotony". Part of the problem was trees that didn't shed their leaves for winter. There was no autumn flush, no salute to the seasons, just that "tiresome, shadeless never-green", as traveller Godfrey Mundey put it.

The evergreen nature of Australia was a puzzle to the pioneers, and it poses a question worth asking today, although one that has earned little attention or study. Why are so few Australian trees deciduous?

Overseas, deciduous forests are more widespread than most Australians think. They are certainly not confined to the cooler latitudes of the northern hemisphere. Most of the woodlands and savannas in Africa are deciduous, and there are vast deciduous forests in temperate and tropical Asia and South America—the Teak (*Tectona grandis*) forests of India and Thailand, for example. Australia seems most out of step when compared to Africa. The savannas there can look remarkably like our outback, until the dry-season leaf drop. The few evergreen trees are found clinging to watercourses and termite mounds.

Within Australia, deciduous trees are by no means rare, with the odd species found in many habitats. White Cedar (*Melia azedarach*), for instance, a well-known tree of rainforests and damp eucalypt forests in northern and eastern Australia, is completely winter deciduous. But this plant is almost the exception that proves the rule—it is native to Asia as well as Australia, and it obviously evolved its deciduous habit there before dispersing to Australia.

To find largely deciduous forests we must travel to the montane beech forests of Tasmania (where Deciduous Beech *Nothofagus gunnii* dominates the understorey), or the monsoon rainforests and woodlands (which usually have evergreen eucalypt canopies) in northern Australia. In both places it is easy to see why leaves are seasonally shed. Tasmania's mountains enjoy a chilly winter, and northern Australia gets incredibly dry—90 per cent of Darwin's rain falls between November and April, with winter virtually rainless. It makes good sense for trees to shed their leaves before this time, rather than lose vast amounts of water through transpiration.

The real question is why deciduous

PHOTOS: TIM LOW

In the woodlands of the Top End, deciduous shrubs such as Kapok Bush (*Cochlospermum fraseri*) grow beneath a canopy of evergreen eucalypts. Aborigines harvest the taproots and flowers as food.

trees and shrubs do not thrive farther south, in the deserts and arid woodlands of outback Australia, where conditions seem so much like Africa. Judy Egan and Dick Williams, two CSIRO biologists, studied woodland sites along a transect running from Darwin to Tennant Creek, and found that the proportion of deciduous plants dropped as they went south, from almost 14 per cent around Darwin, to only two per cent at Tennant Creek.

The explanation for this lies in Australia's erratic rainfall. Rain in central Australia, unlike the monsoon north, is unpredictable. Trees and shrubs need to be quick to exploit water whenever it falls, and the best way to be prepared is to carry foliage at all times. Our larger outback plants have thus evolved tough, thin, long-lived leaves with protective cuticles (hence the grey look). Africa is as drought-prone as Australia, but since rain never falls in the well-demarcated dry season, it is counterproductive to carry leaves then. Instead, the plants produce rather soft, short-lived leaves designed for one wet season.

Australia's infertile soils also contribute to our evergreen status. In the northern hemisphere, there are prominent forests of evergreen trees—made up of pines and other conifers. On fertile soils, deciduous trees usually outcompete conifers, but under harsh conditions, where winters are severe or soils infertile, conifers take over. Ecologically, eucalypts and pines appear to be close analogues. Most of them are quick-growing, aromatic, thin-leaved, sclerophyllous (tough-leaved), fire-adapted trees that dominate well-drained infertile soils. Because they grow so fast on poor ground, they are the most widely planted timber trees in the world. Eucalypts are more obvious in Australia than pines in Europe because our soils are so much worse. On infertile soils nutrients are so hard to come by that trees cannot risk losing them by dropping their leaves each year. Instead, trees and shrubs produce tough, long-lived leaves.

The dominance of evergreens in Australia must have profoundly influenced the evolution of our animal life. Browsing mammals find sclerophyllous leaves much less digestible and palatable than those carried by deciduous shrubs and trees, which may help explain why Australia has relatively few browsing mammals. For insectivorous birds that feed in foliage, evergreen forests can be occupied year-round, eliminating the need for migration, and allowing for the development of highly territorial societies as seen in Noisy Miners (*Manorina melanocephala*) and Bell Miners (*M. melanophrys*). Evergreen forests also drop fewer leaves than deciduous forests (although the leaves are tougher and decay more slowly), with a corresponding influence on the litter fauna.

The dominance of evergreens is yet another of those uniquely Australian characteristics that can be explained by our infertile soils and unreliable rains. ■

The Cape York Lily (*Curcuma australasica*) is one of the many deciduous herbs found in Australia's monsoon tropics. It sprouts new leaves each wet season from an underground rhizome (stem).

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GROUND FROGS ON THE RISE

BY DON DRISCOLL

The earth is so important for these species, that even their 'honeymoons' are spent below ground.

FROGS IN THE AUSTRALIAN FAMILY Myobatrachidae are often referred to as ground frogs, and rightly so. The vast majority of the 100 or so myobatrachid species spend their entire lives either on or below the ground.

The Turtle Frog (*Myobatrachus gouldii*) and its near relative the Round Frog (*Arenophryne rotunda*) from the south-west of Western Australia are ground frogs in the extreme. The earth is so important for both these species, that even their 'honeymoons' are spent below ground. Male and female Round Frogs pair up in late winter or spring, and then spend at least five months together in fossorial foreplay, before subterranean sex and egg laying. The Turtle Frog has gone one step further. Not only does it partake in underground affairs, it also dines down in the dirt. Turtle Frogs eat termites and, although no-one has seen them feeding in the wild, it's possible they need only find a termite gallery to obtain a steady supply of self-propelling sustenance.

Besides bizarre sex lives, Turtle and Round Frogs are among the weirdest looking frogs. In appearance, Round Frogs are essentially the size (about three centimetres long) and shape of squashed dumplings, with four stumpy legs. Multiply the Round Frog's weird factor by ten and you get the Turtle Frog. Imagine a neckless, tailless turtle with its shell peeled off and you'll have an image that approximates the Turtle Frog! Male Turtle Frogs are about four centimetres long, while females are usually larger and may be as long as five centimetres. They have minute eyes on their pimple-heads, and short, powerful limbs equipped with spade-like hands and feet for digging. Unlike most of the other ground frogs, which burrow backwards, Turtle and Round Frogs use their powerful forearms to burrow headfirst into the sand.

WITH THE ROUND AND TURTLE FROGS as its closest relatives, it is not surprising that Nicholls' Toadlet (*Metacrinia nichollsi*) is also reputed to be a committed denizen of terra firma.

The Round Frog, like the Turtle Frog, spends most of its life in the sand.

Nicholls' Toadlets live in the highest rainfall areas of the south-west of Australia. They are usually found under rocks or logs, and have been described as filling the niche of a caecilian, those burrowing, worm-like amphibians of the tropics. I was therefore somewhat flabbergasted when, on a particularly wet February night, I tracked down the calling positions of these tiny (two-centimetre-long) frogs. They were perched in bushes, standing boldly but precariously up to 50 centimetres above the ground! From below, they presented an extraordinary sight. Nicholls' Toadlets have orange spots on their armpits and legs, and a blue-and-white mottled belly. With vocal sac distended, the orange flashes were like beacons on the grey–blue background.

This is extraordinary behaviour for a myobatrachid frog. None of the other

JIRI LOCHMAN/LOCHMAN TRANSPARENCIES

members of the family calls from exposed perches on plants. The only myobatrachids that *do* call from plants are dependent on the ground-like properties of the plants they climb, and are always well hidden. For example, Pouched Frogs (*Assa darlingtoni*) from south-eastern Queensland and northern New South Wales occasionally climb plants in search of suitable breeding habitat. After rain, they call from leaf litter trapped in the nooks and elbows of rainforest plants, up to one metre from the ground. Similarly, Karri Frogs (*Geocrinia rosea*) from the south-west corner of Western Australia occasionally build their breeding burrows in leaf litter that has accumulated on fallen logs. There are also a few myobatrachids that breed in moss, and so technically are plant-climbers. These include

H. EHMANN

The Turtle Frogs are beautiful creatures, once you get to know them. They have powerful forelimbs used to burrow headfirst into the sand.

DON DRISCOLL

Nicholls' Toadlet is the only ground frog that calls from exposed positions in plants. This male was calling 45 centimetres above the ground on a sandy ridge.

the corroboree frogs (*Pseudophryne corroboree* and *P. pengilleyi*), the Baw Baw Frog (*Philoria frosti*) and the Moss Froglet (*Bryobatrachus nimbus*), which live in alpine areas in New South Wales, Victoria and Tasmania respectively. Given the ground-like properties of sphagnum bogs, climbing through moss does not really compare to the arboreal antics of Nicholls' Toadlet.

We know virtually nothing about the biology of Nicholls' Toadlets. There have been no formal studies but, based on anecdotal evidence, they seem to have a bizarre and varied approach to life. Besides calling from shrubs, they also call from the ground, and from burrows of other frog species. Once I even discovered a *female* calling from a shallow burrow! The call was different from a typical toadlet call and, when I tracked the intriguing sound through the swamp to its source, I came across a large and plump Nicholls' Toadlet. In virtually all frogs, only the males call, so if female Nicholls' Toadlets really do call, it is quite extraordinary.

Reports from early this century pointed towards the fantastic possibility that these small blue frogs may live in the nests of the ferocious bull ant *Myrmecia regularis*. Several dozen frogs were found in bull-ant galleries beneath a log near Manjimup in 1927 and could only be collected using a pair of long steel forceps. Fifty-two frogs were also found in the entrances and galleries of an active bull-ant nest near Augusta in the same year. Although this extraordinary association was reported by several observers between 1926 and 1945, the phenomenon has not been reported since. Nicholls' Toadlets have been found in places other than bull-ant chambers throughout their recorded history, so they have never been totally confined to ant nests. Nevertheless, it is an enticing idea that this tiny frog might have evolved a mutually agreeable relationship with an ant that most people in the south-west loath and fear.

This tiny frog might have evolved a mutually agreeable relationship with an ant that most people in the south-west loath and fear.

The reproductive cycle of Nicholls' Toadlets is also somewhat of a mystery. They call from late spring to summer, but the only records of eggs in the field were both from March (1929 and 1943). Does this species have a 'honeymoon' period like the Round and Turtle Frogs? There were 25–30 large eggs (4.5 millimetres in diameter) and, in both cases, adults were found with the eggs. These early observations may represent one of a few records of both frog parents guarding eggs (see *Nature Aust.* Winter 1998). However, it is also possible that the adults were indifferent to the eggs and just had nowhere better to go. Nicholls' Toadlets, Round and Turtle Frogs all have direct-developing eggs, where the tadpole stage occurs entirely within the egg capsule, and they emerge as fully formed frogs.

Nicholls' Toadlet is an enigmatic and remarkable frog. Although largely unstudied, the little we know suggests

Nicholls' Toadlets, at around two centimetres in length, are small frogs confined to the forests in the high-rainfall areas of south-west Western Australia.

that it harbours a variety of bizarre, almost unimaginable behaviours, especially for a 'ground frog'. Together with the Round and Turtle Frogs, the three species in Western Australia form an incredible group of strange-looking frogs with underground sex and a behavioural repertoire that extends from the subterranean to the shrubs. ■

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HAL COGGER

G. HAROLD

Orange ventral patches on a blue-and-grey background are characteristic of Nicholls' Toadlet. The patches are like beacons when these enigmatic creatures ascend vegetation to call.

It may come as a surprise to discover that Peregrine Falcons are gentle, attentive parents.

GOOD PARENTING PEREGRINE STYLE

BY PENNY OLSEN

DAVE WATTS/NATURE FOCUS

A female Peregrine takes a break from feeding her single two-week-old chick to scan the sky for potential predators or pirates.

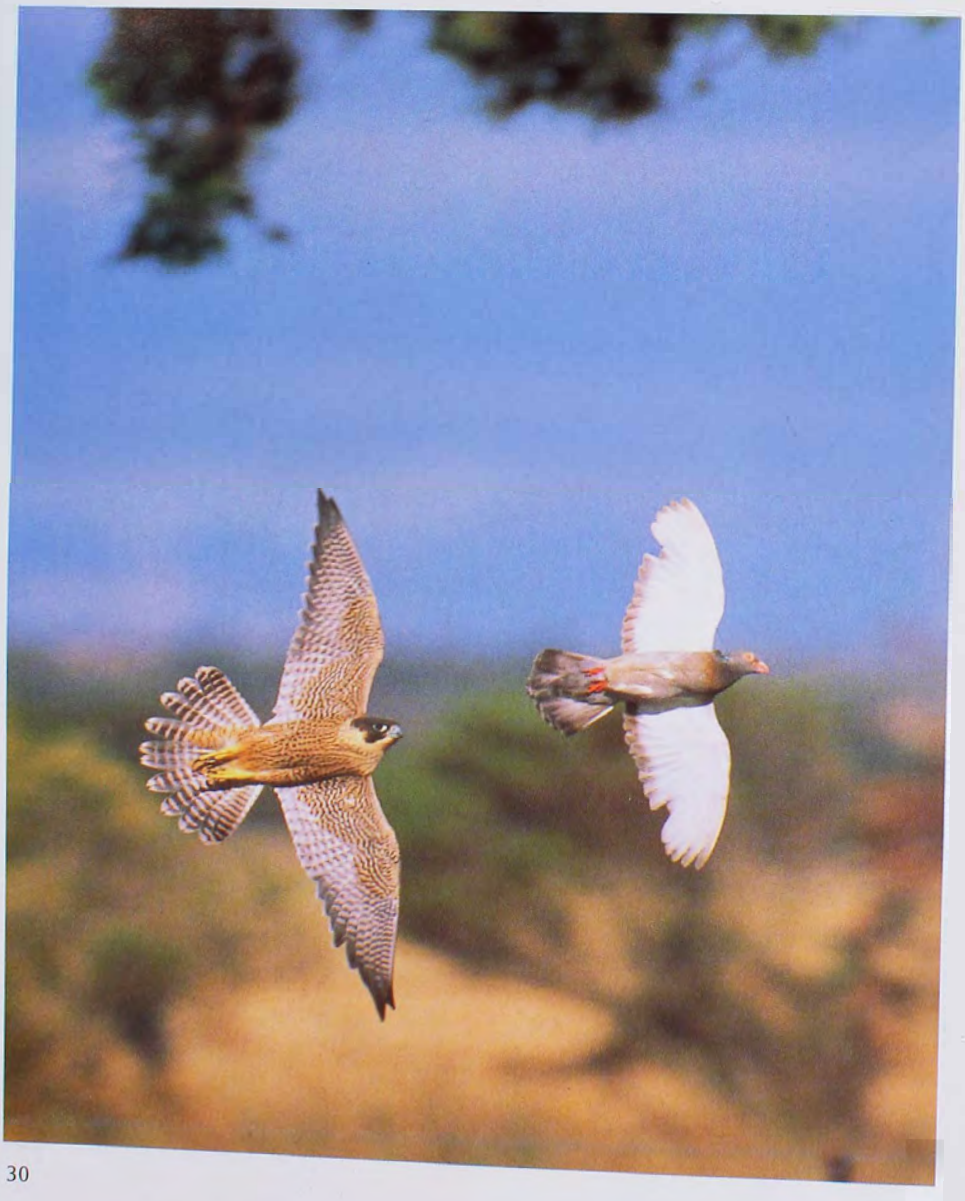
AS THE BOAT NEARED THE NEST site we spotted her above, skimming along the cliff top, relaxed but obviously heading somewhere. We got around the next river bend just in time to see her drop over the cliff to intercept a small flock of Galahs winging their way upstream. A puff of feathers and it was all over. The Peregrine Falcon carried the limp Galah to the cliff where she began to pluck it. We decided that she must have spotted the Galahs from a distance, as they wound their way along the river, and staged an ambush.

Another day and another place, the sickle shape of a male Peregrine materialised from nowhere to slice through a ragtag flock of Common Starlings. In the blink of an eye, he angled through the mass and banked up on the far side clutching a small dark body in his talons. Too late, the startled flock exploded into a squawking melee, then massed into a tight knot.

I have studied Peregrine Falcons (*Falco peregrinus*) for over 20 years and could probably count on the fingers of one hand the number of times that I have witnessed a Peregrine actually making a kill. It is a rare and awesome privilege. To me they are superlative predators that hunt birds on the wing, sometimes at great speed. In level flight they can overtake many other birds and their spectacular stoop, a steep dive in pursuit of prey, has been reliably measured at up to 180 kilometres per hour. They dispatch their prey quickly and cleanly, by the force of the impact of their feet, or by reaching down and severing the spinal chord with a bite to the neck. Yet, occasionally, they are viewed as cruel bird killers—much maligned by some sections of the pigeon-racing fraternity for their alleged decimation of flocks. While Peregrines certainly take pigeons, they are just one of many hazards facing racing pigeons. Making Peregrines the scapegoat will not significantly reduce pigeon racers' losses.

Whatever your viewpoint, it may come as a surprise to discover that Peregrine Falcons are gentle, attentive parents. Indeed falcons have a somewhat conventional home life. It takes two to raise a brood and the male and female cooperate by taking on separate, complementary duties. The smaller male does much of the hunting, while the female stays around the nest incubating the eggs or brooding and minding the chicks. The male may bring home the 'bacon', but typically he gives it to the female to tear up to feed the chicks and herself. If he doesn't bring home enough, he may even be abused by the family members who scream at him mercilessly until he is forced to resume hunting or to fly to a perch out of sight.

The Peregrine is probably one of the best studied of all raptors. I have been researching the general biology of a population near Canberra since 1975. In the early 1990s I felt it was time to study some of the finer points and, in particular, to investigate the relative contribution of each parent and to ask what makes a good parent. While this may seem a rather academic question, it has



NICHOLAS BIRKS/AUSCAPE

Peregrine Falcons are specialist bird hunters that capture prey on the wing. Here a young falcon, a few months post-fledging, closes in on a domestic pigeon, a straggler from a racing flock.

NICHOLAS BIRKS/WILDLIGHT AUSTRALIA

With a downy chick tucked under each wing, a female Peregrine hunkers down for the storm.

profound implications, for it is the good parents that contribute most to future generations. Good parents are also likely to be the offspring of good parents. Because they are the link between the past and the future, good parents also hold clues to the evolution of certain behaviours and characteristics.

MY FIELD SEASON BEGINS ABOUT spring when, after some steep hiking with packs of abseiling gear, I check nest sites with the help of my colleagues to see whether they are occupied. Typically, Peregrines in my study area lay eggs in September, have nestlings in October and their chicks fledge in November. In about August, the male begins to court the female and bring her prey as part of the pair-bonding process. The general consensus is that his prey-delivery skills during this period influence the female's breeding effort. If the male is a good provider during courtship, chances are he will also be a good provider for the family. Thus, during courtship the female may be able to judge what sort of a provider the male is and scale her reproductive effort accordingly. If he is a poor provider, she does not gain enough weight to produce eggs and will not breed. If he is a mediocre provider, she may lay two eggs; if a reliable provider, then three or even four.

In some birds of prey, further finetuning to family size occurs once the nestlings have hatched. If prey is scarce, the weakest nestlings die or are killed by their siblings. This is known as the 'Cain and Abel struggle', after the biblical story of competition between two brothers, and the parents have little direct influence over the conflict. It seems harsh, but the stronger chicks have a better chance of survival if they do not have to share food with weaker nest mates. However, among Peregrines, nestling life is relatively peaceful and siblicide is unknown. A few new hatchlings die if food unexpectedly becomes scarce, but once they are through the first week, most chicks survive to fledge.

