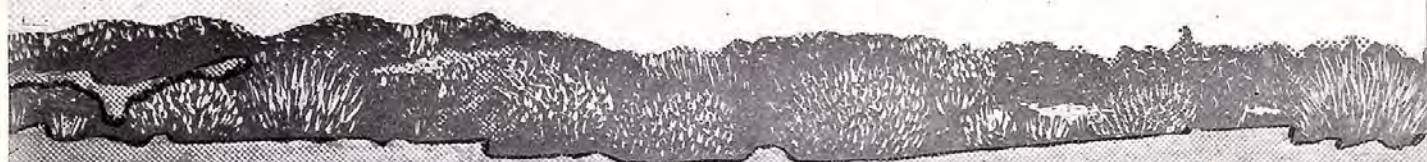




# AUSTRALIAN NATURAL HISTORY

JULY—SEPTEMBER 1977 VOLUME 19 NUMBER 3 \$1\*

# ARID AUSTRALIA

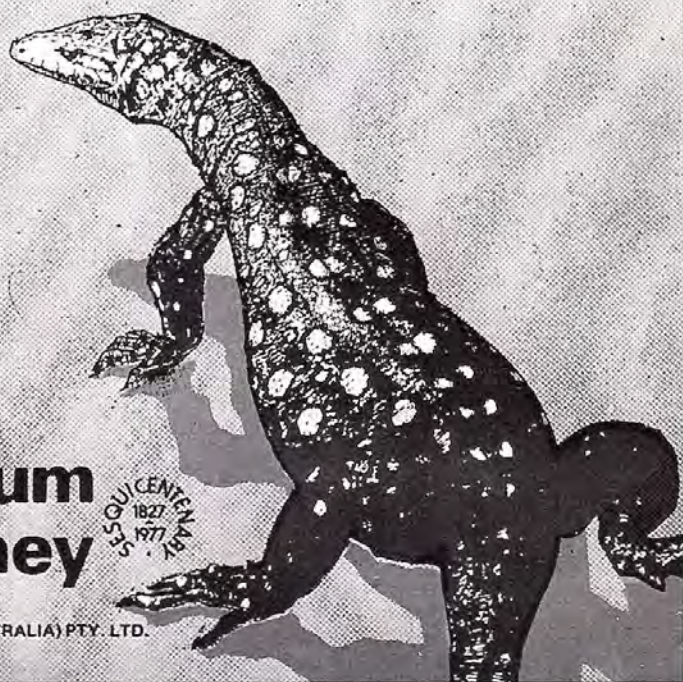


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# AUSTRALIAN NATURAL HISTORY

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Norfolk Island Pines at Bronte Beach, Sydney.

COVER: Sulphur crystals with Aragonite (white mineral), which are deposited from volcanic gases. This specimen comes from a volcanic province in Sicily and is in the collections of The Australian Museum. (Photo: Gregory Millen/Australian Museum).

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# THE OUTFALL CONNECTION

## THE PLIGHT OF OUR COASTAL TREES

By M.G. Pitman, H.G.M. Dowden, F.R. Humphreys, Marcia Lambert, A.M. Grieve and J.H. Scheltema

Robert Stewart

M.G. PITMAN is President of the Australian Museum Trust and Head of the School of Biological Sciences at The University of Sydney. H.G.M. DOWDEN, F.R. HUMPHREYS and MARCIA LAMBERT are from the Forestry Commission of NSW. A.M. GRIEVE, previously at The University of Sydney is now with the NSW Department of Agriculture. J.H. SCHELTEMA specialises in air pollutant effects on plants for the State Pollution Control Commission.



"Have you studied these noble trees, Moss? Have you noticed the odd one deteriorating, withering away? And it's due to that sewerage outlet you can see poking into the sea like a poxy cock, discharging chemicals, detergents and poisons of all types. This discharge creates gaseous air pollution which the easterly winds blow off the sea onto the trees and this has a toxic effect. It's not your average round, healthy turd that pollutes the ocean, Moss, but your square chemicals."

*The Outcasts of Foolgarah* by Frank Hardy, 1971.



Forestry Commission

A 1959 photograph of Bondi Beach viewed from the south showing Norfolk Island Pines. From Dowd, B.T. (Ed.) *History of Waverley Municipal District*, 1959.

Norfolk Island Pine trees have been planted along beachfronts in many places around the world. The trees are well adapted to growing near the sea and normally can thrive even where exposed to sea spray.

During the late 1960's it became clear that many of the well-established Norfolk Island Pine trees along Sydney's metropolitan beachfronts were dying. Efforts to replace them with young trees were unsuccessful. The problem was most severe from Bondi southwards to Maroubra, where most of the trees died or were removed because they had become dangerous. This also happened at the northern end of Manly beach and at Harbord. Similar symptoms were to be seen in trees at a few other

Bondi Beach in 1974. Only four trees remain.



Forestry Commission

places along the Sydney coastline where the trees were exposed to the sea.

It now appears that the damage was caused indirectly by the active components of domestic and commercial detergents (known as surfactants) released into sea water from the sewage outlets. The surfactants helped salt from sea spray enter the leaves, which were killed by the excess salt. All vegetation along the beaches exposed to polluted sea spray can be affected and may be killed, though some plants such as the mirror plant, *Coprosoma baueri*, appear to be more resistant than others.

The damage produced in Norfolk Island Pines starts as a browning of the tips of the fronds. In young trees the foliage may then be completely killed and the tree does not recover. Older trees tend to lose foliage from the lower branches on the seaward side of the tree. Fronds, smaller branches and sometimes entire branches die. Often the tree fights back against the destruction by the formation of adventitious shoots from buds on the branches, producing thick bunches of fronds, which may in turn be killed leaving clusters of twigs or dead shoots. The bark may also be damaged and, characteristically, can split; subsequently, resin oozes from the wounds. These symptoms can be seen in trees along the Manly promenade, particularly toward the north end. On many trees dead branches have been removed for public safety. In other species, the leaves also turn brown, particularly at the tips or along the edge of the leaf, showing typical symptoms of salt damage. Depending on the severity of the damage, leaves, branches or even the whole plant may die.

The problem seemed to be restricted to certain metropolitan beaches in Sydney, and there were indications that it was related to the level of sodium chloride (salt) in



A. Grievé

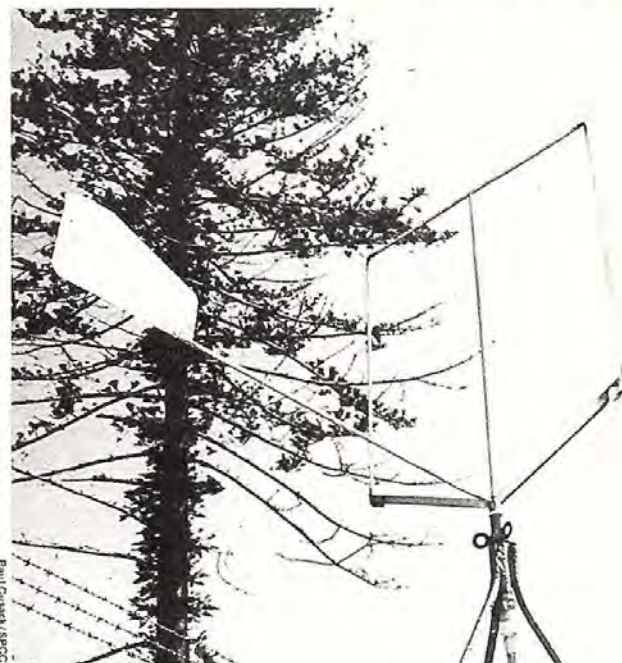
leaves was in turn correlated with proximity to sewer outlets and to the degree of exposure of the tree to the sea. There appeared little doubt, therefore, that something in the sewage was facilitating the entry of salt into the leaves from sea spray, thus killing the trees.

Evidence that material from the sewage reached the foliage came from measurements of zinc content of the leaves, which was high near the major sewer outfalls. Sea water contains a very low content of zinc, but as the level in sewage is known to be much higher, the sewage appeared to be the source of zinc on the foliage. However, the level of zinc present was not sufficient to account for the damage. Norfolk Island Pines survive on the coast not by tolerating high levels of salt in their

A healthy row of Pines growing on the sea front at Normanville, South Australia.

the foliage. A detailed survey of Norfolk Island Pine trees along the New South Wales coast was, therefore, made to determine the distribution and degree of damage, and to relate it to environmental factors. For each sample, the bearing and distance to the sea, the degree of shelter, height above sea level and the distance from sewage outfalls were recorded. Measurements also were made of sodium, chloride and potassium contents of foliage as well as a number of other elements such as boron, zinc, phosphorus, aluminium, magnesium, manganese and iron.

Damage to the trees was most severe in the region between Collaroy and La Perouse, and was highly correlated with the proximity to the large sewage outfalls (at North Head, Bondi and Maroubra). Damage also was found at Newcastle and at Wollongong, again located not far from sewage outfalls. When damage at the beachfront was severe, trees a few hundred metres inland were little affected. The strongest winds on the coast usually blow from the south to southeast and trees sheltered from this direction had more dense foliage than exposed trees. The results showed that the degree of damage, measured by the proportion of the live crown remaining, was very closely related to the amount of salt in the trees. Where deaths had occurred, the trees contained excessive amounts of sodium chloride. The salt content of the

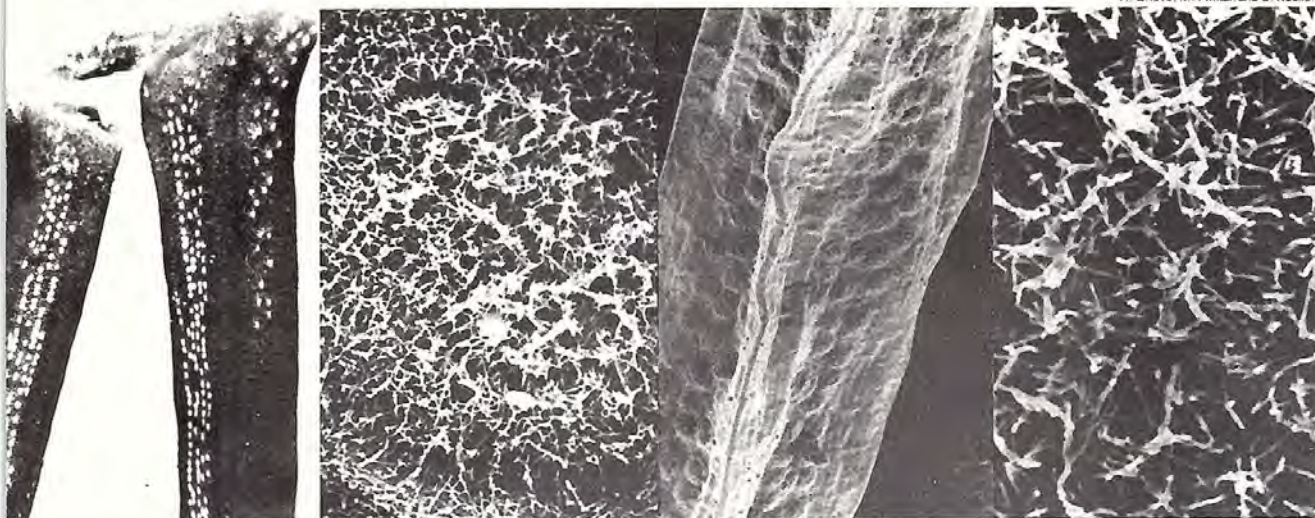


Paul Ockler, SPCC

Sea spray is deposited on the vertical wires of this 'harp' collector and runs into a container at the base.

tissues but by avoiding its uptake. The resistance of the trees to salt depends on mechanisms which minimise uptake of sodium chloride either through the roots or through the foliage. The roots of the plants take up potassium in preference to sodium. The effectiveness of this preferential uptake can be seen either by watering

A. Grievé, M. Pitman and C. Nockold



Views of the surface of Norfolk Island Pine needles. Left to right: the white dots are patches of waxy fibres over the stomata; Scanning Electron Microscope pictures of the waxy fibres at increasing magnification. The width of the pine needle in the first two figures is equivalent to 1.5mm.



A. Grieve and M. Pitman

Norfolk Island Pine foliage sprayed with salt solution.

the soil with sea water, which has little effect on growth of the trees or by growing the plants in nutrient solution to which salt has been added. Such experiments have shown the trees can grow in solutions of up to eighty percent of the sodium chloride concentration in sea water. Though plants grow at the edge of the sea, the roots can be expected to have been in a solution of much lower concentration due to dilution by rain water and seepage.

