Australian Natural History

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Tales from the Mammal Collection

SATELLITE TRACKING
New Direction for Research

FORUM
Saving Whales with Bows & Arrows

STROMATOLITES
Earliest Evidence for Life on Earth

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Front Cover

European exploration in Australia yielded many mammal specimens that are now housed in the Australian Museum's collection. The skin of this hare-wallaby *Largorchestes leichardti* was one of the last collected by Gould's indefatigable field collector, John Gilbert, on Leichhardt's first expedition in 1844–45. Gould's illustration of this specimen is in the foreground. Photo by Anthony Farr.

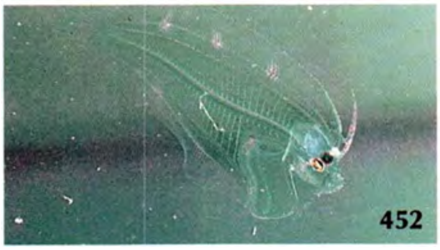
EDITORIAL Future Past

The commitment and dedication of our early explorers is something I admire. Many early mammal specimens, now residing in the Australian Museum's collection, are grim reminders that while the specimens returned to the settlements, often the explorers did not. Just what kind of dedication was it that ensured these specimens made it back? Turn to page 458 and take a step back in time to the hey-day of exploration.

Perhaps it is time we rekindled our interest in discovery. There are many thousands of as-yet-undiscovered species—to put it in perspective, we have 3.5 billion years of natural history to cover. That's the age for the earliest evidence for life on Earth—cyanobacteria that build strange, domed constructions called stromatolites. Fossil and living stromatolites are found in Western Australia (see the article on page 476).

Of the species that are known and studied, there is still much to learn. Take, for example, feral animals. Little is known about their movements, habits and the impact they have on the environment. Often ecological decisions regarding them are based on assumption, mainly because the information required simply is not available. But a breakthrough in research using satellite technology to track animals (p. 436) can provide all the data required quickly, efficiently, and, above all, accurately. The more we understand about our natural history, the more able we are to make sound decisions for the future.

—Fiona Doig, Editor




GERRY WHITMONT

Maatsuyker Island Lighthouse.

Lighten up!

The article on Maatsuyker Island lighthouse (ANH, vol. 22, no. 8) made particular mention of the campaign by local Tasmanian interests to retain lighthouse keepers on the island.

The commercial shipping industry does not require a manned presence on Maatsuyker Island and consequently the cost of maintaining a manned presence there is now borne by all Australian taxpayers. The total cost from financial year 1981–82 to 1986–87 has amounted to $1.64 million (Department of Transport annual reports). At 30 June 1988, the total cost will be close to $2 million.

Australian taxpayers may care to ask why the Tasmanian interests who wanted a manned presence on the Island have not borne the total cost of this manning.

—L. Bowen
Executive Director
Australian Chamber of Shipping

After considering evidence given by proponents from both sides of the manning–unmanning argument, the House of Representatives Standing Committee on Expenditure concluded that the interests of Australian taxpayers were being served by the continued manning of Maatsuyker Island, and of 32 other lightstations around the Australian coast. To quote, "the Committee is of the opinion that the benefits that derive from the human presence are greater than the cost savings of automation and unmanning" (Report from the House of Representatives Standing Committee on Expenditure, December 1983, 6.107).

The cost of running Maatsuyker Island Lightstation in 1986–87 cited in the Department of Transport's annual report was $318,000, less than one per cent of the total annual Australian lightstation budget.

Continued manning of Maatsuyker Island Lightstation is of considerable assistance to national interests including weather forecasting, coastal surveillance, search and rescue, and management of this World Heritage area.

The profitability of—and therefore amount of federal taxes paid by—groups such as professional fishermen and charter aircraft firms would be diminished by the absence of people on Maatsuyker Island to give detailed weather information.

Thus, by various means, the 'costs' of manning are repayed to Australian taxpayers.

—Deirdre Brown
Tasmanian Conservation Trust Inc.

Doublegees

In regard to Ralf Buckley's letter on the derivation of the plant name 'doublegees' (ANH, vol. 22, no. 8), I would like to quote a snippet from a magazine (of several years ago and whose name I have unfortunately forgotten). It is titled 'Nasty Plant':

"A terrible piece of work is the doublegee plant. An inspired English man brought it here from South Africa in 1830 to eat. The runners between the diabolically prickly seed pods taste a bit like spinach. The plant is called 'dub-beltgee-doorn' or 'Devil's thorn' in Afrikaans, hence the 'doublegee' Australianisation.

"In Western Australia it is known as doublegee, in South Australia it is 'three-cornered jack' and in other States the 'spiney emex', which is closest to its botanical name *Emex australis*."

There was also a yarn going round a few years ago about a couple of Australians who were trying to sell doublegees to Americans at Exmouth. Their spiel was that the horrible prickly things were Mountain Devils' eggs, cradled in cottonwool in a matchbox to be kept at a constant temperature. And only $20 a pair.

—Jack Edmonds
Denham, WA

Fostering Forest Fears

My attention has been drawn to Vincent Serventy's article "A Tall Story" (ANH, vol. 22, no. 7), which contains an error of fact as well as creating a number of misleading impressions.

Firstly, the name *Eucalyptus diversicolor* for the Karri tree was proposed by von Mueller to refer to the difference in shade of green between the upper and lower sides of the leaves and not, as stated by Serventy, to its mottled bark.

More importantly, however, Serventy later on in the article is endeavouring to foster fears that native forests are "under threat" from logging and woodchippers: "It is sad to realise that. . .clear-felling is threatening many magnifi-


B.A. AULD & R.W. MEDD

Emex australis, ***showing flowers and immature fruit.***

cent groves of tall trees"; "Surely the emphasis should be on maintaining forests as closely as possible to their natural state".

You will of course tell me that the opinions expressed are those of the author and not those of your journal; but editorially you should surely check that contributors get their facts right and do not indulge in propaganda. Serventy must be aware that World, National and State conservation strategies all provide for rational use of resources on a sustainable basis. Australia's native forests are a resource—a valuable, sustainable resource. They are controlled by university-trained foresters, people who know what they are doing and are dedicated to the principle of sustained yield. Serventy admits that groves of trees of outstanding quality are being held back from cutting where justified, and that the remainder after cutting is regenerated so that the forest renews itself. To claim for sentimental reasons that all our forests should be left untouched in a natural state does no good to the economy and ultimately no good to the forest itself or to the conservation movement.


WA PHOTO INDEX

Karri Tree.

—J.S. Beard
Forest Industries Environmental Advisory Committee, WA

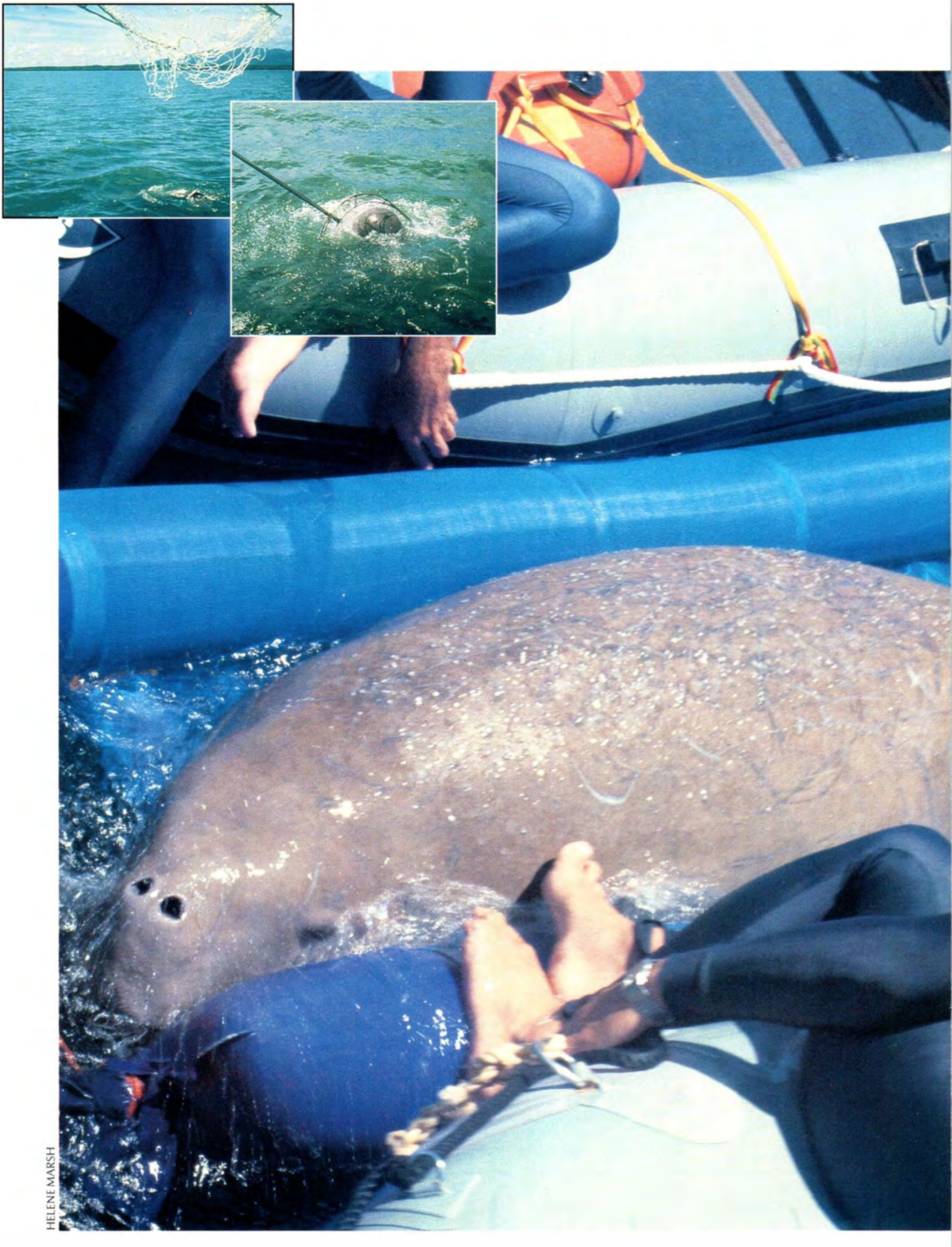
Scapegoats for Creation 'Science'

Why did Tim Flannery decide to make the Latter Day Saints scapegoats for the Creation 'science' theory? By his praising of editors Selkirk and Burrows for their "time and effort" to produce the book *Confronting Creationism: Defending Darwin*, I would have expected him to have presented a book review reflecting thoughtfulness and scholarship (ANH, vol. 22, no. 8).

Unfortunately, his selection of "the Church of Jesus Christ or Latter Day Saints [*sic*]", as the epitome of Creation 'science' is ridiculous. Creation 'science' is the doctrine of those who believe the Bible to be a fixed statement of everything that God has done. On that basis, any ultra-conservative Protestant group would have been a better example than the Latter Day Saint (LDS) church for his lampooning. The broader LDS concept of an 'Open Canon' of scripture allows for unlimited and continuing interpretations in many fields. Latter Day Saints believe that no person can declare final knowledge.

'Creationism' is the realm of those who isolate the Bible as the only authority, and who insist on its literal translation. Certainly, LDSs cannot be tagged as the protagonists in the Creation–Darwin debate.

—Ralph Ferrett
Port Macquarie, NSW



HELENE MARSH

A hoop-net is used to catch Dugongs so that a satellite tracking unit can be attached to their tails by a tether.

Satellite Tracking

A New Direction for Research

By FIONA DOIG and STEVE DYSON
AUSTRALIAN NATURAL HISTORY and CLS-ARGOS

Imagine future scientific research. A scientist in a Sydney office uses a computer to locate a camel in the Simpson Desert. Meanwhile, in Townsville, the movements of a Dugong in the Coral Sea are being monitored. Another researcher in Melbourne, this time studying sea-ice dynamics, locates the position of an ice-buoy in the Southern Ocean, finds out the air and water temperatures and plots the buoy's movements over the past few weeks. All locations are pinpointed to an accuracy of between 150 metres and one kilometre.

Not only is all this possible, it is happening now with the advent of satellite tracking. This is a major breakthrough for research where detailed and accurate location data are required.

What is Satellite Tracking?

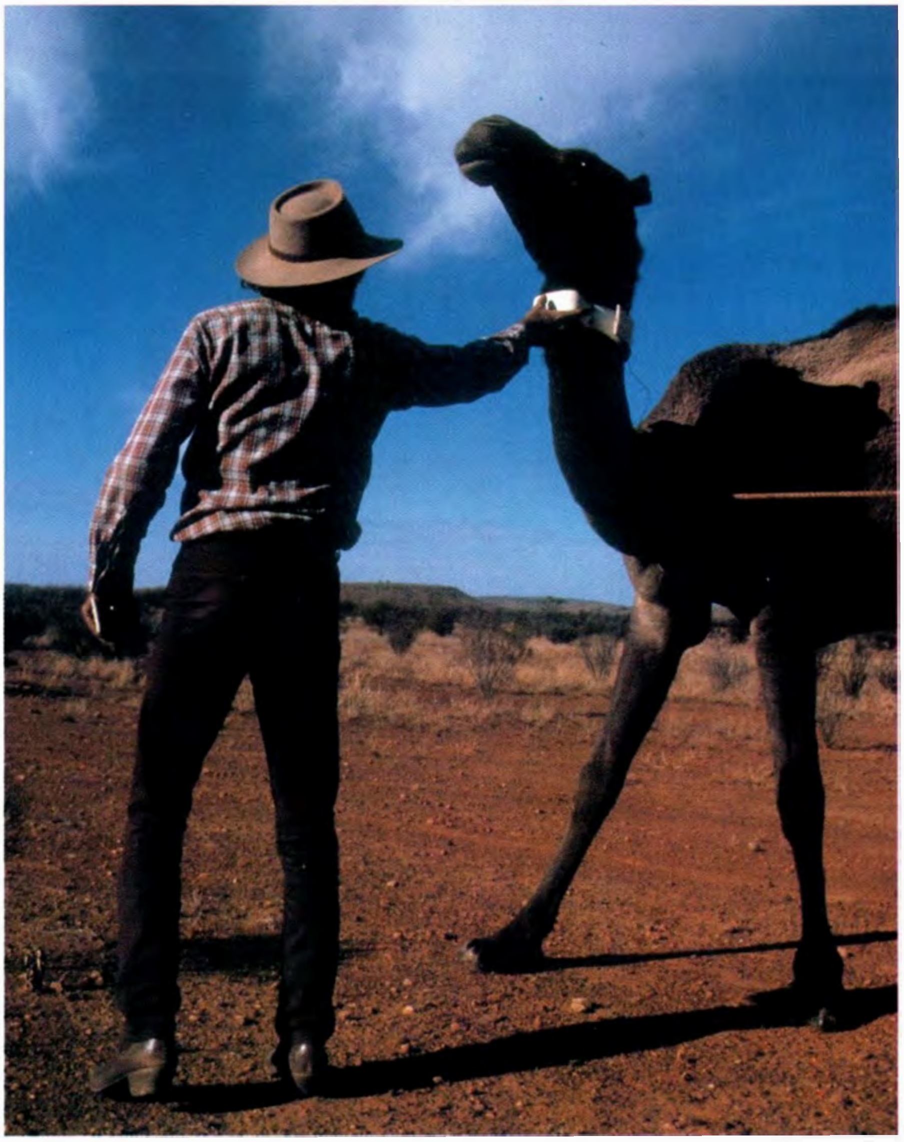
Satellite tracking is the monitoring of a transmitter via a spacecraft orbiting the Earth. The transmitter can be attached to a fixed or mobile platform transmitter terminal (PTT), such as a drifting buoy or a collar placed on an animal. The PTT emits signals that are received by the spacecraft. Signals are formatted and retransmitted to a ground station. Messages can then be relayed to a computer or telex.

CLS-Argos has established a satellite-tracking office in Melbourne for Australasian users. Apart from large-scale applications, like meteorology and ocean current tracking, other Australian environmental uses focus on animal tracking, particularly in remote and inaccessible areas. Such studies will significantly improve our understanding of the movements and behavioural patterns of particular species.

With the system employed by CLS-Argos, two spacecraft are simultaneously in service in polar, circular orbits at an altitude of 850 kilometres, providing full global coverage. At any given instant, each spacecraft picks up all PTT signals within a 2,500-kilometre radius. The daily number of times a satellite passes a location depends on latitude and varies between six and 28.

Conventional Tracking Methods

Dr Gordon Grigg of the University of Sydney, a satellite-tracking pioneer in Australia, first realised its potential in the mid 70s for studying kangaroo movements. He found conventional methods too labour intensive and often biased. In one method, kangaroos are tagged, then released. Shooters return collars for a reward, reporting the animal's location and time of shooting. While this method works well, the data are biased, coming only from areas where shooters operate. It has, however, shown that some kangaroos are



GORDON GRIGG

Gordon Grigg's team catching a camel to put on a satellite-transmitting collar. Professional camel catchers were used for this task.

MALCOLM RICKETTS

Satellite transmitting collar used for Gordon Grigg's camel tracking.

sedentary while others are not. Kangaroo movements have also been studied by radio tracking. Although effective, the area covered is limited (15–20 kilometres maximum, unless expensive aircraft tracking is used) so only reasonably sedentary species can be studied this way. Herein lies another potential bias: available data could be misinterpreted to mean that all kangaroos are sedentary!

But Gordon needed more accurate data. He has been tracking a couple of camels in the Simpson Desert as a pilot study for his kangaroo tracking research (see ANH vol. 22, no. 5). With satellite tracking, the study area is as large as the surface of the Earth. Once the animal is caught and the transmitter attached, tracking can operate continuously and data can be dialled up at any time using a modem-linked computer from a remote location, such as an office. Gordon jokes that one day someone will catch one of his camels and ship it to Saudi Arabia and the computer will show the camel going halfway across the world!

At first investigation, it may seem that the drawback is the high cost: transmitters are about $5,000 each and tracking works out at about $5,000 per animal per year. Then there are the costs to catch animals and attach and retrieve the collars. But it is not *more* expensive than conventional methods of obtaining the same data, where several research assistants plus vehicles (cars, aircraft or boats) have to follow the animals for the duration of the study period. What satellite tracking does, then, is bring previously out-of-reach studies into the realms of possibility—studies that would otherwise be too costly or labour intensive.

So what are the questions satellite tracking can answer? It can provide useful information for wildlife managers. For example, it has shown that camels do not move randomly and for long distances, as is commonly believed, but spend much of their time at the same place, moving intermittently. Feral camels are thought by some people to be pests, so it is important to know the extent of their movements.