Having hatched between one and four chicks, most often two or three, the female continues to spend much of her time on or near the nest. She broods the nestlings until they are around ten days old, by which time they are well covered with thick down and can regulate their own body temperature. After they reach this age she begins to cover them mainly at night or during storms, and spends longer periods perched near the nest rather than on it.

The male occupies much of his day hunting or perched near the nest. When he returns from a hunt he may call the female off the nest and pass the prey to

NICHOLAS BIRKS/WILDFLIGHT AUSTRALIA

A female Peregrine arrives at a perch to collect partly plucked prey from a much smaller male. Such transfers are part of the courtship process and, later, the female ferries the prey to their nestlings. The male Peregrine supplies nearly all the food for the breeding attempt.

PEREGRINE FALCON

(*Falco peregrinus*)

Classification
Order Falconiformes (diurnal birds of prey, including eagles, hawks, kites and harriers), family Falconidae (falcons and allies).

Identification
Medium-sized, compact falcon. Wingspan 80–105 mm. Males weigh approx. 600 g, females 900 g.

Reproduction
Annual breeder. Clutch of 3 (1–4) eggs laid late winter–spring, generally earlier in warmer areas than elsewhere. Incubation 33 days; chicks fledge after about 6–7 weeks in nest. Male hunts for family, female cares for eggs/chicks and hunts a little later in nestling period. Does not build a nest; uses cliff ledges, tree holes and nests of other large birds, especially Wedge-tailed Eagle (*Aquila audax*), occasionally tall city buildings and other man-made structures.

Habitat and Distribution
Prefers open country for hunting, usually near water and with high vantage points (cliffs, trees, buildings). Among the most widespread of all bird species; on all continents, except Antarctica, and many islands. Occurs Australia-wide, but scarce in deserts.

Status
In the 1960s to 1980s organochlorine pesticides caused widespread global population declines, although only local declines in Australia. Now relatively common and secure.

her at a perch. Sometimes he goes to the trouble of preparing the meal by plucking feathers from his catch, but usually he leaves this to the female. If the chicks are small, they beg at the sound or sight of her and she places tiny slivers of flesh in their upturned beaks. She calls 'chup' softly to encourage them as they tire quickly and drop off to sleep. When they are large, they crowd around her and grab the meat offered in her beak.

The parents cache prey, often in a crevice or under a clump of vegetation. This is usually the task of the female, who takes any prey in excess of the chicks' immediate needs to one of these larders. She usually retrieves it again within a day, during a quiet period when the male hasn't returned with food for a while. In this way she helps to keep up a regular supply of food to the chicks.

One of my Honours students, Mark Boulet, sat in hides at Peregrine nest

sites, and noted any prey brought to the nestlings over a three-hour period. The hides are small 'tents' designed to keep the observer out of sight of the falcon and to allow an unencumbered view of the nest. Mark's studies showed that the female does not appear to favour any particular chick. After a few initial frantic grabs, mealtimes are quite orderly affairs. Generally, the female passes most food to the chick closest to her until it nears satiation, and then she feeds the next. Not every chick may be fed equally at any particular meal, but after several meals every chick receives a similar amount for the day. Even female nestlings, which by about three weeks of age are half as heavy again as their brothers, do not eat a great deal more than male chicks. The females could use their size advantage and larger weaponry (talons and beaks) to dominate the males at mealtimes, but do not. One reason for relatively squabble-free mealtimes may be that Peregrines bring in large prey, typically from starling- to pigeon-size, so that there is often enough for everyone. Another explanation may lie in the finetuning that occurred when the female 'decided' to lay a certain number of eggs based on the male's provisioning abilities, so that, quite possibly, in most cases the brood is only as large as the male can support.

It is the female's job to defend the nest from potential predators. She swoops at unwanted intruders, such as the odd goanna or even Tasmanian Devil, and occasionally hits them or rakes them with her talons. Her loud, strident 'cack cack cack' can be a deterrent in itself and often brings the male winging back to the nest to help drive away the offender. She also makes sure that the chicks stay around a comfortable temperature and broods them if they are cold, shades them from hot sun and shelters them from the rain.

Once the chicks fledge, at about six or seven weeks of age, they stay in the parents' territory for a couple of months. The parents continue to bring them prey, and are often harassed and chased around the sky by a gaggle of hungry, screaming youngsters. Perhaps not surprisingly, the parents spend a lot of time away from the fledglings during the day. This may be simply because they are out hunting, but it is tempting to think they make themselves scarce for the sake of peace and quiet! The fledglings gradually learn to hunt for themselves, while being supplemented by their parents. Parental guidance is not essential—fledglings can learn to hunt in the absence of parents provided they are given some food—but the youngsters may learn more quickly by observing their parents or following them to good hunting spots.

The parents continue to bring them prey, and are often harassed and chased around the sky by a gaggle of hungry, screaming youngsters.

PENNY OLSEN/AUSCAPE

The Peregrine is a powerful predator. It has a broad chest, heavily muscled for rapid pursuit of prey, a compact powerful beak, and large, well-taloned feet. The latter give the Australian Peregrine its subspecific name *macropus*, meaning big-footed in Latin.

NICHOLAS BIRKS/WILDFLIGHT AUSTRALIA

These two young Peregrines, between six and seven weeks of age, are almost fully grown and ready to fledge. As is typical, the smaller male (at left) has lost more down than his sister, and will fledge a day or two before her.

WHAT, THEN, MAKES A GOOD FATHER? Because males provide about 85 per cent of the prey needed to support successful breeding, it might be expected that the best providers are also the most successful breeders. This seems to be the case, and fathers that provide a regular supply of prey do raise larger broods. My studies have shown that, during the first five days after their chicks hatch, males deliver an average of one prey item every five hours to broods of one, but one prey item every two-and-a-half hours to broods of two and every two hours to broods of three. And if male hunting skill is important, what are the characteristics of a good hunter? One suggestion is that small males are the best hunters because they are more agile than larger males, and this gives them an advantage in the pursuit of their aerial prey.

Nevertheless, it is difficult to separate male hunting skill from territory quality. Males are the territory-holders, so the possibility remains that males with the best territories, containing abundant food, are the best providers. Most likely, the ability to be a good provider is the result of some combination of male hunting skill and prey availability. Another aspect of territory quality is nest-site quality. Females paired with males that hold a territory with a safe, dry nest tend to produce more chicks than those with a poor nest site. This is because Peregrines lay in about September when spring storms may flood nests, preventing laying or killing the eggs or tiny nestlings. Thus, parents that have access to a good-quality nest site are advantaged over those that do not. An exposed nest on a cliff ledge may be adequate in a dry year, but open to inclement weather and subject to run-off or flooding in a wet year. In contrast, a nest ledge with an overhang above and good drainage will be secure under most weather conditions.

Are some mothers better than others? Certainly some females are more attentive and protective of their young than others. This could be attributable to differences in experience and/or differences in temperament. The most aggressive female in my study area is far and away the most successful breeder. My colleagues and I dread climbing up to her nest, which invariably contains three chicks. She kicks up such a fuss and strikes us over and over so that we not only fear for her safety but for our own as well. Studies of other raptors have shown that larger females tend to be more successful breeders over their lifetimes than smaller females, in part because they begin to breed at an earlier age and so have the opportunity to produce more offspring. Early results from my studies indicate that this is also the case with Peregrines.

I dread climbing up to her nest. She kicks up such a fuss and strikes us over and over so that we not only fear for her safety but for our own as well.

Indeed, the number of offspring produced over a lifetime is a better measure of parental fitness than the success of an individual breeding attempt. Parents that raise the most chicks are the most likely to contribute to future generations; that is, the more offspring they produce, the more likely it is that some of those offspring will survive to breed themselves. Among the few birds of prey that have been studied,

only a few parents actually contribute offspring to future generations and reproductive success varies enormously between individuals. For example, among female European Sparrowhawk fledglings (*Accipiter nisus*) only about one-third survive and attempt to breed, and only one-quarter end up producing young. Of the 25 per cent or so that produce young, the number of offspring produced varies widely, from one chick in a lifetime up to 29. In fact, only seven per cent of European Sparowhawk fledglings produce 90 per cent of the youngsters in the next generation. Although there are no good data for Peregrines, the figures are probably similar. Looking at parental success this way, only seven per cent of females are good parents!

Another way to increase lifetime reproductive success is through cuckoldry. Although Peregrines are monogamous, it is possible that the female may mate with a wandering male, as has been observed in some other birds. This is an easy way for a male to increase his reproductive success at little cost to himself because some other male raises his chicks. I am using fingerprinting with DNA, extracted from a tiny blood sample, to reveal whether the chicks in a brood are of mixed paternity. However, early indications are that there is little cuckoldry in Peregrines. Perhaps, because of the tremendous hunting effort required to raise a brood, males ensure their paternity by means such as frequent copulation and defence of a large territory. Up to 15 copulations per day have been observed in the pre-laying period. Such apparent excess may serve to dilute the sperm of any competing male.

So, what makes a good Peregrine parent? A potential good parent must have a dependable partner, a high-quality territory and a sheltered nest site. In particular the male must be a good hunter and provider, and the female must be able to recognise these qualities in him. In general, larger females seem to be more successful parents than smaller females, while the converse might apply to males. However, chance events can foil even the best-laid plans. Heavy storms and high winds may destroy nests, eggs or chicks and even the adults themselves. Further, because Peregrines reach such great speeds while hunting, they are also subject to fatal accidents, such as collisions with high-tension electricity cables. Good Peregrine parents therefore also need a fair amount of good luck.

Understanding what makes a good Peregrine parent does more than simply satisfy the curiosity of a fellow parent! It can help us manage other raptor species that are not as well off. Often too few remain of a rare species to be able to do meaningful research on them. However, in many cases, knowledge gained from studies of common species can be applied to such threatened species. And, in this day and age of the restricted conservation dollar, where we often have to make "Sophie's Choice" type of decisions regarding which of the threatened individuals are best saved or assisted, such guidelines are extremely useful. ■

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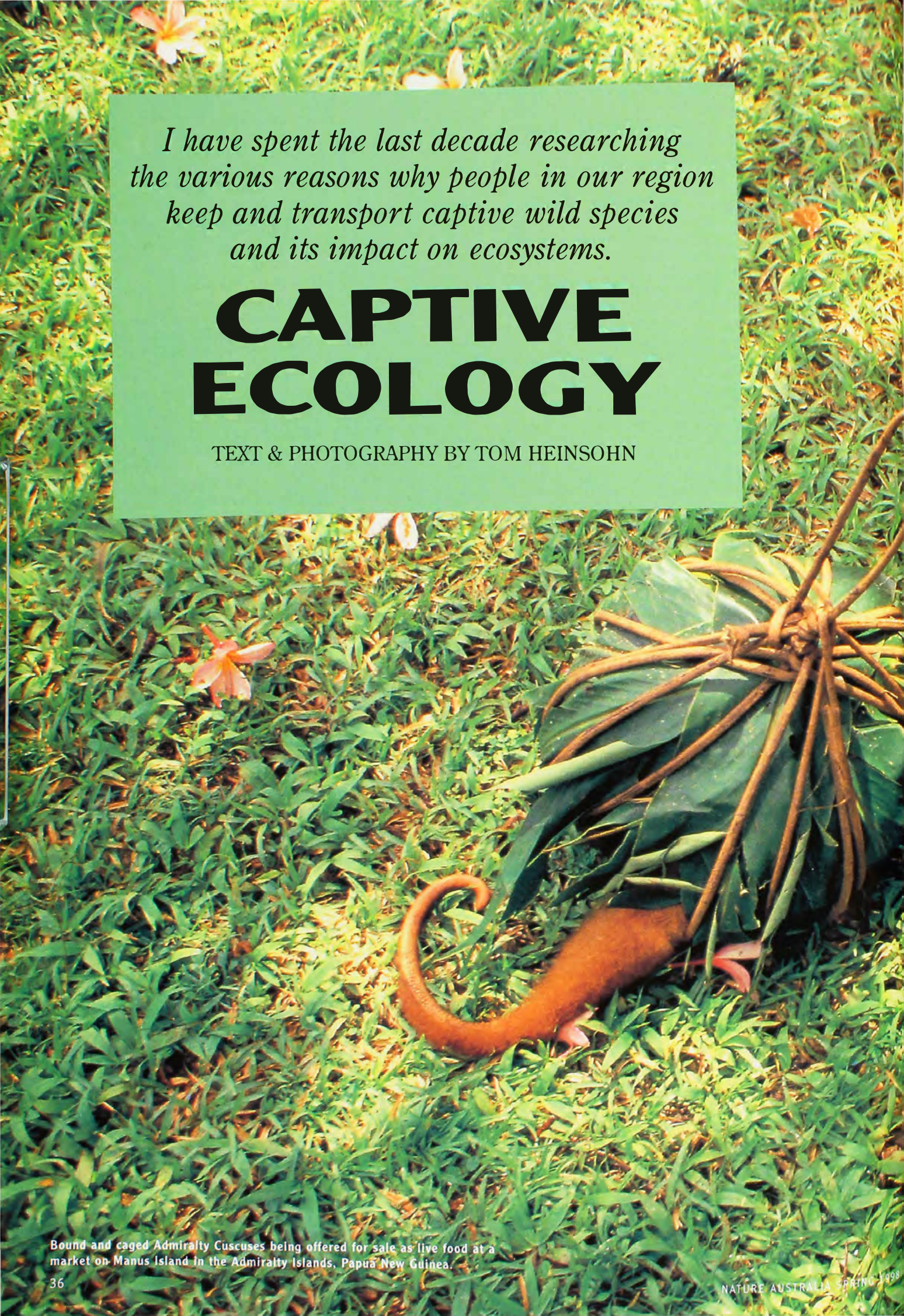
NICHOLAS BIRKS/AUSCAPE

Two three-week-old nest mates, with dark feathers beginning to break through their thick white down, hover hopefully near the female Peregrine.

I have spent the last decade researching the various reasons why people in our region keep and transport captive wild species and its impact on ecosystems.

CAPTIVE ECOLOGY

TEXT & PHOTOGRAPHY BY TOM HEINSOHN



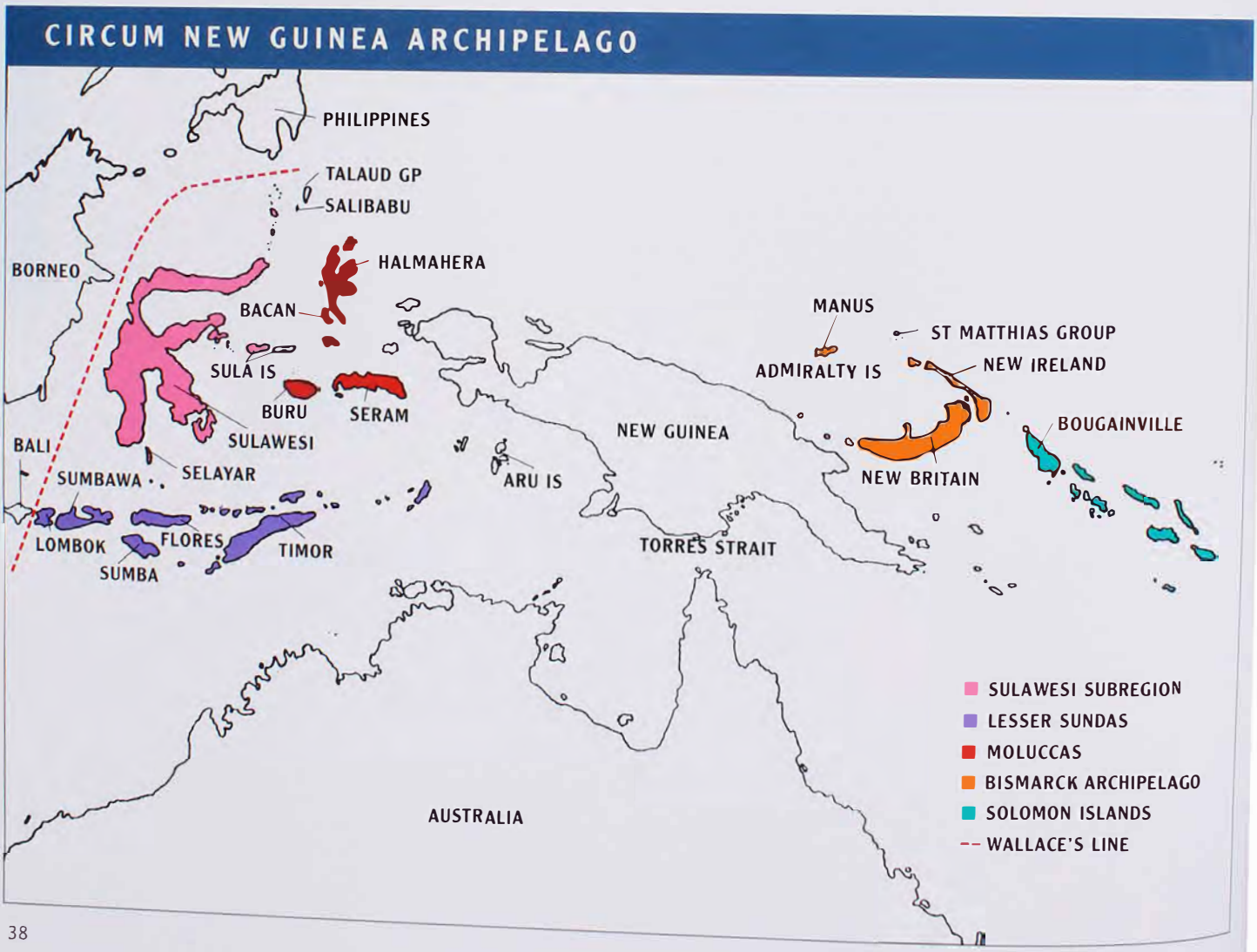
Bound and caged Admiralty Cuscuses being offered for sale as live food at a market on Manus Island in the Admiralty Islands, Papua New Guinea.

WHILE I WAS ON SELAYAR Island to the south of Sulawesi, I came across a Common Spotted Cuscus (*Spilocuscus maculatus*). It was tied to a village shade tree via a long cord leash and waist band. Caged, tethered or tamed animals are a common sight throughout the Circum New Guinea Archipelago of Indo-Melanesia, the chain of islands that stretches from Sulawesi and the Lesser Sundas in the west to the Solomon Islands in the east and Torres Strait in the south. But this particular tethered cuscus bothered me. After all, the people of Selayar are devout Moslems who, unlike their Christian counterparts in central and northern Sulawesi, do not eat cuscus. It was also strange because Selayar Island has the world's most isolated Common Spotted Cuscus population, with the nearest neighbouring population lying 700 kilometres away in the Moluccan Islands. Given that it is extremely improbable that cuscuses could survive rafting that distance on a mat of vegetation or floating tree, it was most likely introduced by ancient cuscus-eating seafarers in pre-Moslem times.

Stimulated by such encounters, I have spent the last decade researching the various reasons why people in our region keep and transport captive wild species and its impact on ecosystems, zoogeography and gene pools. What is surprising is the degree to which humans have meddled with island populations and, as a result, changed the course of evolution. Furthermore, a population that appears natural, after a little bit of historical research, may sometimes turn out to be an artefact of either accidental or deliberate human translocation.

