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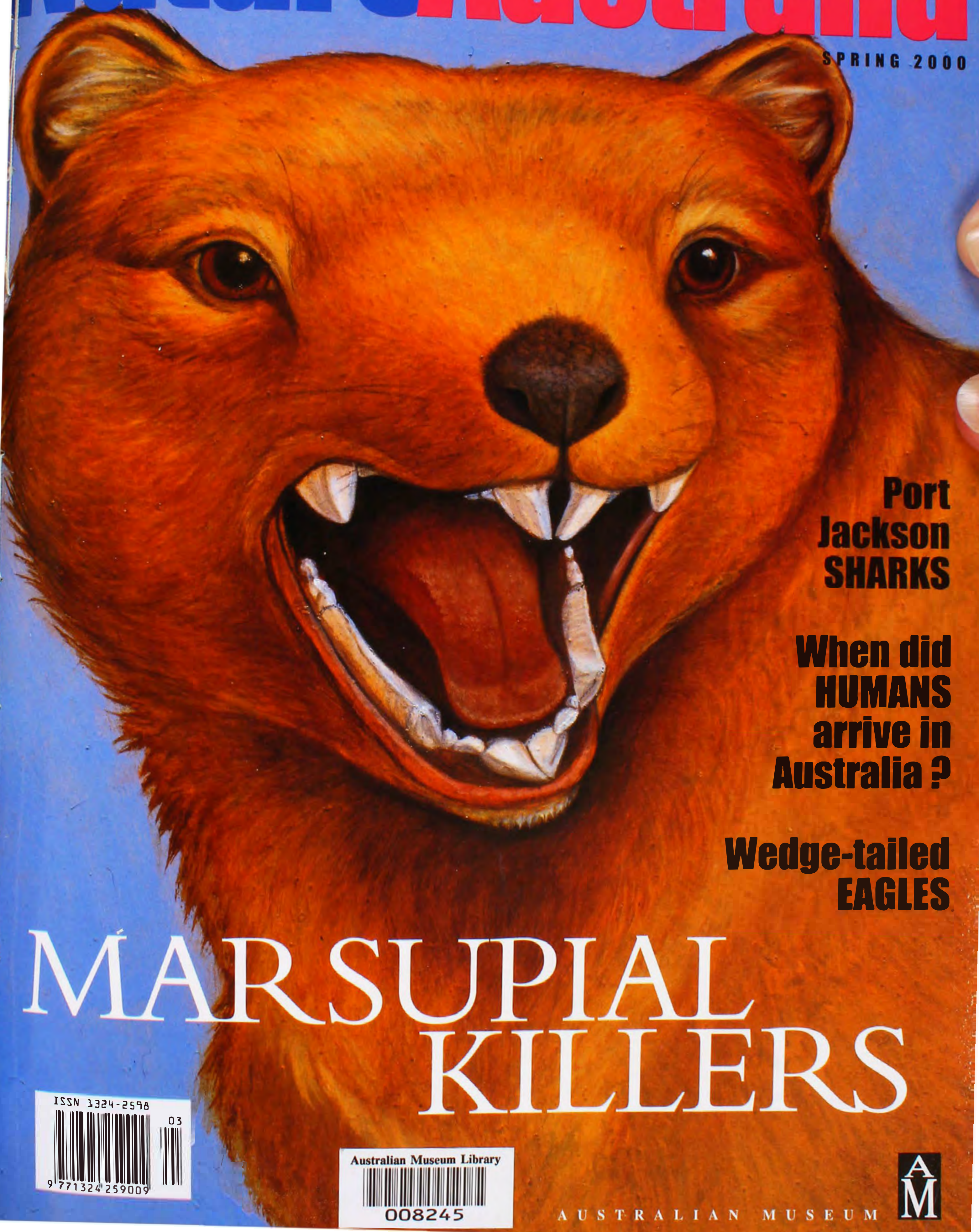

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Wedge-tailed EAGLES

MARSUPIAL KILLERS

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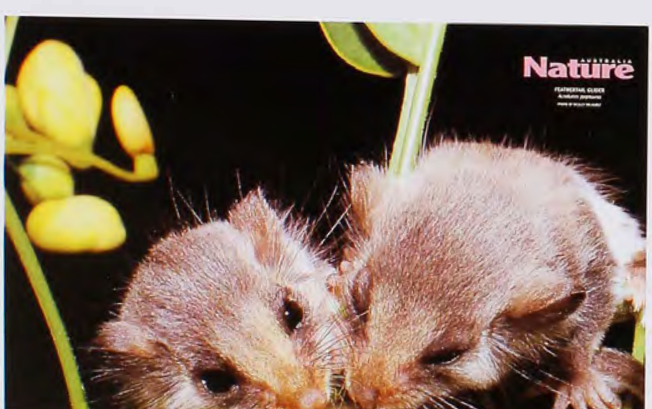

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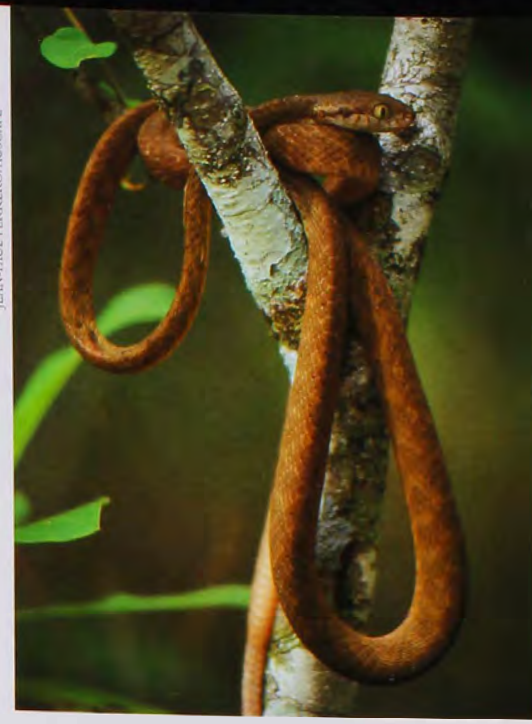

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FRONT COVER
New research suggests that the Marsupial Lion (*Thylacoleo carnifex*) was a highly efficient carnivore and Australia's answer to the sabre-toothed tigers. Illustration by Anne Musser.

up front

When did humans first arrive in Australia? A seemingly simple question, but in trying to find the answer, scientists must employ dating techniques. Unfortunately, no matter which dating technique they choose, and there are many, the answers are often fraught with uncertainty. In his article, "A matter of time", Jim Allen discusses the controversy surrounding the various dates obtained so far and the implications they have for the understanding of early human history worldwide.

Assuming humans arrived in Australia somewhere between 40,000 and 60,000 years ago, there is a good chance they shared their home with some real monsters. Among them were *Diprotodon*, a large wombat-like creature the size of a rhinoceros; *Megalania*, a giant goanna that weighed in at around 620 kilograms; 'Big Bird' that stood over two metres tall and may have preferred the taste of flesh; and to cap them all off, Australia's own marsupial 'lion' *Thylacoleo carnifex*. Unfortunately, the reputation of this marsupial 'lion' as a fearsome beast has suffered at the hands of a number of scientists who have continually downsized it, one recent estimate being as little as 20 kilograms. It was then that Steve Wroe decided enough was enough and set about changing the current thinking on *Thylacoleo* before it disappeared from the record books all together! In "Move over sabre-tooth tiger", Steve argues that *T. carnifex* was Australia's largest carnivore, weighing around 130 kilograms, and definitely comparable to the infamous sabre-tooth tigers.

CARL BENTO/NATURE FOCUS

Steve Wroe measures a *Thylacoleo* skull.

One Australian whose impressive size isn't disputed is the Wedge-tailed Eagle. With a wingspan of up to 2.5 metres and weighing over four kilograms, the Wedge-tail is our largest eagle and one of the largest in the world. These birds can be found all over Australia and are instantly recognisable as they soar through the sky by their wedge-shaped tail and finger-like wing feathers. They are also commonly seen feeding on roadkills. But wherever you see them, you will not fail to be impressed by these magnificent birds.

And from one size extreme to the other, how do one-centimetre-long, transparent, fish larvae manage to find and reach a coral reef when they have spent their entire lives in the open ocean, often one or two kilometres away? Even with everything that technology has to offer, Jeff Leis and crew had to resort to physically following their Lilliputian charges through the big blue to learn how they do this. Some amazing feats of olympic proportions are involved in getting these fish (not to mention the scientists) to where they want to go.

In this issue, we also take a look at the mysterious world of Port Jackson Sharks, discover Brown Tree Snakes in plague proportions, learn of the economic value of a healthy ecosystem, and wonder at the ease at which our shores have been invaded.

—JENNIFER SAUNDERS

letters

Native Pets

How refreshing to read Michael Archer's article (*Nature Aust.* Autumn 2000) on keeping native animals as pets, a sane and humane approach. The thing that keeps striking me about the laws that prevent us keeping native animals is that they are quite irrational. If we did our utmost to prevent habitat destruction, it would be a different matter; but we permit and encourage the destruction of forests and the clearing of land for agriculture and grazing, entirely for our own benefit, thereby actually killing unknown numbers of creatures. Do many of us, when watching logging or land clearing on television, wonder how many animals were destroyed in those few seconds?

Of course a few kept animals would be treated badly, as that is the nature of some humans, unfortunately. But the loss of life would be nothing compared with the results of our own legalised activities.

—Esme Wood
Galston, NSW

Well written, Michael Archer, regarding native companion animals. There seem no reasons (except ideological) why suitably reared Australian animals wouldn't be ideal pets. Anyone who dotes on Pit Bulls will love Tasmanian Devils. Quolls could render Ferrets obsolete.

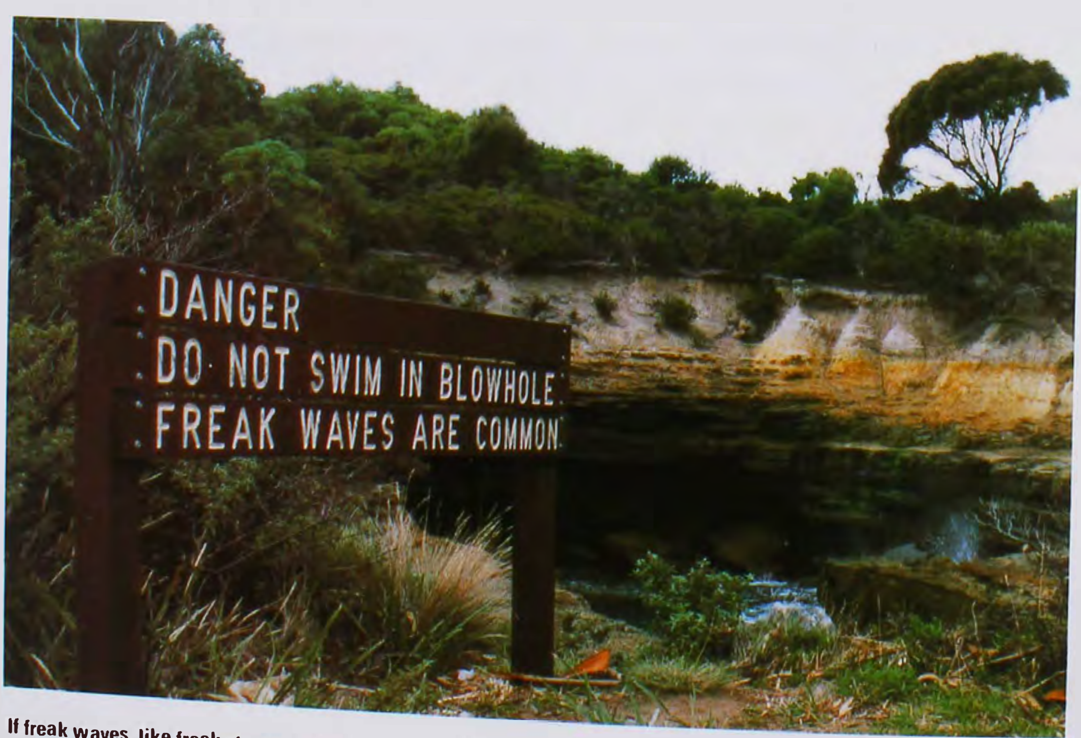
May I push the idea further? How do you stop fauna smugglers? Cut the market out from under the beggars! This approach was taken with the Wollomi Pine and Foxtail Palm. Natural populations are safe from criminals when commercially bred or propagated specimens are humanely, cheaply and legitimately obtainable.

Now I'll get radical and depart from Mike's opinion of Cats. My Persian has done much to assist many native bird species. Blasphemy? In ten years she has killed hundreds of birds. Her tally? One kingfisher, one Striped Honeyeater, numerous introduced starlings and turtle-doves, but mainly (90 per cent) Noisy Miners. And how do I know what she catches? She eats everything at the back door, invariably calling us to admire her prizes.

My suburb has a diverse and plentiful avifauna. There are a variety of habitats and a creek in the local park for water. Perhaps the diversity of bird life here is partly due to Cats. Tim Low wrote in *Nature Australia* (Spring 1994) about how Noisy Miners mob and peck other birds, driving them out of their territory. By culling Noisy Miners is my Cat not assisting gentler species? These could otherwise be excluded by overabundance of aggressive Noisy Miners in colonies with abutting territorial boundaries.

As the motto of one Scottish clan goes, touch not the cat but a glove.

—John MacPherson
Geebung, Qld



COURTESY ROBERT MCNAUGHT

If freak waves, like freak storms, are common, they are not freak!

Freak Storms not so Freak

It was pleasing to see the existence of tornadoes in Australia getting exposure in Geoff McNamara's interesting article (*Nature Aust.* Winter 1998). The news media regularly trivialise tornadoes and severe storms with terms like 'mini-tornado' or 'freak storm'. In the United States, there are no 'mini-tornadoes', only F0 tornadoes, as the news media are well briefed.

Perhaps the most galling term from the above is 'freak storm'. A dictionary definition states 'freak' as meaning something very unusual or irregular. However, 'severe thunderstorms' occur regularly, producing significant localised damage through hail, flash flooding, lightning, downbursts (powerful short-lived winds) and tornadoes. Clearly 'freak storms' are common!

With regard to the article, there is one other major reason for the importance of windshear in the formation of a tornado. Upper-level windshear separates the rising air in a thunderstorm, where a tornado occurs, from the downdrought (rain), thus preventing the downdrought from choking the airflow to an incipient tornado. This organised convection is well presented in the article's illustration.

—ROBERT H. MCNAUGHT
COONABARABRAN, NSW

Crows, not Ravens

John Scanlon's comical comments on crows in Letters (*Nature Aust.* Spring 1999) deserve critical comments in return, especially as they were judged prize-worthy.

While his discussion of the origins and evolution of Australian corvids is in line with current theory on the subject (which is at best at 'likely scenario' level and certainly not hard scientific fact), his knowledge of the birds themselves is perhaps wanting.

Not only could he not have seen a "group of ravens" at lunchtime on the University of Queensland campus (ravens don't occur within 100 kilometres of Brisbane—the birds he saw were undoubtedly Torresian Crows), his knowledge of their calls is obviously not good either, otherwise he would have had no difficulty in making a correct identification. To assert that all five corvids in Australia sound nothing like any of the other 15 species overseas is quite ridiculous.

—GRAEME CHAPMAN
JERVIS BAY, NSW

Anthropomorphism Still Not OK

After replies to my Letter (*Nature Aust.* Winter 1999) referring to Penny Olsen's article on Peregrine Falcons, I feel that I have not only been taken out of context, but wrongly accused as believing all human behaviour is learned and all animal behaviour is instinctive.

Olsen (*Nature Aust.* Summer 1999–2000) replied: "I believe it is human arrogance that asserts, as Portelli does, that animal behaviour is instinctive, not learned". I never made that assertion. Rather, I believe it is human arrogance that asserts animal behaviour is like that of humans and can be interpreted as such.

My opinion on instinctive behaviours in Peregrine Falcons concerned very specific aspects of courtship behaviour I clearly outlined. It's illogical to extend this to say I believe all animal behaviour is instinctive.

Anthropomorphism may lead to a better grasp of what the writer is trying to say, with more "impact and readability" as Angus Martin (*Nature Aust.* Autumn 2000) puts it, but this is not necessarily equivalent to a better understanding of the animal's behaviour.

My original point seems to have been lost. I believe anthropomorphism in describing animal behaviour is scientifically unsound and unnecessary. My intention was not to criticise Penny Olsen but rather draw attention to anthropomorphism.

—DEAN PORTELLI
WESTMEAD, NSW

Not So Remarkable Whiskers

I refer to the Nature Strips item "Seals 'See' with their Whiskers" (*Nature Aust.* Spring 1999). In it P.R. notes that Harbour Seals can detect vibration of prey animals through their whiskers and that "Remarkably, this is the first time that this type of sensory system has been confirmed in a marine mammal."

It is even more remarkable that no biologist has previously noted what thousands of interested spectators have observed in circuses and aquaria over decades, perhaps centuries. There would be very few readers who are not aware that seals can catch and balance balls on their noses. Surely some eager young naturalist has already pondered upon this problem, investigated it and published the findings.

I attended a performance at Sydney's Taronga Park a decade ago at which the young lady in charge explained that when seals/sea lions catch balls on their noses, they angle their whiskers so as to form a flower-like arrangement, with each whisker contacting the undersurface of the ball. You can reproduce the arrangement exactly if you extend your fingers and thumb outwards and upwards and place a ball on them. The young lady explained that whisker–ball contact provides the sensory feedback that enables the animal to keep the ball balanced.

Decades ago I read somewhere that Cats can tell whether a gap in a fence is too narrow for them to negotiate if their whiskers touch the sides. It may well be the first time "this type of sensory system has been confirmed in a marine animal", but remarkable it is not. To this reader, and I would think many others, it is patently obvious that whiskers in general are sensitive and those of seals and sea lions especially so.

—BARRIE GILLINGS
UNIVERSITY OF SYDNEY

Clearly you agree with P.R. that it is remarkable that this type of sensory system has only now been experimentally confirmed in a marine mammal!

—G.H.

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

nature strips

COMPILED BY GEORGINA HICKEY

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

Spitting Spiders

Spiders from the genus *Scytodes* are the picture of spider sociality. Members of the group show highly evolved maternal care that involves egg guarding and feeding the young hatchlings. Some also exhibit a benevolent nature and live in communes. And yet, when it comes to meal times, these civilised creatures lose all decorum, having adopted the vulgar habit of spitting.

Scytodes spiders have discovered the most effective way to immobilise their prey is to spit a goey net of gum over them. The secretion is propelled from the fangs and may be aimed from as far as 60 millimetres away (about ten times the spider's body length). Prey that struggle against the sticky gob are spat at repeatedly. As the spittle sets, the spider comes forward and stabs the prey with its fangs, wraps it up in silk, and either eats it on the spot or takes it back to the spiderlings in the nest.

Daiqin Li (currently at the National University of Singapore) and colleagues have been studying the behaviour of 'spitting spiders', including an undescribed species from the Philippines. They point out that the unorthodox method of prey-capture is necessary because of the spider's choice of prey: other spiders, particularly jumping spiders. A taste for dangerous prey, especially ones with very good eyesight, means they have to develop ways of nabbing them from a distance, to avoid being detected and even eaten by their prey. Remaining at spitting distance is especially important for the females, which carry their egg sacs (and the next generation) in their jaws. These mothers-to-be put down their egg sac while they capture and eat their prey, but return it to their loving jaws as soon as they've finished.

As far as the researchers know, *Scytodes* is the only genus of spiders known to spit for their supper.

—K.H.

On the Wings of a Song

Sounds do not preserve well in the fossil record, but the

COURTESY ROBERT R. JACKSON

Scytodes spiders spit for their supper, which in this case is a jumping spider (*Thiania* sp.) from the Philippines.

JEAN-PAUL FERRERO/AUSCAPE

discovery of six flutes (one nearly 9,000 years old) from the archaeological site of Jiahu, China, gives us insights into early Neolithic music. The flutes are made from the ulnae or wing bones of the Red-crowned Crane (*Grus japonensis*). They have between five and eight holes drilled at regular intervals and would have been played vertically like a recorder.

Juzhong Zhang (Institute of Cultural Relics and Archaeology of Henan Province, China), Garman Harbottle (Brookhaven National Laboratory, New York) and colleagues are waxing lyrical because, unlike previous claims of a 40,000–82,000-year-old flute from western Slovenia (see *Nature Aust.* Autumn 1999), the Chinese flutes are mostly complete and there is no question of their musical function. Indeed, the researchers played and recorded a tune from the best-preserved flute, one with seven holes and free of cracks (you can hear this for yourself; see references). Consequently it is the oldest playable musical instrument known.

In China music is traditionally associated with the order of the universe, and it is important in ritual performances and government affairs. The researchers therefore speculate that the flutes echo the integral role that music would have played in the ruling of a sound Neolithic Chinese society.

—R.F.

COURTESY INSTITUTE OF CULTURAL RELICS AND ARCHAEOLOGY OF HENAN PROVINCE

These ancient Chinese flutes, about 20–22 centimetres long, were crafted from the wing bones of the Red-crowned Crane (top). The flute second from the bottom was the one that was played, reproducing sounds not heard for nearly 9,000 years.

Dinosaurs of a Feather . . .

Over a decade ago, the charismatic and controversial palaeontologist Bob Bakker published some reconstructions of dromaeosaurs, the family of dinosaurs that includes *Deinonychus* ('terrible claw'), the creature on which the fearsome 'Velociraptors' of "Jurassic Park" fame were modelled. Bakker (now at Glenrock Paleontological Museum, Wyoming) thought that dromaeosaur skeletons were extremely bird-like, and accordingly dressed them in bird-like plumage. At the time, there was no evidence for feathers on any dinosaur, and Bakker's fanciful illustrations aroused both mirth and ire from more conservative palaeontologists. Even Steven Spielberg, who based his dinosaur stars on Bakker's reconstructions, baulked from actually covering them in feathers. However, despite

COURTESY XIAO-CHUN WU

their high public profile, dromaeosaurs were rather poorly understood. Many parts of their skeleton were incompletely known. Furthermore, while feathers have now been found in several groups of dinosaurs (see *Nature Aust.* Spring 1997), their presence had not been confirmed in dromaeosaurs. Thus Bakker's daring interpretations could neither be confirmed nor refuted.

Vital new information has recently been unearthed in China. Xing Xu (from the Institute of Vertebrate Paleontology and Paleoanthropology) and colleagues described an exceptionally well-preserved 125-million-year-old dromaeosaur that they dubbed *Sinornithosaurus* ('Chinese bird-like dinosaur'). It seems that Bakker will have the last laugh. The Turkey-sized creature was covered in down-like feathers, just as Bakker predicted. Furthermore, it had long extensible arms and a wide range of motion in the shoulder joint—a likely precursor for flapping flight. The pelvis and legs were also more bird-like than in any other dinosaur.

The Turkey-sized creature was covered in down-like feathers, just as Bakker predicted.

Sinornithosaurus has almost all the features predicted in a dinosaurian ancestor of birds. However, being 20 million years younger than *Archaeopteryx*, the first bird, *Sinornithosaurus* could not have been directly ancestral to birds. Rather, it must represent a late-surviving relict of the ancestral lineage. Nevertheless, it adds to the huge pile of evidence that birds are descended from small, bipedal, carnivorous dinosaurs such as dromaeosaurs. However, a small and shrinking group of sceptics still questions this idea on aerodynamic grounds. To them it seems more plausible for birds to have evolved flight from a tree-dwelling, gliding ancestor than from an Earth-bound 'Velociraptor'-like creature. This last objection has also been recently addressed. Joseph Garner and colleagues from Oxford University have shown how flight could have evolved in ground-dwelling dinosaurs—as an adaptation for pouncing on prey, with longer and longer jumps eventually leading to true flight. And in striking support of this idea, dromaeosaurs have been acknowledged by scientists and film-makers alike to have been extremely agile, leaping predators.

—M.L.

This specimen of the 'Chinese bird-like dinosaur' *Sinornithosaurus*, showing impressions of fine downy feathers, proves that feathered dromaeosaurs were not just figments of overimaginative palaeontologists.

Snorkelling Chicks

The chicks of the Wattled Jacana (*Jacana jacana*) have a clever way of hiding from predators. While the parent bird tries to distract the attention of the intruder by jumping around in a broken-wing display, the young chicks take to the water and fully submerge so only their beaks protrude above the surface. Chicks can remain motionless under water for several minutes as they have nostrils towards the end of their beaks, allowing them to snorkel.

Venezuelan biologists Carlos Bosque and Emilio Herrera (Universidad Simón Bolívar) examined members of four closely related families of wading birds to see if snorkelling was likely in these species too. By measuring the relative position of nostrils in museum specimens, the researchers found that these other species had nostrils located more towards the base of the beak (in the basal 10–12 per cent of the bill, compared to the basal third of Wattled Jacanas). While nothing like the extreme placement of kiwi nostrils at the tip of the bill, which is probably related to their well-developed sense of smell used in the pursuit of soil invertebrates, the difference between Wattled Jacanas and other shorebirds is statistically significant.

Although the researchers were unable to examine all jacana species (there are seven of them altogether), they suspect that the whole family exhibits relative forward placement of the nostrils and that it is probably a derived character that arose in response to predation pressure. The chicks of at least two other jacana species are known to hide under water and use their beaks like snorkels. It would be interesting to see whether Australia's Comb-crested Jacana (*Irediparra gallinacea*) does it as well.

—K.H.

Do Comb-crested Jacana chicks use their beaks as snorkels when faced with danger?

JEAN-PAUL FERRERO/AUSCAPE

Neanderthal Cocktail

Were Neanderthals and early modern humans distinct species, or did they interbreed to produce modern humans? Earlier DNA analyses on Neanderthal bones from Germany suggested that Neanderthals were too different from modern humans to be an ancestral candidate. This argument supported the theory that modern human ancestors emerged from Africa about 100,000 years ago and replaced resident Neanderthals in Europe and other archaic populations around the world. The Iberian Peninsula (Spain and Portugal) was their last European frontier where they are thought to have arrived and replaced the resident Neanderthals perhaps only 30,000–28,000 years ago. Many scientists support this 'Out-of-Africa' theory of replacement by modern humans and argue that Neanderthals were not in our family

COURTESY PORTUGUESE INSTITUTE OF ARCHEOLOGY

This 24,500-year-old child's skeleton, showing a blend of modern human and Neanderthal features, was not simply a product of a random cross-mating.

tree. However, a 24,500-year-old child's skeleton from Portugal is upsetting this received wisdom.

