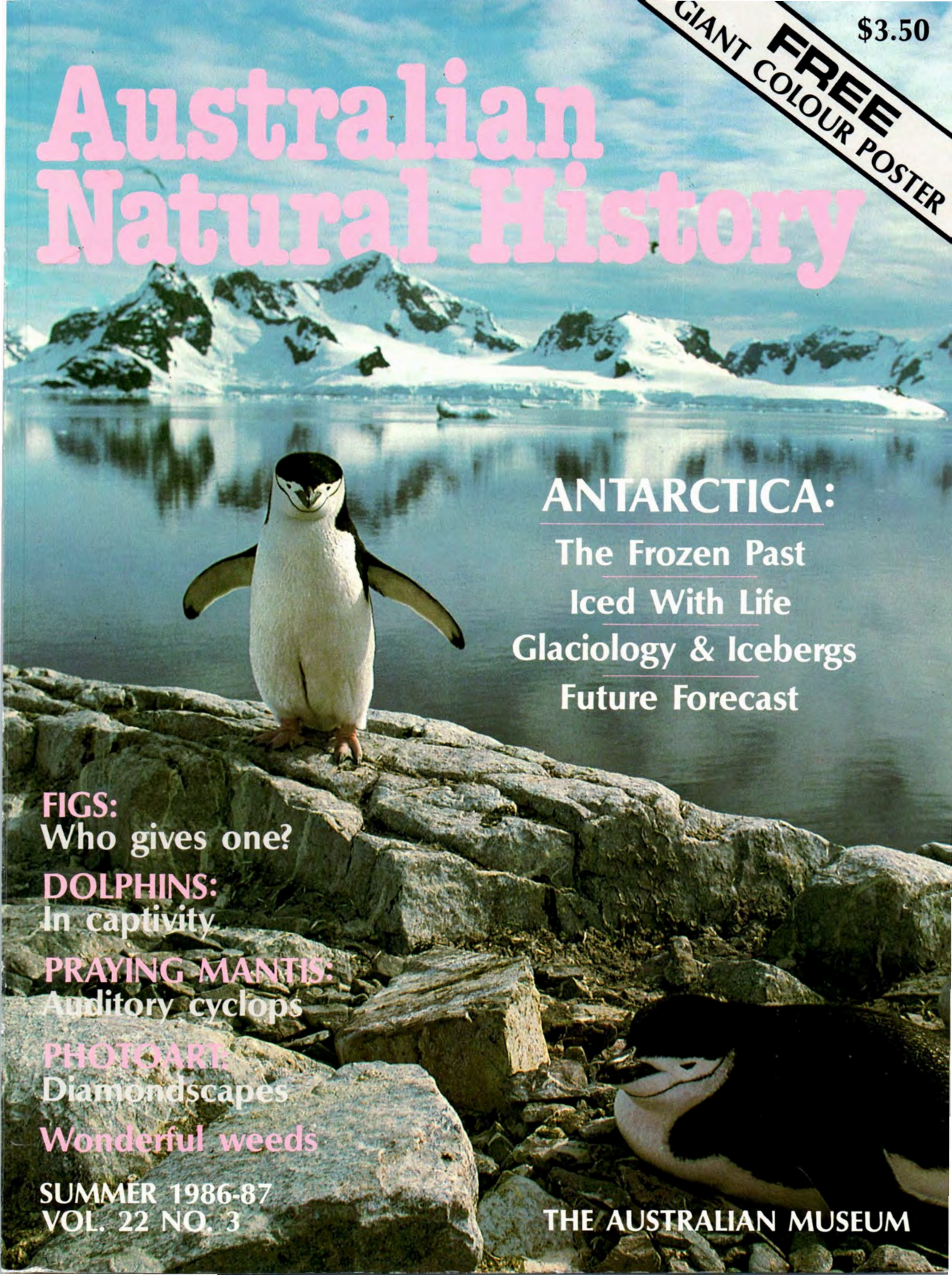
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At our barbies, don't be surprised to see the odd baza and drongo or just a few old bustards.

They're welcome to join us. So are you.

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Never been more serious.
You see, unlike the bazas and drongos that you probably associate with outdoor eating, ours have feathers. And the barbies aren't in backyards.
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N.S.W. has some extraordinary National Parks and they're there for us all to enjoy. But it wasn't always like that.
Which is why the Foundation was formed.

Who is the Foundation?

Our full title is the National Parks and Wildlife Foundation of NSW, a non-government organisation made up of members from every section of the community.
We do not run national parks. The management and control of national parks is carried out by the National Parks and Wildlife Service, a government body financed from State funds.
The foundation was instigated in 1970 when it became clear that the money required to save our unique animals and plants and to conduct research programmes was well beyond the reach of government funds.
In effect, we provide funds for the Service by financing projects jointly formulated by the Foundation and the Service. However, being a non-government body the Foundation reserves the right to make the final decisions on all expenditures.
It's what you might call the people's way of becoming involved in national parks – a way in which everyone can play a positive role in the preservation of our natural heritage.

And we don't sell 'Save the Drongo' stickers.

Not a bad idea really . . . But that's not our role.
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And if you've ever taken one of the many guided tours with a Seasonal Ranger during the holidays then you've see the Foundation's funds at work. Through this programme, countless thousands have discovered first hand the mystery and the magic of our National Parks. And it's totally funded by the Foundation.

Become a member and you're in for a treat!

NATIONAL PARKS & WILDLIFE FOUNDATION N·S·W

Australian Natural History

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The Editor welcomes articles or photographs in any field of Australian natural history.

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Front Cover

The delightful Chinstrap Penguin (*Pygoscelis antarctica*), aptly named for the black band that extends under its chin, is one of several species of penguins that breed in and around Antarctica. Photo: F. Gohier, Auscape.

EDITORIAL

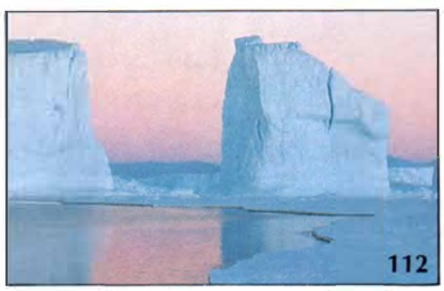
Antarctic Alliance

To commemorate the fiftieth year of the Australian Antarctic Territory, the bulk of this issue of *Australian Natural History* is devoted to Antarctica. The Antarctic Treaty was signed by Australia and 11 other nations in 1959, which neither supported nor denied existing territorial claims and its terms effectively meant that Antarctica could only be used for peaceful purposes.

With sovereignty no longer a stumbling block, it provided an impetus for the exchange of scientific information between these nations.

Australian scientific research in Antarctica is undertaken by the Hobart-based Antarctic Division (part of the Department of Science), for whose assistance in the production of this feature we are extremely grateful. It is refreshing to see that Antarctica, such a large and unique area of the world, is being utilised in the search for knowledge; but disappointing to see the overexploitation of marine life, which threatens the continued existence of many species. Ultimately, however, these problems should be overcome with the unity of the nations under the treaty.

—Fiona Doig, Editor



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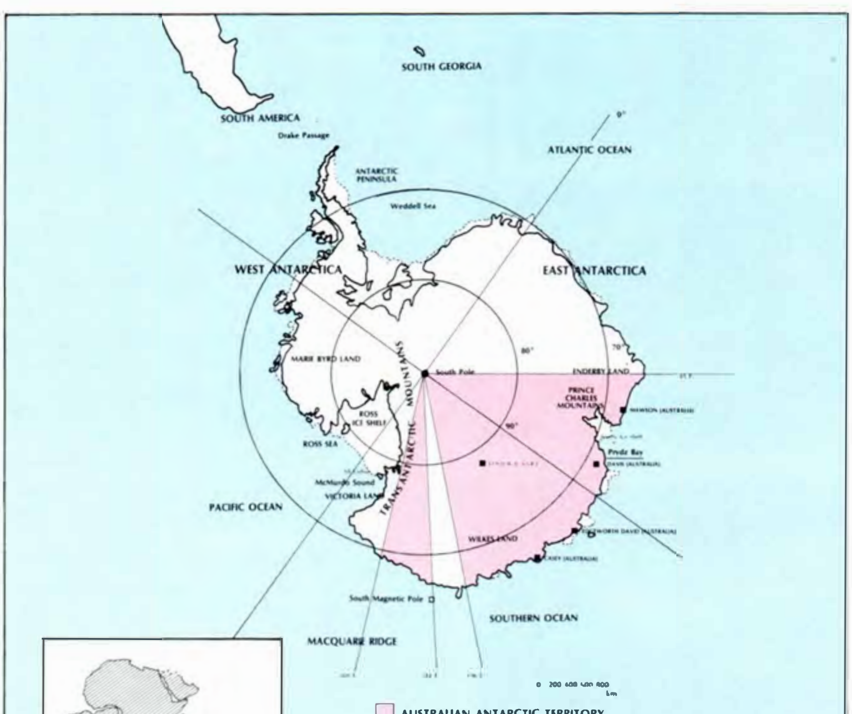
Antarctica's frozen past

Antarctica has not always been the way it now is. Over the last billion years it has been subject to three separate ice ages; it has been to the tropics; it has been covered by forest; and it has supported a considerable plant and animal population both onshore and offshore.

Antarctica is made up of two vastly different parts. The larger area, often called Greater or East Antarctica, consists of an old, stable landmass, most of which falls in the eastern hemisphere. It is roughly semicircular with the base of the semicircle marked by the Transantarctic Mountains, one of the world's greatest mountain chains, rising well over 4,000 metres in many

Life flourishes in Antarctica. Apart from the ubiquitous birds and seals, this cold, vast desert supports a variety of animals and plants not immediately obvious to the observer. The collection of articles here is arranged into Past, Present and Future sections. The Past and Future were written by Dr Patrick Quilty (Antarctic Division) and various authors were responsible for the Present. Drs Harvey Marchant and Rod Seppelt (both from the Antarctic Division) wrote the sections on present-day terrestrial and marine life; Fiona Doig (A.N.H.) compiled the information on seals and penguins; Ian Allison (University of Melbourne) wrote the article on glaciology; and Trevor Hamley has written about icebergs–those awe-inspiring floating giants of the polar regions.



Present-day Antarctica (above), and Gondwana (left) as it was 160 million years ago. The shaded area shows Antarctica's location in Gondwana.

Aerial view of rocky ice-free mountains along coast near Mawson.
Photo: G. Claridge, A.N.T.

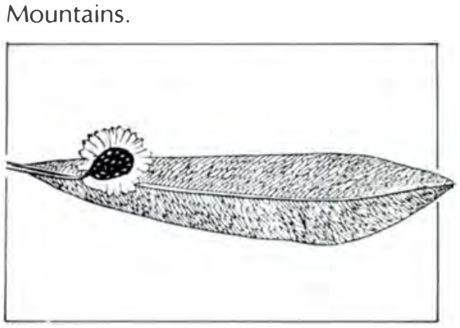
places. The Transantarctic Mountains provide spectacular scenery and the best insight into the geological evolution of the continent between 600 and 200 million years ago.

The rest of East Antarctica is much older and its history is gleaned from study of more scattered coastal outcrops, although one region, Prince Charles Mountains, is over 500 kilometres inland. Parts of East Antarctica are as old as four billion years–only 600 million years younger than the estimated age of the Earth. Other widespread areas have an age of 2.5 billion years.

West Antarctica, dominantly in the western hemisphere, is generally younger, most of its history falling in the 200–40 million year time interval. Rather than a single shield-like entity, West Antarctica appears to consist of a collage of continental fragments assembled during a long period when the Pacific Ocean floor was being subduced (swallowed) along the western side of the Antarctic Peninsula.

The geological history of Antarctica is assembled by studying the widely scattered outcrops which, although small in comparison with the size of the continent, are extremely well preserved and exposed as a result of glacial action. Thus the four billion year old terrane of Enderby Land is an ideal study area for rocks of that age, giving insights into the processes occurring at that time but not since. These processes can be researched here perhaps better than anywhere else on Earth.

Antarctica has not always been as isolated as it is today. It was once centrepiece of the supercontinent Gondwana and thus only a relatively small part of it was open to the sea—that part now marked by the Transantarctic Mountains.



Reconstruction of the Permian plant *Glossopteris*, found on Antarctica. (From R.A. Stirton, 1959, *Time, Life and Man: The Fossil Record,* John Wiley & Sons, N.Y.)

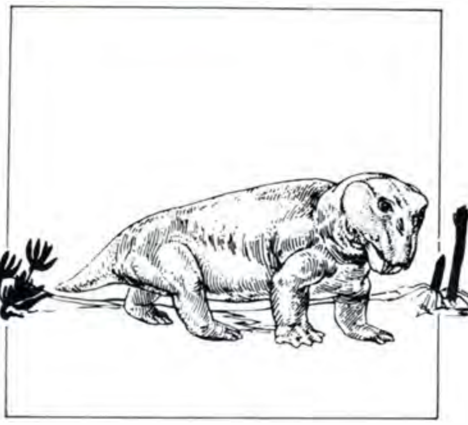
Gondwana seems to have remained intact until some 160 million years ago, when it started to break up by a series of well-documented steps. The first fragmentation began when a unit consisting of Africa and South America began to move northward, incidentally taking with it a piece off north-western Australia north of the Exmouth Plateau. At 125–128 million years, India—considerably larger than at present and often termed Greater India—departed, leaving a residual consisting of a still united Australia–Antarctica. Australia began its northward migration from Antarctica some 86–105 million years ago, initially moving only some 0.9 millimetres per year until 55 million years ago when it accelerated to the present rate of six centimetres per year.

The consequences of the fragmentation and movement were far reaching for life in Antarctica. Until 160 million years ago the Antarctic fauna and flora were similar to those in other parts of Gondwana. The fossils discovered in Antarctica, and their similarity to fossils elsewhere, are indeed important indicators that the continents had initially been conjoined. Nowhere is this better illustrated than in the case of the Permian plant fossil *Glossopteris* and the Triassic (230–195 million years) mammal-like reptile *Lystrosaurus* sp.

The best evidence for continental movements over the last 160 million years comes from the study of magnetic lineation patterns preserved on the sea floor. From these, it is a simple matter to recreate the relative positions of Antarctica and its related continents over that interval.

Other elements of the evolution, such as climate and glacial history, come from piecemeal scientific studies. The development of glaciation and its effects on seawater temperature has best been studied from cores taken by the Deep Sea Drilling Project south of New Zealand and Tasmania, the story having been modified by recent fossil discoveries on mainland Antarctica.

Some 40 million years ago (Late Eocene), extensive vegetation disappeared from Antarctica as some form of continental glaciation began. The flora that existed until then was probably similar to that also existing on other continents of the Southern Hemisphere, then much closer. This vegetation exists today, in a modified



Reconstruction of the Triassic mammal-like reptile *Lystrosaurus* found on Antarctica. Drawing: Margaret Colbert. (From E.H. Colbert, 1965, *The Age of Reptiles,* W.W. Norton, N.Y.)

form, in the Tasmanian cold-temperate rainforests. From this point on, with the exception of a couple of grass species, most of the Antarctic vegetation has been limited to lichen and moss.

At 25 million years ago (Late Oligocene) there is evidence in offshore sediments of iceberg-borne debris, indicating that sea-ice and icebergs existed then. At the same time there are indications of the formation of Antarctic Bottom Water (ABW)—a cold, dense, highly saline water, formed as a residual from freezing surface waters. Development of ABW marked a new phase of deep seawater history.

Conditions for the next ten million years (up to the Middle Miocene) seem to have been rather constant, perhaps only with gradual intensification of ABW. Glaciation developed to approximately its present level between 15 and six million years ago (Mid–Late Miocene).

A major debate is now developing on the events between six and 2.5 million years ago (the Pliocene). The prevailing belief is that this time interval was one of glaciation similar to the present but the discoveries, in the last two years, of fossil wood (3.5–2.5 million years old) at 86° S and the much publicised four to five million year old dolphin near Australia's Davis Station, provide evidence to the contrary. These discoveries suggest a major warm period in Antarctica over the interval 5–2.5 million years. Perhaps much of the continent was even covered by an extensive shallow ocean.

Life in Antarctica's Past

The history of Antarctic life is more poorly known than for any other continent, mainly because of its inaccessibility and extensive covering of ice. Once again, piecemeal fossil finds in Antarctic rocks as young as 210 million years suggest that life before then was virtually identical to that living on or around Australia at that time. On the Antarctic Peninsula there are many areas where excellent fossil finds are known but the faunal similarities, instead of being with Australia, are with New Zealand, Europe, South America or even Alaska.

Evidence of life elsewhere around Antarctica since 210 million years is scant indeed. Reworked pollen, spores and various marine dinoflagellates are known—particularly from studies carried out in Australia from glacial debris dropped at sea by icebergs but originating under continental ice.

Perhaps the best evidence is now coming from studies of plant and animal microfossils which have been reworked into sediments as young as 2.5 million years at high altitudes in the Transantarctic Mountains. These tell mainly of marine life at various ages over the last 100 million years. The fossils are included in glacial sediments and are under study by staff at Ohio State University.

The source of these microfossils is unknown but probably lies to the west of the Transantarctic Mountains from where they have been transported to their present site by glacial action. Again, in contrast to the prevailing belief, they suggest a story of warm conditions, with low tundra-type vegetation of conifers and angiosperms between 2.5 and 3.5 million years ago.

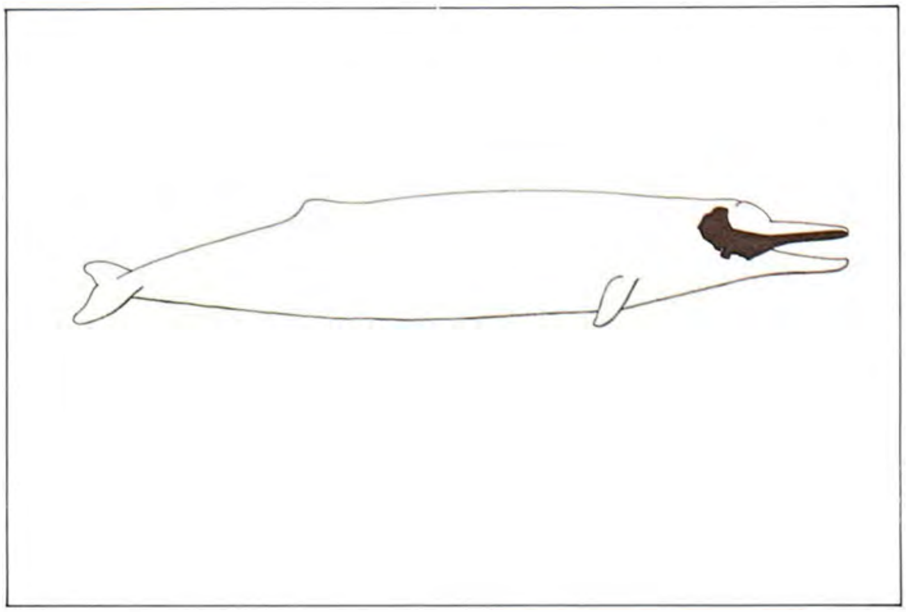
The fossil dolphin, which is currently being described and appears to be a highly derived dolphin, represents the only known fossil vertebrate in the last 40 million years of Antarctic history. Other fossil vertebrates include the skull and vertebrae of whales, found at the northern end of the Antarctic Peninsula, which probably date to around the 40 million year mark but is as yet undescribed; a plesiosaur from the Late Cretaceous of Seymour Island, off the northern end of the Antarctic Peninsula; and three jaw fragments of a primitive marsupial also from Seymour Island, which dates to about 40–45 million years (Late Eocene).

Our understanding of Antarctic life over past ages is in its infancy. But this is only because the continent is covered by a thick icy deterrent. If only we could simply peel back the icing from the Antarctic cake—just imagine what past secrets would be revealed! ☐

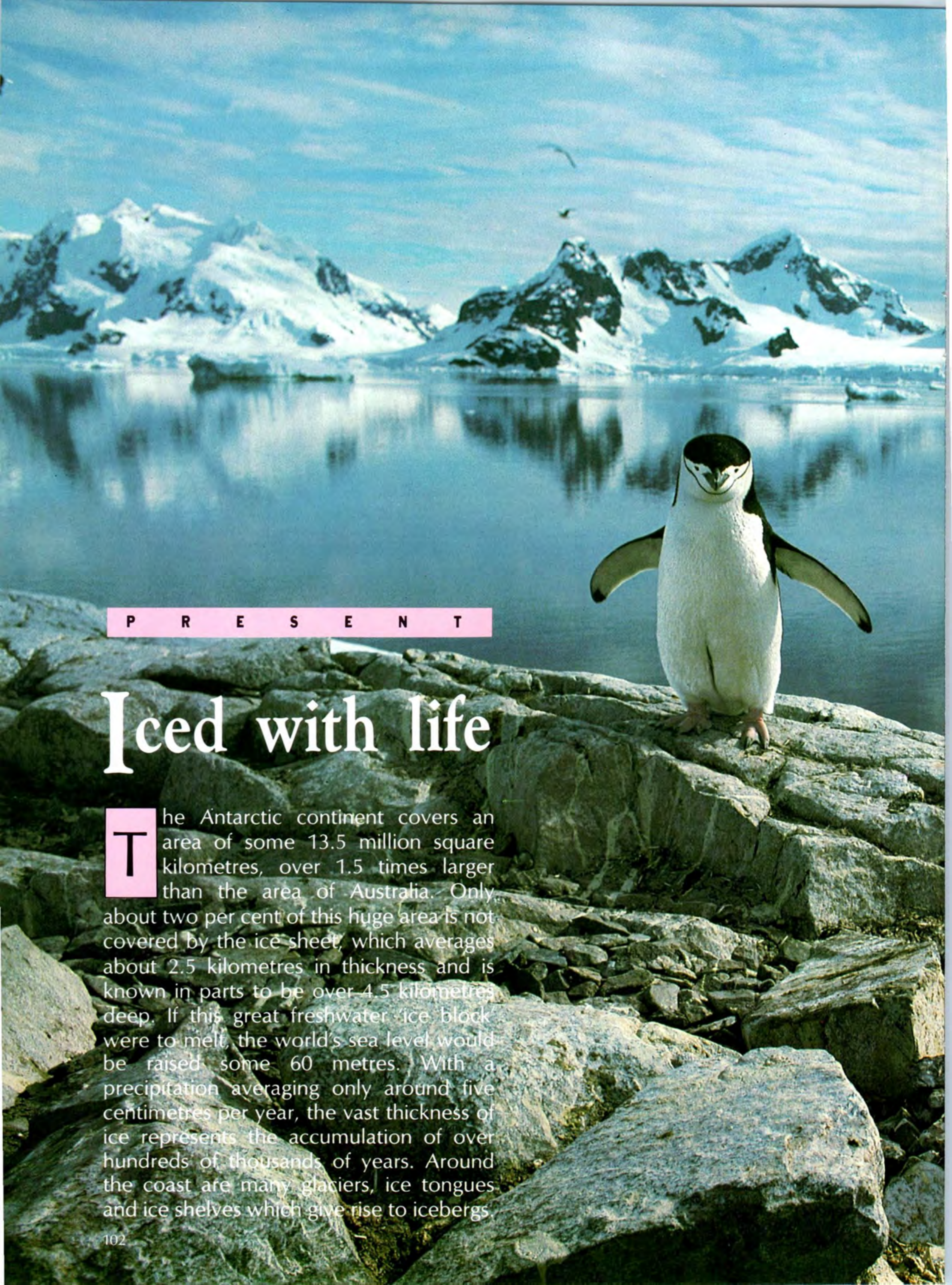
Age	Latitude
580 ± 20	14° S
520 ± 10	18° N
500	12° N
430	32° S
240	60° S
160	57° S
128	54° S
95	77° S
66	83° S
44	85° S
21	c. 80° S
0	90° S

Table of pole movements showing the latitude of the present-day south pole through the ages (millions of years).