WHY DO THE PEOPLES OF OUR region keep captive wild species? During the course of my research, I have found that the principal reason is for food or feast purposes. In the absence of refrigerators, a reality of the past and an ongoing reality in poor rural areas of Indonesia and Melanesia, wild animals may be temporarily kept alive in a bound, tethered or caged state (much the same as lobsters in a seafood restaurant) as a means of keeping a ready supply of fresh meat. This is referred to as keeping a living larder, and sometimes also involves fattening an animal for the table or raising a juvenile to maturity in time for a ceremonial feast. Some of the main animals traditionally utilised in the Indo-Melanesian Archipelago for this purpose are various deer, monkeys, cuscuses, wallabies, cassowaries, pythons, monitor lizards and Coconut Crabs (*Birgus latro*). In still other instances, animals may be kept or raised to supply products other than meat, including feathers, pelts, horn and skeletal material, which are used in tools, adornments, charms and medicines. In Indonesia, the Malay Civet (*Viverra tangalunga*) and Little Civet (*Viverricula indica*) are kept principally as a source of civet, a musk-like substance from which perfume is made, while the Palm Civet (*Paradoxurus hermaphroditus*) is used as a rat catcher.

The second major reason why people in the Indo-Melanesian Archipelago keep captive wild species is for pets. Intelligent wild species such as monkeys and parrots make delightfully responsive pets that are able to entertain their keepers and in many instances provide a source of companionship. Young wild animals may also be kept by children or young adults who are practising their nurturing and parenting skills and, as a general rule of thumb, the closer an animal is in appearance to a human infant, the more likely it is to be retained as a pet. This theory explains why young monkeys and young possums are so popular in parts of Indonesia and Melanesia respectively. Their human-like faces, wide eyes and grasping hands or forepaws can elicit a nurturing response in even the most seasoned of



A Tigak man on New Ireland with a captive young male Northern Common Cuscus being kept as a pet. Evidence gathered by archaeologists of the Lapita Homeland Project indicates that this species was probably introduced to New Ireland between 10,000–20,000 years ago, probably from neighbouring sources in the Bismarck Archipelago or New Guinea.

hunters. Other small mammals such as young Sugar Gliders (*Petaurus breviceps*) in New Guinea and surrounding islands may be kept as delightful pocket pets. Based on my observations, however, the majority of these casual pets end up in cooking pots, being devoured by rapacious village dogs, dying from lack of appropriate care, or escaping to an unknown fate. Relatively few are retained to adulthood.

Indo-Melanesians may also keep captive wild species for status purposes. This appears to have been the case with the Common Spotted Cuscus I saw on Selayar Island. A villager who manages to capture and keep a wild animal may be said to have magical powers over that species and gains status as a hunter, magic worker or animal tamer within the village. Indeed, in some instances the live animal may be carried or worn as an adornment during ceremonies. The beautiful and docile Green Python (*Chondropython viridis*) is used in this way by some New Guinea peoples.

The other major reason why Indo-Melanesians keep captive wild species is for trade. If you visit a market in parts of New Guinea and Island Melanesia, you may see a variety of caged and bound marsupials, such as cuscuses and wallabies, being sold for their meat and pelts; in Indonesia it is not uncommon to see caged parrots and other birds being sold as pets. In both instances, the market is usually supplied by rural people who regard such species as a valuable cash crop. While in some cases these practices may involve elements of ancient traditional trade networks that have been sustained for hundreds or even thousands of years, in other instances, particularly in Indonesia, they may be a product of a powerful and often unsustainable demand to supply the modern pet trade. Paralleling this is a similarly destructive modern trade in exotic game meats, with everything from snakes, rats and bats to marsupials and monkeys being sold in markets and restaurants for human consumption.

A villager who manages to capture and keep a wild animal may be said to have magical powers over that species and gains status as a hunter.

WHAT IS THE ENVIRONMENTAL IMPACT of the captive management and transportation of wild animal species by humans? By transporting live captive animals, humans introduce species across geographical (water, mountain or habitat) barriers to places beyond their natural range. In many instances this is accidental, and occurs when animals escape captivity to form wild populations. I have recorded instances where cuscuses have broken out of cages or freed themselves from tethers and escaped into the bush. I have also seen pythons wriggle out of sacks, Coconut Crabs break free of flimsy vine bindings, and there are countless stories of birds, including breeding pairs, escaping from cages and aviaries.

In other instances, humans, from prehistoric times to the present, have deliberately stocked islands with introduced wild species as part of a 'game park' strategy. One of the most striking examples of this is the case of the Javanese

Rusa Deer (*Cervus timorensis*), which has been deliberately introduced by humans as a source of high-quality meat to the archipelagos of eastern Indonesia, New Guinea and parts of Island Melanesia. A growing body of archaeological and historical evidence indicates that marsupials and cassowaries have also been spread by humans from sources in and around New Guinea to surrounding island archipelagos. The most dramatic cases are those of the Northern Common Cuscus (*Phalanger orientalis*), which is now found all the way from Timor in the west to the Solomon Islands in the east; and the Common Spotted Cuscus, found on Selayar Island near Wallace's Line* in the west all the way to the north Melanesian island of New Ireland in the east.

In the most extreme cases, human translocation of wild animal species creates bizarre isolated populations, such as that of the Common Spotted Cuscus on Selayar Island. However, even when translocation is carried out within an animal's natural range, it can lead to a regional disturbance of natural gene pools due to mixing in of foreign genetic material.

Usually, when observers come across a population of animals on an oceanic island, they are seeing a species that, having colonised the island some time in the distant past, has reached a state of relative equilibrium with its competitors. In other words, within the limits of habitat, available resources and competition, the species has spread to most of the suitable areas on the island. Once in a while, however, one may come across a recently arrived or introduced species that is still in the process of invading a landmass. This can provide a fascinating laboratory-like glimpse into the processes and impacts of the past that have shaped what we see in the present.

One classic study is of the biological invasion of New Ireland by the historically introduced Common Spotted Cuscus. Oral historical records collected by Tim Flannery (Australian Museum) in 1988 and me in 1990 indicate that this cuscus was translocated a distance of 120 kilometres from the neighbouring Saint Matthias Group into the Kavieng

A caged young male Admiralty Cuscus on Manus Island.

area at the far north-western end of New Ireland. Some say it was introduced by a kiap (patrol officer) and his boat crew, sometime during the decade leading up to the commencement of World War 2; others give the Kavieng-based Japanese occupation force, which occupied the island between 1942 and 1945, credit for the introduction. Whatever the case may

*Wallace's Line is an imaginary line, described by the famous naturalist Alfred Russel Wallace, that separates the Oriental and Australasian zoogeographical regions. It runs between Bali and Lombok, Borneo and Sulawesi, and to the south of the Philippines.

INDO-MELANESIAN ANIMALS KEPT CAPTIVE	MAIN PURPOSE
Marsupials	
Common Spotted Cuscus *Spilocuscus maculatus*	LL, AP, TL, P
Admiralty Cuscus *S. kraemeri*	LL, TL, P
Northern Common Cuscus *Phalanger orientalis*	LL, TL, P
Southern Common Cuscus *P. intercastellanus*	LL, P
Sulawesi Bear Cuscus *Ailurops ursinus*	LL, P
other cuscuses	LL, P
ringtail possums	LL
Sugar Glider *Petaurus breviceps*	P
other gliders and petaurid possums	LL, AP, P
Agile Wallaby *Macropus agilis*	LL
Northern Pademelon *Thylogale browni*	LL
Dusky Pademelon *T. brunii*	LL
dorcopsis forest wallabies *Dorcopsis* spp.	LL
tree-kangaroos *Dendrolagus* spp.	LL, AP
Common Echymipera Bandicoot *Echymipera kalubu*	LL
other peroryctid and peramelid bandicoots	LL
Eutherian Mammals	
Rusa Deer *Cervus timorensis*	LL, AP, TL
Barking Deer *Muntiacus muntjak*	LL, AP, P
Babyrusa 'Deer-pig' *Babyrousa babyrusa*	LL, C, TL
Celebes Wild Pig *Sus celebensis*	LL, TL
Indonesian Wild Pig *S. scrofa vittatus*	LL, TL
Long-tailed Macaque *Macaca fascicularis*	P, LL
Celebes Black Macaque *M. nigra*	P, LL
Sulawesi macaques *M.* spp.	P, LL
Silvered Leaf Monkey *Trachypithecus auratus*	P, LL
Palm Civet *Paradoxurus hermaphroditus*	R
Malay Civet *Viverra tangalunga*	AP
Little Civet *Viverricula indica*	AP
Leopard Cat *Felis bengalensis*	?P
Pangolin *Manis javanica*	LL, TL, AP
Javan Porcupine *Hystrix javanica*	LL, AP
Prevost's Squirrel *Callosciurus prevostii*	LL, P
Plantain Squirrel *C. notatus*	LL, P
Giant Black Squirrel *Ratufa bicolor*	LL, P
other squirrels	LL, P
bush rats	LL
fruit-bats	LL
Birds	
Southern Cassowary *Casuarius casuarius*	LL, AP, C, TL
Northern Cassowary *C. unappendiculatus*	LL, AP, C, TL
Dwarf Cassowary *C. bennetti*	LL, AP, C, TL
hornbills	LL, AP
parrots, pigeons/doves, mynas	P
Reptiles	
Reticulated Python *Python reticulatus*	LL, AP
Amethystine Python *Morelia amethistina*	LL
Green Python *Chondropython viridis*	C
other pythons	LL
monitor lizards *Varanus* spp.	LL, AP
Indo-Melanesian Giant Skink *Tiliqua gigas*	LL
Giant Solomon Islands Arboreal Skink *Corucia zebrata*	LL
freshwater turtles	LL
various reptiles	P
Invertebrates	
Coconut Crab *Birgus latro*	LL

LL = living larder; AP = animal product; P = pet; C = ceremony; R = rat catcher; TL = traditional live trade.

Kavieng market on New Ireland, Papua New Guniea. Motor boats and canoes from neighbouring islands come and go with cargoes, which may include various domesticated species or captive wild animals.

be, results from my own oral and field surveys indicate that, since the war years, the Common Spotted Cuscus has spread about 45 kilometres down the 300-kilometre-long narrow island and appears to be extending its range at a rate of about 0.8 kilometre per year. This is slow compared with unassisted invasion rates of between 1.8 and 5.0 kilometres per year recorded for the introduced Common Brushtail Possum (*Trichosurus vulpecula*) in New Zealand. But this may be because the Brushtail, which habitually forages on the ground, is better able to cross unforested areas, whereas the Common Spotted Cuscus, being strongly arboreal, is a more restricted disperser. Furthermore, while invading Brushtails were able to disperse into New Zealand habitats devoid of close competitors, Common Spotted Cuscuses in New Ireland have had to compete with dense pre-existing populations of Northern Common Cuscuses (which were introduced to New Ireland prehistorically). Indeed, in the ensuing ecological battle between the two species, the larger Common Spotted Cuscus appears to have virtually driven the Northern Common Cuscus out of some marginal habitats such as coconut plantation, but the latter species has managed to hold on and coexist with the invader in rainforest habitats. In contrast, in the area beyond the invasion zone, the Northern Common Cuscus is found in all forest habitats, including coconut plantations.

For me the study of relations between humans and wild species has led to a profound loss of biological innocence because so much that I once automatically thought of as natural, must now be examined with a suspicious eye.

A further impact of cuscus introductions to New Ireland is increased browsing pressure on the forests. One tree species, the Kwila (*Intsia bijuga*), had individuals that were up to 50 per cent defoliated by cuscuses. Clearly, introduced wild animal species, whether they be browsers, grazers, folivores or seed dispersers, are likely to have some impact on the composition of plant communities over time, and these amount to an indirect effect of humans.

ONE PROBLEM THAT SCIENTISTS HAVE faced is recognising which animal populations are natural and which are due to human influences. In order to make ancient human influences on biogeography and ecology more obvious, it is necessary to break down some of the artificial boundaries between what are seen as either natural or cultural processes. This can be done by devising new terms that acknowledge links between the two. Central to this is the concept of the 'ethno-tramp'. An ethno-tramp is a species of wild animal that, due to its economic value to humans, has its geographic range either deliberately or accidentally expanded. The Rusa Deer, Common Spotted Cuscus and Northern Common Cuscus are all classic examples of ethno-tramps. Their relationship with humans is referred to as 'macro-mutualistic' because, although individuals may be preyed upon by humans, the species as a whole has its range expanded or maintained and thus becomes more successful and secure, while humans gain a valuable food source.

A species that has a zoogeographically enigmatic distribution, but for which there is insufficient evidence to decide

whether that distribution is due to human or natural influences, is referred to as a zoogeographic 'phantom'. A clear example of a zoogeographic phantom is provided by the Sugar Glider, which may or may not have been introduced by humans from natural sources in Australia and New Guinea to some of its satellite island occurrences. At the extreme end of the scale is the 'camouflaged exotic', an introduced species whose exotic status goes unnoticed because its distribution appears natural.

Another poorly understood interaction is the role that humans may have played in 'creating' apparently new races or species of organism via human-induced founder effect or hybridisation associated with some translocation events. On Manus Island, for example, the sudden appearance of the bones of the Admiralty Cuscus (*Spilocuscus kraemeri*) in archaeological sites indicates it was probably introduced to this oceanic island about 1,000 to 2,000 years ago, yet the exact source population remains to be discovered. As no other cuscuses are known from the island, could it be that humans introduced a mixed cuscus stock (probably of spotted cuscus species or subspecies), which led to a hybrid population that is now recognised as a separate species?

For me the study of relations between humans and wild species has led to a profound loss of biological innocence, because so much that I once automatically thought of as natural, must now be examined with a suspicious eye. Such studies also make one realise that there is indeed a range of conditions between what we term 'wild' and 'domesticated' or 'pristine' and 'anthropogenic' (man-made). Humans, it would seem, are incorrigible meddlers who, long before the invention of genetic engineering, set in place vast biological experiments by manipulating species and playing around with zoogeography. This thought came to me after sitting under a Timorese palm tree like a tropical Isaac Newton and being hit on the head by a falling coconut. Looking up, I saw that it had been dislodged by one of those damn monkeys (a Long-tailed Macaque, *Macaca fascicularis*) that we humans had dragged across Wallace's Line. ■

White variant of the Common Spotted Cuscus in coastal rainforest on New Ireland, Papua New Guinea. This species was introduced to New Ireland from the St Matthias Group.

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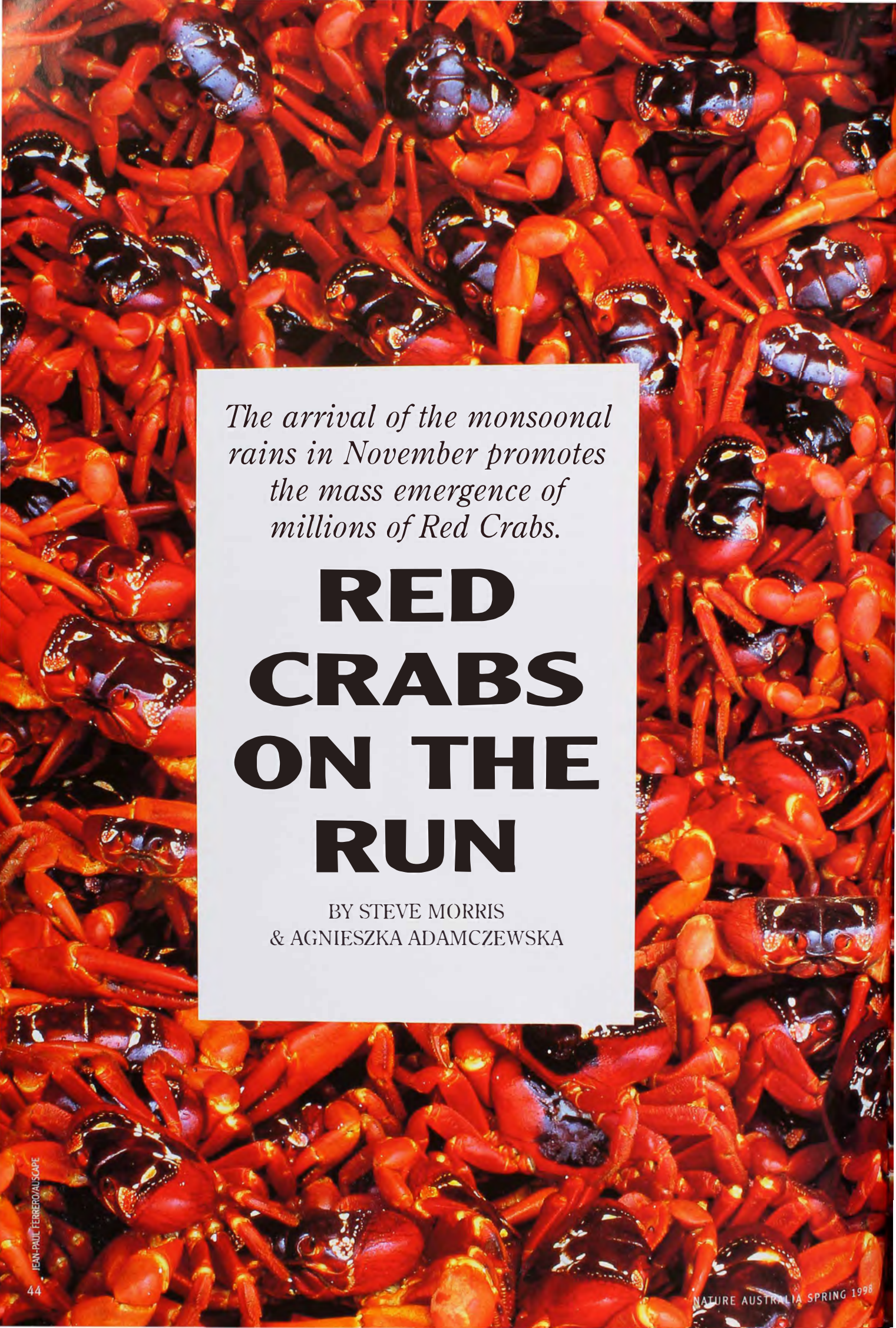


The arrival of the monsoonal rains in November promotes the mass emergence of millions of Red Crabs.

