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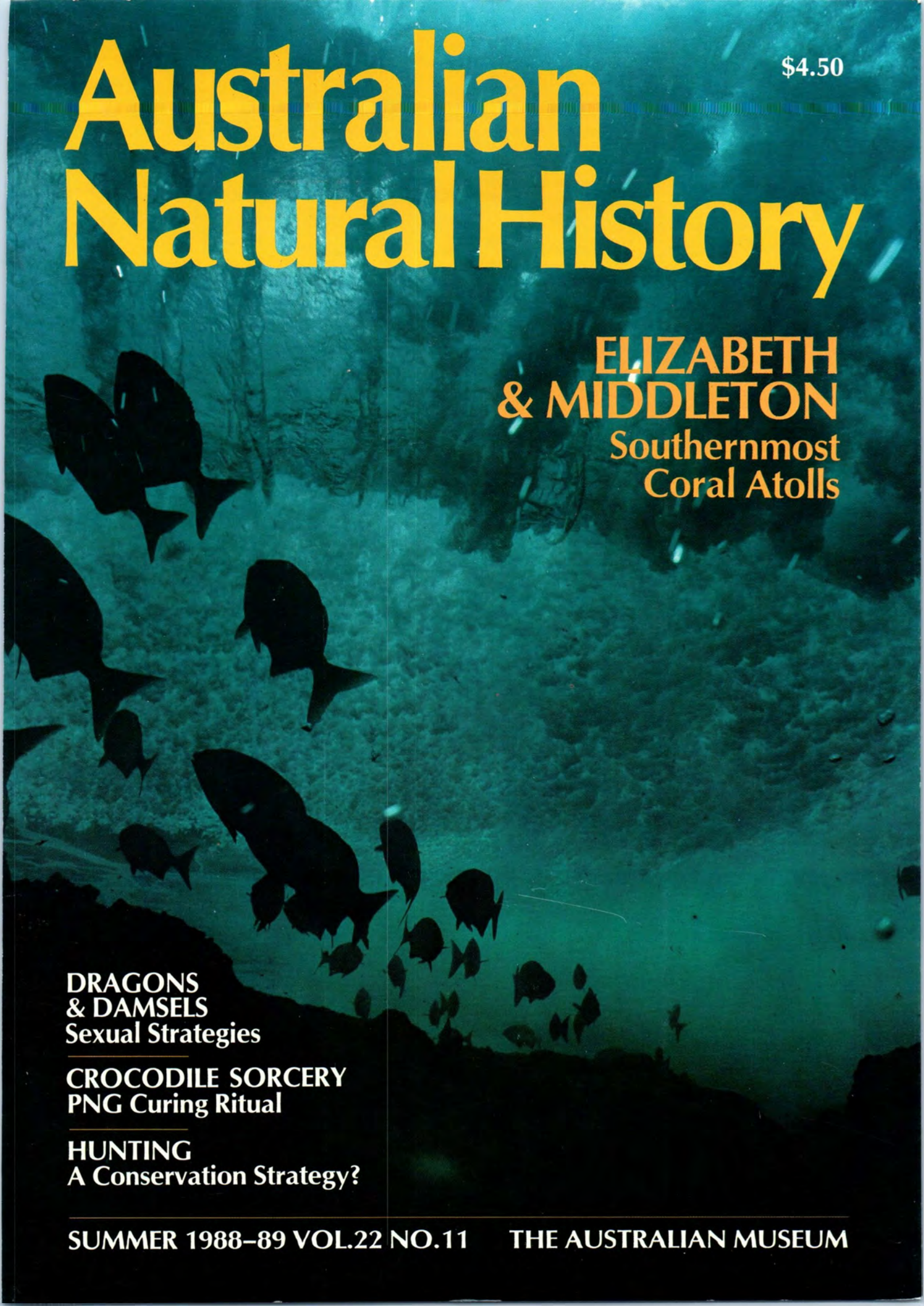

ELIZABETH & MIDDLETON
Southernmost Coral Atolls

DRAGONS & DAMSELS
Sexual Strategies

CROCODILE SORCERY
PNG Curing Ritual

HUNTING
A Conservation Strategy?

SUMMER 1988–89 VOL.22 NO.11 THE AUSTRALIAN MUSEUM

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Front Cover

Surf breaking over the reef crest at Middleton Reef, one of the two southernmost coral atolls in the world. Australian Museum scientists have been studying the ecology of the two reefs in a research project commissioned by ANPWS (p. 484). Photo: Ed Lovell.

EDITORIAL The Ultimate Inventor

Life. That seemingly infinite structure whose boundaries we continuously hope to conquer. It is a kind of writhing, growing time machine of which we are but a small part. Mike Archer discusses his 'Bioblob' concept of Life on p. 512.

The beast called Life continuously changes form and develops new strategies in order to reach new boundaries: fish have developed antifreeze in order to withstand the icy Antarctic waters (see article p. 518); lizards have lost their legs and become snake-like (p. 524); and dragonflies and damselflies (see p. 506) have developed extraordinary penis structures that ensure that sperm deposited from the last mating is used to fertilise the eggs.

And we, in awe of the beast, study, classify, identify and examine all aspects of it. We play a vital role in its future direction for, being a part of it, we affect it, sometimes intentionally, other times not. But in order to look after it, we need to understand it; to know it intimately: any decision that we make about it *must* be based on sound knowledge. One recent quest for such knowledge was undertaken by the ANPWS using Australian Museum staff to study the ecology of Elizabeth and Middleton Reefs (see article on p. 484). To the general populous, such a study may not seem to be of great consequence. Yet it is studies such as this that ultimately contribute towards the future direction of the beast. We are its guardians.

—Fiona Doig, Editor

LETTERS Confusion & Delusion

Algal Blues

Can you please clarify for me an apparent contradiction in the Spring 1988 issue of ANH (vol. 22, no. 10) concerning blue-green algae and cyanobacteria.

In his review of *Evolution in the Outback: Time in the North-West of Australia*, Ken McNamara points out that Jan Taylor "perpetrates a number of myths", specifically ". . .stromatolites are made by blue-green algae. In fact they are largely constructed by organisms in a completely different kingdom, the cyanobacteria". Then some pages later, presumably the same Ken McNamara says in his article on stromatolites: "These [stromatolites] at Hamelin Pool are formed principally by cyanobacteria (formerly known as blue-green algae)". I am left to assume that some finer point of definition has been omitted here, one that I would like to know.

Apart from this point I would like to say how much I have enjoyed reading *Australian Natural History*. As far as I am concerned I think it leaves other 'competitors' in the natural history stakes, such as *Australian Geographic* and *Geo*, for dead! I think the main reason is that you cover such a wide range of topics including items on invertebrates and suchlike rarely covered elsewhere. The quality of photographic art in the publication is outstanding; the photo of the breaching Killer Whale by A. Rus Hoelzel is magnificent. As you can see I'm a confirmed fan and I look forward to future issues from your team.

—Leonie Andrews
Kambah, ACT

As a mere practitioner of what scientists tell me is an Art as opposed to a Science, may I be permitted to comment on two articles in your ANH of Spring 1988.

In a book review, we are informed by Ken McNamara that stromatolites are not made by blue-green algae, but by cyanobacteria, which are organisms from a completely different kingdom. Later, in an article, Ken McNamara tells us that stromatolites at Hamelin Pool are formed principally by cyanobacteria "formerly known as blue-green algae".

Is this a case of 'a rose by any other name', as with Monilia and Candida, or does Ken McNamara come in two sub-types?

—Dr Grahame P. Dodd
Broadbeach Waters, Qld

Ken McNamara in his review of *Evolution in the Outback* takes to task Jan Taylor for stating that stromatolites are made by blue-green algae. He writes "in fact they are largely constructed by organisms in a completely different kingdom, the cyanobacteria". It is unfortunate that such a basic error has crept into his excellent review. Those organisms formerly known as blue-green algae are the same organisms that are now known as cyanobacteria. Ken McNamara should check his own facts before calling the kettle black.

—Harold Spies
Castlecrag, NSW

The term 'blue-green algae' is, in fact, a misnomer. Algal cells contain a nucleus and chromosomes. On closer examination of what were once called 'blue-green algae', the cells were found not to contain a nucleus or chromosomes and thus were not algae. They were instead photosynthetic bacteria, hence the term 'cyanobacteria'. Reference to 'blue-green algae' only confuses the issue. It should be dropped from scientific nomenclature and be replaced with 'cyanobacteria'. This was the point Ken McNamara was making in his book review.

—G.H.

A Potter's Request

I congratulate you on the recent article concerning Lapita pottery (ANH vol. 22, no. 9) and encourage you to continue with more articles on ancient pottery. Perhaps now is the time to further expand by giving us (the readers) a full-size poster of some of the many excellent pieces available. It would make a welcome change from the usual wildlife shots. By the way, the poster of the early Australian plant drawings was excellent.

—Sharon Williams
Busselton, WA

Grants not for Granted

I wish to convey my appreciation and enjoyment of Robyn Williams' article 'What are Museums for?' (ANH vol. 22, no. 9). I fully support his comments. It is unfortunate that many people take for granted the existence of museums or institutions like the CSIRO and forget what they really stand for in the education of humans and the survival of our environment.

As for the comment on reductions in grants or funding, it is very amusing that our politicians can easily muster enough funds to tour the globe, yet refuse to accept the importance of things that really count in society.

Congratulations on the magazine, and keep up the good work.

—Jim Bigelow
Coorparoo, Qld

Confronting Criticism

I found it a trifle annoying that Tim Flannery should use his space in a book review to launch an unnecessarily sarcastic attack against creation science and the Christian churches that teach it to school students (ANH vol. 22, no. 8, 1988). Not only is it extremely rude to refer to the well-mannered (unlike Dr Flannery) and well-groomed representatives of these churches as Paul Keating look-alikes, it is also highly contentious to imply that the churches that support creation science are "outlandish" or "fringe".

Dr Flannery may have had a bad experience with religion that biases his opinions somewhat, but this is no forum to air his views. The unscientific and emotive appraisal of the book also does little to encourage people who were educated poorly about evolutionary science to read it. While assaulting us with his personal views of religious education, he has failed to give a summary of the contents or format of the book, which would

have been more helpful than the vilifications that litter the page.

There is always room for pertinent quips that indicate the author's bias in the relevant subject, but this type of article appears offensive and unprofessional in an otherwise enjoyable and informative magazine.

Being Jewish and in possession of some very good creationist jokes, I'm not writing this letter for personal reasons!

—Jacky Bentel
School of Pathology
University of NSW

Ovulation and Evolution

It may interest you to know that in the Spring issue of ANH there was greater connection than juxtaposition between the books reviewed: *Egg* by Robert Burton, Jane Burton and Kim Taylor, and *Evolution in the Outback* by Jan Taylor. Kim is my brother and we are both zoologists turned nature photographers.

—Dr J.C. Taylor
Dalkeith, WA

Bittersweet

My parents first introduced me to *Australian Natural History* in the mid '60s. I was then a school student who found it a most enjoyable and accurate source of raw information about our own area of the world. I have kept all my copies for future reference. Five years ago, I renewed my long-lapsed subscription to enable my own school-going children to enjoy the same source of information; the new format and colour illustrations are certainly improvements on the old.

We have become very disappointed, however, that you have recently allowed the debate in your pages about the two theories of the origin of life to descend to the level of ridicule. If one is convinced that another human being is misguided, the very best one can do is to present them with the facts as facts, the theories as theories, and let them decide for themselves. The last thing one should do is to hold them up to ridicule. This applies to proponents of both sides of the debate. I am sure that both Tim Flannery (ANH Books, vol. 22, no. 8) and Roger Bourne (ANH Letters, vol. 22, no. 9) would baulk at criticising the Australian Aborigines for teaching their form of creationism in like terms, and yet that is what preservation of that culture in living form must embody. This bears further thought.

Concentrate on presenting the myriad of wonderful facts, present the theories as theories, edit out the fantasy and ridicule on every side and you will have restored the magazine's professionalism and credibility, have pleased everyone, and will continue to get the case for conservation and study of Australasian natural resources across to more sectors of society. A sense of humour is a healthy thing in a scientific publication, and a good vehicle for social change, but not when directed almost solely at belittling people who might otherwise have been your strong allies in other important aspects of your work.

—Andrew Spiers
Jabiru, NT

A fish's eye view of surf breaking on the reef crest at Middleton Reef—one of the two southernmost coral atolls in the world.

Voyage to ELIZABETH & MIDDLETON *Reefs*

By PAT HUTCHINGS
THE AUSTRALIAN MUSEUM
PHOTOS: ED LOVELL

In 1987, the Australian Museum undertook a biological survey of Elizabeth and Middleton Reefs for the Australian National Parks and Wildlife Service (ANPWS). These reefs are unique in that they constitute the southernmost coral atolls in the world. The only coral reef further south is the fringing reef at Lord Howe, about 200 kilometres away. These reefs have recently been declared a National Marine Nature Reserve, and the Service needed information on their fauna and flora to prepare a zoning and management plan.

We chartered a 97-foot research vessel called *Flamingo Bay*. It was particularly suitable because it was skippered by David Tomlinson who knew the area well, which was particularly important as the charts of the region are not up-to-date, and the boat was equipped with a recompression chamber to be used in case of the bends.

We left Sydney on 30 November for Coffs Harbour, where we loaded on board tons of gear, including polydrums, alcohol, formalin, diving and camera equipment, collecting and sorting paraphernalia, and an inflatable dinghy. The personnel was as varied and included seven people from the Museum—Ian Loch (Molluscs), Jim Lowry and Roger Springthorpe (Crustaceans), Patrick Filmer-Sankey (Echinoderms), Tony Gill and

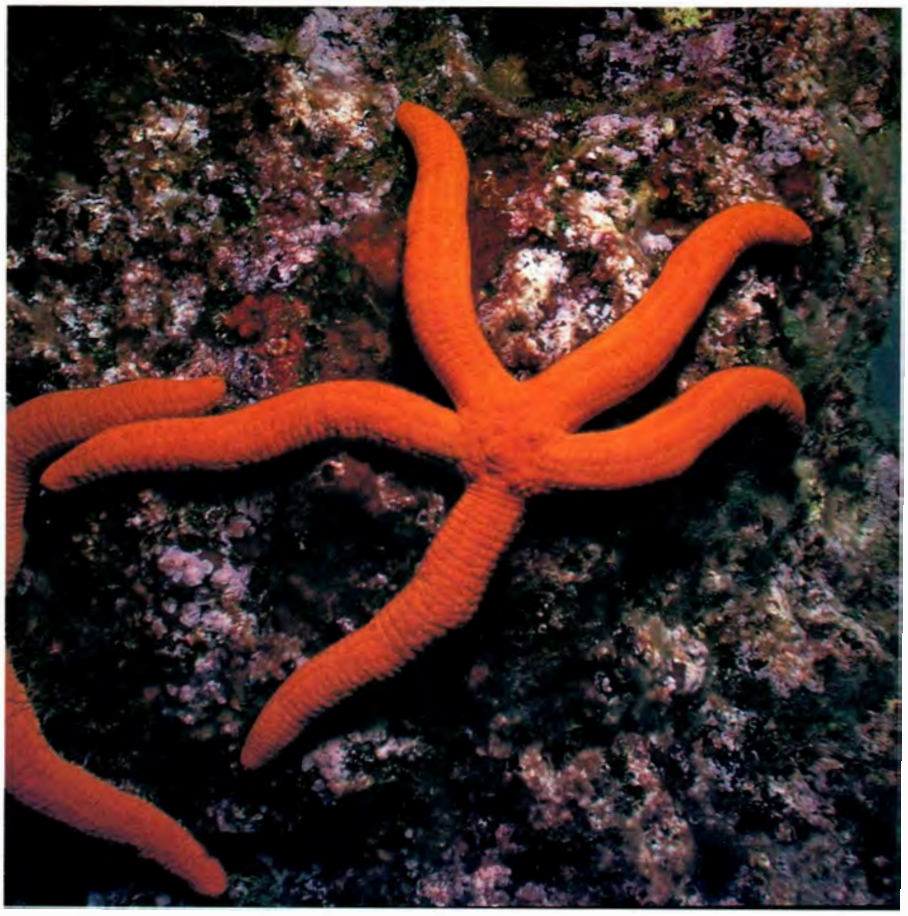
Research vessel* Flamingo Bay*, the boat chartered for the expedition to Elizabeth and Middleton Reefs.

Sally Reader (Fish), and myself (Worms); and some non-Museum personnel—Lindsey Smith (an amateur ornithologist), Duncan Leadbitter (now of the New South Wales Department of Agriculture and Fisheries), Ed Lovell (photographer) and Mike Cordell (journalist). We were due to sail at 4 pm on Tuesday 1 December but a strong wind warning prevented us from sailing until the following day. Early on Friday we sighted Middleton Reef, about 500 kilometres due east of Coffs Harbour. It was not actually the reef, but the remains of the *Runic*—a meat freighter that ran aground on its maiden voyage in 1961 from Brisbane to Auckland during calm weather. Today it is a clear reminder of the many ships that have foundered on the two reefs and represents an important roosting place for seabirds.

Middleton Reef is an oval-shaped volcanic seamount on the Lord Howe Rise, as is Elizabeth Reef to the south. These seamounts and Lord Howe Island are the only ones currently at or above sea level. At least 20 other volcanic peaks are known on the Lord Howe Rise but these are all in deep water. At high tide no land is exposed on either Elizabeth or Middleton, but a small sand cay present at Elizabeth is exposed during spring tides and perhaps at higher tides under calmer conditions.