The skeleton, thought to have belonged to a four-year-old boy, is one of the most complete Upper Palaeolithic hominids ever found. The child had been covered in red ochre and buried, along with pierced shell and tooth ornaments, at the base of a cliff. Cidália Duarte and João Zilhão (Instituto Português de Arqueologia, Lisbon), along with Erik Trinkaus (Washington University) and others, argue that the bones reveal a curious blend of modern human and Neanderthal features. Limb proportions were decidedly Neanderthal, while the presence of a 'chin', the relative size of the teeth, and aspects of the pelvis were more modern. Other features of the skull (the temporal bone) were intermediate.

The evidence is hotly debated, in part because it presents a challenge to 'Out-of-Africa', the popular model of human evolution. And the reason for this rests in the skeleton's 24,500-year-old date, which is at least 3,000 years after modern humans arrived in the region and supposedly replaced the Neanderthals. The researchers therefore argue that the hybrid child is unlikely to have been the result of a rare random mating—a 'love child', so to speak. Rather, they believe the child is the product of a long-term affair between the invading and resident populations. Some would say this sinks 'Out-of-Africa', because you can't have it both ways. However, Duarte and colleagues prefer a watered-down version with long-term (modern) human dispersal out of Africa with a variable degree of interbreeding with the people they met on the way.

—R.F.

Turn Off the Night Light

Night lights left on by well-meaning parents could contribute to short-sightedness in children. That's the disturbing finding of recent medical research from the United States.

Known also as myopia, short-sightedness makes it difficult for the eyes to focus on distant objects. It's a condition that is on the rise in humans. In some Asian populations, for example, up to 70–90 per cent of people are afflicted. Mostly, glasses with prescription lenses help. But more worrying is the fact that myopia predisposes adults to more serious problems that can lead to blindness.

It's known that myopia often results from excessive eye growth after birth, but what causes this is not fully understood. Graham Quinn and colleagues from the University of Philadelphia School of Medicine, however, have shed some light on the matter.

Over a six-month period, parents of children aged between two and 16, who were seen as outpatients at the University's eye clinic, were asked to complete a questionnaire about their children's levels of light exposure. The researchers found a strong association between the prevalence of myopia during childhood and night-time light exposure during sleep in the first two years after birth. No association was found between the development of myopia and use of a night light at older ages. This is heartening, as nightmares in children (the main reason for night lights) don't develop until after the age of three.

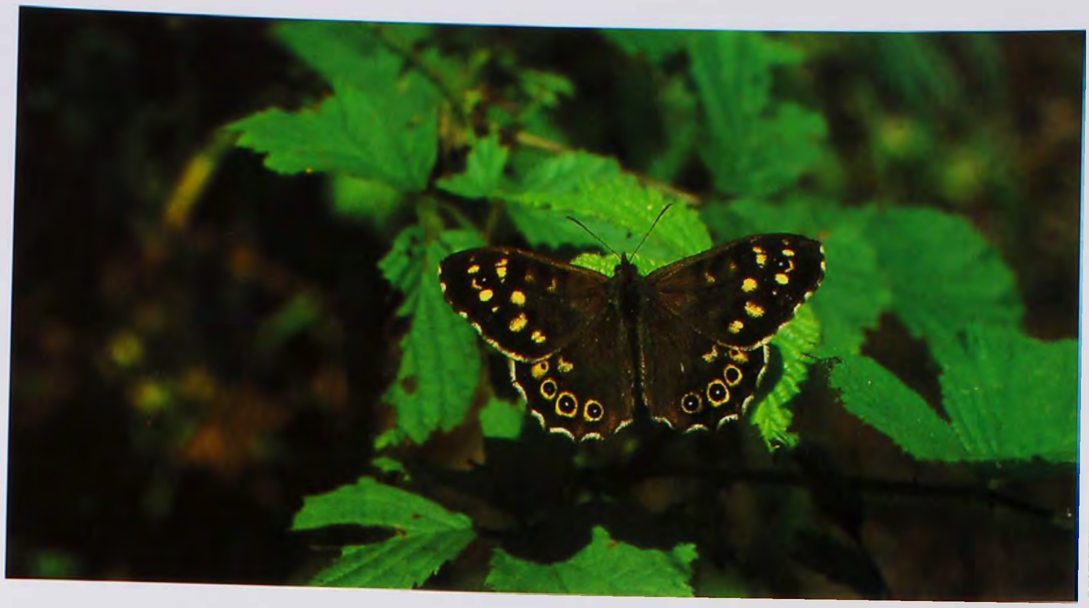
The researchers found a strong association between the prevalence of myopia during childhood and night-time light exposure during sleep in the first two years after birth.

According to Quinn and colleagues, even closed eyelids allow some light through—apparently enough for young children sleeping with a night light to miss out on a daily dose of darkness during a period when it is developmentally important to their eyes.

Two subsequent studies, led by Karla Zadnik (Ohio State University) and J. Gwiazda (New England College of Optometry), did not support Quinn *et al.*'s findings. Instead they believe myopia has more to do with genetics than the environment, so any association between myopia and night-time lighting at infancy would be because of the parents' need to illuminate the children's bedrooms to see them more clearly at night.

Quinn and collegues agree more work is needed to clarify and explain their findings. Until then, they advise parents with kids under the age of two to err on the side of caution and turn off the lights.

—K.McG.



COURTESY CHRISTER WIKLUND

Slight asymmetry in wing size may be used to the Speckled Wood Butterfly's advantage.

Lopsided Butterflies

With all the weird and wonderful shapes in nature, there is one general design rule that applies to most animals—that of symmetry. Any departures from this rule are usually explained as mistakes in the developmental process, for symmetry is the desirable state that makes us sexier, healthier and more mobile. So when a species of lopsided butterfly turns up, how is this exception to the rule explained?

Jack Windig and Sören Nylin (University of Stockholm, Sweden) have measured the wing symmetry in the Speckled Wood Butterfly (*Pararge aegeria*), and their results have proved a little skew-whiff. Scanning-image analysis showed the right wings of the white territorial males to be bigger than the left, while females and the non-territorial black males are even more asymmetrical, although they show no bias to either side. For a butterfly this has major implications for flight, yet the zoologists have suggested a link between these wonky wings, in territorial males at least, and flight combat.

White males defend their

COURTESY JACOB GONZALEZ-SOLIS

territories from intruders by spiralling in a 'spinning-wheel' dance, attempting to eject their rivals by swooping on them and bouncing them out of the way. Males with larger right wings would be able to make sharper turns, giving them the edge in these jostling bouts.

Windig and Nylin suggest that the skewed design of territorial males is a result of sexual selection via male–male competition. While this hypothesis remains speculative, more answers are needed to explain the random asymmetry seen in females and non-territorial males, which need to fly on the straight and narrow.

—K.H.

One Late Tern Deserves No Other?

Getting to the church on time is important for human marriage rituals, but tardiness in terns may be grounds for divorce. Like many seabirds, Common Terns (*Sterna hirundo*) pair with the same mate year after year. But, from one year to the next, 20 per cent of birds divorce their partners for new mates. Previously researchers thought these birds might be choosing better partners but a recent study by Jacob Gonzáles-Solís and colleagues (Institute for Bird Research, Germany) provides a different explanation.

Common Terns arrived in their northern European breeding colonies from South African waters in May. Most birds arrived within two days of their partners and re-affirmed their 'marriage bonds'. But when birds arrived more than seven days apart, divorce increased to 35 per cent. Divorce was not affected by the success or failure of the previous year's breeding, nor did new and divorced partners differ in condition or breeding success. Rather, the terns seemed to divorce only when their old partner failed to turn up in time.

Regular pair-bonds speed up finding a successful partner each year, allowing terns to breed more quickly. But fidelity may cost a bird its breeding season if a partner dies or is delayed for too long. Seeking a new partner after a week of waiting ensures that even a widowed bird can still breed successfully. A late-arriving divorcee, however, is less fortunate. It often fails to pair and has to 'sit out' the season.

So if getting to the church on time was stressful for you, spare a thought for the poor terns that not only have to do it every year after a 10,000-kilometre migration, but also risk being dumped if they're late.

—D.C.

Renewal of marriage vows in Common Terns depends on the timing.

Magpie! Duck!

Early spring: a fellow human is in rapid retreat, arms flailing wildly above his head in a futile attempt to ward off a dive-bombing black-and-white streak. Aggressive attacks on humans by Australian Magpies (*Gymnorhina tibicens*) are the cause of a major human–wildlife conflict. Every year during the Magpie's breeding season (August to November) many people are victims of the birds' defensive behaviour. Most attacks are non-contact, but some result in serious injury. In many cases, people can avoid areas where menacing Magpies occur and simply wait for the problem to pass, but in some circumstances, such as in the schoolyard, the problem is hard to ignore.

Most communities oppose killing the offending birds, which is a common solution of many wildlife agencies. As an alternative Darryl Jones and Paul Finn of Queensland's Griffith University set out to assess the effectiveness of translocating the aggressive few (all males) intent on disturbing the human peace.

Twenty Magpies were trapped and relocated at distances between 17 and 150 kilometres from their capture site. No birds released at distances greater than 30 kilometres returned to their home territory during the study. In nearly half the cases a new male moved into the territory of the translocated male within several days.

Translocating aggressive Magpies solved the human–Magpie conflict, at least temporarily. What remains unresolved, though, is the fate of the translocated males and the long-term implications for the affected Magpie populations. Possums relocated from people's roofs to bushland tend to die within a few days of their release. Available evidence suggests, however, that Magpies may fare better.

In the eyes of the general community, translocation, as opposed to euthanasia, may well be a more acceptable way of dealing with the human–Magpie conflict, but it is still far from certain whether it is less stressful and traumatic for the individual animals involved.

—J.M.

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Translocation may seem a 'nicer' way to deal with the human–Magpie conflict, but does it work?

HANS & JUDY BESTE/LOCHMAN TRANSPARENCIES

It pays to know how to reduce encounters with Eastern Brown Snakes.

Dress Sense for Snakes

Stop for a beer in a pub around Leeton, New South Wales, and the locals may warn you to keep clear of Eastern Brown Snakes (*Pseudonaja textilis*). Take their advice! These reptiles kill more people in Australia than any other snake.

The same well-meaning bar flies may tell you the reason for this: that browns are aggressive snakes and will chase you down for a bite. Assign that one to folklore! It has more to do with the high densities in which Eastern Browns occur in farmland, making them likelier than most venomous species to accidentally encounter a human.

In the interests of saving both species' lives, University of Sydney herpetologists Patrick Whitaker and Rick Shine set out to determine factors that reduce chance meetings between Eastern Browns and humans. Over three years the researchers walked up and down transects across Leeton farms, each time recording the weather conditions, their own behaviour and appearance, and the response of the snakes to their presence. They inserted miniature radio-tracking devices into as many Eastern Browns as possible to indicate numbers of the reptiles around during the transect walks.

The research proved that, contrary to popular belief, Eastern Browns are reluctant to attack humans and, given the chance, will hide or flee with the approach of a person. And it showed, for the first time, that a person's appearance affects the chance of an encounter. Whitaker and Shine recommend people wear clothes that contrast with the prevailing sky colour, to give snakes the best warning of approach and thus the opportunity to avoid contact.

Chance encounters can also be reduced by moving slowly, keeping to thick ground cover (the snakes feel more protected and are less likely to attack), avoiding undisturbed and known refuge areas during the middle of the day (especially in spring), and being particularly wary on cool, windy and cloudy days.

—K.McG.

The Tickle Paradox

Most people say they hate being tickled. So why does it make us laugh so much?

Christine Harris (University of California, San Diego) recently applied her mind to this ticklish problem and found that, while it is easy to imagine an evolutionary function for light tickle or knismesis (the annoying sensation created by crawling parasites would prompt an animal to scratch or rub the tickled spot), it is more difficult to determine the adaptive value of heavy tickle or gargalesis, which occurs when greater pressure is applied to ticklish areas.

One explanation is that it facilitates the bond between child and parent, as it is often a parent that does the tickling. But other work has shown that children still laugh even if they can't see their parents' smiling, masked faces while being tickled. Nor, according to Harris' own experiments with blindfolded uni students, does it matter whether a human hand or machine is doing the tickling, so human interaction is not necessarily the key.

Another suggestion is that we are most ticklish in the places vulnerable in arm-to-arm combat, and being ticklish there motivates people to protect those spots. But in this situation, hands and fingers would be most vulnerable, and they aren't ticklish. Besides, says Harris, it is difficult to imagine what benefits smiling and laughing would confer in the combat zone.

Harris tentatively suggests an alternative hypothesis. She believes that heavy tickling may help in developing combat skills in the person being tickled (recall the desperate struggles needed to stop the tickler). And, if tickling produced a negative facial expression, we would be far less likely to engage in that activity during play.

—R.S.

Shellfish Feelings

Few people think shellfish experience anything like fear (especially as they tip another freshly shucked oyster down their throats). But research by Francesco Rovero (University of Florence) and colleagues into the responses of Common Mussels (*Mytilus edulis*) to predators casts a whole new light on shellfish 'feelings'.

Dogwhelks (such as *Nucella*

lapillus) are ferocious mussel predators. These 'lions' of the underwater savanna sniff down their prey and rasp a hole through the hapless mussel before ingesting its tasty innards. This is no quick death—it can take days to drill through the mussel shell. Some experienced dogwhelks, however, dispatch their mussels more quickly by thrusting their proboscis directly between the mussel's two shells.

So how do the mussels react to all this? Until recently, the only way to measure a mussel's pulse was to drill a hole through its shell—enough to get any mussel's heart racing. Rovero and colleagues instead used a less invasive method that involved gluing a phototransducer with an infra-red diode on the outside of the shell. They were able to show that a mussel's heart rate increases with the mere presence of a dogwhelk, or even just its odour, in the aquarium. The increased heart rate allows mussels to quickly snap shut their shells, which may deter dogwhelks from attacking directly between them. However, there is little the mussel can do to prevent dogwhelks from embarking on their slow drill of death. In this situation, the mussel's heart rate continues to increase even as the dogwhelk begins to feed. This probably has the effect of prolonging the inevitable, but then who can blame a mussel on death row for struggling to the last?

—D.C.

Ants in your Plants

Out on the East African savanna, competition among ants is fierce. Four species of ants vie to establish colonies in the Whistling Thorn Tree (*Acacia drepanolobium*). The ants and acacias have a symbiotic relationship, whereby ants house workers and raise broods in the swollen bases of acacia thorns, and in return remove leaf-foraging insects.

Crematogaster nigriceps prunes its host tree to keep rival ant species at bay.

COURTESY MAUREEN STANTON, UNIVERSITY OF CALIFORNIA, DAVIS

At the Mpala Research Centre in Kenya, Maureen Stanton (University of California, Davis) and colleagues staged conflicts between the different ant species by tying together the branches of adjacent trees. Two of the ant species were particularly aggressive, streaming onto the adjoining tree and attempting to dislodge the resident workers and broods; another species put up a brave fight, successfully defending its colony most of the time; while poor old *Crematogaster nigriceps* was usually evicted.

Although *C. nigriceps* may be a wimp when it comes to defending its colony, it does have a rather ingenious way of dealing with nasty neighbours. It prunes its host tree, chewing off the young shoots, thus reducing sideways growth and the likelihood that the branches will contact adjacent trees. In the process, it may even sterilise the tree. The researchers noticed that trees occupied by *C. nigriceps* were more asymmetrical than those occupied by other ants. It seems that *C. nigriceps* selectively prunes only the sides adjacent to other trees with ant species other than its own. The researchers suspect that *C. nigriceps* detects the presence of aggressive neighbours through potent alarm pheromones, which are known to be produced by some ants when disturbed.

—A.T.

JEAN-MICHEL LABAT/AUSCAPE

Handaxes: stone tools doubling as sex tools?

Sex Axe

Sex and stone—about the only thing they have in common is their first letter. But not according to a study of handaxes by British archaeologists Marek Kohn and Steven Mithen (University of Reading).

Handaxes are two-sided stone artefacts that first appear in the archaeological record of Africa, Europe and Asia about 1.4 million years ago. They are pear-shaped, with a point at one end and rounded at the other, and are thought to have been multi-purpose tools, used by various human ancestors to butcher meat, chop vegetables and fell game. Kohn and Mithen, however, believe they were used to procure more than just a meal—they were used to procure sex as well.

The high degree of symmetry and unusual size of some handaxes suggest they were unnecessarily fancy and over-designed for the proposed mundane economic tasks. What's more, many appear to have been unused and they occur in great abundance at some archaeological sites. To explain these features, Kohn and Mithen argue that handaxe production by males could have operated as a costly indicator of good genes—in the same way that a peacock's train is used to signal the genetic quality of its owner.

A fine, symmetrical handaxe was not easy to make. Not only did it require good eyesight, strength and coordination, but also a sound knowledge of local resources, an ability to plan, and a high degree of determination. As the researchers put it, "handaxe production would have been a 'test of character'," on the basis of which females could have chosen mates. Unlike a peacock's train, however, handaxes were not attached to the body. To rule out cheats who laid claim to another man's tool, a female had to witness the actual process of manufacture. As such, handaxe production would have served as an aesthetic display by males to attract females. The final product may not have had any great economic advantage and may simply have been discarded.

The sex-axe proposal also provides a neat explanation for why the technology, having remained virtually unchanged for over a million years, finally died out. Kohn and Mithen argue that, by this time, humans had evolved bigger brains and slower-maturing offspring. With the increased costs of reproduction, females could no longer simply forage for themselves and instead relied on the males to provide for them. Females were forced to shift their mate-choice criteria from indicators of good genes to proof of reliable food-provisioning skills. So handaxes, which were extremely costly to produce, were ditched in favour of more functionally efficient tool kits, including spears with stone points.

—R.F.

Cuttlefish Do it in Drag

What's the best way to slip undetected into the company of a desirable female? If you're a cuttlefish, dress in drag and make your move when the manly guard is distracted.

Mark Norman (James Cook University) and colleagues first observed these shenanigans while investigating male mate-guarding behaviour in the Giant Cuttlefish (*Sepia apama*) in the Spencer Gulf, South Australia.

Octopuses and cuttlefish possess unequalled ability to change their shape and body patterns. Most noticeable during mating, males dazzle the normally mottled females by pulsing zebra stripes across their bodies and extending the white-fringed, banner-like webs on their arms.

The researchers noticed that, during the mating period, male–female pairs were often closely shadowed by what seemed to be a second female. However, when the larger male was engaged in combat with other males, the shadowy 'she' turned out to be a 'he', seizing the opportunity to mate with the female, often successfully. Some of these sneaky suitors would display banners and moving stripes like a regular courting male; others would remain in drag. The behaviour of the cuckolded male also varied, from ignoring the pair, to aggressively separating them. However, if the satellite male donned protective female colouration, rather than the flashier mate-guarding alternative, any antagonistic behaviour would stop immediately.

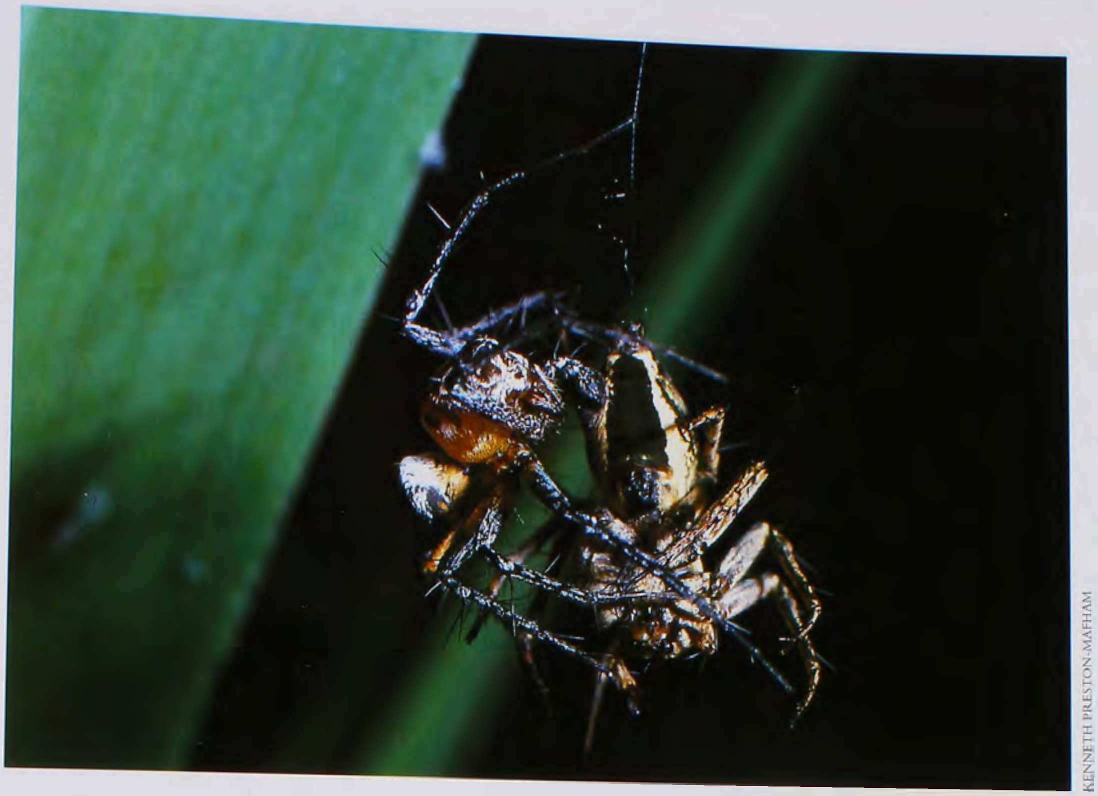
In the absence of larger rivals, males that had previously been seen to mimic females displayed typical male body patterns, and courted females normally. As there is no information on ageing in the Giant Cuttlefish, the researchers don't know whether this behaviour is simply a strategy for younger animals or, more significantly, an alternative strategy for undersized males that can't compete with big beefy males of their own age.

—R.S.

Veils for Spider Brides

Female spiders commonly react to sexual advances with a deadly bite. In response, many male spiders have evolved strategies to distract or control females while they deposit their sperm. The silken net known as a 'bridal veil', which some spiders wrap around their paramours during courtship, is widely regarded as one such strategy. However Kenneth Preston-Mafham from Cornwall (UK), after recording this behaviour in a Ugandan lynx spider *Oxyopes schenkeli*, believes the veils serve a different purpose.

Courtship in *Oxyopes schenkeli* begins with the female resting on top of a blade of grass. The male approaches cautiously from beneath and slowly eases himself onto the upper surface of the blade. He then taps the grass with his front legs and starts to caress her from behind. The female responds by dropping from the grass blade on a silk dragline. While she is suspended head-down, the male follows and twirls the female around and around, wrapping her in a swathe of silk. With the female adorned in her 'veil', the male then tries to insert his palp (copulatory organ). But in all instances witnessed by Preston-Mafham, the females, many of which were already heavily laden with eggs, quickly lost interest and easily shrugged off their gossamer 'bonds'. In only one instance was the male eaten.



KENNETH PRESTON-MAFHAM

A male lynx spider (*Oxyopes schenkeli*) twirls the female around while he wraps her in a silken veil.

The ease with which the bridal veils were torn suggests to Preston-Mafham that they are not a form of arachnid bondage. Rather, he suspects the veils are impregnated with male hormones, which may help subdue or prepare the female for mating.

—K.McG.

Gumnut Babies

Move over Snugglepot and Cuddlepie. Gumnut 'babies', this time of the eight-legged variety, have been discovered in Western Australia.

During a biogeographic study of the Gondwanan spider genus *Carepalxis*, Barbara York Main from the University of Western Australia recorded 47 specimens from Western Australia, 30 of which had been collected from the nests of mud wasps. Previously the genus was only known from the eastern States, and also South and Central America and New Guinea.

One particular specimen, which Main collected while working on canopy spiders in West Cape Howe National Park, was an extraordinary gumnut look-alike that she found amongst the flower buds and seed capsules (gumnuts) of a Jarrah tree (*Eucalyptus marginata*). She would have passed it by without notice, had it not flexed its legs at just the right time. About half a centimetre across and with its legs tucked beneath it, the spider had the same shape and colour of a gumnut, including a dark, circular pattern on its back that looked just like the opening of a nut from which the seeds are shed.

COURTESY BARBARA YORK MAIN

A gumnut-mimicking spider (*Carepalxis* sp.) from Western Australia.

C.B. & D.W. FRITH

Tooth-billed Bowerbirds put their 'pinking shears' to good use to supplement their winter diet.

The spider was kept in the laboratory with some dry Jarrah twigs for a month. During this time it constructed an orb web between two of the branches. It would sit in the web by night, but rest alongside a gumnut by day.

Main believes gumnut mimicry evolved in this spider as protection against bird predators, such as honeyeaters. However she notes that four of the specimens collected from wasp nests also showed the peculiar, round, gumnut-like markings. Apparently the gumnut disguise is no foil for wasps on the lookout for spiders to stock their larval pantries.

—G.H.

Let Them Eat Leaves

A curious feature of tree-nesting birds is that, although they are usually surrounded by a leafy canopy, few of them actually eat leaves. The Tooth-billed Bowerbird (*Scenopoeetes dentirostris*), from the tropical upland rainforests of the Australian Wet Tropics, has proved to be an exception to this rule.

Tooth-bills are the only bowerbirds to have specialised interlocking notches, or 'teeth', on their bills, which resemble pinking shears. Both sexes develop 'toothy' bills but only males use their 'teeth' to bite, snip and saw off leaves to decorate their courts. A recent ecological study by Clifford and Dawn Frith (Queensland Museum), however, has shown that leaves are more than just decoration; they form an important part of both sexes' diet.

During the summer months, Tooth-billed Bowerbirds ate mainly fruits, gulping them down whole, but during winter when fruits were scarce, they were seen tearing off leaves, buds and vine stems, and grinding them between their 'teeth' before swallowing. The Friths estimated that up to 40 per cent of their winter diet may consist of leaves.

As well as changing their dietary preferences during winter, the Tooth-bills also changed their behaviour. The birds became relatively inactive and did not fly as much as they did during 'fruit-full' times. Perhaps this low-energy lifestyle option with a diet of abundant leaves, outweighs the higher-energy option of actively searching for scarce winter fruits.

The Friths believe this change in diet and behaviour during winter evolved, in part, as a response to intense competition with other fruit-eating birds.

—L.S.

Spiders Enjoy the Bright Lights

Many nocturnal insects are attracted to light, 'like moths to a candle' as the saying goes. And wherever there is an abundance of insects, there is an abundance of insect predators, including spiders. Astrid Heiling from the University of Vienna noticed nocturnal orb-weaving spiders (*Larinioides sclopetarius*) clustered along the lit handrails of a footbridge across the Danube Canal. Had individual spiders learnt through trial and error where the abundant insects were, or did the spiders instinctively set up webs in lit areas where prey promised to be more forthcoming?