Four to five million year old fossil of the Davis dolphin compared with the modern dolphin skull (*Tursiops truncatus*). Note the fossil dolphin has a narrower, more elongated skull. Photo: R.E. Fordyce.



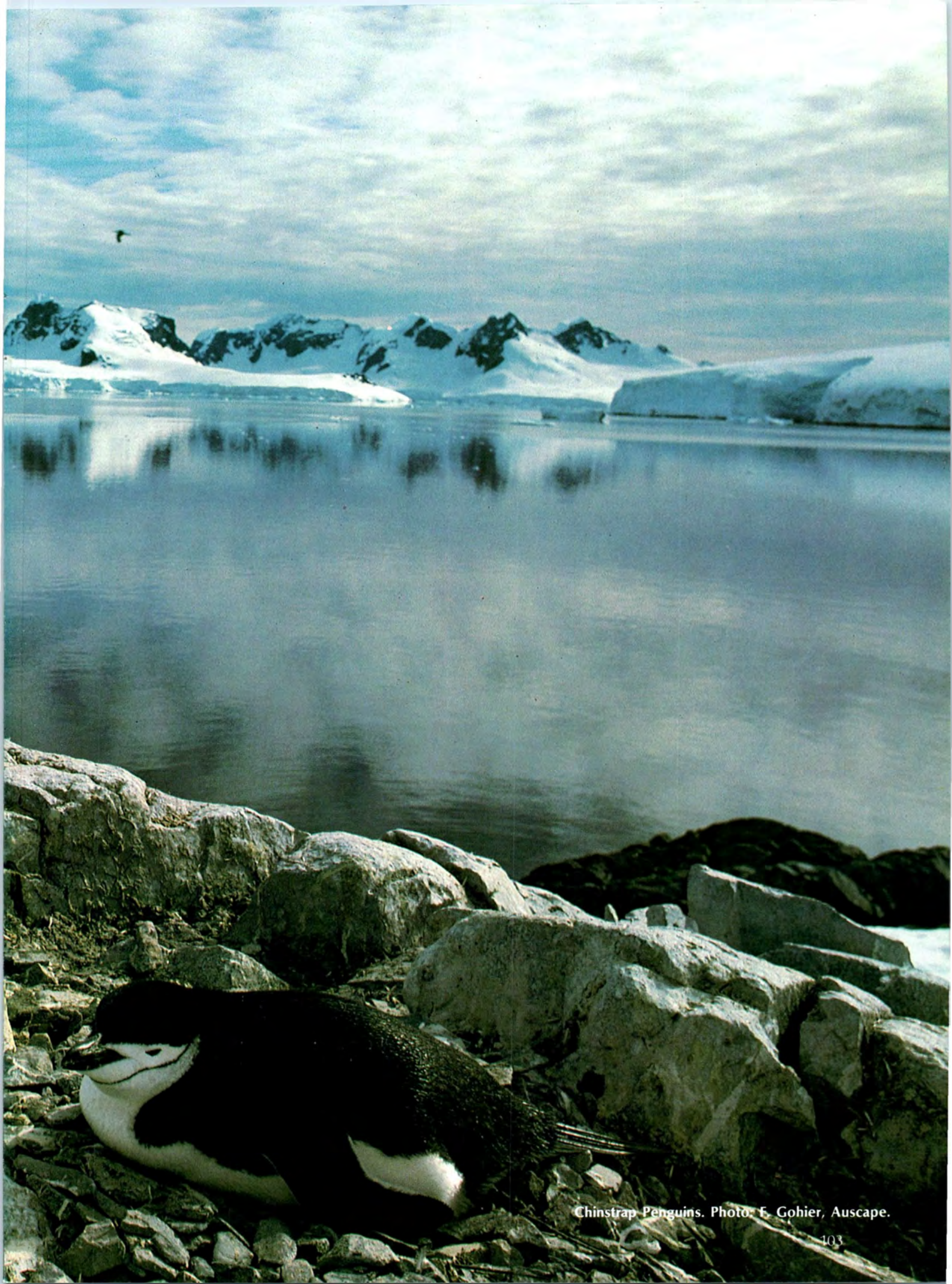
Reconstruction of the Davis dolphin showing the position of the skull. Drawing: R.E. Fordyce.



PRESENT

Iced with life

The Antarctic continent covers an area of some 13.5 million square kilometres, over 1.5 times larger than the area of Australia. Only about two per cent of this huge area is not covered by the ice sheet, which averages about 2.5 kilometres in thickness and is known in parts to be over 4.5 kilometres deep. If this great freshwater 'ice block' were to melt, the world's sea level would be raised some 60 metres. With a precipitation averaging only around five centimetres per year, the vast thickness of ice represents the accumulation of over hundreds of thousands of years. Around the coast are many glaciers, ice tongues and ice shelves which give rise to icebergs.



Chinstrap Penguins. Photo: F. Gohier, Auscape.

Temperatures in the brief Antarctic summer may sometimes reach 10°C near the coast, but they fall to -30°C or lower in winter. The dome-shaped ice cap rises steeply from sea level to over 4,000 metres. Temperature decreases rapidly with altitude. In summer inland temperatures are around -30°C and in winter as low as -70°C. The cold Antarctic air is extremely dry and the almost constant strong winds very desiccating. An enormous amount of fresh water is locked up as ice in Antarctica and is inaccessible to living things. In this respect Antarctica is a vast, barren, cold desert—the largest desert on Earth. Compared with the surrounding sea, which supports an abundance of life, the Antarctic continent is a harsh and virtually lifeless environment. However, a close look at the snow, rocks and soils reveals that the continent is far from lifeless.

Terrestrial Life

The terrestrial Antarctic flora is represented chiefly by algae, fungi, lichens and bryophytes (mosses and liverworts). Two flowering plants—a grass (*Deschampia antarctica*) and a small cushion-forming plant (*Colobanthus quitensis*)—are known from the northern part of the Antarctic Peninsula, which is climatically more akin to cold sub-Antarctic regions than the severe climate of truly continental Antarctica. Availability of free water during the short summer growing season is a major factor determining the distribution and abundance of the visible flora—the lichens, bryophytes and some algae. Many of the algae, fungi and some lichens are not obvious. Snow algae are common in coastal localities and in summer may proliferate to such an extent that the snow appears green or red. Algae and fungi can be recovered from almost all soils. Algae have been found growing profusely beneath small stones, chiefly white quartz, in what otherwise appears to be lifeless soil. Some algae and lichens occupy highly specialised habitats such as fissures in rock or even cavities in porous rocks where they are sheltered from the rigours of the environment. Moss tufts and turves are often encrusted with algae and lichens. *Nostoc*, a cyanobacterium (blue-green alga), is capable of fixing atmospheric nitrogen and converting it to a form able to be utilised by other plants.

Among the moss, lichens and soil exist microscopic animals such as mites, nematodes (roundworms), tardigrades (water-bears) and, on the Antarctic Peninsula, collembolans (springtails). All these animals feed primarily on algae and bacteria.

Many of the ice-free areas of Antarctica contain lakes. The water in some of these is of marine origin, the lakes being formed as the land rose following ice retreat. Antarctic lakes vary in salinity from fresh water to ten times that of seawater. Increasing salinity depresses the freezing point and some highly saline Antarctic lakes will only become ice-covered when the temperature drops below -20°C. Freshwater lakes, on the other hand, may have an ice cover that persists throughout the year.

Pink snow algae occurring near Casey Station. Photo: P.J. Gormly, courtesy A.D.

The lakes usually contain algae and other aquatic organisms, which are found in the water column or in the surface layer of bottom sediments. The hypersaline lakes are particularly interesting since they represent some of the few environments where organisms are exposed to water at sub-zero temperatures. The organisms inhabiting these lakes have been shown to remain active down to at least -14°C. To be able to survive and be motile in such an environment is quite remarkable as the organisms have to contend with extremely low temperatures as well as high salinity. The organisms, particularly algae, synthesise and accumulate chemicals to balance their internal osmotic concentration with that of the surrounding water and to maintain an environment within the cells in which complex proteins and other cellular constituents remain functional. The unicellular motile alga *Dunaliellia*, for example, synthesises and accumulates the sugar alcohol glycerol.

As well as being hypersaline, some of the lakes are stratified, that is they have a less salty layer overlying a saltier, often anoxic, bottom layer. The organisms living close to the boundary between the oxygenated and unoxy-

Lichens growing on a protected rock-face. Photo: H. Marchant, courtesy A.D.

genated water are often quite bizarre. One of these is a single-celled animal covered with a coat of bacteria. It is known simply as 'Eric' as it has not yet been formally described.

Oceanic Life

In contrast to the continent, the Southern Ocean appears rich with life. Seals and whales have been exploited for the last 150 years and, more recently, fish and krill. Phytoplankton, microscopic unicellular plants, bloom in the top 100 metres or so of the Southern Ocean during summer. These organisms are grazed by krill, in particular Antarctic Krill (*Euphausia superba*), and other zooplanktonic animals, which in turn form a large part of the diet of fish, squid, flying seabirds and penguins, some seals and the baleen whales. It is important to remember that the Antarctic animals such as seals, penguins and flying seabirds, which breed on the land or ice, get their food either directly or indirectly from the sea.

The phytoplankton is made up of many different sorts of unicellular plants. These vary in size from about one millimetre across to less than one thousandth of a millimetre (one micrometre). Organisms smaller than ten micrometres make up the bulk of the phytoplankton population and account for most of their productivity.

The most conspicuous of the phytoplankton are the diatoms, which are encased in a wall of often highly ornate silica. These beautiful organisms have captured the attention of scientists and their species composition, distribution and abundance in the Southern Ocean is reasonably well known. Other species of phytoplankton, called flagellates, bear one or more fine hair-like appendages, the beating of which either propels the organism through the water or moves water past it. Many of these flagellates are covered in fine scales, often delicately patterned and made from organic material or silica.

In the process of photosynthesis, phytoplankton, like other green plants, use the radiant energy of sunlight to convert carbon dioxide and water into complex organic molecules—the building blocks of living things. During winter the surface of the sea around Antarctica freezes to a depth of about two metres for hundreds of kilometres out from the coast. This formation of ice in March and April, which reaches a maximum in September, essentially doubles the size of Antarctica. With a layer of snow, the amount of light penetrating this sea-ice is only about one per cent of that falling on the snow. Remembering also that the Sun is low in the sky at this time of year, this means that the amount of light available for photosynthesis, and thus the amount of food available to grazing animals, is minimal during the winter.

Most large animals like birds and seals migrate when the food sources are low but many smaller organisms, unable to migrate, have adaptations which allow them to survive this food shortage. Laboratory research, for example, by the Antarctic Division, suggests that krill actually decrease the size of their outer skeletons when starved. This 'regression' occurs with their regular moult.

In spring, with the return of sunlight, the organisms that have lain dormant in the sea-ice proliferate greatly. For most of the year the majority of planktonic organisms are concentrated either in or immediately under the sea-ice. This community plays an important part in 'seeding' the water with life when the ice finally breaks up. During the summer when light is abundant, the phytoplankton bloom and may reach concentrations of millions of cells per litre.

Of the animals that feed on phytoplankton, Antarctic Krill are probably the most abundant. Mature animals may reach about six centimetres in length and look very much like small prawns. Krill are thought to be central to the Southern Ocean marine food chain, forming an important part of the diet of whales, some seals, fish, penguins and other seabirds.

Frozen lake with pressure cracks in the Vestfold Hills near Davis Station. Photo: G. Claridge, A.N.T.

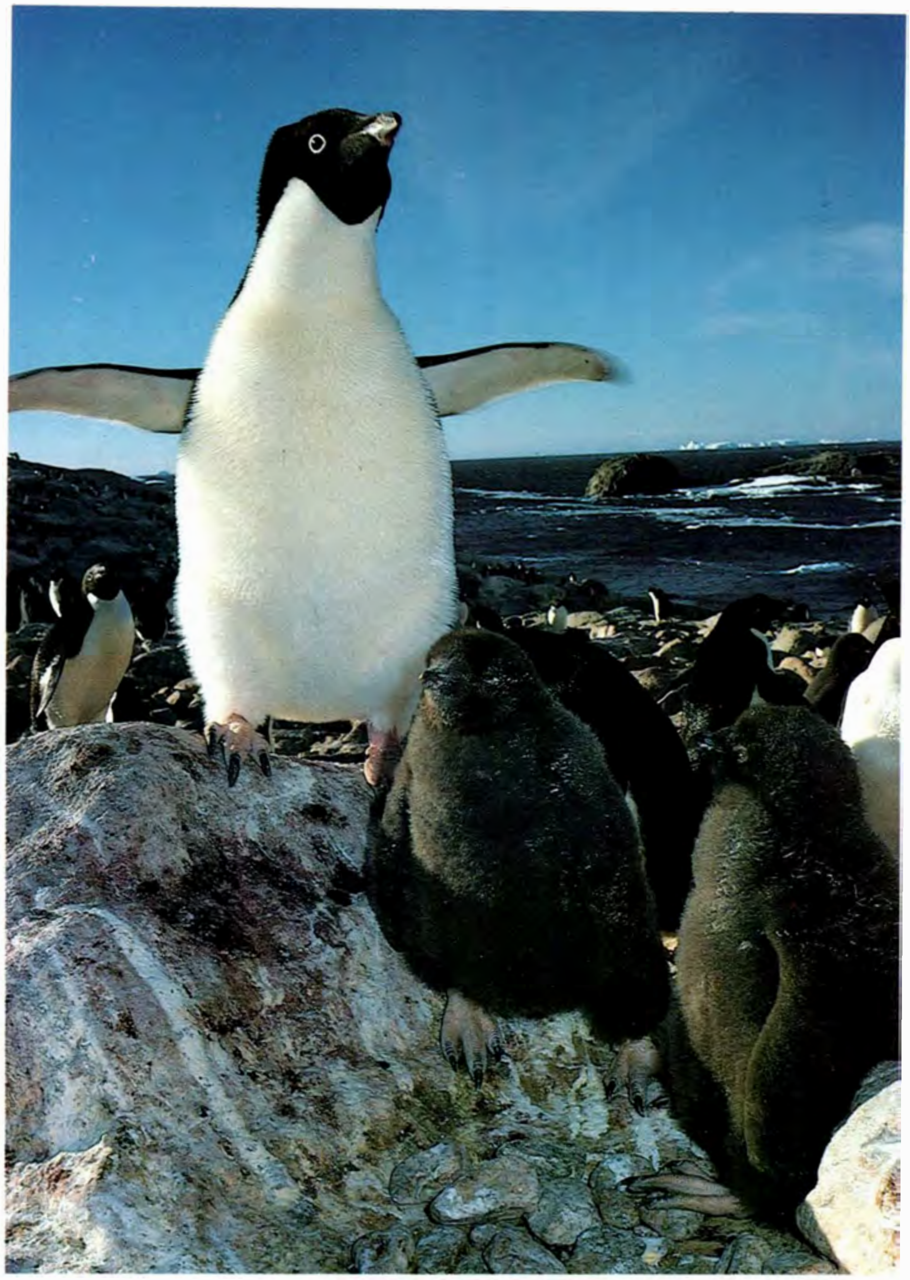
While Antarctic Krill may be the most abundant grazers in the area of the Antarctic Peninsula, the South Atlantic is the centre of abundance. Although they are not as widespread in the Pacific and Indian Ocean sectors of the Antarctic, they still maintain a high abundance but tend to be more localised. To illustrate this, one third of all commercial krill catches were taken from the Indian Ocean sector and two thirds from the South Atlantic.

There is considerable international concern that heavy fishing of krill could so deplete the populations in certain areas that animals depending on them for food could literally starve. Evidence from around the island of South Georgia indicates that Antarctic cod, too, have been severely overfished and, as a result, fewer and smaller fish are now being taken. In the first couple of years of harvest, starting from the summer of 1969–70, over 500,000 tonnes were taken and it is now estimated there is less than 5,000 tonnes total biomass now. There is similar concern for ice fish, which are also being overfished. These fish are particularly important from a research point of view, for they belong to the only vertebrate family (Channichthyidae) that lacks haemoglobin in its blood.

Those Transitional Animals

Many birds and seals are known to be predators of Antarctic Krill, but detailed information on the composition of their diet and how it may change seasonally and from year to year is as yet unavailable. Such information is necessary to relate the potential impact of krill and fish harvesting on bird and seal populations to the observed trends in their breeding numbers. To this end, the diet of Adelie Penguins (*Pygoscelis adeliae*) during the four months that they are ashore for breeding each summer, is being studied by the Antarctic Division. The aim of the study is to investigate the availability of food compared with what Adelies actually bring ashore in their stomachs to regurgitate as food for their chicks.

To anyone interested in Antarctic fauna, the penguins and seals are by far the common favourites. No doubt this is because they are the most readily seen and most human-like, and therefore the most endearing animals to be found there.



Adult Adelie Penguin with chicks. Photo: Ron and Valerie Taylor, A.N.T.

Penguins

During the long, dark winters, the Antarctic mainland is devoid of bird life. . . except for the Emperor Penguins (*Aptenodytes forsteri*) that arrive in early winter to breed on the sea-ice. They huddle together in tight groups of adults and chicks to keep out the bitter cold.

The Emperor is also notable for its diving ability. The deepest dive has been measured at 265 metres and the longest for 18 minutes. Most dives, however, are rarely more than 20 metres and usually only last a few minutes.

In spring, Adelie Penguins, with the prominent white rings around their eyes and reddish-brown beaks, commence their trek over the sea-ice towards their breeding grounds before this ice breaks up. The weather, now warming up, brings a variety of seabirds such as petrels, skuas, albatrosses and terns to the region. Predatory and scavenging birds appear over the penguin colonies, eagerly waiting to snatch up unguarded eggs and young chicks.

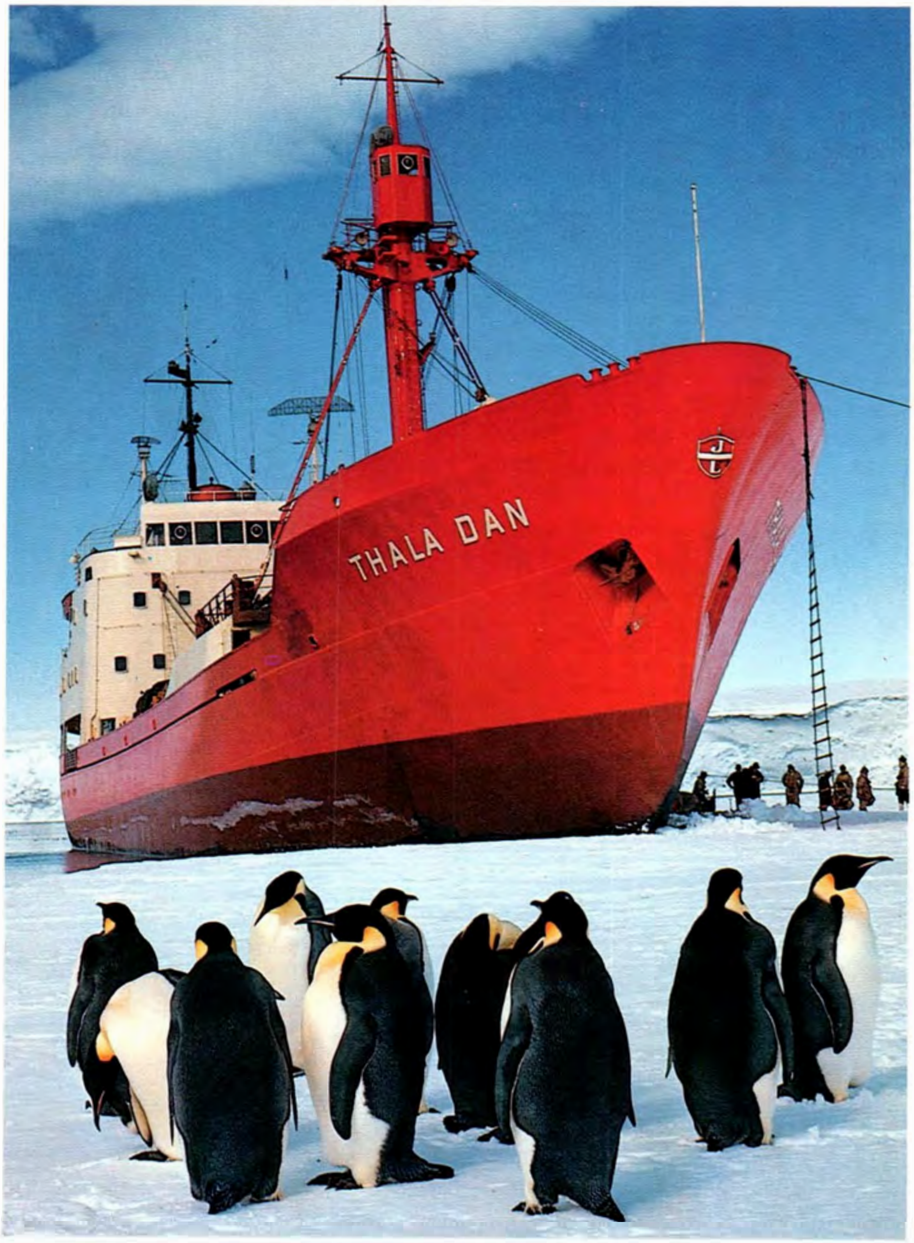
Other penguins that breed in Antarctica, and also on and around sub-Antarctic islands, include the Chinstrap (*Pygoscelis antarctica*), so called because of its conspicuous black band under its chin, extending from ear to ear; the Gentoo Penguin (*P. papua*) with its bright red beak and vivid yellow-orange feet; and the Macaroni (*Eudyptes chrysolophus*) which features a distinctive yellow crest plume.

Like all Antarctic birds, penguins have developed special adaptations to life in an extremely cold environment. The chicks have a thick down coat, eggs are closely brooded and insulation is provided by a thick layer of fat and a heavy down coat next to the skin. Air trapped between the skin and feathers insulates the bird so well that practically no heat escapes from the body. Snow falling on the penguin therefore does not melt and actually functions as another insulating layer. Emperor and Adelie Penguins can reduce their body temperature 4°C or more below normal resting temperature in order to conserve energy stores.

So well adapted are Antarctic penguins to extreme cold that keeping cool in summer can be more of a problem that staying warm. Temperatures during sunny summer days in Antarctica can soar well above freezing. To compensate, penguins can increase their heat radiation by several means. They can expose more surface area of skin by ruffling their feathers and spreading their wings, or by exposing the bare skin on their upper feet (the amount of which varies between species). In the former instance, the radiation from the body is heightened by the flow of warm blood into the blubber under the surface of the skin. In addition, they have developed a vascular heat exchange system between the arteries and the veins. Penguins often stand erect, panting with their beaks open to cool down.