Both reefs have a narrow reef crest that slopes gently on the seaward side to about 20 metres and is deeply dissected by steep grooves and gutters. Often large rounded boulders are present in the gutters. They are washed up and down during storms and effectively abrade the sea floor. Below 20 metres the reef slope drops off steeply and deep oceanic water comes close to both reefs. Inside the reef crest are well-developed lagoons with extensive reticulated patch reefs. Strong winds blow from a variety of directions throughout the year so there is no real development of a leeward or exposed reef slope. Consequently, during our trip, we had to constantly change our anchorages.

The reason coral reefs are found growing at these two southerly latitudes (29°56'S and 29°17'S) is because the reefs lie at the margin of



The starfish,* Ophidiaster confertus, *is restricted to the central-eastern Australian coast.

A graceful Spanish Dancer,* Hexabranchus sanguineus, *at Elizabeth Reef.

Sorting specimens on the back deck of the* Flamingo Bay *during the survey.

A clam,* Tridacna maxima, *at Elizabeth Reef.

the warm water of the Coral Sea. The warm East Australian Current (EAC), which normally flows down the eastern coast of Australia in summer, returns northwards around 156°E before meandering off to the east. This eastward meandering is known as the Tasman Front. The front divides the warmer waters of the Coral Sea from those of the Tasman Sea to the south. In the winter the EAC does not flow as far south before meandering off to the east and northwards. Satellite photos taken of the water masses around Elizabeth and Middleton Reefs in July indicate that water temperatures are as low as 18–19°C, which may retard coral growth during the winter. In the summer, water temperatures are about 25°C.

Returning to the expedition, we knew that at most we had 11 days of diving, possibly less if the weather turned bad, and two very large reefs to study. Middleton Reef is approximately 8.9 x 6.3 kilometres and Elizabeth is about 8.2 x 5.5 kilometres in dimension. For both reefs we therefore selected a series of transects on the outer reef, reef crest and lagoon, which, in the main, coincided with those surveyed by the Australian Institute of Marine Science (AIMS) in Townsville in December 1981. AIMS had undertaken an extensive survey of the hard corals, so we decided not to repeat that survey but rather to utilise their data and concentrate on collecting the crustaceans, echinoderms, molluscs, fish and worms. Our first dive revealed that since 1981 a large percentage of the living hard corals had disappeared and the Crown of Thorns Starfish (*Acanthaster planci*) was present.

We spent six days at Middleton Reef and five at Elizabeth, but the daily routine was basically the same. After breakfast we'd have a morning dive and, if the current was not too strong, set up a rotenone fish station. (Rotenone is a poison that paralyses fish and other animals so that they can be caught easily.) We'd then return to the boat, sort, preserve and label material, have lunch, and another dive or reef-walking collecting trip on the reef crest. Hand-lining for some of the larger predatory fish was also carried out and samples of tissues from BlackCod were frozen in liquid nitrogen for a later comparison with populations from coastal New South Wales. After dinner we'd have another dive, or spotlight from the back of the boat to collect pelagic species. Lindsey would be up on the top deck bird-spotting. A variable level of activity was maintained on the deck, with shouts of "what station was that specimen collected from?" or "do you want those crabs, fish etc. I collected for you this morning?" Others were photographing material alive, before they were preserved and lost their colour. Gradually the 60-odd polydrums were filled, as was the freezer with the larger animals too big to go into the polydrums.

By the time we were ready to leave, we were pleased that we'd been able to dive every day and make substantial collections of the fauna from the reefs. I was especially relieved that we had not had to use the recompression chamber, and apart from a few scratches, we were all intact as we sailed back into Sydney Harbour.

During the next three months, all the material was unpacked and sorted, a substantial proportion identified to species, and the final report prepared and submitted to the ANPWS.

The major finding of the survey was that this area supports an interesting combination of fauna not found anywhere else. It is dominated by a tropical Indo-Pacific fauna, with a small temperate Indo-Pacific fauna and a few endemic species. The dominant tropical component reflects the circulation patterns, with the two reefs lying at the boundaries of the warm Coral Sea waters. Lord Howe, just to the south, has a more temperate fauna and half the number of coral species found on Elizabeth and Middleton Reefs.

The diversity of the fauna is lower than on the southern section of the Great Barrier Reef and some common reefal families are completely absent. This is certainly in part due to the lack of several reefal habitats on Elizabeth and Middleton Reefs, such as sheltered outer reef slopes and protected reef flats associated with sand cays. The low percentage cover of live coral may also have contrib-

Acropora *species coral from the lagoon at Elizabeth Reef.*

The Black Cod,* Epinephelus daemelli*, at Middleton Reef.

Collecting Crown of Thorns Starfish for histological (structural) study and size determination on Middleton Reef.

uted in the loss of some species. Many of the species that are present occur in far lower numbers than in comparable habitats on the Great Barrier Reef.

At this stage we can only speculate as to whether the Crown of Thorns Starfish is responsible for the loss of live coral cover on both reefs. In 1981, AIMS noted the presence of large numbers of Crown of Thorns at at least one site on both reefs and, at Elizabeth Reef, extensive damage by the starfish at one site. Over 120 hard coral species were recorded with reasonably high levels of live coral cover at some sites. Six years later the only areas where extensive live coral cover occurs are in the lagoons of both reefs. On the reef slope, live coral colonies are typically small and restricted to gutters or crevices. Slightly higher coral cover occurs in the surf zone, where it is known to be too rough for Crown of Thorns. Starfish were seen outside the reefs on all dives and were typically absent from the lagoons, although one very large individual was seen. At a couple of sites where percentage cover of live coral was relatively high, starfish were found in large numbers feeding on them. They were also seen feeding on soft corals at many sites.

The Crown of Thorns on both reefs range from one to 20 centimetres in diameter, suggesting that several year classes are present. Histological investigations are currently underway to see if the starfish are reproductively active. It seems likely that the starfish have been responsible for the loss of live coral cover, and the question now is "How long will it take for these reefs to recover?" Probably some time, as these reefs are at the southern limit of coral growth, and winter growth may be limited to the low water temperatures.

We were at Middleton Reef a few days after the full moon in December when some of the corals on the Great Barrier Reef were spawning, but no spawning was observed. We also collected samples of hard corals for a histological investigation of the gonads, which should clarify whether the corals are sexually active and if spawning would have occurred in January, as it did at Lord Howe Island. Much of the fauna of these two reefs is derived from pelagic larvae from the Great Barrier Reef but at this stage we do not know whether this includes corals. Hopefully funds will be made available for other surveys to be carried out, to monitor the rate of recovery from what appears to have been a Crown of Thorns outbreak. Such an outbreak would have to be a natural event, as one cannot evoke the concept of a human-induced outbreak in such a remote location.

In addition to preparing a biological survey of the two reefs, we were asked by the ANPWS to comment on potential threats to the reefs. The main threats to the reefs can be divided into two categories: accidental and planned. Accidental ones include additional shipwrecks and associated oil pollution. The severe weather patterns operating in this area would almost certainly prevent any containment of an oil spill, and the reef, with its low cover of live coral, would be most vulnerable. Planned threats include the proposals for a floating hotel and a beche-de-mer industry in the area. We believe that any such commercial activity should be discouraged; besides the logistic difficulty in policing and enforcing any restrictions in the area, the uniqueness of these two atolls make them worthy of conservation in their pristine state.

As an afterthought, it was appropriate that the Australian Museum had been asked to undertake this survey, as the very first substantial collections made at Elizabeth and Middleton Reefs were by Mr Gilbert Whitley, a fish curator at the Australian Museum. Whitley and others visited the reefs in 1936 to salvage the cargo of the boat *Annasona*, which had been wrecked on Middleton Reef. Bad weather prevented any salvage work being carried out but Whitley made extensive collections both at Middleton and Elizabeth Reefs, which formed the basis of the first scientific paper on these two southernmost atolls and stimulated later investigations. ■

The Australian Museum would like to thank ANPWS for making this survey possible.

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A Curing Ritual from Papua New Guinea

SUPPLICATION OF THE CROCODILE

By PETER DWYER and MONICA MINNEGAL
UNIVERSITY OF QUEENSLAND

Tobasi is elderly. Grey-haired, lithe and short, with an infectious smile, he is a spirit medium. In trance Tobasi's spirit departs to wander where the spirits of the dead reside; the latter then enter him to communicate with the living. When someone is ill or has died people seek advice from the spirits.

At the small Kubo village of Gwaimasi, on the Strickland River of Papua New Guinea, a young man was ill. His body was wasting away. There were no visible injuries but the pain was intense. Within two weeks of the earliest symptoms, Gwase could, at best, hobble with a stick. Sorcery was suspected and Tobasi's help was enlisted.

Towards midnight people gathered in the central room of the village longhouse. Tobasi sat on the long, platform bed with Gwase lying nearby. In the darkness there was subdued talking. A few people sang briefly. Then Tobasi's voice intruded, softly at first but soon dominating the mood. His trance was complete and his body occupied by spirits of the dead who chanted of possible diagnoses and remedies. For three hours the seance continued.

Gwase was the victim of sorcery. Through the past months someone had assembled fragments from Gwase's possessions and bodily wastes and had hidden them in the forest. When the package was of sufficient size the sorcerer had thrown the contents into the Strickland River. A crocodile fed on them and, thereafter, its spirit feasted upon the spirit of Gwase. Gwase was wasting away because, quite literally, he was

A Kubo man, named Kabaiye, holds a young New Guinea Freshwater Crocodile that he captured by hand. The skin of the animal was sold but the people refused to eat the meat. When the authors breakfasted on roast tail of crocodile, people crowded around to watch with horrified interest.

J.B. WILMER

Pigs are killed and butchered only on special occasions. At curing rituals, one pig may be killed as payment to the spirit medium who diagnosed the cause of illness and a second is needed for the ritual itself.

P.D. DWYER

being eaten alive. To effect a cure it was necessary to supplicate the crocodile.

The Ritual Dance

Through the next day bananas were harvested and loaves of sago flour cooked by women. Two domestic pigs were shot with arrows; the larger as payment to Tobasi and the smaller for use in the ritual cure. That afternoon four young men vanished into the forest where they decorated each other in advance of a ceremonial procession to the village.

They came at dusk. Echoing whoops in the distance alerted attention; then silence and anticipation. They came nearer and whooped again. Within the village clearing, at the edge of the forest, a row of finely built young men appeared, wearing fern and feather headdresses, red and white beads, shell necklaces, bamboo nose plugs, intricately designed arm bands and daggers made from cassowary bone. They carried bows and arrows and, in unison, twanged the taut bow strings. With eyes downcast, they moved forward in single file to the longhouse. Their arrival issued a challenge to the spirits that occupied and harmed the sick.

Two of the young men were to dance that night. Designs in red and yellow ochre were painted onto their chests, shoulders and knees. Upper faces were jet black and lower faces red. Painted bark belts were fitted and the dancers wore short front skirts and floor-length rear skirts made from palm fronds. Covering their backs were beaten bark shields with bird of paradise plumes attached. Rattles of crayfish claws were attached to the backs of their belts by lengths of supple vine. The final adornments were head-dresses of cuscus fur, bird of paradise plumes and high inverted 'V's of Sulphur-crested Cockatoo feathers.

Concealed within his costume, one of the dancers carried portions of liver, skin, fat, meat and entrails from the small pig killed earlier in the

To decorate and costume a dancer takes two to three hours. Designs in red and yellow ochre are painted onto the torso, shoulders and knees. The face is painted and a bark belt, shell necklace, bamboo nose plug, feather headdress, and skirts made from palm fronds, are fitted. Torches of burning resin provide light for men who create the designs.

day. These symbolised parts of Gwase's body that were under siege from the crocodile spirit. They might tempt that spirit to abandon Gwase and follow the dancer. An uncooked leg of pig hung above the doorway of the dance room as an added promise to the crocodile spirit of better things to come.

After midnight the dancers appeared within the central room of the longhouse. Resin, burning on a stone, gave light and the ill man sat on the dance floor. A man tuned the drum while the gathering audience sat talking and laughing at the edge of the platform bed.

Tobasi commenced chanting, his voice raised and high pitched. A younger man took over the chant and, stamping a staff on the floor, led the dancers around and around the sick man. The dancers held the sides of their long rear skirts, swinging them back and forth. Three other men followed, chorusing the words. The spirits were being ordered to depart and the dancers were sweeping them away.

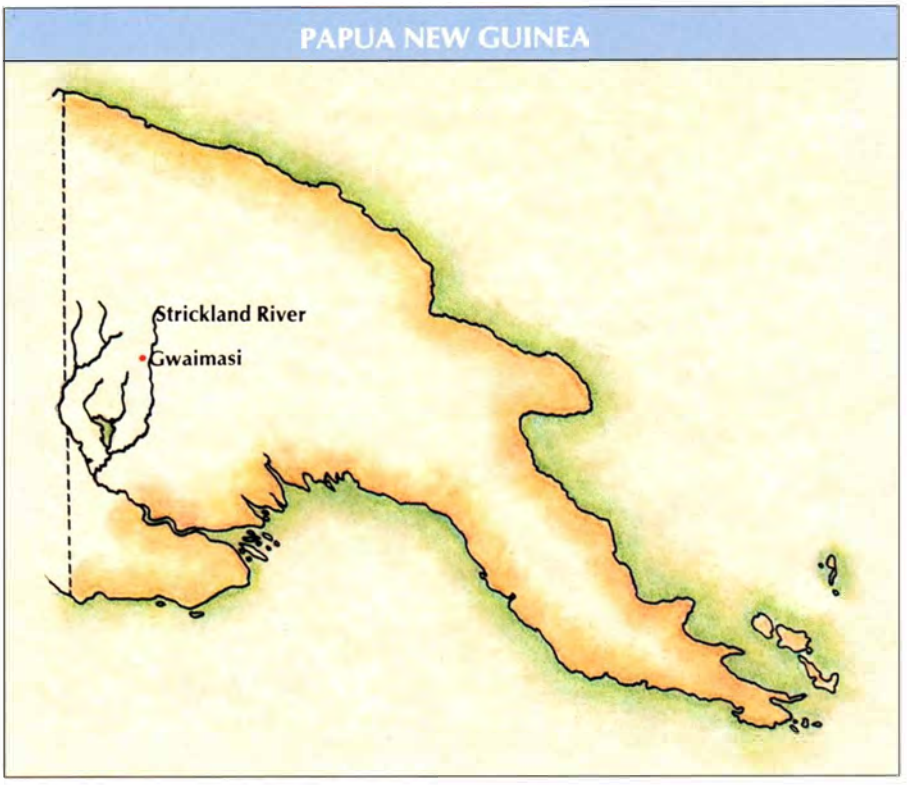
After ten minutes the drum was handed to the first of the dancers. He started to beat it, filling the longhouse with the deep, resonating sound. He moved in rhythm to the beat, bending at the knees, rising and falling, a slight spring at the toes, feet together and the steps slow. His head, held to the side, conveyed a mood of sadness. To people who watched he was a bird of paradise. They sang as he danced, one person leading, others chorusing, but he was oblivious to everyone, his performance controlled, beautiful to onlookers and a focus of attraction to beneficial spirits.

Towards dawn the mood of the ritual intensified. Again and again, each time louder and more assertive, the performers chanted and circled the sick man. They commanded the evil spirits to depart, each circuit ending with an emphatic '*Ya!*' (Go!). The sky lightened. Other men collected bows and arrows and stood guard at the rear of the room so the spirits could not escape that way. Suddenly, pandemonium erupted. Everyone was on the dance floor, the chanting violent, the bowmen twanging their bowstrings. The two dancers moved quickly outside, leading the spirits from the house. The bowmen raced behind, chasing the last vestiges of malevolence from the sick.

The dancers moved a short dis-

J.B. WILLMER

Burning resin throws sparks that light a young man who dances as he beats a carved and painted wooden drum. The beauty of his costume and performance, and the resonating drum beat, attract beneficial spirits. To the audience that watches and sings in accompaniment, the dancer is a bird of paradise.



P.D. DWYER

At dawn the dance is concluded and parts of the dancers' costumes are hung from trees to discourage dangerous spirits from approaching the village.

tance into the forest where their costumes were hung in trees or abandoned on the ground. The spirits would imagine the dancers stood in the forest and would not return past this place. The dancers themselves, and unmarried men who had participated, travelled beyond the village to the place where the spirits of the dead reside. Here, parts of the pig that had been worn by one dancer were burned until nothing remained, and the leg of pig was cooked in a leaf oven. Some was eaten by the men and the remainder thrown into the river where the crocodile that harmed Gwase would accept it as sufficient substitute.

The curing ritual was complete. Within a week Gwase was walking steadily.

The Spirit of the Crocodile

Among Kubo people, dances are common social events. They allow young men to display before potential brides, are a focus at gatherings where meat is exchanged, generate feelings of well-being, and play an integral part in rituals of curing.

The aim of curing rituals is often to supplicate the spirit of the New Guinea Freshwater Crocodile (*Crocodylus novaeguineae*). But the form of the rituals poses a problem. The drum that is used in supplicating the crocodile spirit is itself animate—it has mouth, jaws and a neck and is said to breathe; it is, almost certainly, representative of the crocodile. Thus, in the form of a drum, the crocodile is needed to cure illnesses that were themselves caused by crocodile spirits. Why, in Kubo thought, should the status of the crocodile be ambivalent? Circumstances connected with one curing ceremony provide clues.

The infant son of Kebali and Yawodua had been ill for two months. Sorcery was diagnosed and a dance performed on behalf of the child, who was made to beat the membrane of the drum with his tiny fist and so receive its beneficial powers. Meat from a pig was also cooked and thrown into the river in an attempt to appease the suspect crocodile. Kebali did not attend the ceremony because, it was said, his own life would be threatened. No-one declared the nature of that threat because this would have raised the spectre that something more dangerous than sorcery was implicated.

Kebali had recently netted and killed a large crocodile and, in so doing, released the spirit of the animal. Perhaps the crocodile spirit that harmed Kebali's son had been acting directly in revenge for the actions of the father and not as the agent of a human sorcerer. Acting without human control, the spirit of the crocodile might be uncontrollable.