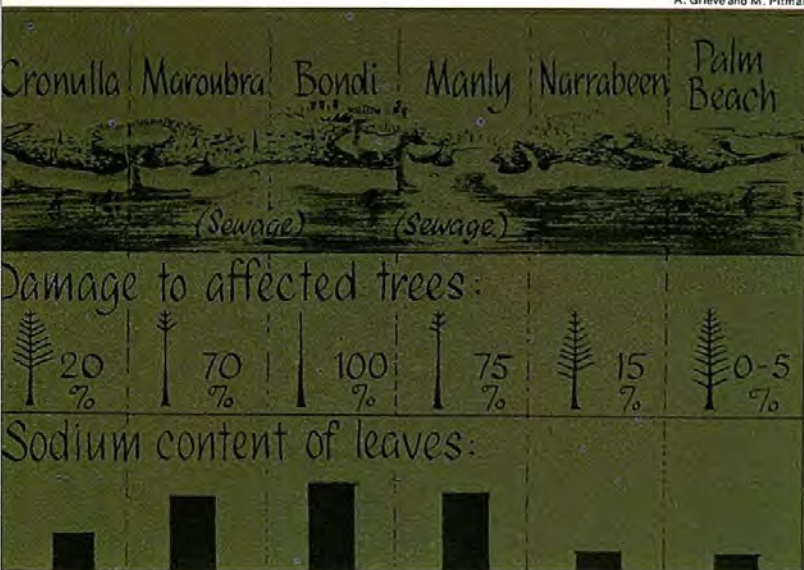
The plants are also well adapted to avoid entry of salt from sea spray. The leaves of Norfolk Island Pines have a thick waxy layer on the surface (the cuticle) that is impermeable to salt diffusion (and to water). In the surface are a number of pores (the *stomata*), which allow gases to diffuse into or out of the leaves. The stomata are arranged in rows on the inner side of the needle and in a

cluster at the base of the needle. Drops of water do not normally penetrate stomata of leaves, otherwise the leaves would become water-logged each time there was a storm. The small size of the pores and water-repellent waxy cuticle give leaves the same kind of resistance to penetration by liquid water as water-proofed cloth, or ducks' feathers. In Norfolk Island Pine needles, the stomata are also covered by a mesh of waxy fibres that can be seen by the naked eye as small white dots against the green of the leaf. It is thought that these waxy fibres prevent water from sea spray blocking the stomatal pores, so that some exchange of oxygen, carbon dioxide and water vapour can take place through the stomata even when there is water on the surface of the leaf. These fibres on Norfolk Island Pine needles may also prevent very small droplets of sea spray from being blown into the stomatal pores.

It was suspected that the damage was caused indirectly by the active components of domestic and commercial detergents (known as surfactants) released into sea water from the sewage outlets. The surfactants helped salt from sea spray enter the leaves which were then killed by the excess salt. There was a number of reasons for this idea. Modern surfactants had started to be used in quantity at about the time the problem first appeared during the 1950's. They were known to be present in large amounts in metropolitan sewage and, unlike the soaps which they had largely replaced, are very effective at lowering the surface tension of sea water. Surfactants are effective in this way because they become concentrated in the surface of the water. As spray is formed in the sea, the concentrated surfactant in the surface layer is caught up into the small spray droplets, and could be carried to the foliage. Finally, workers in Italy had associated death of pine trees on the west coast of Italy with surfactants in sea water.

That the problem was largely confined to the metropol-

A. Grieve and M. Pitman







A. Grieve and M. Pitman

itan area could be associated with the manner in which Sydney's sewage is handled. The waste materials which constitute raw sewage must be disposed of as economically and effectively as possible. The major objective of any system is to biodegrade the organic material which the waste contains and to ensure that its disposal does not constitute a health hazard to the community. This is quite effectively done by a three stage process which can be seen near many inland towns in NSW and elsewhere. Briefly, it consists of a primary stage which removes some suspended material and reduces the remainder to minute particles. This then passes to a secondary treatment which breaks down most of the organic material, often by what is known as the 'activated sludge' process. Finally, the material is oxygenated and filtered to produce water which is almost of drinkable quality.

Surfactants are broadly classified as 'soft' and 'hard', these being relative terms indicating whether or not a surfactant is biodegradable to an 'environmentally acceptable' level by bacterial action within the time limit prescribed by the approved test method. In this test, which is carried out under controlled conditions at 20°C with activated sludge, a surfactant must biodegrade more than eighty percent in 21 days. The greater majority of surfactants used in Australia since December 1971 are eighty percent biodegradable and they are mainly of the 'soft' type, which are, to a considerable extent, decomposed in the secondary stage. Treatment involving three stages will reduce the surfactant content of sewage from about 20 to 0.5 parts per million. Sydney's sewage, like that of many other coastal cities in the world, is not treated in this way but instead is discharged directly into the sea with primary treatment only. The sea very effectively biodegrades the organic material but the rate at which this is done is determined by the ease with which the material can be oxidised. Even with the eighty percent biodegradable surfactants

in common use since early 1972, biodegradation is still a relatively slow process and so there will always be a substantial amount of active surfactant associated with raw sewage outfalls.

The theory that damage to trees was related to surfactant was tested in glasshouse trials. Young trees were sprayed with sea water to which surfactant had been added. The trees turned brown and eventually died if the treatment was continued. The symptoms were the same as trees exposed on the beachfront. Trees sprayed with surfactant alone or with sea water alone were unaffected. The sodium chloride content of the foliage of plants sprayed with sea water plus surfactant increased to levels similar to those at which death occurred along the beachfronts, and was closely related to the degree of

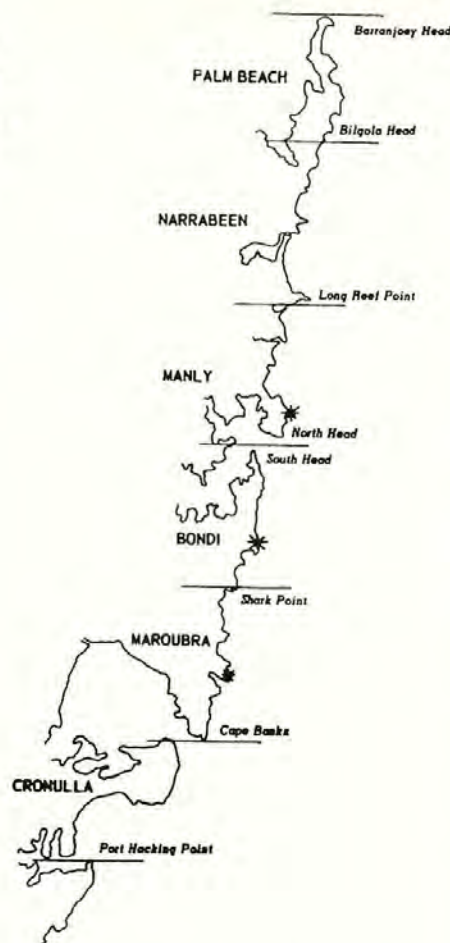
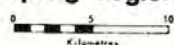
Norfolk Island Pine foliage after spraying with salt solution containing surfactant. Note the browning at the tips of the leaves.

Young trees exposed to sea spray at North Steyne, Manly exhibited greater damage than those at Palm Beach.

J. H. Schellema/SPCC



## SYDNEY AREA sampling regions



mite infestation of other plants in the glasshouse and all plants were sprayed with insecticide, which contains a small amount of surfactant to spread the spray. After a few days, the trees treated with sea water alone turned brown and were found to have a high sodium content. The surfactant in the insecticide had facilitated penetration of the salt dissolved from the crystals on the foliage.

A number of different types of surfactant which produced a large reduction in surface tension of sea water were found to be effective in increasing salt uptake from spray. Soap produced no damage nor salt uptake. The effect of surfactants is interpreted as allowing the sea spray to penetrate the stomatal pores by reducing the surface tension of the sea water to a critical value. The concentration of the most commonly used surfactant (linear alkyl benzene sulphonate) required to reduce surface tension to this value and so facilitate entry of salt from sea water was 5 to 10 parts per million.

A critical point for the hypothesis that surfactant is a necessary factor in the problem is whether there is enough present in sea spray at the affected sites. Samples of spray were collected at different beach sites using specially designed gauges. Measurements estimated the range of the surfactant concentration as between 3 to 25 parts per million at North Steyne (Manly) and 0.5 to 1.5 parts per million at Palm Beach. The level in the spray at Manly would often be adequate to cause damage on the basis of the glasshouse trials. It can also be predicted from the known concentrations of surfactant in the sewage, and from the area of the sewage field estimated from aerial photographs, that the concentration of surfactant in sea spray would be expected to be in the measured range and in fact could be as high as 50 to 100 parts per million at times.

Damage to foliage is not restricted to the Norfolk Island Pines on the metropolitan coast though their plight has been most evident. Die-back of trees has become evident at various places inside Sydney Harbour and in one case, at Ashton Park where trees are dying, there are reasons for suspecting that surfactant laden sea spray may be responsible. Damage is restricted to a part of the promontory that faces northeast, where there is a

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damage. It appeared that the surfactant facilitated the entry of sea spray into the leaf and the salt then killed the leaves. The potency of surfactant was shown in an 'accident' in a glasshouse experiment. In a comparison of different concentrations of surfactant, the trees sprayed with sea water alone were a healthy dark green, though covered with salt crystals, while the surfactant-treated trees had turned brown. At this stage there was a

An aerial view of one of Sydney's major sewage outfalls at North Head. The discharge can be clearly seen on the surface of the water at the bottom left of the photograph.

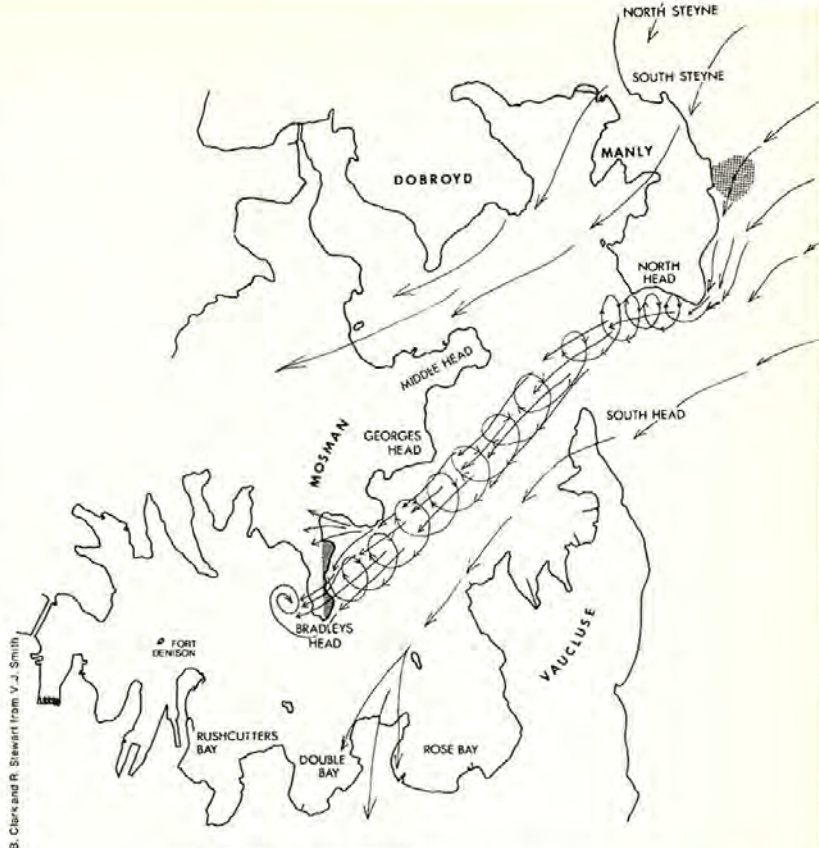


clear exposure across the Harbour to the Heads and to onshore winds. On individual trees there is more damage to foliage at the seaward side of the tree. The affected trees are mainly *Angophora costata* and some *Banksia serrata*. The pattern of winds in the Harbour makes this a likely place to receive polluted spray picked up from the sewage field off North Head.

One difficulty in assessing the cause of damage to trees, as in these cases, is that death may be due to the interaction of many factors. The tree may have local attacks of insects or fungi and face competition from other plants. The tree's resistance to these attacks depends on the vigour with which it can grow, producing new leaves or roots, or containing a local infestation. Loss of foliage due to salt stress may reduce the vigour of the tree so that it can be invaded by fungus or pests. The 'cause' of death may then appear to be, for example, the root rot fungus, *Phytophthora cinnamomi*, but only because of the contribution of other influences such as changes in drainage, periods of extreme weather, other insect attacks or polluted sea spray.

There is a need to continue observations in coastal areas around Sydney and the central coast to detect any long term changes in vegetation due to surfactants in sea spray. The extent of damage and its cause is only now being appreciated. The expected growth in population, particularly to the north of Sydney will require the disposal of much more sewage. If this is released to the sea then care will need to be taken to minimise the levels of surfactants in the sewage if more extensive damage is to be avoided.

At present there is no way of treating the vegetation to avoid this disorder. Plans have been announced to build outfalls to release sewage on the sea bed 2.5km off the coast. These outfalls, built for different reasons, may possibly reduce the surfactant levels in sea spray as well, depending on the water characteristics of the coastal system which are relatively unknown. More information needs to be obtained before any conclusions can be reached. An alternative approach would be to look for different kinds of surfactants that will not be so effective in allowing salt to penetrate the plants' defences.



B. Clerk and R. Stewart from V.J. Smith

#### ACKNOWLEDGEMENTS

Study of this problem has involved many people from different organisations in Sydney. Local councils, (notably those of Manly and Waverley) carried out trials with many species of plants as substitutes for Norfolk Island Pines for beach plantings. A preliminary investigation was carried out by D. Hartigan of the Forestry Commission and extended by the State Pollution Control Commission. In 1971 a Committee was formed by the then Premier (Hon. R.W. Askin) to investigate the deterioration of Norfolk Island Pines on metropolitan beaches. The Committee initiated investigations and submitted a report in 1974. This and subsequent work has involved the Forestry Commission, State Pollution Control Commission, The University of Sydney, Health Commission and, more recently Shell (Australia). Financial support has come from Australian Research Grant Committee, the NSW Government through the SPCC, from the Australian Chemical Specialities Manufacturers Association, the Metropolitan Water, Sewerage and Drainage Board and The University of Sydney.