Heiling found that there were indeed more insects and spiders on the lit segments of the bridge than on the structurally identical unlit segments. She then demonstrated that wild spiders in the laboratory overwhelmingly prefer lit over unlit chambers, even when prey abundance was identical. So is this preference for light innate or learnt? Heiling raised spiders in the laboratory, feeding them equally during the day and night. Nearly all these naive spiders also preferred to set their webs in the lit rather than unlit chambers.

Street lights don't figure prominently in spider evolutionary history, but moonlight-reflecting water does. This species of spider is particularly abundant around waterways, which also attract numerous insects, and the preference for light may allow spiders to spin their webs near rivers and abundant food. So as the orb-weavers gather around lights on a footbridge over the Danube, they are not as far removed from their evolutionary origins as we might have first thought.

—D.C.

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QUICK QUIZ

1. *Who was named Australian of the Year 2000?*
2. *What are GMOs?*
3. *In the waters of which State does Australia's first officially endangered marine fish, the Spotted Handfish, live?*
4. *What is the common name of* Macropus rufus*?*
5. *Which country was formally known as Burma?*
6. *What plumage feature of male House Sparrows distinguishes them from females?*
7. *Name one of the two islands on Australian Territory that have active volcanoes.*
8. *What name is commonly given to fossil plant resin?*
9. *How many penises do snakes and lizards have?*
10. *What is the name of the ancient dye that comes from murexes (marine molluscs)?*

(Answers on page 83)

A coil to account

Brown Tree Snakes are the terminal nightmare of sleeping birds, warm eggs and scrawny fledglings.

ANYONE WHO, IN THEIR YOUTH, kept an aviary of small birds, will remember the gnawing temptation to poke fingers into feathery nests and do a braille reading of what's going on inside. My early proclivity for doing it, undoubtedly inflamed by a Dutch ancestry, was a great undoing. While Canaries were always indifferent to the interference, some of the more timid finches resented physical intrusion near their nests so much that they could dispassionately abandon eggs or chicks if you so much as dreamed about it at night.

So by bitter experience and nail-biting impatience, eventually I learned the lesson of wait-and-see and, by the time I'd saved the two pounds needed to buy a longed-for pair of Gouldian Finches, I'd become a paradigm of patience, determined to sit out the unbearable days of incubation and fledging with the resolve of a fasting guru.

Eventually the prized birds chose a nest box high up, lined it with grass and presumably laid eggs because five weeks and ten fingernails later, six olive-coloured youngsters burst out of the nest, spent the day learning to fly, then returned that night. The next day, curiously, only five came out; the day or so after that four, then three, then the mother disappeared and, by the end of the second week, with no clues to the escalating disappearances, only the stunned-looking father was left.

It was clearly time to reinstate the old index finger to its former glory and do some serious nest-probing. Itching to do what it knew best, it began its house search inside the box, down into the nesting chamber, all the way to the bottom and . . . into the cold bony coils of the snake curled up inside!

The lumpy loops belonged to a well-fed Brown Tree Snake (*Boiga irregularis*)—voyeur inside the honeymoon suite for goodness knows how long, and stuffed by room service each night. Being long and lithe, it had squeezed through the bird wire with little resistance; and being nocturnal (with huge yellow eyes and vertical cat-like pupils), it had gone about its moonlighting undetected.

In the wild, Brown Tree Snakes are the terminal nightmare of sleeping birds, warm eggs and scrawny fledglings. But not for a moment does that mean these snakes are reluctant about tackling more lively prey. I remember watching one coiled and dangling from branches over the entrance to an old molybdenite mine near Townsville. There it snapped bent-winged bats out of the air as easily as King Kong picked off tiger moths flying around the Empire State Building.

When birds, bats and eggs are off the menu, Brown Tree Snakes will readily turn an appraising golden eye toward night-scurrying lizards like geckoes. With so many interesting foods to choose from and such an easily tickled palate, why doesn't Australia have Brown Tree Snakes coming out its ears? Queensland University tree-snake researcher Joan Whittier says that natural regulation of Brown Tree Snake numbers lies somewhere in the delicate balance between predation, prey, pathogens and parasites.

Whatever we have that controls Brown Tree Snake numbers, the tiny island of Guam wishes it had it too. Guam (described by one product-review service as ". . . Gilligan's Island on steroids, a tropical dirty-weekend diorama, and a real nice place for thousands of military personnel to get a tan") is to Brown Tree Snakes what Europe was to bubonic plague. A Northern Hemisphere US military base east of the Philippines, Guam (population 156,000) can probably thank the US for introducing to it a snake that, when it comes to food processing, makes a Kenwood Chef look like a mortar and pestle. The out-of-place tree snake was presumably brought to the island accidentally, curled up inside military paraphernalia salvaged soon after World War 2, and probably from the northern mainland area of Papua New Guinea.

By 1960 the snake had reached all parts of the island and by 1985, when the population explosion peaked, it was calculated that Guam had, in places, up to 5,000 Brown Tree Snakes per square kilometre (that is 50 per hectare, some authors putting it as high as 100 per hectare). Around that time, researcher Julie Savidge (Guam Division of Aquatic and Wildlife Resources) noted that, of the 18 native and seven introduced birds, ten forest-dwelling species could no longer be found throughout the island but only on the far northern tip. Today, those ten and two others are reported to have been exterminated and most of the remaining species are now threatened. Even poultry farmers on Guam lost the battle growing domestic fowls and producing eggs for local needs, and Guam is forced to import around seven million eggs annually. In addition, two species of geckoes and one skink have disappeared from the island, other lizards have declined, and Guam's bats are also at risk.

Their success at gobbling Guam's fauna appears to have gone to their heads because Brown Tree Snakes regularly have a chew on young Guamanians. Between 1989 and 1995, 74 toddlers less than three years old and 42 infants less than one year old were treated in Guam hospitals for bites, most of which had been made on the children while they slept.

And as if that wasn't enough, foraging snakes (in Guam they grow up to 2.9 metres) often slide among electricity lines via guy wires and overhanging foliage. Up there, as monotonously as the wet season storms, they fry themselves trying to reinvent the carbon arc. You might think the plume of flame and smell of cremating scales would bring a wry smile to residents' faces. But since 1978 there have been around 1,200 blackouts and short-circuits in transmitters, to the great cost and frustration of not only the electrical authority but all the consumers that

BY STEVE VAN DYCK

see this foreign coil as nothing more than an infuriating impediment to their steady flow of electrons.

Returning to the question of why Australians sleep better, drink colder beer and eat more omelettes than Guamanians, Joan Whittier explains the Guam imbalance in terms of their Brown Tree Snakes lacking the controlling pathogens, gut and blood parasites, and other diseases associated with normal 'healthy' reptile assemblages. Guam has only one native snake (an unrelated burrower) but an OD of small, introduced lizards (*Hemidactylus* and *Carlia* spp.). Young Brown Tree Snakes have almost unlimited access to a diet of these small lizards, which boosts them to a length of one metre in their first year, and takes them on to full reproductive condition in their third. With no real reptile reservoir for diseases, few intermediate hosts for parasites, and virtually no predators, Guam's introduced tree snakes run riot unmuzzled.

Gobbled Gouldians and Guam don't justify us carrying torches and long-handled secateurs out into the garden every night looking for revenge. It's easy to see change inside cages and islands, not so easy in continents (where we pretend our ecosystems operate in 'balance'). While Brown Tree Snakes decimate Guam's birds, they just might be the same species that regulates the number of Noisy Miners in my yard! They might owe me a few finches . . . but I might owe them my sanity! Who knows? I don't want to be the one to point the finger.

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DR STEVE VAN DYCK IS A SENIOR CURATOR OF VERTEBRATES AT THE QUEENSLAND MUSEUM.

Brown Tree Snake

Boiga irregularis

JIM FRAZIER/AUSCAPE

Classification

Family Colubridae (venomous and non-venomous, rear-fanged snakes, 8 genera).

Identification

Adults around 1.5 m up to a max. of 2 m; brick-red to cream with dark cross-bands; broad, flat head narrowing sharply at neck, large yellow eyes with cat-like pupils. (Guam snakes genetically identical to PNG population but scale count differs.)

Distribution

Occurs naturally in the Solomons, eastern Indonesia (as far west as Sulawesi), PNG and eastern/northern Aust. Stowaways found in Hawaii, Diego Garcia, Texas. Broad range of coastal habitat tolerances from mangroves to open forest.

Behaviour

Nocturnal. Eats mostly birds, eggs, mammals and lizards (but recorded devouring spare ribs and soiled tampons). Astonishingly agile, can hold 3/4 of body off ground, forms figure 8 before striking, kills by constriction, mildly toxic, not considered dangerous to humans. Can last 6 months without food but only 1 week without water.

Breeding

Twelve leathery eggs (up to 2 clutches per year) left in caves, hollows, buildings. Hatching occurs after 90 days, newly hatched young 450 mm. Females can hold sperm internally 6 months before fertilisation.

Banded Hare-wallaby

Hare-wallabies were given their common name because of their hare-like speed and ability to jump.

IN AUGUST 1699, WILLIAM DAMPIER landed on an island in Shark Bay, Western Australia, and glimpsed "a Sort of Raccoon". This strange jumping creature with short forelegs was probably the first description of a Banded Hare-wallaby (*Lagostrophus fasciatus*) by a European. About a hundred years later, François Péron collected the type specimen from Bernier Island in Shark Bay, and recorded in detail a technique used for capturing them, providing valuable information on their habits at the same time. He described how they lived in patches of dense scrub thickets, which were crisscrossed with several covered paths that met in the centre. Beating the bushes with sticks would force the hare-wallabies out of one of these paths, where they would be greeted by hungry "sportsmen". Péron described their flesh as being similar to Rabbit but tastier.

At the time of colonisation, the Banded Hare-wallaby was also found in the south-west portion of Western Australia in areas of shrub woodland and shrubby sand plain. The last specimens from mainland Australia were collected in the wheat belt of Western Australia in 1906. This loss pre-dated the arrival of the Fox by 15 years, and was at about the same time that Rabbits arrived in the area. Their extinction may have been due to a combination of habitat alteration, caused by the introduction of domestic stock and the burning of thickets of vegetation inhabited by the hare-wallabies, hunting, and predation by feral Cats. Fortunately, about 7,000 animals survive on Bernier and Dorre Islands in Shark Bay, which were declared nature reserves in 1957, and today the species is classified as 'vulnerable'.

MARIE LOCHMAN/LOCHMAN TRANSPARENCIES

Hare-wallabies were given their common name because of their hare-like speed and ability to jump. While Rufous and Spectacled Hare-wallabies are similarly named, they belong to a separate genus, *Lagorchestes*. The Banded Hare-wallaby, having first been assigned to the genus *Kangurus*, and then variously to *Macropus, Halmaturus* and *Lagorchestes*, was finally assigned to its own genus, *Lagostrophus*. It is readily identified by its naked muzzle, and also its striking banded colouration, known only in two other marsupials, the Numbat (*Myrmecobius fasciatus*) and the extinct Thylacine (*Thylacinus cynocephalus*). The Banded Hare-wallaby is the only survivor of a large group of 'sthenurine' macropods, characterised by their lower and upper incisors biting together. In all other species of hare-wallaby, and in fact all other macropods, the lower incisors bite behind the upper incisors, and the rumps are unbanded. The other hare-wallabies also sport a hairy muzzle.

Very little of the biology and habits of the Banded Hare-wallaby are known due to its rapid decline from the mainland after European settlement. However, the island populations have provided us with the chance to study this species in its natural habitat. Banded Hare-wallabies shelter during the day amongst dense thickets of scrub, dominated by such species as Umbrella Bush (*Acacia ligulata*), Wirewood (*A. coriacea*), Mingah bush (*Alectryon oleifolius*) and the Wild Rose (*Diplolaena grandiflora*). Adults average 1.6 kilograms and there are no obvious differences between the sexes. Females are able to produce offspring at a body weight of one kilogram. Like kangaroos, females remate shortly after giving birth and retain a dormant blastocyst, which can develop if the pouch young is lost. Pouch life is about six months, with females generally having a single offspring each year. Young typically leave the pouch in spring, at a time when food is abundant. Banded Hare-wallabies are herbivorous, feeding on grasses, herbs and shrubs. They form a significant portion of the diet of Wedge-tailed Eagles on the islands, despite being largely nocturnal. This suggests they may also be active at dusk and dawn, coinciding with times when the eagles are foraging.

An attempt to reintroduce Banded Hare-wallabies to nearby Dirk Hartog Island in the 1970s was unsuccessful. This island was chosen because it was free of Foxes and Rabbits, although Sheep, Goats and feral Cats were present. Predation by feral Cats, a prolonged drought, and grazing by Sheep and Goats were suspected as factors in their demise.

Since the 1980s, there have been major advances in techniques for re-establishing native mammals in their former habitat. Several species have been successfully transferred to island or mainland sites where predator numbers are controlled. Our studies on Bernier and Dorre Islands have highlighted the dependence of Banded Hare-wallabies on dense shrubs for shelter. Knowledge of habitat requirements and effective predator control may provide the keys to the success of future reintroductions of the Banded Hare-wallaby. Perhaps the time is ripe to try again? The Western Australian Department of Conservation and Land Management has recently established a captive colony in the south-west of Western Australia with a view to doing just that.

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JACQUI RICHARDS AND JEFF SHORT ARE SCIENTISTS WITH CSIRO WILDLIFE AND ECOLOGY BASED IN PERTH. THEIR RESEARCH FOCUSES ON CONSERVATION AND MANAGEMENT OF REMNANT POPULATIONS OF RARE AND ENDANGERED MAMMALS.

BY JACQUI RICHARDS & JEFF SHORT

Dune wars

Along our temperate shores, ecological war has erupted.

(Above) Bitou Bush, the weed that dominates New South Wales beaches, was introduced in dry ballast in 1908.

ONE OF THE TOUGHEST PLACES for plants to grow is on the strandline of beaches, just above high tide. Here the ground is unstable and infertile, plants are blasted by salt and sand, and king tides may strike. Very few plants can endure this cruel environment. Those that do best often have long creeping stems that climb the ever-shifting sands.

In the northern half of Australia most of the strandline plants are wide-ranging Indo-Pacific species that presumably colonised Australia long ago via sea-borne seeds. They include Goat's-foot Convolvulus (*Ipomoea pes-caprae*), Beach Bean (*Canavalia rosea*) and Dune Bean (*Vigna marina*). Our southern shores, by contrast, support a small flora of endemic species, such as Hairy Spinifex (*Spinifex sericeus*), Grey Saltbush (*Atriplex cinerea*) and Coast Festue (*Austrofestuca littoralis*).

But two centuries of white settlement have wrought massive change. Along our temperate shores, ecological war has erupted. Our native strandline plants have been forced into retreat by foreign invaders. It's an eco-tragedy that dates back to the days of wooden ships and clumsy colonial cows.

When cargo ships have to travel empty they load up with ballast to maintain their stability at sea. Nowadays, sea water is pumped in as ballast, but during the 18th and 19th centuries sand, shingle and rocks were used. These materials, often taken from beaches near foreign ports, were dumped in Australia after ships berthed. Mixed up in the ballast were seeds of foreign strandline plants.

Australia has gained dozens of beach-infesting weeds in this way, including sea rockets (*Cakile* species), Sea Spurge (*Euphorbia paralias*), Sea Wheatgrass (*Thinopyrum junceum*) and Bitou Bush (*Chrysanthemoides monilifera rotundata*). As well, European Marram Grass (*Ammophila arenaria*) was sown long ago to stabilise dunes damaged by cattle grazing too near the sea. The sad fact is that some of these foreign invaders are better adapted to salt and sea than our small suite of temperate species, and they are fast taking their place and redesigning our beaches along the way.

PHOTOS: TIM LOW

(Left) Ecological warfare: American Dune Pennywort can be seen here taking over the habitat of the native Strand Sedge (left foreground) on a beach at Dee Why, Sydney.

BY TIM LOW

Marram Grass, now the dominant plant along Victorian shores, is a stout tussock grass that facilitates development of steep, tall dunes up to five metres high. European Sea Rocket (*Cakile maritima*) builds communities of low, irregular dunes. Sea Wheatgrass, incredibly salt-tolerant, is building dunes nearer the water than ever before; and on a vast spit on Wilson's Promontory it has, over 30 years, built a dune system 200 metres long, six metres

high and nearly a kilometre long. As well, American Dune Pennywort (*Hydrocotyle bonariensis*) is taking over from the native Strand Sedge (*Carex pumila*) and Coast Festue is losing ground to Marram Grass. This invasion by foreign plants has been so pervasive that few temperate beaches are untouched. In books about vegetation, Marram Grass, Dune Onion Weed (*Trachyandra divaricata*) and sea rockets are now listed as dominant seashore plants. In no other Australian habitat have foreign invaders won control with such ease.

The consequences of all this are serious. Not only has the architecture of our beaches changed forever, but the back-dune environment is suffering. Australian strandline plants are mostly low-growing creepers that trap modest amounts of sand, leaving large volumes to blow inland. They allow for an extensive back-dune habitat, which supports a very diverse flora. According to geographer J.D. Sauer (University of California, Los Angeles), this flora is one of the richest dune floras in the world, and its richness owes partly to the volume of sand blowing inland. Foreign invaders are now starving this system by trapping more sand near the sea.

There is very little we can do about this. Foreign strandline plants are now entrenched over vast areas, their seeds and stems carried widely by waves. European Sea Rocket was dominant on Western Australian beaches by 1906. Our best hope is to stop further weeds joining their ranks. The newest beach invaders are escaped garden plants, with a recent survey in Queensland recording 105 species—a shocking finding. Although very few of them are invading the strand, their colonisation of the backdunes is serious. Gardeners should be very careful about what they grow near the sea and never dump garden wastes. Dune systems are incredibly prone to invasion because they are heavily disturbed by wind, waves and wandering feet, disturbance often creating the opportunity for invasion.

There is one item of consoling news in all this. One of Australia's rarest birds, the Orange-bellied Parrot (*Neophema chrysogaster*), has developed a taste for exotic sea-rocket seeds. In South Australia this threatened parrot has benefited from the takeover by foreign plants.

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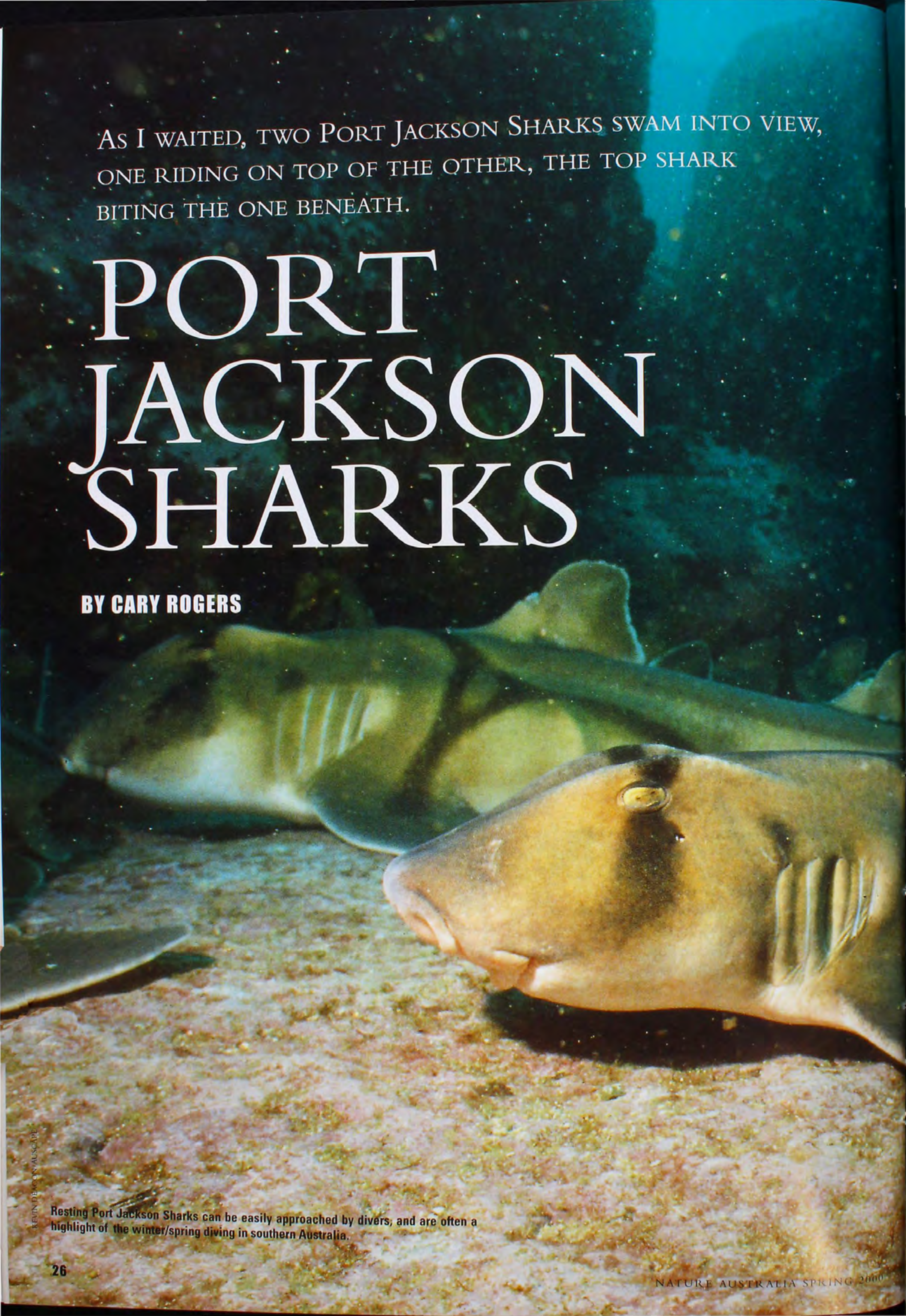
TIM LOW IS A NATURE WRITER AND CONSULTANT. HIS LATEST BOOK IS *FERAL FUTURE* (PENGUIN).

As I waited, two Port Jackson Sharks swam into view, one riding on top of the other, the top shark biting the one beneath.

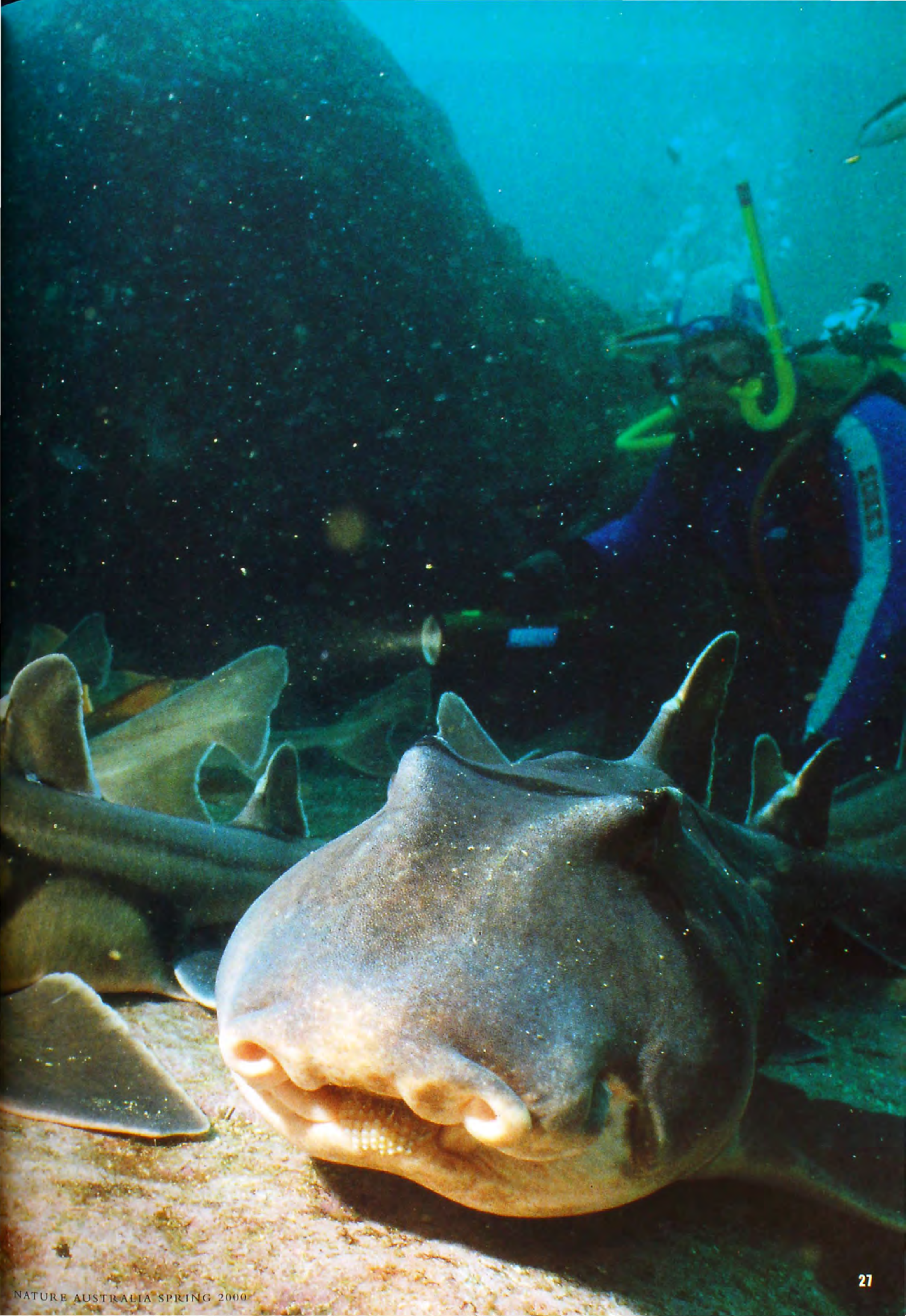
PORT JACKSON SHARKS

BY CARY ROGERS



KEVIN DEACON/AUSCAPE

Resting Port Jackson Sharks can be easily approached by divers, and are often a highlight of the winter/spring diving in southern Australia.