The clumsy, ungainly appearance of the fat penguins makes them look quite 'unbird-like', yet they have evolved this body form as an adaptation to their environment and lifestyle. The fat does not just insulate against the cold. It is essential for their survival during the long bouts of famine. These periods of abstinence from food occur during moulting (when the lack of insulation prevents them from swimming and thus catching prey) and also courtship and incubation. All adult penguins go through a three to five week period of starvation during moulting. A particularly long period of

Adelie Penguins taking to the water. Photo: J. Schou, courtesy Oceanic Research Foundation.



Reception committee of Emperor Penguins meeting an Australian expedition. Photo: J. Bechervaise, A.N.T.

starvation is undergone by the adult male Emperor Penguin during courtship and incubation—three to four months—during which nearly half his body weight can be lost.

Fat is built up during the summer months when long days of sunshine enable penguins to gather the abundant supply of food almost continuously. Chicks become fat and mature quickly so that, by the end of summer, they become independent when the food supply is at its peak.

Because penguins are so well adapted to a life at sea, their stance on land seems awkward. Yet an Adelie Penguin can outrun a human on soft snow! To cross snow drifts, penguins 'toboggan', lying flat on their bellies and pull themselves along with their flippers. Their weight to wing-size ratio, while ideally suited to movement through water, is well beyond the mechanical limits of flight through air. But penguins do fly—at least under water.

Seals

The Southern Elephant Seal (*Mirounga leonina*) is the largest of all the seals. The inflatable proboscis, which is this seal's most outstanding feature and responsible for its common name, is only fully developed in males. It is an enlargement of the nasal cavity and, when breeding, can be erected into a bolster-shaped cushion on top of the snout, with its tip and open nostrils hanging down in front of the mouth. It may act as a resonating chamber—the roar of a large bull may be heard several kilometres away.

Commercial hunting for the Southern Elephant Seals' valuable oil began in the early 1800s and continued almost to the point of extinction. It was not until commercial sealing was banned in the middle of this century that populations began to recover.

Tasmanian archives are currently being meticulously searched by the Antarctic Division, which is compiling a census of seal populations during the 19th century. The journals of commercial sealers record the number of barrels of seal oil and blubber that were delivered to port, and calculations have been formulated to derive the number of slaughtered seals

Southern Elephant Seals haul out at various sites along the coast of Antarctica to moult during the late summer. Photo: H. Marchant, courtesy A.D.

A Weddell Seal swimming under forming sea-ice. Photo: R. Waterhouse, courtesy A.D.

required to provide a barrel of oil. The calculations are supported by measurements of fat thickness of Southern Elephant Seals living near Antarctic stations. So far it seems that one barrel of blubber produced one barrel of oil; that one male Southern Elephant Seal was equivalent to three barrels of oil; one large male equalled four barrels; and one cow equalled two.

That might seem like a lot of oil from one animal, but a Southern Elephant Seal bull can weigh between three and four tonnes and can store enough fat to last two months. In fact, weighing seals has been a problem, with cranes often being broken or buckled. A recently used device is a modified cattle-weighing platform, but its limit is two tonnes.

There has been much concern over the decline since the mid 1950s in Southern Elephant Seal populations. As part of an international program to monitor the global population of Southern Elephant Seals, the Antarctic Division in 1985 recorded their numbers on Macquarie and Heard Islands in the sub-Antarctic. Results of daily counts showed a decline of 50 per cent on Macquarie Island and 60 per cent on Heard compared to that of the mid '50s count. It is not yet clear whether this is a natural fluctuation or if it is a result of commercial fishing in Antarctic waters depleting the seals' food supply.

Southern Elephant Seals are capable of wandering thousands of kilometres from their breeding grounds on sub-Antarctic islands and little is known of their long-ranging life at sea. Until recently it was thought that, during winter, they fed only in the sub-Antarctic. However, winter research by the Antarctic Division involving analysis of Southern Elephant Seals' faecal and stomach contents (the latter achieved by induction of vomiting with apomorphine) might well disprove this. If local Antarctic squid and fish are present in the stomach and faecal contents, it will indicate that they do feed in Antarctic waters during the winter.

Little is known about the Ross Seal (*Ommatophoca rossi*), which is very solitary and almost unknown outside Antarctica. It is extremely rare. It has large protruding eyeballs for perception of movement in dimly lit waters under heavy ice. Squid form the bulk of the diet although fish and Antarctic Krill are also eaten.

The Weddell Seal (*Leptonychotes weddelli*) is the only coastal breeding seal in Antarctica. It is common at all continental stations. Long-term studies in population dynamics, which involve annual tagging of adults and pups, have been conducted at Davis Station since 1973. Other recent research includes diet studies through faecal analysis and work on underwater vocalisations.

Compared to other seals, the outer upper incisors and upper canines in Weddells are more horizontally positioned. This enables them to saw and abrade breathing holes in the ice to keep them open. Hence their teeth are extremely important and it is believed that dental problems commonly occurring in these seals by age eight or nine contribute significantly to their mortality. Abscesses or wearing of teeth can impair tooth function and seals have been known to get trapped under the ice, unable to open their breathing holes.

The most abundant seal in the world and certainly the most numerous in Antarctica is the Crabeater Seal (*Lobodon carcinophagus*). They breed on the sea-ice, close to the mainland, from October to November. After moulting in January, the coat is dark but it fades during the year, particularly in summer, to a pale creamy colour.

Family groups consisting of male, female and pup are commonly sighted on the ice, although it is unlikely that the male is the father of the pup. Rather, he is waiting for the female to come into oestrus. Numerous scars found on the male Crabeater Seal's head and neck are generally the result of his unsuccessful attempts to get close to the female before she is receptive.

Crabeater Seals have crenellated cusps on their teeth which form an efficient sieve when the upper and lower teeth rows are locked. This makes them well adapted to a diet of Antarctic Krill—they suck them in with their mouths open and then sieve out the water through clenched teeth.

Leopard Seals (*Hydrurga leptonyx*) are not particularly pretty—in looks or temperament. They have a long slim body with a disproportionately large and curiously reptilian-looking head, and are known for their vicious nature. They have been reported attacking scuba divers and one poor scientist had his foot snapped at by a Leopard Seal emerging through a crack in the ice and was chased for 100 metres! Leopard Seals eat many species of penguins and it is probable that, from their dim underwater world, they have taken the outline of a human to be that of an Emperor Penguin.

When they catch penguins under water, Leopard Seals shake them vigorously until the skin is loosened. They then eat them quickly, devouring the meat in only a few minutes. Besides penguins they also eat other birds (such as Giant Petrels), fish, squid and large amounts of Antarctic Krill, which they sieve in a similar way to Crabeater Seals. They will even attack young Southern Elephant, Weddell or Crabeater Seals, and will feed on any available seal or whale carrion.

The Whole Ecosystem

Indicative of the international concern about the Southern Ocean marine ecosystem has been the development of the BIOMASS progam (Biological Investigation of Marine Antarctic Systems and Stocks)—an international collaborative research program which investigates the structure and dynamics of the ecosystem to provide information for conservation and management of living resources. Nineteen nations have also signed the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). This international Commission, with its headquarters in Hobart, is concerned with the regulation of harvesting of marine animals, particularly Antarctic Krill and fish.

Further investigation into Antarctica as an ecosystem is vital to our understanding of the individual species that inhabit the area. It has recently been announced that Antarctic field science programs planned for summer 1986–87 will be the most extensive Australia has conducted for two decades. Research planned includes further monitoring of Southern Elephant Seal populations on sub-Antarctic Heard Island, and also studies of the active volcano there that has been observed erupting during the past two summers. Marine research will assess fish stocks and the distribution of Antarctic Krill larvae in Prydz Bay, between Mawson and Davis Stations. Further glaciological studies are also planned. Australia's continued dedication to Antarctic research paves the way to uncovering Antarctica's buried secrets. □

Understanding ice dynamics

The landmass of Antarctica is almost totally covered by a massive ice sheet of more than 12 million square kilometres—an area more than one-and-a-half times the size of Australia. Ice 'sheet' is really a misnomer because the average thickness is greater than two kilometres and in some places reaches a depth of over four kilometres. In wintertime, when the sea-ice reaches its maximum extent, an additional 20 million square kilometre band of pack ice surrounds the continent.

This ice sheet is not just a stagnant mass. Ice and snow are continually being added and removed. When snow falls to the ground in the Antarctic interior, it slowly becomes compressed into ice. Under the force of its own weight, this ice sheet moves inexorably towards the coast. It moves much slower in the centre of the continent because the slope of the ice sheet is minor. Movement there is only one to two metres per year. Towards the coast, the moving ice sheet breaks down into swift-moving ice streams and outlet glaciers. These move several hundreds of metres a year because they are sliding at their base as well as deforming internally. The overall movement towards the coast from the centre, however, is very slow, which means that the ice near the bottom of the ice sheet may actually be hundreds of thousands of years old.

Because the history of this ice is so ancient, core samples of it can tell glaciologists a great deal about the climatic history of the world. Glaciologists don't just study glaciers, they look at all forms of ice and snow that occur naturally. The ice on Antarctica is of great value to them because the continent's remoteness means the water from which the ice is formed is very pure. Small traces of any impurities are therefore readily detectable. Bound into the ice is a unique environmental record that stretches back beyond the start of the last ice age, more than 150,000 years ago. Studying the ice and its impurities, and the air that it trapped when it was snow turning into ice, provides a continual historic record of the Earth's climate as well as other variables, such as volcanic fallout and changes in atmospheric gas composition.

A small ice cap near Casey Station called Law Dome has been the site for taking many ice core samples. Snowfall rates here are high and, although the ice in the cores is not nearly as old as that from depth in the main ice sheet, each annual layer in the core is relatively thick. This ensures that a detailed climatic record can be obtained for the last several thousand years. Information on past atmospheric temperature can be provided by measurement of stable isotopes of oxygen in the ice. Past volcanic events are indicated by the analysis of the composition of the air trapped in bubbles as well as the measurement of electrically conducted impurities.

Concentrations of radiatively imported gases, such as carbon dioxide and methane, can be determined by gas composition analyses. It has been of great concern to climatologists for a number of years that the increase of carbon dioxide in the Earth's atmosphere, caused by the burning of fossil fuels together with deforestation, will create a 'blanket' effect around the planet. Known as the 'greenhouse effect', the carbon dioxide layer acts in the same manner as the glass in a greenhouse, which would result in an overall increase in world temperatures. The results would be disastrous. Melt of the Antarctic ice sheet would be intensified, causing the world's sea level to rise. When we consider that about 70 per cent of the world's fresh water occurs as Antarctic ice, the implications are serious.

Antarctic ice does not merely provide clues to climatic history, it actually has quite an influence over the global climate. Since sea-ice forms an insulating layer between the relatively warm ocean and the cold atmosphere, variations in its extent affect world weather patterns and climate at time scales that range from months to years. The ice sheet, however, interacts with climate on much longer time scales than sea-ice and changes in its extent also affect the global sea level. The Antarctic ice sheet and the much smaller Greenland ice sheet are remnants of huge ice sheets that covered a large proportion of the world's land surface during the last great ice age. Most of these ice sheets were in the Northern Hemisphere and disappeared after the end of the ice age from about 15,000 years ago. The Antarctic ice sheet has probably existed in one form or another over the last 20 million years. By investigating this ice sheet we can gain insight into the growth, behaviour and decay of ice sheets in general and even the possible causes of ice ages.

Another area of research in glaciology is that of ice sheet dynamics. Investigations are carried out on long, difficult oversnow traverses operating out of Casey Station. They are complemented by aircraft-supported studies of outlet glaciers. Such traverses have covered thousands of kilometres on the ice sheet, measuring essential, basic characteristics such as ice thickness and surface elevation, ice velocity and the rate of snow accumulation. These studies have been greatly aided by technological developments. It is now possible to continually sound ice thickness with special radars operated from ground vehicles or aircraft and to determine an accurate relative position on the ice sheet with reference to navigational satellites.

Meteorological data from remote, uninhabited regions is provided from automatic weather stations on the ice sheet and drifting buoys among the pack ice. Since the information is sent automatically via satellites, once these systems are established they need not be revisited. Automatic weather stations, positioned between the coast and interior of the ice sheet, have also been used to study wind formation. The surface winds over much of the ice sheet arise as a consequence of 'katabatic' cooling—the cooling of air close to the surface of the ice sheet causes it to become dense and thus fall, producing a wind that blows downhill.

Drifting data buoys operating within the pack ice in 1985 have shown that the sea-ice within this zone can be very mobile. Even near the Antarctic coastline, hundreds of kilometres in from the outer edge, where the pack ice is usually at its densest, the pack can be moving at speeds of up to 60 kilometres per day. Previously it was thought that the pack was slow moving and generally formed by freezing of the ocean locally. The outer edge slowly advanced as the ocean cooled and ice formed on its surface with the progression of winter. Now it has been shown that much of the ice is formed in the colder waters further south and moved northwards so that the overall extent is controlled as much by the sea-ice dynamics as by the sea surface temperature.

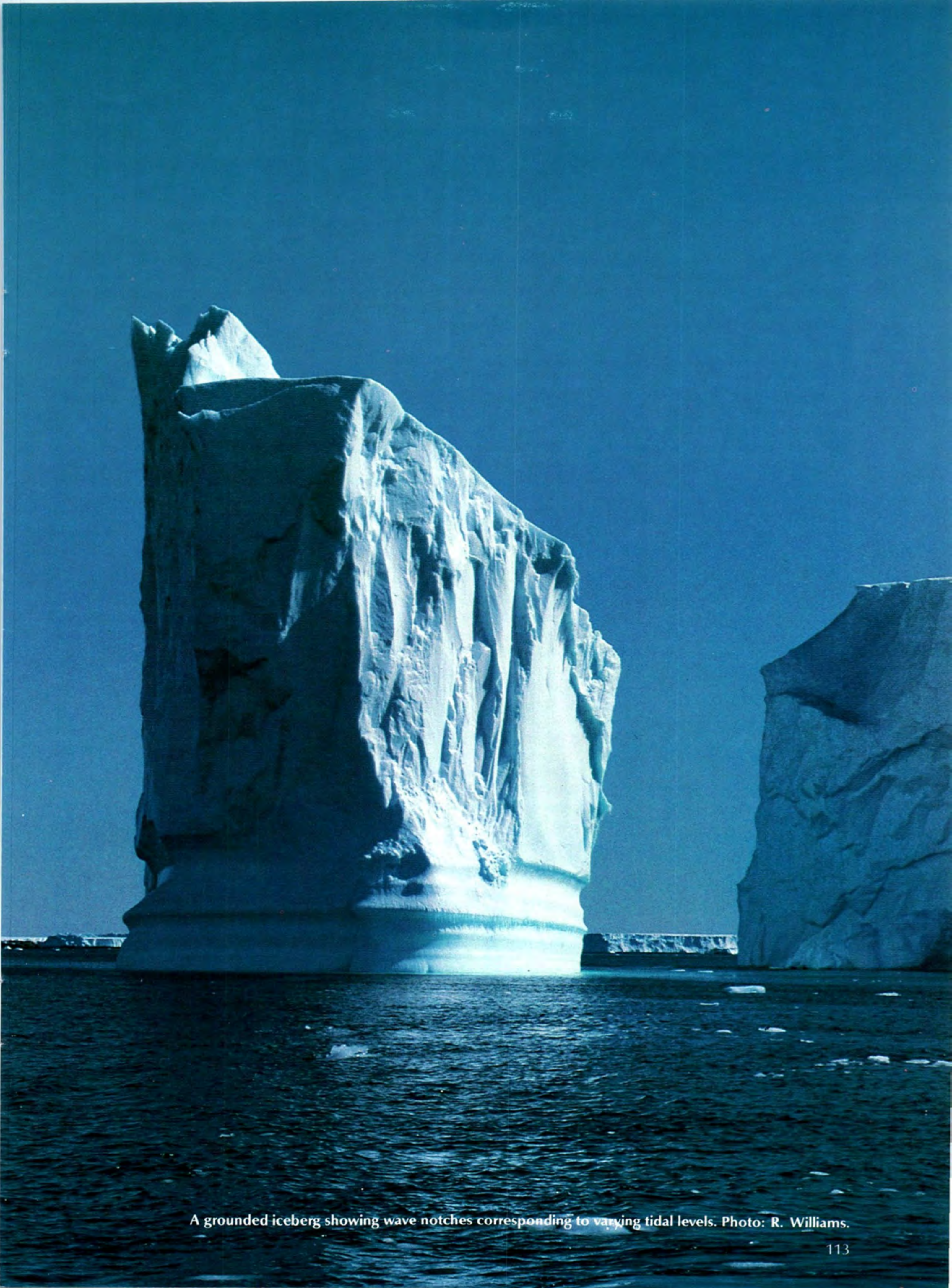
Much of what we now know about Antarctica has been gained by studies on the ground and from aircraft. Over the past decade or so, remotely sensed data collected from a few satellites that cover parts of Antarctica have given the first complete views over large areas of the continent. Data has been collected at visible and other wavelengths. New and sophisticated remote sensing systems are being fitted to polar orbiting satellites to be launched in the next five to ten years. They are expected to provide a wealth of new data covering the whole of the Antarctic ice sheet for the first time, and providing the impetus for major new studies of this remote region of the globe. □

PRESENT

Floating giants

Icebergs originate from the calving events of floating ice at the seaward boundary of outlet glaciers and ice shelves. The thick ice of the Antarctic interior, flowing constantly outwards under its own enormous weight, converges into fast-moving outlet glaciers at the continental margin. As the ice protrudes into surrounding waters, the effect of buoyancy causes further spreading and thinning, forming floating ice tongues or ice shelves. Bending stresses, caused by waves and swell, soon extract their toll and icebergs are born.

Since the days of the earliest polar explorers, Antarctic icebergs have thrilled writers and photographers, terrorised mariners, fascinated civilian and military engineers, and tempted tourists, yet they've all but been



A grounded iceberg showing wave notches corresponding to varying tidal levels. Photo: R. Williams.

ignored by scientists until relatively recent times.

Icebergs (huge frozen masses of fresh water) are a common feature of both Arctic and Antarctic oceans. However, Antarctic icebergs are generally much larger, colder and more numerous than their Arctic equivalents. For example, whereas a 'very large' Arctic iceberg might measure 750 x 350 x 30 metres in length, breadth and thickness, a 'very large' Antarctic iceberg could measure 1,500 x 750 x 400 metres. With these dimensions, it would weigh up to 400 million tonnes—almost the entire annual water consumption for the city of Melbourne—and have a freeboard (height above water) equal to that of a ten storey building (freeboard for tabular icebergs being typically 15 per cent of their total thickness). Of all the icebergs in the Southern Ocean, those over 1,000 metres in width ('width' being the maximum horizontal dimension at waterline) comprise only about four per cent by count, yet 51 per cent by volume. Most Antarctic icebergs, however, are less than 500 metres in width, with the largest numbers (more than a third of all sightings) being in the size range of 50 to 200 metres.

Imagine the mixture of terror and enchantment that must have 'shivered the timbers' of early explorers, who, in flimsy and sometimes ill-equipped sailing vessels, dared to probe Antarctic waters in search of the 'southern continent'. One of the earliest of these explorers, to whom polar regions were not unfamiliar, was Captain James Cook. For Cook, the hazards of sailing among icebergs were not taken lightly. On his second voyage of discovery (1772–1775), Cook (in the HMS *Resolution*) circumnavigated the globe at an approximate latitude of 60°S, crossing the Antarctic circle on three occasions but without actually sighting the mysterious continent they had hoped to discover. He notes:

"...About noon came close under the above mentioned island of ice and were by a kind of indraught or some means or other insensibly sucked so near that we had scarce any probability of escaping being drove against it which must have been inevitable destruction and it was equally as unknown almost how we got off without and we scarce got a cables length from it..."

In the 20th century, icebergs have occasionally created news. The sinking in 1912 of the HMS *Titanic*, for example, was caused by the collision with a relatively small iceberg off the coast of Newfoundland, Canada. The staggering loss of 1,513 lives, making it one of the worst maritime disasters in the history of mankind, jolted maritime authorities into organising the first 'International Convention for Safety of Life at Sea'. This resulted in the introduction of safety measures (today taken for granted), such as a place in a lifeboat for each person embarked, lifeboat drills to be held during the voyage and a compulsory 24-hour radio watch.

Iceberg showing wave notches. Photo: courtesy Oceanic Research Foundation.

Distribution and Dissolution

A traditional method used to collect information on iceberg distributions during Australian National Antarctic Research Expeditions has been shipboard observations, both visual and radar, within a 12 nautical mile radius of the ship. Iceberg sizes are estimated and the numbers within designated size categories recorded in a logbook with latitude, longitude, water temperature, sea-ice concentration and any other relevant information. Detailed size measurements are gathered for tabular icebergs and the more northerly pinnacled icebergs. In these cases iceberg height and width are measured trigonometrically, using a sextant to obtain the subtended angle, in conjunction with a distance obtained by radar.

Satellite surveillance is at present not capable of monitoring iceberg movement and decay, except for gigantic icebergs larger than say ten kilometres in width. Typical problems incurred using satellites include obscuration by cloud, difficulty in distinguishing between sea-ice and icebergs, limited resolution and coverage, and difficulty recognising the same iceberg(s) again after breakage or rollover has occurred.

The mechanisms by which freely floating icebergs are reduced from large to small are as yet not fully understood, although they are known to be a combination of breakage, calving around the edges and subsurface melt. Melt plays a relatively minor part in the dissolution of large icebergs although it becomes the major mechanism in the dissolution of smaller, blocky icebergs. The speed of subsurface melt is easier to appreciate when you realise that typical Southern Ocean water temperatures are around +1°C. Melting of the above water portion by the Sun's direct radiation also has a negligible effect on iceberg dissolution. Generally, the meltwater so produced percolates down into snow and firn (compacted snow) layers and simply refreezes.

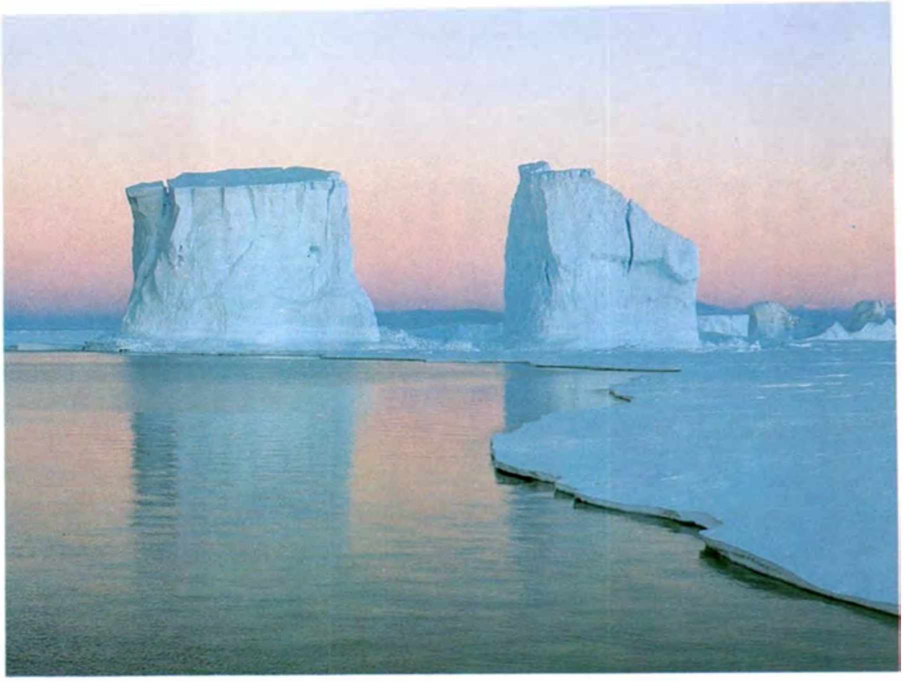
The effect of rollover tends to enhance all of the above dissolution processes, particularly subsurface melting. Icebergs have been observed to roll over abruptly, although the spectacle is one that few are privileged to witness. Rollover will occur when, after breakage and melting, the thickness of an iceberg becomes less than or equal to the width. Sometimes icebergs may 'turn turtle' (180°), although a roll of less than 90° is more common. Rollover is the primary factor responsible for pinnacles—caused by thrusting edges or corners high into the air. When an iceberg 'rolls' it reveals a characteristic smooth and rounded underwater shape. Normally a wave notch is visible, marking the position of the previous waterline. Sometimes the waterline may be stained green from algae, although this is uncommon. Rollover can also identify those icebergs that have sediment layers embedded in the icemass. Particle matter in the ice and sediment from the sea floor can give rise to the appearance of black or dark green icebergs.