According to Aerodynamic Consultant, Mr. V.J. Smith, the prevailing north-easterly winds strike North Head forming a conical vortex which turns over in the lee of the headland and rolls down the harbour as a bound system of coarse grained turbulence, eventually coming into direct physical contact with Bradleys Head, Mosman.

Gregory Millen/Australian Museum



Dead *Angophora costata* and Eucalypts at Bradleys Head. North Head can be seen in the background.

# THOSE BUMPS IN THE GROUND

BY GRAEME BATTEN



In large areas of Holland, Kenya, Iraq, the Sudan, Zaire, the United States and Australia, the ground is difficult to traverse because of small surface mounds and depressions. In vertical section, these may vary up to three metres and depressed portions, up to thirty metres across, can retain rain water. This microrelief is known by an Aboriginal name, 'gilgai', which means small water hole.

Gilgai differ in appearance and similar types are known by different names in different areas. This article describes various types and their basic features, together with some of their effects on man, plants and animals.

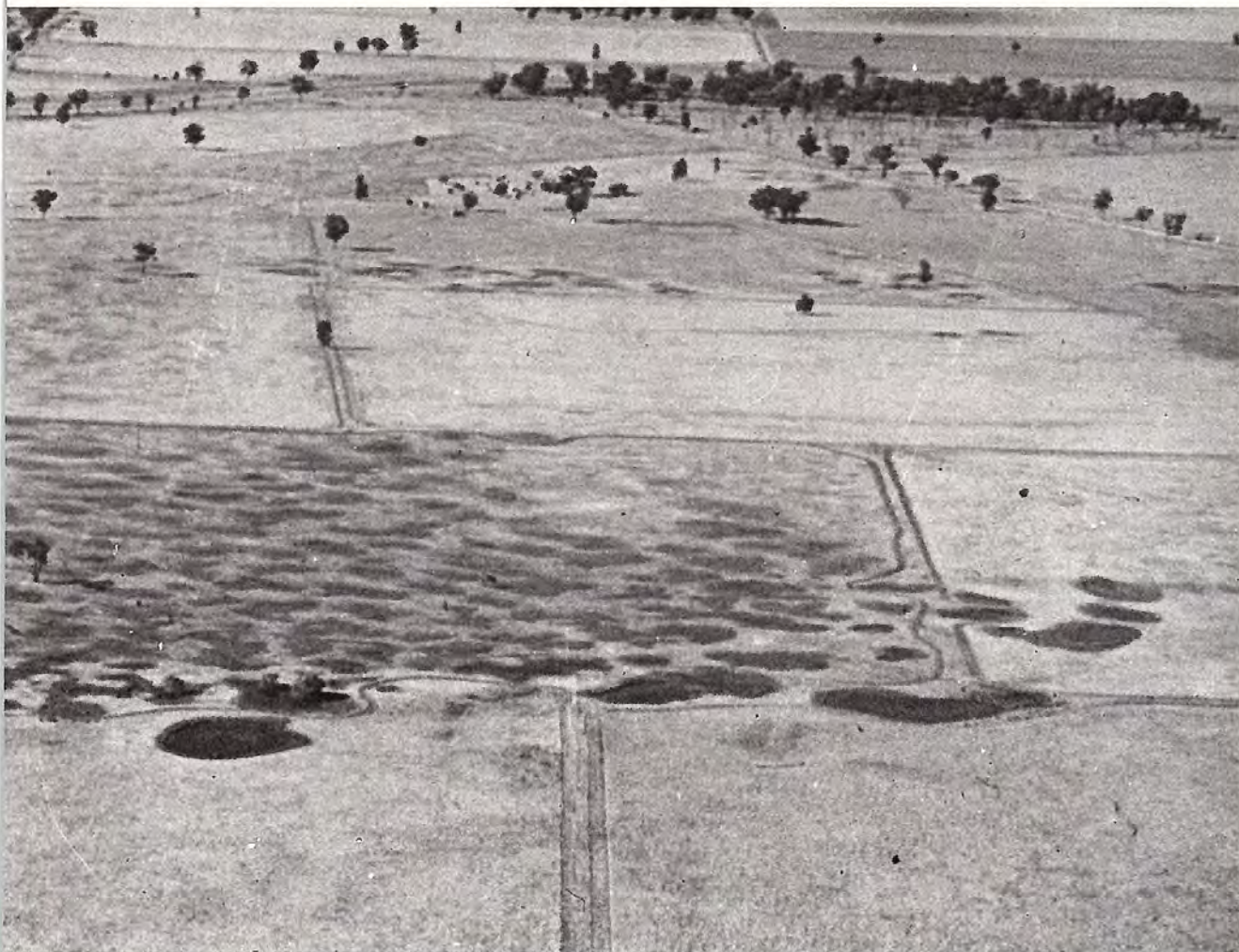
The basic features of Gilgai comprise mounds,

depressions and shelf areas i.e., the undisturbed ground surfaces in between.

These vary considerably with soil type, climate, slope and, possibly, other factors, some gilgai having only two of the three features. When associated with locally derived names, these variations have caused confusion. To avoid this, two classes are recognised, *linear*, when gilgai are elongated in one direction, and *nurum*, when they pock-mark the surface of the ground. Each class is further divided into four basic types, recognised by their vertical section, viz., 1. the alpha-type: mound and depression equally developed, no shelf present; 2. the beta-type: mound of much greater extent than depression, no shelf present; 3. the gamma-type: depression of

A large *nurum* gilgai near Cootamundra, New South Wales.

GRAEME BATTEN is a research officer with the New South Wales Department of Agriculture, Agricultural Research Institute, Wagga Wagga. He has mainly worked on the effects of superphosphate on agricultural ecosystems.



Jan Kuiper

much greater extent than mound, no shelf present;  
4. the delta-type: mound, shelf and depression all present.

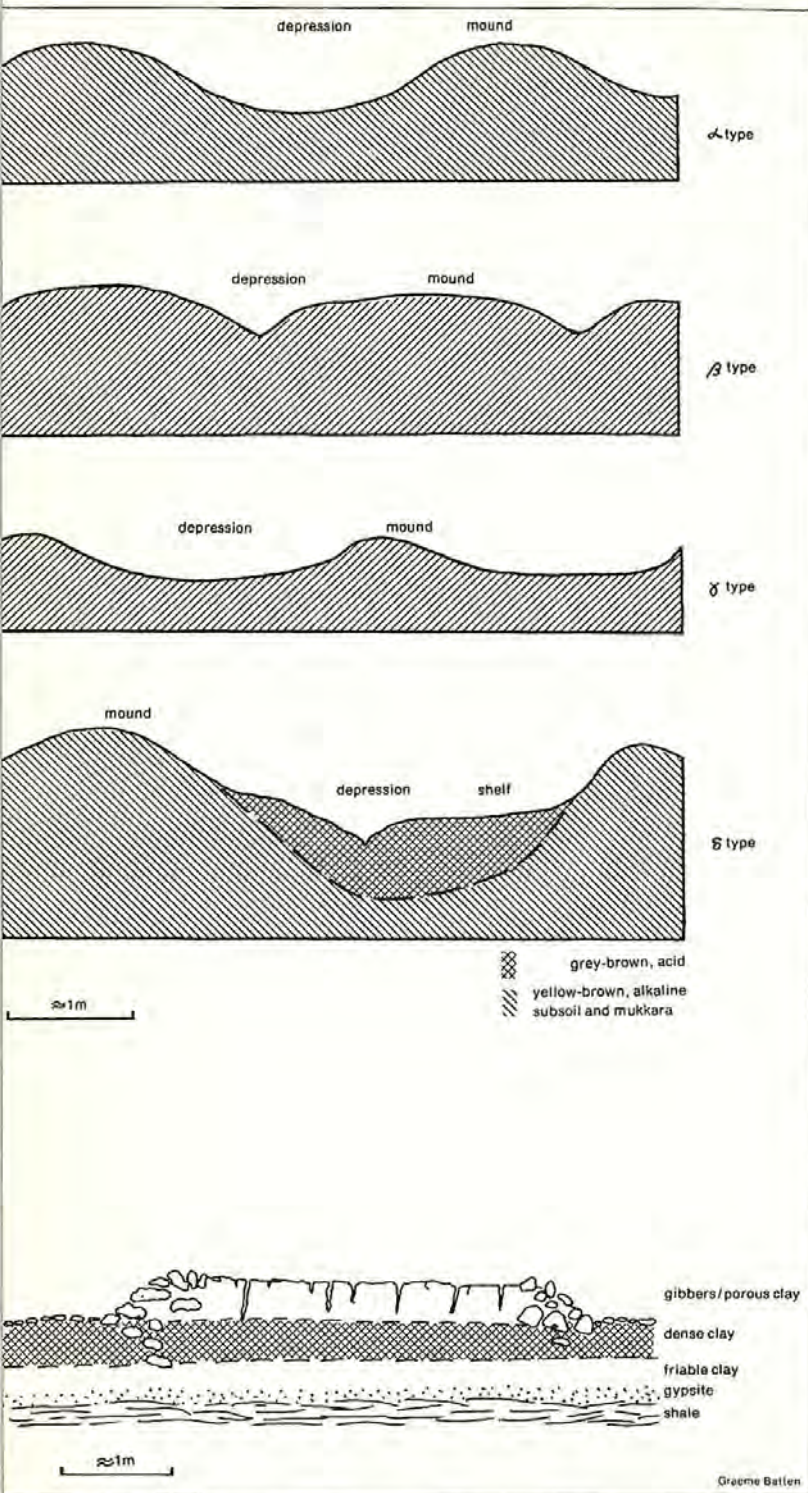
In Australia, gilgai occur widely on desert loam, black earth, chernozem, wiesenboden, grey, brown and red clays and are found in desert to tropical rainfall environments. Near Lismore in northern New South Wales gilgai occur on soils with up to ninety percent clay content. These retain water for much of the year and show the typical *nurum* pattern. Locally they are known as 'melon holes'. The depressions are one to three metres across and fifteen to forty centimetres in depth. Less common, large-scale gilgai, somewhat similar to these, occur in parts of New South Wales and Queensland. They are rectangular depressions, and may be up to twenty metres by fifteen metres, and one and a half metres deep. They are commonly called 'tank' gilgai.

The delta-type gilgai occur on the grey and brown soils

of heavy texture in the Riverina of New South Wales. The Riverina gilgai have depths from a few centimetres to about one metre. The mounds may be simple humps a few metres long or subcircular (curved), covering up to thirty percent of the gilgai area. In cross-section these gilgai may have lighter coloured, more alkaline mound and subsoil than the shelf or have grey clay mounds with a red-brown loam shelf. The clay content also increases with depth — from thirty to forty percent on the shelf to fifty-five to sixty-five percent in the subsoil and in the mound. The mound and subsoil clays expand strongly on wetting.

A similar type of gilgai in south-eastern Queensland differs in size and type of clay. They have a depth of some three metres with mounds ten to twelve metres across and have an acid, weakly expanding subsoil.

How do gilgai form? Soil scientists have been discussing the subject for many years and attempting to relate



The four basic gilgai types are illustrated to show their mound, shelf and depression areas. The dissected cross-section of a Riverina type is included to show the form of the *mukkara* and associated colour and pH changes. The bottom diagram is a cross-section of the flat-topped, stoney gilgai found near Coober Pedy, SA.

Australian and overseas microrelief. While the mechanism which forms the microrelief remains obscure, a number of theories have been suggested.

Most gilgai soils contain clay which swells on wetting and shrinks and cracks on drying. Furthermore, the subsoils and many of the mounds often contain calcareous clay with a higher swelling capacity than the shelf soil. Most Australian workers more or less agree that the swelling and cracking cause differential upheaval of the soil surface at points of least resistance. Once the microrelief has been established, the mounds are subjected to more intense swelling and cracking, as they absorb water rapidly when cracked; they also dry quickly because of their microdrainage and surface area. Dust particles and plant debris which fall into cracks during dry periods also enhance the swelling of the mounds after rain. The overall effect is believed to involve a transfer of soil from the subsoil, via the mound and back to the shelf, creating changes in soil pH, clay content and colour.

This theory assumes that cracks which originate in the subsoil will continue to the surface and allow wetting and swelling of the subsoil following rain. Some gilgai however, such as those in the Brigalow areas of Queensland, do not possess a strongly swelling subsoil; other soils with gilgai do not develop deep cracks. It is thought that the flat-topped gilgai in semi-arid areas were created by the simple upheaval of soil due to the expansion of underlying clays.

A recent theory proposes non-uniform, or differential, loading of one soil material by another. For example, where alluvial or colluvial material covers a previous surface, mounds may form where the subsoil is closest to the surface. Some gilgai on basaltic soils in south-eastern Queensland are thought to develop this way and these gilgai appear to be related to surface erosion processes which move material from the mound back to the shelf and depression areas.

Some gilgai subsoil patterns show no surface microrelief, perhaps because surface erosion proceeds faster than gilgai mound development. The clay subsoil projecting towards the surface, whether associated with surface microrelief or not, has been called 'mukkara', an Aboriginal word meaning finger.