Worldwide studies using satellite tracking include Humpback Whales off Newfoundland (movement, speed, depth and rate of diving); migration patterns of Atlantic Leatherback Turtles in France; population dynamics of African Elephants in Nambia; Ibexes in France; caribou in North America (migratory pathways); and tracking polar movements of the wide-ranging Polar Bear, all with the objective to obtain information useful for protecting animals in areas where conventional methods have been ineffective.

Saving Endangered Species

In Australia, satellite tracking is also used to monitor the movements of Dugongs (*Dugong dugon*), herbivorous marine mammals rated as 'vulnerable to extinction' by the International Union for the Conservation of Nature (IUCN). Some inshore seagrass beds in the Coral Sea, far northern Queensland, where large numbers of Dugongs have been seen on aerial surveys, have been given a high level of protection by the Great Barrier Reef Marine Park Authority. However, until Dr Helene Marsh from James Cook University, Townsville, tracked these animals by satellite, it was not known how much time Dugongs spent within and, in particular, outside these areas and if indeed the boundaries were broad enough.

As PTTs cannot transmit under

water, buoyant housings were attached by a three-metre tether to the Dugongs' tails. One study found that when the water temperature dropped by two degrees, the Dugong moved northwards up the coast, showing these creatures to be extremely sensitive to temperature variations, even in the tropics. Satellite tracking also showed that when Dugongs are not travelling between locations they are remarkably sedentary. Another male made several trips up a tidal creek. The implication is that, if Dugongs do indeed journey up tidal creeks, then the policy of banning gill-netting from the inshore areas and allowing it to continue in creeks is clearly inappropriate; offshore boundaries also need protection. Currently, six Dugongs, including three cows with calves, are being satellite-tracked in Moreton Bay near Brisbane, the southern limit of the Dugongs' range on the east coast.

Disease Control

Perhaps the most useful application for satellite tracking is in disease control and quarantine. It is vital to understand animal mobility in this regard. Imagine if, for example, a group of wild cattle was found to be a reserve for brucellosis. Add to this satellite tracking-studies that showed these animals to be very sedentary. The methods used to control an outbreak would be quite different had tracking studies indicated the cattle to be highly mobile. Such information is vital for applying boundaries to the quarantine areas and ascertaining in which areas stock might need to be destroyed to prevent the spread of disease. Satellite tracking is indeed the best and most accurate method for obtaining data useful for assessing disease propagation. Of course, other factors need to be included in the assessment, such as the nature of the disease and how rapidly it spreads.

Battery Blues

The use of satellite tracking for animal research is still in its infancy. One of the teething problems that needs to be ironed out is the failure rate and short life of the batteries. However, batteries are improving and ultimately solar-powered batteries will be used, as these recharge continuously. Battery life can be increased greatly by transmitting intermittently, say every two to three days for 15 hours.

Batteries are also bulky, making tracking of small animals unfeasible. Although the transmitter itself is only thumb-sized, battery life depends on battery size. To avoid interfering with the animal's natural behaviour, PTTs must not exceed three to five per cent of the subject's own weight. Special lightweight, solar-celled PTTs weighing 160 grams have been developed that can be used on large birds.

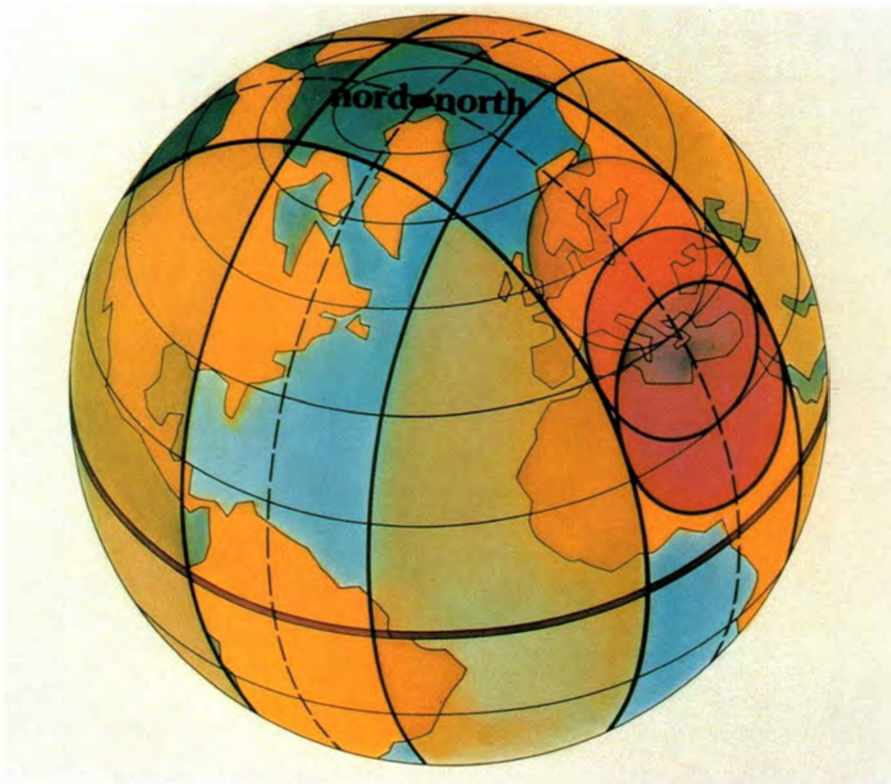
Environmental applications of satellite tracking do not end with animal studies. Many other areas benefit from use of satellite-tracking techniques. These include meteorology, hydrology, oceanography and volcanology.


IAN ALLISON

Typical ice conditions within the East Antarctic pack during late winter. The dark and grey areas are open water leads or very thin new ice. These are formed due to the constant motion of the pack-ice and have important implications in the exchange of heat between the ocean and atmosphere. The motion of the ice-pack is measured by ice-strengthened, satellite-tracked data buoys.

Sea-ice Dynamics

Sea-ice, in quantity and quality, determines the influences that the ocean and atmosphere have on each other. Variations in sea-ice extent



ARGOS

Two Argos-equipped spacecraft are simultaneously in polar, circular orbits. At any given instant, each spacecraft sees all PTTs within a 5,000-kilometre-diameter circle. On each orbital revolution, the visibility circle sweeps a 5,000-kilometre-wide swath around the Earth, encompassing the poles.

ARGOS

A satellite data collection platform at the Fly River, Papua New Guinea, is used to obtain river gradient and other data from this remote location.

are potential modifiers of both regional and global climate. The increase in total area covered by sea-ice from summer to winter in Antarctica is 20 million square kilometres and the extent of the ice (in the areas immediately south of Australia) can be up to 500 kilometres from the Antarctic coast.

Dr Ian Allison of the Antarctic Division uses 'ice-buoys' equipped with Argos transmitters to measure ocean and air temperatures, to track Antarctic ocean currents during the summer, and, later in the year when the buoys freeze into the sea-ice, to determine pack-ice movement. Even when totally ice-bound, the buoys can drift up to 80 kilometres in a single day. The processes controlling the autumn expansion of the ice edge are highly dynamic and include the northward transport of ice formed near the Antarctic coast. Knowledge of ice drift and understanding the processes controlling the extent of the pack are not only essential to determine the role of sea-ice in climate, but also provide valuable information for ship navigation in Antarctic seas.

The Antarctic Division also uses a network of eight automatic weather stations in the Antarctic interior to monitor weather and climate and to study the drainage wind system over the ice-sheet surface known as the katabàtic wind. The CLS-Argos system is particularly useful in Antarctica, not only because of the extreme remoteness, but also because at such high latitudes satellite data are collected almost every hour.

Hydrology Applications

Ian Johns' team, from the CSIRO Division of Water Resources Research, prepares and designs equipment to collect satellite-transmitted information from remote locations. They have developed and set up instrument platforms for a wide range of projects addressing typically Australian environmental problems. One tracking station, on the Fly River in Papua New Guinea, has been designed to receive information on the stream flow as part of an environmental monitoring program set up by the Ok Tedi mining company. Information relayed by satellite in this remote area will help assess the impact of mining on the environment.

The same team is assisting a State water authority in its efforts to set up a large network of automatically monitored stations (up to 200 in all) to generate alerts in the event of rapidly rising stream levels and floods. In such applications, the beauty is the short response time and the high reliability; telephone lines and other means of communication have a nasty habit of failing precisely when most needed.

Future Biological Applications

It is always important to know the extent of animals' movements, as important ecological decisions often need to be based on such information. For example, we need to know where our feral animals, such as foxes, donkeys, cats, rabbits, wild horses, buffalo and wild pigs, go before we can have any concept of what kind of effect they have on the environment. Many are considered serious pests but, until more accurate data on their movements are obtained, it is difficult to manage their populations. Satellite tracking can provide the data, both efficiently and economically.

In the future, animal transmitters could be made to relay more information than just movement data. A transmitter that can relay body temperature, heart rate and other vital signs could be implanted into an animal's body cavity. Many PTTs are already transmitting information additional to movement for hydrological, volcanological and meteorological research. Gordon Grigg is currently tracking Echidnas (*Tachyglossus aculeatus*) by radio and is already investigating this idea. With satellite tracking, he could be getting all that data in the office instead of having to go out on frequent field trips.

On a broad scale, satellite tracking can ascertain or repudiate some unconfirmed ideas that people have about animal movements. Often ecological decisions (such as culling quotas and farming policies) are based on such assumptions, only because there is no other information available. This, of course, can be disastrous. Take, for example, kangaroos. Many people assume that all kangaroos travel widely. Graziers who believe this naturally assume kangaroos won't stay on their properties for long and so are not worth farming. Others argue that kangaroos are sedentary. The only way either can be ascertained is by reliable population studies and rock solid data. Research using satellite tracking can provide this. ■

by A. RUS HOELZEL, Department of Genetics, Cambridge University

Saving Whales With Bows and Arrows

In 1972 American biologist Howard Winn first used a 'biopsy dart' to collect skin samples from humpback whales (*Megaptera* spp.). The dart is typically a metal cylinder sharpened at the leading edge and attached to a broad base-plate to prevent penetration below the blubber. By this technique, a small piece of skin and blubber could be removed without harming or restraining the whale. The dart is attached to the end of an arrow and fired from a bow. The sample is pulled out with the dart by inward facing barbs. Since Winn's initial study, biopsy samples have been collected from a number of species.

Biopsies have been collected for a variety of reasons. Winn and co-workers were trying to determine the sex of whales in their study population. At the time, histological techniques were used, but now karyotyping and other genetic techniques achieve more reliable results. Other researchers have collected biopsies to determine how environmental pollutants are affecting marine mammals.

Genetic techniques that were available in the past worked best with more tissue than a biopsy provides, and didn't offer sufficient resolution to provide detailed information on genetic structure within populations. Recent innovations, such as DNA 'fingerprinting', have changed all that.

I employ these techniques to assess kinship and population genetics of Killer Whales (*Orcinus orca*). Photographic studies (identifying individuals by characteristic markings) have provided us with a wealth of knowledge about Killer Whales and left us with some perplexing questions. For example, it is usual for social animals to leave their natal group at some point prior to sexual maturity. In mammals it is usually the young males that leave. The females remain where the food is predictable and abundant, and the males, when mature, attempt to defend a new group of females for mating. This kind of social system (polygeny) is especially common in species where the male is much larger than the female, such as the Killer Whale. An important part of this social system is that some new animals enter a reproductive group each generation. If not, the group will become inbred, which has been shown to have a devastating effect on fitness (the chance that their offspring will survive and reproduce) in many species. This movement from one social group to another is called 'dispersal'. The Killer Whales in the north-eastern Pacific live in small social groups, but apparently do not disperse. The question of how they breed is therefore very important to the understanding and conservation of genetic diversity in this species.

Another important question is raised by the existence of three apparently separate Killer Whale communities within a relatively small geographic area. It is usually assumed that populations within a given geographic area interbreed through dispersal. When conservation and management agencies make decisions about the impact of human activities on animal populations, an estimate of the effective size of the population is critical. For example, a number of marine mammal species become entangled in fishermen's nets and die. Governments try to regulate the 'take' in a way that is fair to the fishermen and at the same time maintains the threatened population at a viable level. The quotas they set are based on their estimation of population size, natural birth and mortality rates, and other factors affecting population stability. If there are three populations, for example, in an area where it could be assumed there is only one, the quotas will be three times too high. This is a real concern for Killer Whales, as several countries still allow live-capture for public display.

As exhaustive and useful as observational studies are, they will not answer important questions about kinship and population genetics. The only way is to obtain samples of tissue or blood. Traditionally this kind of sample has been collected by capturing or intentionally stranding live animals, or from animals killed during a commercial or 'scientific' catch. Killer Whales do occasionally strand naturally, but not frequently enough to provide sufficient data. We have been interested in conducting a genetic study for some time, but not through any of the available methods. The combination of biopsy sampling and modern molecular biology has now provided a benign way to conduct this work.

Recently Dr Bill Amos and myself, working with Dr Gabriel Dover at Cambridge University, United Kingdom, were employed by the International Whaling Commission (IWC) to conduct an investigation into the application of these techniques to management stocks of whales in the Antarctic. We applied DNA fingerprinting to fin whales and found (by extrapolation) that the existing world population could be individually identified by this method. This is important for two reasons. First, it eliminates the need to use abundance estimation methods that require killing the animal to recover tags. Second, it improves estimations because, unlike most methods, it guarantees the identification of all individuals sampled.

During the current moratorium on commercial whaling, several countries have proposed killing whales for scientific purposes. However, the information critical to the 'assessment' period during the moratorium can be determined from skin biopsies. My own experience, and the far more extensive experience of others, has shown that the biopsy sample is a very minor intrusion, no more than a scratch. Often a whale won't respond at all. For these reasons we have strongly recommended to the IWC that biopsy sampling be used as an alternative to 'scientific' whaling. The information acquired is essential to the long-term conservation of these species. To protect animals from the haphazard interference of human activity we must understand their behaviour and the natural division of the species into local populations. Without this information, traits that are important to the survival of the species over evolutionary time could be eliminated when local populations are disrupted or reduced too far to recover. We now have the technology to learn this information by collecting tiny samples of skin without killing or even harming individual whales. ■

A. RUS HOELZEL

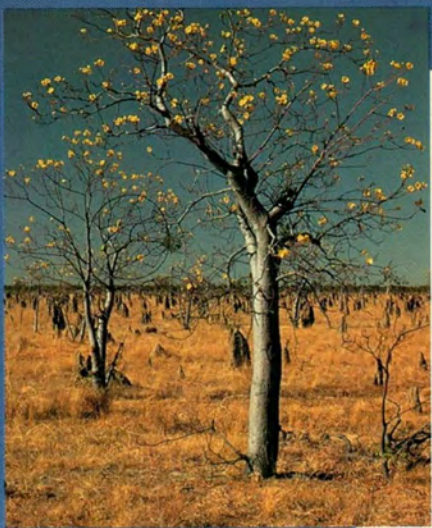
Many Killer Whales are caught for scientific purposes. A simple biopsy sample of their skin could provide all the information required without actually harming the whales.

DNA Fingerprinting

Recent advances in molecular genetics have made it possible to look at genetic differences between individuals in far greater detail, and with a better understanding of how differences were created. The new techniques are applied directly to the DNA molecules. The first step is to extract DNA from the tissue sample. Then a kind of enzyme called a 'restriction endonuclease' is used to cut the DNA in a predictable way into small segments. These segments are then run on a gel so that they assort by size. After lifting the DNA off the gel and up onto a 'filter', a technique is used that identifies only those segments that contain a certain sequence of nucleotides (the building blocks from which DNA is constructed). An English researcher, Alec Jeffreys, has identified a DNA sequence that varies so much in evolutionary time that all individuals in a population will show a different pattern of segments when examined for this sequence. He calls this a 'DNA fingerprint'. With this technique close kin can be identified and paternity can be determined with near certainty.

During the Late Monsoon season Sorghum undergoes a period of rapid growth.

PETER JARVER



HANS & JUDY BESTE/AUSCAPE

The bright yellow flowers of the Bush Kapok burst forth during the Cool Dry Season.

JEAN-PAUL FERRERO/AUSCAPE

HANS & JUDY BESTE

The Northern Green Tree Frog can be heard calling from tree hollows during the Early Storms Season.

TUNING IN TO THE SIX SEASONS OF THE WET-DRY TROPICS

By RICHARD BRAITHWAITE and JOHN ESTBERGS

DIVISION OF WILDLIFE AND ECOLOGY
CSIRO, DARWIN

Magpie Geese flock to drying waterholes during the Hot Dry Season.

Spring, summer autumn and winter are not recognisable in the tropics. Without the pronounced annual fluctuation in temperature of the temperate zone, the concepts simply do not fit. In the Top End of the Northern Territory the prevalence of rainfall dictates the seasonal pattern. Non-Aboriginal residents tend to divide the year into two or three seasons; the dry, the wet and sometimes the build-up. In contrast, the local Aboriginal people recognise six seasons. The start and finish of these seasons are imprecise in terms of our Gregorian calendar but they are precisely identified by the behaviour of particular species of animals and plants. Here we describe the six seasons in terms of characteristic sights, sounds and ▸

JOHNNY A. ESTBERGS

The Swamp Bloodwood, Eucalyptus ptychocarpa, flowers during the Late Monsoon season.

WA PHOTO INDEX

A male Frilled Lizard emerges from dry- season aestivation to breed in the Early Monsoon Season.

smells that the average resident or visitor would perceive. Although we present the six seasons as if of two months' duration each, in reality each season varies in length between years, just as the four temperate seasons do. The months nominated here for each of the six seasons are therefore only a generalised guide.