Large tabular bergs, freshly calved from glaciers or iceshelves, may last for a period of years if they either run aground or remain in waters close to the Antarctic coast. Here the surface water is extremely cold, which minimises melt. More importantly, however, the presence of sea-ice dampens the swell and produces a flat sea, devoid of wave action. This environment is one in which there are minimal bending stresses or erosion forces, responsible for the dissolution processes of breakage and calving.

The deep draught (portion below water) of Antarctic icebergs causes them to drift in the direction of average current movement. Icebergs, unlike sea-ice, are not greatly affected by winds or irregular surface currents. Bergs will simply rip through sea-ice like tissue paper if the overall current is at variance to the top few metres of the watermass.

Large tabular icebergs are known to have travelled tens of thousands of kilometres in westerly moving currents of Antarctic coastal flow (that is, around the coast over the continental shelf). Icebergs tracked by satellite transponder have shown typical speeds of up to half a knot.

Size distributions of icebergs flowing in the easterly-moving Antarctic circumpolar current have been studied statistically to determine life expectancy. Analysis has shown that for icebergs less than 1,000 metres in width a 'median-life' of about 0.2 years may be expected. (The term median-life refers to the time taken for half of the icebergs in *one particular size category* to be reduced to half of their original numbers by breakage into smaller sizes.) This means that a medium iceberg of 350 metres width could be expected to last between six months and two years before all traces of the original berg are destroyed. Estimates of life expectancy are necessarily imprecise because of the fact that icebergs, like human beings, come in all manner of consistency, quality and shape.



An iceberg near the Mawson ice edge that has recently split into two large pieces. During the next major storm, each piece may roll over on its side, possibly fractioning again into smaller pieces. Photo: H. Marchant.

Recent studies of Antarctic iceberg distributions have shown that the common northerly limit seems roughly linked to the average maximum extent of Antarctic sea-ice at about latitude 59°S. One might be forgiven, however, in thinking that the Antarctic convergence (or polar front), at latitude 51°S in the Australian region, would have delineated the absolute northern boundary of icebergs, since this is where a sharp temperature difference occurs between the cooler waters of the Southern Ocean and the warmer oceans of mid latitudes.

Sightings of icebergs north of the Antarctic convergence are relatively rare, however on 15 January 1982, two icebergs were sighted at 48°S, 111°E—only about 1,800 kilometres south of Perth. These icebergs were almost certainly the remnants of a gigantic iceberg and may have come from as far away as the Weddell Sea, more than 13,000 kilometres to the west. Icebergs at these latitudes were well known to the captains of the clipper ships who, after rounding the Cape of Good Hope on their way to Australia, would have had to weigh up the risks of steering further south to pick up the strong westerly trade winds *versus* the increased likelihood of disastrous encounters with icebergs.

Reflections in Ice

Perhaps on the next occasion you find yourself lounging in a reclining chair and sipping a cool lemon-squash, you might like to reflect, finally, on why the ice blocks in your drink have so much less freeboard than that observed for tabular icebergs.

The answer to this question is twofold. First, the iceberg is floating in salt water and therefore has slightly more buoyancy. But second, and more importantly, most of the above-water portion of a tabular iceberg is in fact snow or firn with a density much less than that of ice. A typical thickness to freeboard ratio for tabular icebergs is about 6 or 7:1 although for irregular icebergs this ratio is more likely to be about 2 or 3:1.

Icebergs are a fascinating phenomenon and a surprising amount can be learned about them by simply watching an ice cube melt and roll over in a glass of water! ☐

Formulating the future


Heading towards the Antarctic coast. Photo: P. Gill.

Many would like to see the Antarctic set aside, one way or another, as a continent free from development or exploitation of any kind.

Humanity's history of discovery, exploration and eventual exploitation has seen waves of people move from their native land to inhabit what were for a long time seen as uninhabitable regions. Two hundred years ago, white man moved into Australia shortly after moving into southern Africa. We are now showing signs of moving into space, the deep sea and Antarctica.

What are the possible resources available in Antarctica? Although little hope of exploitation exists realistically in the near future, some possibilities do exist in the medium to long-term future, particularly fisheries (being tentatively developed now), ice (as a water source), minerals (including hydrocarbons), tourism and what I term serendipity—the unexpected results of research.

In discussing the future it is also worth considering the impact on Antarctica of mankind's activities elsewhere on the globe.

Ice as a Water Source

Antarctica contains 25–30 million cubic kilometres of ice, enough to raise the sea level by some 70 metres should it melt. It sheds some 12,000–14,000 cubic kilometres per year as icebergs, with a water purity far in excess of normal distilled water.

There has been much popular speculation about the potential role of icebergs as a water source, most centring on the concept of towing icebergs to the site of water need.

A 30 million tonne iceberg is at the larger end of the medium-sized iceberg range and contains about .04 cubic kilometres of ice, enough water to serve the needs of a city the size of Perth for seven to eight weeks in summer. That amount of water is worth some $14–15 million in Perth or $18 million in Adelaide. Both cities perceive a need for additional water for both water supply and quality control. The iceberg yield from Antarctica could theoretically provide the total water needs for 50,000 such cities.

Recent research has suggested that icebergs of this size do not present an insuperable obstacle for towing. However, the same research suggests that such an iceberg would survive less than two months north of 60° S because it would *dissolve* (as opposed to melt) in seawater as it was towed.

An alternative means of moving such water involves wrapping icebergs in fibre-reinforced plastic. A 30 million tonne iceberg has a surface area of approximately 1.5 square kilometres, about 40–50 times as large as a football oval. There are no technical reasons why such an iceberg should not be wrapped completely in a plastic envelope. Modern trawling techniques could be used to lead a plastic sheet beneath an iceberg 150–200 metres below sea level.

If an iceberg can be wrapped successfully, the towing need is significantly reduced and new advantages become obvious. Nature would provide much of the transport via ocean current systems. Towing would only be needed to move it from one ocean current system to another and to a final resting place where utilisation would proceed. The wrapped iceberg would need to be identified and to have a satellite tracking device installed.

The development of an 'iceberg envelope' would mean that iceberg water could be transported, largely by nature, to such areas of the world as north Africa or California. The value to north Africa would be in providing a reliable basis for agriculture.

A floating envelope would get over one of the other major hurdles in the iceberg utilisation concept—that of grounding on the continental shelf. Once far enough north, the ice in the plastic wrap would melt. The envelope of plastic would then flatten on the sea surface, reducing the draught of the body.

Another useful feature of this concept relates to electricity generation. A body of water or ice at 0°C floating in a sea of 20°C or more allows for power generation simply because of the temperature difference. One authority suggested that the power generated would pay for the cost of the entire operation and that the water would be free.

The time scale? Who knows? But a 10–15 year lead time seems a reasonable guess.

Fisheries

Antarctic waters are perceived to contain the world's largest undeveloped protein source—Antarctic Krill (*Euphausia superba*)—a crustacean that grows about six centimetres long. In addition, fin fish fisheries exist for a group of species often lumped together as 'Antarctic cod'.

The amount of krill living around Antarctica is poorly known but most estimates are in the range of 600–1,000 million tonnes. Several years ago, it was estimated that an annual catch of 140 million tonnes may be sustainable. This figure was obtained by calculating the average amount taken by a baleen whale each year and noting the difference in the baleen whale population size before whaling began and now. It was also based on the assumption that krill are short-lived (two to three years) species.

However, it now seems that there are severe weaknesses in both bases for the calculation. Firstly, since krill-consuming whale populations have decreased, it is highly probable that other predators (likely candidates being Crabeater Seals, *Carcinophagus lobodon*, and penguins) have proliferated to take advantage of an expanded food source. Secondly, recent laboratory studies suggest that krill can live longer—between seven and 11 years. This means that the sustainable annual harvest may be as few as two to five million tonnes per year, although most estimates are now around 25 million tonnes.

Antarctic Krill fishing has been attempted in Antarctic waters by nine nations. Russia and Japan are the major krill takers. Russian fleets were taking up to 550,000 tonnes per year in the early 1980s, but had decreased to 370,000 tonnes in the 1985–86 season. Japanese fleets catch about 50,000 tonnes per year and operate on a commercial basis.

Krill needs to be processed almost immediately as it rots quickly. The 'meat' must be separated from the exoskeleton or shell, otherwise the high levels of fluorine in the shell contaminate the 'meat'. Techniques for speedy separation have been developed and now operate satisfactorily.

In addition to the protein-rich krill 'meat', which may be used as a protein supplement in bread and cattle food; as a fish culture food or fishing bait; as tinned krill tails and more recently as packaged krill in Japanese supermarkets, processes have evolved for separating valuable carotenoid pigment from the shell. The pigment is the only yellow food dye approved by the United States Food and Drug Administration. Whatever the uses, Antarctic Krill fishery has begun and seems to be here to stay.

Because of the emergence of an Antarctic fishery, Antarctic Treaty nations in the late 1970s negotiated the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) with its headquarters in Hobart. The Commission (also CCAMLR) meets each year in Hobart to discuss relevant matters such as potential catch limits, exchange of fishing statistics and other issues raised as the Convention evolves.

Fin fish are taken on a regular basis around the French possession of Kerguelen Island and around South Georgia. Fishing has proceeded to the stage where concern has been expressed for the population of *Notothenia rossii* (an Antarctic cod) around South Georgia. At the September 1985 meeting of CCAMLR a ban was agreed to on fishing for *N. rossii* within 12 nautical miles of South Georgia. The total catch of *N. rossii* from the Southern Ocean has declined from almost 400,000 tonnes in 1969–70 to 1,315 tonnes in 1984–85. By far the greater part of this catch has been from the South Atlantic area.

Minerals

Antarctica has an area of 13.5 million square kilometres, almost twice the area of Australia. There is no reason to suggest that it has fewer minerals than any other continent, in fact rock associations in Antarctica, which are known elsewhere in the world to have mineral significance, have been mapped. However, no economic mineral deposits have as yet been identified.

Several factors militate against successful search for Antarctic mineral resources, the most obvious being the fact that the continent is 98 per cent ice-covered to an average depth of 2,500 metres. However, many types of minerals that may have originally existed would have been removed through long periods of glaciation. These include beach sands, residual minerals such as bauxite, and deep leads such as for gold or diamonds.

Indications of minerals that may lead a prospector to a prospect are virtually non-existent as weathering profiles and scattered traces are also removed by glacial activity. Any mineral search must therefore be directed to the primary ore in the first instance.

In addition to these problems, economics, the need for stringent environmental protection measures, technological and logistic problems, and the need for a regime allowing for secure tenure of title (which is currently under negotiation) are severe hindrances to commercial mineral exploitation.

The Dufek Massif is a large layered intrusive in the Transantarctic Mountains that has been identified as a rock type with potential chromite (ore of chromium) association, and the general geology of the Antarctic Peninsula is consistent with a copper ore association. In neither case has the suggested ore association been proved at a level that would be economic anywhere else in the world.

Hydrocarbons (oil and gas), especially offshore, are often perceived to be the major possible exploitable resource. The world has some 35 years supply of oil and 65 years supply of gas at present usage rates. With the current glut of oil, the oil price has fallen dramatically over the past year, but supply pressures are thought likely to tighten again by the 1990s.

The areas offshore of Antarctica have been subject to several scientific seismic programs, indicating that the Antarctic margin commonly has at least 5,000 metres of sediment. This would be seen as highly prospective if it occurred elsewhere in the world.

Scientific drilling in the Ross Sea and surface sediment coring in the Antarctic Peninsula region have given good indications that hydrocarbons have been generated by maturation of organic matter in Antarctic sediments, although that in the Antarctic Peninsula is probably in a very localised, high heat-flow area and thus means little.

There has been no systematic search for hydrocarbons, no structures have been identified, and no exploration drilling has been performed. In fact Antarctic Treaty countries have, since 1975, maintained a moratorium on exploration and exploitation of minerals in Antarctica while a regime to govern such activities in the future is negotiated. Negotiations on an Antarctic Minerals Regime began in 1982 and are still continuing.

The technological problems associated with Antarctic oil production would be major and one cannot foresee hydrocarbon production within the next, say, 30 years. The prospects for Antarctic gas exploration are even more remote.

Tourism

Antarctica must provide tourists with one of the greatest attractions on Earth. The scenery, cleanliness, colour and generally pristine condition are great drawcards.

Air tourism development was arrested by the 1979 Mt Erebus airplane disaster which claimed 257 lives. However, this was a navigational error rather than a result of conditions peculiar to the Antarctic, and one can only speculate that such flights will expand in the future.

For several years, shipboard tourism on the MV *Lindblad Explorer* was conducted on a regular basis and included periodic visits to the Australian station on Macquarie Island. Today only occasional trips are made.

Most tourist operations in Antarctica are and will be expensive because of distance, lack of Antarctic infrastructure and the high cost of facilities provided, for example, ice-strengthened ships. In the foreseeable future, tourism will be restricted to those in the higher income bracket.

Serendipity

One cannot predict what science will uncover of value to mankind. Antarctic scientists study biology, geology, biochemistry and so on—all areas of study that may reveal unexpected mineral occurrences or chemicals of value to mankind.

Humanity's Influence on Antarctica

For a long time, Antarctica was seen as a remote place, far from the influences of the acts of humanity elsewhere on Earth. This is no longer so. It is now recognised that pollutants generated elsewhere find their way to Antarctica by atmospheric and oceanic pathways. Radionuclides from atmospheric nuclear tests, for example, are known to be present in Antarctic ice. These can be used to date samples as each year's fallout has a unique composition.

Recently much concern has been voiced over the potential destruction of the ozone layer, particularly above Antarctica. The most significant foreseeable effect comes from burning of fossil fuels around the Earth. This produces carbon dioxide, methane and oxides of nitrogen, collectively referred to as 'greenhouse gases' because an increase of these gases in the atmosphere causes the Earth to retain a higher proportion of the Sun's heat, in turn causing the Earth to heat up like a greenhouse. This is referred to as the 'greenhouse effect'.

The content of carbon dioxide in the atmosphere has increased from 270 parts per million (ppm) at the end of World War II to 345 ppm now. Projections of this rate of increase have been made for the next 100 years and, if accurate, are important for mankind.

The predictions provide for a general increase in atmospheric temperature, with the rate greater in the polar regions than in the tropics. The estimated temperature rise in 75–100 years for the Antarctic Peninsula region is 5–8°C. This rise is enough, it is believed, to lead to commencement of melting of the West Antarctic ice sheet, eventually leading to a sea level rise of the order of five metres. The East Antarctic ice sheet, being far larger and colder, does not appear to be at risk in the short term, although there may be some effects at its margin. Governments throughout the world will need to address the situation and to examine possible effects.

Antarctica as a Site for Monitoring the Earth's Environment

Antarctica (both the continent and its surrounding ocean) is that part of the Earth least affected by humanity's activities. It has the unusual glacial environment which prevents permanent habitation and keeps an annual record of pollutant input. It also has a series of environments (lakes, moss-lichen fields, oases and so on) which are sensitive to minor environmental change. These aspects of Antarctica make it the ideal locale to monitor the condition of the world's environment in a situation where local disturbance is minimal.

A detailed knowledge of the chemistry and biota of the Antarctic environment has been accumulating for many years now and provides a useful baseline against which changes can be measured. The South Pole has a complete Baseline Air Pollution Station (another is at the aptly named Cape Grim in Tasmania) and should a marine equivalent ever develop, the Antarctic ocean is an ideal site.

Already, monitoring of the ozone layer over Antarctica has shown that there is now a marked seasonal decrease in its strength—a feature that has developed over the last 20 years. Antarctica's environmental change is issuing a warning to mankind.

The Need for Careful Use of Antarctica

Antarctica is the only continent not subject to exploitation. It is the only continent we can get to know before we use it. There is no significant local input of pollutants and it is surrounded by an essentially unexploited ocean, other than for 200 years of whaling and sealing, and small Antarctic Krill and fin fish fisheries.

It is important therefore that we care for it. It is essentially pristine and the best place on Earth to monitor the global effects of humanity's activities. □

LETTERS Blazing Snail Trails

The article in the Autumn 1986 issue of ANH (Vol. 21, No. 12), discussing the relevance of controlled burning to the survival of certain fauna of the Tanami Desert, has implications far beyond that desert.

My area of expertise is land snails, and my work over the past ten years has involved me in much field work in 'arid Australia', from the Flinders Ranges of South Australia through the centre to the Kimberley region of the north-west. In those years I have seen fire, and its effects, far too often. And mostly I have seen those fires on land exposed to pastoral use, as distinct from the largely pristine state of the Tanami.

The article referred to discussed the long-term ramifications of the absence of 'normal' fire (that is, the absence of "small, periodically-lit fires") on the survival of certain medium-sized animals. In much of the country where I have worked, but mostly in the Kimberleys, the altered pattern of fire use has had a quite different effect. Here, the small, periodically-lit fires of the past have been replaced by large, annually-lit conflagrations, which have probably seen the extinction of several species of land snail and doubtless many other species of fauna and flora. These annual burns are deliberately lit by pastoralists to produce a hopeful crop of green between the annual rains.

The snails illustrated here, which are perhaps our most colourful, belong to the genus *Rhagada* of the family Camaenidae. Most species are closely associated with spinifex, lying dormant within the base of the plant during the dry season and emerging to feed during the brief wet. Annual fires burn the spinifex to ground level and, in some places, I have found tuft after tuft of the burnt, broad stem with a cluster of five to six empty shells lying within. In other places where, according to early collectors at the turn of the century, these snails were collected in the hundreds, today not one live specimen has been found.

Other animals adversely affected by pastoralists' annual conflagrations are termites. Contrary to common thought, not all are wood-eaters. Many, and probably most, of the termite mounds seen in our 'desert' country are made by grass-feeding 'white ants', which annually do much in the way of recycling scarce nutrients by harvesting the dead grass and leaves and carting it underground where it is eventually returned to the system. Annual burn-offs, which eliminate much of their food, must eventually mean a large decrease in termites; and nutrients consumed by fire would be leached out of the remaining ashes.

I don't know what the answer is. I question whether these annual burn-offs do much, if any, good. Certainly in the short term they produce a small crop of green fodder, but at what long-term expense to the system? There must be eventual elimination of shrubs and trees, with saplings being killed each year. Soil exposure must enhance establishment of exotic plants. Erosion must accelerate. In fact I can think of no lasting benefit. It could be that research is already under way in this area, but if it is not it should be initiated immediately. Otherwise, what the Water Buffalo has not destroyed in the Top End will be finished off by man.

Specimens of the genus *Rhagada*. Several species have been described, mostly from the shell only. With the high probability of the group becoming extinct, absence of preserved animals will mean that proper species definition will forever remain unsolved. Photo: Kate Lowe.

—Phillip H. Colmàn
Australian Museum

QUIPS, QUOTES & CURIOS

Who Said Sharks were 'Armless?

On the night of 17 April 1935, a small shark was hooked on a set line off Maroubra Point (Sydney)—an event of seemingly minor importance, that is, until a large Tiger Shark *(Galeocerdo rayneri)* decided to make a meal of it. It seized and swallowed the smaller shark, becoming captive in its turn. The next morning the fishermen took the shark to a Coogee aquarium and here it remained rather subdued for about a week. On 25 April 1935, however, the shark began to thrash and flail the water with its tail and disgorged several pieces of decomposed flesh and bones. Among this grisly collection of stomach contents, to everyone's surprise, was a human arm, almost unaffected by digestion. A pair of boxers was tattooed on the forearm and a piece of rope knotted around the wrist.

The arm was positively identified as belonging to James Smith, amateur boxer, illegal S.P. bookmaker, billiard room owner and bankrupted builder, who had disappeared under mysterious circumstances. He had apparently been murdered and his dismembered body disposed of at sea.

Of all the thousands of sharks on the Australian coast, the fishermen had caught *the* one that had swallowed the *only* and damning clue to James Smith's alleged murder.

Tiger Shark. Photo: Ron and Val Taylor.

According to various sources, the story goes something like this: Smith was employed by Holmes, a Sydney boat builder, as caretaker of a launch, which had apparently been involved in insurance frauds and drug trafficking and was later sunk. Holmes told police that he was blackmailed about the sinking by Patrick Brady and that Brady had confessed to him the murder of Smith. Brady was arrested on 17 May and held on an unrelated forgery charge. Three days later Holmes, with a bullet in his head, was involved in a speedboat chase by the police. He claimed that he had been shot by an unknown assailant near his home and took to the speedboat to escape further injury, having mistaken the police for his attacker.

An inquest on Smith's death was arranged for 12 June, but the key witness, Holmes, was shot dead the evening before. Two suspects for Holmes' murder were later discharged as not guilty.

Despite ominous associations with insurance money, drug trafficking, blackmail, etc., the fact remained that the arm had no body and without a body no inquest could formally be held. After much debate about how *much* of a body comprised 'a body', the inquest was discontinued. Brady was later tried upon a charge of murder but the presiding judge directed the jury to acquit him on the grounds that the evidence was insufficient to establish guilt. How James Smith came by his grisly death (that is, if he *is* dead) remains a mystery to this day.

An Ode to Statistics

Sometime in the 1940s, a biologist was collecting butterflies in Malaysia. He noticed that he collected some species many times, some several times and others only once. He asked the statistician Sir Ronald Fisher to tell him how many species were there that he did *not* catch, using only the number of times he had caught each species...a seemingly unanswerable question to the average person.

However, according to Fisher, Corbet and Williams (*J. Anim. Ecol.* 1943, vol. 12, p. 42), if one assumes that the numbers of butterflies that are captured are in proportion to how many of each species there are, and that the butterflies are randomly distributed in space and time, the number of species present, but not caught, can be estimated.

Fisher's 'negative binomial model', as it is called, was used—just for fun—in an analysis of Shakespeare's vocabulary by B. Efron from Stanford University and his student at the time, R. Thisted, now at

Compiled by Georgina Hickey

the University of Chicago (*Biometrika* 1976, vol. 63, p. 435). Basing their work on the information that Shakespeare used a total of 884,647 words in all his known works, with a vocabulary of 31,534 different words; and that 14,376 of these words appeared once, 4,343 appeared twice, 2,292 three times...five 100 times, Efron and Thisted predicted that the discovery of a new volume of Shakespeare, equal in length to his old, would contain 11,430±178 new words not previously used. In this study, a word is defined as any distinguishable arrangement of letters; plurals, for example, are counted as new words.