Closer examination of land with no surface microrelief may reveal the extent of 'mukkara' formations and help to explain the origin of mukgara and gilgai. However, no single explanation can yet account for the different types of gilgai.

The gilgai microrelief shows striking changes in soil characters over small distances, such as clay content, colour, acidity, degree of cracking and expansion, salinity, level of nutrients, availability of water and aspect. Despite their wide distribution and obvious importance as water sources for plants and animals, gilgai have not been adequately studied.

In the Riverina, the perennial, *Danthonia caespitosa*, remains green in the gilgai throughout the year and when all else is dry, provides summer grazing for red kangaroos (*Megaleia rufa*). When there is green feed on higher land, herbage on gilgai is less attractive to kangaroos, either because it is too rank, or because species characteristic of semi-permanent swamps, such

as the common spike rush (*Eleocharis acuta*), rushes (*Juncus* sp.) and sedges (*Carex* sp.), have become too strongly established. When there is an extended wet period, plants normally only found in the depressions will migrate onto the shelf and mound areas. Similar observations have been made in Central Australia where red kangaroos congregate near open plains to graze on green neverfail grass (*Eragrostis setifolia*) from the edges of gilgai.

In some areas the depressions carry more plants than the mounds but in other areas, or in different types of gilgai, the mounds carry a higher density of larger plants. Some thistles, for example *Cathamus lanatus*, *Carduus pyonocephalus* and *Medicago hispida*, appear to be suited to the alkaline, cracking clay mound soil.

A list of the fauna which use gilgai pools and mounds would assist in understanding the relationships between such animals as frogs and freshwater crayfish and birds such as ibises and brolgas. During dry periods, fauna from gilgai may make significant contributions to the diets of a number of other species.



Graeme Batten

Man is affected by gilgai in both rural and urban areas. Expansion of clay in a gilgai can crack house walls. When planning new housing subdivisions, care should be taken to define gilgai, or expanding clay areas, and set these aside for non-building areas such as playing fields.

Gilgai generally disrupt farming operations. The movement of vehicles and equipment over such areas is difficult and even dangerous. It is advisable to drive slowly through gilgai areas to avoid damage to, or even overturning of vehicles. There is also the risk of becoming bogged in a depression. Cultivation of gilgai presents another problem because the soil is rarely at a uniform moisture level; either the depressions are too wet or the shelf and mound too dry. If the farming activities are intense, then gilgai with a depth of about a metre or less may be levelled with a land plane. This is a temporary measure however, because the microrelief can, with expansion of the clays, reform in a few seasons. Levelling can also lead to trace element deficiencies on the exposed subsoils. At about pH 8, zinc, copper,



Graeme Batten

manganese and iron may be unavailable to plants even though they are present in the soil.

Gilgai in the Riverina with water in the depression areas.

Soil conservation earthworks on slopes with linear gilgai frequently fail. If rain fills a dry contour bank, water may pass through cracks in the bank before the clay expands and seals off the passages. The stream of water may remove sufficient soil to prevent natural sealing of the bank.

In grazing areas, on the other hand, gilgai pools allow sheep or cattle to graze away from the normal watering place.

Wheat shoots are emerging only on the mound area of this gilgai near Coolamon, NSW.

Gilgai are a natural feature of many areas of Australia. Even under cultivation they can exert an influence on their ecosystems. The extent of these influences is not adequately known and further studies are required into their impact on invertebrate and vertebrate animals.

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The effect of different water levels across gilgai is shown by the growth of hydrophytic plants around the depression area.

Graeme Batten



# OPPORTUNISTS IN HIDING

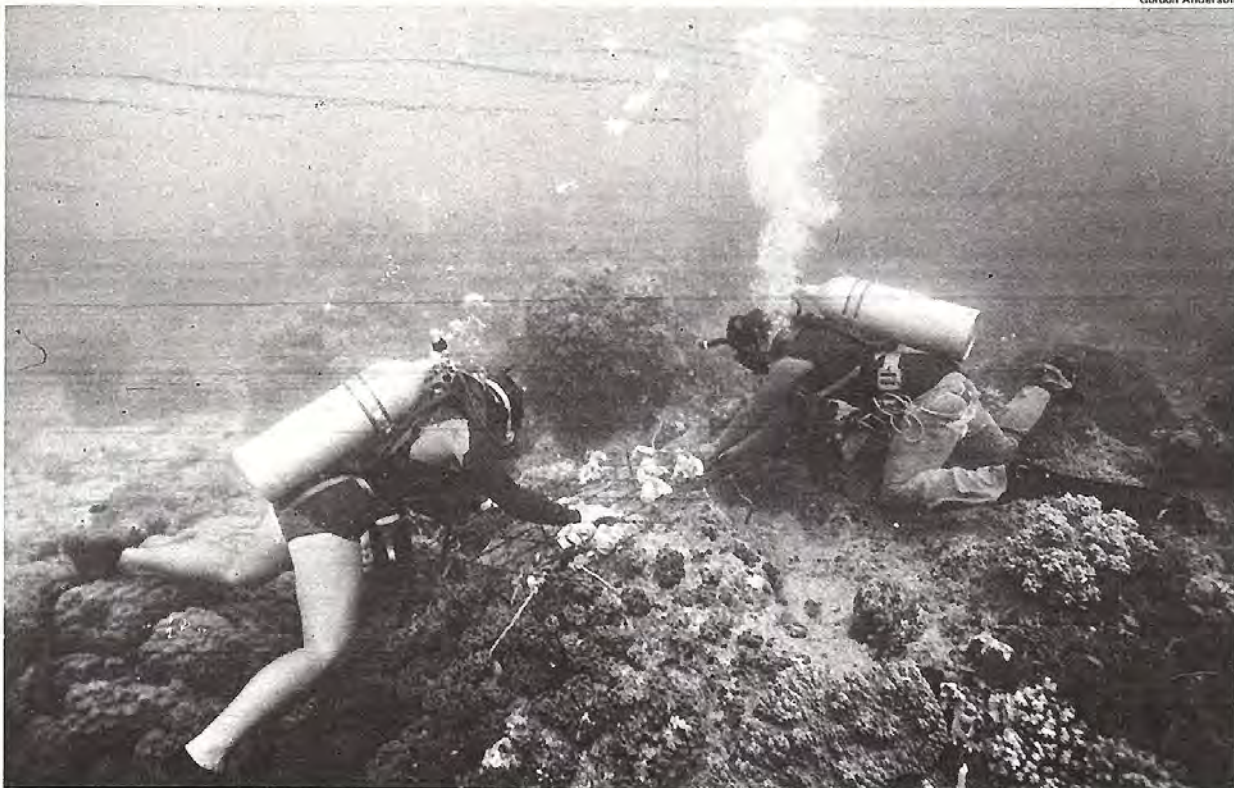
BY PAT HUTCHINGS

Within the dead coral and reef rock which is the main structural component of a coral reef lives a rich and diverse community — the cryptofauna. This community consists of true boring organisms such as many species of sponges, bivalves, (*Lithophaga* sp.), sipunculans (peanut worms) (*Cloeosiphon aspergillus*, *Phascolosoma perlucens*) and certain species of polychaete worms (*Dodecaeria* sp., *Eunice* sp.) and the so called 'opportunistic fauna'. The 'opportunistic fauna' are so called because they cannot themselves bore into the coral, but efficiently use crevices or burrows created by the borers. All invertebrate groups are represented within the 'opportunistic fauna' and some groups such as polychaetes are abundant. For example, at Heron Island on the southern part of the Great Barrier Reef, one piece of dead coral weighing 2.5kg contained more than a hundred species of polychaetes.

The community can be further subdivided into permanent and semi-permanent residents. The perm-

anent residents, all of the borers and some of the 'opportunistic species', consist of those which settle during the larval stage on the outside of the dead coral and somehow penetrate. Some secrete a chemical substance which can dissolve the coral skeleton, others mechanically work their way into the coral. Certain species of sipunculans have a series of overlapping grinding plates at the tip of their proboscis with which they effectively grind the coral skeleton away. Other larvae just creep down into existing cracks or crevices. Once inside the dead coral, they grow and many continue to erode a small chamber. They retain a small passage to the outside through which their tentacles or proboscis can extend for feeding and reproduction. Effectively these animals are sealed inside a chamber which they cannot leave. Recent work has shown that adult sipunculans are unable to penetrate a piece of coral if removed from their chamber, only their larvae are capable of initially penetrating the coral. The semi-permanent

Gordon Anderson



Pat Hutchings (left) and Penny Weate (right) secure blocks of reef rocks to one of their metal grids.

To withstand the effects of storms and strong currents, the grid is both bolted and tied to the floor of the reef. The blocks are secured with plastic coated copper wire. Each grid intersection is coded and the blocks are laid at random.

PAT HUTCHINGS is a Research Scientist in the Department of Worms at The Australian Museum. She has been working on cryptofauna since 1972 at One Tree Island and Lizard Island, Great Barrier Reef. Her general interests are the ecology and taxonomy of polychaetes, particularly terebelliform polychaetes.





Pat Hutchings

residents are always 'opportunistic species' which spend only part of their adult lives within the dead coral. Probably many species of crabs and molluscs are members of the crypto fauna while they are juveniles but once they are larger and mature they live amongst the coral rubble and in large crevices. Many other species are semi-permanent residents for their entire life, such as some of the nereid worms and scale worms which leave the dead coral only at night to feed in the immediate surroundings and return to the protection of the coral during the day.

It is becoming increasingly apparent that this crypto-faunal community is important in the diet of many fishes and certain large molluscs, especially the cones. However, the crypto faunal community has hardly been studied, especially in Australia. In 1973, work began at One Tree Island in the Capricorn Group, Southern Great Barrier Reef, where the Australian Museum had a field station. Study began on the physical properties of the dead coral which are important in determining the distribution and abundance of crypto fauna. Five different types or habitats of dead coral in the lagoon were selected: (1) dead branching coral, (2) solid reef rock, (3) thin plates of dead coral, (4) dead coral with a high percentage of live coral and (5) dead coral with a large surface area covered with a high percentage of epifauna and flora, encrusting animals and plants which live on the outside of the dead coral.

Several samples of these habitats were collected underwater by Scuba diving. Blocks of coral were then broken off with a hammer and chisel and sealed underwater in labelled polythene bags.

The blocks were then put into collecting bags, hoisted to the surface by filling a lift bag with air from our regulators and then taken by boat to the laboratory. The blocks were wet weighed in the laboratory and then broken into small pieces with a hammer and chisel. The small pieces of coral containing the animals were then fixed in formalin, packed into polydrums and transported back to the Museum. The coral was then broken into smaller pieces and the animals extracted under a microscope — many are only a few millimetres in length. The fauna was finally sorted into major groups and each group wet weighed. We estimate that five to six hours is needed to sort one sample.

This study showed that the greatest biomass of crypto-fauna was present in habitat 5. The large surface area and high percentage of epifauna and flora affords protection to the larvae whilst penetrating the coral. Once inside the coral, a full crypto faunal community will then only develop if the habitats have a certain volume. This explains the low biomass found in habitat 3. The presence of live coral colonies on the outside of the habitat is detrimental to the crypto fauna as many species of coral are voracious carnivores and eat the larvae at the time of their settlement. Also important is the internal structure of the dead coral, for each species lays down its calcareous skeleton in a constant geometric pattern for that species. Therefore, species of coral which have a very compact skeleton will be far more difficult to bore than coral with a less dense skeleton.

It was also found that there was a definite sequence in which the crypto faunal community develops. In a block of recently killed coral, a very specialised boring community — one or two species of bivalves, several species of boring sponge, three to four species of sipunculans and two to three species of polychaetes was present. As the block of coral becomes increasingly broken down by the activities of these boring organisms, a more diverse community develops as 'opportunistic species' begin to enter the block of coral. Finally the block of coral may

An aerial view of the south-western end of Lizard Island. The lagoon, containing one of the crypto faunal study sites can be seen in the centre of the photograph, bounded by Palfrey Island on the left, South Island on the right and Lizard Island on the far left. The arrow points towards the research station, situated in a clearing at the back of the beach.

The lighter coloured blocks were laid in August 1976 at the time this photograph was taken. The others had been down from between three to six months and are quite heavily encrusted with marine organisms.

Penny Weate





Thierry Pichon

Research Assistant, Penny Weate breaks up a block of reef rock, removed from the lagoon at the south-western end of the island. The smaller pieces of rock will be killed, cleaned and dried, sanded, weighed and measured and then fixed to the grid on the floor of the lagoon.

completely break down and become part of the coral rubble found at the foot of the reef slope. This work has recently been transferred to Lizard Island on the northern part of the Great Barrier Reef, where the Australian Museum has recently established a field station. At Lizard, we have attempted to measure the physical attributes of the habitat rather than subjectively assessing them as was done at One Tree Island. For

example the surface area is determined by coating the block of coral with several coats of liquid latex. When set, the latex is peeled off and the surface area measured using an area metre.

The volume of microhabitat is measured by first placing the block in a known volume of water and measuring the volume of water displaced. An estimate of 'available living space' within the microhabitat is then calculated by covering the piece of coral in 'Gladwrap'. Its volume is then measured by the previous method as if it were a solid piece of coral. The difference in volumes gives an estimate of the burrows and crevices, that is, the 'available living space' inside the coral. The block is also cut in half with a diamond saw to expose its internal structure for examination.