THE SEA WAS COLD, it was late July 1990, and we were diving south of Bare Island in the Botany Bay channel. I waited for my buddy on top of the reef wall, in an eerie green twilight 14 metres below the surface. In front of me the sheer wall dropped four metres into sand. As I waited, two Port Jackson Sharks (*Heterodontus portusjacksoni*) swam into view, one riding on top of the other, the top shark biting the one beneath. Having read of shark courtship behaviour, I watched the pair with interest as they swam back and forth along the wall. I felt somewhat of a voyeur, yet also compelled to witness the act unfolding before me. My musing ended when Ben struggled out of the gloom, issuing bursts of air like a steam train. His exertions were due to an anchor that he had salvaged and lashed about his waist. Needless to say, the amorous pair parted at his approach and swam off. Although I was tempted to lash the anchor around his neck, this brief encounter of mine with Port Jackson Sharks was to begin a long-term interest in the species, which I fostered during subsequent years of research on the ecology of New South Wales coastal reefs.

Port Jackson Sharks are horn sharks (family Heterodontidae), so named because of the raised crests above their eyes. Horn sharks also have a spine in front of each dorsal fin. The spines are associated with venom glands, and are used in defence against predators, especially by juvenile sharks. These calcified dorsal spines are well preserved as fossils and, along with their dentition, are often the only parts of the shark that are found. The fossil remains of horn sharks have been recovered from Late Oligocene to Early Miocene (24–19-million-year-old) rocks in Victoria, and from Late Jurassic (150-million-year-old) and Cretaceous (144–66-million-year-old) deposits in Europe.

There are eight living species of horn sharks, three of which are found in Australian waters. All are of moderate size compared to other shark species, and generally reach a little over a metre in length. Port Jackson Sharks are one of the largest species, reaching 1.65 metres.

K. AITKEN/OCEAN EARTH IMAGES

Horn sharks are bottom dwellers that eat molluscs, crustaceans, echinoderms and fishes. Their teeth are adapted for generalised feeding. The front teeth are sharp and raptorial, ideal for seizing prey such as fishes, while the back teeth are flattened and rounded for crushing and grinding well-armoured prey such as snails and sea urchins. This broad diet is likely to have greatly assisted the survival and evolution of these sharks during past faunal changes in the oceans.

THE PORT JACKSON SHARKS I encountered at Bare Island had migrated

EVA BOOGAARD/LOCHMAN TRANSPARENCIES

from the deeper offshore waters of the continental shelf. These sharks migrate onto near-shore reefs every year from July to October to reproduce. Large groups of Port Jackson Sharks gather in ledges and caves close to shore, at sites along the New South Wales coast from Newcastle to Eden. Female sharks, their abdomens distended with eggs, rest together during the day, often with dozens of individuals packed into a single cave. About two to five weeks after mating, each female lays two corkscrew-like eggs (which are peculiar to horn sharks) every two weeks, with a total of 10–16 eggs being produced during the reproductive period. The eggs take up to a year to hatch into fully formed juveniles. Some females have been seen gently carrying a newly laid egg in their mouth and wedging it into a suitable crevice. However, not all females secure their eggs in this fashion, as many eggs wash ashore during spring, killing the developing sharks. In contrast to the gentle treatment of eggs by females, male horn sharks are known to crush them and eat their contents.

Most of what we know about Port Jackson Sharks comes from the pioneering studies of Ken O'Gower and Robert McLaughlin (University of New South Wales) and Alan Nash (Prince of Wales Hospital). They found that the species may live for over 30 years, and that sexual maturity occurs at 8–10 years in males and 11–14 years in females. From genetic sampling, O'Gower and Nash determined that there are two

(Above) Port Jackson Sharks are horned sharks, so named because of the raised crests above their eyes.

(Left) Port Jackson Sharks have prominent spines in front of each dorsal fin, with associated venom glands. These spines may deter predators, especially in juvenile sharks.

WHILE MALE PORT JACKSON SHARKS MUST *at some time mate with females, this has rarely been witnessed in the wild.*

major populations of Port Jackson Sharks—an eastern population ranging from Bass Strait to northern New South Wales, and a western population from Victoria to Western Australia. Tagging studies showed the eastern sharks migrate large distances each year (600–800 kilometres) between their feeding grounds in Bass Strait and reproductive aggregations along the New South Wales coast. Female sharks were also found to use the same resting areas over consecutive years, although whether these areas are the same as where they hatched and lived as juveniles is unknown. The movements of Port Jackson Sharks, both about inshore reefs and on a larger scale during migrations, led O'Gower to speculate that these sharks have a complex spatial memory of the reef areas used for reproduction, and other resting sites along their migratory route.

A curious feature of Port Jackson Shark aggregations is that most of the sharks are female, with five to ten females for every male shark. This uneven ratio is not due to any sex differences at hatching, as there are roughly equal numbers of male and female juveniles; and the numbers of adult male and female sharks caught in shark nets off New South Wales beaches are also the same. So why are there so few males found in the breeding aggregations?

While male Port Jackson Sharks must at some time mate with females, this has rarely been witnessed in the wild—my chance encounter with their mating behaviour being one of the few observations. The reason for the scarcity of information about mating in Port Jackson Sharks is probably due to their nocturnal habits, with most of the 'action' occurring at night. It is possible that male sharks move into breeding aggregations at night, and the few males seen during the day are stragglers. However, my encounters with the males of this species suggest another possibility. On several occasions during daylight dives near aggregations of Port Jackson Sharks, I was closely approached and inspected by very active male sharks. In contrast nearby female sharks remained resting in caves and ledges, not at all

CHERIE VASAS/NATURE TRAVEL & MARINE IMAGES

(Above) Egg-case strandings are a natural cause of mortality for Port Jackson Sharks. In some cases many wash ashore, as seen here at Jervis Bay, New South Wales.

(Right) This juvenile Port Jackson Shark hatched from its egg as a miniature copy of its parents. Seagrasses, such as the *Halophila* sp. pictured, are an important nursery habitat for the juveniles, and are often damaged by human activities.

MARK SPENCER/AUSCAPE

Port Jackson Shark
Heterodontus portusjacksoni

Classification
Family Heterodontidae (3 spp. in Aust. waters).

Identification
Medium-sized shark reaching 1.65 m in length. Head blunt with raised crests above eyes. Spines in front of both dorsal fins. Upper body grey to light brown, with white belly. Distinctive black harness-like pattern extends from head to dorsal and pelvic fins. Males smaller than females. Males have prominent claspers that extend behind pelvic fins.

Distribution and Habitat
Continental shelf waters around southern Aust. from Byron Bay (NSW) to Houtman Abrolhos (WA), from near shore to 275 m depth. When inshore, adults frequent reef areas with caves and ledges. Juveniles inhabit sheltered estuaries and coastal reefs.

Behaviour
Nocturnal predator of sea urchins, molluscs, crustaceans and fishes. Adults from eastern population migrate from feeding grounds in Bass Strait to reproductive areas along NSW coast each year. Females rest during day in caves and ledges. Males found near aggregated females are often active.

Reproduction
Adult sharks aggregate from July–Oct. to reproduce. Mating probably occurs at night. Females lay 10–16 corkscrew-like eggs each year, which hatch 9–12 months later depending on water temperature. Males reach maturity at about 70 cm after 8–10 years, females at about 90 cm after 11–14 years.

Status
Not considered threatened, however overfishing and destruction of juvenile nursery areas could weaken populations.

JEFFREY L. ROTMAN-PETER ARNOLD/AUSCAPE

BECCA SAUNDERS/AUSCAPE

(Above) The raptorial front teeth of this Port Jackson Shark are stained purple from consuming the sea urchin *Centrostephanus rodgersii* (right). The sensitive nasal cavities can also be seen. These help the shark locate prey beneath the sediments.

(Far right) A male Port Jackson Shark resting at the entrance to a cave at Bare Island, in Botany Bay. Male sharks are easily distinguished from females by their prominent claspers, which lie beneath the second dorsal fin.

WOODWARD/LOCHMAN TRANSPARENCIES

interested in my presence. I suspect the actions of these male sharks may be a territorial response, their unusual boldness being an attempt to drive off a potential competitor for mates. Such territorial behaviour would explain the low number of males found in breeding aggregations.

PORT JACKSON SHARKS play an important role in the marine ecosystem in southern Australia. The large numbers that gather on inshore reefs during winter and spring consume an enormous amount of invertebrates. On New South Wales reefs, their prey includes the large black sea urchin *Centrostephanus rodgersii*, whose spawning season coincides with the arrival of the sharks. These sea urchins emerge at night from sheltering ledges and crevices to graze on seaweeds. Without predators such as Port Jackson Sharks to keep their numbers in check, they create large 'barren' areas devoid of seaweeds and associated fauna. Port Jackson Sharks, with their predilection for herbivorous invertebrates, thus play an important predatory role in the food web of coastal reefs. But they too have their predators and parasites, including other sharks and humans. They are caught by both commercial and recreational fishermen but are not eaten, and there is little information on the numbers killed each year. The effects of human activity on their reproduction and nursery areas, especially Botany Bay and Sydney Harbour, are also unknown.

PORT JACKSON SHARKS *play an important predatory role in the food web of coastal reefs.*

Port Jackson Sharks are currently not regarded as threatened because they occur along the entire southern coast of Australia below 30° S latitude. However, like other sharks that take many years to mature and reproduce, Port Jackson Shark numbers could be dangerously reduced by overfishing, and by destruction of coastal habitats important to the survival and growth of young sharks. It would be a dreadful shame if the existence of these ancient mariners, which have managed to survive for millions of years and to ride out the various changes in the oceans in the past, were threatened by the activities of just one species. Hopefully, though, our interference will represent just another challenge to these enduring sharks.

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CARY ROGERS RECENTLY COMPLETED HIS DOCTORAL STUDIES IN THE SCHOOL OF BIOLOGICAL SCIENCE AT THE UNIVERSITY OF NEW SOUTH WALES, ON THE CHEMICAL ECOLOGY AND BIOLOGY OF THE HERBIVOROUS MARINE MOLLUSC *APLYSIA*. HIS RESEARCH INTERESTS INCLUDE THE ECOLOGY OF COASTAL WATERS, PARTICULARLY REEF AREAS.

The Wedge-tailed Eagle is the largest of the three eagle species found in Australia, and one of the larger eagle species in the world.

BOLD EAGLE

BY PAULA WINKEL

The wind has raised this bird's neck feathers, giving it a rather unusual appearance. The prominent beak and naked skin around the eyes are two features that help identify Wedge-tailed Eagles when they are on the ground. The shear size of them, their heavily 'trousered' legs and large, strong talons are also dead giveaways.

NICHOLAS BIRKS/AUSCAPE

If you look way into the distance you might see one flying—a small shape just above the horizon with slightly bowed-up wings; the slow, almost languid flap of large wings, followed by a long glide. As it gets closer, you may see it ride up with the thermals, circling higher and higher, until disappearing from sight. With finger-like wing feathers and wedge-shaped tail, it makes its way over Australia's aerial highways with ease. The Wedge-tailed Eagle (*Aquila audax* = Latin for bold eagle) is distinctive—even at a distance—once you know what you are looking for.

In my quest to find out what the Wedge-tailed Eagle was eating in north-western Queensland (for my Honours degree project), I soon learned how to spot them . . . and many other things about their high-flying lifestyle.

With a wingspan of 1.8 to an impressive 2.5 metres, the Wedge-tailed Eagle is the largest of the three eagle species found in Australia, and one of the larger eagle species in the world. It can be found all over Australia—from desert and arid environments, to savanna lands, forests (mountain, subalpine and littoral), and occasionally rainforest areas. But as any wise predator is wont to do, Australia's bold eagle tends to steer clear of areas heavily populated by humans.

One can generally pick the age of a Wedgie by its colour. Young birds are light brown with straw-coloured bands on the wing coverts, and straw-coloured feathers over the head and back of the neck. Older birds present a much more dignified and sombre appearance. They go for basic black, with their white under-feathers only showing through when the wind ruffles them. The basic black of older birds is sometimes broken with the faintest hint of gold epaulets on the shoulders, the only colour that remains of the juveniles' golden mantle. A large pale beak, and pale feet at the end of strong legs trousered in feathers, complete the ensemble. However, Mother Nature rarely deals a straight hand. Although a dark Wedgie is always an older bird (at least five to seven years of age) and the blacker the plumage the older it is, a brown and gold eagle is not necessarily a young one, as some individuals retain their juvenile plumage for the whole of their lifespan.

Breeding pairs of Wedge-tailed Eagles establish a territory that they use all year round. The size of their territory generally depends on the density of prey, and the birds seem to keep their territories, and perhaps their mates, for life. Eggs are laid from around April to September, although this depends on where the birds are in Australia. Food availability and seasonal conditions determine whether and when they start breeding.

Normally a breeding pair builds two or three nests within its territory. The nests are generally used on a rotational basis as the years go by. With a good eye for real estate, and remembering the catchphrase 'position, position, position', Wedge-tailed Eagles choose nest sites with a good view—usually the tallest tree in the area. In the case of one pair that I saw out Boulia way, the birds had made do with all that was available—a short stumpy *Acacia* that was no taller than two metres! Wedge-tailed Eagles have also been known to nest on cliffs and there have

NICHOLAS BIRKS/AUSCAPE

Birds of prey don't have the ability to pick out all the hair, scales and bones from their prey. Instead the crop acts as a gathering place for all the hard and indigestible materials, which are regurgitated as a pellet when the crop is full. The shape and size of these pellets often give clues as to what species of raptor is responsible for them, and their contents are invaluable in identifying what prey items occur in their diets.

Aerial acrobatics or 'cartwheeling' in the sky is sometimes seen in mated pairs of Wedge-tailed Eagles, particularly during the nest-building phase, and also during territorial disputes. With talons sometimes locking together, this can be fatal for birds that refuse to let go.

DENNIS SARSON/AUSCAPE

This adult Wedge-tailed Eagle stands over a kangaroo carcass. Due to the size of the kangaroo, it is unlikely that this bird was responsible for its death, and more likely a case of opportunistic scavenging on the eagle's behalf.

Wedge-tailed Eagle

Aquila audax

Classification
Family Accipitridae. Mainland subspecies, *Aquila audax audax*; Tasmanian subspecies, *A. a. fleayi*.

Identification
Very large raptor with prominent head and pale beak. Long feathered legs, pale feet with black talons, and, most distinctively, a wedge-shaped tail. Black with lighter feathers on the upper part of wings and sometimes across nape. Juveniles are brown in colour, with straw-coloured wing coverts, head and neck. Body length 85–106 cm; wingspan 1.8–2.5 m; average male weight 3.2 kg; average female weight 4.2 kg.

Distribution and Habitat
Desert and arid areas, savanna and forests. Prefers open or lightly wooded areas. Sometimes seen around rainforests. Australia-wide, but away from densely populated areas. Populations range from rare to locally common depending on area, habitat and food availability.

Breeding
Mates for life, lays 1–3 eggs Apr.–Sept. in shallow depression of large cup-shaped nest made of sticks and branches. Incubation by both parents. Eggs hatch after 43 days; 70–88 days before able to fly. Young leave parents' territory at 8 months of age. Breeding age at about 6–7 years. May live for 40+ years.

Diet
Hunts for prey as well as eating fresh carrion.

Parental devotion. These young chicks are being sheltered from the rain. If they get too wet and cold at this age, they may not survive. Note the large size of the nest, the small size of the actual nest bowl and the fresh green foliage on the right hand side of the nest.

even been records of them nesting on the ground when trees are scarce.

The nests are usually located in the forked branches of very strong trees. This is important as the average weight of a nest is 400 kilograms. Each nest is made up of dead sticks and small branches, shaped into a bowl around 70–180 centimetres across and up to three metres deep. The depression for the eggs, though, is quite shallow and is lined daily with fresh leaves and twigs when the eggs (one to three, usually two) are about to be laid. After about 43 days of incubation by both parents, the eggs hatch. The chicks are covered in a fine, snowy white down, a sharp contrast to the adult's black

NICHOLAS BIRKS

plumage. The chicks are fed by food collected by both parents, but the male tends to do most of the hunting (being smaller and far more agile than the larger female), especially when the young are small.

Occasionally some lethal skulduggery goes on between the chicks. While not so common in the Wedge-tailed Eagle (unlike some other eagle species), the older (usually by about four days) and thus larger chick may intimidate and physically attack its younger and smaller sibling in order to get the full attention of its parents and the food. If hunting is good, though, the chances of the adults successfully raising all their chicks is excellent. For their size, Wedge-tailed Eagles are remarkably shy around their nests, and disturbances—from loud noises to nosy biologists popping in to check on the chicks—can make them abandon their eggs or nestlings. About 70 to 88 days after hatching, the chicks have gone from being cute balls of

GRAHAM ROBERTSON/AUSCAPE

It will be a while before these two Wedge-tailed Eagle chicks can fly. The chick on the left is larger and better developed than its sibling. This is normal as the eggs are layed over the course of a few days and, therefore, hatch at different times. Both these chicks should survive to fledge if the food is plentiful.

fluffy white down, through the incredibly unattractive and dishevelled look of first feathers, to straw-streaked juveniles on L plates. The fledglings generally leave their parents' territories at about eight months of age.

Wedge-tailed Eagles may not reach sexual maturity until they are about six or seven years of age. This means, for six or so years after leaving the nest, they mainly just hunt and travel around Australia. What a life! Sometimes they stay in the one area, or they may keep moving along a route, where food is locally abundant. A banding study of Western Australian Wedgies found the average distance juveniles dispersed from the nest was 228 kilometres. One bird was recorded having travelled 784 kilometres from its nest in 11 months. Another report from Queensland (in 1970) told of a seven-month-old eagle that travelled 868 kilometres from its hatching area! It is at this stage of their lives when Wedge-tailed Eagles come into most conflict with humans.

THE LARGE SIZE of the Wedge-tailed Eagle means it can utilise a wide range of live prey—from small lizards to large kangaroos. Wedge-tails are also consummate scavengers. They are true masters at spotting the recently deceased. This increases their dietary range considerably, for when an animal is dead, its size does not matter. Using their powerful beak, Wedgies can get past the strongest of hides.

Wedge-tailed Eagles are not the swift aerial hunters that the Peregrine Falcons are (see *Nature Aust.* Spring 1998). Wedge-tails are built for taking prey on the ground, and will even work together to kill larger species. Although they are capable of lifting prey items up to five kilograms in weight (which is more than their own body weight), they generally dispatch and consume lizards over 40 grams (such as Thorny Devils, blue-tongued lizards, goannas), ground-foraging birds over 100 grams (parrots, doves, Emus, Australian Bustards), and mammals, which make up the bulk of a Wedgie's diet, over 500 grams (Rabbits, possums, gliders, Cats, Dogs, piglets, kangaroos, wallabies, rock-wallabies, rat-kangaroos, lambs, calves, Goats, Foxes). Fish remains have even been found at some nest sites on Bernier Island, Western Australia, but these are presumed to have been scavenged from the tidal zone. Clearly, Wedgies are not fussy eaters. They will hunt and consume whatever is available. But while I wouldn't want to call Wedge-tails 'lazy', they usually go for fresh carrion rather than hunt something if the choice is available.

Like many predators, Wedge-tailed Eagles have had a chequered relationship with pastoralists and other primary pro-

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ducers. What is a farmer to think when he sees a huge predatory bird sitting on the fresh carcass of one of his livestock? Naturally, he assumes the worst, as did many people before him. During the 1970s, bounties, and indiscriminate poisoning and shooting campaigns led to the death of about 30,000 birds a year. This was all rather unfortunate for the Wedge-tailed Eagle, as it really is not the major livestock-killer that people thought it was, but rather prefers eating already-dead livestock and hunting Rabbits and native animals.

Luckily things have changed and the birds are only allowed to be killed if fauna authorities find that they have become a problem with pastoralists in a particular area. Illegal killing still occurs, although thankfully not with the same passion as before. This is not to say that the Wedge-tailed Eagle has been an innocent bystander, unjustly accused of crimes it

(Above) A portrait of maturity. The dark plumage of this Wedge-tailed Eagle indicates that it is a fully mature bird, probably over seven years of age (but perhaps as old as 40 years). The prominent and powerfully hooked beak is perfect for tearing into carcasses and is strong enough to break bones and get through thick hides.

(Left) Up, up and away! Wedge-tailed Eagles can take off from the ground, although there is more than a little effort involved! They can also pick up prey from the ground and fly with it, as long as it is not too heavy. Note the colour of the feathers over the 'shoulders', the tail that is fanned out into the wedge shape, and the 'fingering' of the feathers at the end of the wing.

PHOTOS: NICHOLAS BIRKS/AUSCAPE

did not commit. Wedgies do attack, and kill, perfectly viable young livestock. But, as I found in my study, as did others before me, when they do go for livestock, they generally go for weak, orphaned individuals and those that are about to breathe their last (whose numbers can be quite high in marginal country). The fact that farmers also tend to get large numbers of transient Wedge-tails (all those non-breeding adolescent birds!) arriving on their properties just as lambing starts, really doesn't help. Farmers don't have time to observe wildlife all day, and what they see on occasion tends to look a little incriminating for the eagles.

Many of the animals Europeans brought to Australia were just the right size for a Wedge-tail to munch on and today, in some areas, the bird's diet can be made up almost entirely of introduced species. Rabbits alone can constitute up to 90 per cent of a Wedge-tail's diet. In areas of Australia where Rabbits are few and far between (such as north-western Queensland), the Wedge-tailed Eagle tends to have a larger proportion of native animals in its diet, and a wider range of introduced animals as well, such as piglets, Cats and, of course, Sheep.

(Above) The nests of Wedge-tailed Eagles are very large, so they only occur in trees with strong forked branches to support their weight. This tree also has open areas that give the parents good views of the surrounding area. If there are no trees around, Wedge-tailed Eagles have been known to nest on cliffs and even occasionally on the ground.

(Below) The Wedge-tailed Eagle shown here is probably having a bit of fun, as they are not built for chasing down prey on the ground. At a kill site, most smaller raptors and birds will usually wait until the Wedge-tailed Eagle has finished eating before dashing in to snatch a bit of food. This crow may have presumed too much!

Wedge-tails continue to adapt to humans and human-related occurrences in their environment. For example, with increasing numbers of cars on outback roads, road kills have been an unexpected benefit for them. Although road kills are a very exploitable food source for the eagles, many a bird has lost its life to the vehicle that provided the meal. They often gorge themselves so much that they can't take off fast enough to avoid oncoming cars. Wiser, more experienced individuals discard dignity and break out into a scrambling, bouncing run to the side of the road as traffic approaches.

THE FUTURE FOR the Wedge-tailed Eagle is a little uncertain. While there is no danger of them dying out, there is a small dark cloud on their generally bright horizon.

On the up side, today's farmers are a generally more enlightened lot than their forebears. Most appreciate the benefits of having a couple of Wedge-tails on the place. The birds hunt the ferals and clean up the carcasses, which means that blowflies have fewer places to breed—a huge plus for Sheep farmers. Habitats and stretches of remnant vegetation, thanks to the efforts of Landcare and other organisations, are also being revegetated and conserved, which bodes well for the Wedgie's nesting and resting places.

On the down side, the release of the Rabbit calicivirus will affect the Wedge-tailed Eagle population. Some Wedge-tails depend solely on Rabbits as their food source. With the Rabbit population rapidly decreasing in some parts of Australia, Rabbit-'dependent' Wedge-tails will have to go 'cold turkey' and switch to a more 'native' diet like their counterparts in non-Rabbit areas of Australia. Desperate eagles may even look with a sharper eye at some of the younger and smaller livestock on farms.

Wedge-tailed Eagles are survivors, and evolution has made sure that their diet is not restricted to only a few animal species—that would be catastrophic in a land that is subject to droughts, and seasonal expansion and shrinkage of animal populations. Most of our native species have adapted to respond to Australia's ever-changing environmental conditions, as has the Wedge-tailed Eagle. But most amazingly, the Wedge-tail has even managed to benefit from some of the changes created by humans (even though this sometimes brings them into conflict with us).

So next time you are away from the city, and inland a bit, look out above the horizon. Shade your eyes and maybe you will see the bowed-up wings of a Wedge-tailed Eagle as it majestically circles up into the sky, forever on the lookout for a meal. You can then nudge your companion, point and say "Hey, that's *Aquila audax* out there . . ." because now you know what to look for.

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PAULA WINKEL COMPLETED HER HONOURS DEGREE PROJECT AT JAMES COOK UNIVERSITY OF NORTH QUEENSLAND ON THE DIET OF THE WEDGE-TAILED EAGLE. SHE IS CURRENTLY COMPLETING A MASTERS DEGREE THERE ON THE ECOLOGY OF THE PROSERPINE ROCK-WALLABY AND IS EMPLOYED AS A RANGER FOR THE TOWNSVILLE ROSS DAM AND CATCHMENT AREA.

GARY BELL

This adult bird has picked a good spot to perch. Wedge-tailed Eagles usually choose strong branches in tall trees that have little foliage around them, as it makes it easier for take-off and landing, and also provides a good view of the surrounding countryside. Fence posts also make great resting spots, and when there is nothing else they will stand on the ground or on a bit of fallen timber.

Marsupial 'Lions' were extraordinary beasts, distinguished by enormous meat-shearing cheek-teeth and built-in flick-blade-like claws on their thumbs.

MOVE OVER SABRE-TOOTH TIGER

BY STEPHEN WROE

It has been claimed that, among Australian marsupial carnivores, none was very large. Indeed, recent authors have described Australia's largest-ever marsupial predator to have been about the size of a large wolf or Leopard. As I stared into the empty orbits of a Pleistocene Marsupial 'Lion' (*Thylacoleo carnifex*) skull—almost 26 centimetres long and 23 centimetres wide—I wondered if those who had made these claims had ever seen fossils of this remarkable beast. Someone must have once considered this animal to have been a truly formidable predator, otherwise it would never have been called a marsupial 'lion'. In fact, my own hunch had long been that *T. carnifex* was Australia's answer to those paragons of the mammalian carnivore universe—the extinct sabre-toothed 'tigers' (*Smilodon*) from North and South America.