RED CRABS ON THE RUN

BY STEVE MORRIS
& AGNIESZKA ADAMCZEWSKA

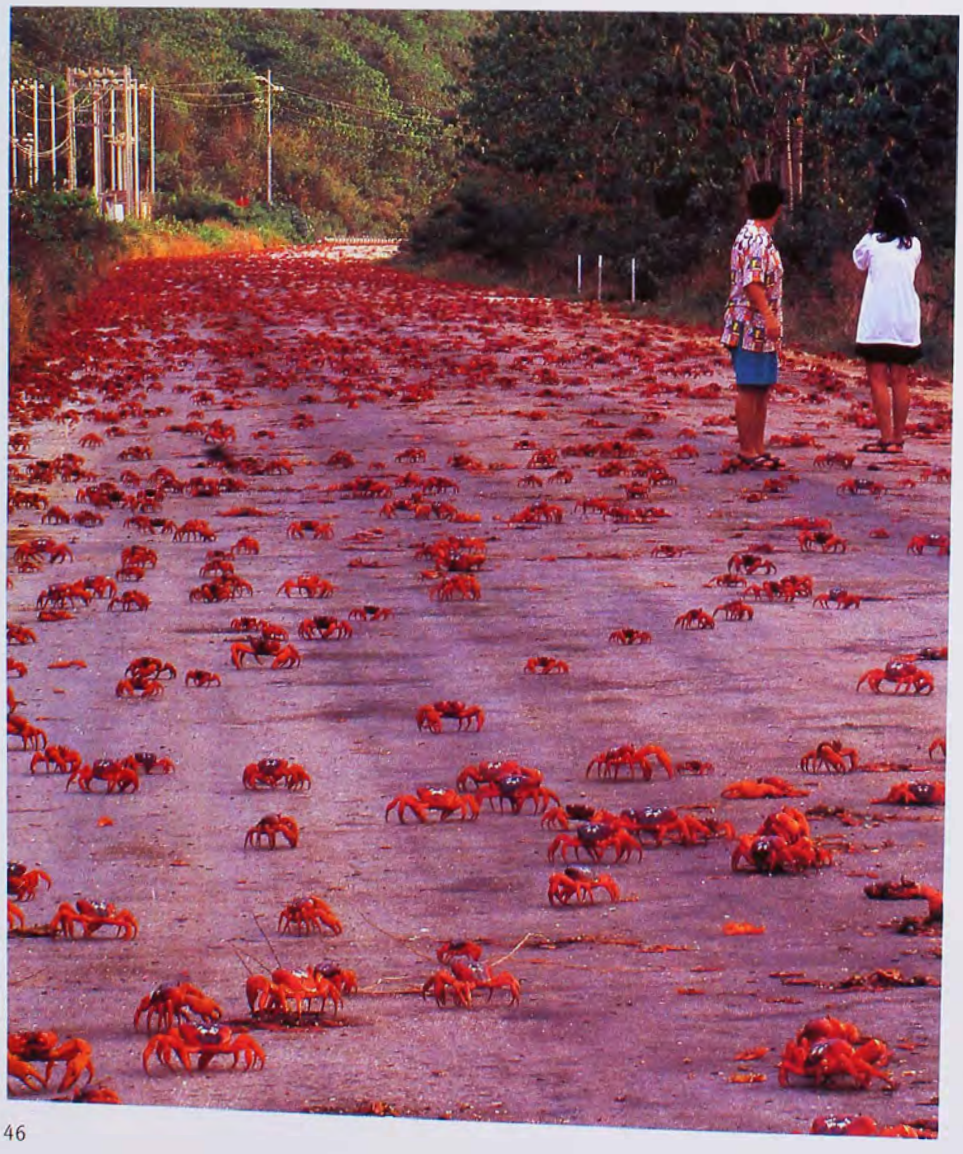
JEAN-PAUL FERRERO/AUSCAPE

REGULAR VISITS TO CHRISTMAS Island had convinced us that there was something quite special about the Red Crabs that live on this small Australian Territory in the Indian Ocean. The Red Crabs are renowned for the visual spectacle of their mass annual breeding migration to the sea. Come November each year, millions of Red Crabs make this annual dash to the coast. However, as we walked through the jungle in the first week of November in 1993, we were hard pressed to find a single Red Crab. Certainly the wilting rainforest trees and the thick carpet of dry leaves crackling underfoot seemed a less than ideal environment for crabs. So where were they, and why and how did they live in such conditions?

The Red Crab (*Gecarcoidea natalis*) is just one of 23 species of air-breathing crabs on Christmas Island. Most people think of crabs as aquatic creatures and are often surprised to learn that there are land-living crabs that will drown when submerged. All members of the Red Crab's family (Gecarcinidae) have a marine larval stage and must return to the ocean to release their spawn. After approximately three weeks, the larvae emerge from the ocean, metamorphosing into baby crabs on dry land. The fascination with Red Crabs is in the huge numbers and the distances they must travel. How do they survive the dry season kilometres away from the ocean? How do they 'know' when the time is right to spawn? Do they have specific destinations and know how to get there? While these seemed obvious questions, getting some of the answers was to require years of study. Complementary studies by Peter Greenaway (University of New South Wales) and Peter Green (Australian National University) have been invaluable. With half of our ten-year program complete, we can now describe the amazing migratory biology of the Red Crab, some of the limitations on their survival in the dry season and, importantly, realise how much we still do not understand.

THE CHANGES AND ADAPTATIONS THAT allow crabs to live on land are the central theme of our research. Land crabs have gills but most, including the Red Crabs, have evolved lungs for breathing. The gills of land crabs have a dual role. Not only do they supplement the lungs in gas exchange, they also play a similar role to our kidneys, reabsorbing needed salts from the urine and excreting nitrogenous waste.

Christmas Island is characterised by a wet and dry season. During the period May to November the island is influenced by the south-east trade winds and, while much appreciated by the yacht crews that pause at Christmas Island, the winds bring dry air. We soon found that we needed to work in the hour after dawn if we wanted to find crabs out and feeding, since relative humidity below 85 per cent restricted them to their burrows. The crabs use this early-morning opportunity to cram their burrows with leaves. This not only encourages a local humid environment but might provide



Monsoonal rains at the start of the wet season trigger Red Crabs to emerge from their burrows by the millions. The crabs keep the forest floor clean of fallen leaves, which are a major part of their diet. They also eat the majority of germinating seedlings.

Each year millions of Red Crabs undertake the migration to the sea to breed. Some of the important migration routes pass through the settled parts of Christmas Island. National Parks staff are implementing procedures to minimise the number of crabs killed by cars.

PHOTOS: JEAN-PAUL FERRERO/AUSCAPE

them with the necessary energy and salt stores for the rest of the day.

We now know that Red Crabs have a water permeability and loss rate similar to that of toads. The island is formed from uplifted coral limestone, which is highly porous, and we could find water only in root hollows and logs, hardly adequate it seems for millions of crabs. In the dry season we have seen Red Crabs drinking the morning dew and chewing on the damp interiors of hollow fallen logs. And, caught in the occasional local shower, we would rapidly be surrounded by thousands of thirsty Red Crabs, frantically transferring water to their mouths using the tips of their claws. Interestingly, persistent rain in the wet season caused Red Crabs to seek dry shelter; too much water it seems is also a problem.

The wet season characteristically begins in November and often delivers 150 millimetres of rain day after day. To us the perplexing aspect was how these crabs survived the dry season with low food and water, and at the same time prepared for the physical challenge of a long-distance breeding migration. Our observations were to reveal that, after months of low rainfall and little activity, the arrival of the monsoonal rains in November, within hours, promotes the mass emergence of millions of Red Crabs. With no obvious preparation or training, the Red Crabs embarked immediately on their trek.

The breeding activities of the Red Crabs are also apparently synchronised with the lunar cycle. Our initial understanding of the migration was largely based on anecdotal observations and the work of John Hicks (Parks Australia), and it appeared that Red Crabs require at least two weeks to complete their migration to the shore. There are few beaches on Christmas Island and the majority of the coast is made up of steep, undercut limestone cliffs that plunge directly into the Indian Ocean. Once close to the shore, the males construct burrows and attract females. Each female has carried a mass of about 100,000 eggs within her body cavity, from the plateau to the shore for fertilisation. We liken this to a person walking 30 kilometres with a seven-kilogram sack of potatoes. Mating generally occurs in the burrows and the males then return to the jungle. The females remain in the burrows for a further two weeks to lay their eggs and to incubate them under the abdomen. A few days prior to the new moon the females walk the short remaining distance to the cliffs and beaches to cast their spawn en

Caught in the occasional local shower, we would rapidly be surrounded by thousands of thirsty Red Crabs, frantically transferring water to their mouths using the tips of their claws.

masse into the ocean before sunrise. In some years the failure of the November rains has prompted the crabs to postpone the breeding migration into the December, or even January, lunar cycle. Thus we knew that the Red Crabs were slightly flexible in their behaviour.

WHEN WE FIRST ATTEMPTED TO resolve some of the mysteries of the Red Crab migration in November 1993, the rains came late. We resigned ourselves to a delayed December migration and a shortened field season. Meanwhile Holger Rumpff from Parks Australia assured us "They will go when the rains arrive, just you wait and see". To our surprise, with only three weeks to accomplish the complete migration, copulation, brooding and spawning, rains in late November caused millions of Red Crabs to boil from their burrows. Our plan was to mark and recapture thousands of the migrating Red Crabs. This involved spray-painting crabs different colours in various locations. However, after transforming only 500 Red Crabs from one site into luminous yellow crabs and 300 from another site a striking blue, it became clear that we would be unable to walk upright the following day . . . and we still had to attach radio-transmitters to selected individuals. Crabs from two locations in the central area of the island, the same 'blue site' and another one two kilometres away, were fitted with miniature transmitters. These could easily be accommodated on a 500-gram male crab, and in the forest gave a range of 200 metres.

PHOTOS: JEAN-PAUL FERRERO/AUSCAPE

RED CRAB
(*Gecarcoidea natalis*)

Classification
Family Gecarcinidae ('land crabs'), in which all species have marine larvae. There are 5 superfamilies of true crabs that contain air-breathing species.

Identification
Normally fire-engine red with black and white dorsal patterning. Occasional yellow/orange morphs occur. Becomes obviously sexually dimorphic at 200 g body weight. Males develop longer and larger chelae used in combat and burrow defence. Females have a broader bulbous body form to accommodate egg mass. Males up to 600 g and females 500 g.

Habitat and Distribution
Endemic to the mature and secondary regrowth rainforest of Christmas island, Indian Ocean. Low numbers on North Keeling Island, possibly from larvae drifted from Christmas Island.

Reproduction
Mass breeding migration of population initiated by seasonal rain in Nov.–Dec. Copulation and egg brooding occur in breeding areas adjacent to shore. Laying and casting of eggs into the ocean synchronised to lunar cycle. Females produce up to 100,000 eggs that hatch on contact with sea water. A 3-week larval phase before juvenile crabs return to forest.

Diet
Mainly partially decomposed deciduous leaves, but some fruits, blooms, as well as fallen comrades and other invertebrates.

Status
Not endangered but severely impacted during breeding season by mining activity and road usage. Estimated road kills vary between 1 and 10% of population. Numbers estimated previously at 120 million now revised to 50–80 million adult crabs. Christmas Island National Park now encompasses 65% of the island.

While sections of Christmas Island are crossed by four-wheel-drive and walking tracks (a legacy of phosphate mining and water-searching activities), these it transpires are not used by the Red Crabs. Following their radio-transmitter signals led to our first encounter with the real Christmas Island. The interior forest floor on the central plateau was an unbelievable chaos of vine-festooned, razor-sharp coral rubble and pinnacles ranging in size from footballs to houses, interspersed with sinkholes to trap the unwary. Movement was extremely slow and tedious. We experienced first-hand just how difficult it was to navigate through this gloomy jungle environment when we discovered our compass was still in the four-wheel-drive! Amazingly, through the interior chaos of the jungle, the Red Crabs chose and navigated migratory paths that were almost perfect straight lines to the coast. The crabs from one of the sites with radio-transmitters walked over four kilometres (as the crow flies) in five to six days. Taking into account the terrain on Christmas Island, we suspect that the crabs probably walked nearly five kilometres in as many days, much of it in a vertical direction.

The next opportunity we had to study migrating Red Crabs was in November 1995. Learning from our previous experiences, we took along volunteers to assist with the marking of over 7,000 crabs from nine different locations. In contrast to the rushed migration in 1993, in 1995 the monsoonal rains arrived early and, to our surprise, the crabs did not wait for the appropriate phase of the lunar cycle but instead took a leisurely stroll, again in uncanny straight lines, to the shore over three weeks. With two seasons of data, patterns in the migratory behaviour of Red Crabs were emerging but, as is often the case in such studies, new questions outnumbered our answers.

One unexpected result from our navigation data was that many of the crabs do not necessarily walk to the nearest coast to mate and spawn but head for a more distant, preferred destination. A disproportionate number head for the

Red Crabs undertake their migration during torrential rain. If the rainfall is excessive, the crabs must seek shelter since they are ill-equipped to deal with immersion in fresh water.

PHOTOS: JEAN-PAUL FERRERO/AUSCAPE

When Red Crabs arrive at the shore, they must be careful to maintain their grip on the rocks to prevent being washed into the ocean. These are land crabs and will drown under water.

northern coast of the island, perhaps reflecting the calmer conditions and possibly previous breeding success on that part of the shoreline. Adults may simply return to the part of the coast where they first came ashore. We also discovered that all the Red Crabs from any one area on the island migrate together to a similar location on the shore. Furthermore, the same routes are used in successive years.

The next important finding was that, while the start of the migration is clearly dependent on the start of the wet season, it need not be synchronised with the lunar cycle. Rather, it seems that fertilisation of the eggs must occur at a crucial time since it is the date on which the eggs are cast into the ocean that is fixed to a particular lunar phase (the pre-dawn high tide near the last quarter of the moon). Additionally, the crabs seem to know how far they have to travel and how long it will take them to get there, since in the 'early' 1995 migration they paused for as long as four days in the middle of their journey to the coast. We still do not know what navigational mechanisms are used by the Red Crabs during the migration. The most likely possibilities include magnetic orientation or tracing their own steps back to the place where they came ashore as larvae, a sort of memory trick. We have not ruled out the use of polarised light as a navigational aid since the Red Crabs walk only during daylight.

FROM THE RADIO-TRACKING AND THE recapture of colour-coded crabs we had a fairly good idea about the ecology of the migration; that is when, where and

The crabs seem to know how far they have to travel and how long it will take them to get there.

pick of the males (if the crab is female), or whether to move more slowly, perhaps pausing to feed, thereby arriving at the shore in a fitter condition for the travails of breeding. There were so many questions.

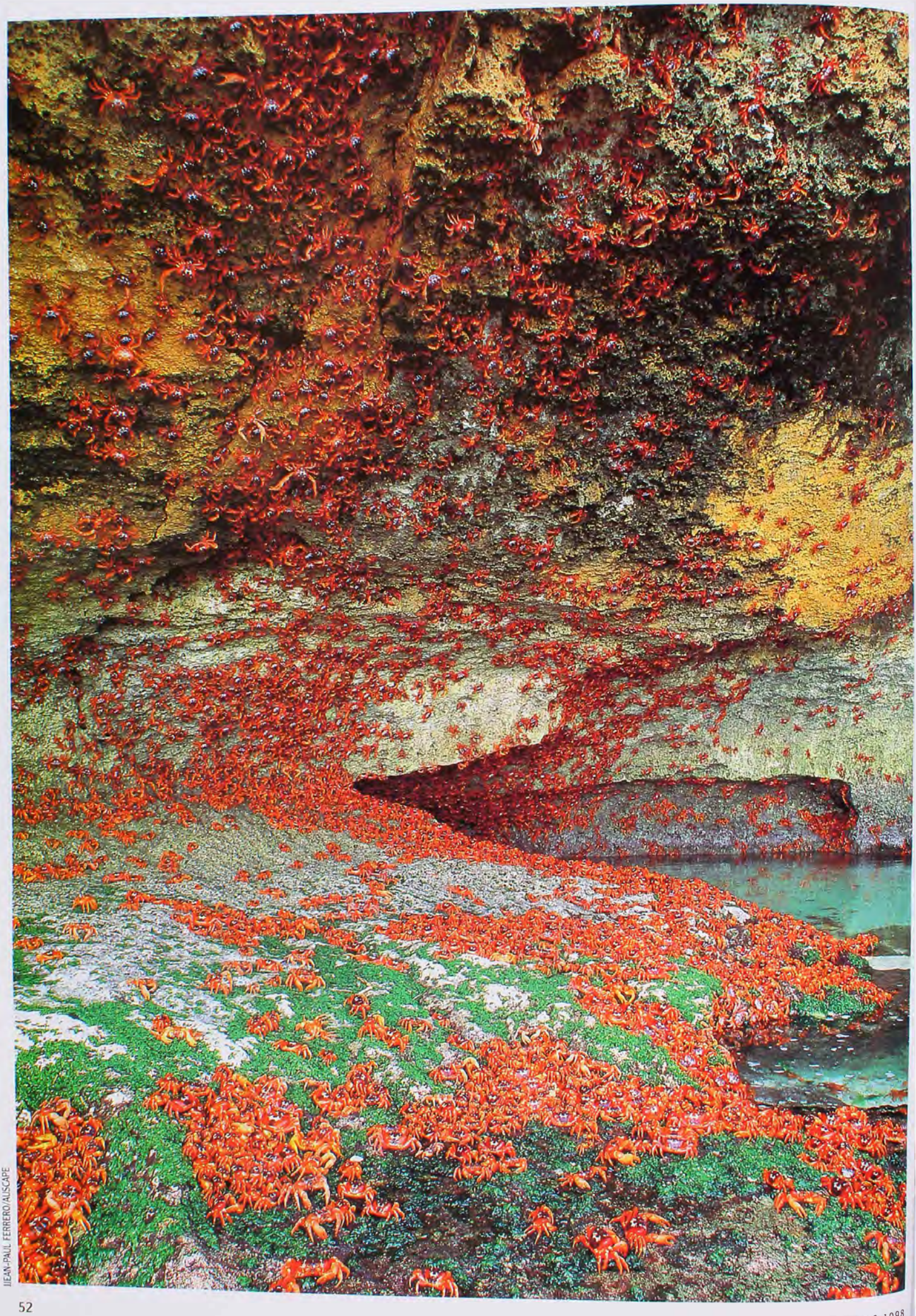
During our field seasons we also collected blood and tissue samples from crabs during various stages of the migration to determine how stressful the migratory activities might be for them. By measuring oxygen and carbon dioxide in the blood, we could determine how well the lungs and gills functioned in gas exchange, while the tissue samples were used to monitor the amount of energy stores.

During the migratory activities, the lungs of Red Crabs were very important and, significantly, the crabs did not experience any problems in obtaining oxygen from their environment. So, if the crabs possess the capacity to walk to the ocean in five days at a speed that causes no obvious stress, why didn't they do this during the 1995 migration? The answer to this question became apparent when we examined the changes in their energy stores during the course of migration and breeding activities.

Red Crabs have substantial energy stores but don't seem to use them very

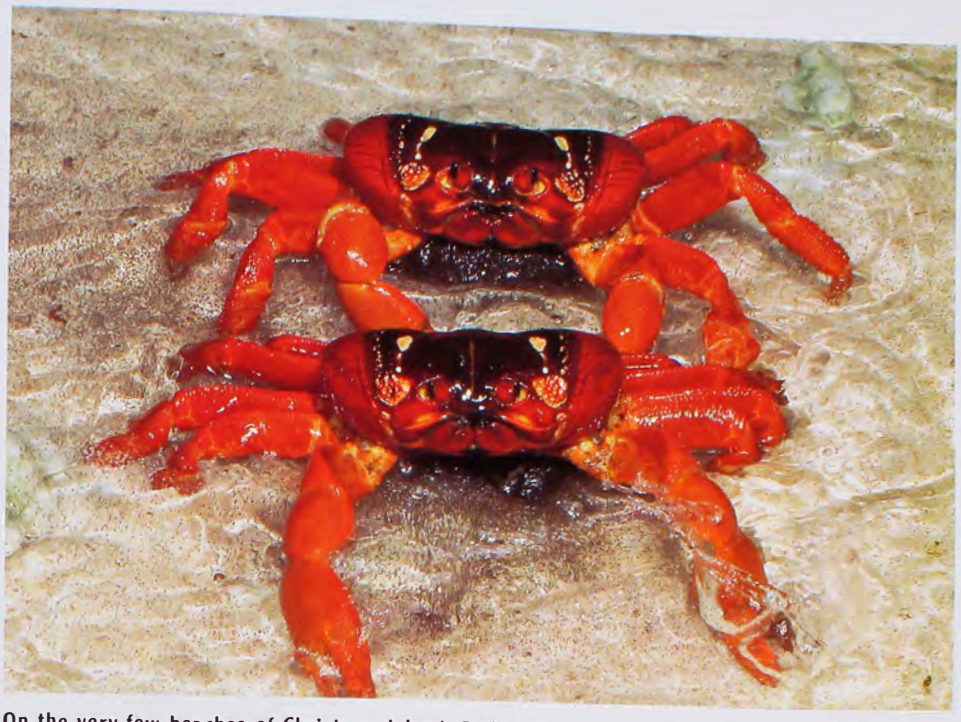
On the terraces above the cliffs, male crabs construct and fight over burrows in which they hope to attract females for mating.

why. However, exactly how these normally quiescent crabs sustained and accomplished this feat of endurance remained unexplained. We therefore turned our attention to the physiology of these crabs. What were the differences between the crabs in the rushed 1993 migration and the casual 1995 migration? If the crabs are capable of travelling to the ocean in only five days, why did they take so long in 1995? Did the crabs have to rely on fuel stores, such as fat, during the migration? If fuel stores were important, how did crabs build them up during the dry season? Alternatively, did they have to pause and eat on the way? For the Red Crabs this is an important dilemma—whether to be first on the scene near the coast and thus get to dig a burrow in a prime location (if the crab is male) or have first



JEAN-PAUL FERRERO/AUSCAPE

The morning after casting their eggs into the sea, female Red Crabs embark on a massed migration back into the forest where they will live for 11 months before their next breeding season.