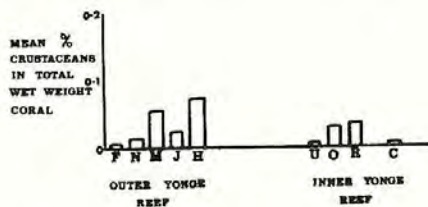
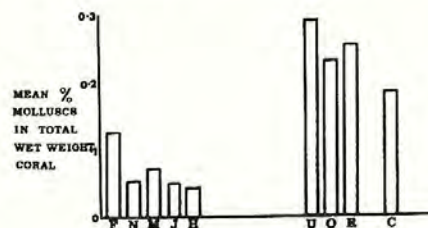
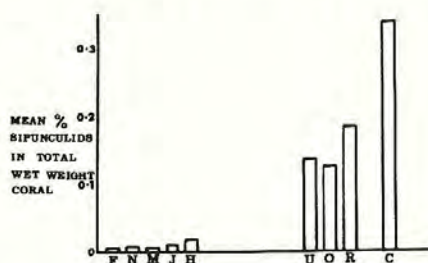
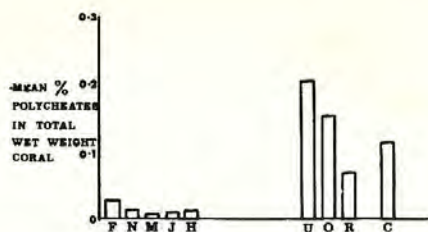
The effect of exposure to strong seas on the cryptofauna has also been studied. Samples were taken from the outer slope and back of Yonge reef, on the outer barrier, about fifteen kilometres due east of Lizard and around the fringing reefs of Lizard. The outer slope of Yonge receives the full force of the southeast trade winds which blow continually for eight to nine months of the year. The fringing reefs around Lizard are also subjected to the trade winds but receive some protection from nearby islands and reefs. The back reef of Yonge, by contrast is relatively sheltered. The biomass of cryptofauna is highest on the sheltered back reef and lowest on the exposed outer slope of Yonge, with reefs around Lizard having intermediate values. Experiments are currently in progress to look at the effect of depth on the cryptofauna. It appears that the cryptofauna at forty metres is very different in species composition from that at ten metres on outer Yonge.

Up until now, we have only discussed the biomass of the cryptofauna, which consists of many species which are new to science or previously unrecorded from Australia. The polychaetes which are the most diverse group of cryptofauna are currently being described and many

Pat Hutchings



Using a power tool, Penny Weate sands a flat surface to a piece of reef rock. Grooves will be cut into this surface to enable it to be seated securely on the wire grid.

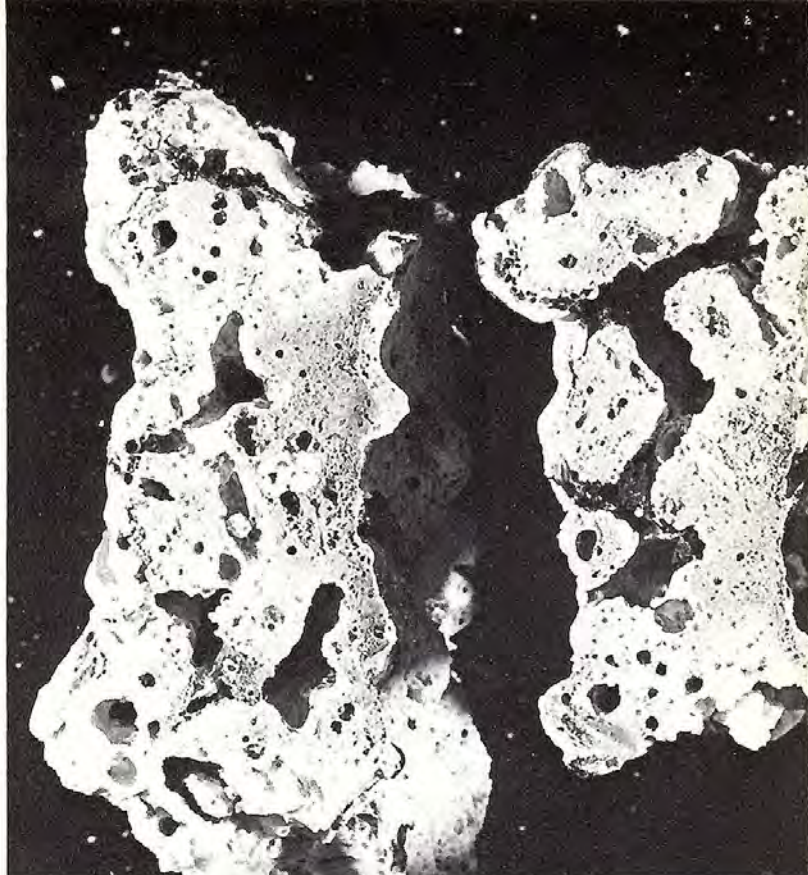


exciting new genera and species are being found. It also appears that the polychaete fauna, at least at Lizard and One Tree islands is very different, whereas many species of fish are common to both areas.

Recently, another set of experiments has been set up at Lizard to investigate the initial establishment and subsequent development of the cryptofaunal community. Blocks of dead coral, cleaned of all cryptofauna are being securely attached to the reef floor and removed at three, six, nine and twelve month intervals. Some very interesting results are beginning to emerge, such as definite seasonal recruitment. It has been widely accepted that species in the tropics breed continuously throughout the year, but our work and the work of other scientists is beginning to disprove this theory.

Until further studies on the cryptofaunal community are carried out, attempts to understand the importance of this fauna will be difficult, but it seems likely that this community which has a very high rate of reproduction contributes significantly to the productivity of the reef ecosystem.

Finally, a thorough understanding of this community may shed some light on the impact of an oil spill on the reef. The chances of an oil spill occurring are continually increasing as larger and larger tankers are using the major shipping lanes which pass within a few hundred metres of many reefs. Also, pressure to commence oil



Gregory Millen / Australian Museum

drilling on the reef is increasing. In the event of an oil spill, the corals would be covered and their only defence would be to produce large quantities of mucous which is then utilised as food by many of the deposit feeders within the cryptofaunal community. The effect of oil and mucous on the cryptofauna is not known but it is probably harmful and may well destroy the community. Therefore, knowledge regarding rates of recruitment and establishment of the cryptofaunal communities is vital if we are to assess the long term impact of an oil spill on this part of the reef ecosystem which may support other sections of the reef ecosystem.

This block of coral was cut in half with a diamond saw to reveal the many burrows and crevices created by the colonising cryptofauna

Pat Hutchings, with two young onlookers, extracts the cryptofauna from a block of coral which has just been broken down.

Penny Weate



# A CANDID LOOK AT CRYSTALS

BY JOAN HINGLEY



Gregory Millen / Australian Museum

Fluorite crystals exhibiting penetration twinning, from Derbyshire, England.

Crystals have always been associated with concepts of purity and perfection of form. The ancient Greeks obviously had these concepts in mind when they named quartz, 'krystallos', meaning frozen ice, for they thought it was formed from water frozen by intense cold. The concepts of perfection and geometrical symmetry have persisted in the definition of crystals, although much more is now known about them.

Almost all non-living solid matter around us exists in a crystalline state. Not only do minerals and metals occur in crystalline patterns but also our food such as sugar, salt, the ice in our drinks and some substances that make up our bodies. Non-living solids, such as glass, that lack a crystalline structure are called 'amorphous', which also comes from the Greek and means 'without form'.

Crystallography, the study of crystals, began in 1669 as a science of morphological description, summarizing the characteristic angular relationships of the crystal faces for each mineral. In 1784, a French botanist, René-Just Haüy, developed the theory that crystals were built up from a large number of tiny units all of which had the same shape. He came to this conclusion after dropping a calcite crystal which broke into several parts. He noticed that even the smallest piece retained the shape of the original crystal. Haüy proposed three basic shapes as 'building stones' to explain the structure of all known crystals. This, however, proved insufficient and later

mathematical work by another Frenchman, Auguste Bravais, revealed fourteen crystal lattices as the possible basic units of crystals.

Crystal lattices consist of small or large molecules, atoms or ions (electrically charged atoms), arranged to form distinctive geometrical shapes. A good example is salt, in which a negative ion of chlorine attracts positive ions of sodium which in turn attract more negative ions of chlorine. This process repeats itself and as the ions pack together, they form a cube. This particular arrangement is common when the ions are about the same size. If they vary, they may pack together in a differently shaped lattice.

At the time that Haüy put forward his theory scientists had only suspected that crystals were constructed in this manner but lacked the means to prove it. A timely experiment with X-rays in 1912, by the German physicist, Max von Laue, gave crystallography its major breakthrough. Laue decided that if crystals did have a regular internal arrangement then they should scatter the X-rays from planes of atoms within the crystal. His assumption proved correct for when X-rays were passed through a crystal, he found that they were scattered to form a pattern of dark spots on a photographic plate placed behind the crystal. Although his initial aim was to prove that the behaviour of X-rays was similar to that of white light he also verified the internal regularity of crystals.

This interested the British physicist Sir William Bragg and his Australian born son Sir Lawrence Bragg. Born in Adelaide in 1890, Sir Lawrence attended Adelaide University where his father held a professorship. Their work on crystal structure was conducted in Britain where, in 1913, they successfully determined the internal structure of sodium chloride using the X-ray Diffraction method. Crystallography changed dramatically from this point, giving scientists the means to study crystals on an atomic level as well as by their external shape.

The use of X-rays led to the development of other techniques which explained much about the mechanics of crystal formation and growth. Before crystallization is achieved, the atoms of a substance exist in a gaseous, vapour or liquid phase. This includes minerals, rocks and metals. In the gaseous state the atoms and molecules move about in a frenzied fashion crashing into each other, continuously rebounding and again colliding. As the temperature drops, their energy drops and the liquid phase is attained. The atoms begin to form groups which exist momentarily and then disperse. The lower

JOAN HINGLEY is a Technical Officer in the Department of Mineralogy and Petrology at The Australian Museum.

the temperature, the longer these groups exist until, at an appropriate temperature, some of the groups do not disperse but become stable. These are called nuclei and are the beginnings of crystals. Nucleation occurs in cooling fluids, vapours, and molten rocks from within the earth. It also occurs in liquids that become saturated with salts through evaporation, as in the desert salt pans. It is common to find gypsum crystals growing on branches and twigs that have fallen into shallow salt lakes. The structure of these nuclei is dependent on the size of the atoms, their electric charges and most important of all, the nature of the forces that hold them together. These forces are called bonds and are responsible for many of the physical properties found in crystals. For example, graphite is a good lubricant because the carbon atoms of which it is composed form flat hexagonal plates which lie parallel to each other. The bonds between the plates are weak in comparison to those forming the hexagons, enabling the plates to slide over each other easily. Diamond is another mineral of carbon but here, all the atoms are strongly bonded to each other in an inflexible manner. This rigid structure gives diamond its extreme hardness. Cleavage or parting in a crystal occurs along planes of weaker bonding in the atomic structure, like the hexagons in graphite. Despite its hardness, diamond has four cleavages, lying parallel to the faces of the octahedron, which are used by jewellers to divide large diamonds. Cleavage can be a disadvantage, however, in that a cut stone can be knocked and form flaws or break apart.

Crystal formation is a complicated matter and can occur in many environments. Crystal growth occurs



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when groups of atoms attach themselves to the nucleus in accordance with the original shape. Heat plays a role in the size to which a crystal may grow. If a liquid cools rapidly, a large number of nuclei are formed, resulting in many small crystals. Minerals which have a fine-grained or massive appearance have formed this way. If a liquid cools slowly, fewer nuclei are developed. Large crystals can grow under these conditions, depending on the amount of space around the crystal, the proximity of other crystals and physical-chemical factors existing at the time of crystallization. Particularly large crystals are commonly found in veins of pegmatitic rock, which occur most commonly in granites. The solutions which form

Crocoite crystals which have grown from the interaction of mine solutions containing lead, and chromium from associated serpentinite rocks. This specimen comes from Dundas, Tasmania.

Pryomorphite crystals from Cumberland, England.

Gregory Millen / Australian Museum

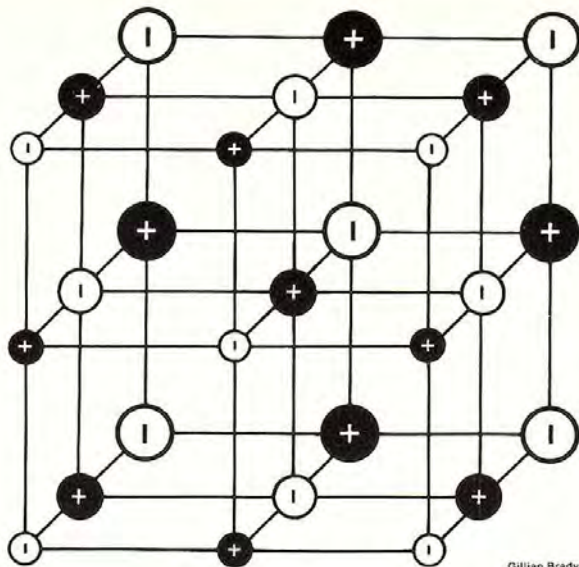




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Above: Groups of fine, acicular (needle-like) crystals give the mineral okenite, a soft, fluffy appearance. From Poona, India.