Early Storms Season

The annual cycle is most appropriately started with the first rains of a new wet season. The Early Storms of October–November are electrical thunderstorms that generally bring relatively little rain and are often very localised or uneven in distribution. At this 'build-up' time, winds are variable. They are most variable in the morning, often strongest and easterly to north-easterly in the afternoon, and northerly at night. The rain produces few puddles and these quickly evaporate, but the deep repetitive croak of the Northern Green Tree Frog (*Litoria caerulea*) can be heard resonating in the hollow branches of the eucalypts. Columns of Magpie Geese (*Anseranas semipalmata*) beat a rhythmic path across the twilight sky as they move from late dry-season refuges to newly available sources of vegetable food. For now the perennial grasses are putting out new shoots, and annual grasses like Sorghum (*Sorghum intrans*) are germinating. New leaves appear on the trees as they steal a march on the awakening insect community, which will consume much of the new growth produced later during the coming wet season. However, ants and termites begin to swarm. These social insects with their large, organised nests are ready to release their winged reproductive castes with the first storms. Biting tabanid flies are also frequently encountered, adding to the discomfort of the high humidity of this season. The first Green Plums (*Buchanania obovata*), more tart than tasty, appear at this time. The sweet purple berries of the Bush Currant (*Vitex glabrata*), purple 'plums' of Damson (*Terminalia sericocarpa*) and the arboreal 'peanuts' of Red-fruited Kurrajong (*Sterculia quadrifida*), also appear in the trees. The Little Curlew (*Numenius minutus*) arrives from its breeding grounds in Siberia and feeds on seeds and insects in the lawns of schools and football ovals in the Darwin area. Swifts (*Hirundapus caudacutus* and *Apus pacificus*) herald their arrival with victory rolls as they forage for small flying insects. Australian Pratincoles (*Stiltia isabella*) leave the margins of roads near wetlands and fly south. Male Frilled Lizards (*Chlamydosaurus kingii*) emerge from dry-season aestivation and silently flaunt themselves on roadsides as they seek to intimidate other males and attract females interested in mating. Big Barramundi (*Lates calcarifer*) move along the coast and down the rivers and into the estuaries. The Koel or Rainbird (*Eudynamys scolopacea*) persistently indicates its arrival from nearest Asia with its eerie mournful 'kooeel'. The Dollar Bird (*Eurystomus orientalis*) notes its return from New Guinea with harsh 'kak-kak-kak' calls and aerial displays of the distinctive white circles on the underside of its wings.

A storm during the build-up in Darwin.

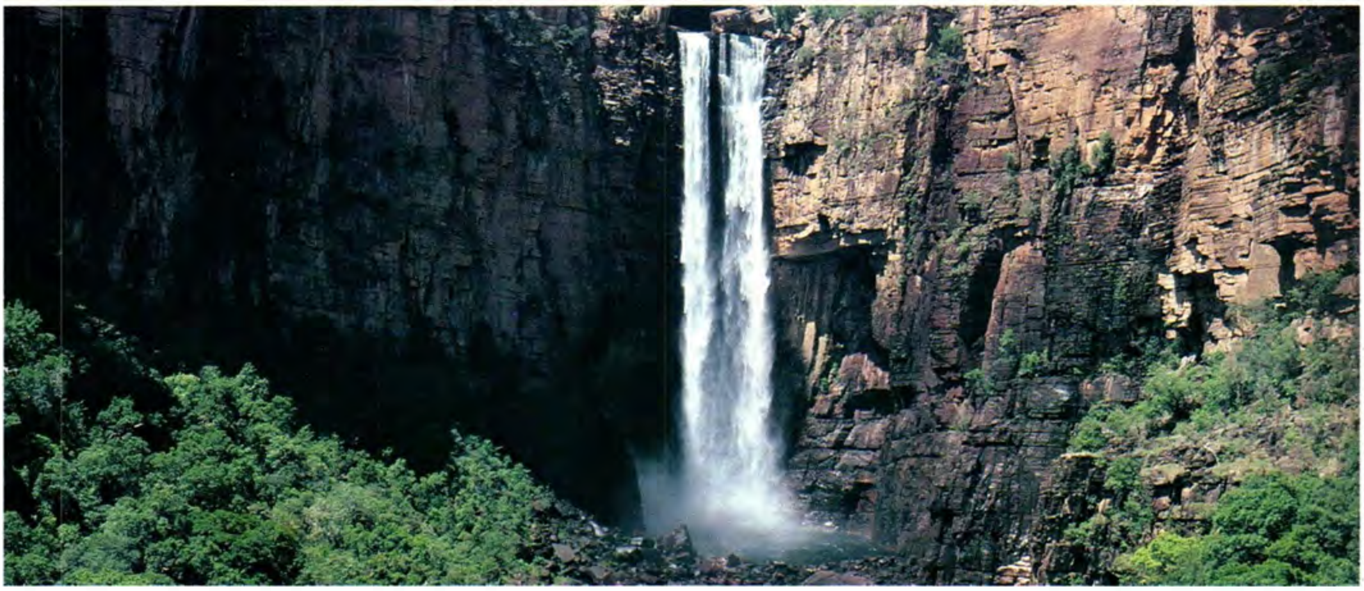
JOHNNY A. ESTBERGS

CYRIL WEBSTER/ANT PHOTO LIBRARY

Young Pheasant Coucals emerge during the Early Monsoon Season.

Early Monsoon Season

The Early Monsoon season of December–January can either be a very wet period with little thunder and lightning or, if the monsoonal trough does not move south until January, there may be relatively little rain. Winds can be southerly and easterly in the morning and evening, but they are rather variable and it is sometimes calm. If the monsoon has arrived, winds generally will be from the north-west. Young Sorghum sprouts are obvious everywhere in the forests and woodlands as if meticulously planted out by a diligent gardener. The Bush Grape (*Ampelocissus acetosa*) erupts from the ground like an instant pumpkin plant ready to trip the unwary walker. The young nymphs of grasshoppers are much in evidence. Ants, native rodents and snakes are forced from flood-prone underground homes and sometimes into people's dwellings. Bush Red-apples (*Syzygium suborbiculare*) and White Apples (*Syzygium eucalyptoides bleeseri*) are ripe for those who can find a tree in the wet forested areas near large rivers. Cocky Apples (*Planchonia careya*) are also ripe in the dry forests but are more palatable to parrots than humans. The descending and accelerating notes of the booming 'coop-coop-coop' of the displaying Pheasant Coucal (*Centropus phasianinus*) are more frequent at this time. Waterfowl and many passerines are also breeding. In the monsoon forest, the colourful Yellow Oriole (*Oriolus flavocinctus*) and Rainbow Pitta (*Pitta iris*) nest. Many Barramundi are moving up channels and into freshwater creeks;



RICHARD W. BRAITHWAITE

Jim Jim Falls in Kakadu National Park is in full flow during the Late Monsoon Season.

PETER JARVER/AUSCAPE

Spectacular storms and rainbows are common in the wet-dry tropics during the storm and monsoon seasons.* Pandanus spiralis *trees frame the foreground.

other landlocked ones use the high tides and increasing water levels to end their isolation. It is a good time for fishermen.

Late Monsoon Season

By the Late Monsoon season of February–March, periods of heavy rain are typical and the soil is frequently saturated. Rain often falls each day in the afternoon and occasionally all day. Cyclones occur most commonly in this season but have been recorded in all months from November to May. Local flash floods occur, sometimes cutting major roads for a few hours. Winds are most often from the west to north but can occur from any direction at any time of the day or night. A cacophony of frog breeding calls radiates from wetlands, both large and small. The 'honk-honking' of Magpie Geese emanates from the particular areas in the wetlands where they breed. The staccato calls of cicadas can be deafening in the forests and woodlands. In the wet forest, the sickly sweet smell of nectar from flowering paperbark trees (*Melaleuca* spp.) may often indicate their presence before they are actually seen. Billy Goat Plums (*Terminalia ferdinandiana*), the richest known source of vitamin C in the world, are abundantly available on their low-sprawling trees in the eucalypt forests. Dragonflies are common near water. Small biting midges and mosquitos are superabundant now and are drawn in vast numbers to any outside lighting. Red-winged Parrots (*Aprosmictus erythropterus*) flock in groups of up to 40 or 50 and produce a kaleidoscope of red and green as they appear to tumble through the canopy of the eucalypt forest. The pale blue of bush everlasting (*Borreria* spp.), dark maroon of bachelor's buttons (*Gomphrena* spp.) and deep red of Crimson Pimelia (*Pimelia humilis*) flowers decorate the ground.

The greatest spectacle of this season is the growth, flowering, seeding and senescence of the Sorghum. Each year at this time, as the rain falls, plants a few centimetres high shoot skywards to about two metres, although occasionally as high as five metres. Over the course of a month the elongating plants change from mid-green to light green and salmon pink and then develop rust-coloured streaks. The small purplish grass flowers yield clouds of pale pollen when the grass is disturbed by a traveller. Then for a few days the chocolate and caramel-coloured seedheads of the Sorghum lend a dark rusty hue to large parts of the previously lush green landscape. The mature seeds spear into and adhere to the clothing of the unlucky walker at this time. However, most seeds hit the ground where they wait until the next wet season. Soon after, the Sorghum starts to dry off, even before the rains have ceased.

Late Storms Season

The Late Storms of April–May are again often localised and frequently accompanied by strong winds. Apart from cyclones, these are the strongest winds of the year. The winds are most commonly easterly to south-easterly throughout the day and night. The strong winds often completely flatten small patches of Sorghum, particularly in the lower areas between the low ridges. The Sorghum quickly cures to a pale straw colour. The first fires rapidly follow but they are of low intensity and go out after a short time. The Black Kites (*Milvus migrans*) are now arriving from the arid interior in increasing numbers and give their whinnying calls as they soar. They are often seen on roadside carcasses doing battle with Whistling Kites (*Haliastur sphenurus*) for a share of the spoils. Spectacular sunsets are commonplace.

Although the dry season is returning, the landscape is saturated. There are tadpoles in all the pools. The blue of the waterlillies (*Nymphaea violacea*) decorates the wetlands as the young Magpie Geese scurry about. Agile Wallabies (*Macropus agilis*) feed on the green grasses at the edge of the wetlands. The perennial grasses along the creek lines are seeding prolifically. Harvester ants busily collect this seasonal abundance of fallen seed. Conspicuous piles of seed husks can be seen around the nest entrances. Beautiful little finches also feed on the seeds and continue to breed. Along the roads the vista is enlivened by splashes of yellow of the various flowering wattles. Barramundi use the flushes of water from the last storms to move upstream to their dry-season billabong homes.

Cool Dry Season

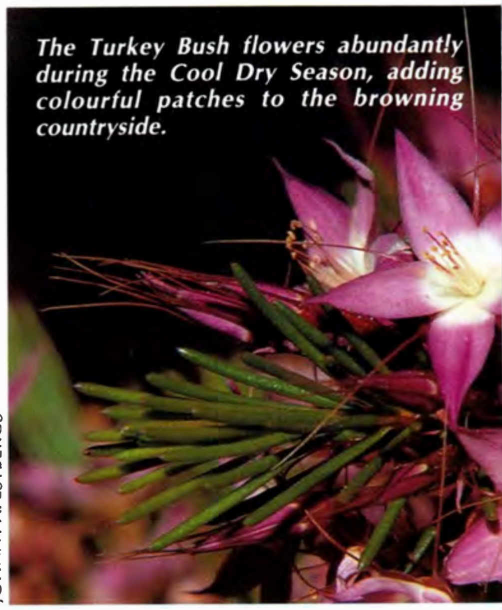
The Cool Dry season of June–July is marked by lower temperatures and lower humidity. Heavy dews occur at night and are often present in the early morning. Winds are consistently from the east and south-east. Fires that occur go out at night. Saltwater Crocodiles (*Crocodylus porosus*) bask in the sun during the mornings. Young Magpie Geese are free-flying by now. White-breasted Woodswallows (*Artamus leucorhynchus*) are seen high in the sky in the late afternoons. The penetrating trill of the Rainbow Bee-eater (*Merops ornatus*) can be heard throughout the day. A number of trees are completely deciduous at this time while others have a diminished canopy. Some of the deciduous trees flower now; the bright yellow of the Bush Kapok (*Cochlospermum fraseri*) is manifest. One of the dominant eucalypts, the Darwin Woollybut (*Eucalyptus miniata*), produces an orange display of colour in its well-leafed canopy. The purple–pink of the Turkey Bush (*Calytrix exstipulata*) is also a common sight. Along the still-moist land near the creeks many ephemeral herbs are in flower. The enchantment of such areas at this time is augmented by the strong aroma produced by walking on patches of the Aniseed herb *Lindernia plantaginea*.

The penetrating trill of the Rainbow Bee-eater can be heard throughout the Cool Dry Season.

HANS & JUDY BESTE/AUSCAPE

M & I MORCOMBE

A fledgling Boobook Owl emerges in its fluffy down during the Hot Dry Season.



The Turkey Bush flowers abundantly during the Cool Dry Season, adding colourful patches to the browning countryside.

JOHNNY A. ESTBERGS

JOHN BROCK

Cottonwool-like fibres escape from the drying seed pods of the Bush Kapok during the Hot Dry Season.

Hot Dry Season

The Hot Dry season of August–September is generally without rain, but the temperature and humidity abruptly increase in this first phase of the build-up to the next wet season. Winds are mainly from the south-east to north-east. Dust, smoke and haze characterise the view. The fires that occur now are of very high intensity, travel rapidly, burn the ground vegetation completely and can continue for weeks or months, covering hundreds of square kilometres. Black Kites and Brown Falcons (*Falco berigora*) are frequently in attendance at fires, hunting small, fleeing animals. Waterholes are drying up, forcing Magpie Geese, herons, ducks, egrets, Jabiru (*Xenorhynchus asiaticus*) and other waterbirds to aggregate in spectacularly large numbers at the remaining water. In the years that this season continues for longer than usual, many animals die. Freshwater Crocodiles (*Crocodylus johnstoni*), however, are laying their eggs in dry sandy creek banks. When camping near water, one hears many breeding owls calling, both the 'wook-wook' of the Barking Owl (*Ninox connivens*) and the 'more-pork' of the Boobook Owl (*Ninox boobook*).

White, downy fibres tumble from the seed pods of the Bush Kapok. The large globular fruits of the Pandanus (*Pandanus spiralis*) turn from green to orange–red. The magnificent orange flowers of the Silky Grevillea (*Grevillea pteridifolia*) drip with nectar and attract honeyeaters, lorikeets and cockatoos. Large red flowers adorn the deciduous Kapok tree (*Bombax ceiba*) on river levees and in monsoon forests.

Seasonal Cycles

These six seasons expand and contract from year to year, for there are no 'normal' years. Although the rains come each year, the variation in amount and distribution within and between years is enormous. The minimum and maximum rainfall records for Darwin for 117 years are 892 and 2,644 millimetres respectively. This means there are often unusual climatic patterns that have a big impact on biological features of the region. We have avoided mentioning these less usual events, concentrating instead on the things that happen each year at the same time and can be used as seasonal indicators.

In European society, the annual cycle of seasons is one of the first big concepts we are taught. It is a mental structure that we use to help define much of our lifestyle. It is so fundamental we take it for granted. Over millennia, the Aboriginal people of the wet–dry tropics have developed a finely tuned calendar of six seasons. Most people who come to the wet–dry tropics are out of tune with its seasonal rhythm. But, just as the four seasons of the temperate zone are perceived through the responses of the plants and animals to that climate, so observation of the very different environment of northern Australia can help us tune in to its six seasons and to form bonds of attachment to this special and distinctive land. ■

Maybe Bats Ain't Bats

All terrestrial vertebrate classes include some species capable of aerial travel. Amphibians, reptiles and mammals are all represented by some gliding species, but only in birds and mammals does true flight occur. All the flying mammals—the bats—are placed in the order Chiroptera. Whether this placement is correct is the question raised by J.D. Pettigrew and B.G.M. Jamieson, both from the University of Queensland (*Science* 231: 1304–6, 1986; *Aust. Mamm.* 10: 119–24, 1987).

The history of bat placement is less than placid, so this question is not new. Linnaeus, in the tenth edition of *Systema Naturae* (1758), included bats in the order Primates (along with monkeys and apes) because of the pendulous penis and pectoral location of the mammae! In the twelfth edition he retained some with the Primates, while including others in 'Glires' (with rabbits and rodents). Other workers shuffled them between the primates, carnivores, insectivores and various permutations of each. Not until over a century later, in 1878, were flying mammals united in a single order, the Chiroptera. Two natural subgroups were perceived: the suborders Megachiroptera and Microchiroptera. The former encompassed the larger, fruit-eating bats or flying foxes; the latter comprised the smaller, insect-eating bats.

What Pettigrew and Jamieson's recent work questions is whether these two groupings are indeed branches on the *same* phylogenetic (evolutionary) line. Although both fly, are nocturnal and superficially resemble each other, the most obvious strong link between them is the apparent structure of the hand-wing. The membranous flight surfaces in both groups are supported by increases in the size and strength of the upper arm (humerus), the forearm (primarily the radius) and digits II to V in the hand. Differences between the two groups, however, abound. Apart from dietary preferences, there are differences in the structure of the ear, nose, skull, teeth and tail, extent of flight membrane between the hind legs, number of claws on the hand, ability to hibernate or undergo torpor, internal anatomy, physiology and distribution.

In a routine investigation, Pettigrew and Jamieson compared the pattern of visual pathways between the midbrain and the retina of the eye in representatives of the two chiropteran suborders. To their surprise, they found that megachiropterans have an advanced pattern of nerve connections—a condition found only in primates—and that microchiropterans have a primitive pattern found so far in all mammals except primates. These results suggest that megachiropterans and primates are more closely linked than microchiropterans are with megachiropterans.

The essence of the question of relationships posed by the findings of Pettigrew and Jamieson is this: did the same complex optic tracts between the midbrain and the eye evolve independently (that is twice), once in the primates and once in the megachiropterans; or did the enormously complicated and interlocking adaptations for flight evolve independently, once in the megachiropterans and once in the microchiropterans? Pettigrew and Jamieson suggest that flight evolved twice, a view not likely to find complete support throughout the community of chiroptologists.

What do I think of the issue? Well, the union of megachiropterans and microchiropterans in the order Chiroptera has never been quite easy. If all the available information were brought together, I believe a reasonably solid case (built on differences, not similarities!) can be made for two separate orders: the Chiroptera (microchiropterans only) and one for the megachiropterans. This is not a new view. Such rank has been accorded them on less evidence in the past. Hopefully, the work of Pettigrew and Jamieson will stimulate further studies in comparative anatomy and comparative embryology—old games with new players. Much remains to be learned and there is no rush to alter the books. But what a marvellous opportunity for Australian chiroptologists—both mega- and microchiropterans are readily available here for study!

—Dan Walton
ABRS, ACT

KATHIE ATKINSON

Could flying foxes be primates? New research on the 'megabats', like this Grey-headed Flying Fox (**Pteropus poliocephalus*****) may indicate that we are more closely related to these bats than previously thought.***

Rats, Ratcatchers and Ratbags

The Australasian region is home to a number of species of giant rats. The largest species, which belong in the genus *Mallomys*, are restricted to the highlands of New Guinea. The scientists and explorers associated with the discovery and description of these rats form a most interesting group in themselves. Their contribution to 'giant ratology' makes an intriguing study.