It never occurred to the statisticians that they might ever have a chance to put their analysis to the test...until November 1985 when an anonymous nine-stanza poem was found in the Bodleian Library (Oxford, England).

The poem consists of 429 words, of which Efron and Thisted predict 6.97±2.64 to be new. The actual number of words never used before by Shakespeare is nine (admirations, besots, exiles, inflection, joying, scanty, speck, tormentor and explain). Seven of the words had been used once before by Shakespeare (Efron and Thisted predicted 4.21±2.05); five had appeared twice before (3.33±1.83 were predicted); and so on up to none that had appeared 99 times before (0.32±.030 predicted; April 1986, Univ. Chicago, Dept Stats, *Tech. Rep.* No. 195).

Other poets' works were also tested but none was even close to the predictions based on Efron and Thisted's analysis of Shakespeare's works. In a poem by John Donne, for example, there were 17 words that Shakespeare had never used (predicted number for a poem of that length was only eight—7.91 in fact).

So, although the analysis cannot prove absolutely that Shakespeare wrote the poem, there *is* no convincing evidence to reject the hypothesis that he did.

Shall I die? Shall I fly
Lovers' baits and deceits,
sorrow breeding?
Shall I tend? Shall I send?
Shall I sue, and not rue
my proceeding?
In all duty her beauty
Binds me her servant for ever,
If she scorn, I mourn,
I retire to despair, joying never.

[1st of nine verses]

Beagle Business

Here's a piece of trivia that may or may not amuse the dog-lover. It is also an example of research that seems to advantage neither the subject, researcher nor man on the street.

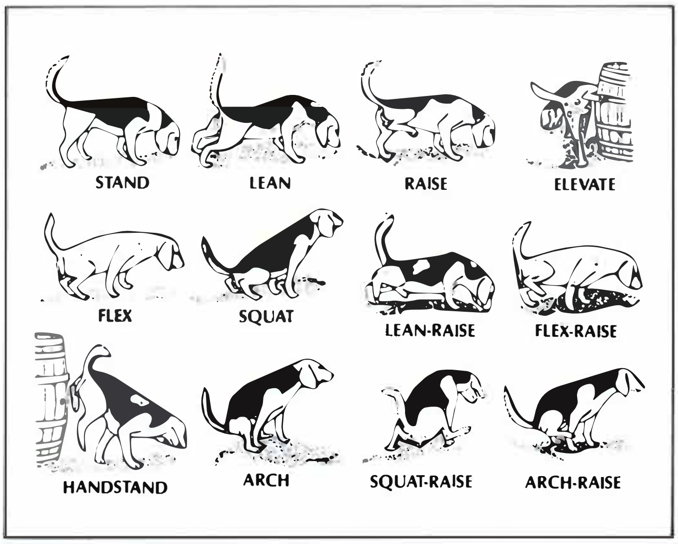
R.H. Sprague and J.J. Anisko, from the University of California at Berkeley, set out to show that the general idea of a sexually dimorphic urination pattern in the domestic dog was indeed oversimplified and in some respects untrue (*Behaviour* 1973, vol. 47, p. 257). Adult males were generally assumed to raise a leg and urinate on vertical surfaces (as part of their scent-marking behaviour), while females, merely squatted and urinated on the ground.

After five weeks of observerserving urination and defecation in 62 female and 62 male Beagles, 12 distinct 'elimination postures' were recorded (see diagram reproduced here). Their data tended to support the male urination assumption but cast doubts on that of the female: 11.6 per cent of female urinations were directed at vertical targets. Also discovered was the fact that females used a greater variety of postures than males (females mostly 'squatted' and 'squat-raised' but also 'flex-raised', 'raised', 'elevated', 'leant' and 'did handstands'; whereas males mainly 'elevated' or 'raised' and sometimes 'squat-raised' and 'leant-raised').

Sprague and Anisko also went into details of the Beagles' defecation postures. Five were used by males (arch, elevate, arch-raise, standing and raise; elevate and raise being postures thought previously only to be associated with urination); and two by females (arch and elevate). What is interesting, however, is that both sexes were recorded defecating on vertical targets—very messy!

Various questions are raised, such as why do female Beagles sometimes lift a leg to urinate and aim at vertical surfaces? And why do males sometimes lift a leg to defecate? Who knows? And, for that matter, does anyone care?

Elimination postures of the humble Beagle according to Sprague and Anisko (1973).



Pink Dolphin: An Amazing Animal of the Amazon

As modern fishing and hunting technology is introduced into the Amazon basin in South America, the number of dolphins being killed is drastically increasing. Dolphin organs are considered by many to have magical or 'lucky' properties. The eyeballs are considered good luck charms, their sexual organs to attract the opposite sex, and other organs are thought to have powers of healing.

These beliefs are not restricted to the isolated villages of the Amazon. Many people from industrialised Brazilian cities, and even European tourists, buy dolphin organs to use in voodoo rituals and potions, or as 'lucky charms'.

The dolphin at issue is the Amazon River Dolphin or Pink Dolphin (*Inia geoffrensis*). Growing up to three metres in length, it is the largest of all the freshwater dolphins (there being three others found in China, India and Argentina).

Amazon River Dolphins' eyes, thought by many to be good luck charms. Photo: courtesy Earth Alert!.

The Amazon River Dolphin has many characteristics that differentiate it not only from marine dolphins but also from the other freshwater dolphins. The most obvious is its skin colouration. This sometimes changes from greyish-white to pink and back again over a period of time (hence the name 'Pink Dolphin'). No extensive research has been carried out to explain this change in colour but it is probably due to a change in water environment, diet or both.

Another special characteristic of the Amazon River Dolphin is the unfused vertebrae in its neck. This allows the dolphin to turn its head 90°, the only dolphin able to do so, and is an adaptation enabling it to better manoeuvre on and off mud banks to search for food. It is on these mud banks and in shallow waters that these dolphins use another physical feature found in no other dolphin—a sixth 'finger' in the bones of the flipper. This helps the dolphin to raise its head to observe surface activities or move about in shallow water.

The Amazon River Dolphin's diet, which consists mainly of fish, river turtles and small crustaceans, includes the infamous piranha fish. There is no record of the dolphins being attacked by piranha and it is thought to use its sonar as a stunning mechanism.

No one knows how many of these intriguing animals are left in the Amazon River but they are suffering from many factors. One is habitat destruction due to pesticides, herbicides and the damming of rivers, not to mention the use of modern maximum-yield fishing aids that destroy their food base. However, the main factor affecting their numbers is hunting by people who sell the dolphins' body parts as curios, sexual attractants, aphrodisiacs and good luck charms. A dolphin eyeball may be sold for three dollars, their jawbones for five, and an entire dolphin for 20 dollars. In an area where two dollars is a good daily wage, these tourist sales are considered lucrative. The Pink Dolphin Project (P.O. Box 38037, Hollywood, 90038), which is organised by Earth Alert!, is a campaign to save these amazing animals of the Amazon.□

AUSTRALIAN NATURAL HISTORY MAGAZINE

POSTER

Lesser Long-eared Bat

Nyctophilus geoffroyi.

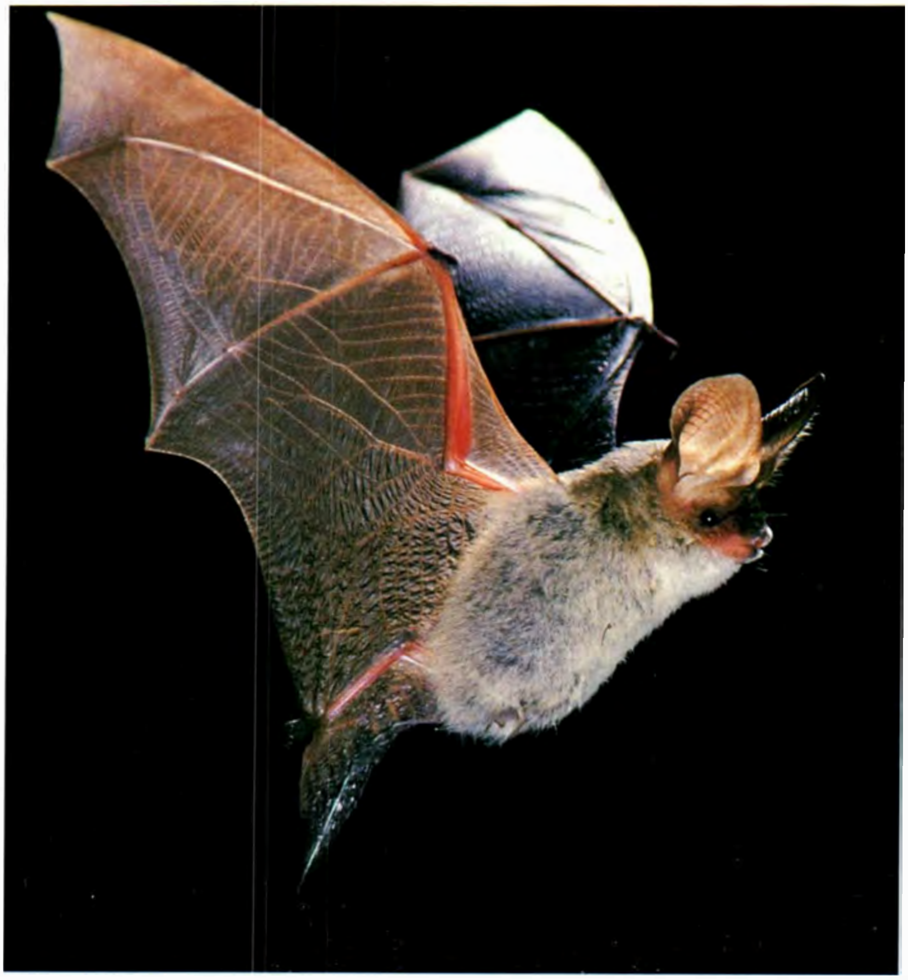


Photo: N.N. Birks.

Few Australian bats have as wide a distribution as the Lesser Long-eared Bat (*Nyctophilus geoffroyi*). It is found throughout the continent including Cape York Peninsula and is widespread in Tasmania. The species lives in a great range of environments–from the arid regions of central and Western Australia to near the summit of Mt Kosciusko. One of the few environments it does not seem to prefer on the mainland, however, is rainforest.

The Lesser Long-eared Bat belongs to the genus of some eight other long-eared species restricted to Australia and New Guinea. The distinctive ears fold down when the animal is asleep or frightened and, in combination with the noseleaf, make these bats an easy group to recognise. The function of the noseleaf is unknown but is thought to be related to the ultrasonic calls emitted through the mouth and nostrils.

While we usually associate bats with caves, the majority of Australian species in fact shelter in cavities in trees or under loose bark. The Lesser Long-eared Bat is no exception. Occasionally, however, it is found in caves and solitary individuals have even turned up under rocks on the ground.

Dietary preferences of this species are unknown but a range of invertebrates including moths, huntsman spiders and beetles have been found in the stomach contents of the few individuals examined. The species is a highly manoeuvrable flier and is able to hover. It emits ultrasonic calls for navigation and communication, which are of low intensity compared to other Australian insectivorous species. Research on various overseas species indicates that highly manoeuvrable species with relatively long ears and low intensity echolocation calls are often 'gleaners', that is they grab prey off foliage or branches, but this has not been confirmed for the Lesser Long-eared Bat.

The average life span of the Lesser Long-eared Bat is unknown but, if better known species are any guide, it is probably between 10 and 20 years. Despite their long life spans, bats tend to reach adult size rapidly. Research at Taronga Park Zoo on a related species (Gould's Long-eared Bat, *N. gouldi*) may give some insight into growth and development of the Lesser Long-eared Bat. In Gould's Long-eared Bat, adult size is reached at about three weeks of age. Young are born naked and the eyes and ears are closed. The long ears are floppy and do not start to become erect until about a week. By four days, the bats are stretching their wings and at about two weeks start to glide but are incapable of sustained flapping flight until after about three weeks.

As is ironically but frequently the case with common, widespread Australian animals, we know very few details of the biology and life history of the Lesser Long-eared Bat.☐

—Harry Parnaby


The Norfolk Island Green Parrot. Photo: A. Fox.

en Parrot

It is often the case when considering the plight of an endangered species that there has been a recent and dramatic population decline. However, in the case of the Norfolk Island Green Parrot (*Cyanoramphus novaezelandiae cookii*) it appears that the bird has been rare and endangered for over a century. Events of the last decade or two have only compounded its vulnerable position.

When Norfolk Island was first settled in 1788, the Green Parrot was a common forest bird. It was often encountered in flocks especially when feeding. By 1869 comments made by a visiting naturalist indicated that the population of Green Parrots was in decline. At the beginning of this century the Chief Magistrate protected the bird under a special protection order, which only allowed the parrot to be destroyed if it was actually eating fruit or crops.

In 1969 the population of Green Parrots was put at 'several pairs' and in 1975 between 20 and 40. In 1978 the Royal Australasian Ornithologists' Union, together with members of the two Norfolk Island natural history societies, conducted comprehensive surveys of the Green Parrots. More than 70 people were involved in an observer-point census on the morning of 4 December 1978. The population of Green Parrots was calculated to contain between 17 and 30 birds. Further comparable surveys were done in 1981. Although population estimates could not be calculated it was disturbing to discover that the population had continued to decline since the 1978 survey.

The decline of the Norfolk Island Green Parrot has been a textbook example of the impact of discovery and settlement on an indigenous species of a previously uninhabited island.

In the early years of settlement the Green Parrot was considered a pest in gardens, orchards and crops. Consequently large numbers of Green Parrots were shot by the first settlers.

Exotic species including Black Rats, feral cats, Crimson Rosellas and European Starlings have become established on Norfolk Island and have contributed to the decline of the parrot. Rats and some exotic bird species compete with the parrot for nesting sites in tree hollows; rats take the eggs and nestlings; and cats prey on the unwary newly-fledged youngsters.

The dense native subtropical vegetation of the island has all but been removed—only 20 hectares (less than one per cent of the island) remains as weed-free native forest. This reduces the availability of nesting sites and forces the birds to become dependent on exotic food sources for at least some of the year.

To add to all these pressures, a disease outbreak was detected in Crimson Rosellas on the island in 1976. The population of rosellas declined dramatically. In 1977 a Green Parrot was reported with this disease. Although not confirmed, it dramatically emphasised the vulnerability of the tiny remaining population of Green Parrots.

In 1983, a combined effort of the Norfolk Island Government, Lions Club and the Australian National Parks and Wildlife Service established a captive colony of Green Parrots on the island. This was seen by all concerned to be a highly risky project and one that had no guarantee of success. However, it seemed to be the Green Parrot's only chance and the only way of immediately halting its continuing decline. A small number of birds is now established in captivity but there has been no attempt by them to breed. Of more long-term importance, the best remaining habitat for the parrots (and many other endemics) has been included in the Norfolk Island National Park. This was declared early in 1986. Programs to control exotic birds and mammals, and to reverse the decline of the native forest, have commenced.

Although the plight of the Norfolk Island Green Parrot is still precarious, significant steps have now been taken to secure its future. □

—Neil Hermes

Australian WILD FOODS

Text and Photos by Tim Low

Pigweed (*Portulaca oleracea*) is a fleshy herb of bare open soil, able to tolerate hot, dry conditions. The leaves and stems are used in soups and omelettes.

The Yellow Wood-sorrel (*Oxalis corniculata*) has heart-shaped leaflets, creeping stems, cylindrical seed pods and bright yellow flowers.

Common Sowthistle (*Sonchus oleraceus*) has shiny leaves and bright yellow flowers, each of which opens only once, during the morning. Sowthistle leaves taste just like Endive.

Wonderful Weeds

European settlement of Australia brought in its wake thousands of weeds from overseas. Weed seeds were stowaways aboard the First Fleet in 1788 and ever since then they have been arriving, mainly from Europe, Asia and South America. So prolific has been the invasion that it has obscured one interesting point—that some of the weeds were here all along.

Consider Pigweed (*Portulaca oleracea*). Easily identified by its fleshy triangular leaves and tiny yellow flowers, Pigweed occurs more or less world-wide and throughout much of Australia, both as a weed of farms and gardens, and as a herb of inland plains. Inland plants have narrower, darker leaves. They sprout in profusion after rain and formed an important food of Aborigines, who heaped them onto kangaroo skins or bark sheets until the tiny seeds fell out. Ground into flour and baked as cakes, these seeds served as staple foods, for they are rich in oil. Indeed, old Pigweed grinding stones can be recognised by their oily sheen.

The outback Pigweed is clearly a native plant, its use by Aborigines pre-dating European settlement. The weedy form, on the other hand, was probably introduced, perhaps in potting soil from England long ago. Native Pigweed probably reached Australia on the feet of prehistoric birds, or by other means. In isolation, it has evolved distinct features, but is not different enough to be considered a separate species. Both forms have edible leaves and the weedy form is eaten throughout much of the world, being cultivated on a small scale in Europe.

Yellow Wood-sorrel (*Oxalis corniculata*) is another very widespread, edible weed. Its heart-shaped leaflets are grouped in threes and the flowers have five yellow petals. Like Pigweed, it flourishes in suburban gardens and often sprouts in pavement cracks. This plant, or something very like it, grows in many native habitats: along coastal dunes, rainforest edges and inland river flats. Again, there are old records of Aborigines eating such plants: tribes ate the roots in South Australia last century and harvested the leaves in Victoria and northern South Australia. The wood-sorrels that grow in native habitats do differ slightly from the urban plants,and botanists now recognise them as Australian native species.

Wood-sorrels (probably the weedy form) were also eaten by early settlers. Victorian gold-miners nibbled the sour leaves to allay scurvy and Tasmanian settlers baked them in tarts (they were said to taste like barberries). Wood-sorrel leaves are also eaten in Asia.

Looking at Pigweed and Yellow Wood-sorrel, it seems obvious that both native and introduced populations occur and are closely allied. With other weeds we can be less certain. Self-heal (*Prunella vulgaris*) is named for its use in Europe in herbal cures. In Australia it sprouts beside streams in native forests and behaves like a native plant—but is it? We will probably never know for sure.

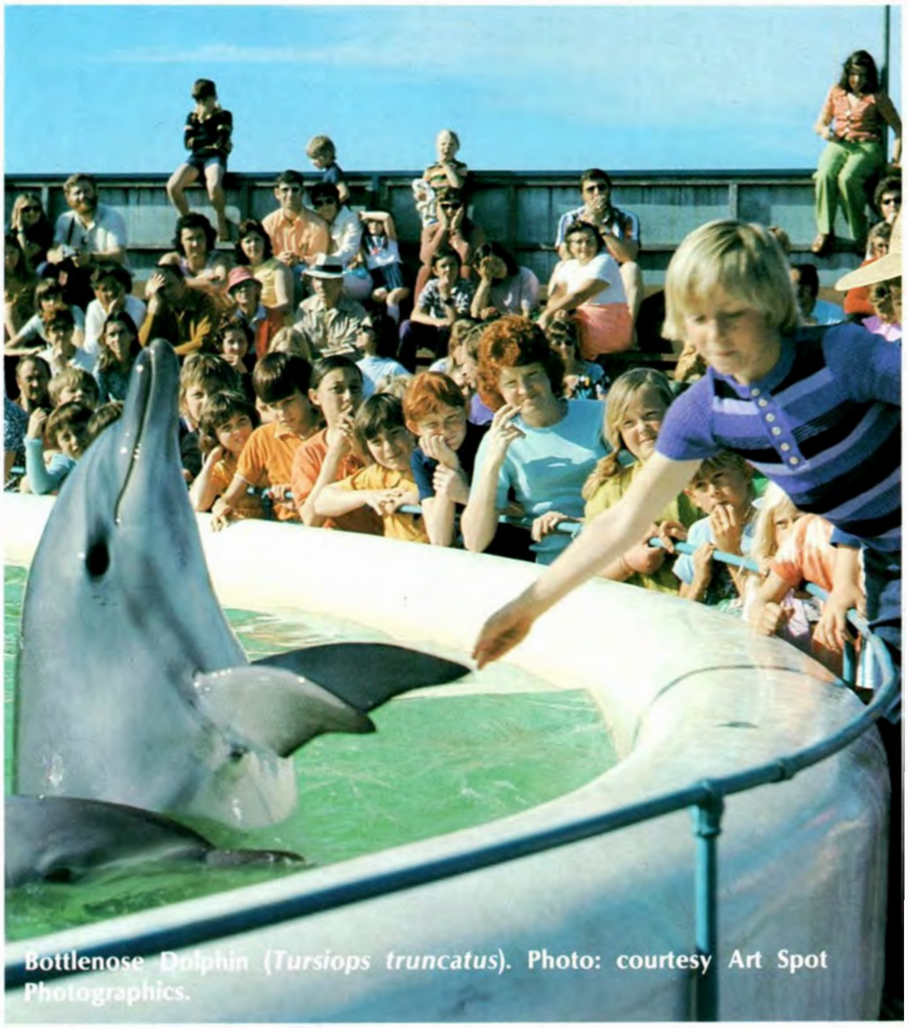
In some cases anthropological data can help us decide. The Commonwealth publication series *The Flora of Australia* lists Marsh Cress (*Rorippa palustris*) as introduced, yet there are old records of Aborigines gathering it for food. Also, Joseph Banks collected a specimen in New Zealand in about 1770. I feel convinced it is native, its seeds being conveyed here long ago on the feathers of water birds.

Anthropological data may also force a reassessment of the Common Sowthistle (*Sonchus oleraceus*), an untidy weed with hollow stems, milky latex and yellow flowers. Most authorities list this as an introduced plant. It certainly behaves like one, running riot in gardens and waste allotments. Yet there are numerous old records of Aborigines eating the leaves and even the explorers George Grey, John Stuart and Ernest Giles made use of them. It seems that there are introduced populations as well as a native form which, through interbreeding, may soon cease to exist.

Sowthistles, like wood-sorrels, are abundant in national parks, where their uncertain status creates a curious ambiguity. Do we uproot them as weeds or cherish them as part of our native flora?

In any event, these plants are good eating, proving ideal as ingredients in spinach pies, soups and souffles. Raw leaves of the Common Sowthistle taste exactly like Endive (*Cichorium endivia*), to which it is closely related, and Yellow Wood-sorrel leaves have the flavour of true Sorrel (*Rumex acetosa*). Pigweed leaves, although slimy in texture, are good in salads and sauces. These edible weeds, and others of their ilk, are the most accessible wild foods in Australia, growing in most urban environments. A range of recipes for using them can be found in my book *Wild Herbs of Australia and New Zealand* (Angus & Robertson, 1985).

Happy eating!



Bottlenose Dolphin (*Tursiops truncatus*). Photo: courtesy Art Spot Photographics.

DOLPHINS
in captivity

by Laura Mumaw

In an emotional atmosphere with claims and counterclaims—of dolphins dying in captivity, of the need to close all oceanaria, of animal rights and human responsibilities—the Senate Select Committee on Animal Welfare released its report *Dolphins and Whales in Captivity* (also called the 'Georges Report' after the Committee Chairman) late last year. Although the Federal Minister for the Environment, Mr Barry Cohen, has not yet responded to its recommendations, various State governments have already taken actions on its basis. The Report documents the "heated and often acrimonious debate" that accompanied presentation of evidence and its interpretation. Similar committees overseas have taken the same evidence and reached different conclusions (for example, in New Zealand, the Officials Working Party Report on the issuing of dolphin catching permits). Why?