Above right: A schematic drawing of a crystal lattice of salt (sodium chloride) showing positive ions of sodium and negative ions of chlorine, forming a cube.



Gillian Brady

Right: A network of Cerussite crystals, Proprietary Mine, Broken Hill, NSW.



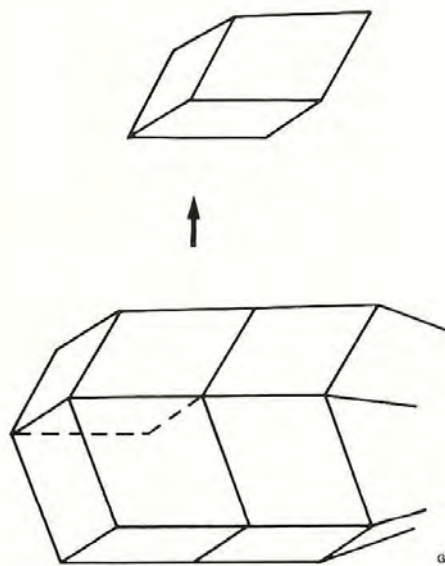
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Below: Tabular crystals of chrome cerussite from Magnet Mines, Dundas, Tasmania.

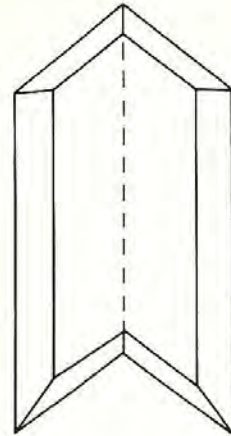
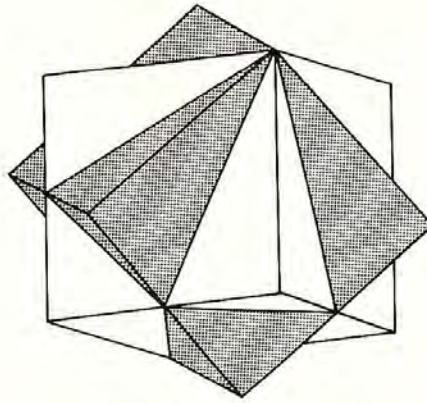
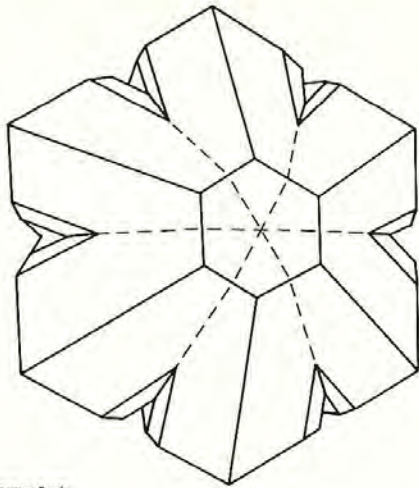


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Below right: One of the many forms of calcite showing its basic crystal shape, the rhombohedron. Calcite also cleaves along planes parallel to the faces of the rhombohedron.



Gillian Brady



Three types of twinned crystals. Left: A contact twin typical of gypsum (the dotted line represents the shared crystal face). Centre: A penetration twin of two cubes. Right: Multiple twinning.

Gillian Brady

these veins are highly charged with gases such as fluorine and chlorine. Some are also rich in rare metallic elements. The corrosive action of these solutions creates cavities in the host rocks in which crystals of the pegmatite can grow undisturbed. When the solutions carry rare trace elements, the crystals are brightly coloured. Many of our favourite gemstones such as emerald, topaz, tourmaline and quartz are a result of this successful recipe for fine crystals.

The pegmatites of Colorado, USA, contain some of the largest crystals in the world such as a blue-green beryl, one hundred and eighty-three centimetres long and a topaz crystal, sixty-one centimetres long.

Pegmatite minerals sometimes reach giant size. A quarry in the Ural Mountains in Russia is worked in a single huge crystal of orthoclase.

Very fine crystal specimens are also found in mines due to the interaction between mineralized solutions and metallic ores. The resulting crystals grow in the cavities of the porous cap which overlies the ore body. Some of the finest and rarest crystalline specimens in the world have been found at Broken Hill, NSW and four large crystals of gypsum, which range in size from seventy-one centimetres to one hundred and twenty-two centimetres long have been found in the Mt. Elliott Mine, near Cloncurry, Queensland.

Once a crystal has begun to develop, it continues its growth from defect points on the face of the crystal or from its corners, as these are areas of high energy and have a strong attraction for atoms. The defects are due to imperfections in the actual crystal lattice and are important for their effects on crystal growth and crystal colours. For instance, dendritic or branch-like growth, found in minerals such as native copper, native silver and native gold, is due to spiral growth around a defect point on the face of a crystal under conditions of rapid growth. Under these circumstances the crystal does not have an opportunity to develop faces and atoms will attach themselves as quickly as possible to these areas of high energy. This and other factors, such as the inhibition of growth due to the presence of impurities adsorbed onto the surface of the crystal, contribute to the irregular growth of crystals, though the essential internal atomic arrangement remains unaffected by external appear-

ances. Crystals may develop some perfect faces but this is rare in nature and accounts for the high value placed on perfect crystals by mineral collectors.

The classification of crystals is based upon the original fourteen crystal lattices of Bravais which were grouped, according to their degree of symmetry, into seven major systems. What puzzles most people is why crystals of the same mineral can occur in so many different forms within the same crystal system. This is explained by thinking of the unit cells of the crystal as building blocks which can be combined in a variety of ways to produce different shapes. The mineral calcite can appear as

Radiating crystal groups of aragonite on calcite spheres, growing inside a cavity in basalt, Collingwood, Victoria.

Gregory Millen/Australian Museum





Eastman Kodak/The Mineralogical Record

A scanning electron micrograph of pyrite, Kentucky, USA. Magnification X440.

slender crystals, although the basic unit is a more equant 'rhombohedron'.

Minerals may also take on different forms, depending on how the crystals arrange themselves. Malachite, for example, can occur as individual crystals or can group together to form spheres, giving the mineral a soft rounded appearance. Groups of long, fine, parallel crystals give a mineral a fibrous form as in the case of asbestos. Lamellar minerals consist of crystal plates or leaves, which, like molybdenite, may radiate to form rosettes or, like mica, may lie flat on top of each other to form 'books'.

Twinning in crystals provides even greater variations.

Eastman Kodak/The Mineralogical Record

Left: A scanning electron micrograph of a jamesonite ring, Felsobanya, Rumania. Magnification X500. Right: A scanning electron micrograph of a boulangerite cylinder, Madoc, Canada. Magnification X180.



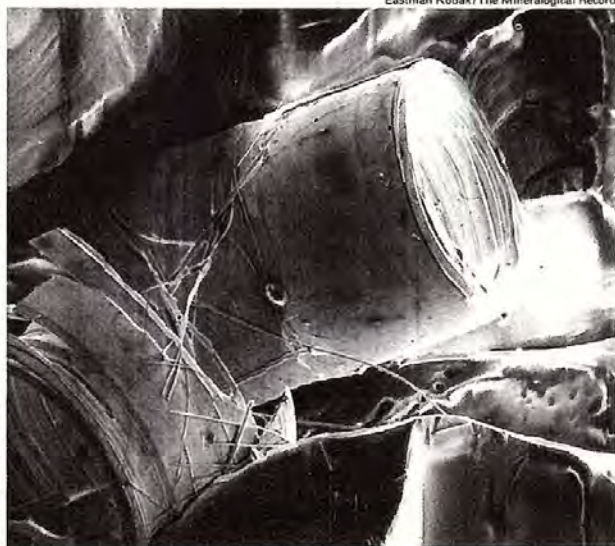
This occurs when the atoms of one part of a crystal grow in the reverse direction to the other part, resulting in crystals that produce mirror-images of themselves. Contact twinning occurs where crystals share a common face but grow in opposite directions. Multiple twinning occurs where crystals repeat the twinning several or many times, and a penetration twin occurs where crystals appear to be growing through each other.

Recently, the scanning electron microscope, used mainly for the examination of biological material, has been turned to discovering strange new forms of minerals which cannot be seen even under powerful optical microscopes. Crystals are viewed under very high magnifications which can only be obtained by using beams of electrons instead of beams of light. The scanning electron microscope has revealed mineral crystals in the forms of regular rings and cylinders most unlike the commonplace multifaceted forms seen by eye. Explanations have been offered for these unusual structures, but the field is still very much open to research.

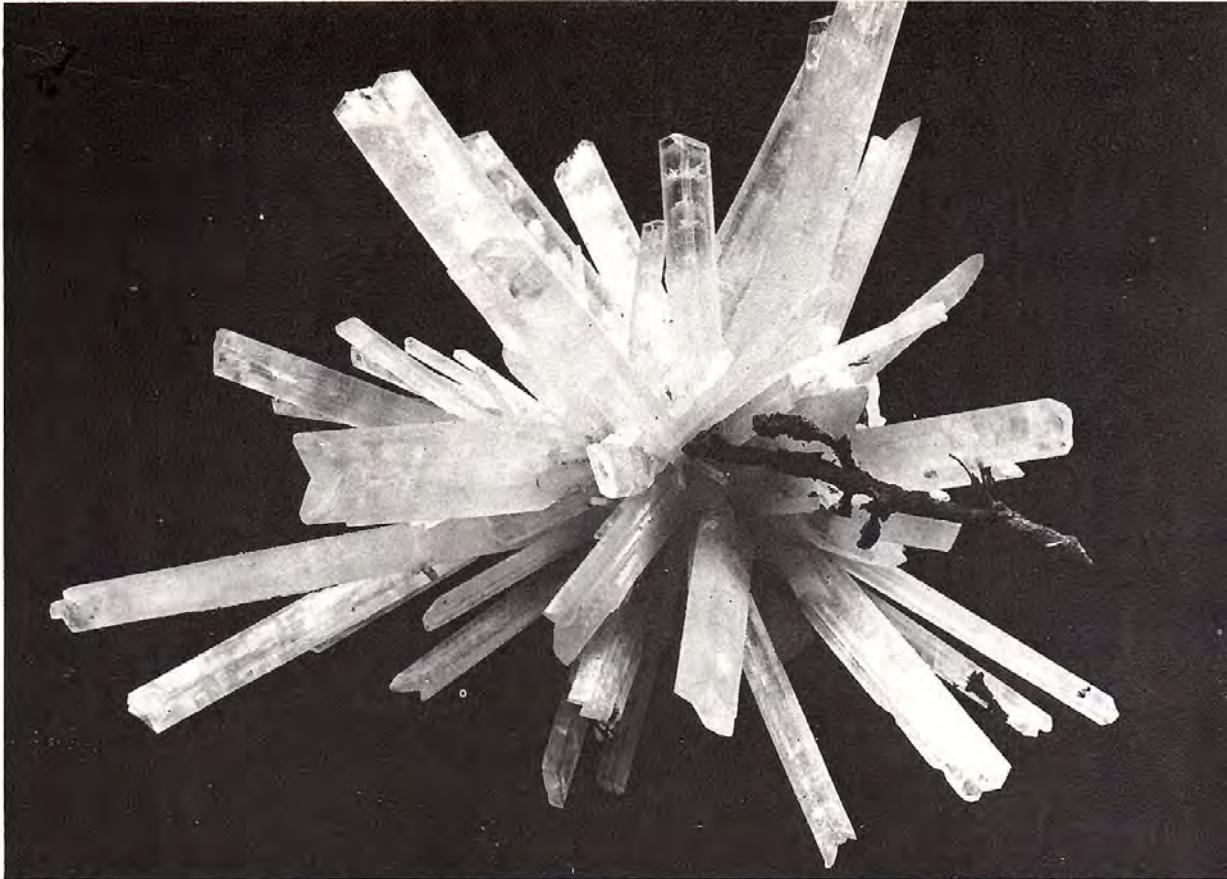
Besides being a useful instrument of analysis and identification, the scanning electron microscope can examine the surfaces of crystal faces to give details of minute structures and atomic arrangements. This information can be used to further the crystallographer's knowledge of the mechanics of crystal formation and growth.

The scope of crystallographic study offered by modern instrumentation is a great contrast to the limited field of descriptive studies that were available to earlier crystallographers. Their work, however, laid the essential foundations of a science which has diversified into many areas of research. Charles Anderson was one of these crystallographers who produced a wealth of information on the morphology of crystals. He was born in 1876 in the Orkney Islands and, together with many other subjects, studied crystallography at Edinburgh University. He took up the position of mineralogist with the Australian Museum in 1901 and carried out many detailed examinations of minerals, particularly those from Broken Hill. He established that the crystal shapes of some of the minerals from this locality were quite different to those from other existing classic mineral localities. For his work, Anderson employed the reflecting goniometer, an instrument which uses the reflections of a beam of light from adjacent crystal faces to determine the interfacial angles.

Eastman Kodak/The Mineralogical Record







Gregory Millen/Australian Museum

The emphasis in crystallography today is placed on the molecular arrangements within the crystal rather than the shape of the crystal itself. This is clearly demonstrated by studies of the mineral inosite, from Broken Hill, carried out in 1968 by Ian Threadgold of Sydney University. To determine the chain structure of its molecules, he used not only X-ray crystallography but many other sophisticated techniques. The significance of this type of research is evident in its application to industry, particularly in the synthesis of materials to replace or improve natural materials. Certain information on materials such as minerals, metals, ceramics, plastics and rubber can be used to modify their molecular structures to create physical properties which meet specific requirements. Results of this research encompass everything from the production of a variety of plastics to the synthesis of opal to replace the world's dwindling supply of natural opal.