JEAN-PAUL FERRERO/AUSCAPE

On the very few beaches of Christmas Island, Red Crabs can enter the water and shed their eggs directly into the surf. Female crabs carrying eggs under their abdomen stand at the edge of the surf zone and cast their eggs into a retreating wave.

much during the migration. The fraction of the energy stores actually used by Red Crabs is enough to support 12 hours of activity. Since the crabs must spend a minimum of five days walking to reach the coast, two to three days for mating, and the females must spend two weeks incubating the eggs, the crabs have to eat to support their breeding activities. The male crabs expend large amounts of energy digging and fighting over burrows. Our measurements clearly showed that these fights often required an extended recovery period. Some never did recover since the forest floor was punctuated by severed claws, limbs and the occasional carcass.

Condensing the entire population of tens of millions of Red Crabs onto a relatively narrow strip of shore for an extended period of time rapidly depletes the locally available food supply of fallen leaves, flowers and berries. By the time the male crabs desert their mates in the burrows, the forest floor on the fringe of the island is completely cleared. It seems that the extended duration of seaward migration in 1995 was a mechanism to minimise the amount of time spent on the narrow area above the cliffs, and to maximise foraging en route to prevent mass starvation.

An undeniable wonder of the natural world, the mass migration of the Red Crab brings this animal into inevitable collision with human activities. Prime habitat has been lost to phosphate mining. Huge numbers of crabs die in road kills as they trudge through settled areas, unfortunately built in the middle of one of their prime migration routes. As we progressively understand the needs, objectives and abilities of these crabs, it will be possible to refine management practices to minimise crab carnage and to preserve the spectacle of the annual migration for the fledgling ecotourist industry on Christmas Island. ■

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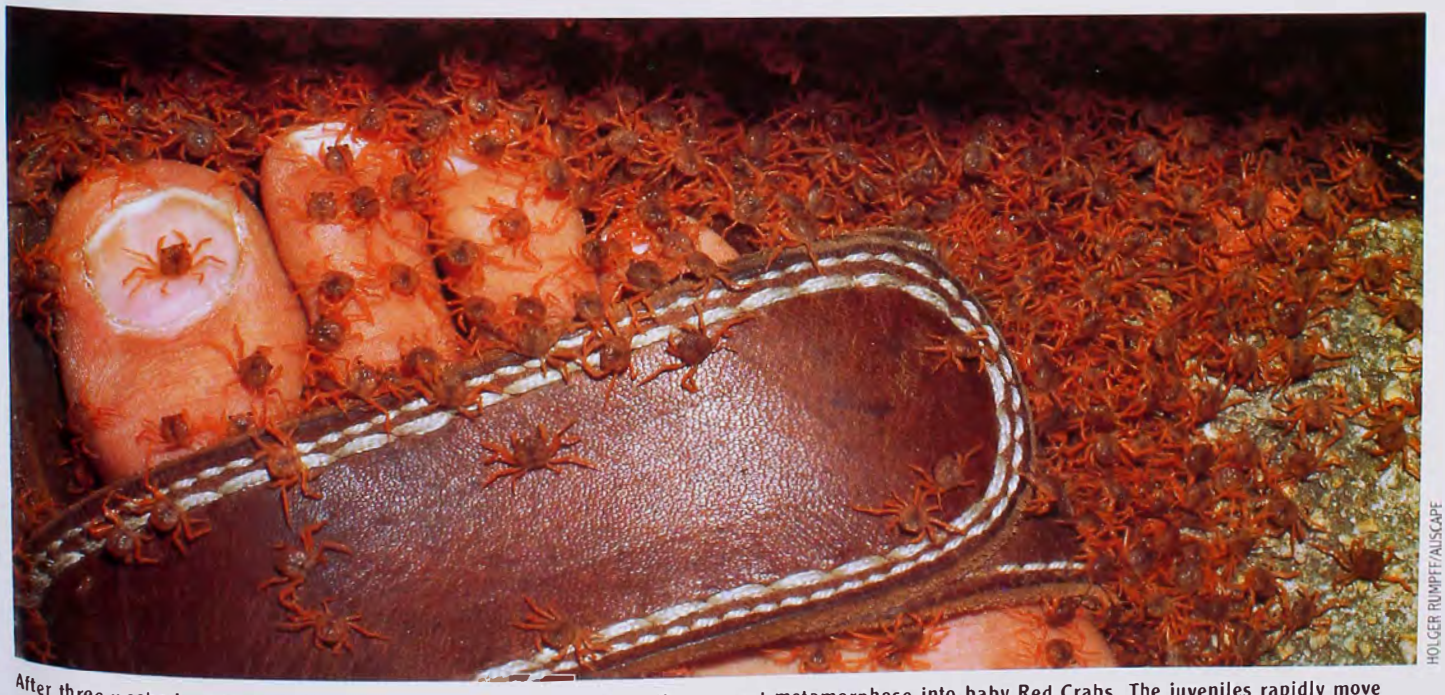

HOLGER RUMPFF/AUSCAPE

After three weeks in the ocean, the final-stage larvae emerge from the sea and metamorphose into baby Red Crabs. The juveniles rapidly move into the forest and disappear.

COURTESY PATRINA BIRT

The proximity of flying-foxes to people has resulted in mixed reactions.

URBAN FLYING-FOXES

BY PATRINA BIRT, NICKI MARKUS, LINDA COLLINS & LES HALL

"THEY ARE NOISY, SMELLY, DIRTY, wreck all the trees, and crap in our swimming pool. And at any rate, I was here before they were." These were the irate comments of a house owner when a mob of Little Red Flying-foxes (*Pteropus scapulatus*) recently set up camp in mangroves on the edge of suburban Gladstone (Queensland).

The flying-foxes, many of which were either pregnant or carrying young, numbered around 500,000 and stayed on the edge of suburbia for about two months. The locals had tolerated the small number of Black Flying-foxes (*Pteropus alecto*), which were regular visitors to Gladstone over the years, but this huge influx of bats was simply too much for some people to bear.

The explanation for such a large camp site close to suburbia seemed simple: flowering of eucalypts was late inland, where the Little Reds were usually found, but exceptionally good around the Gladstone region, and the flying-foxes moved accordingly. While many of the residents accepted that flying-foxes played an important role in forest ecosystems and didn't want them harmed in any way, most wanted the flying-foxes shifted somewhere else.

THE LOCATION OF FLYING-FOX CAMPS IN or on the edge of suburbia is becoming a common occurrence. In addition, urban flying-fox camps that were traditionally occupied for only several months of the year or by small numbers of flying-foxes, are now often occupied permanently or have increased in size.

In Queensland, Little Reds have come to town in Coen, Tolga, Chillagoe, Mount Isa, Dalby, Gladstone, Hervey Bay, Esk and to many areas of Brisbane. Most join camp sites that are already occupied by Black or Grey-headed (*Pteropus poliocephalus*) Flying-foxes. One wonders why these bats

PAVEL GERMAN

Above: unlike other flying-foxes, Little Red Flying-foxes roost closely together in the trees at their camp. Often so many flying-foxes roosting on one limb results in quite large branches breaking under their combined weight. Left: the distribution of Grey-headed Flying-foxes is contracting southwards. Radio-collared individuals have been recorded flying from Lismore to Nowra in search of food.

H. & J. BESTE/LOCHMAN TRANSPARENCIES

The Spectacled Flying-fox is Australia's most endangered mainland flying-fox. It pollinates and disperses seeds from rainforest trees in the wet tropics of northern Queensland.

choose such urban situations when, as in the case of Coen, the surrounding country has what appears to be unlimited habitat potential. The explanation used at Gladstone—that local flowering was good—does not seem to apply to all urban flying-foxes.

In the continuous suburban area comprising Brisbane, Ipswich and Logan there are nine permanent flying-fox camps. These are nearly always occupied by Black or Grey-headed Flying-foxes, but in some, like the camp at Burpengary, flying-foxes disappear for short periods of time following poor local flowering or human disturbance. Little Reds come and roost in at least five of these Brisbane camps during the summer months each year.

In Victoria, a similar phenomenon has also occurred. Prior to 1981, there were few records of Grey-headed Flying-foxes in Melbourne. Now there is a Grey-headed Flying-fox colony in the Royal Botanical Gardens. It became a permanent camp site only in 1985.

In New South Wales the urbanisation

AUSTRALIAN MAINLAND FLYING-FOXES

Family Chiroptera, subfamily Megachiroptera, genus *Pteropus* (flying-foxes).

Species	Identification	Habitat	Distribution	Breeding Season	Status
Black Flying-fox (*P. alecto*)	Black head and body with red–brown fur at back of neck. No fur on lower legs. Head–body length 24–26 cm.	Coastal forests, mangroves, swamps and rainforest.	Coastal northern Australia.	Oct.–Dec.	Vulnerable in NSW, not elsewhere.
Grey-headed Flying-fox (*P. poliocephalus*)	Grey head and body with a collar of orange fur around neck. Fur on legs extends right down to the toes. Head–body length 23–29 cm.	Eucalypt forest, swamps and rainforest.	Coastal Vic. to Maryborough, Qld.	Oct.–Dec.	Nationally endangered.
Little Red Flying-fox (*P. scapulatus*)	Reddish brown fur. Greyish fur on head. Head–body length 19–24 cm.	All forest types.	Widespread but not in arid interior.	Apr.–Jun.	Not endangered anywhere.
Spectacled Flying-fox (*P. conspicillatus*)	Black with pale yellow rings around eyes and yellow on back of neck. Head–body length 22–24 cm.	Rainforest and coastal swamps.	Coastal and rainforests of far northern Qld.	Oct.–Dec.	Nationally endangered.

of flying-fox camps appears to be the result of a somewhat different process. The gradual urban sprawl into rural areas has resulted in camps that were once located in patches of scrub now being close to houses. Flying-fox camps that have had the town come to them include those at Oxley Cove, Dallas Park, Ocean Shores, Ewingsdale, Curry Park, Ballina, Kyogle, Maclean, Bellingen, Arakoon, Wingham Brush, Patterson, Matcham, Kur-ing-gai, Cabramatta and Menangle.

However, as early as the 1930s, the effects of increasing human settlement on the traditional roosting patterns of Black and Grey-headed Flying-foxes were becoming apparent. Where rainforests and eucalypt forests were cleared for agricultural land, flying-foxes were forced to adapt to the loss of their traditional food resources and abandon old roost sites. Increasingly, this has led to a movement of flying-foxes to urban and coastal areas where food resources are more reliable.

As a result of regular watering regimes employed in many gardens, parks and orchards, towns in general are considerably less affected by drought than native forests. Regular watering ensures a higher nectar production in the flying-foxes' main diet of eucalypt blossoms, a food source that is notoriously unreliable in the wild. And while the bats prefer a diet of native blossoms and fruits to introduced varieties, seasonal fluctuations in native food supplies can be extreme. In times of desperation, any food source will be utilised, especially cultivated fruits such as stone fruit, bananas, pawpaws, lychees and mangoes.

Apart from improved food resources that the towns may have to offer, one practical reason for an urban location of a camp site is that it would be easy to find. Unlike the vast stretches of forest, where specific roost sites may be hard to locate on a dark night, townships offer buildings and lights by which these visually orienting animals are perhaps better able to navigate. This may account particularly for colonies located near parks or main roads. Lights have been found to attract curious flying-foxes even when implemented as bat repellents in orchards.

A somewhat ironic advantage of the bats' trend to urbanisation is the protection towns offer from the shooting expeditions of enraged fruit-growers and local residents. Although culling of flying-foxes has been shown to be highly ineffective as a means of population control, this method of orchard protection has a long history. Many orchardists are unwilling or unable to implement netting to protect their trees, and tend to ignore the equally destructive impact of fruit-eating birds. Daytime shooting forays into flying-fox camps usually have little impact on fruit loss

CLANCY HALL

Chris Holman shares her yard with a large colony of Grey-headed Flying-foxes at Woodend, Queensland. Both Chris and the flying-foxes have adapted to living in close proximity.

back at the orchard, and often they only result in a large number of injured bats. Fortunately for the bats, fruit-growers (frequently without culling licences) are more reluctant to let off a round of bullets in the vicinity of settlements, which thus offers a degree of protection for the roosting flying-foxes.

THE PROXIMITY OF FLYING-FOXES TO people has resulted in mixed reactions. Complaints about the flying-foxes' strong odour, their vocal interactions within the colony, their potential to spread disease and to reduce the value of residential real estate, are common. Not infrequently these complaints lead to political disputes between bat-supporters wanting to protect a colony and non-supporters demanding the colony be shifted.

Almost all attempts at moving flying-fox camps have been failures. This is because they are done with little appreciation of flying-fox biology and the intelligence of these animals. Removal of flying-fox camps must never be attempted when females are heavily pregnant or lactating and carrying young, and only done if the animals have an appropriate alternate site to go to. It would appear that, given the decreasing numbers of flying-foxes and the reduction of suitable camp site locations, every effort should be made to preserve and manage flying-fox camps and any notion of their removal discouraged.

While there is some merit in the concern about exposure to possible disease-causing organisms, this issue has been scandalised and exaggerated by the media in the face of two recently discovered viruses in bats (see box). Where responsible advice about direct contact

Left: positive media exposure and orphaned flying-fox fostering programs have helped to dispel the myth that flying-foxes, like this Grey-headed Flying-fox, are frightening or dangerous. However, there is still plenty that can and should be done if these intelligent animals are to get the respect that they deserve. Right: the Little Red Flying-fox is the smallest and most nomadic of all the mainland flying-foxes. It feeds almost exclusively on nectar from *Eucalyptus* and *Melaleuca* flowers.

G. & M. HOYE/NATURE FOCUS

with bats was urgently needed, panic-mongering through inaccurate media coverage resulted in the further alienation of flying-foxes from humans.

Fortunately, all is not lost. Media exposure brings along with it the potential for a more positive attitude to our flying cousins. In the past, the involuntary confrontation with flying-foxes in townships has served to foster prejudice about these unfamiliar animals. However, as orphaned flying-fox fostering programs have shown, a little education can go a long way.

Flying-foxes are thought to be extremely important in maintaining the health of our forests by cross-pollinating and dispersing the seeds of a large number of the native trees on which they feed during the night. More than ever, public education about the irreplaceable role of flying-foxes in our forests' ecology is needed to ensure the continued survival of forests and bats. Accurate information about the disease status and minimising the negative media coverage of flying-foxes will serve to reduce unnecessary panic among local residents. In addition, protected exposure to flying-foxes in zoos and school education programs would dispel any misconceptions of flying-foxes as 'frightening blood-suckers' and encourage the respect that these ecologically vital and highly intelligent animals deserve. ■

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Patrina Birt and Nicki Markus are studying the ecology and behaviour of flying-foxes for their PhDs at the University of Queensland. Linda Collins has been involved in caring for flying-foxes for some time and founded the Flying Fox Information and Conservation Network. Dr Les Hall is a Senior Lecturer in the School of Veterinary Sciences, University of Queensland.

KATHIE ATKINSON

NEW FLYING-FOX VIRUSES

In 1994 there were two separate outbreaks in Queensland of a previously unknown disease in humans and horses. In Brisbane, this led to the death of 14 horses and one human, while in Mackay two horses and one human died. The deaths were caused by a virus belonging to the family Paramyxoviridae. The virus was called equine morbilli virus (EMV).

Following extensive searching (5,000 blood samples from 46 species of wildlife), antibodies to EMV were found only in the four mainland species of flying-foxes. In September 1996, a virus was isolated from the uterine fluid of an apparently healthy flying-fox. This isolate and subsequent isolates have been shown to be virtually indistinguishable from EMV. The virus, called bat paramyxovirus (BPV), has been isolated from flying-fox blood, kidney, uterine fluids and foetal tissues.

In May 1996, while searching for signs of EMV and BPV, another new virus, a lyssavirus, was found in a flying-fox. The virus, which is very similar to the rabies virus, is called Australian bat lyssavirus (ABL) and has since been found in two other species of flying-fox and one species of insectivorous bat. Infection with ABL has resulted in one human fatality.

The human deaths from EMV appear to have been contracted from EMV-infected horses. None of over 130 flying-fox carers and researchers had antibodies to EMV, suggesting that flying-foxes do not pose a threat to humans for EMV or BPV. Researchers have had little experience with the bat lyssavirus, but it is likely that infection by ABL would be as serious as rabies. As a precaution, health authorities recommend that handling of flying-foxes should be done by experienced, rabies-vaccinated people using appropriate protective wear.

A team from the Queensland Department of Primary Industries has been responsible for much of our knowledge about these viruses. How new are these viruses? Why have they just appeared? Are they found in species other than flying-foxes? How do they spread between species? These are just some of the questions being addressed by the team in their continuing studies on these mysterious viruses.

H.MAURER/UNIVERSITY OF INSBRUCK

ICE MAN

In the opinion of many, including myself, Ötzi is the most important archaeological find of the latter part of the 20th century.

BY THOMAS H. LOY

ABOUT 5,300 YEARS AGO A mature and experienced hunter attempted a dangerous route across one of the highest passes in the Alps. Exhausted, he sought shelter in the lee of a rock outcrop. He stacked his bow, arrow-quiver, backpack frame and copper-bladed axe neatly against the rocks, slumped over a large boulder, and eventually died from exposure.

Over the years snow covered him and turned to ice. Here he lay frozen until 1991 when a sirocco wind blew dust from Africa into the central Alps, resulting in a rapid melting of glacial ice and exposure of his skull. Following a series of attempts to free him from the ice, he was taken to the University of Innsbruck in Austria, and most recently to the Museum of Archaeology in Bolzano, Italy, where he is kept in near-glacial conditions to avoid further degradation of his frozen, mummified body.

In the opinion of many, including myself, Ötzi (named after the Ötztaler Mountains in which he was discovered) is the most important archaeological find of the latter part of the 20th century. The opening of Tutankhamun's tomb and discovery of a royal mummy and its associated treasures caused a sensation in the early part of the century. But most mummies, either intentionally prepared as in Egypt, or simply bodies placed in cold, dry or peat bog conditions, have seldom become internationally famous.