The dolphin family, Delphinidae, comprises 32 species (which are here collectively referred to as 'dolphins'). With the exception of the Bottlenose Dolphin (*Tursiops truncatus*), Spinner Dolphin (*Stella longirostris*) and Killer Whale (*Orcinus orca*), largest of the dolphins, little is known about the lives of any of these animals in the wild. Life in water requires far different capabilities than life on land, and dolphins and men are each remarkably well-adapted to their respective environments. Little wonder that as visually-oriented, terrestrial beings we cannot yet assess the intelligence of these sound-oriented aquatic animals. Inter-specific communication is not possible now and until a dolphin can tell us what it 'thinks' of life in captivity or life in the wild, conclusions drawn will inevitably be personal interpretations of the evidence, based on an individual's experience, knowledge and value systems.

There is a myriad of questions to which we have no answers at present. For example, are there conditions under which captivity is acceptable? Is death in the wild better than life in captivity? If the benefits gained from keeping dolphins in captivity include increased survival for more dolphins in the wild, do the 'rights' of the benefited group transcend the 'rights' of the individual? In each of these questions we can replace the word 'dolphin' with that of any other animal including humans.

The very words 'in captivity' carry with them negative connotations, yet the opposite—life in the wild—is also bound by spatial, behavioural and individual limitations. The never-ending hunts for food, evasion of predators, the rigour of established social patterns and the urges of the breeding ritual are all set against the constant threat of illness and death.

How can we assess the conditions of life in captivity? Mortality, longevity and reproductive rates are three commonly used gauges. These rates vary with the species, oceanarium and time under consideration, but if one takes the four commonest dolphin species in captivity—Bottlenose Dolphin, Killer Whale, Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*) and Beluga Whale (*Delphinapterus leucas*)—

R U M

and examines current reputable institutions, the data suggest a mortality rate of four to seven per cent per year, an average survival in captivity of ten years and a longevity record of 37 years. Since 1979 there have been at least 60 recorded Bottlenose Dolphin births. It is difficult to evaluate these statistics: the data is not readily available and *not* available in relation to reproductive and absolute age of captive individuals, groupings by sex, or age of oceanarium. Even more significant, mortality, longevity and reproductive rates in the wild are unavailable for comparison. Nonetheless, there do exist standards for the physical features of oceanaria and husbandry techniques, which have so far proven successful in keeping certain species of dolphin alive in captivity for a number of years.

These are the physical measures; but what of the animals' psychological needs? We do not know or agree on what these are and how they can be measured. The claims that dolphins go mute in captivity or undergo brain shrinkage have been proven false in the first case and unsubstantiated in the second. It cannot be denied that the transition from the wild to the captive state involves substantial change. The older or less adaptable an animal and the more different the captive environment, the more difficult the process would seem to be. But the claim that an 'intelligent' animal would find captivity or the adjustment to it more stressful than another less 'intelligent' animal cannot be justified; one need only examine analogues in the human realm.

For the most part, our information about dolphins comes from work and observations on them in captivity. It was in 1946 that the first captive breeding colony of Bottlenose Dolphins was established at Marineland, Florida, in the United States. (The first calf born there—a female named Spray in 1947—gave birth to five calves herself and lived for 22 years.) New information dispelling erroneous beliefs came from Marineland daily: dolphins had good vision in air as well as water; they made a variety of sounds; they slept in brief naps day and night. The dolphin's echolocating capabilities were first discovered. The early dolphinaria brought dolphins to the public's attention in a way that not only won their hearts but tempered their attitudes towards other cetaceans. The population collapse of many whales by the 1950s, the awareness of the fragility of Earth's ecology in the '60s, our visits to oceanaria and viewing of "Flipper" on television, all combined to make us acutely aware of cetaceans and their plight.

In 1972 the Marine Mammal Protection Act was passed in the United States, one of the first such acts of national protective legislation (now being enacted in Australia). Proponents of oceanaria claim that direct contact with dolphins is still needed to keep alive public awareness and concern for them. Opponents feel that media, film and video presentations can have the same results. But when it comes to learning more about these animals, not only for our sakes but primarily for theirs, it is idealistic to think that information can be obtained well enough from land or vessel-based studies of wild animals.

"Is death in the wild better than life in captivity ?"

The grim fact is that dolphins and whales face threats from man and these are likely to increase: the dumping of toxic wastes at sea; the harvesting of shared food resources; acoustic disturbance from sonic testing and boat traffic; and building of resorts, breakwaters and coastal facilities. Our ability to find solutions is dependent on our understanding of these animals and identification of the problems that our marine-based activities may cause. Methods of transporting, handling and giving first aid to stranded dolphins and whales have come from techniques developed in oceanaria. Methods of diverting dolphins from fish nets, such as the application of surface float lines, have been tested in oceanaria. (Incidental net kill of dolphins has dropped from 100,000 to 17,000 per year in the last ten years—far greater than the estimated 500 animals in captivity world-wide.) Feeding and growth rates, longevity and reproductive biology are among the data obtained from captive animals that can be corrected and extrapolated to assist in understanding and managing wild populations.

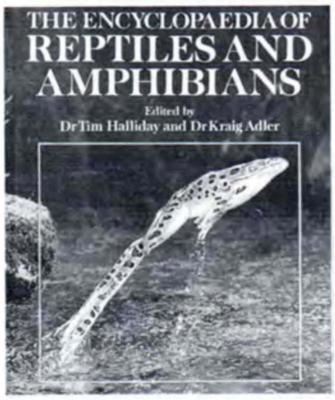
A number of the recommendations made by the Georges Report are widely accepted: that standards for the maintenance and care of cetaceans be drawn up (including financial viability of an institution); that oceanaria be given a specified time to comply with these standards; that education and research be a significant component of an oceanarium's activities; that oceanaria display natural forms of behaviour; that facilities more closely approximate the cetacean's natural environment.

One far-sighted and praiseworthy recommendation, recognising our continuing need to gather information and modify our actions as necessary, suggests that a national advisory body be established "to advise the Federal and State governments on matters relating to cetacea, both captive and in the wild and to encourage and monitor research in this area".

Ironically, the remaining recommendations greatly limit, if not prevent, us from doing so. These propose: that no further facilities for keeping captive cetaceans be permitted; that no cetacean be captured in Commonwealth or State waters; that importation of cetaceans be banned; that oceanaria only rescue and rehabilitate sick and stranded cetaceans if they return them to the wild; that the keeping of cetaceans in existing oceanaria be phased out "unless further research justifies their continuance". But what "further research" can be intended under these conditions?

The issue of keeping dolphins in captivity has no easy answers. In seeking solutions, let us admit our feelings (tempered with reason and wisdom), heed intuition (modified by experience and learning) and understand, as fully as possible, all the consequences of our actions. □

BOOK REVIEWS Basically Botanical



The Encyclopaedia of Reptiles and Amphibians

Edited by T.R. Halliday and K. Adler. George Allen and Unwin, Sydney, 1986, xvi + 142pp. $39.95.

This is a superb overview of the living amphibians and reptiles of the world and their biology. It is written and edited by a group of professional biologists and illustrated with many good to excellent graphs, maps, drawings, paintings and photographs. Information is organised along both taxonomic and topical lines, thus catering to the two current approaches to herpetology.

The illustrations are both informative and striking and are dispersed through the text in a manner that ensures that each turned page brings a new visual delight.

This book would be a good general reference for anyone wanting an introduction to any taxonomic group of amphibians or reptiles at the family level or higher, or to many of the current topics in their biology. It would make an excellent gift for any young person showing tendencies toward a scientific interest in herpetology.

—Dr Allen Greer

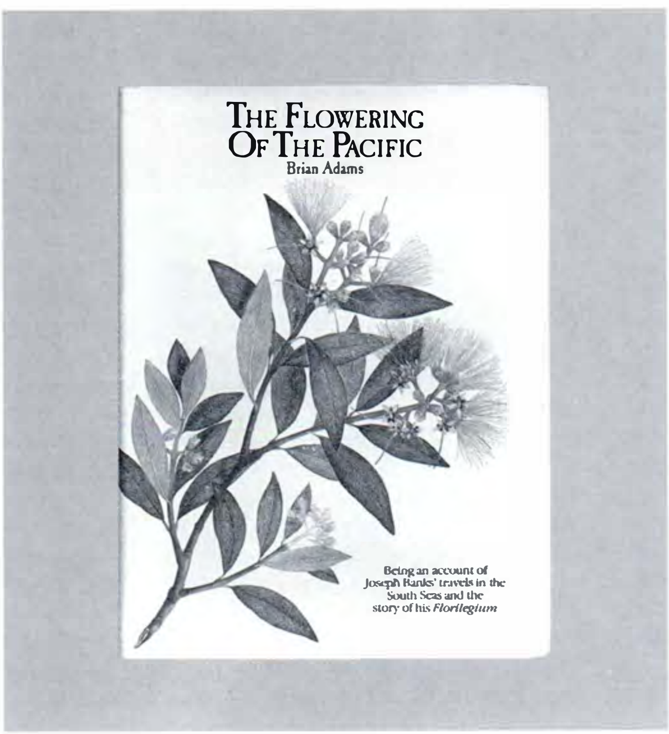
The Flowering of the Pacific; Being an Account of Joseph Banks' Travels in the South Seas and the Story of His *Florilegium.*

Brian Adams. Collins, Sydney, 1986, 194pp. $39.95.

In April 1770, upon sighting the coastline of Australia, James Cook's *Endeavour* sailed into Australian mythology. In addition to the reconnaissance of the coast of eastern Australia, the major achievements of the *Endeavour's* three year circumnavigation of the globe included the observation of the transit of Venus and the charting of much of the coastline of New Zealand. Under the auspices of supernumerary Joseph Banks, the botanical results of the voyage were of similarly impressive proportions. During the 1950–60s, J. Beaglehole edited the massive *Endeavour* journals of James Cook and Joseph Banks; and, in the late 1970s, Alecto Historical Editions commenced printing the 738 botanical plates produced by the *Endeavour's* voyage.

These three achievements, each of heroic magnitude, have been condensed to manageable size by Brian Adams in his *The Flowering of the Pacific*. Adams' book digests the approximately 1,400 pages of the Beaglehole editions, and supplemental information from diaries such as that of Sydney Parkinson, into a very readable 194 page book.

The book, as the subtitle indicates, is really the story of Joseph Banks. The definitive biography of Banks has yet to appear but Banks seems to have been a fairly callow youth. The death of a Greyhound rated a longer entry in his journal than the demise of shipmate Sydney Parkinson, who prepared the original illustrations for the *Florilegium*. In fact the *Florilegium* could more accurately be called the *Parkinson Florilegium*, Banks' contributions were financial and managerial.

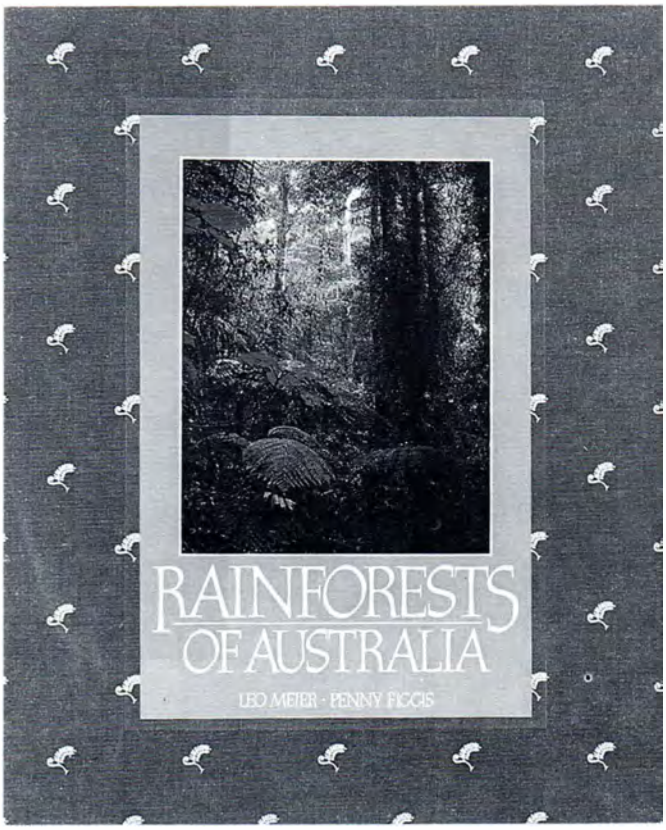


Adams does a good job in rendering the *Endeavour's* voyage and its participants approachable by the general reader. In chasing that accessibility, Adams indulges in considerable journalistic licence, not the least of which is his preoccupation with Joseph Banks' sex life. This 'Dallasification' of the story is evident throughout much of the text and may be related to the need to spice up the documentary film which Adams developed on the same subject.

Other quibbles are minor. Adams' unfamiliarity with the 18th century sometimes becomes apparent. He misinterprets Sydney Parkinson's description of the plants of Tierra del Fuego ("nondescript") to indicate that they were ordinary. Parkinson meant almost exactly the opposite for nondescript was a synonym for undescribed—the plants were therefore unknown to science.

For those who can not afford the $100,000 necessary to purchase the complete *Florilegium*, or several hundred dollars for a single print, the plates in Adams' book, or the *Florilegium* poster sold by the State Library of New South Wales, form a reasonable alternative.

—Colin Finney



Rainforests of Australia

Edited by Penny Figgis, photos by Leo Meier. Weldons Pty Ltd, Sydney, 1985, 264pp. $35.00.

Writers about rainforests often babble on about the unending variety of rainforest animals and plants. What makes this book refreshing is its emphasis on the variety of the rainforests themselves. The reader is shown not only the familiar tropical and temperate rainforests but also the lesser-known monsoon forests, brigalow softwood scrubs, Araucarian vine thickets and the like.

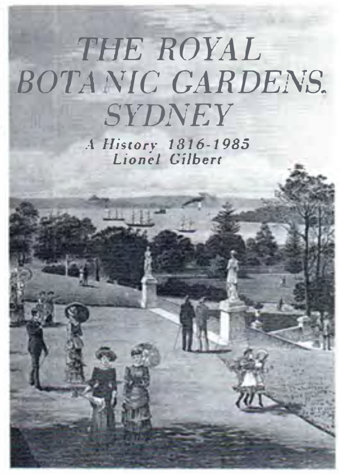
This emphasis is timely, for certain of the so-called 'dry' rainforests of inland Queensland, like the bottle tree scrubs, endure more precariously than the wet rainforests of the coasts. This book should fire an interest in their fate, an intent no doubt of its contributors, most of whom are prominent conservationists.

An informative text looks at each major rainforest category in terms of its location, structure, flora, fauna and conservation. We are reminded that three quarters of Australia's rainforests were destroyed during the last two centuries, often to be replaced by weed-infested pastures of low fertility. Superb photos by Leo Meier create an enduring feel for each rainforest habitat, although they do not closely complement the text. The conservation message remains understated but compelling, a welcome sign of the Australian conservation movement's increasing sophistication.

—Tim Low

The Royal Botanic Gardens, Sydney. A History 1816-1985.

Lionel Gilbert. Oxford University Press, Melbourne, 1986, 210pp. $39.95.



When the English settled a new country they would first found a Club. Usually within a few years they would establish a botanical garden. Botanising was, after all, one of the preoccupations of explorers, although not stemming from a love of plants so much as of plant products. The Vikings, for example, were delighted to find grape vines growing wild in Vinland, while the Europeans' need for good spices for meat that was past its prime was the stimulus for much of the colonisation of the(ir) Far East.

Although the official foundation date of Sydney's Royal Botanic Gardens is 13 June 1816, and although Dr Lionel Gilbert's book is subtitled *A History 1816-1985*, cultivation began there within a few months of the arrival of the First Fleet when Phillip tried to make the new colony self-sufficient by establishing a farm on the site—"nine acres in corn". Despite the drawbacks of the site—poor soil, too near the sea and subjection to floods—plants have been cultivated there ever since, although true farming quickly shifted elsewhere. Gilbert's excellent history consequently traces these early days and, indeed, extends back to the arrival of Cook and Banks.

I can't say that it is an exciting story, but it is a worthy and interesting one. There were no sackings like that of Mueller in Melbourne; nor sales of dirty postcards such as that alleged to have taken place at the sister institution, the museum. There was, however, much political infighting with directors and botanists against governors or governments, and at least one action, and counteraction, resulting from a married couple being unduly uxorious in the gardens. At the end we appreciate the great contributions of men like Kidd, Moore, Maiden, the Cunningham brothers and the later directors, and of the Gardens themselves, to Australia. What was it that Jonathan Swift said in his *Gulliver's Travels* (1726)? The man who makes two blades of grass grow in place of one is worth more than the whole pack of politicians.

One small criticism, but of the genus and not of the species. Because histories of this kind must record everything, almost down to the last spade and barrow, it does slow the narrative for the general reader. Perhaps some details could have been banished to appendices for the benefit of the specialists. Despite this constraint, Gilbert has produced a book that is well worth reading.

—Arthur Woods

ROBYN WILLIAMS Worrying About Creation 'Science'

A.B.C. RADIO SCIENCE SHOW

It was my belief, until recently, that creationism in Australia was little more than a nuisance. Even though I was aware of the serious challenge the movement presents to rationalism and learning in North America, I thought we were protected here by a mixture of good sense and good practice. Not so.

Creationists, and in particular a small but vocal group known as creation 'scientists', have had a disturbing influence on the teaching of science in the United States. Many text books have been rendered useless or misleading, and educators now fear that this sanitising of biology will help produce a generation of scientific illiterates. There has been a similar attempt, in many of our schools, to 'balance' the science curriculum with religious material—and not only in Queensland. The result has been confusion. Rhondda Jones, Professor of Zoology at James Cook University in Townsville, northern Queensland, did a survey of new students arriving at both her own department and Griffith University, Brisbane. These students came from outside as well as within the State. She found that five per cent believed in the straightforward creationist model: that the world had been made by God only a few thousand years ago and that all life was put here at that time. So far so good—five per cent is not too bad. But then she discovered that a much greater percentage held conflicting ideas, both creationist and scientific, at the same time. These youngsters had dreadfully muddled minds.

When I went to discuss the teaching of evolution in schools with Queensland's Minister for Education, Mr Lyn Powell, he was ready and willing but defensive. Mr Powell is said to hold strong views on a number of issues, but he would not tell me anything about his personal feelings on the creationism debate. He was, before parliament, a teacher. When I mentioned the recent statement in the Senate, by New South Wales Liberal Chris Puplick, warning about the incursion of creationism into the science curriculum and about aspects of the funding of the creation 'science' movement (a grant from the Export Market Development Board for $24,693; and the surprising loss 'written off' of $92,358 for Creation Science Foundation funds), Mr Powell dismissed them as the ill-informed mouthings of an outsider.

So what has been the nature of the directive, given by the Minister in 1984, to reinforce the practice of 'balance' whenever evolution is taught in Queensland schools? He says it is merely to reiterate the policy of his predecessor, first given in 1981, which was to prevent young people having their religious beliefs undermined by alternative theories. I replied that most theologians actually say that science and Christian faith are *not* in conflict and that there is no need for biology to be counterbalanced in the classroom. However, the Minister insists that evolutionary theory is open to question and such 'incomplete' ideas must not be allowed to affect innocent minds adversely. When I asked how the ruling is enforced and whether any teachers refuse to teach Genesis in science courses, Mr Powell said the question does not arise because Queensland teachers are 'professional'.

There are two fundamental misconceptions underlying such attitudes. The first misconception is the belief that evolution is 'only a theory'. The second is that the science curriculum is made up of various 'beliefs' and that religious ones are of the same currency.

On the first: many have written at length about the nature of scientific knowledge. It is not demeaning of the scientific process to say that nothing can be proved absolutely. Science can be seen as a method in which hypotheses are challenged and thereby rejected, altered or reinforced. If hypotheses survive continued and rigorous challenges, they become accepted (always tentatively) as theories. When many different such theories combine to explain a large body of data or observations, they mature to the status of a scientific model. Evolution is just such a model—a vast body of ideas that has been, and continues to be, tested and modified. The theory of evolution is no mere speculation—the evidence supporting its theories is overwhelming, despite arguments about punctuated equilibria, missing links and so on.

As for saying that both science and religion are 'beliefs' and so may be brought together by teachers, Professor Michael Archer from the University of New South Wales wrote this in a letter to the New South Wales State Government in June 1986 about the proposal to teach creationism in science classes:

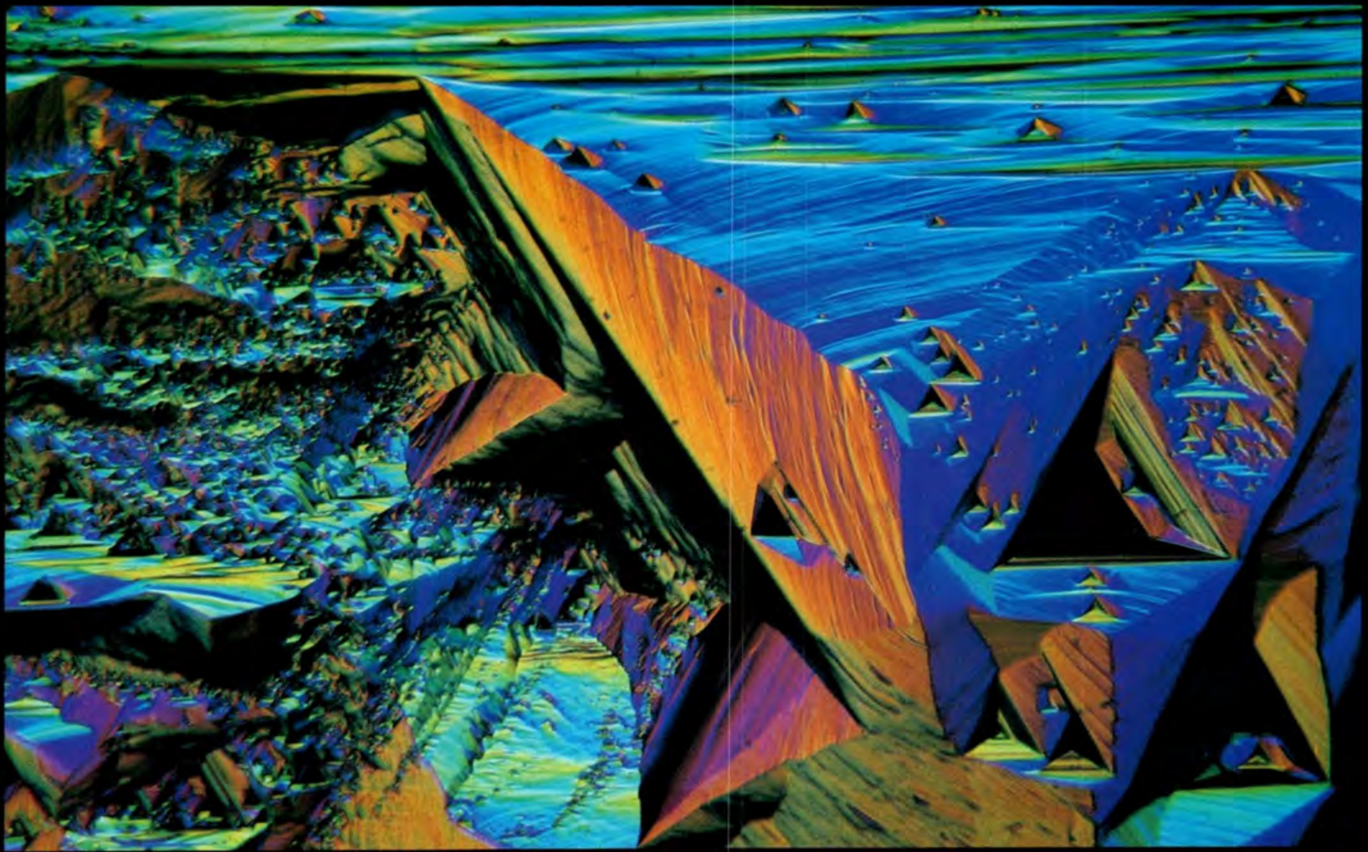
"It would represent the gravest of mistakes to recommend, for whatever reasons, the teaching of any aspect of this sophistry in the science classes of public schools. Its only legitimate place in a public school education would be in a course on the history of religious movements. It is, by its ministers' own admissions, not science."