The recent discovery of the largest of all living murids (rats and mice) has added a new facet to this study. Although still unnamed (the work is in the process of publication), the first specimen to be made known to science was caught in the Mt Hagen district of New Guinea in 1945 by the almost legendary *Kiap* (government officer) Captain Neptune B. Blood. Known as the 'King of the Western Highlands' for his style of administration, Blood was operating on the frontier of the Australian Territory, attempting to extend the Australian Government's control even before World War 2 had ended. Despite the tremendous difficulties that he must have faced, Blood still had time to send interesting natural history specimens to the Australian Museum. Among these was a bird of paradise and a fish, which have been named after him, and the giant rat. The rat, however, through sheer oversight, waited 42 years in the bowels of the Museum before it was recognised as the world's largest. It too might be permanently linked with Blood's name. Blood, unfortunately, is now dead but Olga, his wife, is still living.

Another case involves the first-named species of *Mallomys, M. rothschildi.* Described in 1898, it was named for the Honourable Lord Walter Rothschild. Rothschild must have been one of the most unusual men of his generation, perhaps truly deserving the epithet 'English eccentric'. A Jew, born into one of the most wealthy banking families in the world, Walter chose to turn his back on this vast inherited enterprise and built instead the world's largest and finest privately owned natural history collection. So unconcerned was he with the comfort that wealth could bring that this 180-centimetre-or-more man (nearly six feet tall) slept in the same miniature bedroom in the nursery wing of the family mansion all his life. Unable to speak except in a bellow or whisper (he had a speech defect), one can only imagine what the growing hordes of young Rothschilds made of 'Uncle Walter'! When visiting the British Museum, Lord Rothschild drove a carriage pulled by three zebras and a horse, and, when walking across the road to that venerable institution, never raised his head, the traffic policeman respectfully halting all traffic until the Lord had passed. Despite his personal eccentricities, Rothschild achieved much during his life. He was Signatory to the Balfour Declaration, which initiated the modern state of Israel, and his collections became a major research tool. His greatest tragedy was the forced sale of his beloved bird collection due to the avaricious blackmail of a duchess, one of his many lovers. Terrified that the shock of his indiscretion may harm his aged mother, he parted with his most loved possession to pay the ransom.

The final name that bears mention in relation to these most unusual rats is that of a most unusual Reverend, Charles De Vis (or Devis, depending upon whom you believe), who often published under the name Thickthorn. He described many new species in his characteristically flamboyant style, several of which turned out to be already named (synonyms). By the time he came to describe his giant rat from New Guinea, De Vis (through often vitriolic criticism) had become rather cautious. His description finishes "...I feel hardly justified in running the risk of perpetrating a synonym, otherwise I should propose for it the name *Dendrosminthus aroaensis...*". However, De Vis' earlier works are devoid of this 'bet each way' mentality. He named the teeth of a kangaroo as those of a giant extinct hog from Queensland. A pardalote egg (which remained unhatched in an old burrow) was taken as a fossil by the Reverend, who surmised that in some distant period a bird must have had "an involuntary ovation" as it flew over the clay that was destined to become the "fossil bed". Indeed, unfortunately for future researchers, the only information that De Vis gives about where many of his fossils came from is "a gathering place enriched by agencies of unusual range and efficacy". When he finally left the Queensland Museum early in the present century, zoologists the world over must have given an involuntary ovation, or at least a sigh of relief. And yet he was right about his giant rat.

—*Tim Flannery*
Australian Museum

Walter Rothschild with his zebra-drawn carriage.

ROY D. MACKAY/ANT PHOTO LIBRARY

The Black-eared Giant Rat (*Mallomys rothschildi*) is one of New Guinea's largest living rodents.

The Odd Life of Larval Fish

By JEFFREY M. LEIS
THE AUSTRALIAN MUSEUM

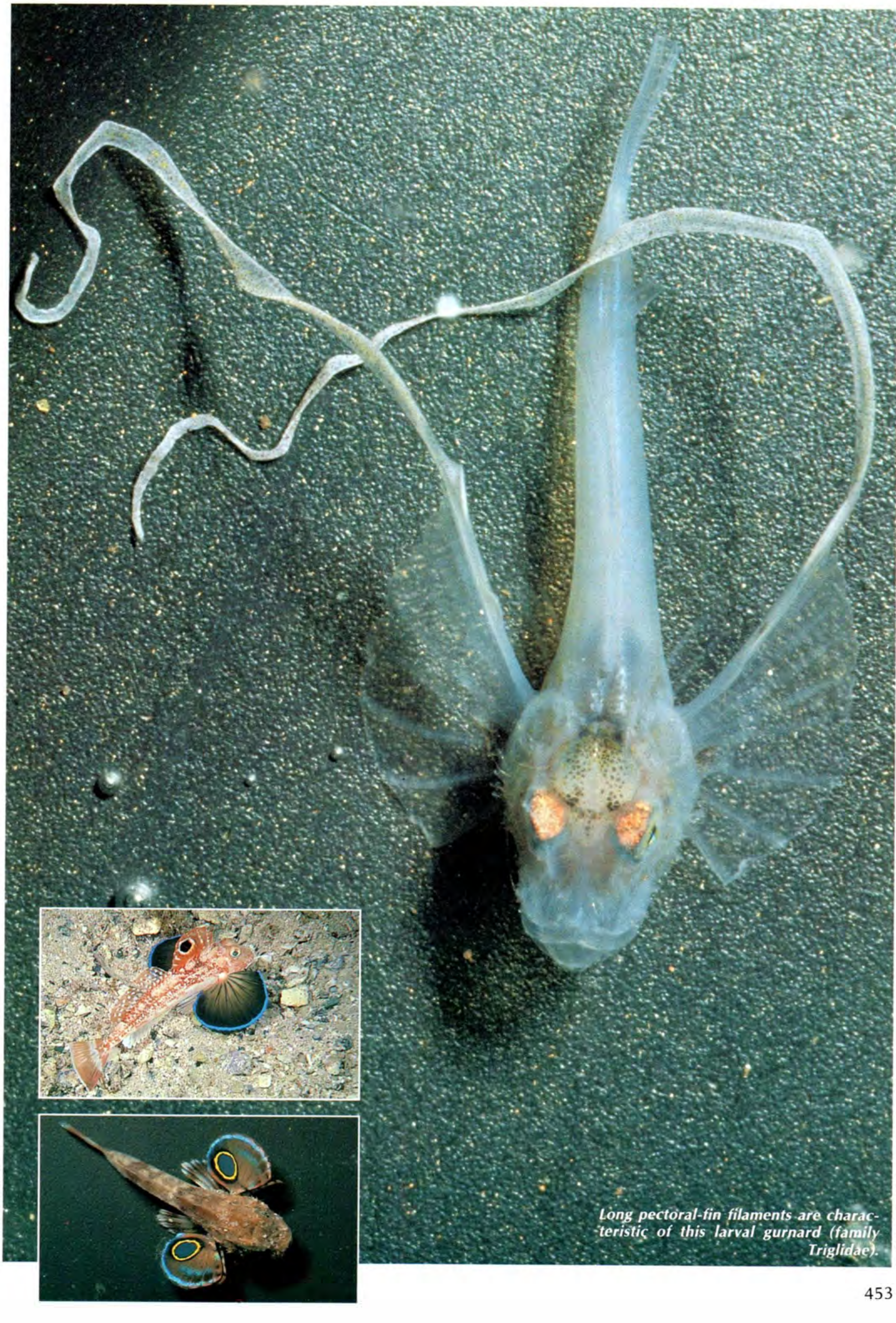
Nothing could be more different from the complex, colourful, highly three-dimensional world of the coral reef teeming with thousands of species packed closely together, than the dilute, featureless, monochrome blue of the open-water (pelagic) environment. Could any animal be perfectly adapted to both these extremes? Oddly enough, the answer is yes—because most animals that live on coral reefs inhabit both at different times of their lives. Even stranger is the fact that the form of the early pelagic life-history stages of these reef animals is extraordinarily different from the reef-bound adult animals; so different, in fact, that these larvae have confused generations of taxonomists (scientists whose speciality is identifying animals and working out their relationships).

We'll focus on fish here, for more is known about their pelagic stages than other reef animals. However, as knowledge of reef species is limited, non-reef species will often be used as examples. Nearly all bony fishes of coral reefs have a pelagic larval phase. For reasons not yet clear to scientists, the eggs and young of these fishes are pitched off the reef into the pelagic environment. There they spend days or even months before making their way back to a reef to settle, metamorphose and adopt a more sedentary adult mode of life. During this pelagic interlude, the larvae eat different types of food, have entirely different behavioural patterns and, most interestingly, do not look a bit like their adult phase. To all but a genetic definition, they appear to be different species. This has fooled many an ichthyologist (a scientist who studies fishes), and many larval reef fishes have wrongly been declared as species or even families new to science. Larval fish biologists are even today unravelling such mistakes.

How do larvae differ from adults? Well, such is their diversity that an overall, simple statement cannot be made. However, for the most part, larvae have relatively bigger eyes and larger heads, differ in other body proportions, are largely transparent, are armed with head spines absent in adults and, not infrequently, have the spines of their fins modified into weird and wonderful streamers or ornamented, barbed, spear-like structures. In their own way, they differ as much from the adult as does a caterpillar from a butterfly. Some of these differences are merely intermediate steps on the morphological path to adult specialisations. For example, larval flatfishes (order Pleuronectiformes) resemble most fishes in having one eye on each side of the head, but they metamorphose into the familiar adult flounder or sole, which has both eyes on the same side (right or left depending on the family). However, most of the differences are adaptations of the larvae to the pelagic environment. Some of the larval structures have no adult counterpart, but most are modifications of structures found in the adult fish (such as the highly ornamented spines of the fins) or precursors of them.

Unfortunately, we know relatively little of the functions of such amazing morphological disparities. Transparency may well be the most effective means of concealment in the featureless pelagic environment.

The triglid* Lepidotrigla papilo *in its adult form (top) and juvenile settling colours (bottom).



Long pectoral-fin filaments are characteristic of this larval gurnard (family Triglidae).

RUDIE H. KUITER

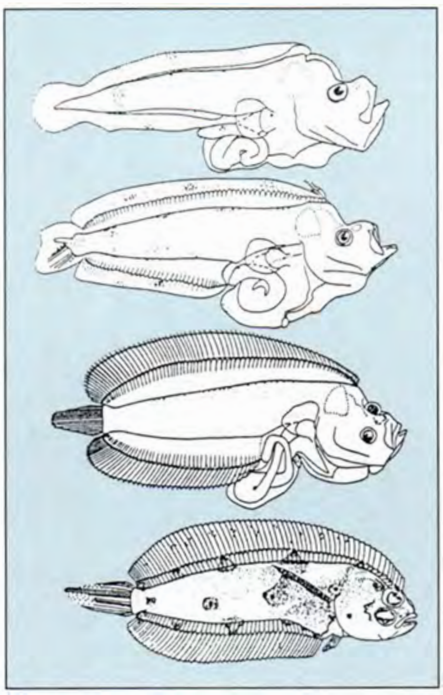
RUDIE H. KUITER

But I have seen a white larval sole (family Soleidae) at the surface, mimicking a patch of foam. Only when it swam against the wind and the real foam patch did it give itself away. While most larvae are crystalline-clear, a few are heavily pigmented. Some larvae are silver at the sides and dark blue above in the classic, beautiful countershading of adult pelagic fishes. Most of these heavily pigmented larvae (such as the long toms, family Belonidae, and the goatfishes, family Mullidae) live at the interface of the water and atmosphere where the pigment, in addition to providing camouflage, provides protection from ultraviolet radiation. Other larvae have a delicate red or yellow hue, such as the cardinal fishes (family Apogonidae). Most larvae have some limited areas pigmented with melanin (the same dark pigment that gives humans their range of skin colours) and scattered small dots of pigment (chromatophores) of yellow and red. If the transparency of the body is an attempt at camouflage, these bright colours would seem to be counterproductive.

The elongate, ornamented spines of some larval coral cods (*Cephalopholis* spp.) are probably a means of making them much bigger and less palatable mouthfuls, thus removing the threat of many small predators. But how do they manage to swim with all that baggage, and why do some members of the same family have equally huge but smooth spines? The spiny head armour of the Striped Scat (*Selenotoca multifasciata*) may protect the head but leaves the rest of the body unprotected, and a head without a body isn't much use. The pelagic adult Ocean Sunfish (*Ranzania laevis*), although not a reef fish, is one of the most bizarre of fishes, and its larvae are even more strangely adapted for life in the ocean. The body of an Ocean Sunfish larvae is covered with large, ornamented, transparent, pyramidal spines that have no counterpart in adults. Here again, protection from predation is probably involved. But the spines of some larval fish serve no obvious purpose. The relatively small head spines of the Black-banded Kingfish (*Seriolina nigrofasciata*), for example, seem too small and weak to offer any protection.

Perhaps the most curious specialisations are the frilled, trailing guts of larvae tentatively identified as deep-sea brotula (subfamily Neobythitinae), and the extremely long, plumed fin ray of pearl fish larvae (family Carapidae). Some ichthyologists speculate that these fantastic appendages mimic a siphonophore (a deep-sea coelenterate) or some other oceanic jelly with stinging tentacles.

RUDIE H. KUITER



The left eye of this right-handed flounder (family Pleuronectidae) moves across the head to join the right eye. Once this process is complete, the dorsal fin slides forward over the eye. The larvae in this developmental series, from top to bottom, are 3.6, 6.8, 10 and 10.3 millimetres long.

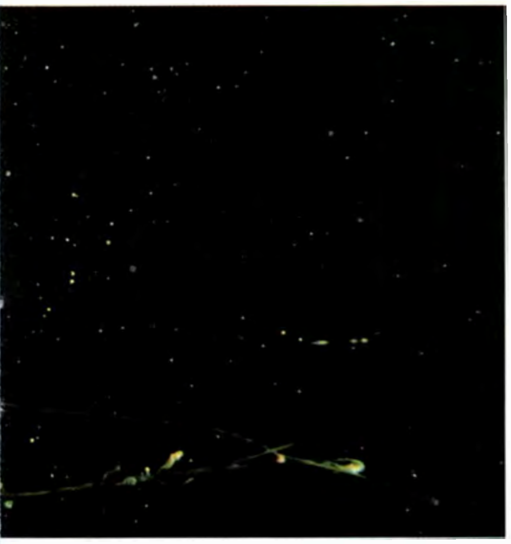
Two very different life histories are found in left-handed flounders (family Bothidae). The transparent larvae live near the water's surface and, at this stage, are bilaterally symmetrical. The adults live on the sandy bottom, camouflaged by elaborate pigment patterns, with both eyes on the left-hand side.

RUDIE H. KUITER

RUDIE H. KUITER

While little is know about the reasons for the morphological specialisations of fish larvae, even less is known about their behaviour in the ocean. Most observations have been made in the laboratory; still, these indicate that fish larvae have a wide range of intriguing behavioural traits. Larval Hawaiian Anchovy (*Encrasicholina purpurea*) approach their prey cautiously, flex their bodies into an 'S'-shape, and suddenly spring, snake-like, at their intended meal. Initially they often miss and, given their small reserves of yolk, many probably starve before they learn how to feed properly. Larval California Jack Mackerel (*Trachurus symmetricus*) only bend their bodies into a 'C'-shape and are generally more successful at initial feeding attempts than the Hawaiian Anchovy. At least one type of larval wrasse (the Atlantic Hogfish, *Lachnolaimus maximus*) spins itself a mucus cocoon in which to sleep at night while in its pelagic environment. Dr Pat Colin of Florida State University has also observed that larval jawfishes (family Opistognathidae) settle to the bottom in shallow water while still very small, and immediately start to construct burrows, excavating grains of sand nearly as large as themselves, before they fully metamorphose.

How the larvae find their way back to a reef from the pelagic environment is largely unknown. By the time larvae are ready to settle onto a reef, they are anywhere from ten to 200 millimetres long, depend-

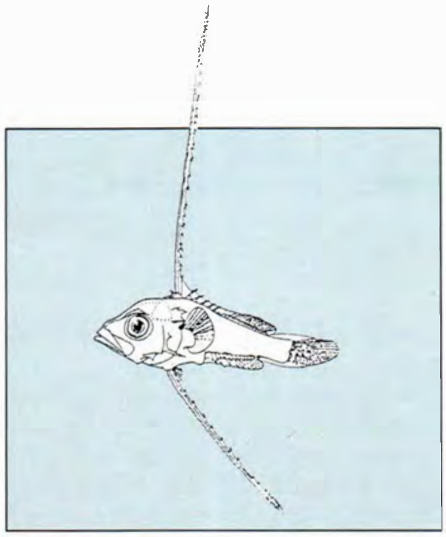


This juvenile ribbonfish (family Trachipteridae) has long spines and is extremely brightly coloured.

ing on species. At such sizes they are reasonably competent swimmers, but how do they know which way to go? The nostrils, eyes, auditory apparatus and vibration sensors of fish larvae form soon after hatching, and appear to be well developed and functional from an early age. Larvae, therefore, are probably as sensory-capable as the adults. But it is unlikely they see their way back, for visibility in seawater is less than 60 metres even in the best conditions. Perhaps they can smell the reef? Or hear it—the snapping of shrimps, the coral-scraping of parrotfishes, or the breaking of waves?

A number of types of larvae (such as triplefin blennies, family Trypterygiidae) do not move far from the reef where they were spawned so that, when they are ready to settle, they don't have far to go. However, most larvae can be anywhere from a few to hundreds of kilometres away from a reef when ready to settle. They have a difficult trip back to the reef, if they make it at all; many never do. Every summer thousands of reef fish larvae inadvertently catch a ride on the East Australian Current from the Great Barrier Reef to the New South Wales coast as far south as Eden. They settle onto the rocky reefs and temporarily brighten the scene. But they are poorly adapted to New South Wales reefs and few survive the winter.