In addition, the skin of the crocodile that Kebali had killed was sold but the meat was not eaten. Kebali had declined out of concern for his son. A second man would not eat because his wife was menstruating and a third recalled that once before he had eaten crocodile and had vomited. By traditional standards this behaviour was peculiar. The flesh of crocodiles is forbidden to members of just one Kubo clan, for whom this species is the mythological ancestor, yet nowadays everyone avoids eating the animal. They do not behave this way when, for example, goanna, the mythological ancestor of another clan, is on the menu.

Thus, the status of the crocodile as food has changed—so recently that excuses for not eating the meat must still be improvised. This change is connected with the mix of emotions with which Kubo now regard the animal. There is a feeling of danger that was not there before. Perhaps recent history can help explain why.

During the 1960s and 1970s many Kubo people died when flu epidemics ravaged the population. In the same period Europeans visited Kubo territory. They came in power boats carrying firearms, killed crocodiles, took skins and left the carcasses to rot. Was the world of Kubo suddenly overpopulated with the homeless spirits of murdered crocodiles? Did those spirits seek revenge for the actions of foreigners who had departed, and was that revenge now enacted upon the innocent? Might not Kubo people have connected these events with the mysterious and often fatal illness with which they were coincidentally afflicted?

If our speculation is correct, for many years to come young Kubo men will dress as birds of paradise and dance through the night to supplicate the revengeful spirit of the crocodile. The resonating beat of the drum and the sad songs will reach beyond the village to fill the surrounding rainforest. The spirits of the dead will be aroused and will come to assist the living. ■

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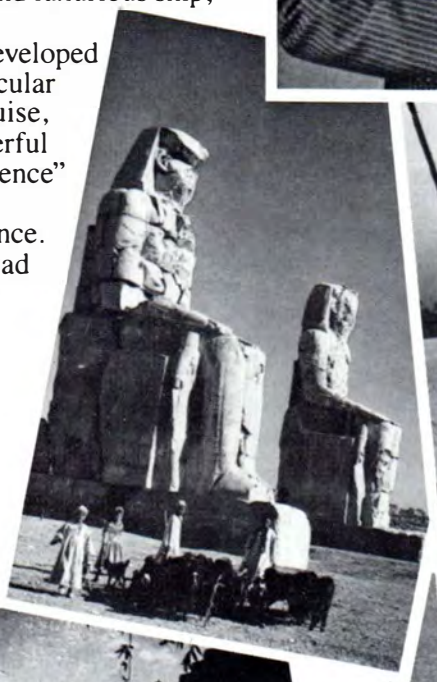

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QUIPS, QUOTES & CURIOS

Birds of Prey and Shades of Grey

For centuries the eyesight of raptors (birds of prey) has been considered superhuman and extraordinary. There are many estimates suggesting, for instance, that eagles can resolve detail up to eight times better than humans, or that certain owls can see in total darkness. Such estimates are generally based on field observations where a flying bird is easily lost from the sight of a stationary observer, or where other factors, such as the contribution of the sound of prey movement to capture, cannot be adequately assessed. For six years I have studied the resolving power of three Australian raptors—the Wedge-tailed Eagle, the Brown Falcon and the Tasmanian Masked Owl—in controlled laboratory conditions and have found some surprising results.

Birds were trained to fly to a pattern of black and white stripes, rather than a grey field, for a food reward. The stripes were similar to those used by opticians to test human eyesight. Once the birds mastered this task, the stripes were made thinner and thinner. Eventually the birds were unable to correctly distinguish between the thin stripes and the grey field. The thinness of the stripes was then used as a measure of the limit of the bird's ability to resolve detail.

The birds were tested over a range of brightnesses typical of our daily 24-hour cycle. Humans were also tested on the same task and the performances of birds and humans compared. In addition the anatomy and optical properties of the eyes of raptors were investigated.

It turns out that only the Wedge-tailed Eagle's resolving power is superior to ours. It can resolve about twice as much detail as we can. The Brown Falcon has about the same resolving power as humans, while the Tasmanian Masked Owl has only about one sixth. More importantly, it appears that the resolving power of each bird's eye can be directly related to its structure. Resolving power in raptors, as in humans, is proportional to the focal length of the eye and the graininess of the retina.

So how can raptors capture prey from such apparently remarkable distances? Within the eyes of all raptors that hunt during the day is a structure known as a deep fovea. It seems that the fovea acts as a movement detector that allows birds to detect prey from a great distance, even though they cannot actually resolve the prey. The fovea may fixate on the prey until the bird can get close enough to decide what it is and whether it is worth attacking. Interestingly many prey species freeze when they encounter raptors.

LIZ REYMOND

The deep fovea of a Wedge-tailed Eagle may act as a movement detector, enabling these birds to detect prey from a great distance.

—Liz Reymond
Canberra CAE

A Case of Mistaken Identity

One September morning in 1981, while collecting insects in the Dongara area of Western Australia, two entomologists spotted a number of beetles close to a dirt road. These were male jewel beetles (family Buprestidae), later identified to be *Julidomorpha bakewelli*. The collectors' attention was drawn to these beetles not for any striking colouration—they are drab brown—but because they were apparently trying to copulate with carelessly discarded beer bottles ('stubbies') of passers-by. The beetles' genitalia were everted and they were making sore attempts (no doubt quite literally) at inserting the aedeagus (penis). In fact, in a couple of cases, ants were seen biting at the soft parts of the genitalia. The beetles, however, seemed determined to complete their unrewarding tasks, only leaving the bottles when physically displaced by the collectors.

The collectors, Darryl

Only the Wedge-tailed Eagle's resolving power is superior to our own.

HANS & JUDY BESTE/AUSCAPE

Compiled by GEORGINA HICKEY

DAVID C. RENTZ

This jewel beetle is being attacked by ants. The reflection of the stubby's non-slip tubercles is similar to that of the beetle's pitted elytra.

Gwynne (University of Western Australia) and David Rentz (CSIRO), conducted a simple experiment whereby they placed four empty stubbies in an open area away from the site (*J. Aust. Entomol. Soc.* 22: 79–80, 1983). Within 30 minutes the two bottles were being mounted by lovesick beetles. There was nothing in the bottles to attract the beetles' attention, and a wine bottle of a different shade of brown did not attract them.

It was noted that the colour of the stubby was remarkably similar to the colour of the beetles; and the rows of tubercles at the base of the bottle—apparently designed so that the stubby doesn't slip from the hand when wet—reflected light in the same way as the pits on the beetles' elytra (hard wing coverings). In other words, the bottles were acting as 'super females' (in ethological terms, as supernormal releasers of male sexual behaviour).

Male jewel beetles contribute little to rearing their young, and the observations with the beer bottles support the theory that males with the lowest parental investment are the least selective in female mate choice. In other words, they tend to make the most 'mistakes'. It also goes to show that the improper disposal of stubbies not only creates a physical hazard and a visual blight on the landscape, but can interfere with the mating success of beetles.

—G.H.

WILD NATURE/ANT PHOTO LIBRARY

Duck shooting: are tighter regulations the answer to conservation problems?

Hunting: A Conservation Strategy?

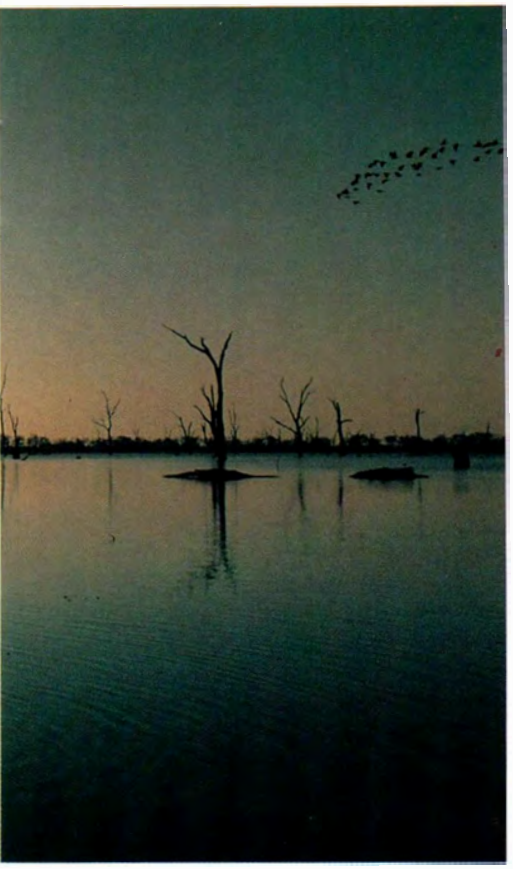
For centuries hunting has been an acceptable form of recreation. Although initially for survival, it is probable that hunting for recreation and trade became important at an early stage of history. In some continents subsistence hunting is still a feature of tribal life. Hunting was once considered the province of the nobility, the rich or the country-dweller, being conducted mainly on hunting grounds restricted to these users. Now anyone in Australia may, if they choose, hunt on publicly owned areas during proclaimed open seasons provided they are licensed.

Decisions on whether a species is hunted should primarily depend on technical conservation criteria. If hunting demonstrably jeopardises the long-term future of a species, then it should cease and any further debate (in relation to hunting that species) is irrelevant. However decisions on hunting usually involve aspects of wildlife conservation, firearm use and animal welfare—complex community issues.

Justification for recreational hunting is usually linked to a human instinct to hunt, based on traditions of hunter-gathering, and in modern times is related to the impact on game and non-game species.

Recreational hunting can provide useful products, such as food or fur, or ornaments, such as a trophy head or decorative skin. Of course, the popular Australian game species (duck, quail and deer) are good to eat, and this is further inducement to hunt.

It is valid to distinguish between



hunting for a useful or consumable product, and simply for trophies, and to debate the ethics of each. I can understand the rationale of hunting deer for venison and also having the head mounted as a trophy, but I cannot support hunting for the trophy alone.

From a conservation viewpoint, hunting has had benefits. A great deal of knowledge about wildlife has been generated throughout the world as a direct result of hunting and game management. It is unlikely that in the absence of hunting there would have been as much research and management experience on major groups of game as well as many non-game species. However in Australia, as elsewhere, there is still a need for more information on game species and hunter behaviour to monitor and refine procedures. Far more needs to be done about the provision and protection of habitat, especially wetlands.

Variations in weather in Australia and changes in land-use have a considerable impact on the levels of wildlife populations, such as on the various species of wild duck. Therefore it is important to continually review our management tools. This monitoring is particularly important in ensuring that the conservation of protected non-game species, such as the Freckled Duck, is not jeopardised by hunting.

Useful game management tools are the timing and duration of open seasons, bag limits, closed areas, hunting methods, and hunter education and testing. It is important that we get these details right, especially the education of hunters. It is essential that hunters not only have necessary skills, such as the ability to identify species beyond gun range, but also that they have a responsible attitude towards wildlife. Stringent training and testing can address the skills aspect but a broader education process is needed to instil the right attitudes. Educated and responsible hunters can be a powerful influence for better wildlife conservation.

It needs to be recognised that wildlife management is, in some respects, an inexact science, and different conclusions can be drawn from information on breeding, population levels and movements of wildlife. The wildlife manager, the hunter and the anti-hunter may all have the common objective of long-term conservation of a species. But they may have different views on the long-term implications of data on the breeding, food supply or hunting events in a year.

Wildlife managers recognise the carrying capacity concept. At any time the environment can support a certain population and often the mortality caused by hunting would be replaced by other less 'humane' kinds of mortality if hunting did not occur. This is one argument in support of recreational hunting but it must be applied with caution. Some population studies on islands and similarly isolated environments have indicated that in the absence of hunting the population extremes are greater because the resultant overpopulation creates severe food shortages and is more subject to disease.

The animal liberation and animal welfare aspects of the hunting debate are more related to people's feelings than to wildlife management. There are less objective data on which to base judgments and decisions than those related to wildlife biology. Fundamental to the animal welfare debate on hunting is the justification for killing animals. Whether or not hunters may kill game is determined by whether or not the community allows recreational hunting. Governments attempt to reflect the prevailing community viewpoint in the enactment of game laws, but of course some sections of the community may disagree. State wildlife laws in Australia provide for a conscious decision to declare game species and open seasons. All Australian States have decided to allow recreational hunting, as well as allowing other non-game animals to be killed for food and other products, or because they are considered pests.

Even if the community accepts that game animals can be killed by hunters, there is still the question as to whether cruelty can arise from the method of killing or from other hunting activity. No responsible hunter condones methods that would result in a slow death. Indeed the whole hunting process (game laws, hunter behaviour and hunting equipment) is based on a quick, clean and therefore 'humane' kill. This is in keeping with the accepted procedures in other circumstances where the community recognises that animals are killed, for example at abattoirs or in pest destruction. Thus any cruelty associated with hunting should not arise from killing if accepted community standards are met. It is possible for hunters to avoid unnecessary wounding by exercising responsibility, such as ensuring that the game is well within range.

Judgments become very subjective when considering cruelty in relation to pursuit and disturbance. For instance, there is no doubt that many non-target species such as Pelicans and other waterbirds take to the air during duck hunting and move to other waters such as refuges and sanctuaries. Is this disturbance cruel or are the birds simply moving away from noise, as do many humans in urban situations?

There are some hunting practices

that, although not demonstrably cruel, are questionable. For instance, while many hunters use dogs to retrieve gamebirds, the use of dogs to pursue game, including wounded animals, is difficult to defend.

But several questions still remain. Should hunting be primarily a wildlife management issue concerned with the long-term survival of species? *Yes.* Should decisions be made solely on a technical rather than on an emotive basis? *Not solely but certainly largely, taking into account the range of community views.* And would the long-term conservation of a game species be any more secure in the absence of hunting? *I doubt it.* While the ban on crocodile hunting allowed the recovery of its populations, some people are now advocating their control and even eradication in at least some parts of their habitat. Solutions in the best long-term interests of both wildlife conservation and the community lie somewhere between total protection and uncontrolled hunting.

In Australia hunting groups pioneered the conservation of wetlands decades before it became a more widely popular cause. They badgered governments into reserving or buying back wetlands, and restoring habitats in them, partly by seeking government funds to match their own. And while this might seem to be self interest, it must be remembered that not only have the eight or so ducks on the game list benefited, but so have the remainder of the 107 Australian birds that rely on wetland habitats. In Australia fees for hunting licences and registration of hunters and their firearms contribute at least $5 million annually to the State governments. This revenue is spent at the discretion of those governments and not of the hunters, although a proportion of these funds are dedicated to wildlife conservation and not to general revenue. In Australia over the past three decades hunters have focused more attention on wildlife conservation, and have directly and indirectly resulted in more funds being devoted to wildlife in general, as well as to game species.

However, if the hunting issue is a political as well as a biological question, then how are the feelings and facts evaluated to ensure that the answer is in the best interests of the community and of wildlife? Obviously there is no simple answer to this complex situation. Even with wise and generally accepted laws there are always some people who choose not to conform. This is evident not only in the use of firearms and hunting, but also in a host of other activities: driving dangerously, drinking alcohol to excess, robbery, tax evasion and so on. A major question continually facing the community is "how much should we restrict the activities of honest, responsible persons in order to restrict the opportunities or activities of dishonest or undisciplined persons?"

My approach to a decision on hunting would be based on the following question: are there data to indicate that hunting of a species will jeopardise its conservation, or that of another species? If the answer is yes, then clearly hunting that species should not be allowed. If the answer is no, then there is a further set of complex and interrelated questions regarding hunting methods and animal welfare considerations, hunting seasons and areas, hunter education programs, and fees for the privilege of hunting that should go towards conservation.

These decisions would involve extensive consultation with many interest groups and be made in the best interests of both the community and the conservation of wildlife. ■

photoart

JUMPING SPIDERS

This **Cosmophasis** *species belongs to a genus ranging from Indochina to tropical Australia.*

My introduction to the world of jumping spiders occurred in the tropical forests of South-East Asia. There I was captured hook, line and sinker by their remarkable beauty and antics. In an anthropomorphic sense I suppose I was captivated by that seemingly sentient gaze that appears to follow your every move.

Photographing jumping spiders requires a number of diverse skills, including patience, macro lens, extension tubes, ring flash, good focusing light, authentic props, an esky or fridge and possibly a nip of something strong to calm the photographer's shattered nerves resulting from an unco-operative subject. Once the subject is placed on the authentic prop, which should be positioned out of the wind and away from escape routes, the spider will generally show some alarm and charge off at a great rate or behave in

PHOTOGRAPHY BY DAVID KNOWLES

a way somewhat akin to a Mexican jumping bean. Pre-cooling in the esky will slow the subject and the shot should be taken at the quickly reached point of alertness when the cooling wears off. Once the subject is warm it will undoubtedly give you a benign glare and very likely jump onto the lens, often before there is a chance to refocus and press the shutter. This can become a frustrating scenario indeed when repeated relentlessly. ■

1. An unidentified jumping spider from Ubud in southern Bali. The continuous dragline of silk serves as a safety line in case of a fall and as a medium on which the hormones of sexual activity may be deposited.
2. Most jumping spiders exhibit pigmented rather than metallic colouration and are usually well camouflaged. An unidentified male spider from Ubud in southern Bali goes against the cryptic trend in favour of bright yellow and black, a combination recognised by predators as warning colours.
3. Myrmarachne is the largest genus of ant-mimicking spiders. This Balinese species mimics an ant almost twice as large as its body by an amazing adaption of its massive jaws, which are expanded anteriorly in mimicry of an ant's head. The front legs are not used for walking but are waved like antennae.
4. Even though the great majority of jumping spiders are less than 1.5 centimetres in body-length, they are nevertheless able to immobilise surprisingly large prey. This centimetre-long female (probably belonging to the genus Cytaea) hails from Maleny, south-eastern Queensland.
5. This male Rhene species from Celuk in southern Bali tends to sit and wait for prey, rather than hunt actively.
6. The genus Maratus is endemic to Australia. The spiders are known as peacock spiders because of the male's beautiful abdominal markings.