Professor Archer is right because creationism is treated as dogma, and real science, when taught properly, is not. Of course there are some teachers who dispense information as if they are delivering the Sermon on the Mount, whether the subject is divinity or nature study, but this is folly. If one is giving a vigorous intellectual grounding to a young mind trying to learn scientific principles, the process is bound to be ruined if, at the end of it, one plonks down some statement confounding all that's been said. "Yes, Darwin's hypotheses have been supported by modern genetics and the fossil record. . . but meanwhile let me tell you about this chap Noah and his Ark."

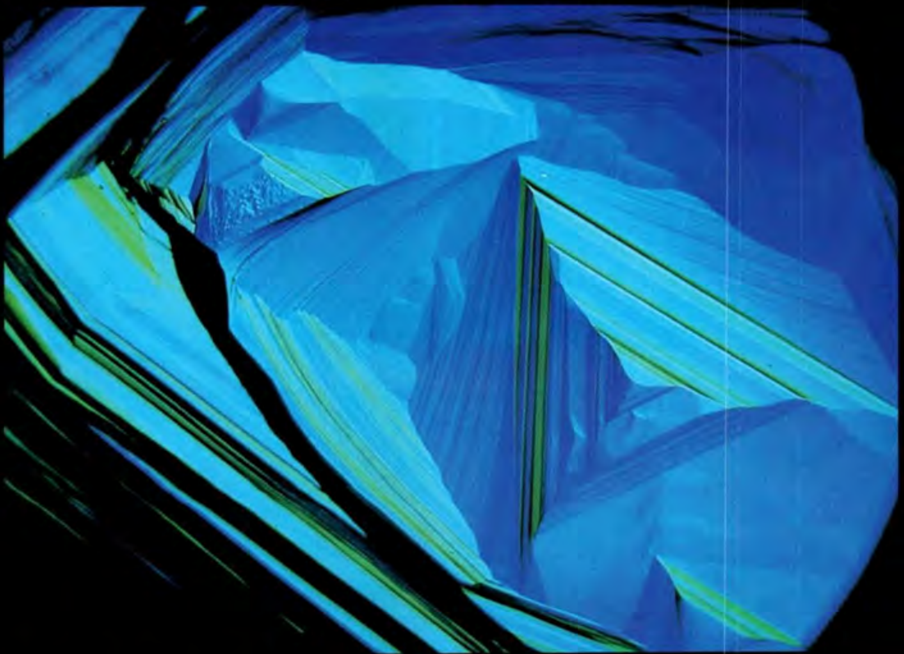
Michael Archer likes to quote biologist C. Loring Brace on this:

"It is creation and not evolution, then, that is 'indoctrination', and if students are required to spend equal time learning it in the public schools, these institutions would indeed degenerate into a 'hatchery of parrots'.".

photoart



Diamond from AK1 diamond mine in the Kimberleys, Western Australia.



Diamond from Wellington, New South Wales.

DIAMONDSCAPES

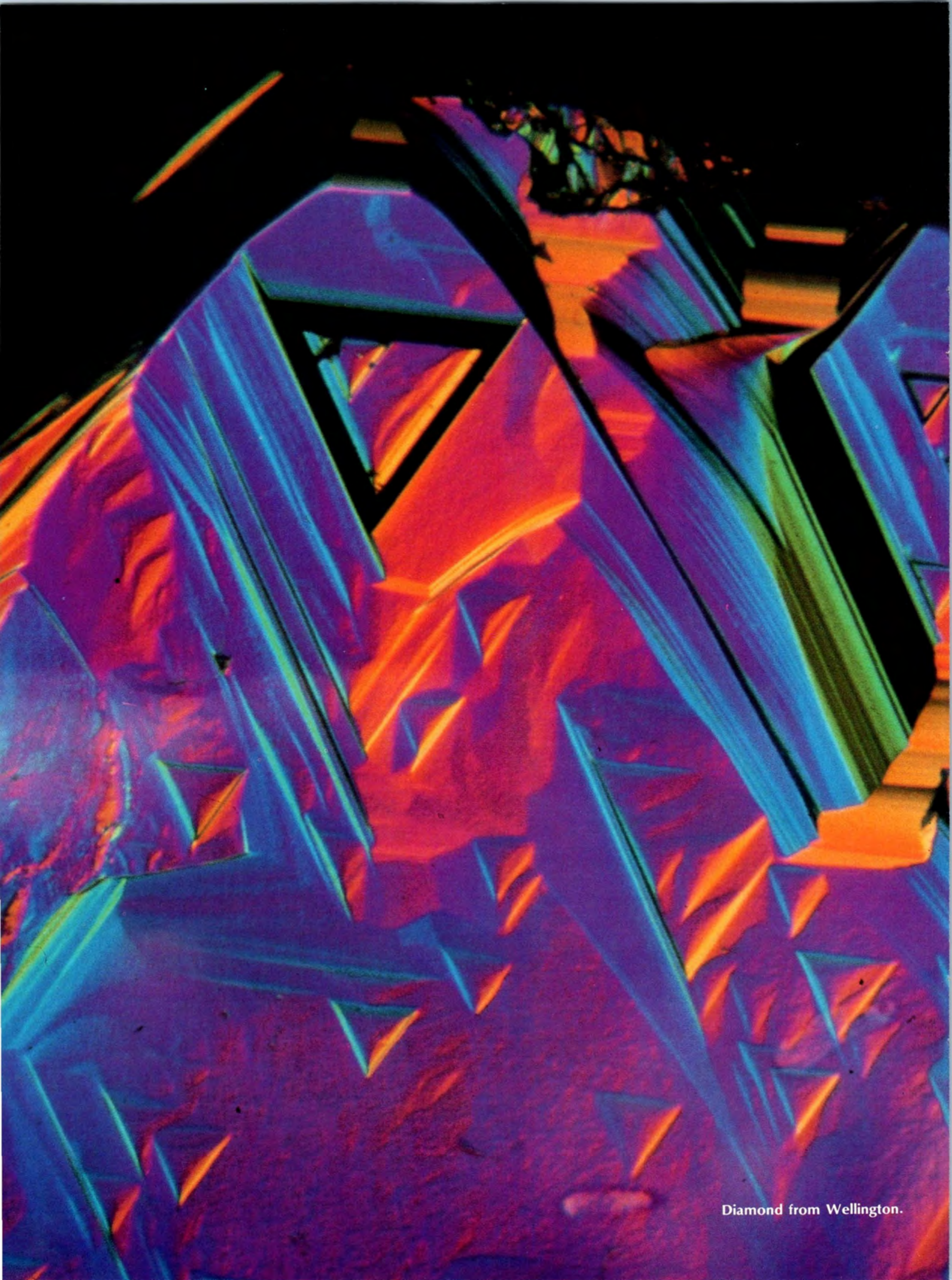
PHOTOGRAPHY
BY BILL SECHOS
AND RUDY WEBER

GEM STUDIES
LABORATORY

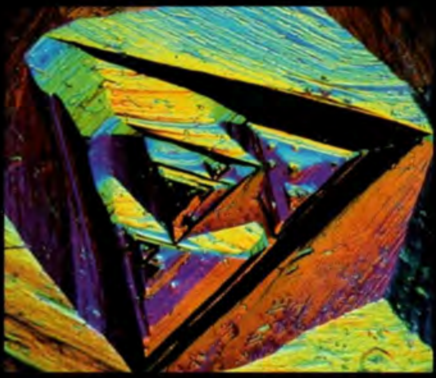
These fascinating abstract shapes and colours appear more like surrealistic paintings than photographs of the surfaces of rough diamonds.

The function of these photographs is not merely artistic. They serve to explain a lot about some features of the stones themselves.

Bill Sechos and Rudy Weber took these photos as part of their research into the surface features of Australian diamonds. The external



Diamond from Wellington.



Diamond from AK1.

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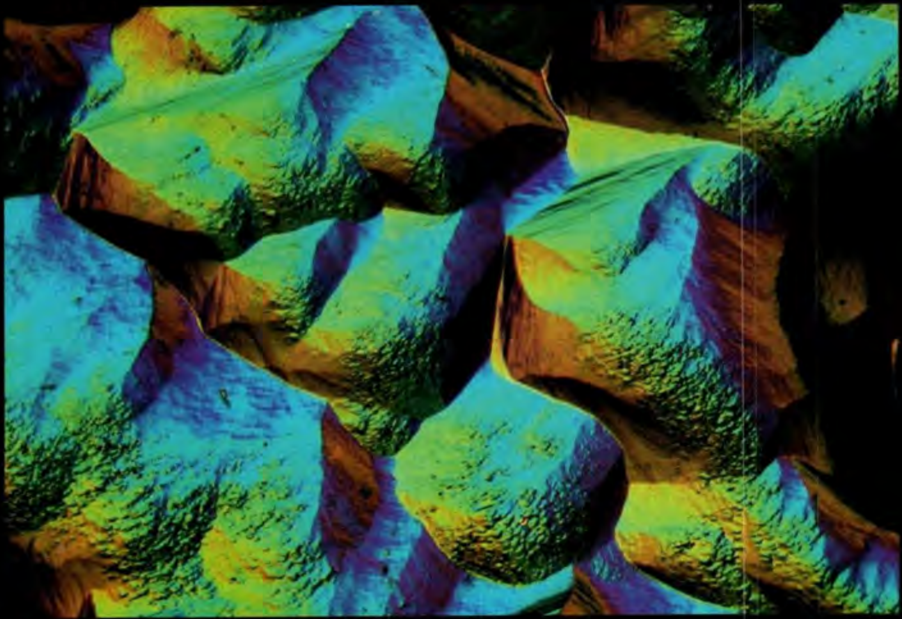

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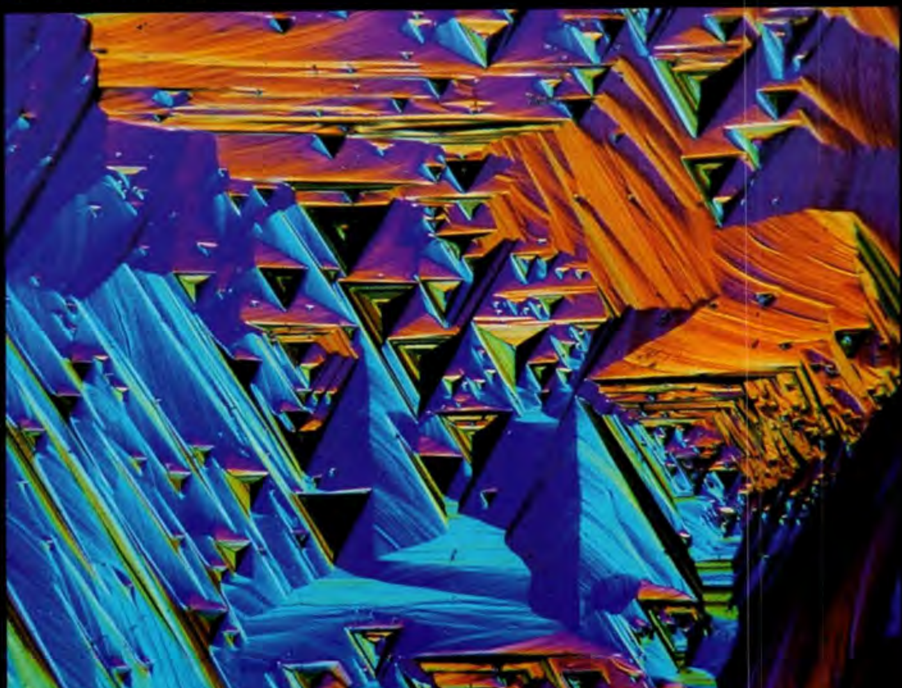


Diamond from AK1.

growth and etch features on a rough diamond reflect its internal structure and symmetry. These features give clues to the environmental conditions a crystal has undergone after its formation.

Some Australian diamonds show specific surface features that can be used to pinpoint sites from which they originate. For example, diamonds from the Argyle mine in Western Australia exhibit distinctive rough hexagonal surface depressions.

The photographic process is meticulous. Stones must be scrupulously clean and the face of the stone should be relatively flat. The process is known as differential interference contrast photography and involves using a Nomarski prism, acting as a beam splitter, on a universal research microscope. The interference caused by this prism reveals textures that cannot be made visible by classical methods of microscopy. The colours used are determined by the operator: certain features are highlighted better under particular settings. The features help explain the nature of the stone being photographed, thus providing a useful research tool.

This process can also be used to 'fingerprint' individual cut and polished diamonds (but not other gemstones). Just as people have distinctively different fingerprints, each diamond has a unique structure and this method of photography has been used in court cases to identify a particular diamond that has been stolen.

The Gem Studies Laboratory is an independent gem and minerals testing laboratory that performs functions such as gemstone identification, diamond grading and photography of gemstones and inclusions. ☐

—Fiona Doig

Birds of the Reef: Noddy does a Good Tern

Over the vast sweeps of ocean, seabirds travel in search of food and a place to breed. Perhaps the most spectacular of all the seabirds are the Sooty Terns (*Sterna fuscata*), nesting in their tens of thousands on many islands of the northern Great Barrier Reef and Coral Sea—and, in fact, just about all the tropical seas.

Sooties belong to the group of birds called terns (subfamily Sturninae), and are similar to gulls but slimmer and often smaller. Their forked tails were responsible for their once-common name 'sea swallow'. An even older name was 'sea mell' or 'sea mew'. Shakespeare used this term in *The Tempest* (Act II, Scene 2) where Caliban, speaking to Trinculo, tried to curry favour by promising delicacies.

Black noddies returning to their nests after feeding at sea.

Sometimes I'll get thee
Young sea-mells from the Rock.

Australia has about 20 of the world's 42 tern species, 17 of which breed here. The Sooty Tern is one of the most common of the tropical seabirds, with an estimate of 30 million individuals in the mid-central Pacific region. Except when breeding, the birds range over the oceans of the world, possibly sleeping on the wing as there are few reports of the birds landing on water.

Oceanic feeding groups usually number several thousand but, when the breeding urge strengthens, many such aggregations coalesce and produce one of the most spectacular sights nature has to offer. The first warning of the return of the birds is at night when the shrill yet musical cry of 'wideawake' drifts down from the dark sky. By morning the skies are clear again and there is no sign of the birds. A few weeks pass as this mysterious pattern is repeated night after night—until one magical afternoon when a dark mass appears on the horizon—thousands upon thousands of Sooty Terns have returned to breed.

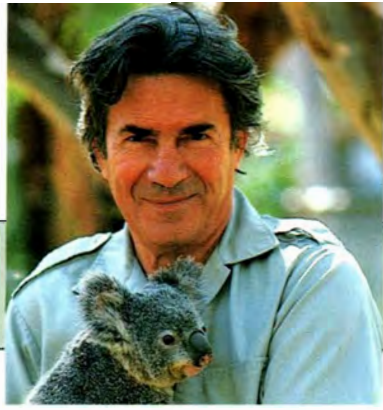
The wheeling flocks, however, only move higher and spread over the island. Even with the setting of the Sun the birds remain landshy and stay aloft. The hours pass until, when it is nearly dawn, the calls cease and the birds disappear, presumably to fish out at sea. This teasing pattern is repeated day after day until a group finally lands and begins the task of nesting. Each day the numbers of landed birds increase until the ground disappears under a mass of birds, each laying a single egg in a small hollow in the sand. Each nest is about a metre from the others, out of pecking distance but not out of squabbling range.

Sooty Terns breed during the spring in south-western Australia and

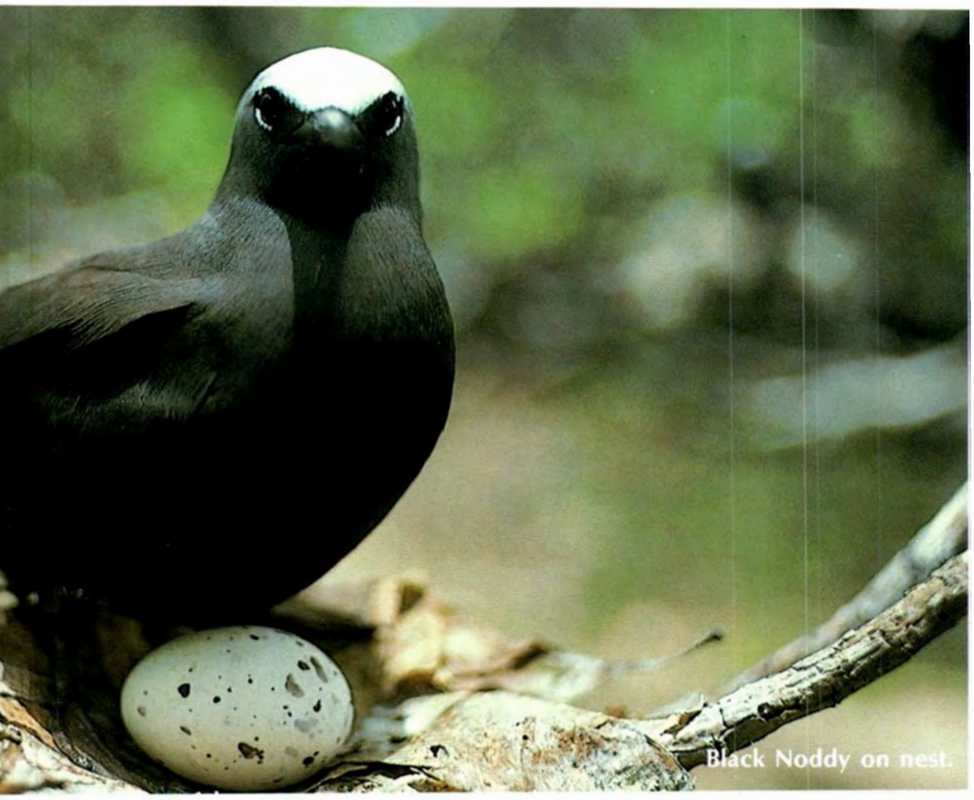
the Great Barrier Reef region. North of this area they breed during autumn, although autumn breeding has been observed in recent years at Michaelmas and Upolu Cays. Regardless of season, once the nesting days are over, the birds again disperse over the oceans.

Evidence is gradually being gathered on how far they wander. One Sooty Tern, banded on the Seychelles in the western Indian Ocean, was found near Darwin six months later. Another banded at Lord Howe Island was found in the Philippines.

One remarkable feature of the Sooty Terns' nesting pattern occurs on Ascension Island in the South Atlantic. Instead of an annual cycle, the birds here breed every 9.6 months. This shorter cycle can only be established in an area where both food and climatic conditions are favourable all year round. This was the situation at Lake Eyre during the last flooding when breeding by gulls was almost con-



OF VINCENT SERVENTY



Black Noddy on nest.

tinuous.

Sooty Terns feed on fish and small squid, snipping them up from or just near the surface, although at times a bird will dive through a wave crest. Bedraggled parents leaving a nest site always return with clean feathers, so they must take short dips on feeding flights.

In contrast to the Sooty Terns with their white underparts, there are other terns that are mostly dark. These are the noddies and Australia has four: the Lesser Noddy (*Anous tenuirostris*) nests on the Abrolhos Islands off the western Australian coast, the Common Noddy (*A. stolidus*) breeds in northern Australia, the Grey (*Procelsterna cerulea*) on Norfolk and Lord Howe Islands, and the Black (*A. minutus*) in north-eastern Australia.

The Black Noddy is the species best known to tourists since it breeds in spring in thousands on Heron and nearby islands in the Capricorn Group at the southern end of the Great Barrier Reef. There are few more charming sights than a pair of Black Noddies courting. So unafraid are the birds that an incubating individual may be nudged gently aside, enabling its single egg to be seen. Because of this lack of fear, all details of their courting, nest building and breeding behaviour have been well studied.

It is most encouraging that the increase in tourist numbers on Heron Island is paralleled with an increase in nesting noddies. In 1910 there were only 53 occupied nests. By 1946 this had grown to a small colony and by 1972 there were between 13,000 and 25,000 pairs. A similar increase occurred on the islands nearby, where tourist visits were less frequent, and the total on the whole of the Capricorn Group was estimated to be 1.5 million pairs.

At least where seabirds are concerned there is no obvious danger of tourists 'loving the animals to death' as is often feared by conservationists. On both offshore islands and mainland regions I have found no evidence that increasing numbers of tourists have damaged either the landscape or its wildlife, both plant and animal. Indeed the opposite can be true, for although wildlife protection laws tend to be ignored in many parts of Australia, this does not happen where tourists are plentiful. Law-breakers know that when the general public becomes involved there is a high chance their crime will be reported and action taken.

These few species of tern are only a fraction of the wealth of seabird beauty on the Reef. It is only fitting that the beauty of the underwater world of coral seas should be matched by the beauty of the abovewater world of the sky. □

Nesting Sooty Terns on a coral cay. An old name still occasionally used for these birds is 'wideawake', after the call they make.

Sooty Tern and chick.

Photos: Vincent Serventy.

MORE TO THE MANTIS THAN MEETS THE EYE

BY PAMELA MAITLAND

The Cyclopes were a race of giants in Greek mythology having a single eye in the middle of their forehead. Perhaps the most famous Cyclops was Polyphemus, son of Neptune, who captured Odysseus and his crew and kept them in his cave, as told in Homer's *Odyssey*. But the ingenious Odysseus had a plan. He and his men made wine for the giant which he drank until he was quite merry; then, with his senses dulled, they poked his eye out and ran for it.

So what has this to do with the praying mantis? Well, until recently it was believed that the praying mantis could not hear because no obvious acoustic behaviour had been observed, such as singing in crickets, and because no obvious hearing organs could be found on its body: crickets hear through structures on their knees, certain moths have specially adapted mouthparts, but praying mantises, it seemed, were stone deaf. However, two scientists at Cornell University in New York, David Yager and Ronald Hoy, have shown that a North American species of praying mantis, *Mantis religiosa*, is indeed sensitive to sound. Not only this but, unlike any other hearing animal, it does not have two ears, just one. In other words, it is an auditory Cyclops.

The praying mantis is named for the pious attitude in which it holds its front pair of legs but it could just as easily be called the 'preying' mantis as that is exactly what it does: it stalks, attacks and eats other insects and some species even eat small mammals and frogs.

The praying mantis is well-adapted for its carnivorous lifestyle. It has excellent vision and its enormous bulging eyes at the top of its triangular head give it an other-worldly look. After a praying mantis has stalked its prey, it sizes up how far away it is by swaying back and forth, then grabs it with its long, powerful and spiky front legs. With the victim tightly clenched, the praying mantis begins to chomp away on it, reducing it to a pulp which is then swallowed.