What happens to the larvae that are successful in returning to a reef? Here new dangers and problems await. The larvae must make their way through a wall of hungry



D.R. ROBERTSON

The larvae of rock cods and coral cods* (Cephalopholis *spp.*) *have enormously enlarged, serrated spines, which are much longer than this six-millimetre larva. These spines are resorbed to become 'normal', shortened adult finspines.

mouths, ranging from corals to large fishes. Then, suitable places to live must be found—suitable by juvenile standards, for example, some coral reef fishes are highly specialised and will live only among the branches of one particular species of coral. Then the larvae, which are so magnificently adapted for the pelagic environment, must change into another type of animal—one that is adapted for living on a coral reef. A jack of all trades will not do—a specialist is required. Some species begin the change while still pelagic but most change once they have settled on the reef. This change (called metamorphosis) involves loss of larval specialisations, a change in colour, often a change in body shape and, frequently, changes to all parts of the body involved in feeding because the foods of the reef are different from those of the pelagic realm. For example, parrotfishes (family Scaridae) eat animal plankton at the larval stage but scrape algae off coral as adults: this change in feeding involves a complete change in dentition and also a change from a short gut specialised for the digestion of animal matter to a long gut specialised for the digestion of plant matter. How these changes are accomplished is unknown. But the fact that larvae in the process of metamorphosis are rarely seen is an indication

Moving Larval Bits

One of the strangest aspects of larval development is the movement of parts of the body. The dorsal fin of anchovies and their relatives initially forms near the tail. When the larva is about 12 millimetres long, the fin, complete with all its rays, begins to move towards the head. It stops at around the middle of the back when the larva is about 20 millimetres long. At the same time, the gut becomes shorter, and the anus, which was initially located more than 90 per cent of the way along the body, comes to rest at only 60 per cent. The anal fin stretches to fill in the gap left by the retreating anus. In other types of larvae, fins may move in one way or another; a moving anus is also common, although it more often moves posteriorly than anteriorly.

In larval flatfishes, one eye moves to join the other on one side of the head. The eye may move through a hole in the head that opens to allow its passage and then closes behind it. Or, it may simply glide over the top of the head. In either case, it remains attached to the brain by the optic nerve. Eyes that move are found only in the eight families of flatfishes.

The means by which these movements are accomplished are among the many aspects of larval fish biology that are unknown.

of how fast this occurs. Of course, it must be fast, for to be half-adapted to an environment would be dangerous.

The fish is now a small juvenile on the reef. It has survived a former life in open water, a life that was terminal for 99.9 per cent of its siblings. It faces a juvenile existence on the reef in which it has probably a ten per cent chance of surviving to adulthood. Once an adult, it can at last fulfill the role that began when it was pitched off the reef into the pelagic environment as a tiny egg or larva: to spawn and pitch yet another batch into that blue, pelagic environment so different from the reef. ■

ROBYN WILLIAMS

The Unfitness of Fat

As a child I could never fathom why the ideal of female beauty seemed to be fat. Sessile, podgy, ripples of dimpled thigh and tum, the women of Rubens filled the huge canvases like monuments of lard. Even the Venus of Milo—classical sculpture of Aphrodite—looked hefty. As for the Venus of Willendorf, from the stone age, she actually approached the spherical.

Why this standard of beauty? Why not the athletic, active model I preferred (and still do)? Well, the answer appears to be fertility. For hundreds, probably thousands of years, adequate size has been associated with a woman's ability to procreate. Thinness, even an unremarkable leanness, has been linked vaguely to infertility. Now, Professor Rose Frisch of the Harvard School of Public Health, and her colleagues, have worked out the details of how this is so.

Frisch has shown that there is a clear association between female body weight and the production of an oestrogen (sex hormone) that is less potent than the common oestrogens. The conversion to a less active form occurs more readily in thin women than in fat women. The female body, you see, needs certain reserves of fat for the full reproductive capacities to be released. (This is presumably why 25 per cent of a woman's body weight is fatty tissue, compared to only 12–15 per cent for a man.) A baby requires 210,000–335,000 kilojoules to grow to term in the womb; and another 2,000–4,000 per day are required by the mother to produce milk for it. If the woman does not have the stores to tackle that long burden, then her body switches off the hormonal systems that enable her to conceive in the first place. Frisch has published tables of height-to-weight ratios, which can be used as a guide for those wishing to adjust their own fertility.

Frisch and her colleagues have just finished a study of about 5,000 college women, comparing those who were athletic with those who were not. Athletes, as expected, had had a later menarche (the age at which periods start; 15 instead of 12), and then often missed periods altogether. A certain body weight is necessary for the onset of menstruation and hence fertility. What was startling about this study, however, was that the lean girls later in life had *less than half* the amount of breast and cervical cancers as did their more slothful sisters.

I attended the press conference in Boston, Massachussetts, when Frisch announced these results. She was flanked by Professor Jack Fishman from Rockefeller University, New York, who explained how they had deduced the physiology of this fertility control. It is mediated via the hypothalamus in the brain when a certain critical leanness is reached, and results in the production of an enzyme that changes the hormone to a different, 'low-potency' kind of oestrogen. Dr Rachel Snow, also of the Harvard School of Public Health, followed up this research with oarswomen to see whether *their* oestrogen was changed by intense training. The results bore out Fishman's theses—a low-potency oestrogen was being produced.

What should we make of all this? Firstly, it bears out what biologists have known for centuries—that lean animals are less fertile. Charles Darwin even stated "hard living retards the period at which animals conceive." With abundant good food and less disease, girls in rich countries tend to be larger earlier in life and therefore start periods younger, as early as 11 or 12. They are fertile long before their mental maturity.

Secondly, we have in Frisch's work a clear indication of the advantages of early vigorous exercise. Not only may menstruation be postponed and hence fertility reduced, but there is the benefit of avoiding those cancers, if such an association turns out to be the case. Reasonable leanness is sufficient and there is no suggestion that the extremes of anorexia need be risked. Sport is one option, ballet or modern dance another.

The subtleties of all this are, of course, too extensive to summarise in a brief article. They are presented by Frisch in *Scientific American* (March '88) and will no doubt be refined further. But the findings do bear out my youthful (and present) aesthetic sensibilities. Indolence has never been attractive to me. Except in sea-slugs. ■

In the past, fatness has been looked upon as a sign of feminine beauty as in this painting 'Les baigneuses' ('The bathers') by Renoir.

POSTER Banksia Beetle


BRETT GREGORY

This brilliant black and yellow jewel beetle was described by Fabricius in 1801. The so-called 'Banksia Beetle' (*Cyria imperialis*) has a wide distribution throughout coastal Australia where the larvae feed on Native Honeysuckle (*Banksia integrifolia*). The female deposits the eggs in the bark of the host plant, and the larvae, on emerging, tunnel through to the heartwood of the stems. Frequently the tunnels extend some 25 centimetres below the ground surface.

The adults are very active during the warmer periods of the day and can be found feeding on *Banksia* or various flowers. As an escape behaviour, they will either take flight or simply release their hold on the substrate and fall down through the foliage. Like many jewel beetles they are extremely smooth and often difficult to hold.

The jewel beetle family, Buprestidae, contains over 11,500 described species in the world, with over 800 being described from Australia. Many of these beetles have vibrant colour patterns and for this reason collectors, including Charles Darwin, have shown an avid interest in them. In South America, some women have used these beetles as living ornaments: little silver chains wound around the beetles' bodies attach them to their owners. ■


ANTHONY FARR

A 19th-century South American jewel beetle ornament.

—Geoff Holloway
Australian Museum

Stuffed & Pickled

Treasures from the Historic Australian Museum Mammal Collection

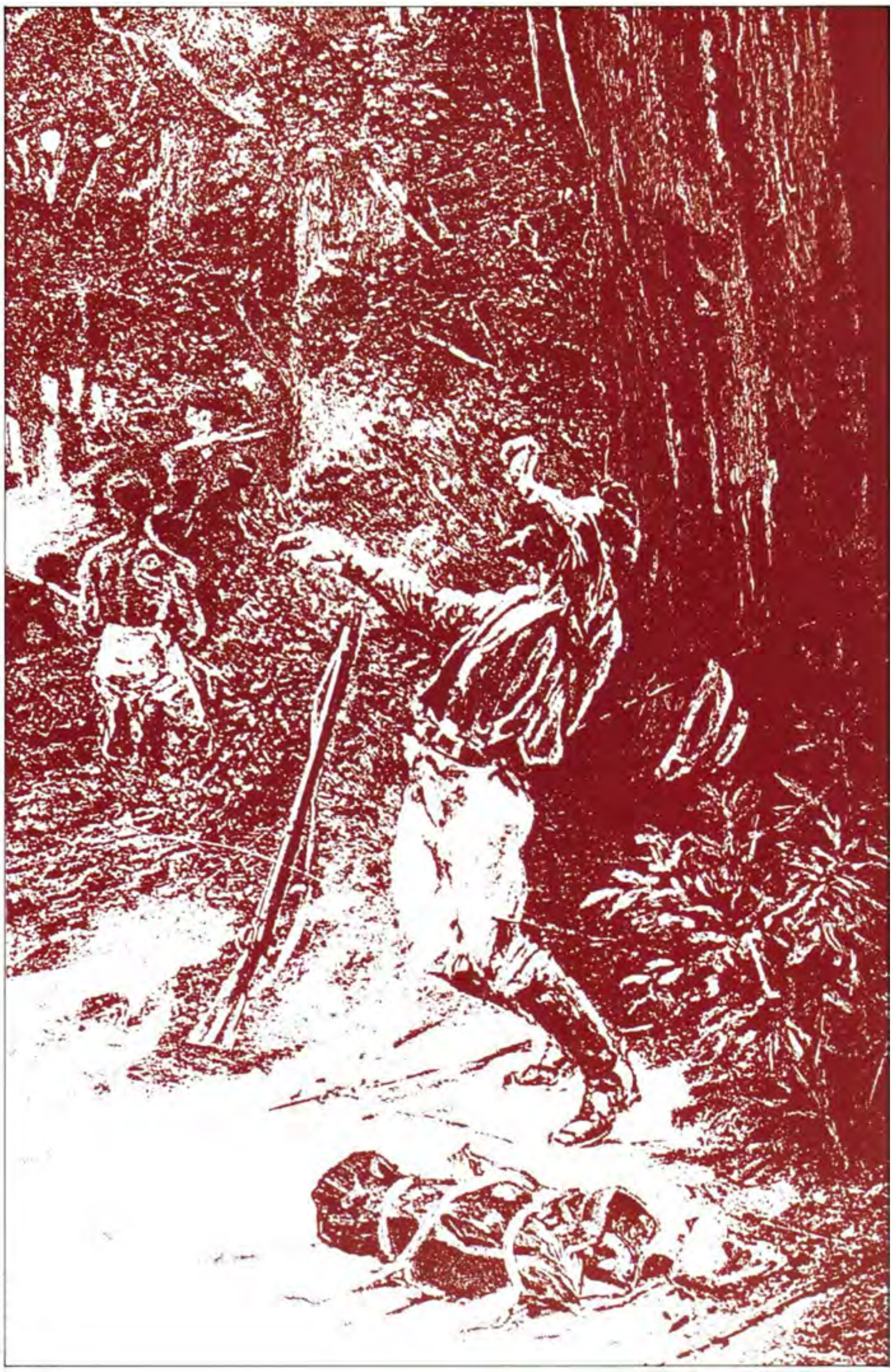
By **TIM FLANNERY**
THE AUSTRALIAN MUSEUM

The Australian Museum in Sydney has special significance in Australasia because of its early foundation. Before the capital cities of many other States were settled, the Australian Museum was already operating as a repository for the rare and curious specimens that explorers, settlers and early naturalists were discovering in the new land. For a large part of the 19th century it was expected that the most interesting and important natural history specimens would be sent to Britain for study. However, chance, foresight and perhaps an embryonic patriotism on the part of some early employees ensured that the Australian Museum retained many items of inestimable value to the nation.

A mere 39 years after Governor Phillip stepped ashore at Sydney Cove to establish the first European colony in Australia, the Australian Museum came into being. In its early years the Museum consisted of a small natural history collection housed in the old Post Office build-

ANTHONY FARR

*Specimens of Mitchell's Hopping-mouse (*Notomys mitchelli*) with Mitchell's sketch, portrait and expedition route.*



The Death of Kennedy. A small rat species (Leggadina *sp.*), *held in the Museum's collection, might just be the only surviving specimen from Edmund Kennedy's ill-fated expedition of 1848.*

ing in Bent Street. It was open between 10:00am and 3:00pm to "respectable individuals". Remarkable as it may seem, there are in the Museum's mammal collection today specimens that were collected during the first decades of operation. And extremely important specimens they are, too.

Some of the earliest specimens, and certainly those with the most romantic histories, were collected during the famous exploring expeditions during the first half of the 19th century. In some cases, the specimens returned to Sydney when the explorers failed to do so. The oldest specimens in the mammal collection were probably collected in 1836 during Surveyor General Thomas Mitchell's exploration of the Murray and Darling Rivers. Although precise identities are confused because of lack of early cataloguing, it seems likely that one of two tiny hopping-mice, destined to be named *Notomys mitchelli* after their discoverer, dates from this expedition. Mitchell's Aboriginal guides captured "this very curious and rare little quadruped", which was stuffed by the Museum's third-ever employee, a convict referred to as "that rascally bird-stuffer", John Roach. When it arrived in Sydney the hopping-mouse evidently created great interest, as an early visitor, the Frenchman du Petit Thouars, commented that he had seen the recently discovered kangaroo-mouse, and that the big kangaroo was now called the kangaroo-sheep to distinguish it from the smaller hopper!

Quite apart from their historical interest, these specimens are of great value to research, for one of them may be the type specimen of the species (the specimen from which the original published description was made). For many taxonomic purposes, it is imperative to examine all type specimens of the group under study. For Australian researchers that usually means a long and expensive sojourn in European museums. But, in this case, the material is close at hand and readily available to all.

Some other remarkable early specimens survive in the collection. Among these are a tiny mouse and a rat collected during two of the explorer Edmund Kennedy's expeditions. The rat is important as it is the type specimen of the Australian Long-haired Rat (*Rattus villosissimus*) and was the basis of Gould's description and colour plate of *R. longipilis* (the name was later changed). It was collected on Cooper Creek, south-western Queensland, on Kennedy's successful 1847 expedition to that region. The second specimen is a small species of *Leggadina*. The only data associated with it is that it is from "Kennedy's Expedition". But which one? It does not appear in the records of the 1847 expedition, so it may have been from the fatal 1848 enterprise. This was perhaps the most tragic expedition in Australian exploring history, ending as it did in the deaths of ten out of the 13 participants, with two of the survivors being found in such a desperate state that their bones were protruding through the frail skin of their withered bodies. The circumstances of the expedition's end make the retention of the specimen seem unlikely, however, for when found, the camp of the two white survivors was surrounded by hostile Aborigines. The relieving expedition barely had time to grab the items closest to hand and carry the survivors to the boat. Perhaps future research will reveal whether the tiny mouse was among the few items grabbed when the camp was evacuated. Whatever the case, the specimen stands as one of the few physical relics of Kennedy's expeditions, and of the dedication to science that the starving and doomed explorer maintained as he struggled on, refusing to jettison his invaluable natural history finds.

Also in the collection are other tragic reminders of men who sacrificed their lives for science. A small, stuffed hare-wallaby is one of the most poignant. This skin and another partial specimen were some of the last specimens collected by the famous naturalist John Gilbert, during Ludwig Leichhardt's first expedition in 1844–45. Gilbert was an indefatigable field collector of John Gould's. It is through his field notes that much of our knowledge of Australia's extinct species comes. Tragically, Gilbert was speared by Aborigines in northern Queensland, within a month of collecting the wallabies and, although suffering but a single wound while others were horrifically speared and beaten, was the only member of the party to die. The beautiful mounted specimen of the hare-wallaby is one of the few animals collected by him to remain in Australia. Gould named the specimen *Lagorchestes leichardti* after the expedition leader, who was soon to disappear himself, presumed dead, while trying to cross Australia from Brisbane to Perth in 1848. I have often wondered how this specimen ended up in the Australian Museum, suspecting that it should have gone to Gould. However, while writing this article, I found part of the answer: Leichhardt virtually stole much of Gilbert's collection. Gilbert had joined the expedition voluntarily, bringing all his own supplies, on the understanding that he could collect for Gould. Gilbert was the most competent bushman of the group, and Leichhardt watched Gilbert's collection grow while his own remained pitiful. Soon Leichhardt could not control himself: he simply decreed that all of Gilbert's material, except the birds, was his own. Gilbert, furious, could do nothing. The specimens were donated to the Museum by Leichhardt, and Gould probably just assumed that they were collected by the explorer, who couldn't even handle a gun!

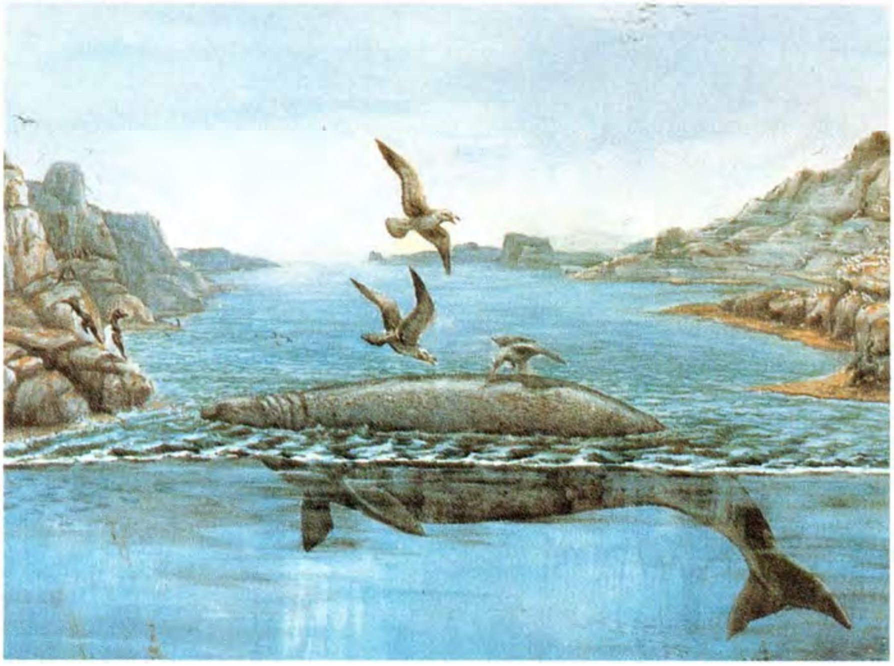

ANTHONY FARR

The skin of this hare-wallaby,* Largorchestes leichardti, *was one of the last specimens collected by the naturalist John Gilbert during Leichhardt's first expedition. Gould's illustration of this same specimen is in the foreground.