POSTER Weddell Seal

JOHNATHON CHESTER/WILDLIGHT

Sometimes called the 'champion diver', the Weddell Seal (*Leptonychotes weddelli*) is the most southerly of the Antarctic seals. Considering its remote and hostile habitat, it is surprising that perhaps more is known about this seal than many others. However, observing and recording data on Weddell Seals is made a lot easier by their apparently placid nature. They appear to have no fear of humans, exhibiting instead curiosity.

The Weddell Seal's remarkable ability to dive to great depths and stay there has received the most attention from researchers. It has been recorded diving to a depth of 600 metres and holds the record for seal time under water—73 minutes. The average time under water, however, is rarely more than 30 minutes.

Like most seals, the Weddell is primarily a fish eater, although they are also avid feeders on various crustacea and cephalopods. Weddell Seals also use their teeth to maintain their breathing holes in the ice. This biting and sawing at the ice eventually leads to worn incisor and canine teeth, reducing their ability to feed successfully. In some instances, seals unable to maintain air holes can become trapped under the ice.

Weddell Seals have been recorded making a variety of noises ranging from trills, whistles and chirrups to a rapid tooth clattering, the latter particularly evident when seals pass each other at breathing holes. They are not gregarious and tend to stay at a distance from each other when out on the ice. At some times of the year, however, such as in the summer breeding season, groups of pregnant females may form loose aggregations on the ice. Birth occurs anytime between mid October and mid November, and the single pup is born clothed in a greyish woolly coat with a darker stripe along the spine. About two weeks later the pup begins to moult, a process taking about four weeks, by which time it looks very much like the adult. Should moves go ahead for wide-scale exploitation of marine mammals in Antarctica, these animals will be extremely vulnerable. ■

—Linda Gibson
Australian Museum

ROBYN WILLIAMS

The Nature of Australia

Early in May I went to the Melbourne Zoo with my colleagues from the ABC Natural History Unit. The time had come, after three years of extraordinary effort, to face the critics. We pushed past crowds going to see the two Giant Pandas and entered the delightful restaurant area, surrounded by water and trees, with small hairy monkeys leaping about and staring through windows at us.

Here then was the media launch, complete with champagne, too much food and two dozen cynical TV writers. After the speeches we saw a 35-minute compilation from the six one-hour films. It was during this showing that I suddenly realised that we had a hit on our hands. The journalists sat utterly silent, sometimes gasping at the unbelievable shots, occasionally laughing at the droll sequences. At the end there was an incredibly long pause followed by thunderous applause. "Boy, that was powerful!" exclaimed the person from the *Mirror*. Others remarked how strong the messages seemed to be; "Not just furry animals and sunsets!" they exclaimed.

The series went to air first in Britain. There it headed the ratings for BBC 2, scoring 6.75–8 million viewers per show. In Australia, despite being up against the likes of 'Sixty Minutes' and 'ALF' (!), 'The Nature of Australia' attracted splendid audiences and unprecedented critical acclaim.

Who would have thought it? In the sometimes desperate months in preparing the documentaries and after all the countless films by Attenborough and others intruding on the most intimate moments of beasts—large and small—all we dared hope for was to avoid failure. Yet this ABC effort was singled out as special. Why? There are several reasons why 'The Nature of Australia' worked so well. Perhaps I can recount them somewhat objectively because I was not so closely involved in the production beyond reading the commentary and discussing some philosophy. First, as with 'Life on Earth', everyone insisted on trying for the best possible shots. Co-producers David Parer and Liz Parer-Cook would spend weeks finding a pair of Platypus, securing a Tasmanian pool so the animals wouldn't escape, then lying submerged for an eternity in freezing water to obtain unique footage.

". . .the producers chose to tell a story. Not the Disney kind, so beloved of anthropomorphising film-makers of yore. . .this had to be one of biological significance."

Second, the producers chose to tell a story. Not the Disney kind, so beloved of anthropomorphising film-makers of yore, with our friendly bear (which was actually several different bears) growing up, having adventures and meeting life. No, this had to be one of biological significance. Trouble was, the reality often stymied the plot, as when the Parers travelled to the central deserts to film an arid zone and the heavens immediately opened with torrential rains and the greatest floods for a decade!

Third, they used the latest techniques to blend location pictures with indoor intimacy. This was usually how they achieved shots most viewers found incredible, like following a mother parrot from the sky to the tree and next finding yourself actually *in the nest* among the chicks and watching behaviour apparently unaffected by the presence of a camera. Such filming invariably depends on an artificial hide in a laboratory in which animals have become accustomed to bright lights.

The fourth reason the series was such a success, and for me one of the most important, is that we suddenly saw an Australia that few thought existed. There was a land so subtle and dramatic in its natural history. There were plants and animals most of us were unaware of and there were familiar ones, like kangaroos, monotremes and Koalas, that we thought we knew about but turned out to be much more sophisticated than any of us had dreamt. Australia was revealed as more than a burnt rock with left-over beasts.

Finally, as producers Dione Gilmour, John Vandenbeld and the Parers insisted, this was going to be a series that *said* something. The conservationist messages were unequivocal, the main theme carried throughout the series being that damage to the continent is caused by a lack of understanding of how it works. In fact, the messages were a little *too* strong for the BBC, which dropped the odd paragraph. But in Australia no-one seemed to mind (beyond the odd creationist) because the things you saw were so very powerful that the script did not seem indulgent.

And so the series has gone around the world. In the United States a chap called George was hired to re-record my words. Not because, as I thought at first, the American audience wouldn't understand my pronunciation. But because the States, so poor in its output of documentaries, chooses to disguise foreign films by Americanising them to appear homemade. Elsewhere the broadcasts have been as they were seen in Australia. Now video cassettes are on sale and the book by John Vandenbeld has been a best-seller.

What next? For a start, I think this is a lesson for natural historians (recognise the pricelessness of your heritage); for ABC film-makers (do it well and the expense will be repaid); and for future broadcasts (why not a regular natural history magazine program?). ■

Dragons & Damsels

AN IN-DEPTH PENETRATION OF THEIR SEXUAL STRATEGIES

By DAVID THOMPSON
UNIVERSITY OF LIVERPOOL

Dragonflies and damselflies are remarkable insects. They are often beautifully coloured, both on the body and wings. They can fly forwards, sideways and backwards. And in the Carboniferous, some 250–300 million years ago, there were giant representatives with wingspans of over 60 centimetres. However, in modern times, it is not their colour or size that has brought them to centre stage in the zoological world, but rather the structure and functioning of their penes.

The reproductive behaviour of dragonflies and damselflies (the order Odonata, see box) is unique in the animal kingdom. Males extrude sperm in the ninth abdominal segment as do other insects. However, unlike other insects, the male odonate transfers the sperm to accessory genitalia situated between his second and third abdominal segments by curling his abdomen round to contact them. This transfer takes place when the male arrives at the breeding site or just after he has

A Green Damselfly* (Lestes sponsa) *in flight (family Lestidae). This family of damselflies boasts a penis with an extensible head with which the male scrapes out sperm from previous matings before inserting his own.

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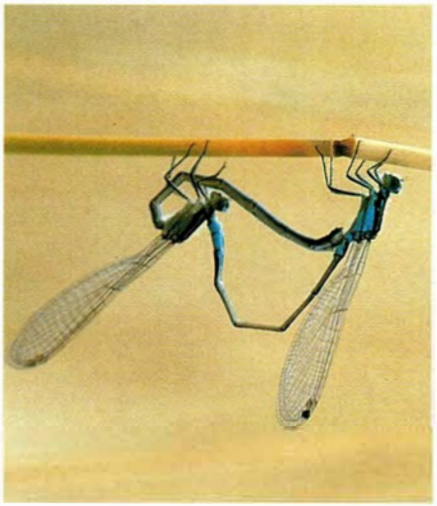
RALPH & DAPHNE KELLER/ANT PHOTO LIBRARY

Damselflies and dragonflies adopt a tandem position before mating. The male damselfly shown here (family Coenagrionidae) grasps the female's prothorax with his claspers.



SARAH WING/AUSCAPE

Damselflies mating. Copulation begins when the female (left) bends her abdomen forward to the secondary genitalia of the male to form the 'wheel' position.

grasped the female. The male dragonfly holds the female by her head, while in the damselflies the male's claspers grasp the female's prothorax. The pair then flies off in 'tandem' to copulate, usually on some waterside vegetation. Copulation begins when the female bends her abdomen forward to the secondary genitalia of the male to form the so-called 'wheel' position.

Dragons and Damsels—the Order Odonata

The members of the insect order Odonata belong to one of three suborders, of which only two are of any significance (the third contains only two species). The Anisoptera, commonly called dragonflies, have dissimilar fore and hind wings, are generally large, fast-flying insects and usually rest with their wings open. The Zygoptera, known as damselflies, have fore and hind wings similar in shape, are generally more delicate, thinner, slow-flying insects, and most rest with their wings closed. In Australia, there are about 200 species of dragonflies and 100 species of damselflies. The world list of Odonata stands at around 5,000 species.

In most insects, the eggs are fertilised at egg-laying (oviposition) by sperm that has been stored by the female from previous matings. When a female has been mated by two or more males, the sperm do not necessarily have equal chances of fertilising her eggs. In some insects, there is precedence of the sperm from the last male to mate, but in others there is lack of precedence with mixing of sperm from successive matings. Competition among males to fertilise a female's eggs should be especially intense among those insects whose females can mate repeatedly before oviposition using sperm obtained from successive matings. This has been called sperm competition.

The mechanism of sperm precedence in most cases is poorly understood, but this is not so in dragonflies and damselflies. The unique structure of the odonate penis enables the last male to mate with the female to maximise the probability that his sperm will be used to fertilise eggs about to be laid and thus promote the passage of his genes to the next generation. In most damselfly species and some dragonflies, the act of copulation for the male involves removing the sperm of other males from the female's sperm storage organs (the spermothecae and bursa copulatrix) before inserting his own. Scanning electron micrographs of the penes of members of several damselfly families (including three of those found in Australia, the Lestidae, Protoneuridae and Coenagrionidae) have revealed quite complex and intriguing structures. The penis in these families has an extensible head with which the male scrapes out sperm deposited in the female, trapping it behind a flange. The base of the penis is covered in backward-pointing barbs and hairs that serve to trap globules of the stored sperm.

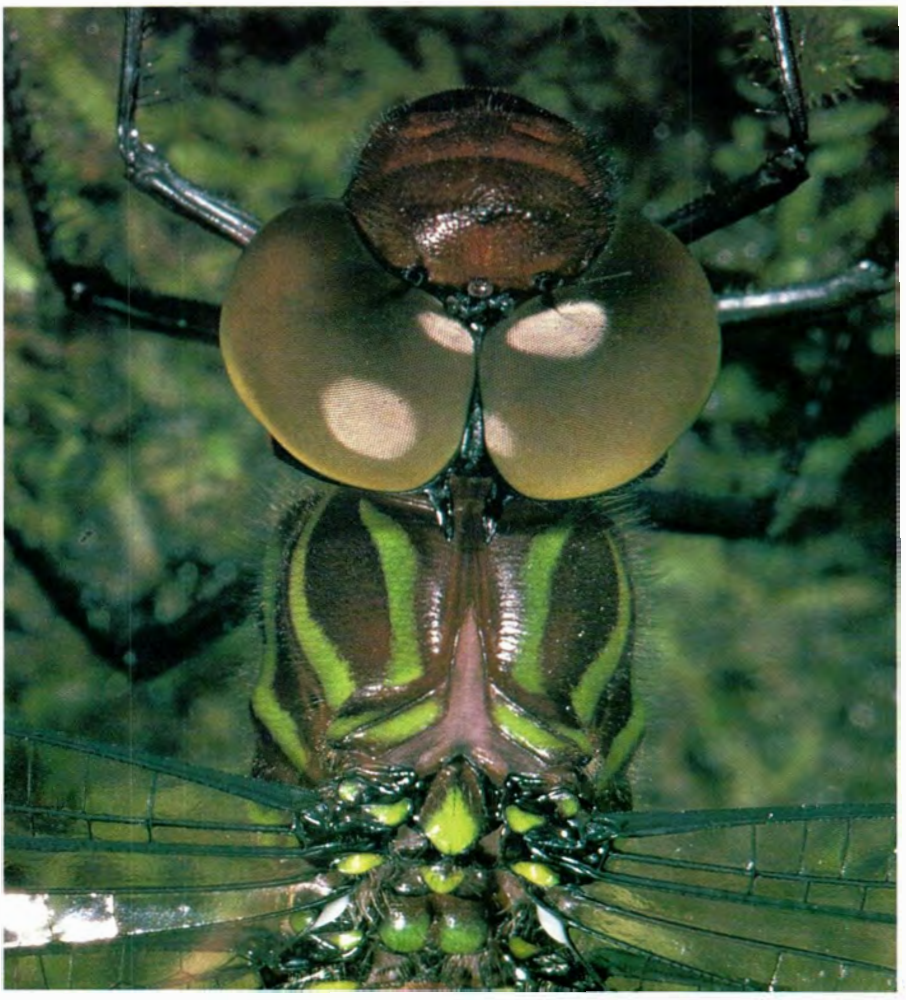
In other dragonflies, males do not scoop out sperm. Their penis head is extended and inflated in such a way as to pack sperm previously deposited by other males into areas of the female sperm storage organs further away from the oviduct (where the eggs are released). This renders such sperm less likely to fertilise eggs during the ensuing oviposition period.

The duration of copulation is understandably very different between sperm removers and sperm packers. Sperm removers require a longer period of time to extract previous sperm; whereas sperm packers need no such time—one jab and the job is done. *Orthetrum cancellatum*, a European dragonfly species similar in appearance to the ubiquitous Australian species *O. caledonicum*, may copulate for up to 16 minutes, but the first 15 minutes are spent by the male removing sperm. Only in the last minute does he introduce his own sperm. Another European libellulid dragonfly, *Crocothemis erythraea* (a close relative of the Australian *C. nigrifrons*) takes only a few seconds to complete copulation and must, therefore, be a sperm packer.

There are some species in which copulation duration can take an extraordinary length of time. The sperm-removing damselfly *Ischnura elegans* can take up to eight hours to complete copulation. This is much longer than would be necessary to complete sperm removal. The males may be ensuring that females will refuse further copulations that day and so obtain paternity by a 'war' of sexual attrition!

Having gone to great lengths to ensure that the sperm currently occupying prime position in the female's sperm storage organs are his, the male of most damselfly species retains a grip on the female ('contact-guard') while she lays the eggs, to ensure that other males do not displace his sperm. With the dragonflies there is more variation in the mate-guarding strategies. Some libellulid species contact-guard females, like most of the damselflies. Other dragonflies hover close to ovipositing females (but not attached to them) keeping rival males at bay, while being in a good position to grab another female should one arrive at the breeding site unattended. And a further group leaves the female completely alone after copulation. This whole complex range of odonate post-copulatory behaviour, over which biologists have puzzled for years, is now making sense when viewed in the light of sperm competition and penis structure. Sperm removers are generally contact-guarders, whereas sperm packers whose sperm will eventually mix with the sperm of previous maters tend to have shorter copulation times and are usually non-contact-guarders.