What makes Ötzi so special? He is the oldest mummified human so far discovered; but that in itself is probably only of passing importance. More significant is the fact that Ötzi's tools were never buried in the soil and so are vitally important for the study of the first steps in the preservation of ancient organic tool residues. Also, because he was found with his entire tool kit and fully dressed in his 'work' clothing, we now have a complete example of a Neolithic hunter engaged in his normal occupation. In contrast, most other human mummies appear to have resulted from

KENNETH GARRETT

Above: Ötzi is kept in a special environment that simulates the conditions of his burial in the ice. The air is filtered to prevent fungal and bacterial growth. When he died he slumped across a boulder with his left arm across his chest. Right: The skin quiver is attached to a grooved and perforated stick, which acts as a stiffener. Only two arrows in the quiver were actually functional. The other arrowshafts were in various stages of manufacture. Also found in the quiver were broken arrowheads, a bowstring and a long thin curved piece of antler that was used during the skinning process.

Forensic science provides accurate methods for facial reconstruction. Shown below is the reconstruction in progress, the pegs marking specific reference points, and above is Ötzi as he probably looked about the time of his death 5,300 years ago. His is the face of the European past.

ritual burial, and so the goods and clothing found with them may not be representative of their daily life.

No similar human mummy has been reported from Australia. To reconstruct Australian prehistoric hunting practices and the tools associated with food-gathering, archaeologists have drawn largely on the 'snapshots' of Aboriginal societies provided by living Aboriginal elders, ethnographers and early European settlers. Ötzi and his tools, however, may be used as an ancient, comparative 'baseline' from which to characterise the task associations of the more usually scattered and mixed tools found at most archaeological sites. Until Ötzi's discovery, the singular lack of information about individual tool kits carried by prehistoric hunters in Europe or in Australia, and the relationships between the tools in the kit, have prevented archaeological reconstruction at a 'personal', as opposed to the broader 'cultural', level.

During the past 14 years I have developed methods for analysing traces of prehistoric organic residue materials, such as starch, blood, hair, feathers and woody tissue (see *Nature Aust.** Spring 1990) and ancient DNA. These methods, which include optical microscopy and biomolecular and genetic analysis of proteins and DNA, are used to identify the type of residue and the species of origin of blood residues. Modern experiments have been used to develop and test these techniques, and burial effects have been simulated to see how (or if) they alter the use-patterns and whether or not they damage the molecular structure of organic residues. Ötzi's tool kit thus, in a sense, provides an experiment that has lasted 5,300 years.

As part of an international team studying Ötzi, I spent two weeks in the Romano-German Central Museum, in Mainz, Germany, where the artefacts are being studied and conserved. I microscopically examined most of the remains associated with Ötzi, chemically screening many of the tools for the presence of blood, and collecting samples of residues for biomolecular analysis in my laboratory back home. Cellulose acetate peels were also made of the tool edges. Their wear patterns are being studied with my colleague Richard Fullagar from the Australian Museum.

The results show that Ötzi made and maintained his tools carefully, and that some of the stone tools were used to make or modify other tools in the kit. Comparison of edge-damage patterns on

PHOTOS: KENNETH GARRETT

*Previously *ANH*

The copper axe blade was seated in a groove in the yew-wood handle. The hunter would have periodically removed the rawhide lashing, soaked it in water and then stretched it while rewrapping the blade in place. Rawhide shrinks as it dries and would have bound the blade tightly.

the axe blade with the finishing marks on his bow indicates that Ötzi made his own yew-wood longbow. Both arrows were broken (he missed his target) and he was in the process of using a small flake to dismantle them and make one temporarily functional arrow. The small flake was also used to prepare feathers for the arrow fletching.

Residue analysis reveals that many of his tools were multipurpose. One tool that was initially thought, on the basis of wear-pattern analysis alone, to have been used only as a stone sickle-blade for cutting grass, was also found to have cleaned meat and collagen from bone, carved dry bone, and to have scraped skins. Most importantly, the residues were found to be perfectly preserved indicating that, by the time they were frozen, the necessary biochemical reactions had occurred to ensure their long-term preservation. The structural features and the preservation of residues on Ötzi's tools resemble in all aspects those I have studied on buried prehistoric tools from Australia and elsewhere, some in excess of 100,000 years old. This goes to show that a residue

The flint-tipped and wooden-handled knife, together with its grass scabbard, show a long history of use. The handle of split wood, bound tightly around the flint blade, is impregnated with blood proteins. It is interesting to note that, if the flint blade were found in an archaeological site where wood is rarely preserved, it would undoubtedly be classified as an arrowhead.

PHOTOS: KENNETH GARRETT

buried in soil is as stable and long-lasting as one frozen in ice, confirming my understanding of the biomolecular processes underlying the preservation of residues.

Although the chances of finding an Ice Man in Australia are, of course, zero given our climate, it may be that one day a similar mummified person will be found. (A 5,000-year-old mummified Thylacine was retrieved from one of the underground caves in the Nullarbor.) Until that day, however, Ötzi will remain a unique archaeological discovery, and one that is relevant not only to the study of archaeology in Europe, but also here in Australia and elsewhere. ■

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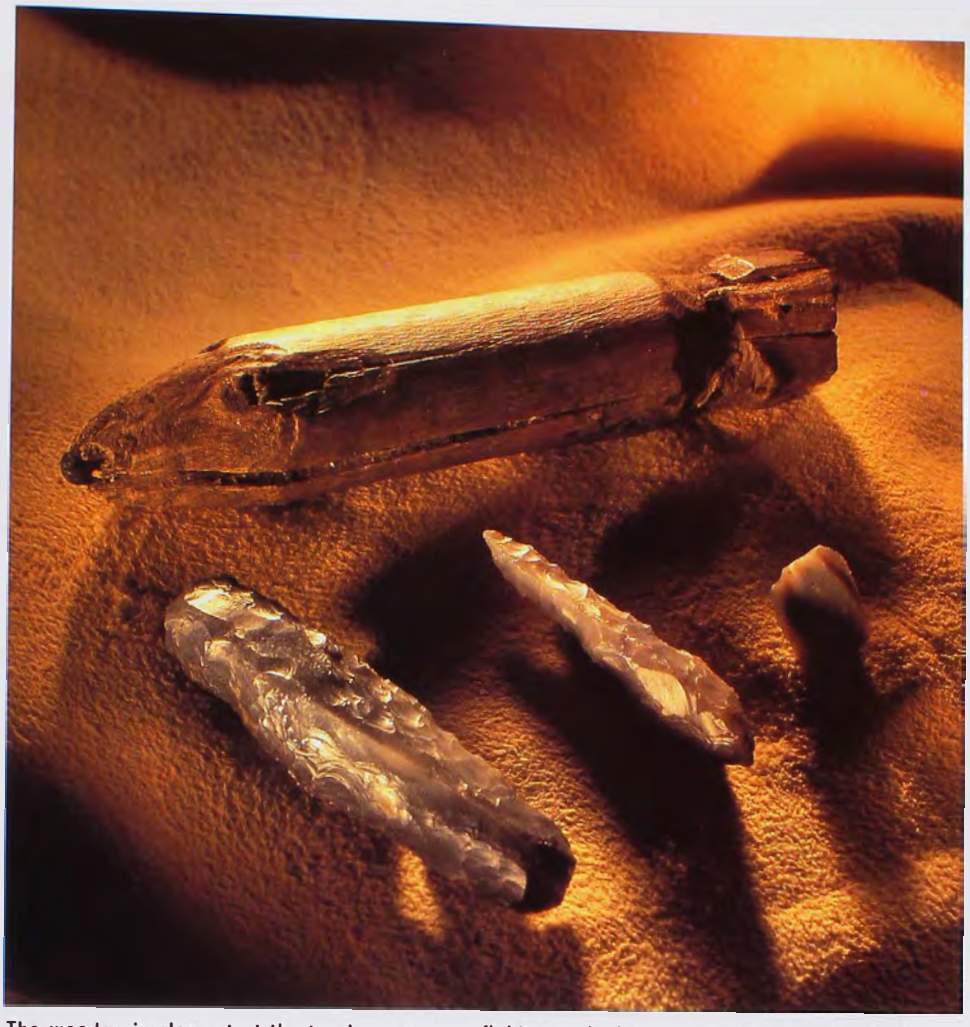
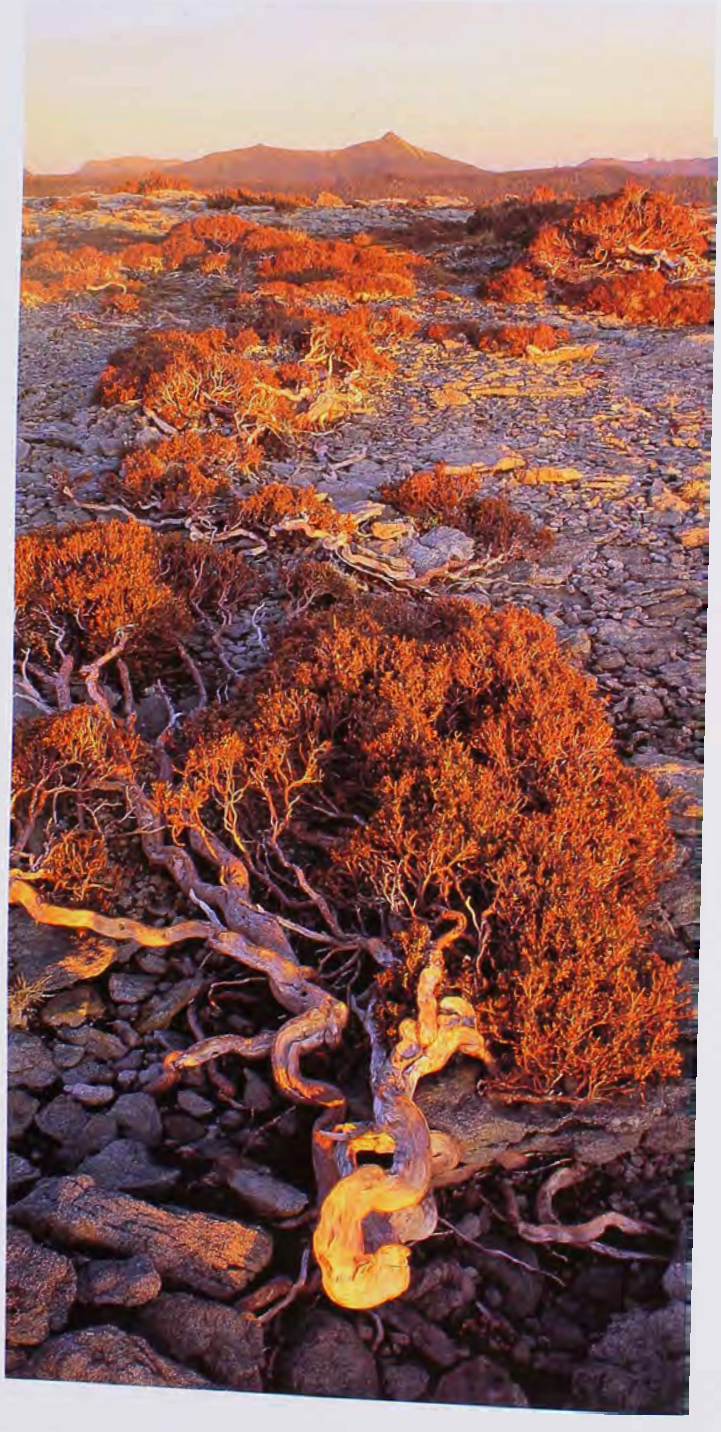
Dr Thomas H. Loy is a Principal Research Fellow, cross-appointed between the Department of Anthropology and Sociology and the Centre for Molecular Biology and Biotechnology at the University of Queensland. He specialises in the analysis of prehistoric organic tool-use residues and the analysis of ancient DNA. He also has the distinction of being the only non-fictitious scientist mentioned in Michael Crichton's best-seller Jurassic Park.

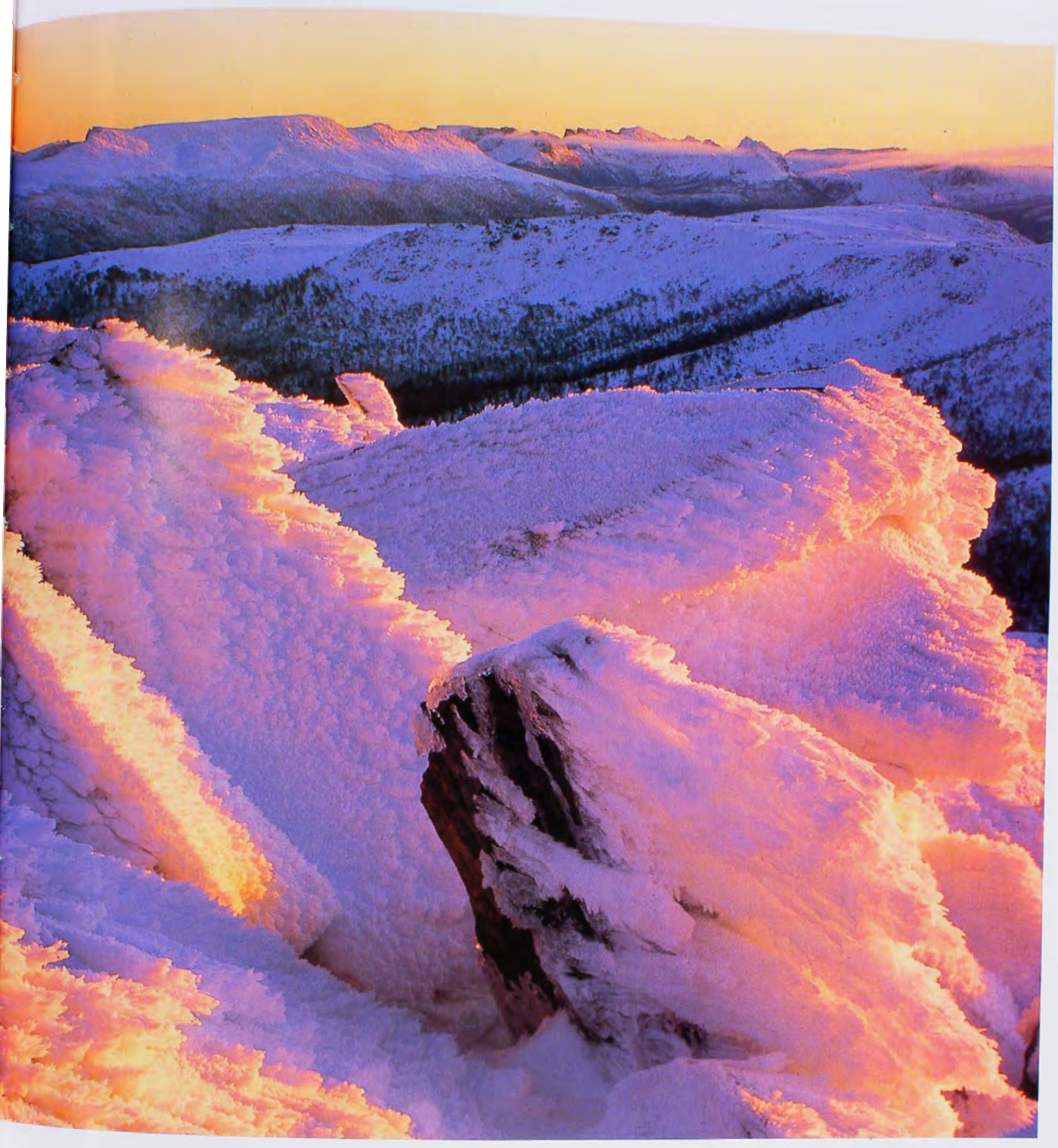


The wooden implement at the top is a pressure-flaking tool with an antler tip. Careful shaping of flint edges requires the use of antler, for it is relatively hard but not brittle. The three flint implements shown are (from left to right): a classic 'scraper', which residue analysis reveals was used for several purposes, including cutting grass, removing tendons from fresh bone, smoothing and shaping bone and antler, and scraping skin; a combination drill and woodworking tool, which was used to make the holes and groove in the wooden stiffener of the quiver; and a small flake used for trimming the feathers on the arrows and for removing the pitch and string lashings that held the arrowheads to the shafts.

Part of the grass cape worn by Ötzi. It provided warmth and protection from rain and snow.