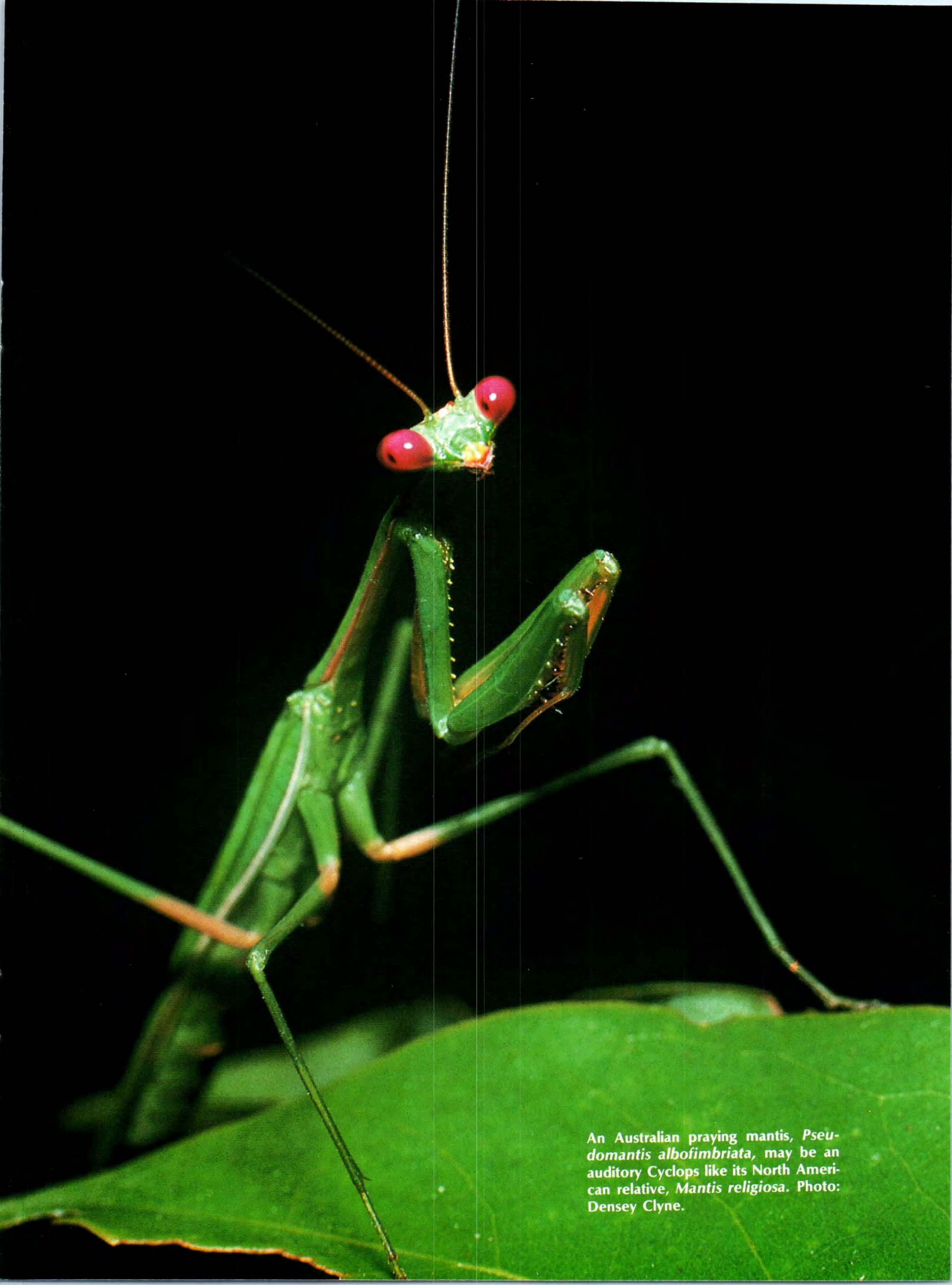
The hunter is in turn hunted and to protect itself when threatened the praying mantis, in response to visual stimuli, will rear up on its back pair of legs, spread out its wings and raise its front legs. The markings on the legs are such that when positioned properly they look like huge eyes. These actions, which give the impression of a large and menacing animal, scare potential predators away. Before it was known that the praying mantis could hear, it was assumed that it either saw something coming for it or it didn't . . . with the expected consequences. But Yager and Hoy have discovered that, at least in flight, *Mantis religiosa* can indeed hear and, in particular, is most sensitive to the frequencies emitted by the echolocating, insectivorous bats.

By hooking up the nerve cord of the praying mantis to two electrodes that recorded the electrical activity passing through the central nervous system, Yager and Hoy could record the mantis' response to a range of sound frequencies. The electrical activity increased in a predictable and characteristic way, which was a sign to them that the mantis was responding to noise. *Mantis religiosa* was also found to be most sensitive to the ultra-high frequencies that certain lacewings, crickets and moths are sensitive to. They think that the praying mantis, in common with these other night-time flyers, is able to detect the ultrasonic cries of insectivorous bats and take evasive action, such as flying erratically or nose-diving, to totally confuse the bat.

If the praying mantis is sensitive to sound, then where are its ears? Crickets have ears on their legs but removal of all the mantis' legs had no effect on its response to sound. By severing the nerve cord at different places along its length, starting from the lower abdomen, and testing the mantis' response to sound, Yager and Hoy were able to localise which segment of the body was doing the hearing. The metathorax, the segment bearing the third pair of legs and the hindwings, was where the action was. On close scrutiny a suspicious-looking groove of unknown function was found in between the legs—unknown, that is, until they put a drop of wax on it which immediately deafened *Mantis religiosa*. It was the cyclopean ear.

They went on to look at its anatomy and found that inside the groove were two tympana (eardrums) made from very thin cuticle, facing each other and very, very close together. Because of the juxtaposition of the tympana, which thus act as a single organ, the ear probably cannot provide information about the direction of the sound, unlike the widely separated ears in other animals. Yager and Hoy believe that perhaps the praying mantis localises a sound by making scanning movements with its body.

Before it was always thought that the mantis' life and behaviour revolved around its remarkable visual abilities. Now that it is known that the praying mantis has independently evolved a novel hearing structure, we learn that there is another side to the mantis' life. Rather than go down with the sun, using their ear and 'nose' (they also use pheromonal signals) they may spend their nights looking for mates, courting, perhaps hunting by listening to singing insects, but most certainly trying to avoid marauding bats. □



An Australian praying mantis, *Pseudomantis albofimbriata,* may be an auditory Cyclops like its North American relative, *Mantis religiosa*. Photo: Densey Clyne.

Fruits of the Cluster Fig (*F. racemosa*) sprout from the trunk, beckoning greedy fruit-bats, which relish the succulent flesh. The darkest of the figs illustrated here are ripe. Photo: T. Hawkeswood.

Who gives a Fig?

By Tim Low

When Aborigines in northern Australia needed sandpaper to polish their tools, they had only to pluck the leaves from certain kinds of fig trees. Fig-leaf 'sandpaper' worked remarkably well, as a curious Joseph Banks observed at Endeavour River in 1770: ". . . they use shells and corals to scrape the points of their darts, and polish them with the leaves of a kind of fig tree (Ficus radulo), which bites upon wood almost as keenly as our European shave grass usd [*sic*] by the Joiners".

Sandpaper fig leaves contain glass-like silica—a deterrent to plant-eaters, whose teeth are ground down by the chewing. Fig-leaf sandpaper really works, easily removing the paint from pencils, for example. Aborigines in Dampierland, Western Australia, in keeping with modern times, use the leaves to clean saucepans and spark plugs. Papuan women use them to shave their legs.

The Versatile Fig

Sandpaper is but one of the myriad products furnished by the extraordinary plants of the genus *Ficus*, known popularly as figs. To pre-industrial societies throughout the world, fig trees provided a cornucopia of useful products, ranging from fruits and vegetables, string, rope and blankets, to rubber, bird traps, canoes and religious symbols.

Consider the white latex of figs. Nearly all kinds of figs (800 species occur world-wide) ooze a milky latex from broken stems. So sticky is this that northern Queensland Aborigines used it to trap birds, smearing the latex over branches where cockatoos and other parrots perched. The hapless birds were then cooked and eaten.

In Asia last century, latex from one kind of fig (*F. elastica*) was a source of rubber, harvested from small fig plantations in Malaysia. But rubber from South America's Para Tree (*Hevea brasiliensis*) proved more elastic and the fig-rubber industry never succeeded. *Ficus elastica* continues to be planted, although nowadays as an ornamental, especially indoors in public buildings in Australia, where it is called the Indian Rubber Plant. Few Australians realise that this is a fig for, in the absence of its pollinating wasps, it does not bear fruit. But more on this later.

The so-called 'fruit' is the most characteristic feature of fig trees, and most kinds are edible to people. The fig of commerce is *F. carica* of western Asia. In Australia, Aborigines ate a variety of wild figs, especially those of the Cluster Fig (*F. racemosa*). In central Australia Aborigines pounded the dried fruits of the Small-leaved Rock Fig (*F. platypoda*), forming fig cakes that were stored for future use.

Explorers also ate figs. Captain Cook, Joseph Banks and Ludwig Leichhardt sampled Cluster Figs, and scurvy-stricken convicts at Port Jackson ate Rusty Figs (*F. rubiginosa*), which the early writer D.D. Mann condemned in 1811 as "nauseous, full of seed, but eaten by the natives". Around Gladstone, Queensland, early settlers made sweet jelly from Cluster Figs, one of the tastier species.

Figs are not the only food to come from fig trees. The young shoots of many species may be eaten raw or cooked. Northern Aborigines actually ate young sandpaper fig leaves and, in Java, Indian Rubber Plant leaves were used in various dishes. (The shoots of ornamental Indian Rubber Plants are well worth trying as dinner vegetables, but need first to be boiled to remove the offending bitterness.)

Fig tree wood is soft, which may explain why most species produce sticky latex or fibrous bark—to thwart borers. The tough inner bark can often by spun into string or stripped in slabs and hammered laboriously into coarse blankets or cloth. Aborigines used at least six native fig species for dillies or blankets, and in Africa the 'Bark Cloth Fig' (*F. natalensis*) is especially important. Because fig wood is soft it is easily carved. In the Northern Territory Aborigines hewed dug-out canoes from Cluster Fig

The Moreton Bay Fig (*F. macrophylla*) has speckled figs about 2.5 centimetres wide. Aborigines ate the figs and spun the bark into twine. Photo: T. Low.

trunks and Egyptians made mummy coffins from Sycamore Fig trunks (*F. sycomorus*).

The diversity of products that comes from this one group of plants is remarkable. Yet these items touch only the surface of the fig–human relationship. Much more extraordinary is the role of fig trees in religion. Throughout history across much of the world, men and women have revered fig trees as sacred beings. Genus *Ficus* has served both body and mind.

The Religious Fig

Tree worship is an ancient rite and fig trees have served as its supreme icons. Romans revered the cultivated fig, Hindus the Banyan (*F. benghalensis*) and Bo Tree (*F. religiosa*), and Buddhists believe that Buddha grasped enlightenment beneath a fig (*F. religiosa*). Figs find mention over 60 times in the Bible, often as symbols of prosperity or impend-

The interconnecting roots of a strangler fig, probably *F. watkinsiana*, are beginning to envelope this rainforest tree on Lamington Plateau in southern Queensland. Strangler figs do not literally strangle their host but do compete for sunlight and soil nutrients. When rainforests are logged the strangler figs are invariably left standing, where they provide an important food resource for hungry birds and bats. Photo: T. Low.

Australian Figs

Australia has some 40 native fig species, growing in eastern and northern Australia, and many have figs worth trying. Of these, a few warrant special mention: the Crowned Sandpaper Fig (*F. coronata*) is easily distinguished by its bristly black figs, about 1.5 to three centimetres long. They are sweet and succulent and well worth trying. This is the most southerly ranging of the figs and the only species occurring in Victoria where it is restricted to eastern Gippsland. It grows mainly in damp gullies and along streams in rainforest.

Two other sandpaper figs occur across eastern Australia: the Sweet Sandpaper Fig (*F. opposita*), found south to Brisbane, and the White Sandpaper Fig (*F. fraseri*), which reaches Newcastle. Both have delicious, black and unbristly figs. Sandpaper figs are easily distinguished by their harsh leaves. They are small trees without buttresses or strangling roots, usually encountered along stream banks, especially in rainforests. The Sweet Sandpaper Fig is the tree Joseph Banks saw in use at Endeavour River, which he called *F. radulo*.

The Small-leaved Rock Fig (*F. platypoda*) is Australia's most wide-ranging fig. It is the only species to reach central Australia where it is restricted to rock outcrops and gorges. It is an adaptable tree, found also in tropical woodlands and Queensland rainforests, usually on rocks. On St Helena Island near Brisbane it grows on the convict ruins. Being a typical fig, it has the characteristic sinuating roots, milky latex, seed-filled figs, which are reddish when ripe, and young shoots enveloped in a spike-like stipule—a characteristic of all but the sandpaper figs. Central Australian Aborigines relished these figs, which are extraordinarily rich in protein, fat and calcium.

The Moreton Bay Fig (*F. macrophylla*) shares all of the Small-leaved Rock Fig's features, except that its ripe figs are purplish-red with pale spots. This fig is widely planted in public parks, both for its stature and for the generous shade cast by its big leathery leaves. Its figs are tasty, although filled with gritty seeds. Like most figs it is a rainforest tree, found from southern Queensland to the Illawarra scrubs. Aborigines ate the figs and spun string from the bark.

The Cluster Fig (*F. racemosa*) bears its large (five to seven centimetre-wide) figs on its trunk as food for fruit bats, although Aborigines ate them as well. Cluster Figs grow along river banks in northern and eastern Australia, south to about Gympie.□

ing doom. And one doesn't need to be reminded of what sort of leaf Adam was clutching (nor what he was hiding) after he'd tasted the forbidden fruit! Across Africa, Asia and the South Pacific, fig trees invoke respect as abodes of spirits or ancestors. Even in outback Australia the native Small-leaved Rock Fig (*F. platypoda*) was held sacred in some areas and anyone damaging certain trees was risking death.

Fig worship reached its zenith in Sri Lanka. Buddhism was borne to the island upon a fig branch, reputedly from Buddha's own enlightenment tree. Planted at Anuradhapura, Buddhists believe this branch survives as the sacred Bo Tree flourishing there today. Cuttings planted throughout Sri Lanka were zealously protected—early punishment for fig tree killing was death. When Tamil terrorists rampaged recently through holy Anuradhapura, they took time out from slaughter to desecrate the holy Bo Tree, drilling its trunk with bullets of bigotry.

Gun wounds notwithstanding, fig religion has proved beneficial to some figs. For example, the distribution of the Bo Tree has been extended by Buddhists from India to Sri Lanka and South-east Asia, aided by birds no doubt, and it is now a weed in Singapore. In western Malaysia, where rainforests were cleared for villages, fig trees were often protected and enshrined by the Chinese. In India, fig trees are not harmed, even where their roots damage houses and drains.

Fig worship is so widespread a phenomenon that it begs explanation: why feel reverent towards a fig? To anyone who has beheld a giant strangler fig in a Queensland rainforest, the answer immediately suggests itself: fig trees are awesome. Their snake-like roots coil about rocks and stumps, and the enormous crown thrusts beyond the forest canopy. Most fig trees possess special adaptations for germinating on rocks, stumps or other trees. The remarkable success of the genus, and its religious mystique, owes much to these adaptations.

Figs do look eerie. Strangler figs sprout in crevices in other trees and throw down tangles of interlocking roots that enclose the host in a prison of criss-crossing coils (although they do not actually strangle it). Small-leaved Rock Figs send roots slithering into crevices and trailing over cliffs. Banyans drop bristly prop-roots from heavy boughs, forming forests of trunks from one tree. Other fig trees sport enormous buttresses, thick ropes of figs from limbs, and even strings of figs underground.

To further the mystique, some fig trees thrive on bare stone, where no other trees may grow. They sprout mysteriously atop Hindu temples and throw shade over sacred Aboriginal rock sites. Questing tiny pockets of soil, their eager roots snake between boulders and around cornices, wedging into creases and cracks. These eerie organs are the bane of archaeologists, dislodging brickworks at such disparate locations as the Angkor Wat temple in Kampuchea and the convict-built walls of St Helena Island near Brisbane.

The sheer size of figs helps magnify their mystery. The world's broadest tree

Rusty Figs (*F. rubiginosa*) also known as Port Jackson Figs were consumed by scurvy-stricken convicts. Photo: T. Hawkeswood.

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Ripe fruits of the Pink Fig (F. *microcarpa*), showing the orifice at the base through which the tiny fig wasps (agaonids) have escaped. Pink Figs grow in Queensland rainforests, often close to the sea. Photo: T. Low.

is a Banyan in Calcutta spread over 1.2 hectares! With 1,775 trunk-like prop-roots, it is a veritable forest of one tree. In Brisbane, the suburb of Fig Tree Pocket commemorates an old Moreton Bay Fig (*F. macrophylla*), which was so enormous that a horse and dray could hide between its buttressed roots. Some strangler figs tower above the rainforest canopy, using their encumbered host as a ladder to the sky and throwing down a shade of ineffable gloom. No wonder these trees evoke awe!

A Naturalist's Delight

Even the naturalist may fall in thrall to the fig. So much about these sylvan giants seems designed to enthrall.

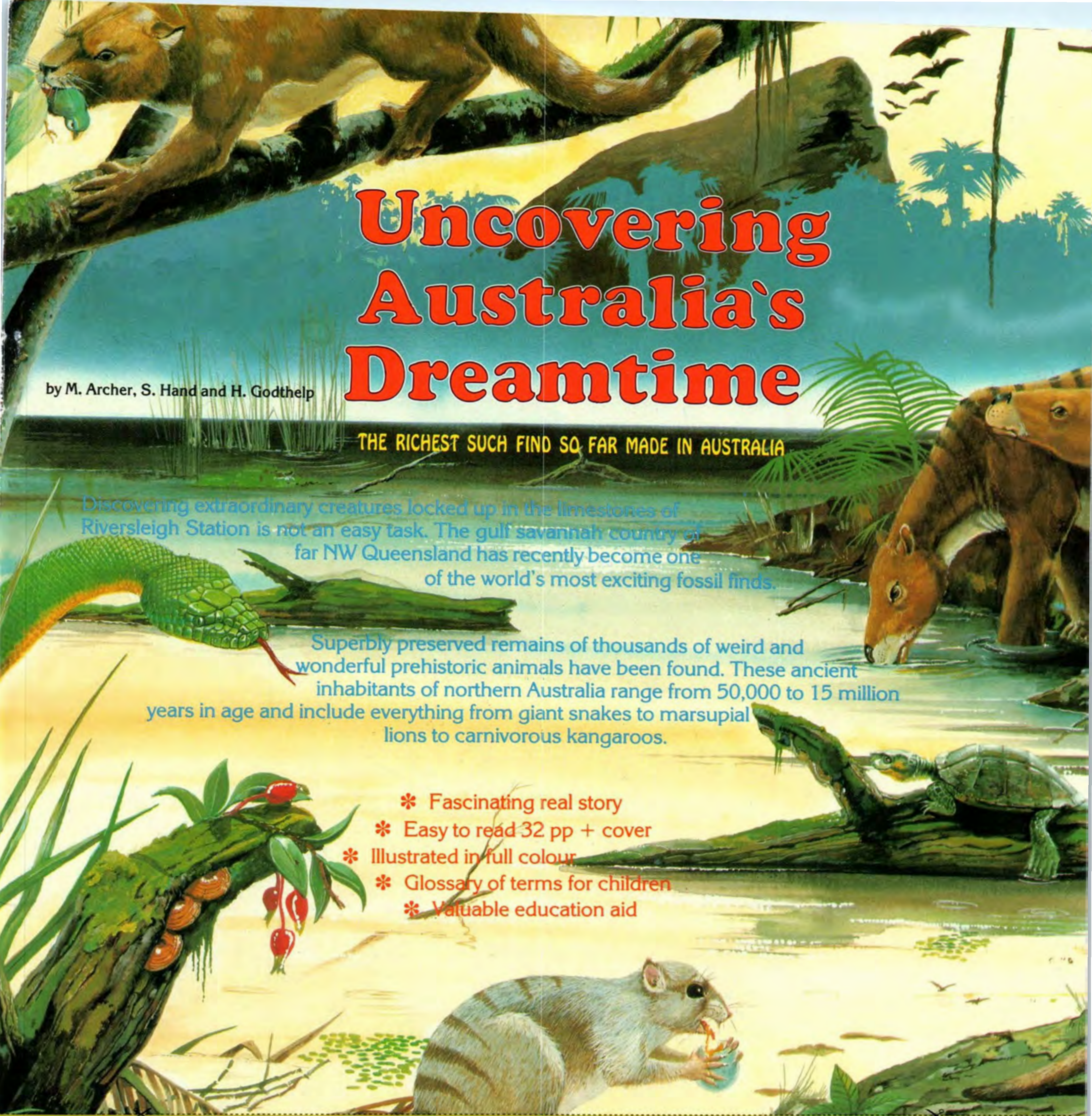
Tear open an almost ripe fig, for example, and you may see a unique feature—a seed mass writhing with tiny adult wasps of the family Agaonidae. These wasps, barely a millimetre or two in length, form a unique symbiotic relationship with fig trees.

The figs enclose the minute flowers, which are pollinated only by these wasps. Some of these flowers form galls to house and feed the wasp larvae. After mating, pollen-laden female wasps (the males are all wingless) fly to new figs, entering via a special hole at the base, and the cycle continues. The relationship is remarkably intricate and much remains to be discovered. We know that each fig species has its own species of wasp, and that some fig species produce two kinds of fig—one for rearing wasps, the other containing seeds. This might explain why Captain Cook thought so poorly of the Cluster Fig, while later writers praised it: Cook probably sampled the gall figs containing wasps, which neither ripen nor taste sweet.

Consider seed dispersal, too. Figs depend entirely on animals to convey their seeds to new rock and tree crevices, and the range of fig-eating animals is astonishing. In Costa Rica in central America I stood entranced beneath a tree visited daily by Capuchin, Howler and Spider Monkeys, by Raccoon-like coatis, squirrels and various birds, and at night by Kinkajous, coatis and a prehensile-tailed porcupine. In Thailand I watched a squirrel gnaw at unripe figs while a barking deer waited below for the remains. In Asia, fruiting fig trees evoke a village market mood, as hornbills, gibbons, civets, bats and even Indian Elephants jockey for their share.

This generous free-for-all approach isn't characteristic of all figs. Malaysia's remarkable Earth figs, for example, only ripen underground as treats for grubbing pigs and deer. Queensland's bat-dispersed Cluster Figs, heavy-smelling like bat body odours, sprout along trunks where fruit pigeons cannot perch. Sandpaper figs bloom green, yellow, orange, red and then purplish-black in a calendar of colours to inform birds (most mammals are colour blind) of impending ripening.

Phenomena like these provide the key to understanding these trees—that figs excell at symbiosis. Fig seed dispersal, the fig-wasp interdependence and, ultimately, fig religion: all are triumphs of co-adaption. The naturalist can but stand in awe. All praise to the fig!☐



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by M. Archer, S. Hand and H. Godthelp

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