As well as the recent interest in the Odonata resulting from the dual function of the penis, it is becoming increasingly clear that dragonflies and damselflies are excellent study animals for the behavioural ecologist. They have a number of advantages over most invertebrates in that they are relatively large, can easily be marked and subsequently watched through binoculars, and breed in relatively distinct places (ponds, lagoons, streams etc.). Dragonflies and damselflies also score heavily over the more conventional subjects of behavioural work, the vertebrates, in that they are usually far more numerous (therefore give larger sample sizes) and are relatively short-lived so that all their mating success can be measured over a breeding season



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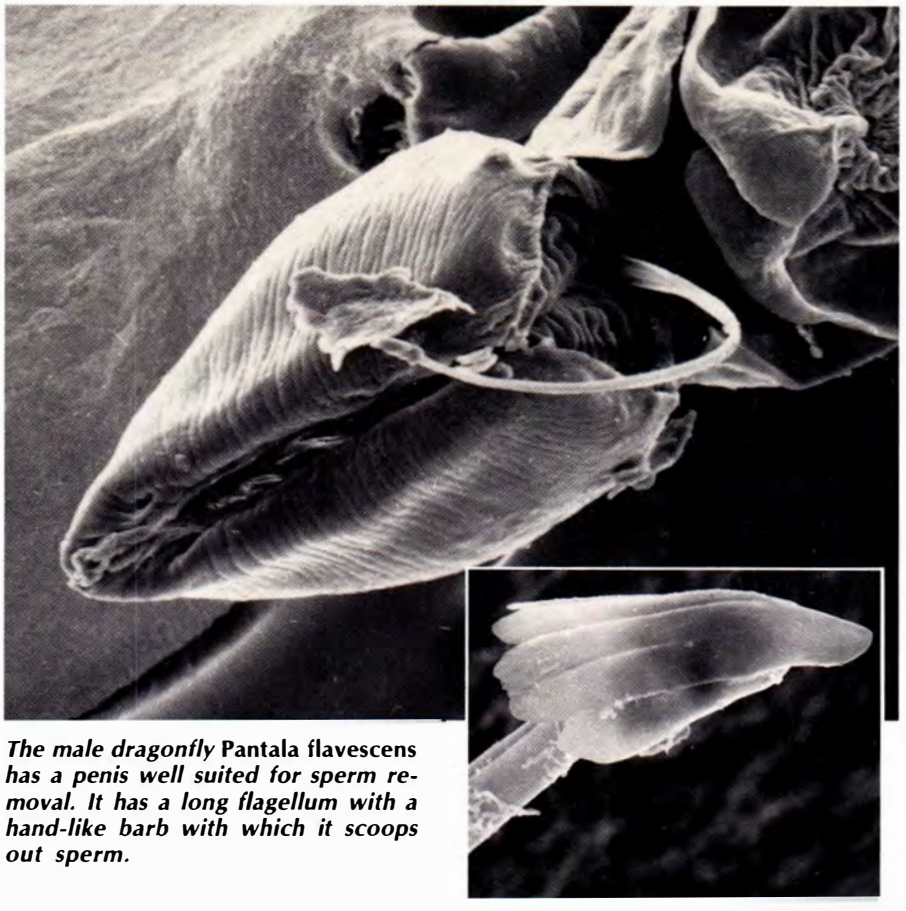
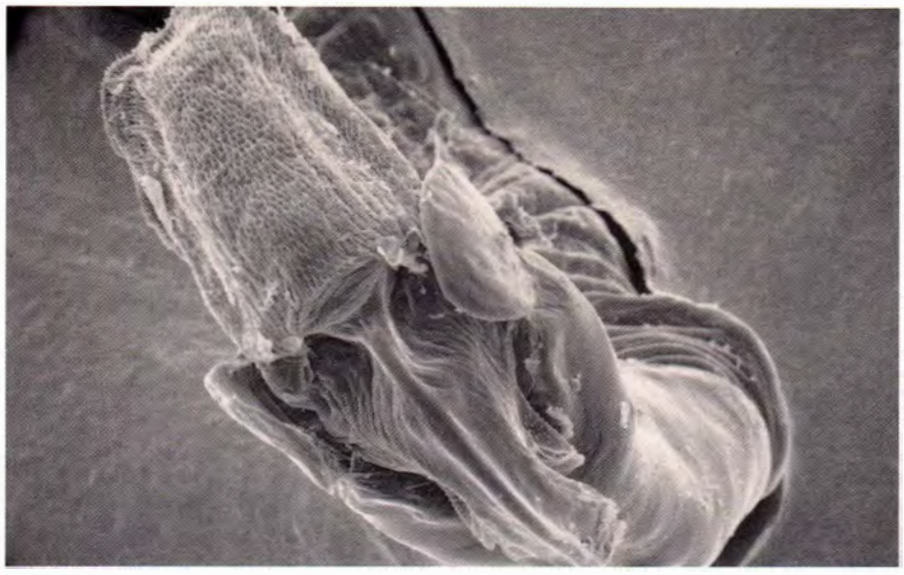
Closeup of a young female dragonfly's head (*Austroaeschna forcipata*).



PETER MILLER

The male dragonfly* Pantala flavescens *has a penis well suited for sperm removal. It has a long flagellum with a hand-like barb with which it scoops out sperm.



PETER MILLER

The penis of* Crocothemis erythraea*, a European libellulid dragonfly. This species is a sperm packer, whereby sperm from previous matings is packed into areas of the female's sperm storage organs furthest away from the oviduct, thus ensuring his sperm will be used to fertilise the eggs.

Sexual and Natural Selection

Darwin recognised two types of selection pressure that might filter successful from unsuccessful genes. The more conventional form of selection was that imposed by the environment, hence the term 'natural selection'. Food shortages, predators and bad weather, for example, all limit an organism's chances of contributing genes to future generations by shortening its life.

However, Darwin also recognised that, in those species that reproduce sexually, competition for access to mates can also form a basis for selection of those traits that allow individuals to compete more successfully in the sexual arena. This he called sexual selection. We generally distinguish between two types of sexual selection. In the first, intrasexual selection, features arise as a result of competition between members of the same sex for mates of the opposite sex, for example, a deer's antlers are used to fight other males. In the second, intersexual selection, certain features evolve as a result of attempts by members of one sex to attract mates of the other sex, for example the plumage of birds of paradise.

of just a few weeks.

With these advantages in mind, several behavioural ecologists have used the Odonata in attempts to assess the relative importance of sexual selection and natural selection (see box) in determining reproductive success. One such study was that of Michael Banks and myself working on *Coenagrion puella*, a close relative of the Australian *C. lyelli*. We attempted to mark all individuals that visited an isolated pond in northern England. Over 4,000 animals were marked (with a number on the left forewing and a dab of paint on the thorax); they were also weighed, their wing lengths and head widths measured. Mature adults of this species do not alter their breeding sites once chosen and so we could watch who mated with whom throughout the ten-week breeding season.

There was a large degree of variation in male mating success. Over 20 per cent of males in our study obtained no matings while one particularly successful 'stud' mated 18 times in his adult lifetime of 29 days. Conventional wisdom would have it that variation in male mating success was not only evidence for the existence of sexual selection but also a measure of its intensity. But by analysing the causes of variation in mating success, we were able to establish that sexual selection had a relatively minor role (if any) in determining male mating success. Body size, a parameter often implicated in sexual selection studies, was shown to explain only two per cent of the variation, and stage in the breeding season had only a small effect on mating success. The most significant factor determining mating success in both male and female damselflies was the number of days they were able to spend at the breeding site (accounting for 70 per cent of the variation). 'Days spent at the breeding site' is a natural rather than sexual selection factor. Chance factors accounted for the remaining variation.

Walter Koenig and Stephen Albano of the University of California have confirmed these general findings with similar work on a territorial libellulid dragonfly, *Plathemis lydia*. They provided a figure of between 11 and 17 per cent for the influence of sexual selection on mating success in *Plathemis*. Conventional estimates based only on the variation in mating success between males would have suggested a figure of around 79 per cent. The difference between these two estimates constitutes the disguised influence of natural selection

F. INGWERSEN/AUSCAPE

Dragonflies in the 'wheel' position, mating on a bulrush. The head of most male dragonfly penes can be extended and inflated in such a way as to pack previously deposited sperm further away from the female's oviducts, thus rendering his own sperm more likely to fertilise her eggs.

on lifetime mating success. In other words, the reproductive success of a male depends primarily on how long he can *survive* during the mating season, rather than on some feature of his anatomy or physiology that aids his ability to acquire females. In particular, predator avoidance or high feeding efficiency, both of which contribute towards survival, are likely to be major influences on mating success. This work strongly suggests that although sexual selection, through sperm competition, has undoubtedly shaped odonate reproductive success in the past, it may not be such a potent force in determining current reproductive success as was previously supposed. ■

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The Four-Dimensional 'Bioblob' Called Life

JEANETTE MUIRHEAD

Although it is impossible to portray the four-dimensional Bioblob concept in two dimensions, at the crux of the matter is the idea that all organisms—both living and extinct—are intimately joined, cell to cell, in space and time.

Doctor Who's leggy assistants, his mechanical dogs, sonic screwdrivers and even his own bodies come and go but that dyspeptic police box, his 'hee-haw'ing time-machine called the Tardis, seems to last forever. Like many science fiction heroes before him, the two-hearted Doctor depends on this improbable device to zip him through four-dimensional space in a constant battle with the universe's most gruesome nasties. Of course, it's all delightful nonsense — no creature could simultaneously exist at different times because, if its future self could do something that jeopardised the ability of its former self to survive, the future self might not have existed to have done what it nevertheless did do!

But *is* this entirely nonsense? *Could* a single living creature really travel through space and time to emerge millions of years later at some other point in the universe? There is not the slightest doubt in my mind that *it* not only could, but *we* most certainly have—for the last 3.5 billion years, without the aid of a mechanical Tardis.

Life, the whole collosal thing that it is, was and will be, is quite literally one gigantic time-travelling creature, without a single physical or temporal break in its gigantic being. All of it, from Amoebas, Apples and Aardvarks to Zebras, Zygomycetes and Zen Buddhists, is in reality a single shape-changing mass of trillions of pulsating cells that first evolved on Earth approximately 3.5 billion years ago.

Let's personalise this four-dimensional Bioblob concept. Your whole body, as you sit there reading this, is a mass of replicating cells, each and every one of which (less those of any parasites you may unwittingly harbour) are the descendants of your parents' sperm and egg cells that united when you were conceived. If you could see these same cells within the fourth dimension of time, you would see that the cytoplasm of *every* cell in your body is quite literally an amoeboid extension of those first two cells. Not a single cell of your body, throughout its entire history, has ever been physically isolated because along that fourth dimension every cell is in tangible contact with the one from which it arose. Further, at any point along that time-dimension axis, *every* one of those dividing cells is still alive. Death is an illusion of limited vision.

Now let's look further back along time's axis. Those sex cells of your parents are themselves living extensions through space and time from the original cells that united to become your parents' bodies, and so forth back to the first cell that gave rise to all subsequent life on Earth.

Hold your fingers upright in front of you. Visualise the appearance of your fingers if you could see only *two* dimensions: length and width (pretend you're incapable of perceiving height). Your fingers as you previously knew them will vanish, to be replaced by isolated flat rings of soft tissue surrounding inner rings of bone. Blood cells will mysteriously appear out of nowhere in circular rings of arterial epithelium and just as instantly vanish from view. To see

by MICHAEL ARCHER

your fingers as you normally do, you *must* (and of course can) perceive the third dimension: height.

In exactly the same way, if you could see your fingers in *four* dimensions, as they *really* exist, it would be instantly obvious that they are quite literally linked in time and space by a continuous flow of flesh to the fingers of an australopithecine and those to the digits of a mammal-like reptile and so forth back through millions of years of time—without a *single* physical break in the whole chain of reshaping flesh. Your fingers, like the rest of your body, are tiny portions of the organism *life*, which gradually changes its shape while travelling through time.

On the real four-dimensional Earth, quite literally there have *never* been isolated individuals of any kind apart from the single 4-D Bioblob out of whose prehistoric being we, as cellular extensions, have steadily grown like fingers of a hand. From each of these fingers, more projections have developed and then still more from them to produce a tree-like growth of protoplasm that continuously expands outward through time and space.

The *appearance* of individual life-forms such as you, me and a gum tree is caused by a simple incapacity of our sensory systems to perceive the fourth dimension. If we had another sensory organ that could visualise this fourth dimension, we would instantly understand that the *apparent* gaps between individuals perceived by creatures with only three-dimensional vision are illusions. In reality, all of these illusory gaps are bridged by living protoplasm of the four-dimensional, time-travelling Bioblob.

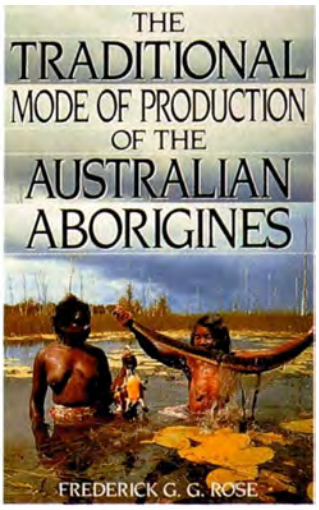
This heretical vision ought to at least challenge common understanding about the biological world. For example what we perceive as 'species extinction' should in reality be understood as changes in the relative growth of parts of the Bioblob. 'Individual deaths' as we now understand them are in fact illusions. Because we *are* the cells of our parents extended in time and space, no creature has ever really died because it is a part of the four-dimensional organism that is already at least 3.5 billion years old. What of diseases? Clearly these are part of us, mindless tendrils of the same Bioblob exploring time and space in response to an opportunity to more efficiently expand the creature in new directions.

Next time you open the front door to be confronted by a Biblical fundamentalist who smugly asks you "Why, if 'apemen' [australopithecines] were more 'successful' than chimpanzees, didn't they survive while chimpanzees did?", restrain your urge to tell him how much your neighbour wants to learn about his religion. Instead, invite him to consider that we, as the growing tip in time and space of the Bioblob's australopithecine tendril, *are* those "apemen"—the product of four million years of evolutionary growth of a living tendril that physically and continuously connects *Australopithecus afarensis* to *A. africanus, Homo habilis, H. erectus* and, as the bud of the moment on the end of the tendril, to *H. sapiens*, atheists and fundamentalists alike.

Earth's fossil record is the refuse pile where discarded fragments from the Bioblob, like dandruff, have been cast off during this creature's travels through space and time. Through study of these discarded fragments, we can obtain a vision, albeit imperfect, of the true shape of the Bioblob and the undeniable bridge of prehistoric life that makes us part of this enormous creature.

Faced with the reality that we, the whale and the watermelon are of the same living flesh, metamorphosing tendrils from the surface of a single four-dimensional, time-travelling being that began its cosmic travels in the hot waters of a young Earth—a minor planet in a relatively small solar system on the edge of one of millions of galaxies racing through the blackness of an infinite universe—who could *possibly* believe that the whole purpose of Existence (as if it needs one) revolves around an infantile minor cell mass we call people.

Pass the wrinkle cream and fold up the Tardis; I'd far rather revel in awesome reality than the anthropocentric delusions of the Biblical fundamentalists. ■



The Traditional Mode of Production of the Australian Aborigines

Frederick G.G. Rose. Angus & Robertson, Sydney, 1987, 292 pp. $39.95.

This book contains a Marxist analysis of Australian Aboriginal traditional mode of production written by a practising Marxist. Professor Rose carried out social anthropological research in northern Australia between 1937 and 1942. He settled permanently in the German Democratic Republic in 1956 and continues to live there today where he is Emeritus Professor attached to the anthropological museum in Leipzig.

He wrote this book because "Frequently I was asked to write something on the method I was using in dealing with traditional Aboriginal society" (p vii).

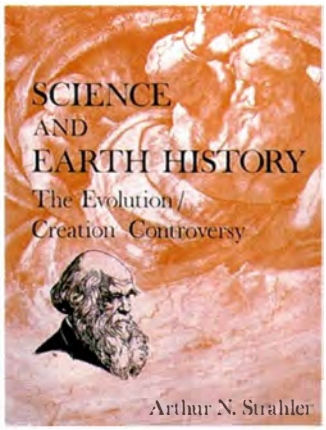
Rose examines only 'traditional' Aborigines, by which he appears to mean those whose mode of production has not been influenced by foreign systems. He believes that once European money entered the Aboriginal economic system it ceased being 'traditional'. In northern Australia, apparently, World War 2 was the watershed: Aboriginal societies studied before that time were 'traditional', those examined after this event were not. Fortunately for Professor Rose, his own work on Groote Eylandt was finished just before the cultural earthquake and so stands on the 'traditional' side of the chasm! This is a rigid view of cultural process. True, Aboriginal society changed when money was adopted. It is likely, however, that the changed mode of production maintained strong links with past practices. Let us not forget that Macassan traders had been visiting northern Australia for several hundred years before Europeans settled there, long before Professor Rose carried out his own fieldwork. They brought with them *rupiya* or money, as is evidenced by the continued use of this term by Aboriginal people today to refer to Aussie dollars and cents.

No anthropologists that I know believe that they have observed Aboriginal people living exactly as they did 200 years ago. Many believe, however, that what they observe is connected to the past by 'tradition'. What happens today has continuity with the past as well as new elements, and can provide clues as to the content and functioning of past systems.

There is much to be critical of in Rose's book and much to recommend. The approach he adopts provides many opportunities for lively debate. His materialist analysis gives students a chance to compare this approach with other anthropological Marxist interpretations.

Had he a slightly more flexible view on the way in which culture changes, and not been quite so rigid in his acceptance and rejection of other people's data, the book may have been much better. Perhaps its weaknesses reflect the fact that he lives in Europe far away from the mainstream of Aboriginal studies in Australia, where scholars are able to formulate and exchange ideas long before they are committed to print.

—Betty Meehan



Science and Earth History: The Evolution/Creation Controversy

Arthur Strahler Prometheus Books, Buffalo, New York, 1987, 552 pp. $75.00 approx.

Arthur Strahler, a former Columbia University geology professor, has written what he admits is "a very strange book", one that would have been unnecessary ten years ago. He wrote it after realising the increasingly serious threat to science education in the United States posed by fundamentalist religious groups calling themselves 'scientific creationists'.

Unfortunately the same elements are also at work in Australia, trying to infiltrate religious beliefs in the guise of 'Flood Geology' into the school science curriculum. Unlike many American science books where Australia never gets a mention, Strahler discusses recent Australian creationist claims, analyses them and convincingly refutes them. His "very strange book" is thus invaluable to anyone interested in the practice and teaching of science (not just Earth sciences) in Australia.

The 54 chapters, in nine sections, cover virtually every significant aspect of Earth sciences and related evolutionary topics: science and pseudoscience; creationism, its roots and tenets; cosmology and astronomy; geology and crustal history; origin of landscapes; stratigraphy and the fossil record; integrity of the evolutionary record under attack by creationists; the rise of man and emergence of the human mind; the origin of life on Earth—naturalistic or creationistic? In each section Strahler compares and contrasts the scientific evidence and how it is interpreted, with equivalent creationist explanations based on strict literalist interpretation of biblical texts, especially Genesis.

The book presents a wealth of information from many sources not readily available to most readers. Strahler combines an encyclopaedic knowledge with an enviable ability to organise and present an enormous amount of information in an accessible and readable form. It is a 'fun' read, packed with fascinating facts. In the process of discovering why creation

'scientists' are, in fact, pseudoscientists the reader painlessly learns a great deal about Earth history. Strahler also takes scientists to task for carelessness and arrogance in presenting their case.

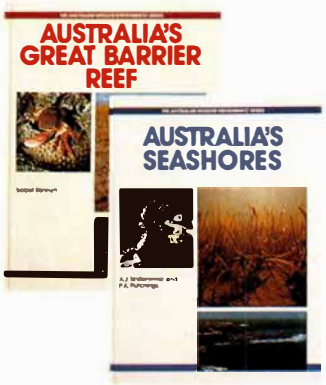
This volume is a *must* for anyone seriously concerned by the creationist threat to science education in this country. It should certainly be in every university, public and high school library. To school librarians—it may be the best investment your school will make this year, even if it prevents just one promising student from being turned away from science by misguided pseudoscience.