By the 1870s exploration had begun to focus on the islands to the north of Australia. Missionaries had begun to infiltrate the margins of Melanesia, and soon others followed. Much of the early knowledge of the mammals of Melanesia came from these sources. Because Sydney was the centre from which most of these adventurers departed, it was also the destination to which many curious specimens were sent. Perhaps the most unusual of circumstances in which material was collected was during the voyage of HMS *Cormorant* in 1881. The *Cormorant* was sent to Ugi Island to avenge several atrocities committed against Europeans in the Solomons in 1880. Foremost was the murder of an English gentleman, Commander of HMS *Sandfly*, Lieutenant Bower. Described as having a magnificent physique, and being a first-class front-row forward, before his death Bower had been seen swinging a native club around his head exclaiming "I say, you fellows, just think of an Englishman among a crowd of these Johnnies armed with one of these." Caught with his pants down on Mandoliana Island while bathing, Bower was not in a position to defend himself with dignity, and his head was soon added to the trophy collection of the Islanders. On board the *Cormorant* was a young Museum taxidermist named Alexander Morton. After the obligatory shelling and destruction, Morton got his chance to explore for material. The most interesting specimen obtained by him was a largish rat now know as *Solomys salamonis*. Although he collected a skin and skull, only the skull survives today. Remarkably, it is still unique, no other large rats ever having been collected on Ugi. Furthermore, recent research has shown that some species of giant rats from the Solomon Islands are gravely endangered, and so we may never know more of this interesting animal. It must surely remain one of the world's least known animals, for all


DAVE WATTS/ANT PHOTO LIBRARY

Now confined to Tasmania, the Eastern Quoll* (Dasyurus viverrinus) *inhabited Sydney's Nielsen Park up until 1966.



Steller's Sea Cow* (Hydrodamalis gigas), *was extinct by 1768, just 27 years after its discovery.

we have is a skull and a very brief description of its fur.

On the mainland of New Guinea, things progressed a little more peaceably. The Reverend W.G. Lawes of the London Missionary Society was the first European inhabitant of Port Moresby. By 1877 he had begun to send specimens of mammals and birds to the Australian Museum for study. Among these was an echidna that represented a new subspecies and was named after him (*Tachyglossus aculeatus lawesi*).

Through the pioneering efforts of such men, the Melanesian mammal collection of the Australian Museum has grown to be among the most important in the world. It includes the type specimens of the largest known bandicoot (*Peroryctes broadbenti*), the rarest and least known species of tree-kangaroo (*Dendrolagus spadix*), and all three of the endemic murid rat species of Bougainville Island, to name but a few.

The Museum mammal collection and research based upon it have grown greatly from its beginnings. Through exchanges, researchers donating their materials, and collecting, today the collection comprises over 20,000 specimens, and makes up one of the three or four great research collections available to scientists interested in Australasian mammals. Among the many national treasures in this great repository, space allows mention of only four of the more curious.

In a small glass jar in the spirit (alcohol and formalin) collection sits a small mouse that was collected in 1895 at Alice Springs during the famed Horn Expedition to central Australia. If it were not for this single specimen, we would never have known that one of Australia's more beautiful 'pseudo-mice' ever existed, for the Alice Springs Mouse (*Pseudomys fieldi*) has never been heard of since. It is rather sad to think that the sum total of our knowledge (apart from fossils) of one of Australia's unique species can be cradled in the palm of one hand, and that, through our senseless destruction of central Australia, it disappeared almost before we became aware of it.

Another specimen bears ample testimony to our continued lack of regard for our environment. It is an Eastern Quoll (*Dasyurus viverrinus*), found run-over outside Nielsen Park in the Sydney suburb of Vaucluse, in 1966. It was the last of its tribe known to have survived on mainland Australia. It seems that Nielsen Park had been a refuge to the species for many years and, rather than being regarded as the most remarkable national treasure, the population was allowed to dwindle, and finally die out, probably as a result of 'park improvements'. Now, rather than making a small trip into inner Sydney to see this beautiful species, we must travel to Tasmania, its only remaining refuge.

Two other specimens are poignant reminders of humanity's atrocious mismanagement of our environment. One is a young female Thylacine (*Thylacinus cynocephalus*) preserved in alcohol. I sometimes wonder if it would have made any difference to the ultimate fate of the species if this animal had been hand-reared and allowed to breed. Strangely, even in its present state, it offers some distant hope to those who would like to see a live Thylacine. For alcohol preserves DNA, the 'blueprint' for life. Perhaps the body contains just enough well-preserved DNA that, at some long-distant time, cloning and genetic engineering will allow someone to 'grow' a new Thylacine from this fortuitously preserved specimen.

Finally, the least expected and one of the scientifically most valuable specimens in the collection is a partial skeleton of the now-extinct Steller's Sea Cow (*Hydrodamalis gigas*). Discovered in the waters surrounding Bering and Kupreanof Islands in the far north Pacific during the Bering Geographic Expedition of 1741, it was extinct by 1768, just 27 years after its discovery. Our specimen of this largest of sirenians was found as a skeleton on Bering Island after the species became extinct. The bones of many individuals must once have littered the island, as the animals were dragged there from the shallows with grappling hooks and flayed alive for their blubber. The bones arrived in Sydney last century as part of an exchange with Swedish scientific institutions. It is a literally irreplaceable specimen of the highest scientific importance. I hope that one day it can be put briefly on display so that the wider public can meditate upon the fate of this magnificent and now-lost animal.

The Australian Museum continues to grow and add to the nation's heritage. The uses that its collections are being put to also grow every year. It is difficult to foresee just what will be most useful to future generations, so it is part of our strategy to preserve as wide a range of material in as many forms as possible. A deep-frozen tissue collection has just been started. Perhaps future generations will be as pleased with this material as we are with the unique heritage built up by those dedicated discoverers of yesteryear. ■

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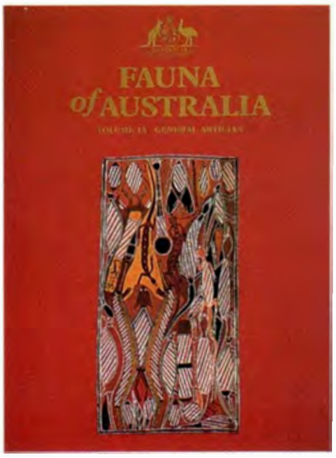


Fauna of Australia. Vol. 1A. General Articles

Ed. by G.R. Dyne and D.W. Walton. Australian Government Publishing Service, Canberra, 1987, 339 pp. $44.95.

If the quality of Volume 1A of the *Fauna of Australia* is sustained throughout the series, Australian biologists are in for a great treat. For the professional biologist and student there can be only one recommendation: make it your number one priority purchase for 1988.

The depth of planning and professionalism shown by the editors are obvious from the foreword on. They note that current knowledge makes it impossible to give meaningful descriptions of many families planned to be included in forthcoming volumes. To improve knowledge of these groups to the extent that they could be included, Australian Biological Research Study (ABRS) grants have been made available. Thus the preparation of the series has acted as a focus and stimulus for much zoological research in Australia. With this in mind, and considering the breadth of material covered, I consider this series one of the most outstanding achievements in the history of Australian biology.

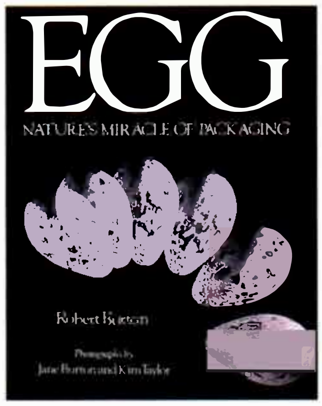
Most of the articles in Volume 1A are excellent. The first, "Evolution of Australian Environments" by Frakes, McGowran and Bowler, is perhaps one of the most universally useful. It provides a baseline for the subsequent studies of individual groups. Subsequent chapters deal with the biota of various environments, and all are of high quality, the only possible exception being Heatwole's contribution, which tends to rely heavily on secondary sources.

Other chapters deal with the discovery of the fauna and collections, human exploitation and classification. All of these are highly useful but by far the most stimulating to me is Wilson's chapter dealing with cultural values and conservation. The inherent conflicts between animal liberation, management, conservation and our current legislation are cleverly drawn out in such a way to make us re-evaluate our basic attitudes.

The final chapters by Cogger and Baverstock contain much information that should be second knowledge to all biologists, but which unfortunately is not. Every student of biology should read and digest these chapters. Although primarily systematic, they are most useful synopses for all.

It only remains to me to heartily congratulate the editors on this magnificent project. It is in my understanding unique in the history of zoological endeavour, and I am sure that within my lifetime we shall not see its like again.

—Tim Flannery



Egg: Nature's Miracle of Packaging

Robert Burton. William Collins, London, 1987, 158 pp. $24.95.

It rained recently up here in the Pilbara and Nature took quick advantage. Within 24 hours, frog spawn was visible in the puddles, dragonflies were mating, and insect and spider egg cases appeared on tree trunks. It is with these matters that *Egg* concerns itself—that is with the strange and rich ways in which animals manage to pass their genes on to the next generation through sexual reproduction.

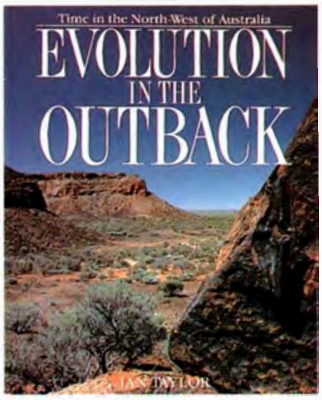
After a brisk introduction, Robert Burton considers the origin of the egg, which can be defined as the larger of the two sex cells involved in reproduction and whose manufacture defines the female. The next five chapters look at some of the extraordinary ways that animals make use of eggs in their reproduction. He explains how, for example, the *Copidosomopsis* wasp lays two sorts of eggs: the first to hatch are voracious soldiers that attack and kill any other insects in their vicinity; however, since they lack excretory and respiratory organs, they soon die, leaving the way clear for their more thoughtfully equipped siblings.

Chapter 7 provides a good summary of development, which the next three chapters consolidate by exploring topics such as hatching and parental care. It is annoying, though, to come across so many anthropomorphisms in the text. For example, in a discussion of predator-deterring toxins we are told "Other animals may have attempted to evolve poisonous eggs but never found a way of doing it without harming the embryos." This conjures up the silly image of conventions of animals designing their own eggs and attempting to build in desirable features!

As is all too common in books published overseas, our own fauna gets undeservedly short shrift. For example, one of the most extraordinary features of mammalian reproduction is the ability of some of our macropods to hold a fertilised egg in a state of arrested development while a second develops normally. Thus, if a pouched young is lost, its replacement is already in the pipeline. This unique ability, alas, goes unremarked.

One of the great features of this book is the high quality of the photographs, taken over a period of three years by Jane Burton and Kim Taylor. They are worth the cover price in their own right!

—Patrick Filmer-Sankey



Evolution in the Outback: Time in the North-West of Australia

Jan Taylor. Kangaroo Press, Kenthurst, NSW, 1987, 128 pp. $24.95.

Evolution can be a dry topic, but in the hands of zoologist Jan Taylor it takes on all the excitement of a gripping novel. We are taken on a tour of Western Australia from Perth up to the Pilbara and back. On the way we are introduced to a myriad of topics including the formation of the bizarre pinnacles in Nambung National Park and the stromatolites at Shark Bay. Throughout the book everything is put into a time perspective. The living stomatolites are the great link with the earliest known life forms on Earth, the 3,500 million-year-old equivalents in the Pilbara. We are shown not only how time has fashioned the animals and plants of this ancient continent, but how the very landscape itself contains a fascinating story of evolution over millions of years, if only you know how to read it. Jan Taylor certainly does. He shows us, for example, how the banded iron formation in the Pilbara owes its existence to the activity of early simple-celled organisms.

The book is well illustrated with a wide range of beautiful photographs (although why the map and time charts should be typewritten and not properly typeset in an otherwise immaculate book is beyond me). However, as much as I think this book is a must for anyone contemplating a trip to the north-west, a word of caution. In his introduction Jan Taylor notes the danger of writing in fields directly outside one's own experience; but in a number of places his own fears are well founded. For instance he perpetrates a number of myths. One is that pinnacles are solution pipe infils. Not so, they are quite the reverse (see ANH vol. 22, no. 1). Another is that stromatolites are made by blue-green algae. In fact they are largely constructed by organisms in a completely different kingdom, the cyanobacteria. It is unfortunate that such basic errors crept into the book. While I applaud the author's attempts to explain the evolutionary wonders of Western Australia to the general public, there is a heavy responsibility when doing so to ensure that it is factual.

Bearing in mind this caveat, this book is excellent value for $24.95.

—Ken McNamara

AUSTRALIAN WILD FOODS by TIM LOW

Reminiscing

There is a fascinating old book called *Tom Petrie's Reminiscences of Early Queensland.* It was transcribed at the turn of the century by Petrie's daughter Constance, and first published in 1904.

Tom Petrie, after whom the Queensland township of Petrie is named, was an exceptional man for his times. Against the prevailing racism of colonial Australia, Tom was deeply interested in and sympathetic to the Aborigines. His father, Andrew Petrie, arrived in Brisbane in 1837 and designed many of Brisbane's earliest buildings. According to *Reminiscences*, "From early childhood, 'Tom' was often with the blacks, and since there was no school to go to, and hardly a white child to play with, he naturally chummed in with all the little dark children, and learned their language, which to this day he can speak fluently."

At 15, Tom trekked with a party of 100 Aborigines from Brisbane to a Bunya nut feast in the Blackall Ranges—a distance of over 100 kilometres. *Reminiscences* describes the Aborigines gathering yams and honey, and hunting "paddymelons" and "opposums": "To them it was a real pleasure getting their food; they were so light-hearted and gay, nothing troubled them; they had no bills to meet or wages to pay. And there were no missionaries in those days to make them think how bad they were."

At 28, Tom decided to set up a cattle station, and asked Dalaipi, "head man" of the North Pine tribe, to suggest a site. Dalaipi offered his own tribal territory of North Pine River, even though this land now 'belonged' to the Griffen family. Petrie inspected the land, then came upon John Griffen riding through the forest bristling with pistols and carbine. Griffen gladly offered Petrie the land, touching his pistols and complaining angrily that the run was unusable be-

Broad-leaf Geebung is a shrub of sandy infertile soils in southern Queensland and northern New South Wales. The fruits are about 1.5 centimetres long and ripen only after they fall to the ground. The fibrous pulp is like sweetened cottonwool. Australia has more than 70 species of geebung, and nearly all have edible fruits.

Midyim has a soft, delicious, slightly aromatic pulp containing only a few small seeds. It grows on a small shrub of coastal heaths in far northern New South Wales and southern Queensland. The leaves are between one and three centimetres long, tapered and produced in pairs; the flowers are white, and the fruits ripen mainly in autumn.

PHOTOS: TIM LOW

Coast Pandanus is a tree of beaches and coastal headlands north of Port Macquarie. It has large orange fruits the size of a human head that, when ripe, crumble into a number of wedge-shaped segments, the bases of which are edible after cooking. They taste like sweet mashed pumpkin with a hint of apricot.

cause of the hostile blacks.

Petrie obtained title and, with Dalaipi's help, built stockyards and a house, where he lived out the rest of his life. During long sojourns in Brisbane, Petrie could always leave his house and cattle under the care of Dalaipi and other Aborigines. Nothing ever went amiss. At the same time, stockmen on adjoining properties were shooting Aborigines and poisoning them with arsenic-laced flour.

Dalaipi seems to have been an astute old man. Realising he could not repel the white invaders, he chose to live under one sympathetic white man's patronage. Nonetheless, he remained angry at his people's dispossession, and *Reminiscences* includes a long dialogue where he berates the white man for stealing tribal land, killing his people, and for teaching the survivors to "drink, smoke, swear and steal".

Reminiscences includes four chapters on food-collecting by Aborigines. Around Brisbane the staple plant food was the starchy underground stem of Bungwall Fern (*Blechnum indicum*; see 'Australian Wild Foods' in ANH vol. 22, no. 2). Other staples included yams (probably *Dioscorea transversa*), and the underground stems of bulrushes (*Typha* species) and Cunjevoi (*Alocasia macrorrhizos*). Among fruits there was Midyim or Midgin Berry (*Austromyrtus dulcis*)—a small (about one centimetre wide), deliciously sweet berry of coastal forests—and wild raspberries (*Rubus* species). The fruit of the Coast Pandanus (*Pandanus tectorius*, formerly known as *P. pedunculatus*) was chewed at the inner end and sucked, but probably after roasting as the raw fruit is irritant. This plant was known locally as 'Winnam', hence Brisbane's bayside suburb Wynnum.

Brisbane's suburb of Geebung is also named after a fruit (genus *Persoonia*), although *Reminscences* states that this was not a local name: "The fruit of the geebung *Persoonia*, or 'dullandella', as the Brisbane tribe called it, was eaten raw, and greatly relished. The natives got dillies full of these in the right season." The geebung may well have been the Broadleaf Geebung (*P. cornifolia*), although there are other species in the Brisbane area, all with edible fruit.

Tom Petrie's Reminiscences of Early Queensland has been reprinted in paperback by Angus & Robertson. I heartily commend it to anyone interested in a sympathetic and highly readable account of the Aboriginal way of life. ■

1. Eggs of the White Nymph Butterfly, Mynes geoffroyi guerini, *showing ribbing on outer shell and pattern of eggs at different stages of maturity, Burleigh Heads, Queensland.*
2. Arrangement of spores on a rainforest fern, Mt Glorious, Queensland.
3. Bracket Fungus, Polyporus diversicolor, *showing pattern of concentric rings of colour, Mt Glorious, Queensland.*
4. Globular flower head of the Leichhardt tree, Nauclea orientalis, *Townsville, Queensland.*

photoart

3

4

PATTERNS IN NATURE

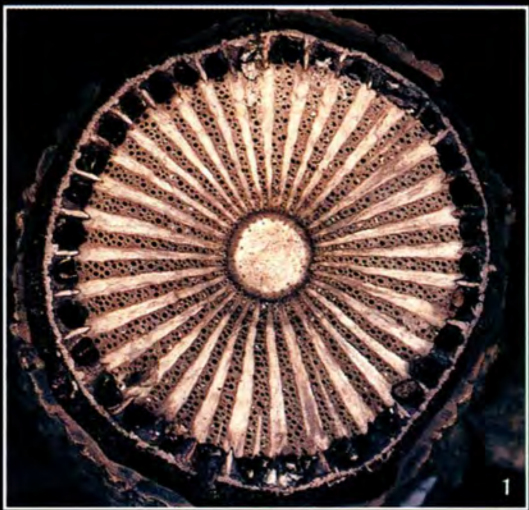
A pattern can be simply defined as a decorative design on a surface of an organism or an inanimate object. They can also be formed by an arrangement of objects or their parts. In nature, patterns are very common and diverse but, since many are subtle, they are not recognised by the majority of people. Patterns may result by colour, shape and texture, or by a combination of these. Colour patterns are perhaps the most common pattern in nature and are usually the result of genetic factors. Many creatures possess patterns on their bodies that provide them with camouflage as protection from predators or act as an

PHOTOGRAPHY BY TREVOR HAWKESWOOD

attraction to the opposite sex. Other patterns may be created as a result of environmental factors such as the mosaic arrangement of leaves of certain trees in a tropical rainforest, resulting from competition for light in a dim environment. Whatever the cause, there exists a wide range of interesting, diverse and often striking patterns in nature, and these represent a rewarding and productive subject for wildlife photographers.