P H O T O A R T

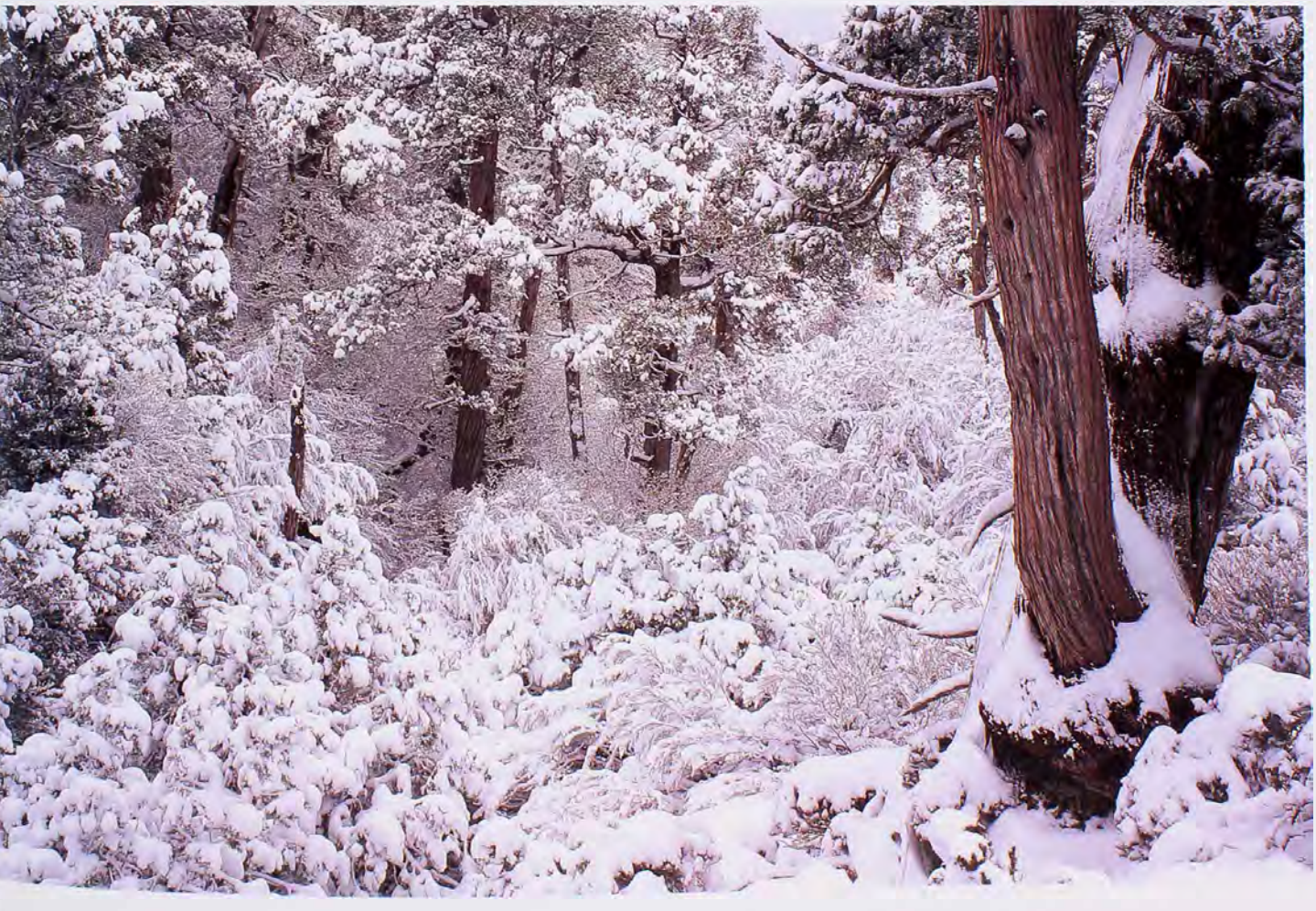




THE WILD SHAPES OF TASMANIA

BY ROB BLAKERS
NATURE FOCUS PHOTO LIBRARY

PHOTOART



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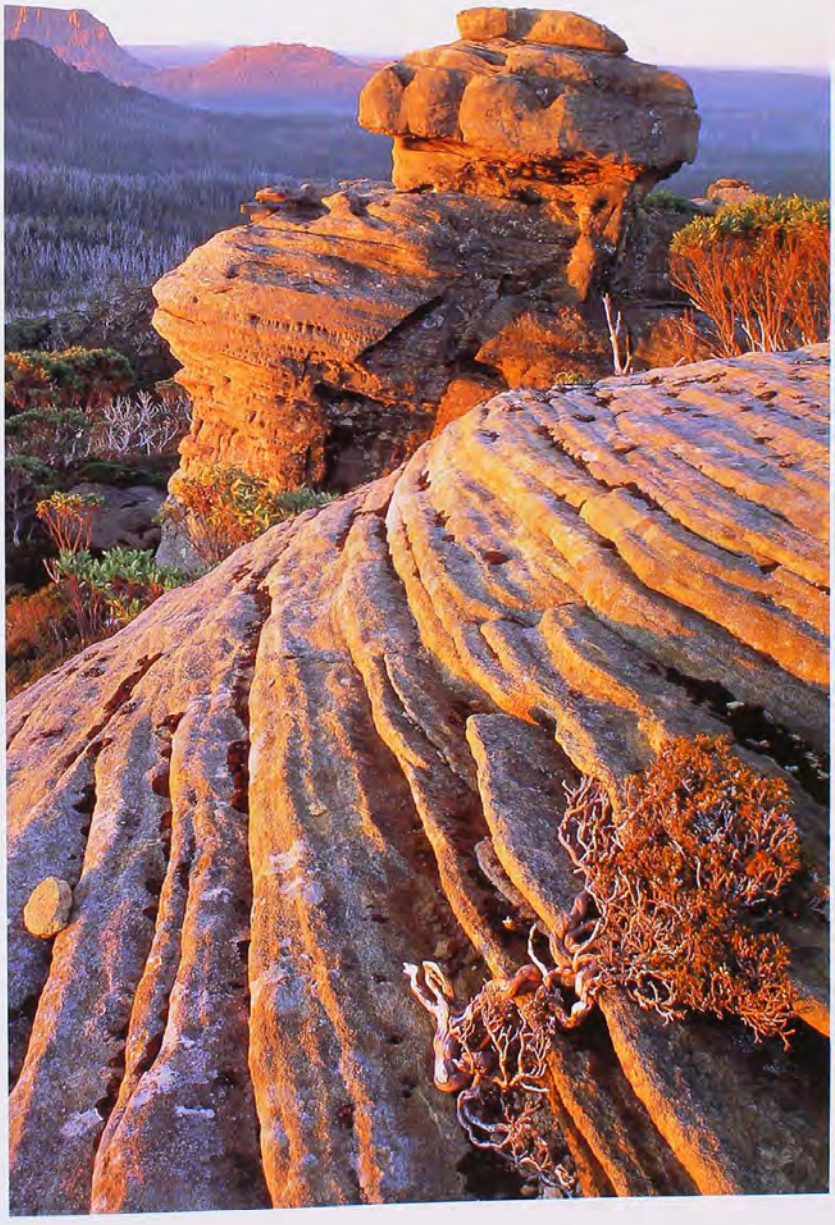

The Lesser Short-tailed Bat spends a lot of its time hunting for food on the ground, scurrying about on its wrists and hind feet like a Transylvanian rodent.

BIZARRE BATS OF THE BURROWS

BY MICHAEL ARCHER

EACH NIGHT, ONE OF THE oddest beasts in the world flaps its way through New Zealand's Gondwanan rainforests, smacking its lips at the thought of tender baby muttonbird dragged screaming out of its burrow to be consumed in the moonlight! Well, even though its culinary interest in muttonbird flesh is in fact argued about, every bat biologist agrees that the Lesser Short-tailed Bat (*Mystacina tuberculata*) is one of New Zealand's most striking biological claims to fame. But New Zealand's claim to sole possession of this group has now been challenged by the discovery of 23-million-year-old fossils from Riversleigh in north-western Queensland. These reveal that the oldest-known and probably ancestral members of this very strange group first honed their skills in the ancient rainforests of Australia.

Like the recently extinct Greater Short-tailed Bat (*Mystacina robusta*) of New Zealand, its Lesser cousin has short, stout hind legs and uniquely shaped claws. It also has proportionately narrow wings, which help it to fly in the cluttered understorey of New Zealand's lowland rainforests—the only habitat in which it lives. But its slightly odd outward appearance gives no indication of its extraordinarily odd behaviours.

Unlike normal bats, the Lesser Short-tailed Bat spends a lot of its time hunting for food on the ground, scurrying about on its wrists and hind feet like a Transylvanian rodent. During these forays, the outer parts of its wings are tucked away in pocket-like folds of skin developed along the body. When in pursuit of insects or other small creatures, it burrows through leaf litter like a mole. More surprising was the discovery by Mike Daniel (New Zealand Department of Scientific and Industrial Research) that the bat also feeds on fruit and possibly nectar, foods routinely utilised by only two other groups of bats: Old World fruit-bats (pteropodids) and South American New World leaf-nosed bats (noctilionoids). The tip of its tongue has hairy papillae ideally suited for collecting nectar and pollen from flowers. As a possible measure of the antiquity of this habit, one of New Zealand's parasitic plants, *Dactylanthus taylorii*, whose flowers appear at ground level, appears to be totally dependent on these bats for pollination.

But most bizarre in terms of feeding behaviours, these bats reputedly (there are doubters!) raid the burrows of muttonbirds to consume the hapless chicks. New Zealand muttonbirders were evidently so annoyed about the depredation on southern muttonbird colonies that some time prior to 1936 they used smoke to kill or drive the bats from their caves. But even if the muttonbird stories are exaggerated, captive individuals have definitely eaten the flesh of birds.

Their roosting behaviour is no less unusual. While they inhabit caves when

New Zealand's Lesser Short-tailed Bat.

BRIAN LLOYD/KEY-LIGHT

available, they are far better known for the incredible labyrinths they excavate within the trunks of giant Kauri trees (*Agathis australis*). If their worn incisors are any indication, they must gnaw through the wood like giant hairy beetle larvae. Communal chambers linked by tunnels, some of which are metres in length, honeycomb the interior. Within these bat-burrowed berths, the humidity is 100 per cent, temperatures range from 15–39° C depending upon how active the tenants are, and the telltale ammonia smell of a thousand trapped wee-wees can be detected in the forest 100 metres from the roost tree.

If their worn incisors are any indication, they must gnaw through the wood like giant hairy beetle larvae.

To add to the overall mystery, there has been considerable uncertainty about the evolutionary relationships of this unique family of bats, the Mysta-cinidae, to others. Dixie Pierson (University of California) who studied albumin serology, and most recently John Kirsch (University of Wisconsin) who studied DNA-hybridisation, both suggested that these New Zealand bats are most closely related to South America's noctilionoid bats, a hugely diverse group including insect- and meat-eaters, fruit- and nectar-feeders, as well as the infamous blood-sucking vampire bats. Pierson suggested that ancestors for mystacinids must have flown to New Zealand from South America via Antarctica about 35 million years ago.

A lovely story of relationship, but one almost certainly misinterpreted. When palaeontologist Suzanne Hand (University of New South Wales) first saw the strange 23-million-year-old bat jaw poking out of the limestones of Wayne's Wok Site at Riversleigh, she instantly knew it had nothing to do with any other previously recognised group of Australian bats—living or extinct. It didn't take her long to realise, with great excitement, that she was holding the world's first non-New Zealand mystacinid. This unexpected but delightful discovery was followed by many others, including one from the 12-million-year-old Bullock Creek assemblage in the Northern Territory, and it soon became obvious that Australia was the centre of a major radiation of these fascinating bats.

New Zealand's mystacinids were almost certainly Australian (not South American) high-flyers blown eastwards by the prevailing Westerlies. Considering that for at least the last 65 million years New Zealand has been more or less parallel to the Australian coast and spread over 20° of latitude, it has long been an easy target for wind-blown creatures. And blow in they have. Australian birds and butterflies regularly drop in, as do other kinds of bats, the most recent being the Red Flying-fox (*Pteropus scapulatus*). The close relationships of New Zealand's other unique bat, the Long-tailed Bat (*Chalinolobus tuberculatus*), to Australian species of the same genus suggest that it probably emigrated from Australia no more than a few million years ago.

We may now know where New Zealand got its mystacinids from, but what about the origin of Australian mystacinids? Considering that molecular data link living mystacinids to South America's noctilionoids, could South Ameri-can bats have invaded Australia (via Antarctica) to become mysta-cinids which then flew off to New Zealand?

Perhaps, but other undescribed bats from Riversleigh, some of which show striking similarities to noctilionoids, tempt Sue to consider a previously unimagined possibility—that a common stock for both noctilionoids and mystacinids originated in Australia. Then one mob, driven by an urge to fly south, flapped across West Antarctica to claim South America's fruits, bugs and blood. Another mob, after evolving into Australian mystacinids, blew across the Tasman to scrabble on all fours after fruits, insects and maybe the odd slow bird. When the Australian ancestors of both mobs faded away, they left behind two very strange but closely related groups of bats at opposite ends of the Earth—the missing links being the tiny fossils of Riversleigh. The stone bones rattle and the tiny teeth speak. ■

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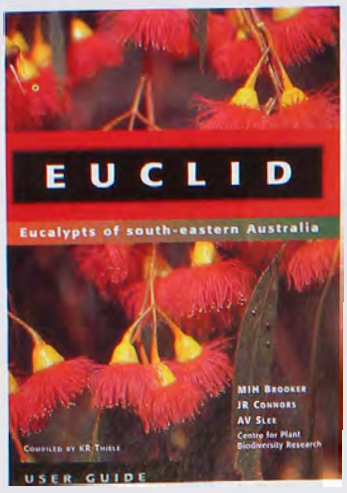
Professor Michael Archer lectures in biology and geology at the University of New South Wales. Most of his non-teaching hours are devoted to the study of the fossil faunas of Riversleigh, north-western Queensland.

REVIEWS



EUCLID: An Interactive Key to the Identification of Eucalypts CD-ROM

By M.I.H. Brooker, J.R. Connors and A.V. Slee. CSIRO Publishing, Vic., 1997, $120.00rrp.

This computer program follows in the wake of that other successful computer identification program "Australian Tropical Rainforest Trees" by Bernie Hyland and Trevor Whiffin. This computer identification program covers all eucalypts found in New South Wales, Victoria, Tasmania and the south-eastern corner of South Australia.

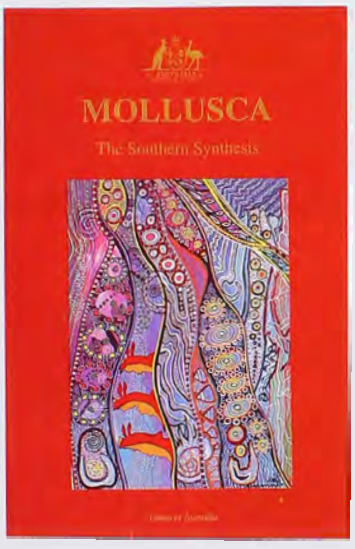
By following the simple instructions on the back of the CD cover, the program is quickly and easily installed. The program is exceptionally user-friendly and I had no difficulties in working through the various options available.

With my unknown eucalypts in front of me, I proceeded to work through the interactive identification key. I preferred the "Best Fit" character list over the "All Characters" list, as I found I was able to identify my specimens using only about five to ten characters. Most of the characters have illustrations on to which you can double click to make your choice and there are definitions for each character. For the novice to EUCLID I recommend you read the definitions of the characters in case your concept of a particular character differs from that of the authors.

The similarities/differences option was very useful when I had narrowed down my list of possible taxa to ten or less species. The photos of the habit, buds, fruit, bark and juvenile foliage of each species are excellent, with the resolution of your computer monitor being the limiting factor. There are also distribution maps of each species, which are quite detailed.

I found this program a pleasure to use and look forward to future editions covering the remaining eucalypt species.

—Peter Jobson
National Herbarium of NSW
Royal Botanic Gardens, Sydney



Mollusca: The Southern Synthesis

By Australian Biological Resources Study. CSIRO Publishing, Vic., 1998, 1,234pp (vols A and B). $295.00rrp.

Trying to write a review in 300 words of a two-volume 'encyclopaedia' of 1,234 pages is no easy task. But trying to find a reviewer who is not one of the 71 authors is no easy task either. I have had the pleasure of knowing the majority of those authors and have been on the periphery of this work for many years, so can but congratulate them all for a work that can only be described as magnificent. The molluscan volumes in The Treatise on Invertebrate Palaeontology series, for so long on the front shelves of any library, can now be relegated to second place.

There are certain works on malacology that are seminal, such as Thiele's 1935 *Handbuch der Systematis-chen Weichtierkunde*. And there have been other elegant studies detailing specific areas of interest, such as Thorson's 1946 *Reproduction and larval development of Danish marine bottom invertebrates*, or even Hickman and McLean's 1990 *Systematic revision and suprageneric classification of trochacean gastropods*.

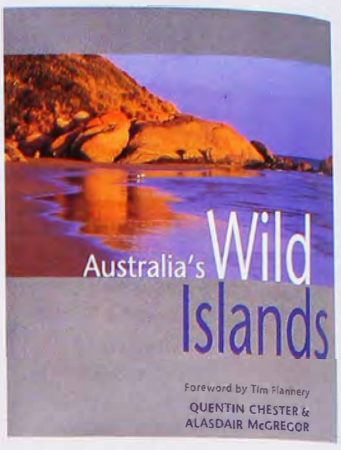
But *Mollusca: the southern synthesis* says it all. As the publication's description says, "The majority of molluscan families described are found throughout the Southern Hemisphere as well as the Northern Hemisphere making this title an essential reference for malacologists around the world".

What I have said above is directed to professional malacologists and those skirting the field. But this work is readable, understandable and sensibly designed to become a valuable tool for biology and zoology students, environmental educationists, staff attached to environment centres, and those not au fait with scientific terminology.

Over 500 superb colour and black-and-white photos, even more superb line drawings (over 2,500 of them), all supported by a text contributed to by the current world experts in their field, make this work an essential inhabitant of any zoological, biological, ecological, palaeontological or conservation library. The price is irrelevant. The value is worth many times the price. As well, these volumes won't date easily.

I must admit that I just had to buy the two-volume work because—I just had to. Then I was asked to write this review. What a present I have for somebody!

—Phil Coleman
Australian Museum



Australia's Wild Islands

By Quintin Chester and Alasdair McGregor. Hodder & Stoughton Australia, NSW, 1997, 276pp. $60.00rrp.

Australia possesses one of the world's most diverse collections of offshore habitats. Their history, geology and wildlife are of great importance to the mainland and go towards making Australia the unique and challenging land that it is.

This book is basically divided into the eight major island groups that lie dotted around Australia, including those near the Antarctic. If you read the book in sequence, you can get a sense of the changing climates and stark differences between many of these islands.

There is a feast of information provided, including historical backgrounds, early inhabitants, animals likely to be encountered, and facilities that might be there for prospective visitors. There are also maps, archival photographs, and bibliographic references at the end of each island description to the many quotes included within the text. McGregor combines photographs of wildlife and landscapes with his paintings of lush vegetation that add to the overall richness of the experience, which is very satisfying.

Chester and McGregor have produced an exciting and beautiful book on the islands off Australia. Its combination of evocative writing

and strong images makes it well worth having.

—Kate Lowe
Australian Museum

Fungi of Southern Australia

By N.L. Bougher and K. Syme. University of Western Australia Press, WA, 1998, 391pp. $75.00rrp.

There are very few comprehensive guides to the identification of Australian fungi and so it is pleasing that a new book on macro-fungi of southern Australia, containing descriptions of a large number of species, should appear. This book combines the beautiful paintings of Katrina Syme with the comprehensive mycological knowledge of Neale Bougher in a manner that is both pleasing to the eye and full of details on each of the fungi described.

The first part of the book provides information on the basic biology and ecology of macro-fungi, how to find, collect and process fungi, and how fungi are described and named. This section contains a great deal of useful information, particularly the sections on finding and describing fungi, which are rarely outlined in texts of this nature.

The descriptions of species, each with a water-colour painting of the fruiting body in its habitat, make up the bulk of the book. All the essential details are here, including habitat and distribution, taxonomic relationships, and references to the original taxonomic description. Line drawings are provided of the spores, basidia and other features, and details of the microscopic features are provided. It is a very comprehensive description of each species.

My only criticism is that the book is perhaps slightly incorrectly titled. The majority of fungi in the book are from south-western Australia and, while it is true that many do occur in south-eastern Australia, there are also many common species from south-eastern Australia that are not included in the book. Despite this, the book is an essential addition to the library of any mycologist, be they professional or amateur.

—Brett Summerell
Royal Botanic Gardens, Sydney

The Perils of Progress: The Health and Environment Hazards of Modern Technology & What You Can Do About Them

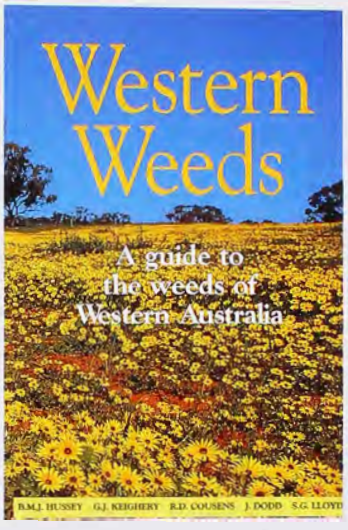
By John Ashton and Ron Laura. UNSW Press, NSW, 1998, 3346pp. $29.95rrp.

From electric razors to margarine, from traffic noise to the invisible electromagnetic smog that surrounds us, we are, willingly or otherwise, intimately affected by the technological advances that have transformed the modern world. The authors of this book have considered a vast range of areas that have apparently benefited from technology. They present well-referenced arguments, however, to suggest that, in many cases, any potential benefits are also accompanied by other less desirable effects that may have significant implications for human health and ecological integrity.

The views of the authors are clear: the natural alternative is invariably the best. This is well illustrated in the section of the book that deals with food technology. It is tragic to think of the ends we go to to manipulate food products which, in their natural state, are more nutritious and beneficial to our health than their bland, genetically modified, flavour- and colour-enhanced, hydrogenated or salt-laden derivatives.

I would challenge even the most hardened technophile not to question their reliance on technology based on the information presented in this book.

—Tim Norman
Australian Museum



Western Weeds: A Guide to the Weeds of Western Australia

By B.M.J. Hussey, G.J. Keighery, R.D. Coussens, J. Dodd and S.G. Lloyd. The Plant Protection Society of Western Australia, WA, 1997, 256pp. $25.00 plus postage & packing.