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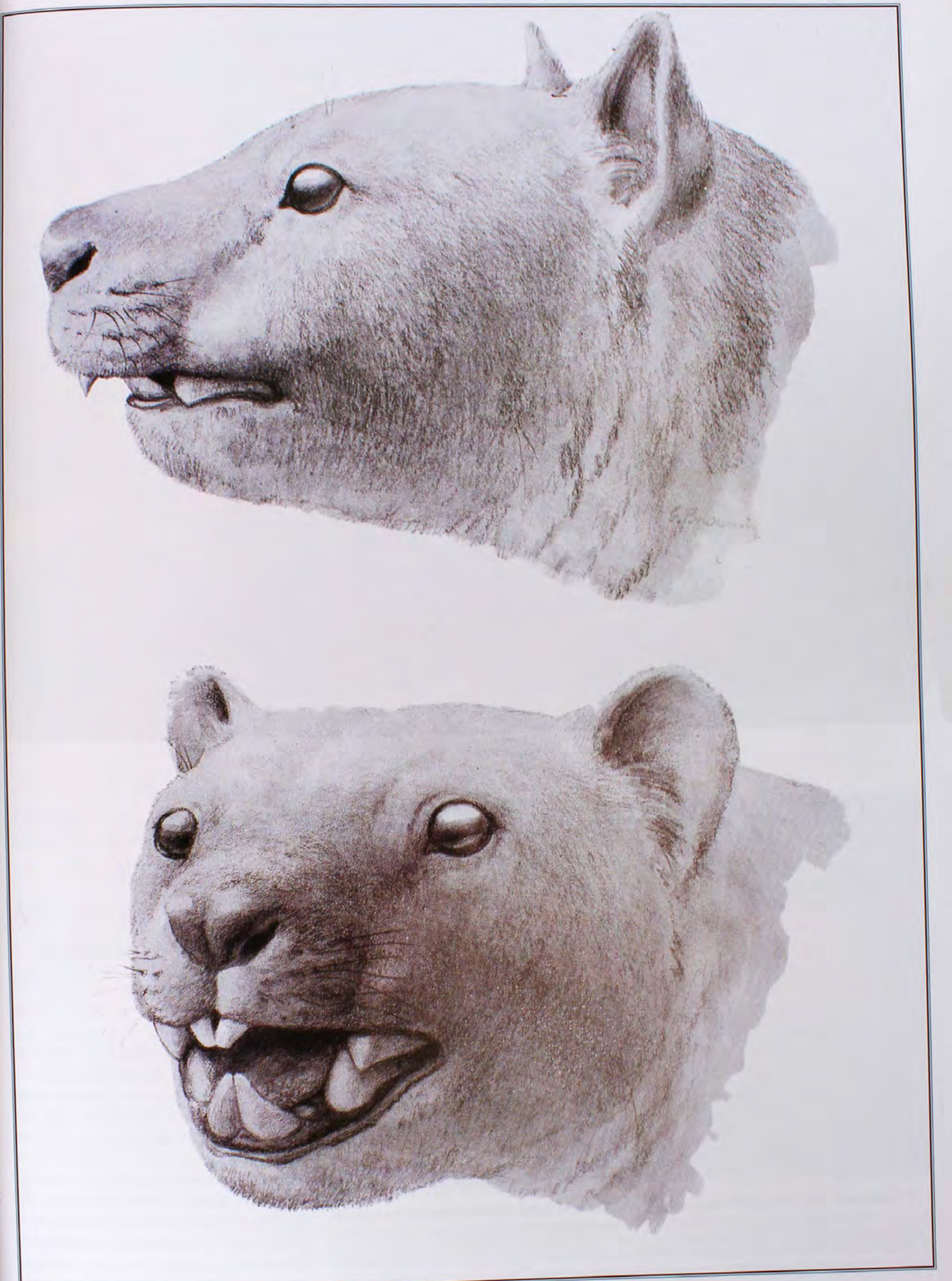
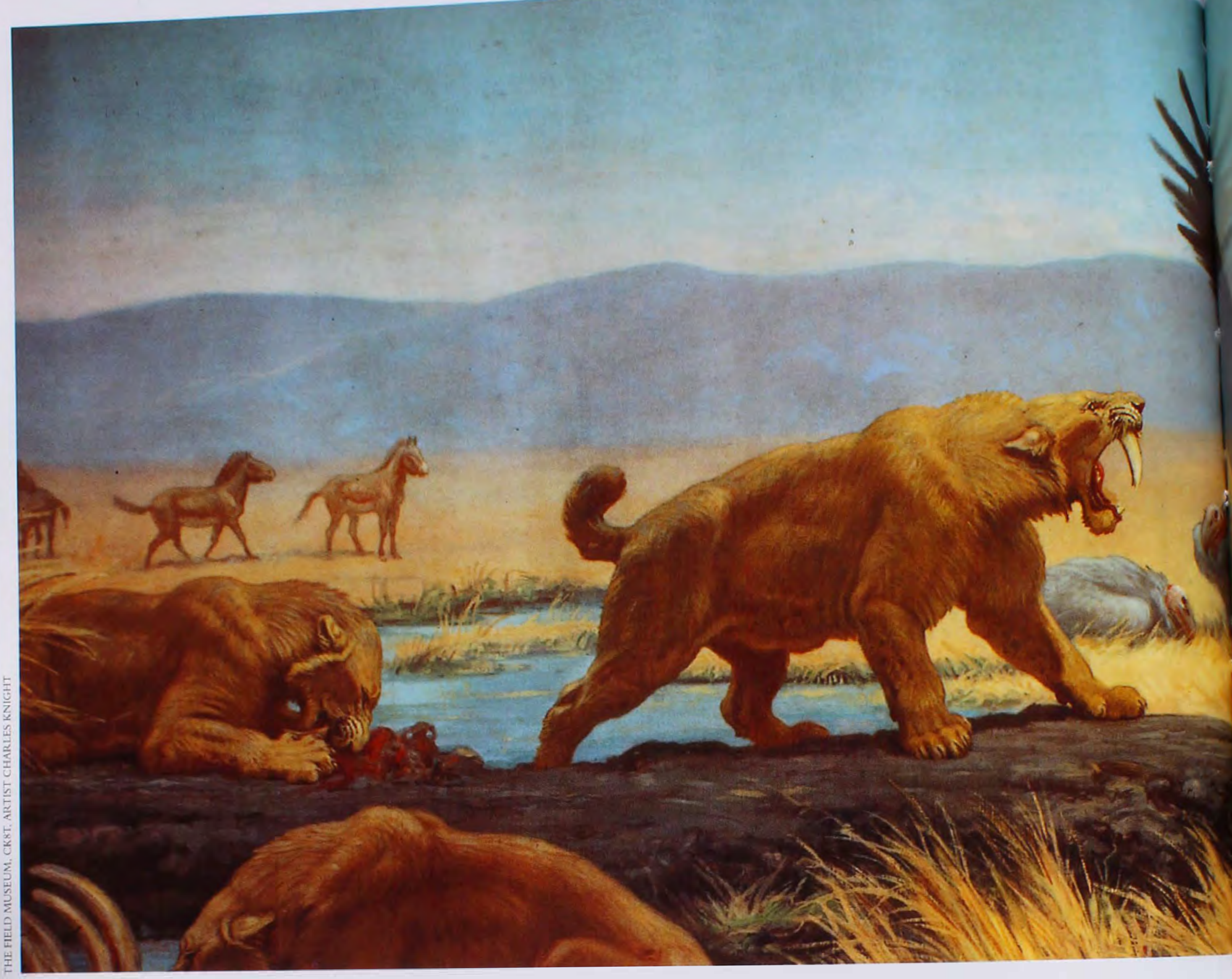
An illustration of *Thylacoleo carnifex*—an impressive carnivore whose fossil remains have been found across the length and breadth of Australia.





THE FIELD MUSEUM, CK87, ARTIST CHARLES KNIGHT

OVER 25 MILLION YEARS AGO,

the first recognisable ancestors of the Pleistocene Marsupial 'Lion' began taking their first tentative steps on the road to a fully carnivorous lifestyle.

That Australia was perceived as a continent never graced by large warm-blooded carnivores had always bugged me. In late 1998, reading a review of a colleague's article finally drove me to action. Anna Gillespie, pursuing her PhD at the University of New South Wales, had just submitted a summary of marsupial 'lion' evolution. In it she noted that the family, Thylacoleonidae, included species ranging from the size of a Domestic Cat to that of a Lion. The reviewer took exception to the proposition that any marsupial 'lions' grew to be as big as the 'King of Beasts', observing that most scientists had compared *Thylacoleo carnifex* to the Leopard. In this the reviewer was right. The problem was, we were convinced that 'most scientists' were wrong.

A review of the literature did nothing to instil confidence in previous estimates of marsupial 'lion' size. In fact, it became clear that none of the estimates amounted to anything more than educated guesswork. In 1984, Peter Murray (Central Australian Museum) reckoned *Thylacoleo carnifex* may have reached up to 100 kilograms, but in 1991 Tim Flannery (now at the South Australian Museum) suggested 50–70 kilograms for the beast (see *Nature Aust.* Winter 1991). Tim revised this down further to 40–60 kilograms in his 1994 book, *The future eaters*. Most recently Esmée Webb (Yamaji Language Centre) suggested that *T. carnifex* was a 20-kilogram animal. Clearly, desperate action was needed. At this rate *Thylacoleo carnifex* seemed fated to disappear altogether! Anna and I, and another two colleagues, Troy Myers (University of New South Wales) and Rod Wells (Flinders University), resolved to settle the matter. As things stood, Australia was the only continent, bar Antarctica, that had never had a bona fide mammalian super-predator, while the biggest thing we had was, evidently, getting smaller by the minute.

Reconstruction of the sabre-toothed 'tiger' (*Smilodon fatalis*), one of the best known of fossil mammals. The remains of this big cat have been found in large numbers at the Rancho La Brea tar pits of Los Angeles. Although shorter in head–body length than a modern Lion, it was far more robust and may have weighed 1.5 to 2 times as much. *Smilodon fatalis* was one of three species of the genus *Smilodon*. A smaller and older species, *S. gracilis*, is thought to have weighed about 80 kilograms.

This had become a matter of more than scientific significance . . . national pride was at stake!

WAY BACK IN the Oligocene, over 25 million years ago, the first recognisable ancestors of the Pleistocene Marsupial 'Lion' began taking their first tentative steps on the road to a fully carnivorous lifestyle. Small, with poorly developed canine teeth and a distinctly vegetarian heritage, any casual observer at the time might well have voted them as the marsupial carnivore family least likely to succeed. But succeed they did. Eight species of marsupial 'lions' are now recognised, and Anna is about to describe at least two more. The pinnacle of marsupial 'lion' evolution was the most recent species, *Thylacoleo carnifex*, a widely distributed and common find in fossil deposits across the length and breadth of Australia. Precisely when the last died out is unclear, although it was probably within the last 50,000 years or so. Pleistocene Marsupial 'Lions' were extraordinary beasts, distinguished by enormous meat-shearing cheek-teeth (carnassials) and built-in flick-blade-like claws on their thumbs. Their meat-butchering carnassials were the largest of any known mammalian predator, living or extinct. In terms of its dentition, many scientists now believe that *T. carnifex* was the most specialised mammalian carnivore of all time.

However, this was not always the case. For decades following Sir Richard Owen's description of *Thylacoleo carnifex* back in 1859, marsupial 'lion' biology was the subject of ongoing controversy (see *Nature Aust*. Summer 1999). Admittedly Owen, an eminent palaeontologist of the 19th century, made some serious mistakes in his professional lifetime and backed some well-known losers. Posterity may well best remember him for his steadfast and vocal opposition to the the-

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Skulls of a sabre-toothed 'tiger', *Smilodon fatalis* (left) and Pleistocene Marsupial 'Lion', *Thylacoleo carnifex* (right). Despite the lack of large canines in the marsupial, these two animals may have occupied similar niches in that they both specialised in taking relatively large prey. General similarities include shortening of the face, elaboration of the main vertical shearing blades in the dentition, loss of bone-cracking tooth cusps and a powerful build, with particularly well-developed forequarters.

ROD WELLS

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ories of one Charles Darwin. But, whatever his shortcomings, Owen certainly possessed a broad knowledge of mammalian anatomy. Examination of the skull and teeth of *T. carnifex* left him in no doubt that he was looking at an exceptionally large and ferocious carnivore, in his words among the "fellest and most destructive of predatory beasts". Owen's emotive interpretation kick-started a debate that would rage for decades.

Pleistocene Marsupial 'Lion' anatomy was weird. Certainly it departed from the mammalian carnivore stereotype in a number of important respects. Moreover, as a member of the predominantly herbivorous diprotodontian marsupial radiation (koalas, wombats, kangaroos, possums etc.), *Thylacoleo carnifex* just didn't seem to have the pedigree required of a true, blue-blooded predator. A supposed clincher for those arguing for herbivory was the animal's conspicuous lack of large canines. Consequently, Owen's original interpretation was brought into question and the matter of diet remained open until 1982, when Rod Wells and others finally settled the argument in favour of a predatory lifestyle. Their work was based on an analysis that related structure to function and convincingly showed that *T. carnifex* was best adapted to a carnivorous habit. To the best of my knowledge, no-one has suggested otherwise since.

But, with the lifestyle debate put to rest, a major change in Owen's original perception seems to have slipped through, almost unnoticed. Somehow the Pleistocene Marsupial 'Lion' has shrunk, quietly becoming the Pleistocene Marsupial 'Leopard', without exciting much, if anything, in the way of argument. This 'down-sizing' effects not only our interpretation of the animal's biology, but of

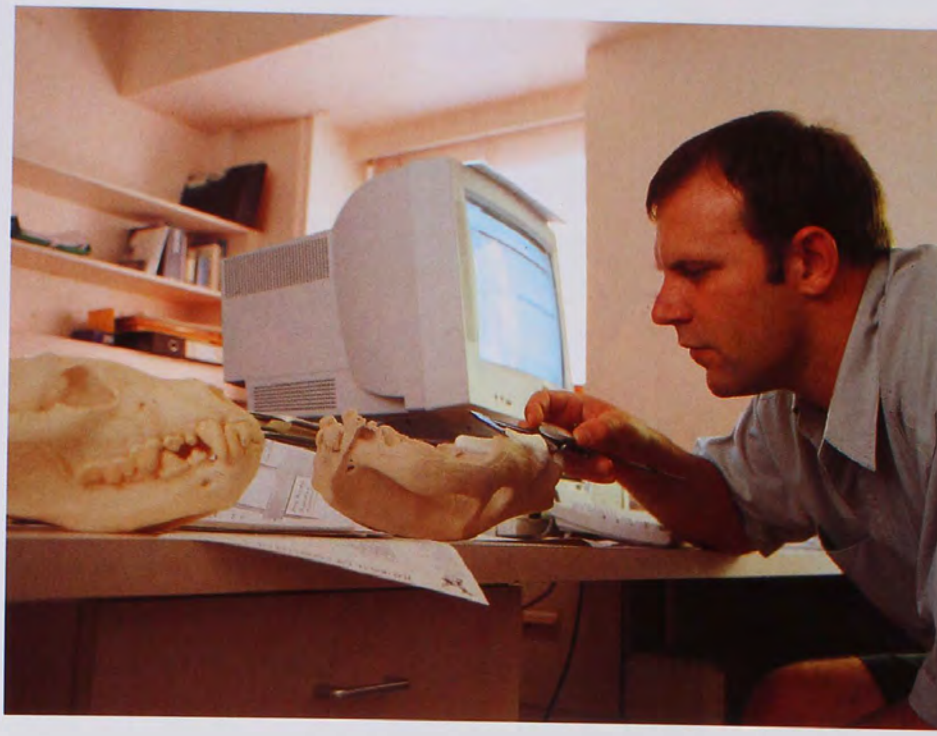
(Top left) Staring down the gullet of this mounted skeleton, it's hard to imagine that *Thylacoleo carnifex* was ever seen as anything other than a formidable marsupial carnivore. But with the debate over diet finally laid to rest, another issue has heretofore gone unnoticed . . . the Pleistocene Marsupial 'Lion' has been shrinking. One recent estimate was as low as 20 kilograms. However, the latest empirically determined weight estimates demonstrate that *Thylacoleo carnifex* had an average weight of between 100 and 130 kilograms, a big carnivore in anyone's book.

(Bottom left) From left to right the humeri (upper bones of the forelimb) of two specimens of *Thylacoleo carnifex* and a Leopard of average size. Even the smaller of the *Thylacoleo* humeri is far more massive than that of the Leopard, indicating that the animal was far more muscular.

the Australian ecology in general. For example, in 1975 Max Hecht (University of New York) argued that the giant goanna *Megalania prisca* was our continent's supreme terrestrial carnivore during the Pleistocene. At around 5.5 metres long and 620 kilograms in weight, it certainly seemed reasonable that this all-time biggest lizard could have been a major predator of large herbivores. However, accepting and further developing Hecht's views, Tim Flannery argued that this alleged reptilian 'supremacy' was intimately related to Australia's low-nutrient soils. The premise underlying Tim's argument was that reptiles, being cold-blooded, needed much less food per kilogram of body weight than warm-blooded predators. Consequently, they were inherently better adapted to cope with low-productivity regimes than energy-hungry mammalian counterparts.

Exactly how and why this all happened is not quite clear to me. But at least one identifiable factor seems to have been important. Owen's original description of *Thylacoleo carnifex* was based on a skull only. Little else was known until 1966, when a near-complete specimen was found in Moree, New South Wales. From this new material it was obvious that the Pleistocene Marsupial 'Lion' had a rather short body—closer in length to that of a Leopard than a Lion.

Of course length is, at best, a very rough indicator of weight. A big Leopard (*Panthera pardus*) is longer than an American Black Bear (*Ursus americanis*), yet the Black Bear can be three times heavier than the biggest of Leopards (270 versus 90 kilograms). Similar disparity can be found within the cat family (Felidae). Historically, the largest sabre-toothed 'tigers' (*Smilodon*) have been compared to the Lion (*Panthera leo*), based on gross similarity in form. However, recent analyses suggest that the best-known species, *Smilodon fatalis*, was 1.5–2 times heavier than the average Lion (around 170 kilograms). Still, with not much else to go on at the time, the downward revision of *Thylacoleo carnifex* to 'Leopard-sized' was perhaps reasonable. However, increasingly sophisticated means of estimating the weight of extinct animals have become available in recent years. One simple but accurate method was forwarded by John F. Anderson (University of Florida) and others in 1985. By adding together the minimum mid-shaft circumferences of the femur and humerus (upper bones of the back and front legs) and plotting these data against known weights for a wide range of extant animals, the scientists demonstrated that the two variables were closely correlated. On the assumption that these underlying principles apply to fossil species as well, this was a boon for palaeontologists, enabling reliable estimation of weight for extinct animals based only on data from two leg bones. William Anyonge (University of California at Los Angeles) employed a similar methodology in 1993 to provide a means of estimating the weight of placental carnivores.



The author, Steve Wroe, measuring the skull of a Pleistocene Marsupial 'Lion' (*Thylacoleo carnifex*).

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LITTLE ELSE *was known until 1966, when a near-complete specimen was found in Moree, New South Wales.*

Although shorter than the biggest of living cats, there is no doubt that *Thylacoleo carnifex* was exceptionally robust, far more so than any Leopard (30 to 90 kilograms). With this in mind, we decided to obtain weight estimates for the Moree *Thylacoleo* using the equations provided by Anderson and colleagues, as well as that of Anyonge. We were confident that these would give higher figures than estimates based on head–body length.

Even so, the results were surprising. Depending on whose methodology we used, the weight estimates came out at a whopping 112 and 143 kilograms. On the basis of skull dimensions, the Moree *Thylacoleo* was not the largest. In fact, four of the 13 skulls known were significantly larger, and at least one of these was a subadult or juvenile! Even if we take the lower figure of 112 kilograms, then the biggest specimens must have been very big. How big? Well, mass increases geometrically with length. Although the precise relationship between mass and length is debated, most agree that length cubed is proportional to mass. Assuming that other *Thylacoleo* were of a similar shape to the Moree specimen, then the biggest weighed in at as much as 164 kilograms. This is larger than the average female weights for Tigers (*Panthera tigris*) and Lions (130 and 150 kilograms respectively). Our average weight estimates for *T. carnifex* were 101 to 130 kilograms. No matter how you look at it, this is big for a specialist mammalian meat-eater.

Among specialist living carnivores, only Lions and Tigers fall into this mammalian predator 'super-league'. Moreover (and it comes as a surprise to many), even if we

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From left to right are the skulls of a medium-sized sabre-toothed 'tiger' (*Smilodon fatalis*), a Tiger (*Panthera tigris*), the Pleistocene Marsupial 'Lion' (*Thylacoleo carnifex*), a Leopard (*Panthera pardus*) and two Miocene marsupial 'lions', *Wakaleo vanderleueri* and *Priscileo roskellyae*. The *Thylacoleo* skull dwarfs that of the Leopard to which it has commonly been compared and is of comparable size to that of the Tiger, slightly shorter but considerably wider.

'dig' into the fossil record, only a handful of big cat-like mammals are thought to have ever exceeded average weights of 100 kilograms. For example, from the well-known and intensively researched North American fossil record of the last 40 million years, only four or five felid or 'felid analogues' are known to fall into this 100-kilogram-plus category. Among marsupial carnivores, only one species, the South American Marsupial Sabre-tooth (*Thylacosmilus atrox*), comes even close. Powerfully built, with upper canines over 15 centimetres long, *Thylacosmilus* was the ultimate mammalian predator of its day in Plio-Pleistocene South America. Still, at around 116 kilograms for the largest known individual, it didn't hold a candle to a big *Thylacoleo*.

These new weight estimates have major implications regarding the interpretation of lifestyle for *Thylacoleo carnifex*. No-one has ever suggested that the animal ran its prey down in wolf-like fashion. Most have argued it was a stalk-and-ambush killer, possibly even surprising its victims by aerial assault from the trees. Given the size suggested by our results, we agree that *T. carnifex* was simply too bulky to have run down anything except perhaps for the most ponderous of herbivores, although it was probably capable of short, explosive bursts of speed. It also seems unlikely that adults would have habitually climbed trees. This leads us to an interesting subject. Just what was the preferred diet of *T. carnifex*?

A SHORT SNOUT *enables a more powerful killing bite and well-developed carnassials are typical of all mammalian specialist big-game hunters.*

A number of palaeontologists have drawn analogies between the Pleistocene Marsupial 'Lion' and the sabre-tooth 'tigers' (*Smilodon*). The three species of *Smilodon* varied in size. The smallest, *S. gracilis*, had an average weight of around 80 kilograms. The other two, *S. fatalis* and *S. populator*, were more robust and much heavier—as noted above, perhaps up to twice the weight of modern Lions. Despite this variation, it is widely held that all were specialised hunters of big game. Like *S. fatalis* and *S. populator* in particular, *Thylacoleo carnifex* was extremely robust, with tremendously powerful forelimbs. From examination of attachment sites on its bones, there can be no doubt that *T. carnifex* positively rippled with muscles that would make any body-builder green with envy. It also had an even shorter snout and more elaborate carnassial teeth than the sabre-tooth 'tigers'. A short snout enables a more powerful killing bite and well-developed carnassials are typical of all mammalian specialist big-game hunters.

Further evidence supports the idea that, like *Smilodon*, *T. carnifex* was a meat-specialist (as opposed to bone-cruncher). Blunt, conical tooth cusps, especially pronounced in the Spotted Hyena (*Crocuta crocuta*), are smaller but present in most cats. Such dental modifications are indicative of at least some tendency to crack bones. However, the teeth of *Smilodon* and the Pleistocene Marsupial 'Lion' have absolutely none. They evidently extracted all their nutritional requirements from flesh and other soft tissue alone. In 1981, following a study that showed a high proportion of *Thylacoleo* tooth marks left on fossilised herbivore rib bones, David Horton (Australian Institute of Aboriginal Studies) and Richard Wright (Sydney University) even went so far as to argue that, like *Smilodon*, *Thylacoleo* concentrated on eating internal organs. And still other evidence places *T. carnifex* at the scene of some of Australia's all-time biggest 'murder' cases. At least two studies have identified *Thylacoleo*'s distinctive tooth marks on the fossilised remains of the world's largest marsupial, *Diprotodon australis*. Overall, the picture of Pleistocene Marsupial 'Lion' biology indicated by these findings is of a muscle-bound, 'purpose-built' ambusher, wrestler and dispatcher of large prey. This beast probably didn't waste time taking out small fry.

ADMITTEDLY, TO DATE, the evidence for '*Thylacoleo* the giant-slayer' remains circumstantial, and while features shared with species of *Smilodon* and *Thylacoleo* are highly suggestive, they don't constitute proof that the two occupied similar niches. But, taken together with upward revision of weight, I believe that the prima-facie case is strong; certainly grounds enough to warrant more thorough investigation.

On the issue of deciding which was the most significant predator of terrestrial mammals in Pleistocene Australia—*Thylacoleo carnifex* or the out-sized goanna *Megalania prisca*—a few points need mentioning. First, the Pleistocene Marsupial 'Lion' has, as mentioned, been strongly implicated in the killing of mega-herbivores, whereas *Megalania* has not. Second, *Megalania* fossils are very rare, while *T. carnifex* fossils are relatively common. Third, because it was 'cold-blooded', even a 620-kilogram *Megalania* would not have required as much food as an average-sized (100–130-kilogram) *Thylacoleo*. Consequently, my colleagues and I have argued that, unless *Megalania* was much more common than the fossil record indicates, then it was a far less significant predator of big mammals than *Thylacoleo*.

In conclusion, if the Marsupial 'Lion' is to be compared with placental cats, then the strongest analogies are with the species of *Smilodon*—despite the conspicuous lack of sabre-like canines in the marsupial. Although the largest *Smilodon* was certainly bigger, our new estimates of weight suggest that *Thylacoleo carnifex* would have been more than a match for *Smilodon gracilis*, and few would suggest that *S. gracilis* was anything less than a large and fearsome predator. Certainly it seems high time that Australians stopped short-changing themselves regarding the size and ferocity of their largest mammalian carnivore. Sir Richard Owen may have backed the wrong horse on the subject of Creation versus evolution, but regarding the Pleistocene Marsupial 'Lion', the big man of 19th-century palaeontology got it right from the start. The enigmatic fossil species he described in 1859 really was one of the "fellest and most destructive of predatory beasts".