Strahler's book is also strongly recommended to anyone who sincerely believes that creationism does have a place in the science class. It may not change your views but you will appreciate more clearly why scientists vehemently and almost unanimously reject young-Earth creationism as a valid *scientific* interpretation of Earth history and evolution.

—Alex Ritchie

The Australian Museum Environment Series

Australia's Seashores *by A.J. Underwood and P.A. Hutchings;* Australia's Great Barrier Reef *by Isobel Bennett. William Collins, Sydney, 1988, 64 pp. $14.95 each.*



One of the greatest joys of children is their inquisitive nature. These two books, part of a wonderful new series from the Australian Museum, deal with a wide range of questions that children ask about their environment. If you're not an expert on the subject, chances are that you won't be able to give them clear, accurate answers.

The books are aimed at stimulating children to discover their natural surroundings by using the skill of observation through field trips and experiments. They help foster the development of an enquiring mind by encouraging children to investigate, describe, infer, classify and communicate their discoveries. Simple scientific terms and words are explained in detail.

For teachers, this series provides a useful reference with pictures, drawings, illustrations and suggested practical activities. For parents, it can help answer some of the tricky questions children ask and provides a starting point in the quest of knowledge for the whole family.

—Vicky Kapatos

Possums and Opossums—Studies in Evolution. Vols 1 and 2

Ed. by Michael Archer. Surrey Beatty & Sons and The Royal Zoological Society of New South Wales, Sydney, 1988, 788 pp. $112.00.

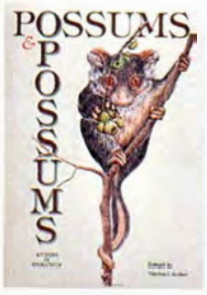
Possums and Opossums is the latest epic publication on fossil and living Australian and American marsupials to appear under Michael Archer's energetic editorship. The two volumes continue the multidisciplinary phylogenetic review of marsupials begun in 1982 and complement two earlier volumes on carnivorous marsupials by the same team of editor, publisher and society.

The catchy title (from a 1984 symposium of the same name) doesn't adequately reflect the range of contributions, which covers *all* Australian fossil and living diprotodont marsupials as well as their early Cainozoic South American counterparts. Fifty papers by 38 Australian and American contributors provide the most comprehensive review of marsupial evolutionary relationships in two decades. Five new marsupial families and many more new species are described and profusely illustrated. And, in a major review of marsupial phylogenetics, Aplin and Archer assess all previous classifications since 1945. New information presented here is incorporated in a new marsupial classification.

Although the Australian fossil marsupial record still hasn't broken through the early Miocene barrier, the American record extends to the Cretaceous and is increasingly well documented. For the early Australian marsupial evolution, unrepresented by fossils, we are still reliant on molecular systematics.

Nineteen colour plates illustrate such features as colour variation in New Guinea cuscusses; and an imaginative (or speculative) touch is provided by restorations of extinct marsupial heads by Peter Murray. The widespread use of stereopairs is especially effective, with one reservation. For those who, like myself, cannot see these 3-D images without a viewer, I issue a plea for standardisation of lateral spacing of stereopairs. Here they range from three to about 9.5 centimetres; both extremes are uncomfortable. Stereopairs should ideally be between five and seven centimetres apart.

In a publication of this magnitude and complexity errors are inevitable, but even a casual perusal picked up more spelling errors than one would expect. When one encounters, in the space of 13 lines, *Wynyardia* (correct) and two other versions, *Wynayardia* and *Wynyaridia*, the editing leaves something to be desired.



These reservations apart, *Possums and Opossums* is a fine production and an invaluable contribution to a fast-developing field of research. As Archer states, the flood of new ideas and data currently being produced means that some of the phylogenetic concepts may rapidly be outdated. But this merely demonstrates that marsupial systematics in Australia is a healthy, rapidly advancing field of science. No-one seriously interested in the origins and evolution of Australian marsupials can afford not to own this fine production.

—Alex Ritchie

Native Fruiting Weeds

Just north of Broken Hill there is a paddock blanketed in impenetrable thickets of spiny shrubs. In small spaces between the shrubs lie shards of rusting iron and the desiccated droppings of rabbits. The scene speaks of land mismanaged, of the kind of rural desolation to be found around many Australian country towns. But the shrubs in this paddock are of interest for they are not, as might be expected, exotic weeds, but the native Nitre Bush (*Nitraria billardieri*).

In summer these fleshy-leaved shrubs are covered in bright red fruits, one to two centimetres long, tasting much like salty grapes. The journals of early settlers tell us that Nitre fruits, known also as Wild Grapes, were important Aboriginal foods. The writer C. Wilhelmi in 1860 described bushes "so full of fruit, that the natives lie down on their backs under them, strip off the fruit with both hands, and do not rise until the whole bush has been cleared of its load". The fruits are a staple food of Emus, and the seeds from up to 1,350 fruits have been found in a single Emu dropping.

J.C. Noble of the CSIRO suggested that Nitre Bush might serve as a food crop for arid areas. But he had a sample of the fruits canned, and found they tasted bitter and astringent and scored low in vitamin C.

Around Broken Hill the fruits are rarely eaten by humans (unlike the popular Quandong, *Santalum acuminatum*) but the plant is undergoing trials for mining stabilisation. It may also help in halting erosion and stabilising drifting sands. On disturbed saline soils it behaves like a weed, forming monotypic stands much like Lantana (*Lantana camara*) and Bitou Bush (*Chrysanthemoides monilifera rotundata*) further east. In southern Australia it has reclaimed abandoned wheat farms and infests overgrazed paddocks, stock routes and river flats. It is probably more common today, especially on soils ruined by rising salt, than in pre-European times.

Nitre Bush is but one of Australia's many native 'weeds'—plants that colonise unstable areas, such as those disturbed by wind erosion, floods and fire, and that benefit from human disturbance. Many of Australia's native weeds produce edible fruits. In coastal regions are kangaroo apples (*Solanum* species), wild raspberries (*Rubus* species) and elderberries (*Sambucus* species) among others. In the outback there is Ruby Saltbush (*Enchylaena tomentosa*), Desert Lime (*Eremocitrus glauca*), a significant weed of grazing lands on the Darling Downs, and Quena (*Solanum esuriale*), common along inland roads.

The large number of fruit-bearing species shows that, for colonising

The resplendent fruits of the Nitre Bush attract Emus, which by swallowing the seeds assist their germination. Nitre Bush is common along beaches and on saline inland plains in southern Australia.

PHOTOS: TIM LOW

Nitre Bush has smothered this overgrazed paddock just north of Broken Hill to the exclusion of almost all other native plants.

Coast Beard Heath is one of the beard heaths (genus* Leucopogon*), so-named because the small flowers have hairy petals* (leucos*—white,* pogon*—beard). This species grows mainly on coastal headlands and dunes in southern Australia.

plants, fruits are an ideal way to disperse seeds. Birds eat the fruits and excrete the seeds in new patches of disturbed soil.

Along the coast of southern Australia, Coast Beard Heath (*Leucopogon parviflorus*) is proving to be one of the most successful of native weeds. A shrub or small tree growing one to three metres tall, it sprouts along roadside verges and forms thickets where stands of Drooping She-oak (*Allocasuarina verticillata*) once grew. Drooping She-oak seedlings are so intensely grazed by rabbits and cattle that the once-vast she-oak woodlands of South Australia have vanished, surviving only as annotations on the maps of 19th-century surveyors.

Coast Beard Heath has been the main beneficiary of the she-oak's decline. Its small creamy fruits, four to five millimetres long, have a sweet lemony flavour, and were probably a popular snack-food of Aborigines, although scant record of this survives. They are avidly consumed by seagulls, silvereyes, fairy wrens, Emus and even rabbits, all of which help spread the seeds. Coast Beard Heath is now the most common shrub along the Coorong Highway and the Great Ocean Road in Victoria, and in bushland around Port Campbell and Robe. Its fruits ripen mainly in summer.

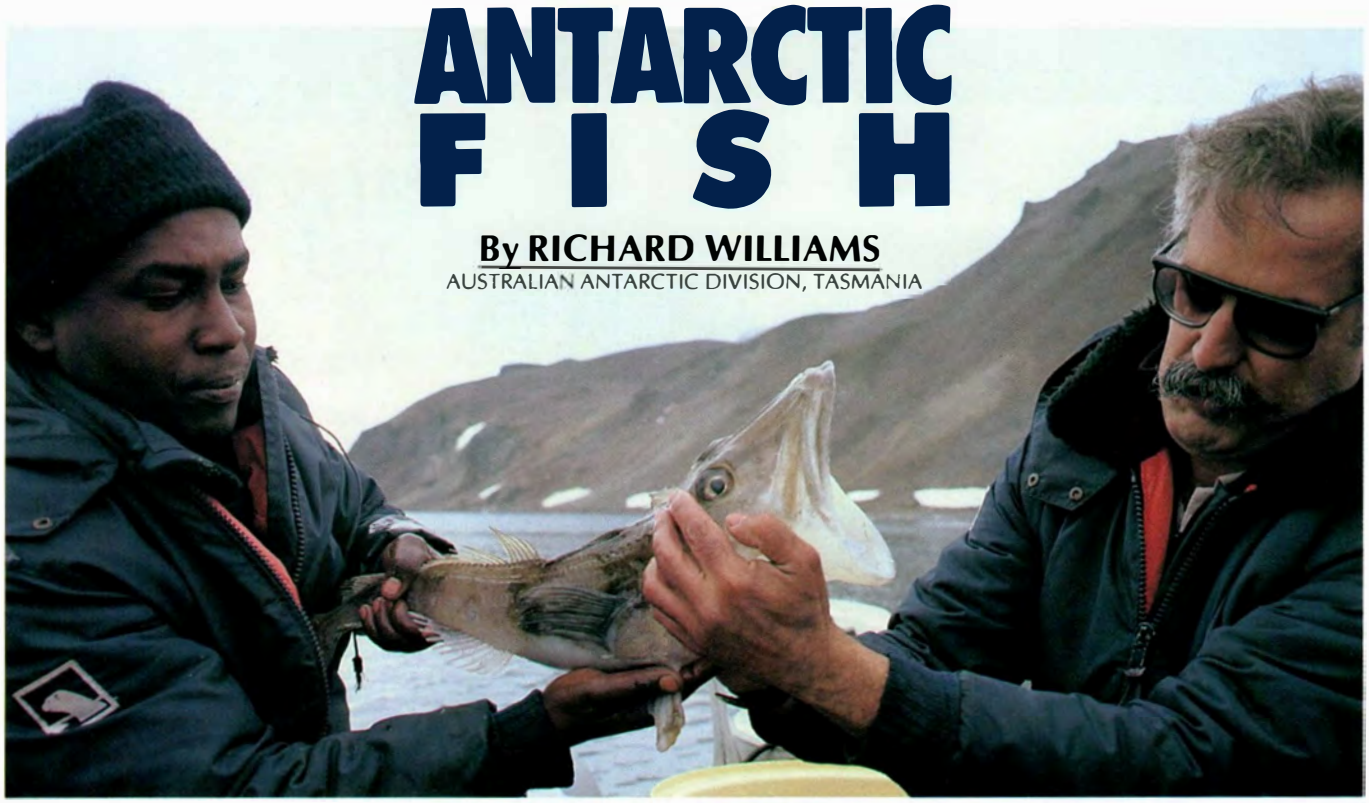
There are two lessons in all this. First, one cannot assume that the wild fruits found in bushland today grew there in the same abundance in pre-European times. A significant proportion of fruit-bearing plants behave like weeds, especially in such situations as rainforest clearings, river banks and coastal dunes. Apart from Nitre Bush and Coast Beard Heath, such food plants as the wild raspberries, wild tomatoes (*Solanum* species), pigfaces (*Carpobrotus* species) and Ruby Saltbush may be more common now (where bushland survives) than two centuries ago. Second, we must recognise that the changes wrought by Europeans to the Australian landscape have been so pervasive that even a forest of native plants is not necessarily a natural event. ■

Tim Low's book Wild Foodplants of Australia *has been released by Angus & Robertson.*

Coping with Life in Icy Waters

ANTARCTIC FISH

By RICHARD WILLIAMS
AUSTRALIAN ANTARCTIC DIVISION, TASMANIA



COLIN MONTEATH/AUSCAPE

Icefish caught for research in Admiralty Bay, King George Island.

Most people's mental picture of Antarctic fauna is dominated by penguins, seals and whales, for which the region is justly famous. They may also know something of Antarctic Krill (*Euphausia superba*), the crustacean that is so abundant and important as food to many of these larger animals. Antarctic fishes are largely unknown, except to the few scientists who study them, despite their importance in the ecosystem and their sometimes unique adaptations to the extreme environment in which they live.

Despite being surrounded by vast tracts of ocean, coastal Antarctica, from a fish's point of view, is extremely isolated. The relatively shallow seas normally associated with continental shelves are where the greatest production and diversity of fishes generally occur, but around Antarctica the shelf is narrow and significantly deeper than elsewhere. This results from the weight of the ice cap depressing the continent. The Antarctic continental shelf is physically separated from the neighbouring shelves by great distances of deep ocean, and further isolated by the Antarctic Convergence—a complex of fronts where the water temperature decreases rapidly as the cold Antarctic waters meet the northern subtropical waters. The extreme isolation has meant that the fauna consists of a relatively small number of distinctive species.

The fauna is dominated by the suborder Notothenioidei, a group of benthic (bottom-living) perch-like fishes, which probably invaded the area from the Patagonian region at the time Australia split from Antarctica about 40 million years ago, when the cold circumpolar ocean circulation commenced. Only about 200 species of benthic fishes have been described from the Antarctic regions (including the sub-Antarctic islands south of the Convergence), compared with the worldwide total of about 20,000 known fish species. The notothenioids comprise about 58 per cent of the species but over 90 per cent of the numbers of the fauna, with the other main groups being the generally deeper-living and sparsely distributed Liparididae (snail fishes), Zoarcidae (eel-pouts) and occasional representatives of the Rajidae (rays), Bothidae (armless flounders), and assorted deepwater species from such families as Macrouridae (rat tails) and Moridae (deep sea cods). The degree of isolation and specialisation imposed on the Antarctic fish fauna is illustrated by the degree of endemism: about 88 per cent of all species are endemic to the region (that is, they do not occur elsewhere) and, among the Notothenioidei, this rises to 97 per cent.

The Antarctic notothenioids consist of five superficially dissimilar families, but their relationship is well demonstrated by shared skeletal and anatomical characters such as the lack of a swim bladder to regulate buoyancy. Most of the species have special proteins in the blood to prevent freezing, have lost the red blood pigment haemoglobin to some degree, and share other physiological and behavioural traits such as the production of a relatively small number of large yolky eggs.

The family Nototheniidae has the most species (52) and is the most widespread and common group. They are commonly known as Antarctic cods, and the more generalised members of the family are probably similar to forms that originally colonised the Antarctic regions. Several of these generalised species remain today in Patagonia, and this family is found from the coast of the Antarctic continent to the relatively warm seas surrounding the sub-Antarctic islands, and as far north as the southern tip of New Zealand. Like the northern cods after which they were named but to which they are not closely related, most species are moderately active bottom-dwelling fishes that feed on a variety of benthic invertebrates.

Three other families, the Harpagiferidae, Artedidraconidae and

Bathydraconidae, contain few species (six, 19 and 16 respectively) and are specialised for a more strictly benthic habitat. Their bodies are more compact and dorso-ventrally compressed, and some have quite heavy armour or spines associated with the head. Members of these families are usually small and not very common. The harpagiferids or plunder fishes are most common in the sub-Antarctic regions. They are small, naked, spiny fishes that occupy the littoral and shallow shelf waters. The closely related artedidraconids, also called plunder fishes, are more characteristic of the colder Antarctic shelf waters, from the coast to the deepest parts of the shelf. Bathydraconids (deep dragon fishes), as their name implies, are often, although by no means always, found in the deeper waters of the Antarctic continental shelf and slope, and some of the offshore sea mounts. They are moderately slender fusiform (spindle-shaped) fishes like the Antarctic cods, but are characterised by the presence of only one dorsal fin.

The final family, the Channichthyidae or icefish, is one of the most important and interesting groups. Although containing only 16 species, its importance is due to the abundance of many of its members,

PAUL ENSOR

Around the Antarctic continent, the fish fauna is limited to a few characteristic types. Samples from a catch near Australia's Davis Station show the main types. Clockwise from the top are: the ray* Bathyraja maccaini, *the Antarctic cod* Trematomus lepidorhinus, *the plunder fish* Artedidraco *sp., the dragon fish* Prionodraco evansii, *the Antarctic Silverfish, an icefish* Chionodraco myersi, *and another Antarctic cod* Trematomus eulepidotus. *The scale bar is graduated in one-centimetre and five-centimetre intervals.

R. WILLIAMS

A resource of the past: the Marbled Rockcod was once the mainstay of the large fisheries around South Georgia and Iles Kerguelen. Harvesting this species is now totally banned.