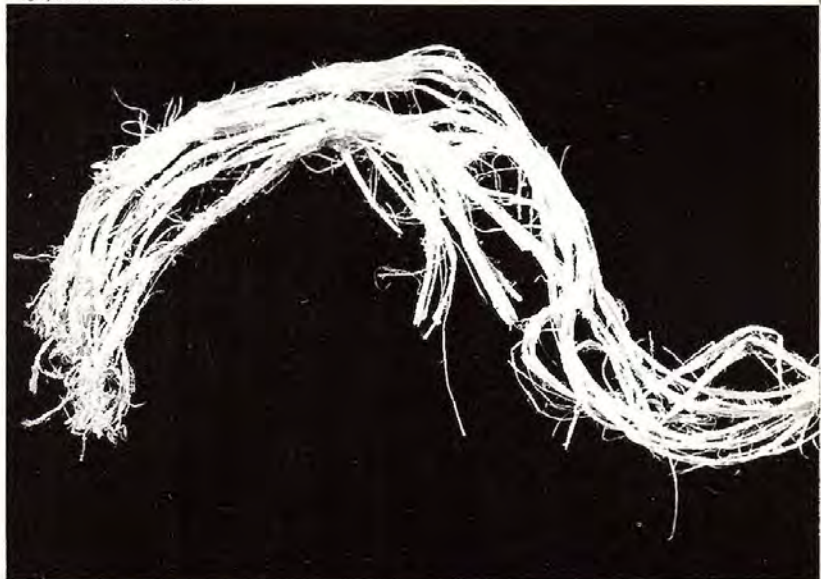
In the biological sciences, X-ray crystallography was instrumental in discovering the structure of the DNA molecule, important for its role in genetics. In 1952, Rosalind Franklin, a British crystallographer working at the Cavendish Laboratory of Cambridge University undertook the study of the DNA molecule using X-ray methods on crystalline specimens of chromosomes. The resulting photographs indicated that the structure of DNA was a helix. With this in mind two biologists, James Watson and Francis Crick, 'played' with model atoms to find a likely molecular structure. When the atoms 'fitted' they found the structure was actually a double helix. This was one of the major events of this century and it not only inspired research into genetics but transformed the science of biochemistry. It is significant to note that Sir Lawrence Bragg, one of the founders of X-ray crystallography, was present during

these events and had always promoted the use of crystallography in solving difficult structures in molecular biology.

#### FURTHER READING

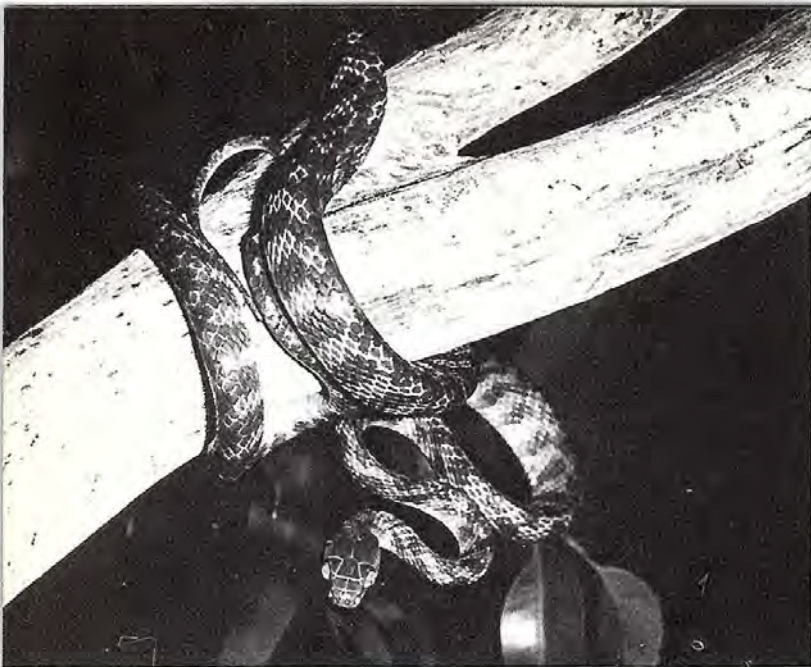
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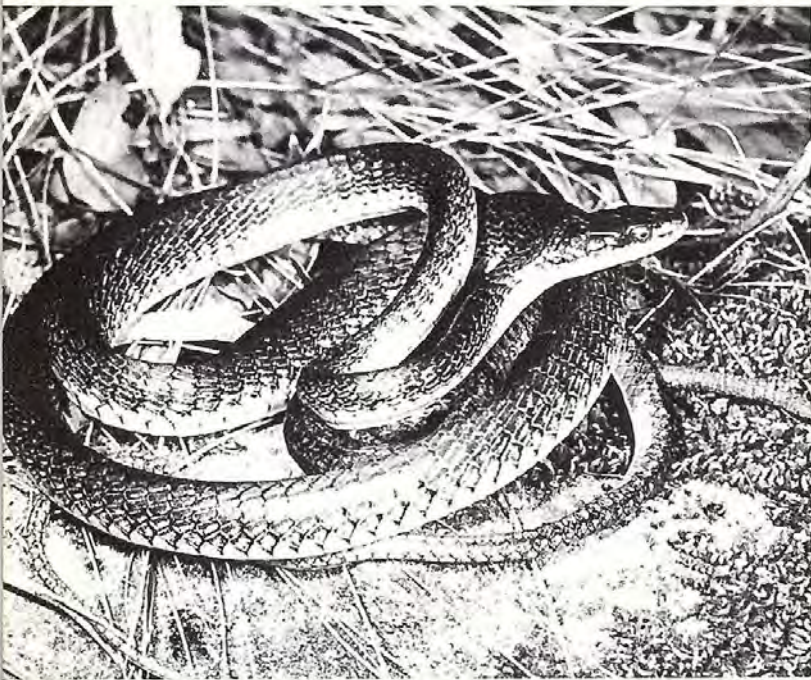


Stellate (star-like) growth of gypsum crystals on vegetation, Myall Creek, South Australia. These crystals show contact twinning.

Fibrous crystals of Asbestos from Sandrio, Italy.



H. G. Cogger



H. G. Cogger



H. G. Cogger

Of approximately twenty seven hundred species of snakes found throughout the world, the family Colubridae embraces a staggering fourteen hundred species making it by far the largest and most diverse of modern reptile families.

As one would expect, such an assemblage presents a myriad of structures and behavioural adaptations making the succinct definition of Colubrids extremely difficult. Essentially Colubrids are structurally advanced snakes and, in the majority, unspecialised. The arrangement and shape of the teeth, together with various modifications of the skull and vertebrae are the principal diagnostic characters for separating this group from other snake families. However, a number of species possess peculiarities in structure, particularly in regard to teeth, which implies a close relationship with other families. As a result, the evolutionary relationships of Colubrid snakes have been in a state of constant change for many years. Numerous rearrangements have been proposed but few have been successful.

Presently the family is divisible into several sub-families, some of dubious standing. One sub-family, the Colubrinae, has about thirteen hundred and fifty species containing forms which, though possessing a few common characteristics, appear to have been placed together artificially, mainly because they do not fit into the other sub-families.

Nevertheless, the sheer size of this sub-family has perplexed scientists for many years and even with the aid of sophisticated biochemical studies, still resists attempts at further sub-division.

The abundance and world-wide distribution of the Colubrinae coupled with a comparatively recent fossil record infers that this group has achieved considerable success in recent times. Originating during the Oligocene, some thirty million years ago, the primitive Colubrid-types probably gave rise to a number of other modern groups, notably the Elapids and Hydrophids. They are regarded as the only major group of reptiles to achieve any significant radiation since most reptile families disappeared or were much reduced by the closing of the Cretaceous about seventy million years ago. The adaptability of the Colubrinae is adequately demonstrated by the fact that they occupy every continent with the exception of Antarctica and occur in all habitats — terrestrial, freshwater and marine. Not only are they widely dispersed, but they are also abundant in almost every place they occur. The Colubridae family has fewer species in Australia than any other family with representatives in this country as it appears the group

# FANGED BUT FRIENDLY

## DARWIN'S COLUBRID SNAKES

BY GRAEME GOW

has only recently established itself here. Australia has more representatives of the venomous Elapid snakes and no doubt competition from this long established group along with the aridity of the continent, limited the distribution of Colubrids to the tropical northern coast and along the margin of the east coast southwards to about Latitude thirty-three degrees.

Colubrids lack the specialised fang development typical of Elapids (such as cobras, mambas, taipan), Hydrophiids (sea-snakes) and vipers (rattlesnakes, puff-adders, etc) and is basically a harmless group of snakes. Some possess numerous solid teeth while others have barely any at all, such as the African Egg-eating Snake, *Dasypeltis scabra*. Several, mainly tropical Colubrids, possess moderately developed or enlarged grooved teeth at the rear of each maxillary bone. Such teeth have access to secretions from large venom glands, thus making them technically venomous. These are termed 'rear-fanged', the Australian Brown Tree-snake, *Boiga irregularis*, being one example. Only two African species are currently regarded as dangerous, the most notable of which is the Boomslang, *Dispholidus typus*. At least one death has been attributed to the other species, the Vine Snake, *Thelotornis kirtlandi*. Both produce severe symptoms, death usually resulting from widespread blood-clotting and respiratory failure. It would thus be wise to exercise a degree of caution regarding the potency of the lesser-known types as meagre research has gone into the nature of their venoms and many supposedly harmless types may prove otherwise. Of the eleven species of Colubrids known from Australia, six are of this rear-fanged type and are for a variety of reasons, regarded as harmless. Such a venom apparatus, though inefficient in comparison to that of the Elapids or Vipers, is used primarily as a means of quietening and securing struggling prey as well as the initiation of the digestive process. Hence with most species, constriction and nocturnal hunting play a large part in feeding.

As previously mentioned, there is tremendous diversity in the group and this is true of their method of feeding for in their conquest of available niches, numerous specialisations were required to exploit different food sources. Dramatic illustration of this can be seen in a number of cases. The African Egg-eating Snake, *Dasypeltis scabra*, underwent changes both in its vertebrae and teeth as a result of the exploitation of birds' eggs as

a sole food source. Feeding is accomplished by slowly manipulating its near-toothless mouth over the egg in a progressively distended action while preventing the egg from moving by firmly retaining it against its body coil. As this snake's head is only about twenty-five millimetres wide, enormous distention is required to allow the passage of a whole hen's egg. Once in the neck, the egg is pierced by special structures on some of the vertebrae and collapsed by muscular contraction, forcing its contents into the stomach. The empty shell, held in the neck, is then regurgitated.

Another group found in Asia and America feeds almost exclusively on snails and slugs. Known as Snail-eaters (sub-family Dipsadinae) this group has evolved a lower jaw structure that can be protruded and retracted relatively independently of the upper jaw and palate for the specific purpose of removing living snails from their shells. When a snail's body is seized, it is held tenaciously by the long teeth of the upper jaw while the lower jaw extends into the shell. After the sharp anterior teeth secure the body, the lower jaw retracts, thus extracting the mollusc from its shell. This may sound a fairly simple matter, but the mechanics are really quite amazing.

Since Colubrids are more abundant on the Asian mainland and tend to decrease in speciation as one travels eastwards, it appears that their presence in the Australian region may be a result of one of the most recent migratory pathways. Most are adept swimmers and this may have been how they arrived in Australia. Simultaneously, members may have rafted across from island to island as well as utilizing land bridges existing between Australia and New Guinea during the last ice age. It would appear however that they reached Australia in a number of successful invasions. The Northern Territory coastline by virtue of its location in relation to the nearby islands such as Papua New Guinea has undoubtedly played a major role in the Colubrid colonisation of Australia. Of Australia's eleven representatives, the Northern Territory has nine and all can be found in the vicinity of Darwin. Although the majority of species can be found around rivers and estuaries fairly close to the coast, three species, *Boiga irregularis*, *Dendrelaphis punctulatus* and *Amphiesma mairii* extend inland some four hundred kilometres. The numerous rivers present have acted as southern dispersal routes.

The Darwin Colubrids fall into three sub-families,

A Red-banded Tree Snake, *Boiga irregularis*, poised, ready to strike. This species feeds mainly on birds, which are seized from trees as they sleep. Just prior to striking, the fore-part of the body is laterally compressed into an 'S' shaped coil.

The Green Tree Snake, *Dendrelaphis punctulatus*, from eastern Queensland. This dark colour form occurs in restricted areas of dense forest in coastal northeast Queensland and is rapidly becoming uncommon as a result of land-clearing practices.