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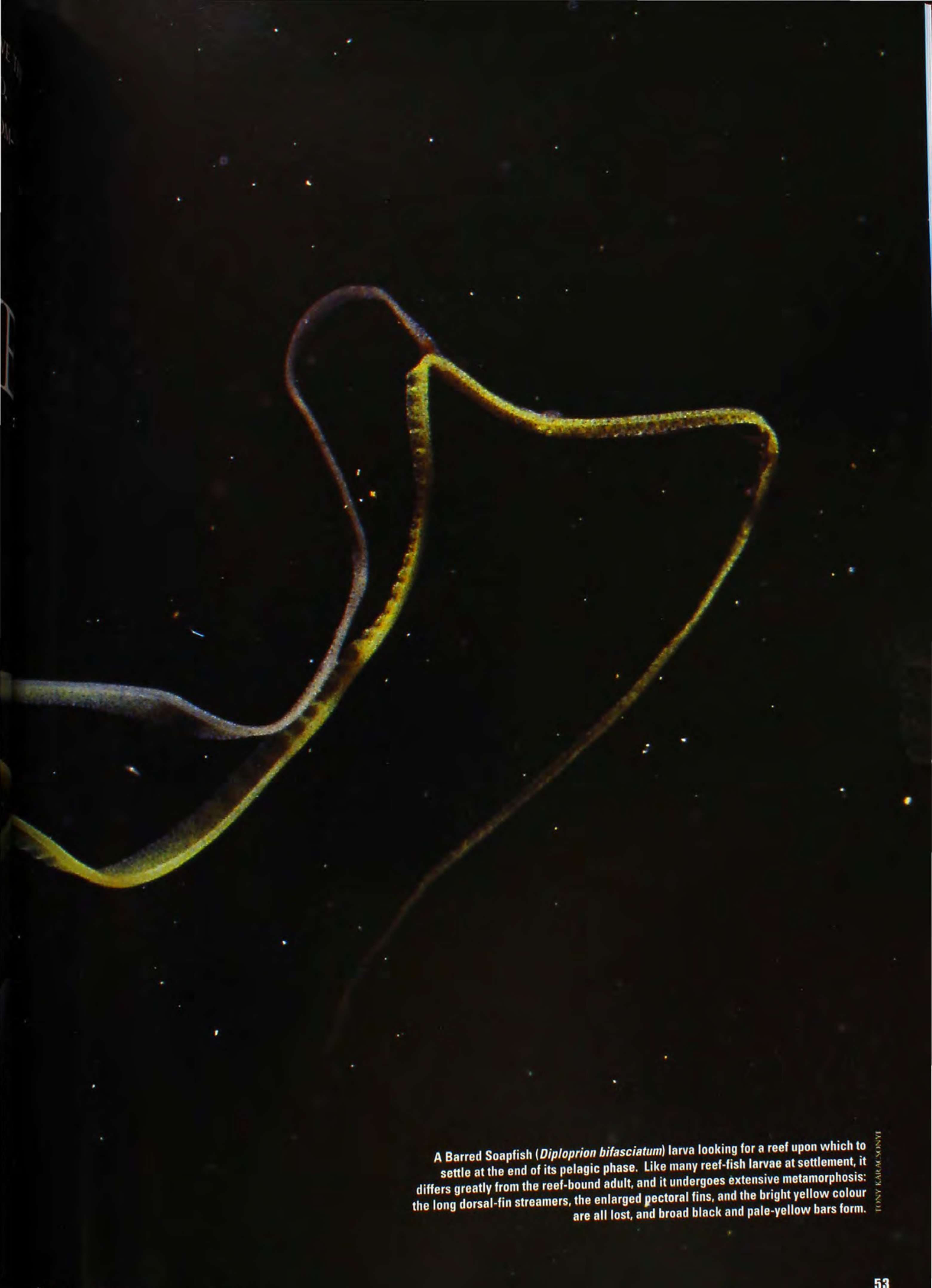
MAURICIO ANTON

Reconstruction of the Marsupial Sabre-tooth (*Thylacosmilus atrox*). This animal shows remarkable convergence with sabre-toothed 'tigers' in its possession of two huge canine teeth. *Thylacosmilus atrox* was the most fearsome mammalian predator of its day in Plio-Pleistocene South America, but at a maximum of around 116 kilograms it wouldn't have held a candle to a big *Thylacoleo carnifex* (up to 164 kilograms).

HOW DOES A ONE-CENTIMETRE-LONG ANIMAL LEAVE THE ONLY ENVIRONMENT IT HAS EVER EXPERIENCED, FIND A CORAL REEF AND CHANGE INTO A BOTTOM-DWELLING REEF-FISH, AFTER A MONTH IN A SEEMINGLY FEATURELESS OCEAN?

OUT OF THE BLUE

BY JEFFREY M. LEIS



A Barred Soapfish (*Diploprion bifasciatum*) larva looking for a reef upon which to settle at the end of its pelagic phase. Like many reef-fish larvae at settlement, it differs greatly from the reef-bound adult, and it undergoes extensive metamorphosis: the long dorsal-fin streamers, the enlarged pectoral fins, and the bright yellow colour are all lost, and broad black and pale-yellow bars form.

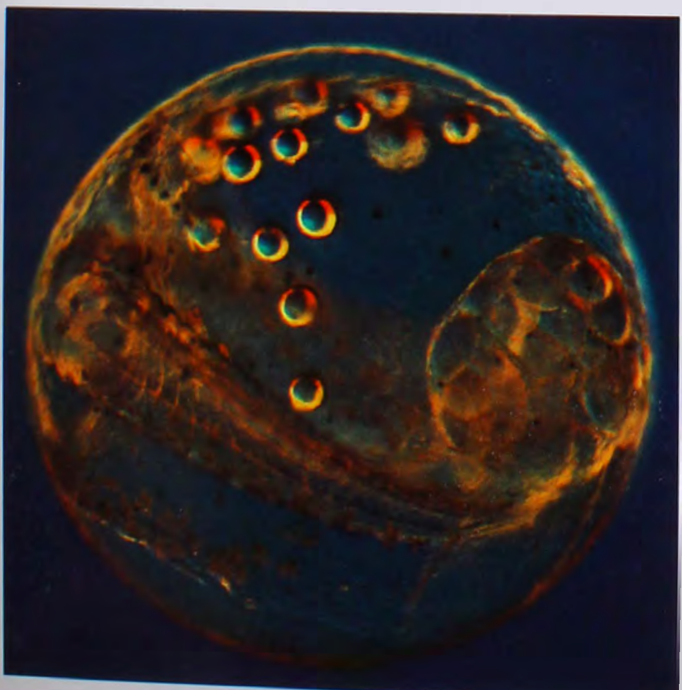
TONY KARACSONYI

BLUE. A BIT BRIGHTER above, darker below, but blue in every direction. The warm, blue, featureless environment of the pelagic ocean is the only one the small fish larva has ever known. Conceived in a cloud of eggs and sperm just off the edge of the reef, the tiny larva drifted on the outgoing tidal currents into the open sea. The parents' sole contribution to its well-being was the small yolk that sustained it until hatching within 24 hours, and for the two to three days beyond. It was then entirely on its own—left to find food and avoid predators with no training or adult help save the genetic instructions in its cells.

The trip in the blue began a month ago. The larva has survived all the perils of the open water and has developed from little more than a one-millimetre glob of yolk with a small tail to something recognisable as a fish, although not much like the adult. Except for a few small silvery patches, it is transparent compared with the adult's gaudy colours of the reef; its body is a very different shape, it lacks scales, and it has spines and serrations on the head where the adult is smooth. It looks like a different species; so different, in fact, that upon first seeing such a fish larva 100 years ago, naturalists declared it not only a species different from the adult reef fish, but also placed it in a different genus. Now an interaction of its genetic instructions, its state of development and the environment itself, tells this one-centimetre-long pelagic animal that it must find a coral reef, leave the only environment it has ever experienced, and change into a bottom-dwelling reef-fish. After a month in the seemingly featureless blue, how is this accomplished?

SCIENTISTS HAD LONG thought that, because larvae of reef-fishes were small, they could not swim strongly and were therefore at the mercy of the currents. No-one had measured their swimming abilities, but larvae of temperate, Northern Hemisphere fishes such as cod and herring of similar size were weak swimmers, so it seemed reasonable to conclude that the same applied to larval reef-fishes. In any case, even if they could swim strongly, it would make little difference if they didn't know where the reef was, and that ability had not been demonstrated in any fish larva. Besides, such simplifying assumptions made life much easier for the computer modellers who were asked by reef managers to work out where the larvae from a given reef ended up at the end of their sojourn in the blue. By assuming the larvae were embedded in the water currents like plums in a pudding, and that they settled onto the first reef they bumped into, all the modellers had to do was work out where the currents went, and they'd know where the larvae went too. Unfortunately, this comfortable set of assumptions is wrong, but this hasn't been easy to demonstrate.

The first hint that the assumptions were wrong came from research by Australian Museum scientists on the distribution of larvae caught in fine-mesh nets in the seas near coral reefs. Different types of larvae originating from the same reef had different distributions. If they were all passively



PETER PARKS/IMAGE QUEST 3-D

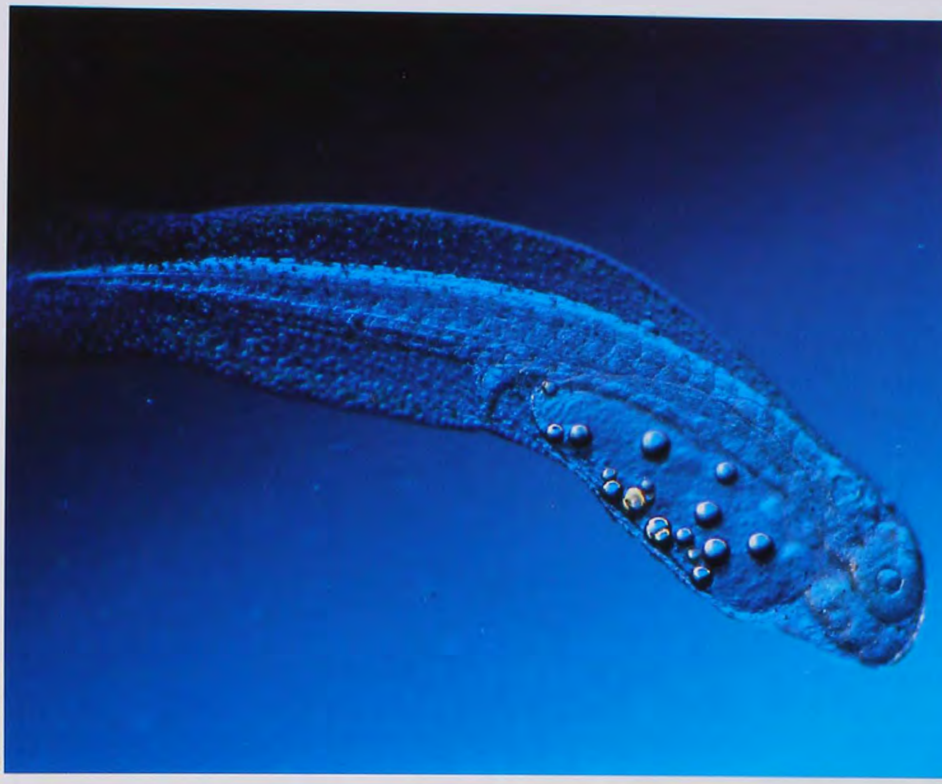
Flatfish or flounder eggs are typical of most reef-fishes. The eggs are about one millimetre in diameter, and float freely in the open water for only a day or so before hatching.

drifting with the currents, this didn't make sense. The next evidence came from laboratory studies by Ilona Stobutzki, then a student at James Cook University. Stobutzki captured larvae about to settle from the blue onto a coral reef, put them into a swimming chamber, and had them swim to exhaustion at the average current speed in the region (in this case, the Australian Museum's research station at Lizard Island, on the northern Great Barrier Reef). The swimming-endurance measurements were so surprising that Northern Hemisphere scientists at first refused to believe them: the one-to-two-centimetre-long fish could swim for up to 100 kilometres in the chamber. The actual distance ranged from 10–100 kilometres, depending on species, but for all species tested, larval swimming endurance was far beyond expectations. Still, doubts lingered.

To get a true picture of what the larvae are doing out in the ocean, our Australian Museum research group decided to get into the water with them and follow them around in the blue. However, one can't merely hop over the side of a boat and hope to see fish larvae—they are far too widely scattered and too well camouflaged for that. Larvae of some species can be lured into traps with lights at night, in much the same way moths are attracted to a light. These larvae can then be released by teams of divers at particular times and places, and observed in the blue. Simple in theory.

In practice, blue-water diving can be very unnerving. One feels very exposed out there, often kilometres from the reef, with the sea floor up to 300 metres below, entirely surrounded by blue. Not everyone's cup of tea, especially for the observer-diver who must totally concentrate on what the larva is doing—even a brief glance away, and the tiny larva is gone. The second diver follows close behind the observer and every 30 seconds records direction, depth and speed. The data-diver must also keep an eye on air supply and time, plus make sure that only shadows, or pilot fish on the lookout for a free meal, are following. At the surface, the driver of the boat circles the divers' bubbles, ready to provide another larva for pursuit, or to pick up the weary divers. The information gathered allows us to plot the trajectory of the swimming larva in three dimensions.

Imagine yourself cruising through the apparently bottomless blue—attention



PETER PARKS/IMAGE QUEST 3-D

CHRIS PARKS/IMAGE QUEST 3-D

The newly hatched flatfish larva (above) is little more than a big yolk (in this case, with numerous oil droplets) with a tail that provides limited swimming ability. The eyes are unpigmented and non-functional, the gut is incomplete, and only a rudimentary fin-fold is present. The flatfish larva (below) is only a few days old, but has well-developed sensory organs and a functional gut. Swimming abilities are good due to well-formed fins and musculature, and efficient feeding and food handling, including storage of reserves.

THE AVERAGE ONE-TO-TWO-CENTIMETRE-LONG LARVA WAS SWIMMING

at 20 centimetres per second, or an average of 14 body lengths per second. To put this in perspective, if Daniel Kowalski swam at 14 body lengths per second, he would complete 100 metres in 3.6 seconds!

fixed on the one-centimetre-long fish larva a metre ahead. Plankton in the water streams by with the hypnotic effect of a starfield-simulation screen saver. Only occasionally do your fins brush the data-diver behind you, assuring you you're not alone. The damselfish larva you are following today is silvery except for the blue on its back, a hint of the adult's colour on the reef. It swims in a near straight line, taking small diversions to grab the odd bit of planktonic food. It begins to ascend, at first slowly but then, with a flick of its tail, it disappears. You turn to the data-diver and shrug. Not quite the full ten minutes that we usually follow a larva, but enough to obtain a good trajectory. Time to start back to the surface to get another larva from the boat circling above. Something flat-headed and streamlined catches your eye, boring in rapidly with long strokes of its tail. Your heart stops for an instant, but it is only a 50-centimetre-long remora, trying to hitch a ride. No more than a nuisance, but every time it happens, you can't help but wonder if the shark it normally latches onto is around. This is a slow, labour-intensive way to obtain data, but it's the only way to get it; and for each fish on which we get information, we gain a little more insight.

THE FIRST THING that became obvious from our studies was that the reef-fish larvae were swimming much faster than Northern Hemisphere temperate larvae. In full scuba kit, we struggled to keep up with some of them. The average one-to-two-centimetre-long larva was swimming at 20 centimetres per second, or an average of 14 body lengths per second, compared with the one to two body lengths per second reported for temperate larvae. To put this in perspective, if Daniel Kowalski swam at 14 body lengths per second, he would complete 100 metres in 3.6 seconds (the world record for the 100-metres freestyle is about 48 seconds)! Surgeonfish larvae, a bit larger than average at 2.5 centimetres, cruise at 50 centimetres per second—about one knot. We got plenty of exercise trying to keep pace with these guys for ten minutes at a time. Interestingly, the average speed selected by larvae in the ocean was about 50 per cent greater than the speed used in Stobutzki's endurance trials, indicating her extraordinarily high values are probably conservative.

Why should these larval reef-fishes be so much better swimmers than temperate species of similar sizes? Perhaps it is just an artefact of the different experimental procedures used. Our measurements were

KEVIN DEACON/OCEAN EARTH IMAGES

(Right) The coral reef is a complex, busy place filled with reef-fishes of an astonishing array of shapes, colours, habits and lineages. However, they nearly all have a larval stage that is passed in the blue, featureless and comparatively empty pelagic environment of the open ocean.

(Below) Australian Museum research divers (Tom Trnski, left, and Brooke Carson-Ewart) out in the blue. The divers are about to 'bag' artificial reef units to census settlement of reef-fish larvae onto experimental moorings in open water.

LYLE VAIL

KEVIN DEACON/OCEAN EARTH IMAGES

VALERIE TAYLOR/NATURE FOCUS

This two-centimetre-long surgeonfish larva (left) has just settled from the blue onto a coral reef at night. At this stage it is mostly transparent and glassy, and has not yet begun to metamorphose into the colourful adult (above), which can reach about 60 centimetres in length.

done in the ocean with wild larvae, whereas the work on temperate species was largely done in the lab with captive-reared larvae. Wild larvae are probably better swimmers than domesticated ones, especially in their natural environment. Swimming may also be more efficient at warmer, tropical temperatures. It is more likely, however, that reef-fish larvae are better swimmers because, at any given size, their bodies, particularly their fins, are much better developed than those of temperate species. The coral-reef environments are very different from the temperate seas of the Northern Hemisphere, and natural selection may have favoured strong swimming by larvae that have to find a coral reef from open water to complete their life cycle.

So, we now know that larval reef-fish are strong swimmers, and can swim more rapidly than the average current speeds they encounter, and for days at a time. But what about swimming direction? Our preliminary work showed that most larvae swim more-or-less in a straight line, and that the individual trajectories were orientated in a way that indicated the larvae knew where the nearest reef (a kilometre away) was located. At the same time, Stobutzki devised an experiment using damselfish larvae in cages designed to detect their swimming direction. The cages were positioned about 50 metres off reefs at Lizard Island during the night. She found that most of the larvae swam toward the reef, again indicating they knew where it was. We are now following up in more detail our preliminary measurements of swimming trajectory by releasing larvae at various distances from the reef. This work is still in progress, but the initial results suggest that larvae of at least some species swim toward the reef regardless of whether they are released 100, 500 or 1,000 metres from it. Surprisingly, when we release larvae of these and other species adjacent to the reef, 30–50 per cent swim back into the blue, while the remainder settle on the reef or are eaten by predators. Perhaps the fact that such a large proportion swim away is an indication that reefs aren't really that difficult for larvae to find.

The most recent blow to the simplifying assumption of passive drift by larvae was provided by Eric Wolanski and colleagues at the Australian Institute of Marine Science. They have shown, by a combination of field measurements and computer modelling of currents, that larvae coming into a reef from the blue would not be found where they were actually captured if they were drifting passively. In other words, active, directed swimming by the larvae is required.

So far, all indications are that larvae can detect reefs from distances of up to one to two kilometres away. But how? Although work is just beginning on this question, the most likely answers are that the larvae either hear or smell the reef. Reefs are very noisy places with waves crashing, parrotfishes scraping coral as they feed, shrimps 'snapping' and a variety of fish 'talking' to one another. Sound carries very well under water, and the ears of fishes develop at an early stage. Intriguingly, research by Doug Cato (Defence Science and Technology Organisation) and Rob McCauley (Curtin University) has discovered that sound levels on Australian coral reefs peak in the summer, at night, and during new moon—the exact times of peak settlement of reef-fish larvae onto the reefs. So there are a number of reasons to think sound is involved. Reefs also give off all sorts of smells from corals, plants and fishes, and fish larvae over about eight millimetres in length (that is, about halfway through their larval development) have well-developed nostrils. However, some of our observations of larvae orientating toward reefs were across currents, whereas smells should be carried with currents. At this stage, some other possibilities cannot be excluded, and much more study remains to be done.

It is important to note that much of the work so far has been on species of one family—the extremely abundant damselfishes. We are now observing and obtaining results on larvae of other, less abundant families such as groupers, snappers, surgeonfishes and butterflyfishes. This will tell us how general the results are. Also, most of the work to date has been on larvae at the end of their blue-water phase. At hatching, larvae are too small and undeveloped to have much influence on where they end up. At settlement, they are very capable and clearly able to control where they go. Sometime out in the blue, during the four to five weeks that it takes to increase in size from one-to-two millimetres to one-to-two centimetres, the larvae start to violate the simplifying assumption of passive drift. We need to find out at what stage during the pelagic larval period the larvae start to swim strongly enough, have sufficient sensory capabilities, and the inclination to use them, to influence their trajectories.

One reason why scientists and managers would like to know how fish larvae find reefs is to help design the best conservation policies. For example, if marine reserves are to function effectively, the reef-fish populations in them must be able to restock themselves with larvae. However, these same populations are also expected to restock unprotected areas in the vicinity. If larvae are capable of remaining near, or of returning to, the reef from which they were spawned, then different spatial distributions of reserves will be needed than if larvae are widely spread during the pelagic phase. By determining what sensory cues the larvae use to home in on reefs, we may be able to use these to restock depleted reef-fish populations on certain reefs, or increase settlement of larvae onto reefs damaged by cyclones or pollution. Finally, it may be possible to use observations of settlement behaviour as a biological measure of the health of reefs. If, for example, larvae refuse to settle on a reef, it may indicate that something is wrong, and that the reef is not sending out the correct cues.

ALL INDICATIONS *are that larvae can detect reefs from distances of up to one to two kilometres away. But how?*

We will have to return to the blue with the tiny larvae to gain further insight into just what these larvae can do. But, even at this stage of investigation, it is clear that the comfortable, simplifying assumptions of old will have to be left behind, and scientists and managers alike will have to become accustomed to the idea of larvae with extraordinary powers of locomotion and sensory perception. Both theory and practical management of coral reefs need a thorough reassessment in light of what we've found so far.

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THE SEEMINGLY SIMPLE QUESTION, "WHEN DID HUMANS ARRIVE IN AUSTRALIA?", CONTINUES TO BE A HOT TOPIC.

A MATTER *of* TIME

BY JIM ALLEN

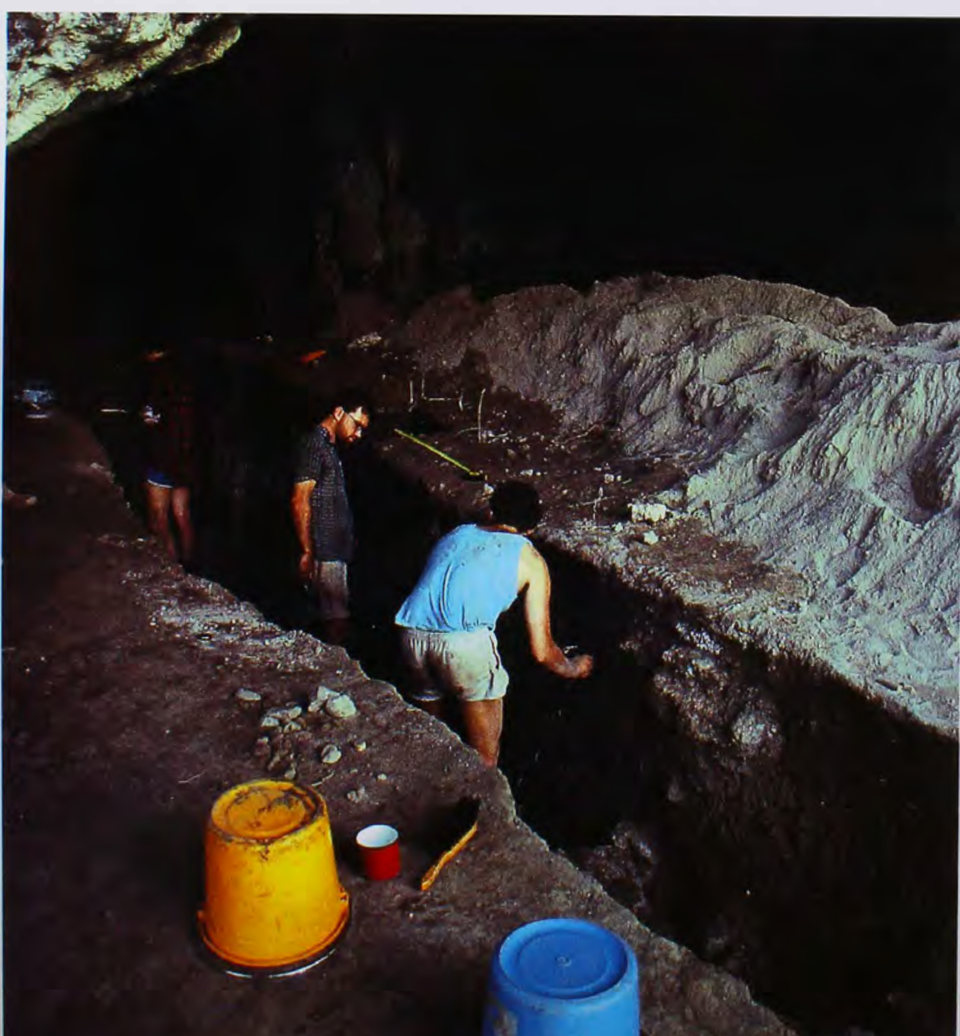
WHEN SHAKESPEARE HAD HAMLET OBSERVE THAT TIME WAS "out of joint", little did he realise that by the end of the 20th century the proliferation of ways to measure past time, and the disjointed results from some of these techniques, might engender disputes among scientists as heated as that between Hamlet and Laertes. The seemingly simple question, "When did humans arrive in Australia?", continues to be a hot topic in Australian archaeology and one the press is quick to exploit. Sensational newspaper headlines announcing the latest early date for an event that took place at least 40,000 years ago might seem odd, but we are intrinsically curious about our own history as a species. Furthermore, in Australia there is an increased awareness of the role of Aboriginal culture and history in the development of our national ethos.

COURTESY JIM BOWLER

The controversial Mungo 3 skeleton being excavated in 1974 by Alan Thorne and Anthea Carstairs. New dates for its burial have caused quite a stir in archaeological circles.

How fast can things change? In a review article in *The Australian Financial Review* in March 1999, aptly titled "The Dating Game", journalist Nick Hordern noted that Mungo 3, one of the human skeletons from the World Heritage Site of Lake Mungo in western New South Wales, was 25,000–30,000 years old. This adult male, discovered by ANU geomorphologist Jim Bowler (now at the University of Melbourne) in 1974, had been buried fully extended on his back, with his head and slightly flexed legs turned to his right. His hands had been gracefully crossed in front of him. His body had been covered with powdered red ochre during the burial. Then, in May 1999 a press release announced that Alan Thorne (ANU) and colleagues had redated Mungo 3 at between 56,000 and 68,000 years old, an increase of between 26,000 and 43,000 years.

What changed? In the first instance only the techniques used to date the skeleton, but by implication our fundamental understanding of the history of our species worldwide. The team involved in the redating now claim that Mungo 3 represents the earliest known human presence in Australia. At 56,000–68,000 years old, Mungo 3 would also be the oldest physically modern human outside of Africa–South-west Asia, and his burial the oldest example of modern human ritual behaviour anywhere in the world by some tens of thousands of years (excluding one or two ambiguous claims associated with earlier hominid species). Such claims in turn beg an avalanche of questions and draw some heated responses. When Bowler, the scientist most responsible for identifying the great importance of the Mungo region as both a human and natural landscape, was asked by an *Age* reporter for a reaction to the new Mungo 3 dates, he replied "Nonsense!".