—**Trevor Hawkeswood**

photoart



1. Broken rainforest log showing vascular tissue pattern, Mt Glorious, Queensland.
2. Cluster of bug eggs on a Blackboy leaf, Xanthorrhoea johnsonii, *Brisbane, Queensland.*

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RARE & ENDANGERED Freckled Duck

The Freckled Duck (*Stictonetta naevosa*) is Australia's rarest and most peculiar duck. It resembles a true duck in general appearance and proportions but it is not a normal 'dabbling duck'. Its uniformly spotted or 'freckled' dull grey-brown plumage is only relieved by a paler shading on the belly and off-white linings to the underwings. There is no well-defined facial pattern and no speculum—the sharply contrasting patch of colour on the inner wings of many true ducks. The neck is long and the head large, the latter accentuated to a triangular shape by a small crest. The bill is high at the base, narrow and markedly dished, giving the duck an unmistakable profile. The heads of males in breeding condition become very dark and the bill turns pillar-box red. Females never have red bills and are slightly smaller and paler than males.

John Gould illustrated a Freckled Duck in *The Birds of Australia* (1848) and gave a short account of what was then known about its natural history. Little new information was added for more than a century, despite the recognition that Freckled Ducks were unusual and their affinities with other waterfowl puzzling. Freckled Ducks were thought to be most closely related to the swans but recent studies on their behaviour tend to support an affinity with the stifftail ducks. The stifftails are primarily diving ducks and include the Bluebill Duck (*Oxyura australis*) and the Musk Duck (*Biziura lobata*) of Australia. Much work still remains to be done to resolve this matter of affinity, but it is clear that the Freckled Duck is only distantly related to the other 150 or so extant species of waterfowl in the world.

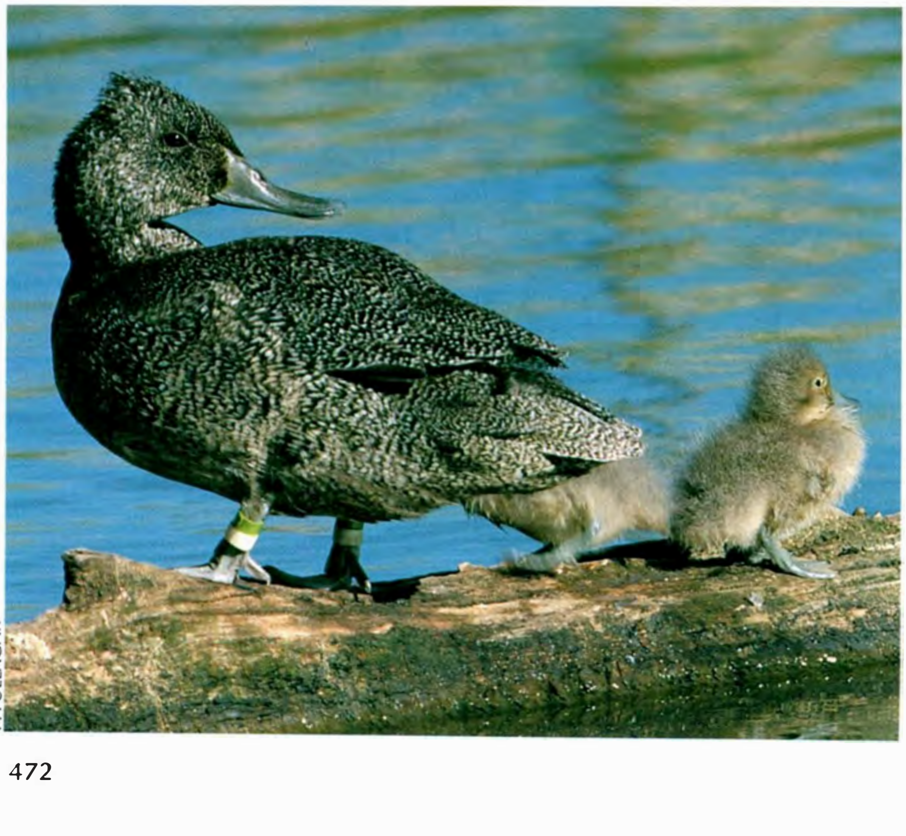
The general biology of the Freckled Duck is now much better known, mainly because of the recent success of the CSIRO's captive breeding program.

Freckled Ducks usually feed in shallow water while slowly walking. The head sweeps from side to side with the bill at the surface. The pump action of the bill acts as a powerful filter mechanism creating a constant stream of expelled 'waste' water from the upper edges of the beak. With this 'suzzling' action the ducks filter out food (invertebrates and some vegetable matter) from the surface film and soft muds. They tend to feed at dusk and dawn and often by night, probably because of the diurnal rhythms in availability of their preferred microscopic foods.

Freckled Ducks are not loudly vocal, although at close range querulous calls can be heard. By nature they are irascible and frequently bicker among themselves between long spells of silent loafing during the day.

Pair formation is accomplished with simple and rather cryptic postures and calls. A male-advertising display known as the 'axle-grind' is used to challenge other males and to attract females. A 'head-up-chin-lift' is the only response given by breeding females. The pair-bond is brief and males are polygamous.

Unlike most ducks, male Freckled Ducks perform nest-building actions and probably contribute to nest-site preparation. They do not incubate or play any part in brood rearing, nor guard their mates beyond the period of egg laying.



P. FULLAGAR

Female Freckled Duck and downy ducklings.

Adult female and male Freckled Ducks.

The distinctive white underwing can be seen on this Freckled Duck.

The breeding season is usually September to December, but a few clutches have been recorded in late summer. Clutch size is small (five to seven eggs) but larger clutches of up to 14 result from 'dump nesting'. This occurs when additional eggs are added by one or more different females. The nest is located at or near water level, often in large, dense and well-compacted Lignum (*Muehlenbeckia cunninghamii*) bushes. Incubation in 28 days and ducklings are covered in grey down. They begin to show feathering at the end of the fourth week and are fully feathered and capable of flight at two months. They can breed at one year.

The enigma of the Freckled Duck revolves around questions of why its numbers fluctuate widely over long periods (maximum numbers no more than 20,000) and exactly where its principal breeding areas are. If, as now seems to be generally agreed, it is dependent on the transitory wetlands created by floods in the enormous Lake Eyre drainage basin of central-eastern Australia, then the pattern of filling and drying of the vast Lignum swamps of the Diamantina and Cooper Creek floodplains may hold the key to its erratic population numbers. Just to the east, the swamps of the Bulloo and Paroo floodplains are probably also important. The swamps of the Murray–Darling basin and the few coastal wetlands of south-eastern and south-western Australia, however, do not appear to be such critical breeding areas. This is because, following any major flood event and therefore population increase, the inevitable drying of the inland swamps will drive Freckled Ducks towards the coasts, where they may survive for some years with limited breeding.

Now that captive breeding of Freckled Ducks has proved successful, a program should be designed to maintain viable populations. This will provide security against the possibility of extinction in the wild. Such a project must recognise the need for sufficient numbers to provide genetic diversity in the captive flocks. ■

—Peter Fullagar
CSIRO, Division of Wildlife and Ecology

Our Oral Arsenal: A Natural Legacy of Primate Aggression

Sunk deep in the clutches of my favourite armchair, unsuccessfully fighting off a nap attack, I was suddenly jerked back to life by the sight and noise of 'Jacko' (Mark Jackson) threatening to hurl a giant battery out of the TV set straight at my head. I shrank back into the chair as he shook his electric weapon and pummelled my ears with a final shattering "Oiii!" It most definitely did not incline me to rush out to buy batteries; instead I felt like leaping up and riveting a giant battery-proof board across the front door.

But it was not until I walked into a shop a week later to be confronted by a poster of Jacko still threatening to do me in (this time with two normal-sized batteries instead of that gigantic thing he was tossing around in the TV ad) that I realised what it was about *him* that caused me to react this way—it was his face. It was wound up in a violent leer, his right upper lip raised above his canine tooth and his lower jaw displaced outwards below the raised lip—a grimace that made me feel distinctly uncomfortable. My life had been threatened, it seems, by a tiny corner of Jacko's face, not his giant battery. Why?

The answer is part of a new science pioneered and named by New Zealand dentist Dr Ronald Every as thegotics—the science of tooth sharpening. For 30 years, through publications[1] and discussions with anyone willing to listen, Dr Every has challenged the common presumption that our ancestors long ago lost the capacity to defend themselves and compensated for this disability by using tools.

This venerable view appears to be wrong for two main reasons. First, the oldest-known australopithecines, which included our distant ancestors, had reduced their canine teeth to near modern size by at least four million years ago, but the oldest undoubtedly manufactured tools do not appear in the record until 1.7 million years later. So what did our ancestors do in the meantime to protect themselves? The answer is Every's second reason for rejecting the conventional view of human defence systems: we *never*, in fact, lost the ability to use our teeth as weapons, although the human arsenal no longer involves the slashing, stabbing canines characteristic of our cousins the African apes. Instead, the short-canined australopithecines developed the equally dangerous *horizontal* segmentive biting weapon, which we still have. It works by slicing chunks out of victims as the lower jaw is first pushed outwards when opening and then pulled back hard against the upper jaw with the bite. A check with your tongue will reveal that the outside cutting edge of your upper incisors and inside cutting edge of your lower incisors are sharper than the other edges of these same teeth. Because of this, these teeth can function like a pair of horizontally held scissors.

Anyone with doubts about our ability to use these front teeth as weapons should swap places with dentists who have to put their hands

Jacko's leer is not only an inherent part of an advertising campaign to sell batteries—it is also part of the tooth-sharpening process called thegosis.

COURTESY UNION CARBIDE

in the mouths of unwilling patients, or a football player who picks up the ear bitten off his own head by an angry opponent, or the intended victims of sexual assaults, many of whom discover that to effectively stem the attack they can—and do—instinctively bite off the nose or fingers of their assailant. In 1984, in New York City alone, 1,593 humans were severely bitten by other humans, this number of mouth attacks being second only to the number inflicted by dogs.

The cost of using teeth to kill, cut, slice or chew is the need to periodically resharpen these tools when they become dulled by use. Dr Every has called this essential resharpening process 'thegosis'. We thegose our molars to restore their horizontal sharp edges to better enable them to masticate food into small pieces; we thegose our front teeth in order to maintain the sharp horizontal edges of the incisors and canines—our natural weaponry as well as the teeth we use to selectively slice off edible titbits such as muscle from bone.

In order to thegose or sharpen our front teeth, the lower jaw is forcibly moved into the posture displayed by Jacko. Repeated thegosing of this kind usually takes place at night when the tensions of the day reform as threatening dreams. This nocturnal tooth-sharpening produces a 'graunching' ('grinding' or 'gnashing') sound that makes a wakeful listener instinctively shudder—it sounds menacingly similar to the sound animals make when they deliberately sharpen their teeth, often in preparation for battle.

Through his dentistry practice, Every began to understand that there was generally a good correlation between the degree of psychological tension in his patients and the degree to which they thegosed their teeth. Normally, thegosis is not only healthy but essential to maintain dental function. Yet tooth grinding is traditionally described as 'bruxism' and regarded as anything but healthy and essential. Although Every agrees that some unfortunates do suffer conditions now attributed to 'bruxism' (damage to jaw joint, teeth, cheeks and tongue, severe headaches and facial pain), these are more the result of variations in their anatomy (bones, nerves, blood vessels, etc.) and are much less likely to effect those whose anatomy is normal. Every realised that in most cases the solution to these patients' problems first involved finding ways to reduce the levels of tension in their lives. Without this first aid, efforts to repair the damage were often a waste of time because the repairs could be destroyed during the next bout of severe thegosis.

Part of the science of thegotics also concerns itself with the behaviour of apes and monkeys equipped with oral arsenals and the mechanisms of thegosis to maintain their function. Jacko's snarl is clearly a display of his oral arsenal and its preparation for battle. In contrast, the smile, which is a feature of many great apes as well as humans, conveys the opposite feeling—because it displays the teeth in a non-threatening, non-tooth-sharpening position with the lower jaw directly beneath the upper. Try, if you can, to smile while holding your lower jaw in the posture of Jacko's—it can't be done without making you feel ridiculous. The non-vocal message of the smile is clear: "I'm not thegosing so you're safe to approach!"; and our non-vocal reaction is a similar smile and a feeling of welcome.

The science of thegotics is an exciting integration of palaeontology, morphology and behaviour, and is poised to rattle conventional understanding about many aspects of ourselves. We are, in practice and in fact, the human animal and no different from our pre-human ancestors in our ability to use teeth as effective weapons, despite the fact that the idea may not sit well with those committed to the view that we were created as gentle occupants of the Garden of Eden rather than the outcome of millions of years of evolution of primate aggression. ■

[1] For example, 1960 *Lancet* 2: 37–39; 1965 *Lancet* 1: 685–88; 1970 *Postilla* 143: 1–30; 1975 in *Approaches to Primate Biology*, ed by Martin, Walker & Doyle (Duckworth: London); and Every's up and coming book *Right Under Your Nose: The Toothprints of Man's Violence.*

"You spit Dr Harper out this very minute!"

Stromatolites

The Ultimate Living Fossils

By KEN McNAMARA
WESTERN AUSTRALIAN MUSEUM

At the southern end of the eastern-most inlet of Shark Bay in Western Australia, there is a quiet, rather peaceful place called Hamelin Pool. Stepping across the low dunes that surround the pool, and descending to the beach, you could be forgiven for thinking that you had slipped billions of years back in time. Stretched out before you, where the seawater gently laps on the shore, are stromatolites, rising like a field of concrete cauliflowers. Some of these domed mounds, which reach about 30 centimetres in height, are clear of the water and are hard, brown stony

LEE McELFRESH/AUSCAPE

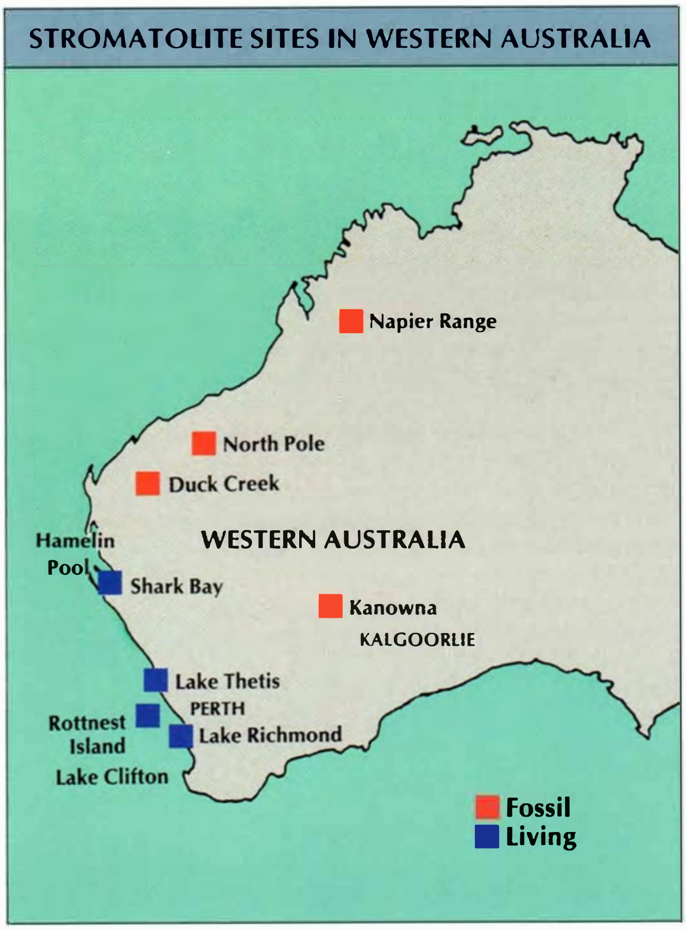
Watching the evening tide wash over the stromatolites at Hamelin Pool, Shark Bay, is like taking a step back in time. Simple, single-celled organisms have been making these strange, domed constructions for the last 3.5 billion years.

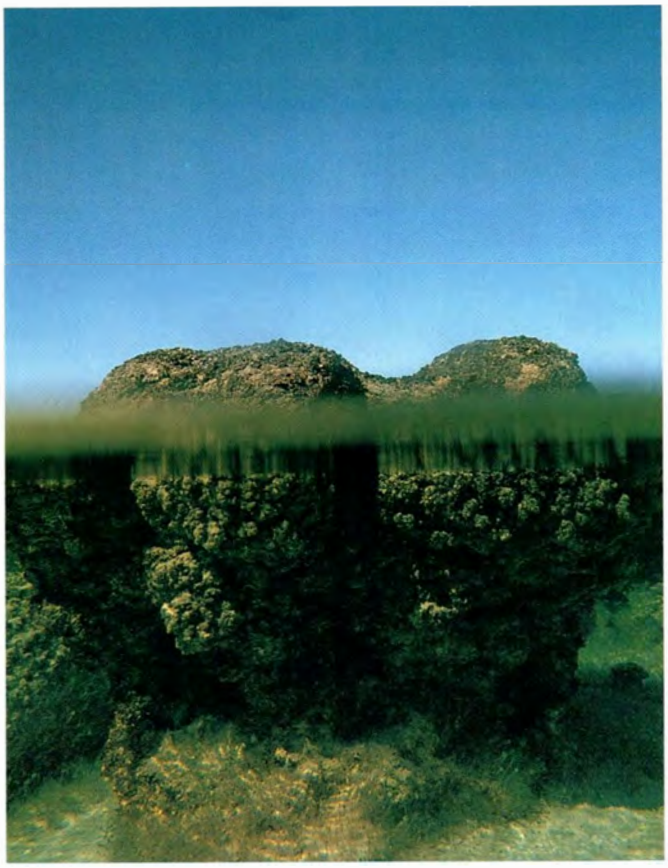
structures cemented to a flat limestone pavement. Some are partially covered by the water, while the murky outlines of others can be seen submerged beneath the sea. It is only when you gently touch one of these submerged mounds that you realise they are not inanimate rocks, but alive: their surface is soft and spongy.

Herein lies another world: a complex ecosystem composed of a wide range of micro-organisms, ranging from photosynthetic prokaryotes (cells, such as bacteria, that lack both a nucleus and chromosomes) through microalgae to a wide range of other microbes. Known as benthic (bottom-dwelling) microbial communities, these minute organisms have been responsible for building stromatolites for at least 3.5 billion years.