R. WILLIAMS

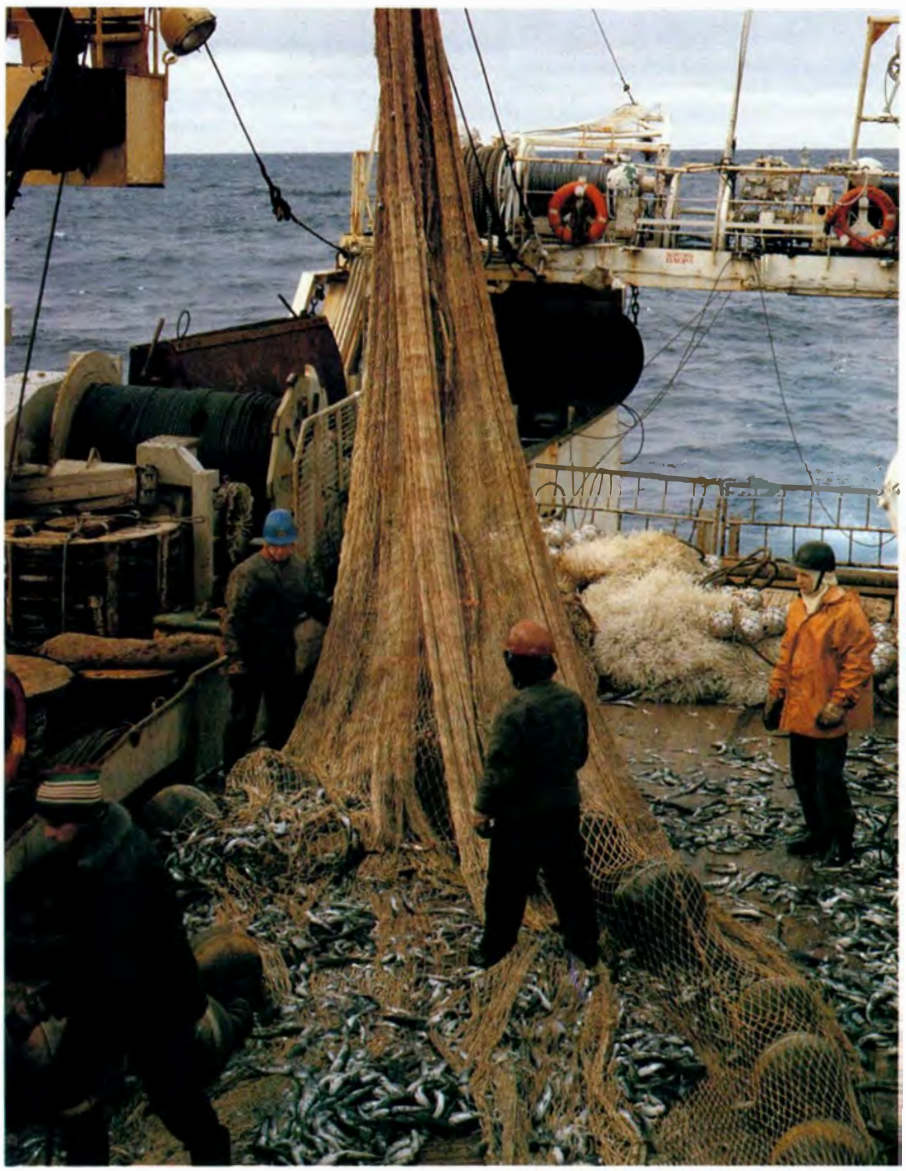
***One of the most colourful Antarctic fish is the inshore-dwelling Magellanic Rockcod,* Paranotothenia magellanica.**

some of which support commercial fisheries, and to their ecological role as predators of Antarctic Krill. They are of great scientific interest because they are unique among vertebrates in completely lacking the red blood pigment haemoglobin and its associated muscle respiratory pigments. They also virtually lack red blood cells (erythrocytes) and, for these reasons, have characteristically cream-coloured organs (such as gills, heart and liver), which in other fishes are bright red. In spite of this apparent disadvantage, the family is widespread and common, although not generally found in the warmer waters of the region. Many members retain their benthic habit but some have become at least semi-pelagic, occupying the water column and feeding on Antarctic Krill or other zooplankton. Many grow quite large (40 or more centimetres long) and some species (notably the Mackerel Icefish, *Champsocephalus gunnari*) form dense aggregations that are exploited commercially.

The isolation and extreme environment of Antarctic waters have resulted in a marked lack of fishes inhabiting the pelagic (upper water) zone, such as the herrings and tunas of warmer seas. No representative of typically pelagic families occurs in the shelf zones. This has led, in a manner similar to the classic case of Darwin's finches on the Galapagos Islands, to an adaptive radiation of some of the originally benthic notothenioids to a secondarily pelagic habit. This has happened particularly among the Antarctic cods and icefish, in which a range of species from strictly benthic through occasionally pelagic to fully pelagic can be identified.

This adaptation has led to some fundamental physical changes in the fishes. The benthic species are typically robust, relatively heavy and lack a swim bladder whereas the pelagic species have to be neutrally buoyant and are usually more slender and manoeuvrable. The Antarctic cods have achieved this transition in the absence of a swim bladder by reducing the mineralisation of the skeleton (and thereby its weight), reducing the weight of muscle to a certain extent and, most significantly, by lowering the specific gravity as a result of increasing the lipid content of the body—either as fat deposits under the skin and between the muscle blocks (for example, the Antarctic Toothfish, *Dissostichus mawsoni*), or as subcutaneous oil sacs (Antarctic Silverfish, *Pleuragramma antarcticum*).

A series of species can be identified with increasing specialisation



PAUL ENSOR

Remnants of a catch of icefish cover the deck of this Soviet trawler, fishing near Heard Island. The size of the net indicates the enormous capacity of these modern boats. Large bobbins are used to prevent the net from being snagged on the bottom.

for a pelagic habit. Among the Antarctic cods, the Emerald Rockcod (*Pagothenia bernacchii*) is an example of a completely benthic species, with a fully ossified (bony) skeleton, well-developed muscle blocks and few lipid deposits. It has a relatively short, thick-set body and is cryptically coloured blotchy brown and reddish. The Antarctic Toothfish is a semi-pelagic form with intermediate characteristics. The skeleton is much weaker and muscle blocks are relatively smaller with considerable lipid deposits between them and also subcutaneously. The body has become longer and more streamlined and is a uniform brownish colour. The trend towards pelagic specialisation reaches its full expression in the Antarctic Silverfish, which, although still an Antarctic cod, superficially resembles a herring in being a medium-sized (up to 30 centimetres long) streamlined fish with silvery, easily detachable scales. Its diet is even similar, feeding on small planktonic crustaceans such as copepods and larval krill. In this fish the skeleton is very much reduced, there are large intervertebral spaces filled with a jelly-like substance, and obvious subcutaneous and intermuscular oil sacs. This species is the only wholly pelagic Antarctic fish.

Another group of Antarctic cods has undergone similar adaptations for slightly different reasons. Fish such as the Bald Rockcod (*Pagothenia borchgrevinki*) live under the sea ice, where they capture the small crustaceans that feed on the microscopic algae on the ice undersurface and also derive protection (at least during the juvenile stages) by hiding in the ice crevices. For this cryopelagic habit they also need a fairly slender shape, neutral buoyancy and cryptic colouration, and hence skeletal reduction and lipid deposits are also seen in this species, along with a moderately streamlined shape and pale colouration.

Normally a fish's body fluids freeze at about −1°C, yet some Antarctic fishes have to withstand temperatures below −2°C. Without protection, a fish will become supercooled and vulnerable to freezing if it came into contact with ice, as do some species. Protection is provided by special molecules (glycoproteins) in the fish's blood and tissues, which act as an antifreeze by binding to the surface of an ice crystal and blocking further binding of water molecules. In essence, glycoproteins are 'antibodies' against ice. As one might expect, those species experiencing the lowest temperatures, or most exposed to ice, such as coastal and shallow water species, have the greatest freezing resistance; those species from deeper water where the extra pressure depresses the freezing point, or from lower latitudes, have less antifreeze. At the other extreme, fish such as Grey Rockcods (*Notothenia squamifrons*), which only occur around the relatively warm sub-Antarctic islands, have no antifreeze proteins at all. The amount of cryoprotection seems to be genetically fixed: after prolonged acclimation to higher or lower temperatures, antifreeze levels do not change in individual fish. It has been suggested that these antifreezes (or at least similar synthetic reproductions) could be useful to humans in such fields as food processing, where much of the spoilage due to freezing food is caused by ice crystals disrupting the cell structure.

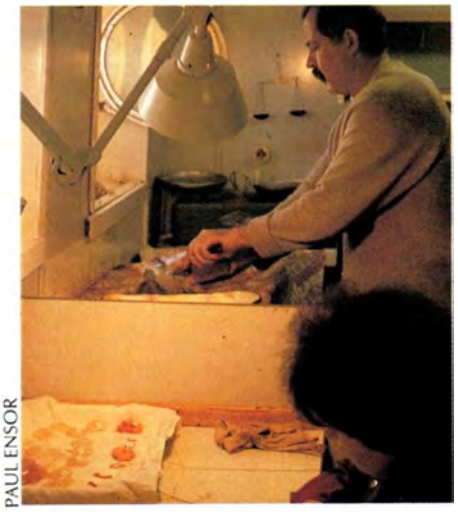
Icefish lack haemoglobin and functional red blood cells entirely, while Antarctic cods have about a 35 per cent reduction in these. It is hard to identify an obvious selective advantage, especially considering the potential disadvantages in the reduction of respiratory efficiency, but the consequent reduction in blood viscosity and thus the relative ease of pumping it around the body may be a signficant advantage in a cold environment. The icefish still have functional gills and have a large blood volume to compensate for the

lack of red blood cells. They appear to acquire sufficient oxygen by simple dissolution into the plasma through the naked skin, gills and lining of the large mouth. This is helped by the greater solubility of gases in fluids at low temperatures and by the behaviour of the fish. Most icefish are rather sluggish predators that capture their prey by quick lunges requiring only short bursts of energy and high oxygen consumption. Many are so sluggish that they can easily be caught by hand.

Although often unseen and rarely remarked, fishes are important in the Antarctic ecosystem. As scientists attempt to unravel the complexities of the Antarctic marine ecosystem, the role of fishes is seen as more and more important, even though they do not have the sheer biomass of, say Antarctic Krill, or the visibility and appeal of the birds, seals or whales.

Fish as a group originally were not considered to be important predators of Antarctic Krill, with most attention being paid to the whales and seals. During the last 20 years, as commercial fisheries have developed and studies on fishes have increased, the importance of Antarctic Krill in the diet of many fish species has been realised. For example, the two species that have constituted the bulk of the catch around South Georgia at various times—the Marbled Rockcod (*Notothenia rossii*) and Mackerel Icefish, both feed largely on Antarctic Krill.

Most Antarctic fishes have pelagic larval and juvenile stages, even though the adults may be strictly benthic. Because of the low water temperatures, hatching times can be three months or more, and low growth rates may mean the juvenile pelagic stages last two years or more. Studies by Australian and Polish scientists have shown that these young fishes are often associated with Antarctic Krill swarms, and can constitute up to five per cent by weight of Antarctic Krill catches. This means that a large Antarctic Krill fishery (currently almost 500,000 tonnes per annum) could have a serious effect on these fish populations with their low reproductive rates.



PAUL ENSOR

The large Soviet fishery is supported by a considerable research effort. Here researchers inspect the gonads of samples from a catch taken near Heard Island to assess the reproductive condition of the fish.

Recent work by Australian scientists at Davis Station has demonstrated the value of fishes, particularly the pelagic Antarctic Silverfish, to birds and seals. Adelie Penguins take up to 40 per cent by weight of their diet as fish while feeding young chicks, and Emperor Penguins and several of the smaller petrel species also feed on fish from time to time. Weddell Seals feed mainly on fish, taking a mixture of bottom-living species as befits its reputation as one of the deepest diving animals known, and Antarctic Silverfish. Crabeater Seals, although best known for their Antarctic Krill diet, also take Antarctic Silverfish, perhaps incidentally while pursuing Antarctic Krill.

Because of the narrow continental shelf providing relatively little suitable habitat, and the ice and bad weather providing little opportunity, the Antarctic continental margin has not to date supported a major fishery. The more temperate sub-Antarctic islands and the Antarctic Peninsula, however, have supported fisheries for almost 20 years. These locations are the only extensive areas of relatively shallow shelf (less than 500 metres deep) in the sub-Antarctic zone, and are close to the highly productive region of the Antarctic Convergence. In spite of the relatively brief history, nearly all stocks have suffered heavy fishing followed by a marked decline in stock size and catches.

Over 95 per cent of the total fish catch has been taken by the Soviet Union, with the balance being taken by Poland, East Germany and Bulgaria. The shelf around South Georgia was the first to be fished in 1969, closely followed by the Kerguelen Plateau in 1970. No locality at that time was under any national jurisdiction and in both cases the history was the same. Initially the highly valued Marbled Rockcod was taken in huge quantities, with catches declining rapidly in the first few years. Subsequently, other species have been harvested and have suffered a similar fate, and other areas, notably around the tip of the Antarctic Peninsula, have been fished. More recently the Kerguelen Plateau has come under the jurisdiction of France (around Iles Kerguelen) and Australia (around Heard Island) by the establishment of 200-mile exclusive economic zones in 1979, which has resulted in more stringent control.

Since the establishment of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) in 1981, a more general regulation and management of the region's living resources has been attempted, although progress on such a complex subject has necessarily been slow. The CCAMLR was initially established because of concern about the potential damage to the ecosystem of harvesting large amounts of Antarctic Krill. However, the most pressing problem has become the management of the fin fisheries, because of the serious position of some of the species. The convention under which CCAMLR operates is unique because it requires an ecosystem approach to management, unlike all other fisheries-type agreements that generally deal only with the target species. Thus, while accepting that conservation includes rational use of living resources, the convention requires that harvesting be conducted in such a way that dependent and related species are not unduly affected, and changes to the ecosystem that are not potentially reversible are avoided. Unfortunately the lack of historical data on the fisheries and ignorance of the biology of most species have made it difficult to agree on the best procedures. In the last couple of years, however, some important regulations have been introduced, such as a total ban on catching Marbled Rockcod and, for Mackerel Icefish around South Georgia, a total catch limit and ban on harvesting during its spawning season. While much work still needs to be done to resurrect the stocks of some species and control the exploitation of others, jurisdiction is at least now in place to conserve these interesting and valuable animals. ■

RARE & ENDANGERED 'Extinct' Plants Rediscovered

In Australia, a plant is presumed extinct if it has not been found in recent years despite thorough searching, or it has not been collected for at least 50 years having previously been known from areas that are well settled.

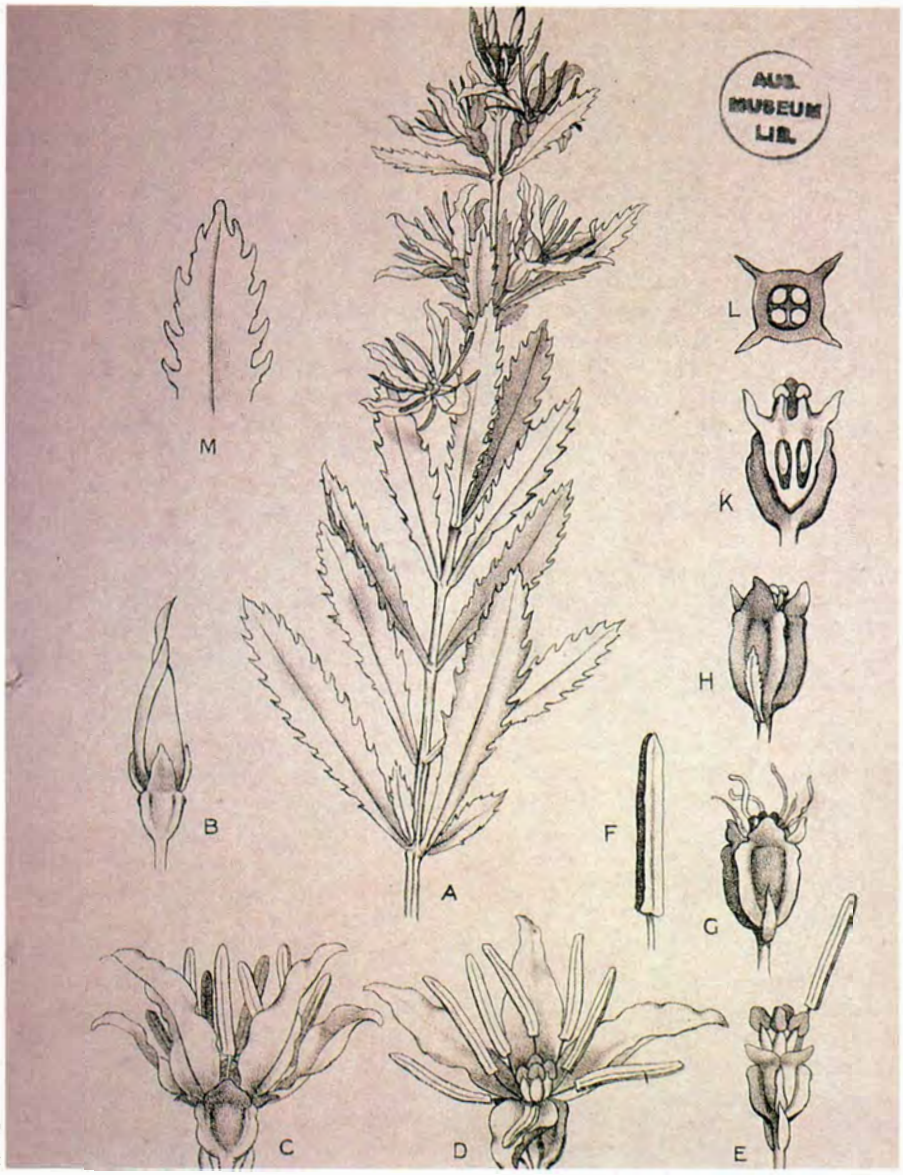
Since the arrival of Europeans in Australia 200 years ago, more than 130 plant species are presumed to have become extinct. Occasionally, however, a species presumed extinct is rediscovered. Such rediscoveries occur not only in remote, seldom-surveyed areas, but also in the midst of urban development. Two such species recently rediscovered in New South Wales are *Haloragodendron lucasii* and an undescribed species of *Zieria*.