PHOTOS: JIM ALLEN

Why might these dates be nonsense? How do we examine and make scientific judgements on competing claims? What is the debate about?

THE QUESTION of when humans first arrived in Australia is as old as European settlement here. In the beginning scientists attempted to locate human arte-

facts either within particular geological strata, or in association with the bones of extinct animals, both without much success. Even if such associations had been found, they would have provided no accurate age for the presence of humans, since precise dates for geological formations and animal extinctions were also unknown. This is why the development and use over the last 40 years of radiometric dating techniques—initially radiocarbon (^{14}C), but subsequently a range of other techniques (see box)—have revolutionised archaeology and other Earth sciences.

These increasingly diverse and sophisticated techniques are also a two-edged sword. They have enabled archaeologists to divide sites into narrower chronological units that can reflect change, development and differences in the behaviour of humans and earlier hominids through time and across space. However, unless the scientist is both archaeologist and physicist (and few of us are!), there is a growing dichotomy between generating the dates and exploring their historical implications. Physicists are concerned with developing and defending the accuracy of laboratory techniques and the reproducibility of the numbers they generate; archaeologists are concerned with the stratigraphic integrity of the dating samples, their physical relationships to the human objects or events they purport to date, and whether the resulting dates make historical sense. Normally archaeologists are unable to evaluate the technical propriety of the dates they use. Frequently physicists exonerate themselves from

(Above) Nauwalabila rock shelter in Kakadu National Park. In the early 1990s, thermoluminescene techniques yielded ages of about 55,000 years for stone artefacts found at this site and another in the same region. Apart from the current claims for Mungo 3, a decade of subsequent research has failed to duplicate this antiquity elsewhere in Australia or Papua New Guinea.

(Left) Excavations in Matenkupkum Cave, New Ireland. This is one of the three oldest sites in New Britain and New Ireland, all dated to about 35,000 years ago. The discrepancy between the oldest dates in Papua New Guinea and those in northern Australia questions whether a human arrival much before 45,000 years ago is likely.

Radiometric dating techniques

The following is a list of explanations for radiometric dating techniques used in the text.

Radiocarbon Dating (^{14}C)

All organisms at death begin to undergo conversion of carbon-14 (^{14}C)—a radioactive isotope that they have accumulated while living—into stable nitrogen-14 (^{14}N) . This conversion is at a set rate, such that after 5,730 years the amount of ^{14}C is reduced by half, and after another 5,730 years half of what remains has further disappeared, and so on. The period 5,730 years is thus known as the half-life of ^{14}C. To accommodate for uncertainties, radiocarbon ages are expressed with an error range of one standard deviation. This means that, for a date of 30,000 ± 1,000 years, there is a 68 per cent chance that the real age falls between 29,000 and 31,000 years. ^{14}C is derived from cosmic radiation reacting with ^{14}N in the upper atmosphere, and the dating method assumes there has been no variation in atmospheric ^{14}C concentrations over time. But we now know this is untrue. ^{14}C years therefore differ from calendar years and require calibration to bring them into line. Accurate calibrations, based on tree-ring data, go back about 12,000 years; less accurate calibrations are available to about 22,000 years; and recent estimates suggest that between 40,000 and 50,000 years ago, ^{14}C ages may underestimate calendrical ages by 1,000 to 2,000 years.

After 37,000 years, less than one per cent of original ^{14}C remains in the sample and so it is very prone to contamination by modern carbon, which would produce erroneously young ages. The development of **accelerator mass spectrometry (AMS)** has improved this situation. Previously, residual ^{14}C was measured by converting carbon in a sample to a gas or a liquid and counting the number of nuclear decays over a period of days. AMS directly counts the number of atoms of different carbon isotopes in a sample. It allows the use of smaller samples than previously required and produces a smaller error range. AMS provides acceptable dates at least back to 45,000 years ago. However, if the sample is contaminated, AMS is subject to the same limitations as earlier techniques. Most recently, a new technique to remove contamination, labelled **ABOX-SC**, promises ^{14}C dates that may extend back to 55,000 years ago. The redating of older Australian sites using this technique will enable direct comparisons between ^{14}C and other techniques up to this age, and reduce current uncertainties with this dating method.

Uranium-Series Dating

Uranium- or U-series dating relies on the fact that, after burial, bones may incorporate uranium, which decays into isotopes of thorium (^{230}Th) or protactinium (^{231}Pa). Ages are calculated by measuring the ratios of ^{230}Th and ^{231}Pa to uranium. The dating range of the technique is limited by the half-lives of the radioactive isotopes; if both are used this is about 150,000 years.

Understanding the process of migration of uranium in the ground and its uptake into the bone is important for this technique. Dates calculated on an early-uptake model, which assumes that uranium was accumulated in a short period soon after the bone was buried, may be two or more times younger than dates calculated on a model assuming continuous uranium accumulation.

(continued right)

the responsibility of assessing the historical implications of the dates they generate.

Potentially at least, this dichotomy can make for unsatisfactory science and questionable results. Radiometric dating techniques have various potentials for error, and too often insufficient consideration is given to assessing spectacular new results within their wider historical contexts. Some prominent Australian examples make the point.

SUCH AN EARLY AGE *for humans in Australia questioned our understanding of human prehistory on a worldwide scale.*

Before 1990 most Australian archaeological sites were dated using ^{14}C but no site had produced an age greater than 40,000 years. Then Richard (Bert) Roberts (now at La Trobe University) used luminescence techniques to date two Northern Territory sites, Malakunanja and Nauwalabila, in Kakadu National Park. Roberts and colleagues argued that the sites had been occupied by humans 53,000–60,000 years ago. To explain the discrepancy between these dates and those less than 40,000 obtained everywhere else in Australia and New Guinea using the ^{14}C method, they argued that, by the time an organic sample has been dead for about 35,000 years or more, so little ^{14}C remains in the sample that it is both difficult to measure and highly susceptible to contamination by modern carbon, both in the field and the laboratory. Even atmospheric carbon may have an appreciable effect. Simply put, when the amount of residual radioactivity in the sample is so low that it approaches the detection limits of the available measuring equipment, contamination of the sample by even very small amounts of younger carbon will yield ages that are too young. Roberts and colleagues dubbed this limit of detection the 'radiocarbon barrier'.

As initially appealing as this argument was, it begged some questions. One concerns the fact that by 1990 new techniques such as accelerator mass spectrometry (AMS, see box) routinely allowed reasonable measurements of ^{14}C to be made back to about 45,000 years ago, so that there was a small but significant period in which dates could occur if samples were really that old or older (currently the oldest published ^{14}C date for human occupation in Australia/New Guinea is about 41,000 for the Carpenter's Gap site in the Kimberley). As well, many ^{14}C dates for non-archaeological sites, such as soil formations, swamp and lake deposits or faunal accumulations in caves, had frequently exceeded this 40,000-year barrier (even though contamination may have reduced their real ages). No obvious source of contamination peculiar to archaeological sites can be nominated. In the case of Nauwalabila and Malakunanja, the older archaeological layers in these sites were devoid of datable organics, and it has also been suggested that lack of preservation of organic dating samples in other old sites might explain the absence of ^{14}C dates beyond 40,000 years in archaeological sites. However, most of the older sites have datable charcoal throughout their sequences. The most parsimonious explanation is that few (or perhaps none) of these sites are much older than about 40,000 years, or 43,000–45,000 calendrical years after calibration (see box).

Luminescence techniques have different problems. In 1996 Richard Fullagar (then an ARC Research Fellow at the Australian Museum) and colleagues claimed that thermoluminescence (TL) dates placed humans in the site of Jinmium, just east of the Kimberley region in the Northern Territory, between 116,000 and 176,000 years ago. Such an early age for humans in Australia questioned not only our understanding of human prehistory on a worldwide scale, but also the effectiveness of luminescence techniques themselves. The ensuing debate thus concentrated on scientific methods rather than historical implications. ANU's Nigel Spooner argued that the laboratory analyses used had led to age overestimation and concluded that the actual date range fell between 10,000 and 30,000 years. Subsequently Roberts and colleagues redated samples from the site using optically stimulated luminescence (OSL) techniques and concluded that the dated sand grains included at least some derived from sand-

Electron Spin Resonance (ESR)
This method, along with luminescence techniques, is based on the accumulation over time of electrons in the crystal lattices of certain common minerals. A sample in the ground absorbs radiation (traps electrons) from radioactive sources within an approximately 30-centimetre radius, together with some cosmic rays. The trapped electrons are mildly magnetic and this magnetism can be measured to give the ESR signal. Because the total amount of radiation absorbed (the 'accumulated dose') increases with time, the sample age can be calculated by dividing the accumulated dose by the dose rate (the level of natural radiation affecting the sample), assuming the dose rate has remained constant in the past. The dose rate is measured from the sample and the surrounding soil matrix.

The ESR technique can be applied to a variety of materials—speleothems, corals, quartz, mollusc shells etc.—but in archaeology it is most commonly applied to the dating of tooth enamel.

ESR shares the general limitations of trapped-electron techniques. In particular, the ESR 'clock' must have been set at zero—that is, had the electron traps emptied—at the same time as the event being dated. (For teeth this means burial at death, at which time the ESR signal is effectively zero.)

In dating tooth enamel using ESR, a particular concern is the unknown history of uranium uptake by the sample, since this is fundamental in determining the dose rate. Usually, ages are calculated on both an early-uptake and a linear-uptake model. While this produces a large error range for most ESR dates, the technique can be used in conjunction with other techniques, such as U-series dating, to determine which uptake model is most appropriate.

Luminescence Techniques
Thermoluminescence (TL) and **optically stimulated luminescence (OSL)** are the two major luminescence dating techniques so far used in Australia. TL is the light emitted from a mineral when heated, and OSL is the light emitted when the mineral is exposed to visible light. As with ESR, the intensity of the signal determines the accumulated dose, and age is calculated in a similar manner to ESR. Most commonly, quartz grain samples are used for luminescence dating in Australian sites.

For the luminescence 'clock' to be accurate, the quartz grains need to be heated or bleached by sunlight prior to burial, to set the clock to zero, and it is this 'zeroing event' that is being dated. Once buried, and no longer exposed to heat or light, the trapped electrons begin to accumulate again. Because some traps are emptied slowly by sunlight, residual luminescence can affect the signal measured by TL. OSL, on the other hand, uses only the most light-sensitive part of the luminescence signal, which in quartz is quickly bleached by sunlight. For this reason, OSL has mainly superseded TL in dating Australian sites.

If the luminescence clock has not been reset to zero, samples will produce erroneously old dates. In particular, weathering of quartz-bearing rocks buried in deposits can release and mix grains that contain many more trapped electrons than their neighbours and yield older dates. One direction of research has been to refine techniques so that samples consist of fewer grains of sediment, even down to single-grain analysis. This enables multiple samples from the same locations to be dated and compared to determine and eliminate rogue samples.

stone rocks that had decomposed in the site after burial, so that their 'clocks' had not been zeroed (see box for explanation of dating techniques). Thus they were indicating erroneously old ages.

Greater certainty is claimed for the recent dates for the Mungo 3 skeleton, because three different techniques were used: OSL on quartz grains from the soil unit containing the skeleton, electron spin resonance (ESR) on a tooth enamel fragment, and uranium-series (U-series) dating on parts of the skeleton itself. While the general concordance of the results from these three techniques is encouraging, the dating scientists involved are at pains to emphasise the limits of the methods used.

U-series dating of four bone samples from the skeleton provided apparent age ranges from 50,000 to 70,000 years. However, the authors agree that, under conditions where uranium was not taken up by the skeleton for some time after burial ('delayed U-uptake'), the skeleton could be even older than 70,000 years; or, if uranium was removed from the skeleton, as might occur through oxidation after erosion of the surrounding sand dune, it could be younger than 50,000 years. For the ESR dating of tooth enamel, two models (one involving early uptake of uranium, the other linear uptake) provided age ranges of 57,000–69,000 years and 71,000–85,000 years. The authors believe that combining the U-series dates for bone and the ESR dates for tooth enamel gives a best estimate of 56,000–68,000.

The two OSL dates for the sediment in which the skeleton was found produced ages of 59,000–63,000 years. These dates are concordant with the age estimate for the skeleton, although they are significantly older than previous luminescence dates obtained for this soil unit. A specific issue is that the skeleton is apparently not younger than the soil containing it, as might be expected, given that the grave must have been dug from a higher level. When the skeleton was found, the soil around it had eroded until bones were exposed, so that where the ground surface was when the grave was dug is uncertain. Thorne and colleagues believe ground level was only a little higher in the same soil unit and that the grave was shallow, but there is no clear stratigraphic confirmation of this; however, the assumption is necessary if the OSL dates are to agree with the older U-series dates.

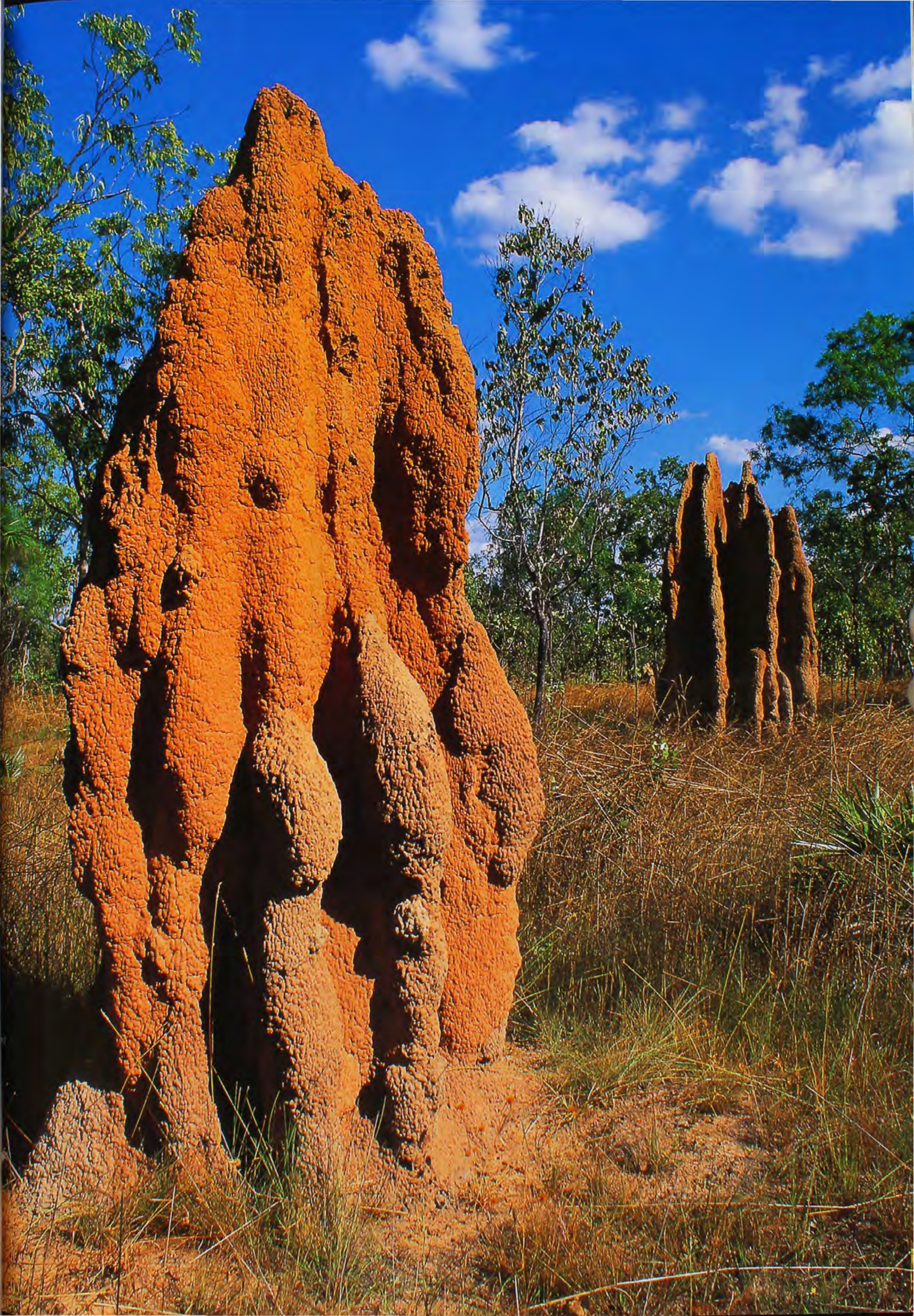
This uncertainty about where ground level was when the grave was dug is an example of a much wider general problem in dating humans in Australia. A range of post-depositional processes may blur or destroy the original relationship between the dating material and the archaeological 'event' (in this case the burial) being dated. Direct association between the archaeological evidence and the dating medium, be it sand grains for OSL or charcoal for ^{14}C, requires demonstration, even more so for dates that might radically challenge consensus views of the past. Many events, from volcanic eruptions and earthquakes, to underground water activity, and even to the effects of soil-moving animals like worms or ants, can have

DENNIS SARSON LOCHMAN TRANSPARENCIES

Termite mounds comprise millions of sand grains carried up through tunnels from metres below the ground. When abandoned, they disintegrate, forming the new ground surface. A new mound built above it will repeat the process, so that over thousands of years the soil may circulate, causing larger objects such as artefacts to move lower in the deposits. Artefacts dated using adjacent sands may appear older than they are; at the same time the luminescence clock of each grain exposed to light will be reset, so that luminescence dates will continue to be in sequence.

PAUL TAÇON

Senior traditional owner Paddy Carlton and archaeologist Richard Fullagar holding discussions at Jinmium rock shelter, Northern Territory. The site of Jinmium yielded initial thermoluminescence dates of 116,000–176,000 years for human occupation. Subsequent dating of this site now indicates that the real age of occupation is probably less than 30,000 years.



PHOTOS: JIM ALLEN

(Left) Excavations in a small underground cavern provide the only access to deposits in Warreen Rockshelter, one of more than 20 Pleistocene sites in south-western Tasmania. Currently the oldest known site in Tasmania, Warreen was first occupied nearly 35,000 years ago. It is difficult to envisage that the Mungo region was occupied 20,000–30,000 years earlier.

(Right) Walls of China, Lake Mungo. The long-term effects of deep erosion channels such as these undermine the general stratigraphic integrity of the region and make precise dating of single artefacts more difficult.

significant effects on the integrity of sites. Fellow archaeologist Jim O'Connell (University of Utah) and I have raised the issue of what effects termites might have had on the deposits of Nauwalabila and Malakunanja. This might seem a comic criticism, but consider for a moment that every sand grain in those giant mounds commonly scattered across northern Australia derives from the ground below. Termite mounds occur not only in open country, but also in archaeological sites. It is easy to envisage the continual recirculation of grains excavated by termites, while other grains and larger objects such as stone tools, move deeper below the surface. In central African sites, where the same termite activities occur, stone flakes that fit together and were struck from their parent core at the same time in the distant past, have been excavated from levels up to a metre apart. However, because resurfaced grains have their luminescence clocks zeroed before being buried again, luminescence dates continue to increase in age with depth and, in this respect, are indistinguishable from undisturbed sites.

WHENEVER WE place undue emphasis on any exceptionally old claim without examining it very critically, we run the risk of the tail wagging the dog. Currently in Australia and New Guinea there are more than 160 archaeological sites of Pleistocene age (older than 10,000 years). With the exceptions of the Mungo 3 skeleton and the two Northern Territory sites, none is presently claimed to be older than 43,000–45,000 calendrical years. This is despite a decade of redating the oldest known sites using TL and OSL techniques. In the north, the two semi-arid Kakadu sites are offset against the food-rich northern coasts and islands of New Guinea—the logical pathway of initial colonisation if we assume that people first occupied regions most familiar in terms of food resources to those they left behind—where a coherent pattern of human settlement does not begin until 15,000 years later. The same problem occurs with Mungo, where arid western New South Wales is now said to be occupied perhaps 30,000 years before a dozen known sites in the food-rich upland valleys of south-western Tasmania, only a thousand kilometres to the south and accessible at that time across the land bridge that is now Bass Strait. The Tasmanian sites are intact, well-dated, and rich in artefacts and the bones of animals used as food. They form a coherent pattern of human land use, which began about 35,000 years ago. People visited these valleys specifically to capture Bennett's Wallabies (*Macropus rufogriseus*), whose bones constitute over 90 per cent of the identifiable bone material from at least three of the sites. For the following 20,000 years, right through the height of the last Ice Age, people made regular visits to these valleys to capture Bennett's Wallabies, which were a dependable resource. It seems at least improbable, both in the north and south of the continent, that arid and semi-arid zones, which require specialised local knowledge, high mobility and small group sizes to survive, were occupied tens of thousands of years before more food-productive regions.

Viewed in the wider world context, Australian sites considerably older than 45,000 years challenge consensus views that anatomically and behaviourally modern humans moved out of Africa into South-west Asia 45,000–50,000 years ago then into Europe, Siberia, South-east Asia and Australia by 40,000–45,000 years ago. The presently oldest known date for modern humans from South-east Asia is about 43,000 years and, despite some special pleading, a large amount of exploration in China has produced no conclusive older evidence of behaviourally modern humans there. Supporting data for this 'Out-of-Africa' model include genetic indications of world population increase at this time; along with the first appearance of modern human skeletons outside Africa (leaving aside Mungo 3) and the disappearance of earlier hominids such as Neanderthals; changes in stone and other technologies in the eastern hemisphere; and the appearance of art, personal decoration and formal burial. Global expansion as a single event is the simplest explanation of the evidence. Having modern humans in Australia before about 45,000 years ago requires significant adjustments to world prehistory, and at least two dispersals out of South-west Asia, with no other evidence for the first of these than the claimed Australian dates beyond 50,000 years. If such a dispersal occurred, evidence of it should also appear in Asia.

Just as these few extreme claims for antiquity are not supported by the wider body of evidence, so too do the claims for the relevant Mungo soil unit being 59,000—63,000 years old conflict with the much wider body of knowledge that comprises the geomorphological history of western New South Wales, itself based on hundreds of dates. This is the basis for Bowler's scepticism. In his view the soil unit containing the body did not exist before about 47,000 years ago. Bowler himself believes that Mungo 3 may be about 42,000 years old and that older artefacts exist in the Mungo sands. However, the stratigraphic integrity of these few pieces is far from established.

Nick Hordern, in his newspaper article, compared watching the development of Australian archaeology to watching a trial. Just as you begin to decide what the outcome will be, new evidence changes the case. Mungo 3 is the latest example of such new evidence, which, as I write, is under review by peers who question the dating techniques employed and thus the ages claimed for the burial. Increasingly, because we now know so much about early human history, it grows more difficult to alter what we know on the basis of data from one or two sites. New results cannot be rejected or ignored, but neither can they be uncritically embraced. To accept modern humans in Australia at 60,000–70,000 years ago will require a fundamental restructure of what we know of early human history worldwide. Of course, that continual possibility is what makes archaeology interesting.

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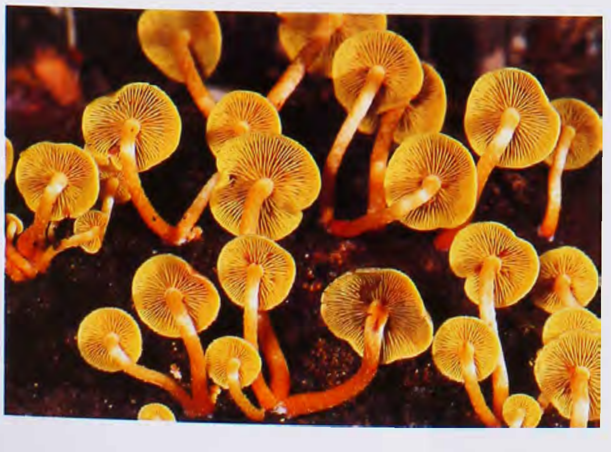
JIM ALLEN IS EMERITUS PROFESSOR OF ARCHAEOLOGY AT LA TROBE UNIVERSITY AND A VISITING FELLOW AT THE AUSTRALIAN NATIONAL UNIVERSITY. HIS CAREER AS AN ARCHAEOLOGIST HAS SPANNED MORE THAN 30 YEARS, DURING WHICH TIME HE HAS EXCAVATED SITES IN MOST AUSTRALIAN STATES AND IN MELANESIA. SINCE 1985 HE HAS CONCENTRATED ON PLEISTOCENE ARCHAEOLOGY IN NEW GUINEA AND TASMANIA.



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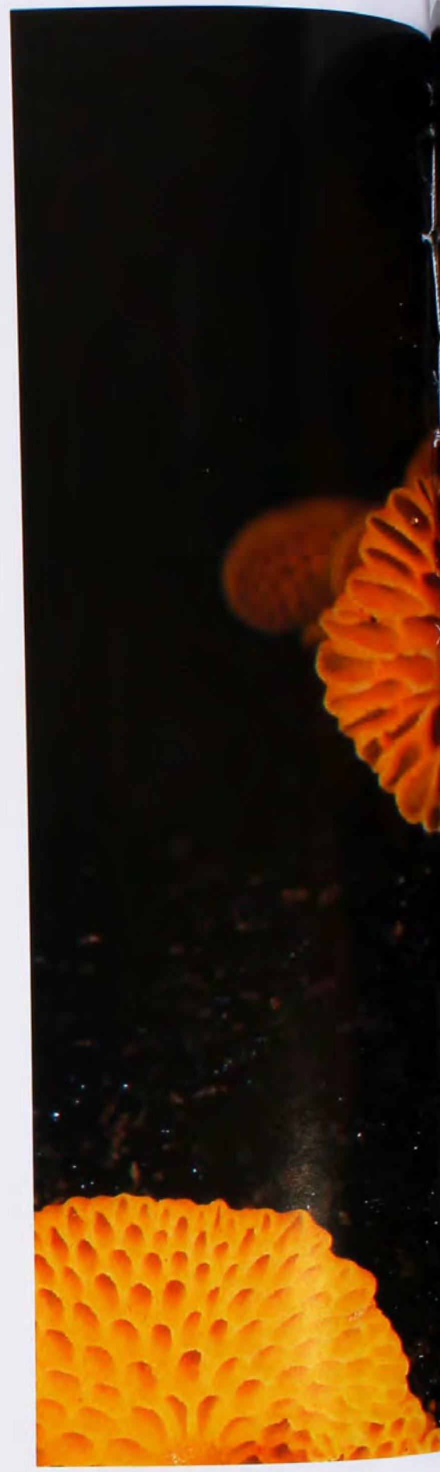
BY BRIAN CHUDLEIGH



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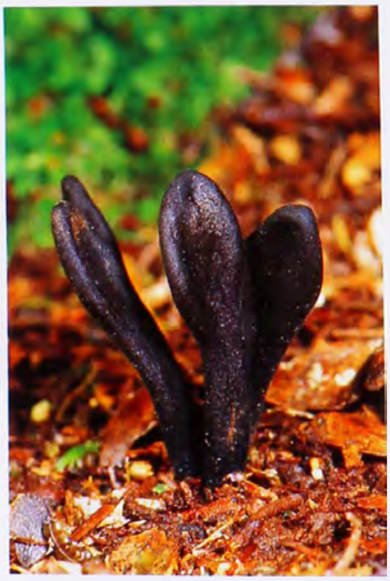

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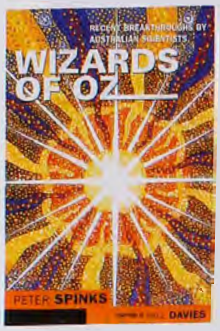


Wizards of Oz

By Peter Spinks. Allen & Unwin, NSW, 1999, 243pp., $19.95rrp.