By definition, a stromatolite is an organosedimentary structure produced by the sediment-trapping, binding and precipitation activity of micro-organisms. In other words, microbial communities can construct stromatolites in different ways: either by trapping and binding sediment, or by precipitating their own inorganic framework. Those at Hamelin Pool are formed principally by cyanobacteria (formerly known as blue–green algae) trapping fine sediment particles from the water and binding them with a sticky film of mucus that they secrete. The cyanobacteria are photosynthetic and so respond to light. They are also motile, and so are able to move towards the light, keeping pace with the accumulating sediment and therefore always remaining on the outer surface of the stromatolite.

Most stromatolites grow extremely slowly. Maximum growth rates of less than one millimetre per year have been recorded for those at Hamelin Pool. The tracks of horse-





R. WOLDENDORP/WA PHOTO INDEX

An iceberg-like protrusion in the clear water of Hamelin Pool, a stromatolite just breaks the water's surface.

drawn wagons, which crossed extensive platforms of coalesced stromatolites earlier this century, are still visible today, highlighting the vulnerable nature of these stromatolites. While domed structures that have taken hundreds of years to grow just 30 centimetres high might not seem very impressive, it is intriguing to consider what the construction of such a stromatolite might mean to the cyanobacteria that made them. These organisms range in size from four to nine microns (millionths of a metre). So organisms, say, five microns in diameter that build a structure 30 centimetres high and 20 centimetres across can be considered equivalent to humans erecting a structure 105 kilometres high and 75 kilometres across. No mean feat!

Stromatolites are constructed by complex communities of many species of different microbes. If these microbes had never developed the ability of trapping sediment or precipitating a framework, neither the stromatolites nor the communities would ever have existed. And, as we shall see, if that had not happened, other life forms that ultimately developed on Earth, including our own species, may not have evolved.

The stromatolites at Hamelin Pool vary in their internal structures, depending on their position relative to the shoreline. This arises because different groups of micro-organisms construct the stromatolites at different water depths. In the intertidal zone, so-called 'pustular-mat' stromatolites are constructed principally by the coccoidal cyanobacterium *Entophysalis*; these stromatolites are unlaminated (unlayered) and have a coarse internal structure. From the lower intertidal region down to the upper subtidal zone 'smooth-mat' stromatolites occur that are constructed by a community dominated by the filamentous cyanobacterium *Schizothrix*; these are laminated and have a fine internal texture. The deepest stromatolites occur to a depth of about 3.5 metres, where they occur as weakly laminated, coarse-structured 'colloform-mat' stromatolites up to one metre high, constructed by a complex microbial community, including the cyanobacteria *Microcoleus* and *Phormidium*. Some algae, mainly diatoms, are also commonly found in this zone. Work by Stan Awramik of the University of California at Santa Barbara has shown that these subtidal stromatolites are inclined northwards, under the influence of the sun.

Having been the first large, living, marine stromatolites to be described (surprisingly as recently as 1961), those in Hamelin Pool have tended to become the model for all living stromatolites, particularly in terms of their environmental setting. Because this part of Shark Bay is an area of poor water circulation, salinity levels can be seasonally high and so few organisms can survive. Thus it has long been argued that the stromatolites only exist here because of the absence of grazers, such as gastropods and fish, which would otherwise crop the microbial mats to such an extent that stromatolites would not form. However, stromatolites do *not* only live in hypersaline marine environments

Photomicrographs of living cyanobacteria from Lake Clifton, Western Australia. Such micro-organisms are responsible for constructing stromatolites, either by trapping and binding sediment or by precipitating their own inorganic framework. From top to bottom,* Chroococcus, Scytonema *and* Dichothrix *cyanobacteria.

such as at Hamelin Pool. They also develop in open marine conditions; fresh-, brackish- and saltwater lakes; and in hot springs.

Although occurring in the United States, the Bahamas and the coast of the Persian Gulf, Australia is the world's Mecca for stromatolites, in particular Western Australia. Here they can also be seen in the saline Lake Thetis, near Cervantes; in hypersaline lakes on Rottnest Island, near Perth; in the freshwater Lake Richmond at Rockingham; and in the brackish Lake Clifton, where they are particularly well developed. This is a long, thin lake that runs parallel to the coastline some 100 kilometres south of Perth. It is one of a number of lakes, within or close to Yalgorup National Park, that are populated by algal–cyanophyte mats. However, only in Lake Clifton do they develop as stromatolites. At the northern end of the lake they form an enormous reef made up of coalesced stromatolites, about 30 metres wide and extending for more than five kilometres. Most individual stromatolites do not exceed 40 centimetres in diameter, but some are up to one metre across.

Unlike the Hamelin Pool stromatolites, those in Lake Clifton are largely the product of the precipitation of calcium carbonate by the filamentous cyanobacterium *Scytonema*, although some fine sediment does get trapped within the structures. These stromatolites also differ from those at Hamelin Pool in that they grow in brackish water and are populated by a diverse metazoan fauna, including isopods, amphipods, gastropods and bivalves. The stromatolites provide both a source of food and refuge for these animals.

Linda Moore, of the University of Western Australia, has found that differences in discharge of ground-water greatly affect not only the distribution of these stromatolites, but also their form. The presence of such ground-water seepage appears critical to the development of the stromatolites because it allows *Scytonema* to flourish and provides the prime source of carbonate and bicarbonate ions necessary for stromatolite construction.

The freshwater stromatolites of Lake Richmond also appear to form by the precipitation of calcium carbonate, perhaps under similar conditions to those at Lake Clifton. Indeed, the link between all these Western Australian stromatolites, irrespective of the salinity of the water in which they grow, is that they develop in environments rich in calcium carbonate: either lime-rich sand or limestone. The source of calcium carbonate for the stromatolite's structure, whether as primary framework material or cement, may well be ground-water that has passed through such lime-rich substrates.

Not only are there many places in Western Australia where stromatolites are still living today, but there are many localities where their fossilised remains have been found. At a site in the Pilbara, rather inappropriately named North Pole, stromatolites have been found in rocks dated at between 3,450 and 3,550 million years old. These represent the oldest firmly established evidence for life on Earth. Although these stromatolites have not yielded evidence of the micro-organisms that constructed them, cherts (silica) within the same rock formation (Warrawoona Group) contain four different kinds of filamentous microfossils and two different kinds of coccoidal microfossils. These fossilised cells resemble the prokaryotic cells that construct stromatolites today. It is not clear, however, whether or not they were photosynthetic.

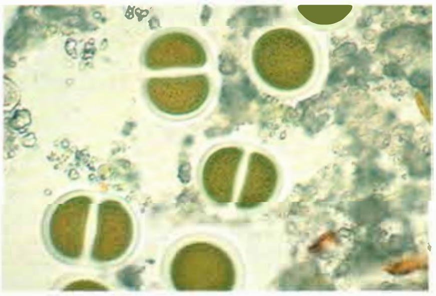
For the rest of the Archaean Eon up to the beginning of the Proterozoic Eon (about 2,500 million years ago) stromatolites are rare. However, from around 2,500 million years ago when shallow marine environments with broad stable platforms developed, stromatolites increased greatly in number and diversity. From the simple domes

KEN McNAMARA

The intricate, layered structure of stromatolites can be seen clearly in this fossil cross-section. Peculiarly shaped like a map of Western Australia, this particular specimen is from the North Pole in the Pilbara, Western Australia. It came from 3,500 million-year-old deposits and represents the earliest evidence for life on Earth.

formed in the early Archaean, branched, conical, spheroidal, planar and wavy forms developed. Stromatolites became widespread and even developed reefs. Throughout the remainder of the Proterozoic, up to 570 million years ago, they were the dominant form of life on Earth, their greatest diversity having been about 850 million years ago.

Research by Kath Grey of the Geological Survey of Western Australia indicates that these Proterozoic stromatolites are proving to be valuable tools in the relative dating of these ancient rocks. Furthermore, because different forms seem to be restricted to certain sediment types, they are providing invaluable information on interpreting palaeoenvironments. For instance, she has shown how, in the 2,000 million-



L. MOORE

L. MOORE

L. MOORE

year-old Duck Creek Dolomite, which occurs in the south-western Pilbara, two forms of stromatolites can be recognised: a columnar variety that grew in shallow lagoons and into the lower intertidal zone; and another broader-domed variety that appears to have inhabited high intertidal or supratidal regions. These two forms can be recognised in many Proterozoic rocks, and similar analogues can still be seen living today in Lake Clifton.

Other modern-day analogues are seen in even older stromatolites. Dated at between 2,700 and 2,800 million years old, small, conical stromatolites found at Kanowna, just east of Kalgoorlie, are the oldest so far found in the Yilgarn Block. Preserved in chert in a sequence of volcanic rocks, these stromatolites are similar in appearance to forms still growing today in hot springs in Yellowstone National Park in the United States. Fossilised microbial filaments found within the Kanowna stromatolites indicate that they were probably growing towards the light. It is tempting to speculate that, like those in Yellowstone National Park, the Kanowna stromatolites were growing in hot springs in a volcanically active region. Volcanic eruptions would periodically have showered ash and debris onto the stromatolites, killing them, but also helping to fossilise them.

Stromatolites in Yellowstone National Park are often inclined towards the sun. Inclined fossil stromatolites from Proterozoic rocks have also been interpreted as having grown towards the sun. The orientation of the columns follows a curved growth pattern, which is thought to represent the stromatolites tracking the sun over one year. By counting the number of layers or laminae (which are thought to have been deposited daily), it has been possible to calculate that about 1,000 million years ago there were about 435 days in the year.

In addition to an increase in diversity of stromatolite structures during the Proterozoic, there was also an increase in the variety and size of the microbiota that constructed them. Around 2,000 million years ago unicells and filaments were of the order of six to seven microns in diameter. But by about 1,000 million years ago filaments ranged up to 20 microns in diameter, and by the latest Proterozoic, closer to 700 million years ago, some were up to 100 microns across. Although their importance as part of the whole biota declined dramatically from about 570 million years ago, when the great evolutionary explosion in marine invertebrate life began, stromatolites still played a major role in many ecosystems. For instance, the fringing reefs that formed around the Kimberley Block 360 million years ago, now exposed in places such as the Napier Range, have stromatolites as one of their major components.

If the whole of Earth's history was compressed into a day, humans can be seen as having existed on this planet for just a fraction of a second. By contrast, stromatolites would have persisted from about 5:30 in the morning of that day and alone dominated life on Earth until after 9:00 in the evening. Indeed, it was from such simple, prokaryotic cells that all subsequent life on this planet, including ourselves, evolved. Even though an immense profusion of animals and plants has evolved within the last 570 million years, stromatolites have persisted. This resilience has meant that stromatolites have been able to survive for 3,500 million years to become unquestionably the ultimate living fossils. ■

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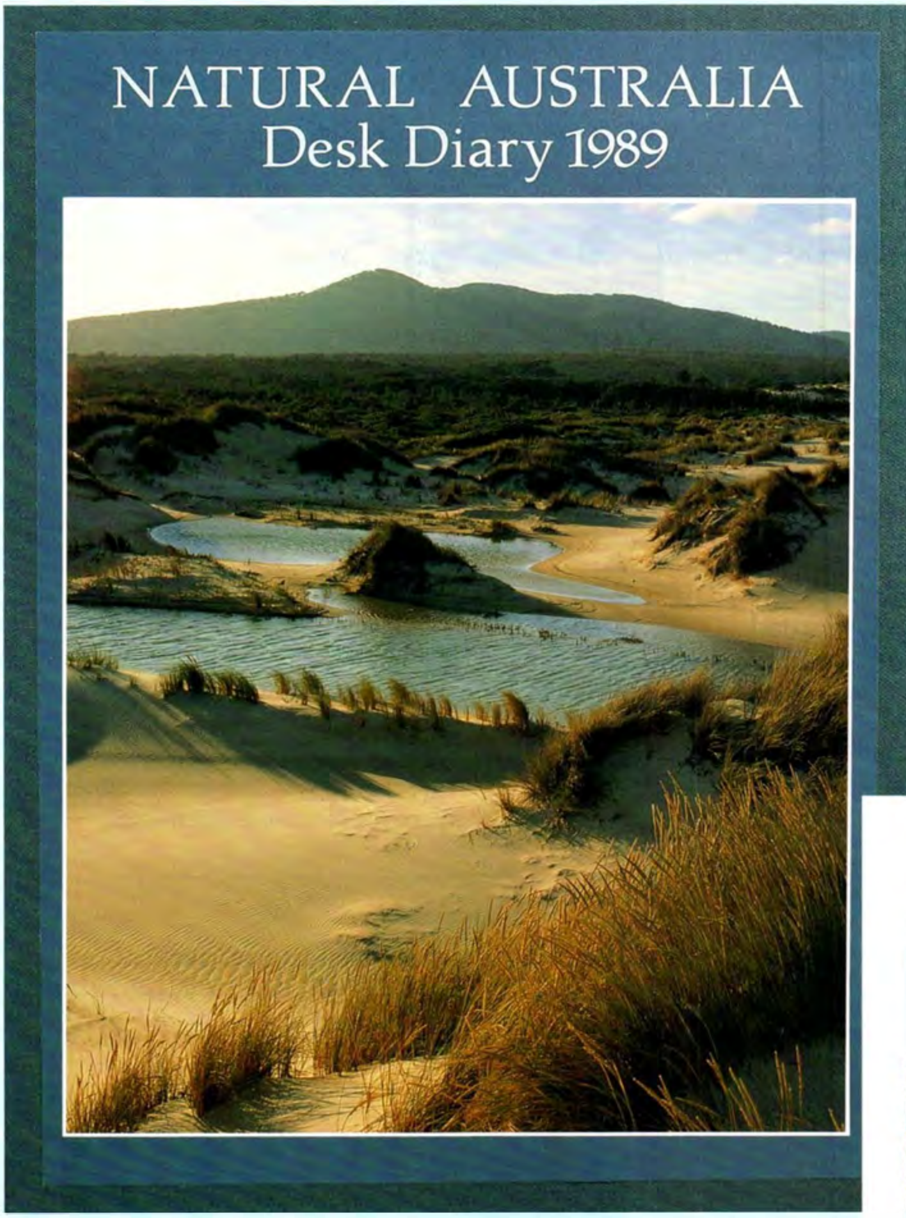

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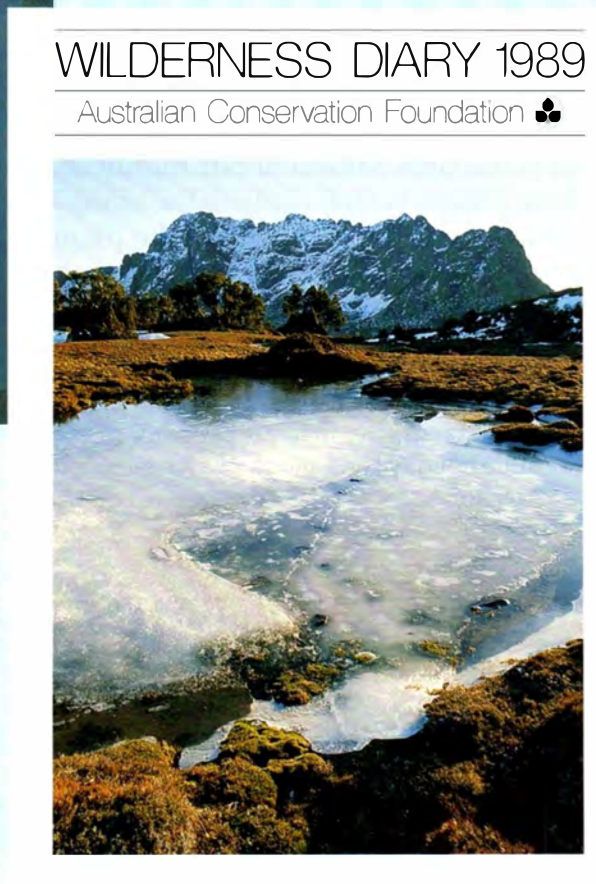

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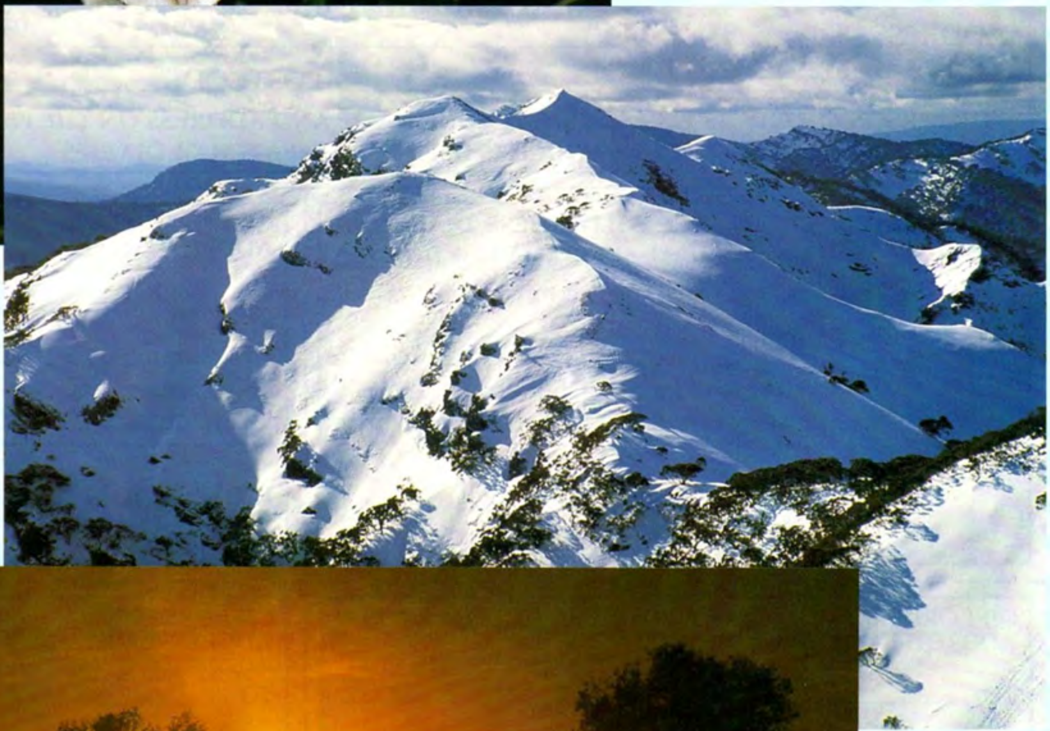

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