Haloragodendron lucasii is a member of the Haloragaceae, a family of herbs and shrubs found throughout the temperate areas of the world, but having its greatest diversity in Australia. It is a bright green shrub that grows to about two metres in height. Opposite pairs of oblong serrate leaves are arranged with adjacent pairs at right angles; and creamy white flowers, which are relatively large compared with most others in the family, are grouped together in a leafy inflorescence. The species was named after Arthur Henry Lucas (1853–1936), a headmaster of Sydney Grammar School and honorary algal specialist at the Royal Botanic Gardens in Sydney, and was originally recorded in 1908 from a small area now in the north-eastern suburbs of Sydney.

The species was unsuccessfully searched for in 1969 and, as it had last been collected in 1926, was presumed extinct. It was thought that urban development was most likely the cause of its extinction. Searching for the species was made difficult by the limited amount of information that had previously been recorded. Its locality on one herbarium specimen, for example, was recorded as "a wild gully near Gordon".

By chance, in 1986, a local resident and amateur botanist collected a specimen of *H. lucasii* near St Ives in Sydney only 100 metres from houses. This is most likely near the site of the original collection and similar gullies in the area are worth searching. Fortunately, the plants so far discovered are within a reserve, which will improve the species' chance of survival. However, the 1,000 or so plants are in a small area (150 x 25 metres) and are more or less even-aged with few seedlings. Given the population structure, the species is still regarded as endangered. It is particularly threatened by encroaching weeds (privet, camphor-laurel, crofton weed, rhus, wandering jew and lantana) from the surrounding urban areas. There is also a degree of 'people pressure' in the area since there are a number of small walking tracks passing close to the plants.

The second species to be removed from the 'presumed extinct'



KAREN HANDLEY

***Line drawing by Margaret Flockton from the* Proceedings of the Linnaean Society, *1909, of* Haloragodendron lucasii.**

MARK RICHARDSON

Rediscovered* Zieria *species found near Nowra, New South Wales.

list is an undescribed species of *Zieria*. The genus *Zieria* belongs to the family Rutaceae—perhaps best known for its edible citrus fruits (oranges, lemons, grapefruits) and, in Australia, for such plants as *Boronia, Correa* and *Eriostemon*.

This rediscovered *Zieria* species, which had previously been referred to as the more widespread *Zieria cytisoides* (Downy Zieria), will be described in a forthcoming revision of the genus. It is an open shrub growing to about half a metre high with small grey-green heart-shaped leaves and small pink-white flowers. It was originally recorded in 1883 from a population on the "lower Shoalhaven". A search in 1976 using locality information from a later collection made in 1943 failed to relocate the species and it was presumed extinct. Fortunately, a recent search in 1987 relocated the species. This site is near Nowra, New South Wales, within view of a suburban development and only a short distance from a major water pipe.

Although not an outstanding plant in any aesthetic sense, biologically the population is very interesting. When discovered, cuttings were taken from five of the 120 plants. Tests carried out at the Australian National Botanic Gardens showed little if any genetic variation between the plants sampled. Further samples were collected from plants up to 50 metres apart and still no variation was detected. The possibility that the population has developed from vegetative or asexual reproduction is strengthened by the finding that pollen collected from the flowers within the population is 95 per cent sterile. The lack of genetic diversity not only makes this population more vulnerable to disturbance, but also means that factors other than its morphological characteristics will have to be taken into account when considering its status as a species. Like *H. lucasii*, this species of *Zieria* is still considered endangered and the site of the population has been nominated for protection through the Register of the National Estate.

Since their rediscovery, both *Haloragodendron lucasii* and the *Zieria* species have been brought into cultivation by the Australian National Botanic Gardens. This is part of the Garden's program to establish an Endangered Species Collection to provide plant material for research and education and, by so doing, hopefully prevent overcollection from wild populations. The work at the Gardens is to be expedited by a grant from the World Wildlife Fund.

While it is likely that many of those plants currently presumed extinct are truly gone forever, it is highly probable that a number still await rediscovery. Rediscoveries of plants such as *Haloragodendron lucasii* and the *Zieria* species will continue to keep our hopes alive. ■

—Mark Richardson
Australian National Botanic Gardens

JOHN BENSON

Missing, presumed extinct:* Haloragodendron lucasii *recently rediscovered alive and well in Sydney suburbia.

Life Without Legs

THE PYGOPODID LIZARDS

By MICHAEL HUTCHINS and BARBARA SLEEPER
NEW YORK ZOOLOGICAL SOCIETY

When we think of evolution, we normally think of systems becoming more complex. But there are cases in which nature simplifies rather than elaborates. A spectacular example is provided by Australia's unusual pygopodids, also called snake-lizards or legless lizards.

Pygopodids superficially resemble snakes. The body is elongated, the forelimbs are completely absent, and the hindlimbs are small and scarcely noticeable—mere flaps usually carried closely against the body. Vestiges of limb bones, however, are present, indicating that ancestral forms had four legs.

Frequently confused with snakes, this harmless Hooded Scaly-foot, a legless lizard, draws back its head and bends its neck into an 'S' when threatened. Should the threat persist, it hurls its head forward like a striking adder.

The family Pygopodidae is thought to be closely related to geckos (so much so that some people prefer to include them in the family Gekkonidae). There are eight genera and 32 species, two of which occur outside Australia—in New Guinea. If indeed pygopodids warrant their own family status, it is the only reptile family endemic to the Australian region. Highly variable in both size and colouration, these lizards inhabit deserts, as well as coastal forests throughout Australia—with the notable exception of Tasmania. Virtually all areas of mainland Australia contain at least one species.

When encountered by the casual observer, these harmless lizards are often mistaken for venomous snakes and killed. Several characteristics, however, readily distinguish them from snakes. Unlike snakes, most legless lizards have a tail that is three to four times longer than the body, and all have a broad, fleshy tongue. Most species also have external ear openings. In contrast, snakes have no external ear openings, a tail that is usually less than a quarter of the body length, and a deeply bifurcated or forked tongue. In addition, whereas snakes have a single row of widened scales under the body, the belly scales on legless lizards occur in two rows and are only slightly broader than the other scales of the body.

Despite these differences, the snake-lizards are deserving of their name in that they do have several characteristics, both structural and behavioural, which are similar to those of snakes. In addition to their leglessness and elongated bodies, pygopodids have lidless eyes with vertical pupils, which remain permanently open behind a clear covering called the 'spectacle'. Like the

A.C. WILLIS

PETER ROBERTSON

The vestigial hindlimb of the Common Scaly-foot illustrates the ancestry of pygopodids from the limbed lizards.

KEN GRIFFITHS

Legless lizards have an immovable transparent scale or 'spectacle' over the eye, similar to that found in snakes. Unlike snakes, however, they have a broad, flat tongue and usually an external ear opening, as in this Common Scaly-foot.

geckos, the pygopodids 'clean' the 'glasses' over their eyes by licking them with their tongues.

Apart from their serpentine locomotion, which consists of a sideways undulation, some pygopodids behave like venomous snakes when threatened. The Hooded Scaly-foot (*Pygopus nigriceps*), for example, draws back the head and bends the neck into an 'S'. If the enemy does not retreat the scaly-foot hurls its head forward like a striking adder. In situations like this, it is little wonder that this species is confused with snakes and often persecuted.

Snake-lizards often move about in search of food at twilight and at night. *Delma* species are primarily insectivorous, feeding on various arthropods, ants and termites and are found throughout the arid interior of Australia. Scaly-foots, however, are more variable in their habits. For example, the Hooded Scaly-foot, like *Delma* species, prefers arid, sandy habitats and is primarily nocturnal and insectivorous. But the Common Scaly-foot (*P. lepidopodus*) tends to live in cooler, wetter habitats, is active during the day and at twilight, and has a highly specialised diet of spiders, especially large, burrowing forms.

In contrast to the active feeding strategy of *Pygopus, Delma* and other pygopodids, Burton's Legless Lizard (*Lialis burtonis*) is a 'sit and wait' predator that feeds day and night almost exclusively on other lizards such as small skinks and geckos. This cryptically coloured species, which may reach a length of 70 centimetres, lies in wait and then ambushes its unsuspecting prey, seizing it with a rapid snap of the jaws. If the prey is not killed outright by the bite, it suffocates as it is swallowed head-first. The sharply pointed teeth, rather long and with a slight backward curve, serve well to overcome large prey. It has also been known to consume the occasional snake.

The feeding habits and adaptations of the genus *Lialis* are remarkably similar to those of snakes. Such similarities probably arose through convergent evolution. In this process, distantly related species evolve comparable adaptations because they exploit similar ecological niches. A key specialisation of snakes is an ability to ingest very large prey; this ability is extremely important in elongate animals because they have heads that are small

PETER ROBERTSON

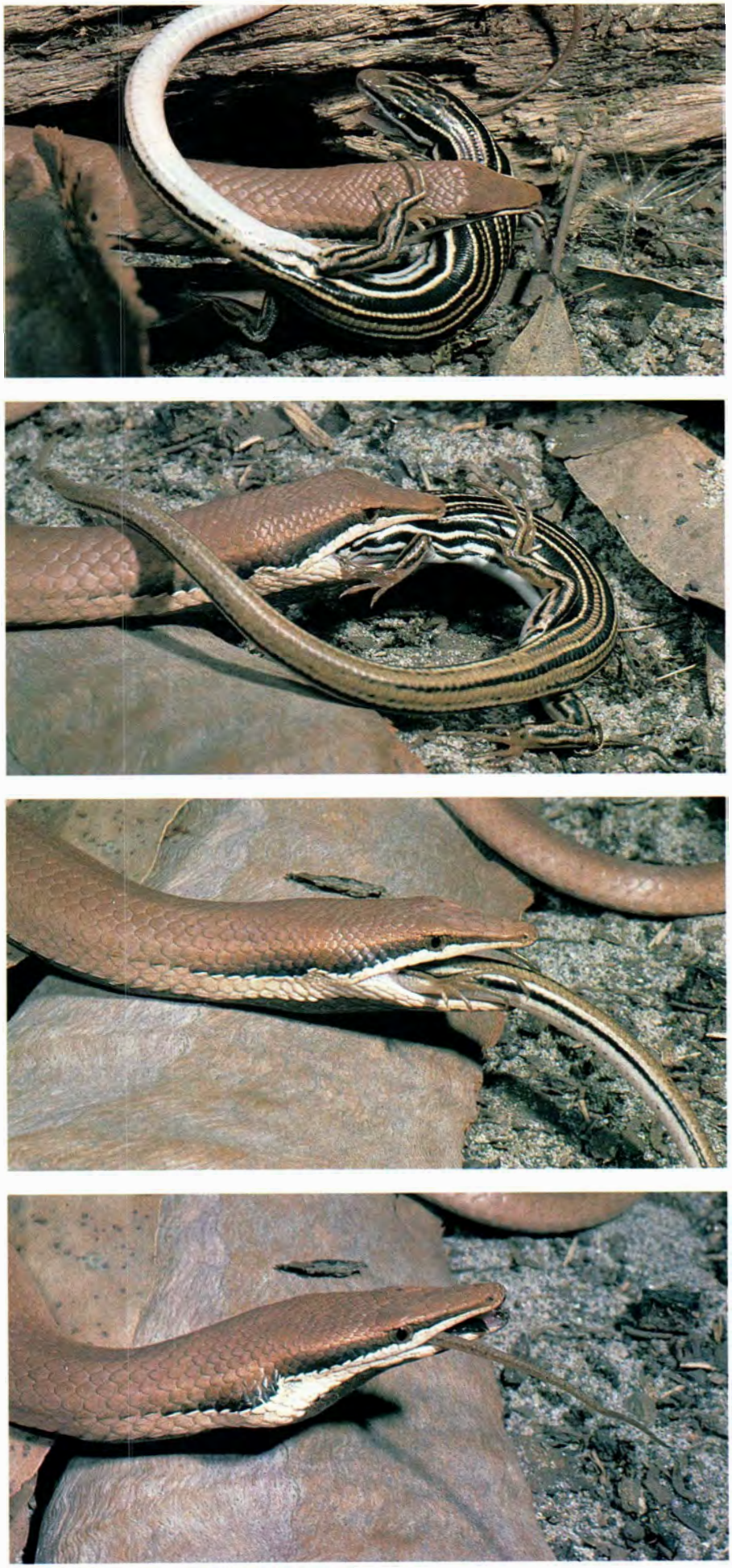
Lialis burtonis ***emerging from shell. Pygopodids generally lay two soft-shelled eggs, usually hidden in a sheltered site beneath cover or in the soil. After laying, the female displays no maternal care.***

relative to their body size (and hence energetic requirements). Some snakes also do not eat very often, thus making it important that large prey be ingested as they become available. Indeed, snake jaws are hinged in an elastic fashion (cranial kinesis), so that they can open widely and allow something as big or even bigger than the body to pass into the digestive system. Their teeth are also pointed, recurved and sometimes hinged in such a way that they point backwards when pushed from the front but remain erect when pushed from behind. Pygopodids of the genus *Lialis* possess similar morphological adaptations, and their diets are nearly identical to those of elapid snakes that live in the same area. Unlike *Lialis*, however, most small lizard-eating elapids are nocturnal and search actively for sleeping lizards.

The snake-lizards best adapted to burrowing life are those of the genus *Aprasia*. These small, thin, worm-like lizards spend most of their time underground. Their hindlegs are the most reduced of all pygopodids, consisting of only a single scale, and the external ear opening is often completely absent or much reduced. Little is known about their natural history, although they are thought to feed exclusively on ants and termites.

Female pygopodids appear to be larger than males of the same species. This trend is also evident in many species of geckos. All pygopodids are oviparous (that is, lay eggs) and the usual clutch size is two. Ovulation typically occurs in spring and early summer and females are gravid (that is, carry eggs) until midsummer. The cylindrical eggs are extremely thin and elongated, and are encased in a parchment-like shell.

The phenomenon of limblessness raises some interesting evolutionary questions. The anatomy of pygopodids clearly indicates that they once possessed limbs. So, why did they lose them? As it turns out, elongation of the body and



MARK HUTCHINSON

Skinks beware!* Lialis *species are formidable predators of small lizards and have a specialised skull morphology for handling such prey. The elongate upper jaw is 'hinged' across the centre between the eyes, allowing it to bend around lizards and hold them securely. Prey are captured, subdued and suffocated by pressure from the jaws—and swallowed whole.

DENSEY CLYNE/MANTIS WILDLIFE

The Hooded Scaly-foot has a highly specialised diet of spiders, especially large burrowing forms like this wolf spider.

ANTHONY HEALY

Among the smallest of pygopodids,* Aprasia *species rarely exceed 15 centimetres in length. They are burrowing lizards and may have highly specialised diets. This species,* Aprasia inaurita*, is believed to feed only on the eggs of small black ants,* Aphaenogaster *sp.

A Fragile Tale

When handling a snake-lizard, one must take care not to grasp it by the tail. Except for chameleons, monitors, bearded lizards (agamids) and a few others, most lizards—including pygopodids—can voluntarily shed (autotomise) their tails when attacked by a predator. This behaviour reaches its pinnacle in the Australian Marbled Gecko (*Christinus marmoratus*). It will slowly undulate the vertically erect tail from side to side, presumably to draw the predator's attention. The tail, once shed, continues to wriggle convulsively for several minutes, distracting the predator while the tailless lizard makes a quick get away.

Fracture planes in one or more of the vertebrae makes this startling feat possible. A wall of connective tissue or cartilage passes through each vertebra, creating a weak point, where muscles and blood sinuses have been modified to allow an easy break. A new tail slowly regenerates if the break occurs along a fracture plane.

limblessness have evolved independently in a wide variety of reptilian families worldwide, including the skinks (Scincidae), blind lizards (Dibamidae) and anguid lizards (Anguidae). Indeed, the snakes themselves are thought to have originated from a monitor-like ancestor; the inability to regenerate a tail (see box), the narrow and deeply bifurcated tongue, and certain aspects of skull and tooth structure are common to both groups.

Noted herpetologist Carl Gans of the University of Michigan has long been fascinated by the evolutionary trend toward elongated bodies and reduced limb size in reptiles and amphibians. Although common among ectothermic ('cold-blooded') vertebrates, the phenomenon is rare among endotherms ('warm-blooded' vertebrates). This pattern is thought to be due to heat conservation restraints. Elongated bodies generally have larger surface areas, thus making it more difficult and energetically expensive to maintain high temperatures. Ectothermic reptiles and amphibians, which regulate their body temperature primarily through behavioural rather than physiological means, are free of such constraints and were presumably able to evolve a greater diversity of body shapes than the endothermic mammals.

Based on his studies of modern limbless reptiles, Gans suggested that body elongation may have been the first step towards the reduction and eventual elimination of limbs. The initial advantage of elongation would have allowed ancestral pygopodids to use narrow crevices to obtain food, for thermoregulation, or for shelter, and therefore exploit a niche that was heretofore unavailable to other lizards. Once the initial advantage was established, further selection may have occurred both for greater elongation of the body, loss of limbs, and serpentine locomotion or burrowing. This hypothesis is supported by several lines of evidence, including the fact that modern geckos have a tendency to use cracks and crevices, and that some pygopodids, such as *Aprasia*, are highly adapted to a burrowing lifestyle.

During Australia's long isolation from other landmasses, the continent's animals have pursued their own courses of evolution, producing many strange and wonderous forms. The region's unique wildlife makes it an important laboratory for biological scientists. Indeed, Australia's legless lizards have taught us much about the evolutionary process. In losing their legs, they appear to have gained a niche—an essential prerequisite for winning the evolutionary game. ■

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