Western Australia is usually thought of as the Wildflower State with an interesting native flora. It is sad then to think that the remnant vegetation and native bushland near settlement is steadily being replaced by introduced plants—weeds. This book, with its broad coverage from the Kimberleys to the wet south-western corner of Western Australia, presents the majority of weedy plants occurring in the State, and because of this wide coverage, it is also applicable to much of the country.

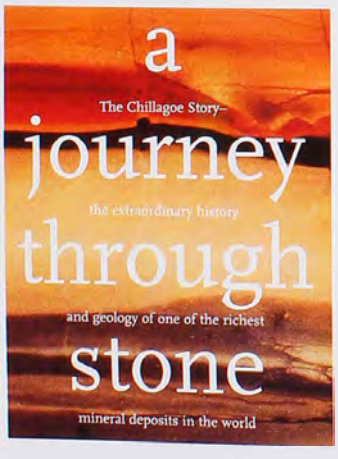
The preface and introductory chapters are an excellent background in weeds and

their management. They discuss how botanists decide which plants are weeds, how damaging they are to the environment, how they become established in the wild, and the procedures in notifying the official authorities on localised spread and introduction of new weeds.

Most of the plants are illustrated (600 out of the 800 presented) and the brief descriptions are very informative. The majority of the photos are good enough to use for identification purposes. Some of the mustard plant (Brassicaceae) photos show the habit well, but have poor focus on the fruit (the main feature for identifying this group). Fortunately, they have a table with drawings of all the mustards presented, which is very useful. The captions for *Acacia baileyana* and *A. dealbata* on page 179 have been switched, which is annoying. The reference list at the end is very good and presents all of the current identification books and floras available in Australia, as well as the more recently published weed management books.

This book is a must for agricultural students, bush regenerators and farmers who are environmentally conscious.

—Peter Jobson
National Herbarium of NSW
Royal Botanic Gardens, Sydney



A Journey Through Stone: The Chillagoe Story

By Ian Plimer. Reed Books, Vic., 1997, 176pp. $29.95rrp.

Ian Plimer's name became almost a household word in 1997 with the intense media coverage of his failed attempt to put a stop to false and misleading claims made by creationists, using the judicial system. This is indicative of Plimer's passion for his subject, being willing to go to extraordinary lengths in the name of science. Plimer has been advancing the cause of geology and geological learning for years through teaching, media appearances and writing. As a result, he is one of the most well-respected geologists in the country.

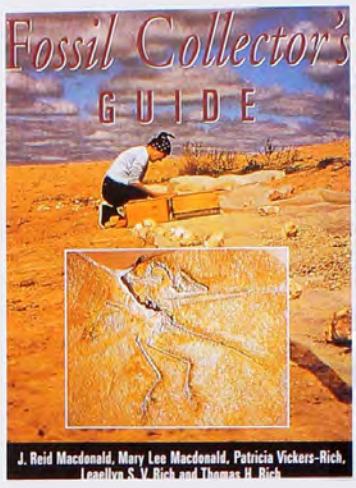
The story of Chillagoe is interesting from both a geological and historical point of view. Geologically it spans approximately 500 million years and historically over 100 years. As a geologist but not one specialising in minerals I found the book easy to read. Plimer simplifies geological processes very well while giving an overview of the geological history of Australia and how it led to Chillagoe's amazing mineral deposits.

Most of the book is taken up with the ancient history of Chillagoe. Five hundred million years are dealt with in 108 pages! It is here that I feel the non-geologists may be lost, although I don't think it could be simplified any further without loss of geological accuracy. The last 37 pages detail the ongoing chequered history of mining at Chillagoe. It has quite an interesting history with its fair share of scandal and intrigue. As with many of the old mining fields in Australia, Chillagoe has enjoyed a revival in the last ten or so years as new technology is applied to mineral exploration and extraction.

The text is interspersed with more than adequate maps and diagrams. The 36 plates (grouped together) are of varying quality. The mineral photographs could have been better. Many lack depth of field and some have poor colour definition, which detracts from the high quality of the text. The design and production of the book is commendable. An interesting feature is the time line down the right-hand margin of each page, indicating the corresponding time period of the text.

I have a feeling that the book could have a limited audience, mainly geologists, both professional and amateur, and local historians. It does not have general appeal to the vast number of Australians who may have never heard of Chillagoe. At $29.95, however, it is a good buy if the subject interests you.

—Robert Jones
Australian Museum



The Fossil Collector's Guide

By J. Reid Macdonald, Mary Lee Macdonald, Patricia Vickers-Rich, Leaellyn S.V. Rich and Thomas H. Rich. Kangaroo Press, NSW, 1997, 172pp. $29.95rrp.

Many years ago I purchased a copy of *The fossil collector's handbook* by J. Reid Macdonald. At the time it was the only book of its type available, with lots of worthwhile information on collecting fossils. It had one major drawback and that was it was written for the US market like so many other books on palaeontology. Sure it was useful but in a limited sort of way.

Obviously I was not the only one to suffer the frustration of having to tolerate mapping systems, fossils and terminology that would never be encountered in this country. Now in a blatantly family affair J. Reid Macdonald's handy book has been made totally Australian user-friendly, well almost.

Most of the illustrations have been replaced with Australian examples. Many references to things American have been changed to Australian examples. North American terminology has been largely replaced with Australian terminology. You know it is written only for use in Australia when Vegemite is included in the shopping list of supplies for the field kitchen! The book retains all its worthwhile information and is now even more useful to Australian fossil enthusiasts.

In six chapters the book deals with most of the areas of fossil collecting, identifying, classification and preparation, with background information on geology and where to get more information and help. The book begins with acknowledgements, which is fine, but then reproduces an article on the well-publicised *Tyrannosaurus* skeleton nicknamed 'Sue'. What is not explained is that this is only the first half of the story and since the article was written 'Sue' has been put to auction and sold. Also the section on the state of legislation concerning fossils and their ownership in the US is interesting but a bit out of place. No mention has been made of Australia's Protection of Moveable Cultural Heritage Act 1986 concerning export of fossils, or other Australian State legislation concerning collection and ownership of fossils, which would have been far more appropriate.

Chapter 4, where practical field and prepararion skills are dealt with, is probably the single most useful chapter in the book. Much of the information in the other chapters can be found elsewhere and it is this chapter that sets the book apart from other geology or palaeontology texts.

Sadly a lot of errors have crept in from what appears to be poor proof-reading, especially in the addresses of institutions in the section on "Where to go and who to contact for more information".

It might appear that I am overly critical of the book, which is not my intention. In praise of the work I feel the criticisms mentioned above do not detract from the usefulness of this book. Except for the problems with the addresses, the information it contains is not at all compromised by my critical view.

With the best intentions the authors have done a commendable job, which should bring about an increase in popularity and usefulness of the book here in Australia.

—Robert Jones
Australian Museum

SOCIETY PAGE

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

ANIMAL WELFARE

WIRES (Dubbo Branch)
PO Box 1456
Dubbo, NSW 2830
Ph: (020) 6884 4995
Contact: Sandra Ferguson

Membership fee: $37.00

WIRES (NSW)
PO Box 260
Forestville, NSW 2087
Ph: (02) 9975 5567
Contact Jennifer Stevenson or Lucy Andrews

Membership fee: Varies

Sydney Metropolitan Wildlife Services
PO Box 78
Lindfield, NSW 2070
Ph: (02) 9413 4300
Contact: Sonja Wesley, Director/ Public Officer

Membership fee: $75.00 (includes 2-day training course)

BIRDS

Bird Observers Club of Australia
PO Box 185
Nunawassing, Vic. 3131
Ph: (03) 9877 5342
Contact: Mrs E. McCulloch

Membership fee: Varies

CONSERVATION

Friends of the Platypus
c/- Australian Platypus Conservancy
PO Box 84
Whittlesea, Vic. 3757
Ph: (03) 9716 1626
Contact: Geoff Williams

Membership fee: $30.00 adult; $45.00 family; $20.00 full-time student

EARTH SCIENCES

Dino Club (WA)
WA Museum
Dept of Earth & Planetary Sciences
Francis St
Perth, WA 6000
Ph: (08) 9328 4411
Contact: Angela Davis

Membership fee: $12.00; $20.00 group

EDUCATION

Science Teachers' Association of Qld
c/- Dept Mathematics Science & Technology Education
QUT- Kelvin Grove Campus
Victoria Park Rd
Kelvin Grove, Qld 4057
Ph: (07) 38643340
Contact: Ms P. Havenschild

Membership fee: $85.00 basic

ANGFA (NSW) Australia & New Guinea Fishes Association
23 James Watt Dr
Chittaway, NSW 2261
Ph: (02) 4388 2276
Contact: Lorraine & Derek Girkin

Membership fee: $10.00

CSIRO's Double Helix Club
PO Box 225
Dickson, ACT 2602
Ph: (02) 6276 6647
Contact: Lynn Pulford

Membership fee: $25.00

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PO Box 190
Richmond, Vic. 3121
Ph: (03) 9428 2633
Contact: Julie Mills

Membership fee: Varies

ENVIRONMENTAL

The Society for an Ecologically Sustainable Population Inc.
PO Box 70
Dural, NSW 2158
Ph: (02) 9939 6889
Contact: Jill Curnow

Membership fee: $25.00

Gould League (Vic.)
Genoa St
Moorabin, Vic. 3189
Ph: (03) 9532 0909
Contact: Alan Mayberry

Membership fee: $7.50

MICROSCOPY

The Postal Microscopical Club
PO Box A1017
Sydney South PO, NSW 1235
Ph: (02) 4758 7128
Contact: Michael Dingley

Membership fee: Varies

MUSEUM

TAMS, The Australian Museum Society
6 College St
Sydney, NSW 2000
Ph: (02) 9320 6225
Contact: Michelle Ball

Membership fee: $55.00 single; $70.00 household; $40.00 student/pensioner

NATURAL HISTORY

Field Naturalist Association of Canberra
GPO Box 249
Canberra, ACT 2601
Ph: (06) 240 8152
Contact: Joyce Weeks

Membership fee: $20.00 single/family; $12.00 concession (pensioners & full-time students)

Field Naturalists Club of Victoria
Locked Bag 3
Blackburn, Vic. 3130
Ph & Fax: (03) 9877 9860
Contact: Geoffrey Paterson

Membership fee: $40.00 metropolitan; $30.00 concession; $30.00 country; $15.00 junior

Launceston Field Naturalists Club
PO Box 1072
Launceston, Tas. 7250
Ph & Fax: (03) 6344 1076
Contact: Dr A. Pegler, Hon. Secretary

Membership fee: $15.00 single; $20.00 family

Linnean Society of NSW
PO Box 457
Milsons Point, NSW 2061
Ph: (02) 9929 0253
Contact: Mrs B.J. Stoddard

Membership fee: $50.00

PALAEONTOLOGY

Dinosaur Club Vic.
Monash Science Centre
Monash University
Clayton, Vic. 3168
Ph: (03) 9905 1370
Contact: Prof. P. Vickers-Rich

Membership fee: $12.00 or $20.00

REPTILES

SA Herpetology Group
c/- SA Museum
North Terrace
Adelaide, SA 5000
Ph: (08) 8201 2805
Contact: Tim Milne

Membership fee: $25.00 adult; $30.00 family; $20.00 student/junior

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Manunda, Qld 4870
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Contact: Michael Anthony

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Q&A

Pied Rat Catcher

Q: *I recently witnessed a Pied Currawong (Strepera graculina) attack and carry away a fully grown rat in its beak like a Kookaburra, at least I think it was a rat as it was much larger than a mouse. Is this an unusual thing for a Pied Currawong to eat?*

—Russell Smith
Clareville, NSW

A: Pied Currawongs are omnivorous and opportunistic feeders, eating young birds, carrion, invertebrates, small vertebrates and fruit. It is entirely possible, although not common, that a Pied Currawong would attack and kill something as large and potentially feisty as a rat. These birds are 'bullies' and usually prefer to go for things that are unable to fight back.

—Kate Lowe
Australian Museum

Never underestimate a Pied Currawong.

Beach Toothpaste?

Q: *On a beach at Bribie Island, Queensland, I found a tangle of what looked like grey toothpaste about the thickness of a pencil on the wet sand. Could it be some kind of worm casting?*

—P. Cameron
Gladesville, NSW

A: From your photograph and description it would appear to be the tube-like excreta from a holothurian or sea cumber. They are worm-like or sausage-shaped creatures with a mouth at one end surrounded by tentacles. This connects to a straight food canal with an anal aperture at the other end. Holothurians are related to sea-stars, although they do not look anything like them. They are abundant in tropical waters where certain species are edible and are known as Bêche-de-mer or trepang.

—Kate Lowe
Australian Museum

Spider Tactics

Q: *Why do spiders sit upside down in their webs?*

—Susannah Lang
Cooma, NSW

A: It's all to do with catching prey. Spiders that are positioned head down can catch their prey more quickly by moving down the web than up the web. This may help explain why the central part of the web, the so-called hub where the spider sits and waits, is found slightly higher than the actual centre of the web (to increase the chance that prey blunders into the area of web below the hub). It also probably explains why, when spiders live in a retreat just off the web, the retreat is located at the top of the web, rather than at the bottom.

—Mark A. Elgar
University of Melbourne

COURTESY PETER CARLSON

Who or what produced this?

Waspish Ways

Q: *When I was playing a round of golf last week I*

T. & P. GARDENER/NATURE FOCUS

DENSEY CLYNE

A spider wasp (*Cryptocheilus* sp.) with its victim.

happened to see a bird drop a spider from its beak. Almost immediately a very large black-and-orange wasp grabbed the spider and flew away. Strangely, the bird did not pursue its prey. What kind of wasp was it and why didn't the bird try to get its meal back?

—Barrie Walsh
Coogee, NSW

A: The wasp you saw was most probably a spider wasp (family Pompilidae). These are large (up to 35 millimetres long), solitary wasps that prey on spiders or parasitise other spider wasps to feed their larvae. Female spider wasps prepare nest chambers for their larvae by digging a burrow with the long spines on their front legs. They then search rapidly around tree trunks and on the ground for a spider. The wasp stings the spider in order to paralyse it, and takes it back to her burrow. There she lays an egg on the spider's body and seals it in a chamber or cell at the end of the burrow. The larva hatches and feeds on the body of the spider before pupating in a thin silky cocoon in the cell.

Although the females can sting with their ovipositor (egg-laying organ), they do not form colonies to defend nests and are not aggressive. Stings from these wasps are uncommon and should be treated like bee stings.

Birds must weigh up the amount of energy expended and possible hazards encountered in getting food. Because spiders are easy to find and the warning colours of the wasp would signal danger, the bird probably thought better of trying to retrieve its prey.

—Kate Lowe
Australian Museum

Answers to Quiz in Nature Strips (page 16)

1. Blue and orange
2. Clockwise
3. A flying or gliding membrane of skin
4. A comet (Comet Hale-Bopp)
5. Female
6. Fish
7. Kyoto, Japan
8. The millennium bug
9. 100,000
10. South Australia

P I C T E A S E R

Do you recognise this? If you think you know what it is, then send your answer to Pic Teaser, *Nature Australia* Magazine. Please don't forget to include your name and address. The first correct entry will win a Foldable Magnifier from the Australian Museum Shop. Winter's Pic Teaser was an antplant (*Myrmecodia* sp.) cut to show the ants and chambers within.

MERRIDY CAIRN-DUFF/NATURE FOCUS

It's rather like worrying about exceeding your duty-free allowance while sitting in an aircraft with engine failure.

CONSERVATION MYTHS

BY MARK A. ELGAR

POPULATION GENETICISTS were quick to recognise how their subject might contribute to conservation biology. A key concept of theirs is that small populations generally have less genetic variation than large populations, and it is held that populations with little genetic variation are vulnerable in the long term because they are less able to respond adaptively to environmental changes. Typically, threatened or endangered species comprise small, isolated populations, and so population geneticists were well placed to argue the importance of their subject in 'saving' species, and thus a share of conservation research funding. But how good are their claims? The emerging evidence is equivocal.

Levels of genetic variation have been measured for many vulnerable and endangered species, but the data are difficult to interpret because of inadequate replication and an absence of a benchmark for comparison. For example, an endangered species may have little genetic variation, but this may be a characteristic of the taxon irrespective of its conservation status. And we simply cannot tell whether the low variation is responsible for, or a consequence of, the decline in population size.

More significantly, there are few, if any, data demonstrating an unambiguous link between genetic variation and the viability of natural populations. Supporting evidence is mostly circumstantial or anecdotal. Indeed, several recent studies suggest that the case for genetic concerns has been overstated.

The Cheetah (*Acinonyx jubatus*) provides a salutary case story. The survival prospects of this magnificent species are poor because few breeding individuals are recruited into wild populations. Genetic factors were originally thought to be the problem; cub mortality was high and male fertility low, both of which were attributed to the apparently non-existent genetic variation. However, field work by Tim Caro and Karen Laurenson (University of California at Davis) has now shown that most Cheetah cubs are killed and eaten by Lions and Spotted Hyenas; genetic factors are presumably irrelevant. Ironically, the low levels of genetic variation in Cheetahs are probably the result of a population crash some 10,000 years ago; an impressive record of survivorship in the face of low genetic variation!

FERRERO-LABAT/AUSCAPE

The enigmatic Cheetah.

Similar stories are emerging for other species. The Barrow Island population of Black-footed Rock-wallabies (*Petrogale lateralis*; see *Nature Aust.* Winter 1998) has persisted for thousands of years, despite comparatively little genetic variation. Numbers of Northern Elephant Seals (*Mirounga angustirostris*) have increased substantially following cessation of hunting, even though they too have minimal genetic variation. And, most recently, the tiny, highly inbred and genetically uniform population of Seychelles Warblers (*Acrocephalus sechellensis*) has increased following introductions to adjoining islands. It seems that the conservation of these species, in the short and probably long term, depends more on ecological than genetic factors.

These emerging data must cast some doubt over the relevance of concerns about a species' genetic diversity. Essentially, the question is whether management programs for endangered species are best administered over the ecological short term or evolutionary long term. The threats to most endangered species are usually contracting habitat, introduced species, human predation and disturbance, and so on. An endangered species' potential inability to cope with a changing environment over the long term is probably academic; it's rather like worrying about exceeding your duty-free allowance while sitting in an aircraft with engine failure.

The small pool of money available for research in conservation biology raises the issue of funding priorities. Conservation biology aims to provide rigorous data upon which we can make sensible management decisions about preserving habitat and species. Population genetics has practical uses; for example, it can provide estimates of the size of populations that are otherwise difficult to count. But can data on genetic variation really assist management action plans? What difference does it make if all populations of an endangered species have little genetic variation? Knowledge of the threats to the survival and recruitment of breeding individuals may be of more practical use. Contemporary techniques in genetic research are also hideously expensive; can we afford the luxury of obtaining these data on single species if they are of marginal practical relevance?

This underlying issue of relevance is neither trivial nor exclusive to genetic studies; a disturbing proportion of 'ecological' research in conservation biology, together with the currently fashionable 'biodiversity' industry, is of dubious management value. Resolving conservation issues is vital; but research effort might better serve conservation goals if the focus were on current management problems rather than academic futures. ■

Further Reading

Caro, T.M. & Laurenson, M.K., 1994. Ecological and genetic factors in conservation: a cautionary tale. *Science* 263: 485–486.

Komdeur, J., Kappe, A. & van de Zande, L., in press. Influence of population on genetic variation and demography in Sechelles warblers: a field experiment. *Anim. Conserv.*

Dr Mark A. Elgar is a Senior Lecturer at the University of Melbourne. His research is in evolutionary and behavioural ecology.

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

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