WE READ ALL TOO OFTEN of the brain-drain of Australian scientists to more lucrative contracts and better-funded research overseas. Hence this book is in no small way an uplifting one. It renews one's confidence in Australia and in the dynamic research activities of its often under-resourced scientists.

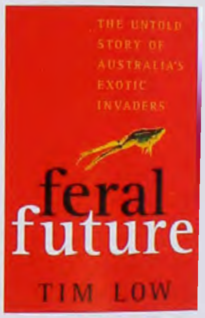
The coverage is, of course, selective. A book like this cannot be expected to be comprehensive, whatever that may mean and impossible as it is to achieve. The book consists of broad-topic chapters, each with a series of short, almost newspaper-like reviews of research projects and researchers. It reminded me of a written "Movietone News" of science, a "Quantum" in print. These are bite-sized chunks of science, quickly consumed and easily digested. Some readers may find this style a little dry and certainly anyone expecting a series of essays, *à la* Stephen J. Gould, will be disappointed. The bibliography is very short. I may be in the minority on this, but I would have liked a fuller reference to the scientific publications of the scientists mentioned. It would then have been a unique resource in linking popular and scientific literatures.

All in all, if approached for what it is, this is a worthy enough book. I would like to think, but almost certainly will be wrong, that more than a sprinkle of politicians and leaders of industry will read it. The rest of us can give thanks for the achievements of the scientists briefly spotlit in this book . . . and hope that most of them stay in Australia.

—GARY MORGAN
WESTERN AUSTRALIAN MUSEUM

Feral Future

By Tim Low. Penguin Books, Vic., 1999, 380pp. $24.95rrp.



IN THE COMING MILLENNIA, WHEN SAPIENT BEINGS wish to understand how the 3.6-billion-year-old natural world first began to be destroyed by humans, *Feral future* will be a key document. This is because it describes one of the main processes in that destruction—the human translocation of organisms from places where they occur naturally to other places, with the inevitable deleterious impact on the species amongst which they are placed. The author, a skilled scientist and science writer well known to the readers of this magazine, provides many accounts of the critical early stages of these translocations and details both the active and passive decisions that not only permitted, but in many cases actively promoted, the process. And in the course of his work, he fingers some of the more unlikely aiders and abetters: animal keepers, biological controllers, botanic gardens, game stockists, government agencies and their scientists, and horticulturalists. And the attitudes providing underlying support for this practice continue to occur in the most surprising places. For example, I recently heard a senior New South Wales National Parks and Wildlife officer speak admiringly about an enormous Emu farm in the central west of the State that was stocked in part with Emus from Western Australia and consisted of enormous paddocks planted with a vigorous species of African grass, the seeds of which were supplied by the CSIRO. When asked about the genetic implications of Western Australian Emus escaping and breeding with local Emus, and the possibility of yet another vigorous exotic grass being unleashed on Australia, he gave me a look of contempt tinged with pity. Small wonder the natural world is being done like a dinner.

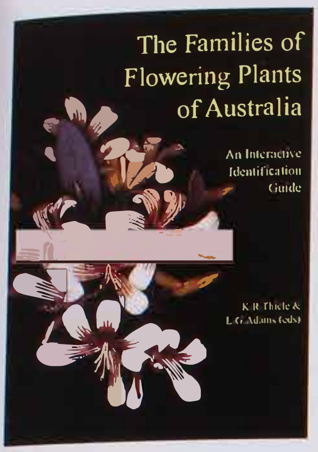
—ALLEN GREER
AUSTRALIAN MUSEUM

The Kangaroo Betrayed: World's Largest Wildlife Slaughter

Ed. by Maryland Wilson. Hill of Content Publishing, Vic., 1999, 78pp. $19.95rrp.

THIS BOOK IS EDITED BY MARYLAND WILSON, President of the Australian Wildlife Protection Council. It comprises 40 short contributions from various authors opposed in some way, shape or form to the commercial killing of kangaroos. A range of perspectives is offered on this emotive issue. Several authors argue that there is no need to manage kangaroo populations at all because numbers have not increased and because kangaroos do not compete with stock or contribute to land degradation. Some oppose philosophically the consumptive exploitation of any wildlife species. Others believe that the kangaroo-harvesting industry is cruel, corrupt, self-serving, undervalues the resource, defiles our national emblem and is non-sustainable in its current form. David Croft offers ecotourism as an alternative to consumptive use of wildlife using southern Africa as a model. Des Cooper provides a timely critique of the much-touted potential 'panacea' of wildlife population-control options—immunocontraception. Although this book is peppered with supposition and personal opinion, it also contains useful facts and does raise some issues of concern. Perhaps the most important is the long-term impact of the selective removal of the largest animals from harvested kangaroo populations.

—GLENN EDWARDS
PARKS & WILDLIFE COMMISSION OF THE NT



The Families of Flowering Plants of Australia: An Interactive Identification Guide

CD-ROM ed. by K.R. Thiele and L.G. Adams. CSIRO Publishing, Vic., 1999. $69.95rrp.

AUSTRALIA LEADS THE WORLD in interactive computer keys to identifying native plants and animals. This is the third in a botanical series (the first two deal with Australian tropical rainforest trees and the eucalypts of south-eastern Australia); others are in the pipeline.

This computer package is of the same high standard as the other two. The installation instructions are easy to follow and the process is remarkably quick. Once installed, the program is very easy to manoeuvre through. I recommend all first-time users, both professional botanists and dedicated naturalists, to read the general information. It gives definitions of the terms used in the key. This is important as some of the terms are given a broad definition for simplicity's sake and it will avoid errors when coding your unknown specimen. Overall, the terminology has been kept to a bear minimum, catering for people without an extensive botanical background. Most of the characters are illustrated with thumbnail sketches and, for those characters that regularly cause confusion (for example rotate versus funnel versus bell-shaped corollas), both a sketch and brief note defining the character are presented.

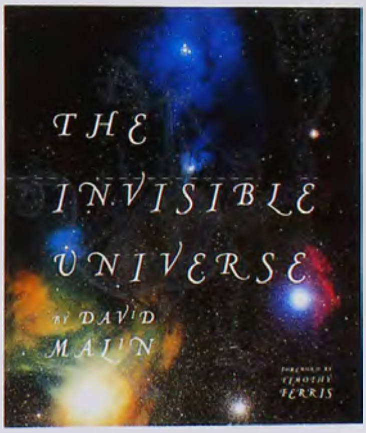
All of the families have photos of flowers and fruits showing a selection of the diversity present in each family. There are also thumbnail descriptions highlighting main diagnostic features, along with a full family description, the list of genera recognised for that family, and in which volume of the *Flora of Australia* that family will or has appeared in.

This computer-interactive key is a must for all people interested in the Australian flora and will be an excellent tool for teaching students or people hoping to become familiar with our flora.

—PETER JOBSON
NATIONAL HERBARIUM OF NSW

The Invisible Universe

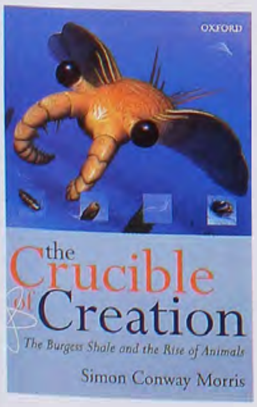
By David Malin. Penguin Books, Vic., 1999, 132pp. $75.00rrp.



FOR DECADES, ASTRONOMER DAVID MALIN has made his wonderful astronomical photographs available to the rest of us. *The invisible universe* is the latest of Malin's celestial offerings. This is a big book about big ideas: a collection of superbly reproduced photographs—each measuring a whopping 40 x 30 centimetres—accompanied by a brief description of the object displayed. As much as this is a visual book, Malin has blended text, both scientific and poetic, so that the emotional response evinced by the photographs is reflected in the readings. The historical context of our understanding of each object is also described. This is not a rehashed collection of Malin's images. Some will be familiar, but all of the photographs in this book are either new, or are reproduced as never before (in terms of size and fidelity). One of the best examples is the Great Nebula in Orion, displayed in such fabulous contrast you tend to become lost in the image. You might wonder how it could get better . . . until you turn the page. There is another image of the same object, this time closer in. And so it is throughout the book: splendid images, one following the next, each trying to outperform the other.

Why the "invisible" universe? Simply because, due to the insensitivity of the human eye, the largest, most spectacular objects in space will never be seen by most of us, and none of us would ever see them in colour. Malin shows us a universe that is immense, intricate and colourful. Thanks to his efforts this 'invisible universe' is visible at last.

—GEOFF MCNAMARA

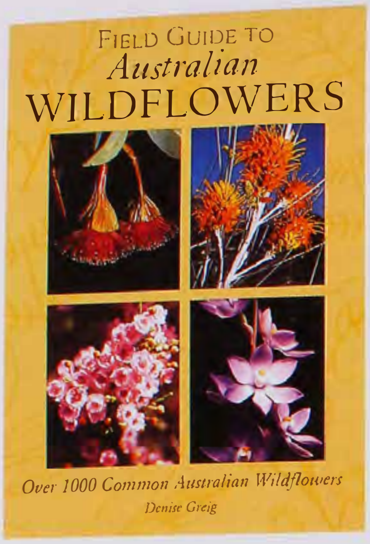


The Crucible of Creation: The Burgess Shale and the Rise of Animals

By Simon Conway Morris. Oxford University Press, Vic., 1999. 242pp. $29.95rrp.

THE BURGESS SHALE IS FAMILIAR to armchair natural historians (and not just a handful of boffins) because of Stephen Jay Gould's 1989 book *Wonderful life*. In *The crucible of creation*, Conway Morris argues that research on the Cambrian menagerie over the past ten years requires that we discard the earlier author's ideas about the place of the Burgess Shale in evolution. Conway Morris' criticism of Gould is relentless, and leaves the reader feeling slightly grubby after a while. Chapters in which Conway Morris deals with his own field of expertise—Cambrian animals and their ecology—make for an engrossing read. The author's attempts to marry recent work on developmental genetics and the origin of body plans are courageous, if not entirely compelling (for example a scenario by which brachiopods evolved their shells falls short of the mark). A supposedly damning critique of the cladistic approach to reconstructing evolutionary trees founders because Conway Morris reveals a limited grasp of the subject. The book rankles when Conway Morris lapses into dreary moralising and opines on such matters as architecture and society's post-Saussurean malaise. He's much better when he sticks to ancient 'penis worms'.

—GREG EDGECOMBE
AUSTRALIAN MUSEUM



Field Guide to Australian Wildflowers

By Denise Greig. New Holland, NSW, 1999, 442pp. $39.95rrp.

PERSONALLY, I PREFER REGIONAL FIELD GUIDES to guides that cover the whole country as their coverage is never extensive enough. However, I have to concede that, as far as wide-ranging field guides go, this has a number of commendable features. The introduction is one of the nicest features of this guide in that it presents a clear but easy-to-understand introduction to taxonomic terminology and general botany. The section on Australian vegetation is very informative, although in the map I would have coloured-coded the wheat belts of Western Australia as a mosaic of heathland and woodland rather than just woodland.

The family headings and species descriptions are very informative and overall the little line drawings in the margin are useful. The photos, which are the crux of this book, range from excellent, presenting all diagnostic features, to downright useless, as is the case in a number of the *Eucalyptus* shots where only flowering branches are shown. There are also surprisingly few misidentified photos, considering the range of families covered in the book.

This book has a strong bias towards the south-west corner of Western Australia and temperate south-eastern Australia. The back cover claims to cover the tropical north, but there are less than ten species represented from this area, and a number of the more spectacular species, such as *Melaleuca leucadendra, Bauhinia cunninghamii, Eucalyptus miniata* and *Adansonia gregorii* (Boab), are missing. Tasmania is also poorly represented; *Nothofagus gunnii, Richea pandanifolia* and *Bellendena montana* are noticeably absent.

The further reading section is very extensive, except a couple of key references covering the Top End are missing. The glossary covers all the botanical terms used in the text, and is concise and informative. Unfortunately, some of the diagrams in the glossary are misleading or inaccurate, particularly those illustrating superior and inferior ovaries, and the compound umbel.

This book has a lot of potential, especially for tourists travelling around the country who have limited space. I hope the second edition has an expanded tropical plant section, making this a desirable throw-in-the-car field guide for long-distance travellers.

—PETER JOBSON
NATIONAL HERBARIUM OF NSW

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

Australian Wildlife Protection Council
247 Flinders Lane
Melbourne, Vic. 3000
Ph: (03) 9650 8326 or (03) 5978 8570 a.h.
Web: www.geocities.com/awpc
Contact: Maryland Wilson
Membership fee: $20

Fauna Rescue of South Australia Inc.
PO Box 241
Modbury North, SA 5092
Ph: (08) 8264 4958
Web: www.frosa.org
Contact: Mrs Sheila Burbidge
Membership fee: $20 single, $30 family, $10 student/pensioner, $20 family concession, $50 organisation

BIRDS

Birds Queensland
PO Box 6097
St Lucia, Qld 4067
Ph: (07) 3870 8076
Contact: Dawn Muir
Membership fee: $35 city, $30 country, $20 student, add $5 for family

Hunter Bird Observers Club
PO Box 24
New Lambton, NSW 2305
Ph: (02) 4951 3872
Web: http://users.hunterlink.net.au/hboc/home.htm
Contact: Tom Clarke

CONSERVATION

Australasian Wildlife Management Society
Threatened Species Unit, Sydney Zone
NSW National Parks & Wildlife Service, PO Box 1967
Hurstville, NSW 2220
Ph: (02) 95856827
Web: www.awms.org
Contact: Dr Debbie Ashworth
Membership fee: AUS$30/NZ$33 ordinary, $60/$66 institution, $15/$16 concession

National Parks Association of Qld Inc.
PO Box 1040
Milton Centre, Qld 4064
Ph: (07) 3367 0878
Web: www.npaq.org.au
Contact: Leon Misfeld
Membership fee: $40 single, $60 household

EARTH SCIENCES

Australian Field Geology Club
16 Arbutus St
Mosman, NSW 2088
Ph: (02) 9969 2135
Contact: Doug Raupach
Membership fee: $20

EDUCATION

CSIRO's Double Helix Science Club
PO Box 225
Dickson, ACT 2602
Ph: (02) 6276 6643
Web: www.csiro.au/helix
Contact: Lynn Pulford
Membership fee: $26.25

Marine Education Society of Australasia
PO Box 461
East Bentleigh, Vic. 3165
Ph: (03) 9503 9823
Contact: Jody Plecas
Membership fee: $30

ENVIRONMENTAL

Greening Australia/Earth Keepers
Natural Resource Centre
5 Fitzgerald Rd
Pasadena, SA 5042
Ph: (08) 8372 0120
Contact: Sheryn Pitman
Membership fee: $10 to $25

Nature and Society Forum Inc.
PO Box 11
Canberra, ACT 2601
Ph: (02) 6288 0760
Web: www.natsoc.aust.com/~natsoc
Contact: John Schooneveldt
Membership fee: $25 single, $40 group, $12 concession

WIRES
PO Box 260
Forestville, NSW 2087
Ph: (02) 8977 3333
Web: www.wires.webcentral.com.au
Contact: Sheridan Thomas
Membership fee: $30

FROGS

Queensland Frog Society
PO Box 7017
East Brisbane, Qld 4169
Ph: (07) 3366 1806
Web: www.qldfrogs.asn.au
Contact: Jenny Holdway
Membership fee: $10 adult, $15 family, $7.50 U18, $5 U10

INSECTS

Entomological Society of Victoria
56 Looker Rd
Montmorency, Vic. 3094
Ph: (03) 9435 4781
Web: www.vicnet.net.au/~vicento/
Contact: Ian Endersby
Membership fee: $20 single, $12 students

Society for Insect Studies
Search & Discover, Australian Museum
6 College St
Sydney, NSW 2010
Ph: (02) 9523 7933
Contact: Graham Owen
Membership fee: $15 p.a.

MICROSCOPY

The Postal Microscopical Club
PO Box A1017
Sydney South PO, NSW 1235
Web: www.pnc.com.au/~dingley
Contact: Michael Dingley
Membership fee: $20–$40

MUSEUM

Queensland Museum Association Inc.
Box 3300
South Brisbane, Qld 4101
Ph: (07) 3840 7632
Contact: Carol Middleton
Membership fee: $20 single, $40 family, $15 concession, $20 country

TAMS—The Australian Museum Society
6 College St
Sydney, NSW 2000
Ph: (02) 9320 6225
Web: www.austmus.gov.au/tams/
Contact: Michelle Ball
Membership fee: $55 single, $75 household, $40 student

The Waterhouse Club
SA Museum
North Tce
Adelaide, SA 5000
Ph: (08) 8207 7389
Web: www.waterhouseclub.org.au/whc
Contact: Mary Lou Simpson
Membership fee: $60 single, $80 family

NATURAL HISTORY

Field Naturalists' Association of Canberra
GPO Box 249
Canberra, ACT 2601
Ph: (02) 6258 4724
Contact: Rosemary Blemings
Membership fee: $20

Field Naturalists' Club of Victoria
Locked Bag 3
Blackburn, Vic. 3130
Ph: (03) 9877 9860
Web: http://calcite.apana.org.au/fncv
Contact: Felicity Garde
Membership fee: $42

Linnean Society of NSW
PO Box 137
Matraville, NSW 2036
Ph: (02) 9311 2587
Contact: Claudia G. Ford
Membership fee: $53

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q&a

Elephant Fish

Q: *This unusual object (bottom) was found on the shoreline in Port Phillip Bay, Victoria. Is it a shark egg casing?*

—Margot Craddock
Montrose, Vic.

A: The image shows an egg case of the Elephant Fish (*Callorhinchus milii*). This strange-looking fish grows to 1.2 metres and has a hoe-shaped structure on the snout.

The Elephant Fish lives to depths of at least 200 metres on the continental shelf of southern Australia and New Zealand, where it is caught commercially. In spring, females migrate into coastal bays and estuaries to lay their eggs in sand and muddy substrates. The distinctively shaped egg cases are sometimes found washed up on the shore after storms. They are up to 25 centimetres long, ten centimetres wide, and take up to eight months to hatch.

—Mark McGrouther
Australian Museum

Crook Cockatoos

Q: *Sulphur-crested Cockatoos are common visitors to our bird feeder. Normally they present their usual immaculate appearance. Recently however there have been a couple that are anything but immaculate. They have practically no feathers left on their heads; one has no yellow crest feathers left, the other only one or two. Each bird has a considerably enlarged mandible, in one case the upper and in the other the lower. This makes it difficult for either bird to pick up seed and they normally do so by laying their beak flat. Both birds look to be on their last legs. Can you tell me the reason for these birds being in such a miserable-looking condition?*

—Kevin M. Clarke
Eden Park, Vic.

A: The appearance of the cockatoos suggests that they are suffering from Psittacine Beak and Feather Disease. This is a viral infection that attacks feathers, beaks and claws, causing abnormal growth and deformation. It occurs both in captive and free-flying birds, and can be common in flocks of Sulphur-crested Cockatoos. There is considerable variation in the severity of the symptoms. Some birds, such as those you have observed, manage to maintain good health despite their rather ragged look, while others show different levels of illness. In the acute form, this disease causes death. At present, there is neither a vaccine nor effective drug to treat it.

—Walter E. Boles
Australian Museum

Mulga Nests

Q: *Can you identify the builder of this nest or burrow (above right) for me? We found this and a number of similar ones at the junction of Luritja Road (to Kings Canyon) and Lassiter Highway (to Ayres Rock), in the Northern Territory on our recent holiday. It was raised about 15 centimetres above the ground and seemed to be largely constructed of very narrow flat grevillea leaves. The one we photographed had only one entrance but my children inform me that they saw one with multiple entrances. We didn't notice any footprints or scats in the vicinity.*

—E. Campbell
Narrandera, NSW

A: These nests are made by mulga ants (*Polyrhachis* spp.) and the narrow flat 'grevillea' leaves you mention were most probably Mulga (*Acacia aneura*) leaves. Steven Morton (CSIRO) discovered that the red desert sand doesn't absorb water very well and the raised fence of leaves supports the sand, preventing it from collapsing and blowing away. The combination therefore makes an effective flood control in wet weather by

K. Graham/NSW State Fisheries

(Above left) The unusual-looking Elephant Fish is caught commercially off southern Australia.

Courtesy: Margot Craddock

(Below left) The egg case of an Elephant Fish that washed up in Victoria.

COURTESY E. CAMPBELL

This unusual nest is the work of mulga ants.

creating a waterproof barrier around the nest entrance. You wouldn't have seen the actual ants unless you went back at night as they are nocturnal. Morton and a few other scientists studying the ants around Alice Springs noted there are two similar species in the area. One builds a nest with a single entrance and the other species builds a nest with several entrances. So between you and your children you've seen them both!

—Martyn Robinson
Australian Museum

Answers to Quiz in Nature Strips (page 19)

1. *Sir Gustav Nossal*
2. *Genetically modified organisms*
3. *Tasmania*
4. *Red Kangaroo*
5. *Myanmar*
6. *Males have a patch of black chest feathers.*
7. *Heard or McDonald Island*
8. *Amber*
9. *Two*
10. *Tyrian Purple*

Pic Teaser

Do you recognise this? If you think you know what it is, then send your answer to Pic Teaser, *Nature Australia* Magazine. Please don't forget to include your name and address. The first correct entry will win a copy of *Tree kangaroos* by Tim Flannery. Winter's Pic Teaser was a regurgitated pellet from a Pied Currawong containing seeds.

C.V. TURNER/NATURE FOCUS

Ecosystem services

The term 'ecosystem services' is becoming popular as a way to describe this biological underpinning of human life.

In today's world of previously undreamed of technological capabilities, many people think the only essential services are a computer and the Internet. It comes as a surprise to some that human wellbeing, economic prosperity, and even our very existence are underpinned by essential biological processes that occur only when suites of species interact with one another and with the non-living environment in what are called 'ecosystems'. The term 'ecosystem services' is becoming popular among ecologists and ecological economists as a way to describe this biological underpinning of human life. But continuing ignorance of the importance of ecosystem services means they are undervalued or ignored in decisions that may have huge implications for human welfare.

Ecosystem services include the purification of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, natural pollination and pest control, and production and maintenance of biodiversity, from which our agricultural, pharmaceutical and industrial enterprises are derived. The greatest delivery of ecosystem services comes from the least 'human-dominated' ecosystems. But even highly altered ecosystems, such as those in farmland and even city parks and suburban gardens, provide ecosystem services. The problem is that we often don't know what services we are reducing or even losing by our management practices.

Some ecosystem services can be replaced by technological fixes—but at great cost. Recently, for example, it was estimated that cleaning up New York's water supply would cost over ten times more using water-filtration plants than by repairing the ecosystems in the catchment. Maintenance of natural ecosystems also protects against damage from floods and other extreme weather much more cost-effectively than constructing and maintaining levy banks or other engineering solutions. Other examples are the costs of using fertilisers and pesticides to supplement or replace natural fertilisation and pest-control services; these costs could be halved by improved management of soil micro-organisms.

For other ecosystem services, it is difficult to imagine technological replacements, yet we take the services for granted and even push them to their limits. Soil itself is produced by interactions between species and the non-living environment; if we were silly enough to consider technological alternatives, they are estimated to cost millions of dollars per hectare. Similarly, we would be crazy to contemplate pollinating crops and native vegetation by hand or machine over large areas, yet we steadily destroy the habitat of insects, birds and mammals that provide pollination services for 'free'. Breaking down the waste products of people in European cities requires a combined area of ocean, wetlands, forests and farmland equal to about 300 suburban house blocks per person per year; imagine the treatment plants that we'd require if we lost our ecosystems!

There have been some controversial recent attempts to estimate the economic value of ecosystems. In 1997 Robert Costanza (University of Maryland) and others estimated the world's ecosystems to be worth US$16–54 trillion per year, while Roger Jones and Barrie Pittock (CSIRO) estimated Australia's terrestrial and marine ecosystems to be worth US$529–1,258 billion per year. Although attaching monetary values does at least bring home the message of how important ecosystem services are, it has limited meaning because we are unlikely to want to sell the world's ecosystems or even replace large proportions of them. The big issue that ecologists and economists are grappling with is how to estimate the long-term, large-scale effects on ecosystem services from the relatively small daily changes in ecosystems that occur at a local level.

Ecosystem services are a hot topic in Australia at present. CSIRO has begun a collaborative project with the Myer Foundation, communities, and State and Commonwealth governments to provide a detailed assessment of ecosystem services in a selection of Australian ecosystems, and to provide the information to all people making decisions about the environment. But we are certainly not alone. Other coalitions are forming around the country to assess the benefits from better management of natural resources. There are even early moves to list ecosystem services on the Australian stock exchange. Coupled with moves to see taxation and other financial incentives for conservation improved, the emerging focus on ecosystem services promises big advances in environmental policy and management over the next decade.

FURTHER READING

Costanza, R. et al., *1997. The value of the world's ecosystem services and natural capital.* Nature *387: 253–259.*

Jones, R.N. & Pittock, A.B., 1997. Assessing the impacts of climate change: the challenge for ecology. Pp. 311–322 in Frontiers in ecology: building the links, *ed. by N. Klomp and I. Lunt. Elsevier Science: Oxford*

Dr Steven Cork is a Senior Principal Research Scientist at CSIRO Wildlife and Ecology, Canberra. He is coordinator of a new initiative between CSIRO and the Myer Foundation aimed at providing information on ecosystem services in Australia to support decisions about natural-resource management.

BY STEVEN CORK

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