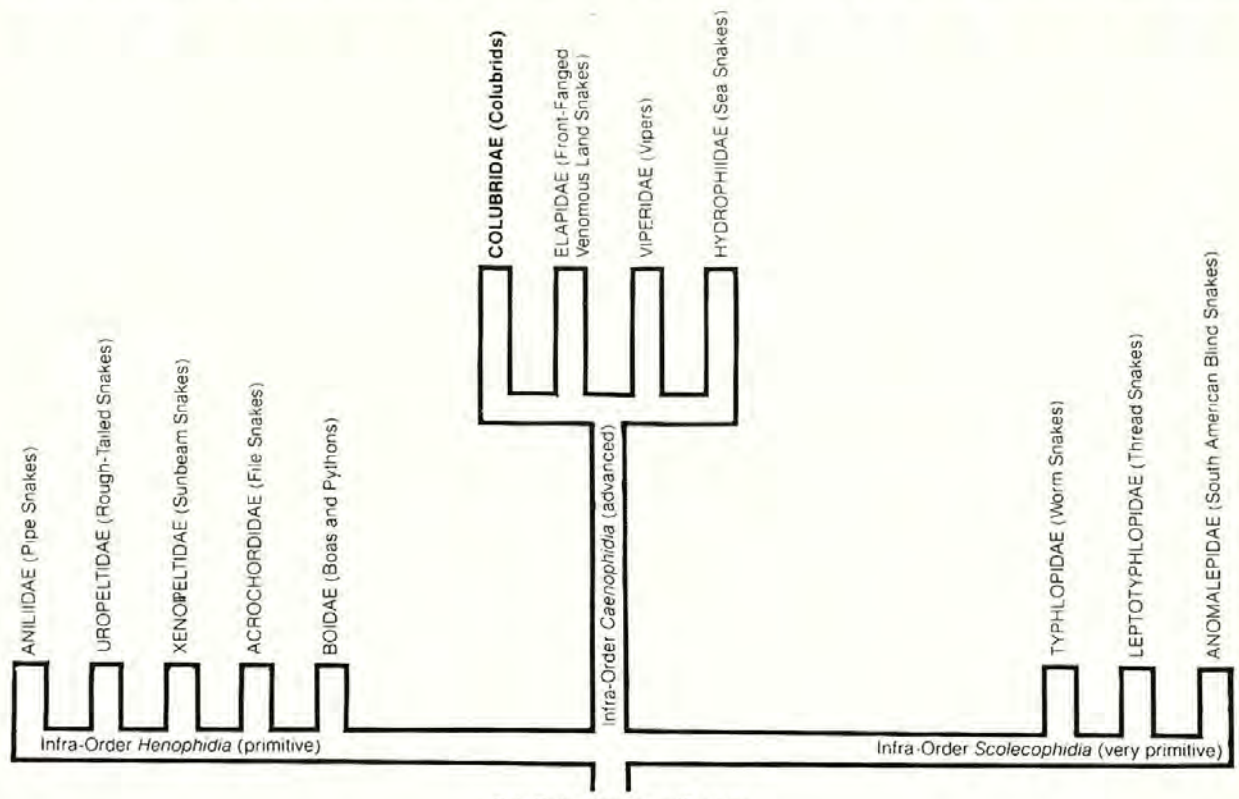
An eastern Australian form of *Dendrelaphis punctulatus*, showing the characteristic flattening of the neck during a display of aggression. This form inhabits the coastal fringe from mid-eastern Queensland to Sydney.

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namely the Colubrinae, Homolopsinae and Boiginae. The Golden Tree Snake, *Dendrelaphis punctulatus*, is a long, slender species with a whip-like tail. The head has an elongated appearance with rather large eyes and is slightly distinct from the neck. This species is highly variable in colouration throughout its range and has therefore been given several common names. The most common phase along the east coast is green to olive green above, with a yellow undersurface and is known as the 'Green Tree Snake'. It ranges from southern NSW to Cape York however, in areas of north coastal Queensland two other phases occur. In the Townsville area, specimens may be dark brown to black above and yellow below and are known as 'Black and Yellow Tree Snakes' whilst further north in dense rain forest, entirely blue specimens occur; this phase of course is known as the

The Freshwater Snake, *Amphiesma mairii*, is a moderately built species which, because of its ridged scales, is often referred to as 'keelback'. Its head is distinct from its neck and the colour on its back varies from olive-brown or reddish to almost black with scattered black and white markings, giving a 'peppered' appearance. The undersurface is creamish to yellow and in some specimens the belly scales are distinctly edged with black. This semi-aquatic species attains a maximum length of almost a metre and is usually found living along the verges of streams and marshy areas, feeding almost entirely on frogs. It is mainly nocturnal in habit being most active during the wet season when large numbers are killed crossing roads at night. The Freshwater Snake is highly nervous in disposition and when first captured, particularly if held by the tail, will thrash about frantically,

A Phylogenetic Tree — a reconstruction of the presumed evolutionary relationships of the snake families.



Order Squamata (Lizards and Snakes) R Stewart from Richard Wells

'Blue Tree Snake'. In Darwin this species is invariably rich yellow to gold or golden-brown on the upper body and tail while the head and neck are bluish. The undersurface is white. The Golden Tree Snake is an entirely diurnal species and is often observed along the banks of creeks and rivers where it forages in trees or on the ground for frogs. It is extremely agile and a competent swimmer, often taking to water to hunt or to make good its escape if danger threatens. If cornered or provoked it dilates the neck and body, displaying light blue skin between the scales. Although this behaviour is mostly bluff, some individuals will bite but owing to their small fine teeth, they cannot inflict a bite of any magnitude. This snake grows to a maximum length of about two metres and produces an average of twelve eggs in a clutch.

ally, some specimens dismembering their tails in the process. This is the only Australian species of snake known to possess this habit, tail-casting occurring more commonly amongst certain groups of lizards. However, unlike the lizards, snakes' tails will not regrow.

The Freshwater Snake reproduces by laying eggs, up to seventeen in a clutch. This entirely harmless snake is popular with all naturalists who recognise the important role it plays controlling (to a certain degree) one of Australia's greatest pests, the imported Cane-Toad, *Bufo marinus*.

The Slaty-grey snake, *Stegonotus cucullatus*, has a long stout body with smooth shiny scales. It grows to almost two metres in length and is leaden grey to black above, the undersurface being white. This species lives around rivers, creeks and marshy areas, where it hides



H.G. Cogger

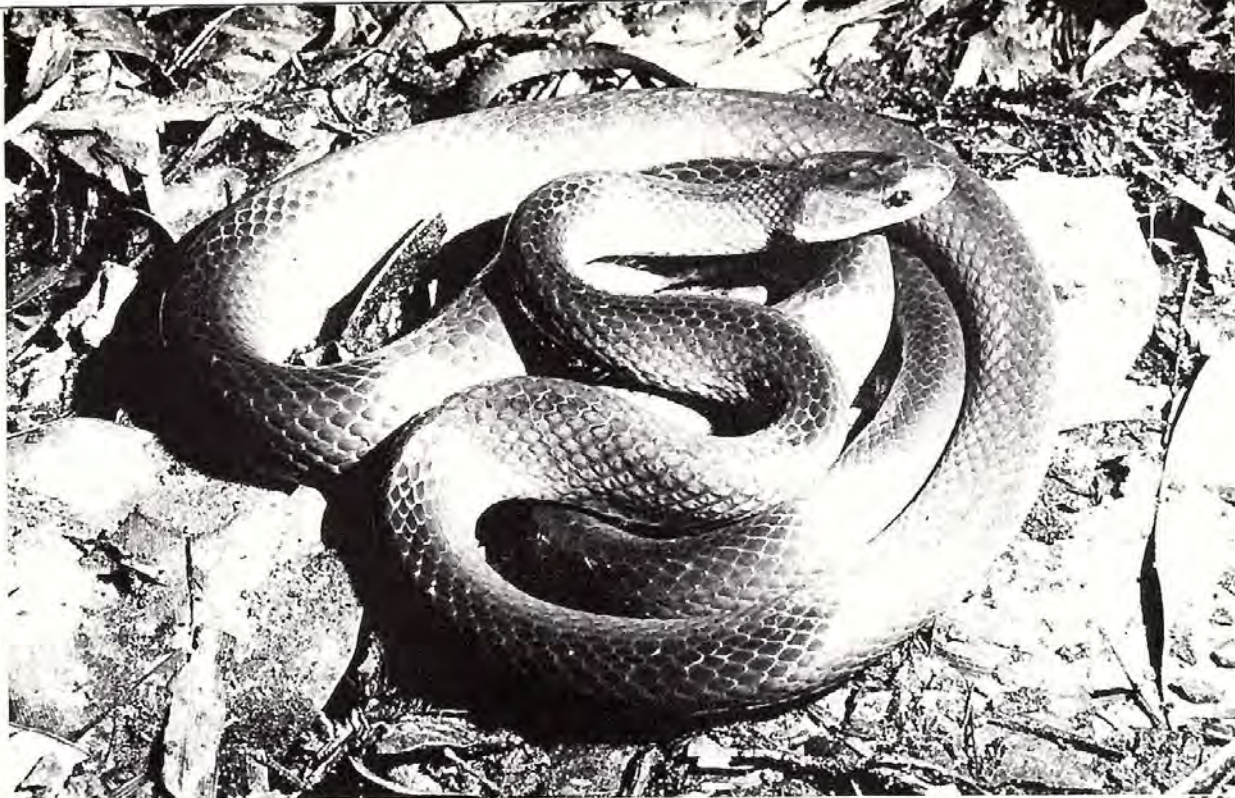


H.G. Cogger

Above: The Golden Tree Snake, *Dendrelaphis punctulatus*, photographed at Humpty Doo, Northern Territory. This typical 'Golden Phase' occurs throughout the 'Top End' of the Northern Territory. Like the eastern forms, this variety may be ill-tempered but they soon lose their aggressiveness after a short period in captivity.

Left: The Californian King Snake, *Lampropeltis zonata*, illustrates well the magnificent colouration found in many of the Colubrids.

The Slaty-grey Snake, *Stegonotus cucullatus*, a nocturnal frog-eating species, is confined to Northern Australia. Although shy and seldom seen, it is by no means rare; its activity appears to be closely associated with periods of high rainfall.



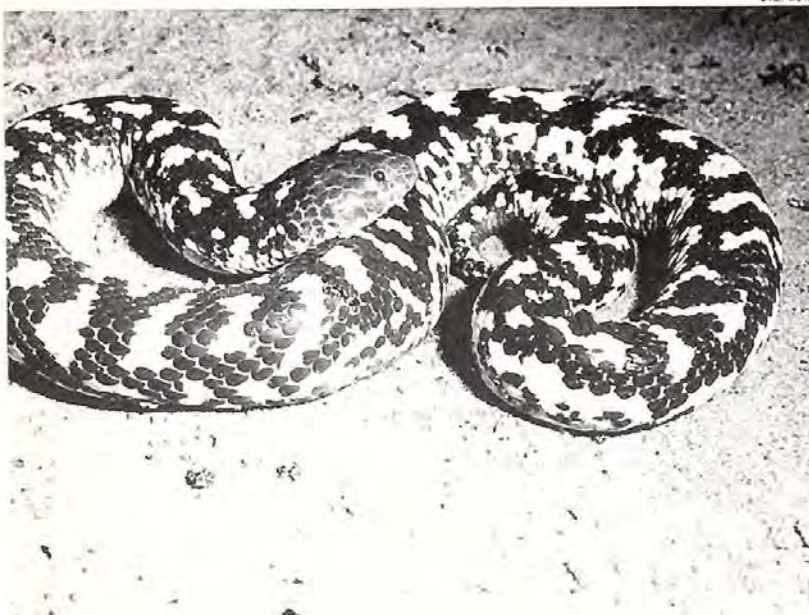
G. E. Gow

The White-bellied Mangrove Snake, *Fordonia leucobalia*, occurs throughout the Indo-Australian Archipelago. Nocturnal and a strict crab-eater, this species prowls around mud-flats in mangrove areas. Occasionally, specimens are found swimming in open sea, hundreds of kilometres from land.

during the day beneath damp leaf-litter or in deep earth-cracks. It is nocturnal and therefore seldom seen which probably accounts for our poor knowledge of its habits. Activity is usually confined to periods of high-humidity, particularly after rain when they pursue their favourite food item, frogs. This species is renowned for its bad temper, often biting with little provocation. Like the Golden Tree Snake and Freshwater Snake, this species lays eggs but the exact number in a clutch is uncertain.

The sub-family Homalopsinae is essentially an oriental group of venomous rear-fanged water snakes. Throughout Indo-China and the Indo-Australian Archipelago there is considerable species diversity but currently only five species are recognised as occurring along the tropical north coast of Australia. All five species can be found in Darwin, principally in estuarine areas but some,

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for example, Macleay's Water Snake, *Enhydryis polylepis*, are more commonly encountered in freshwater habitats. They are closely associated with the mangrove community and feed on crustaceans and some species of fish. All have valvular nostrils on top of the snout which they close when diving. Living young are produced but the number born is uncertain with most species.

The Bockadam, *Cerberus rhynchops*, is one of the more common species, occasionally attaining a length of just over a metre. It is a solidly built snake with a broad head and strongly keeled scales; the head has prominent, slightly raised eyes which tend to transform the appearance of the snake's head to something suspiciously like that of its main food item, the mud-skipper. When the Bockadam is foraging for food or lying motionless and partly submerged in mud, it finds little difficulty in securing these fish since they are apparently oblivious to the snake's presence — possibly they regard the Bockadam's head as another mud-skipper. This species is usually olive-green to grey above with widely spaced black transverse bands and blotches; the undersurface is either salmon or yellowish, chequered with black. Live young are produced, numbers varying between eight and twenty-six.

Macleay's Water Snake, *Enhydryis polylepis*, is a robust species which grows to about one metre in length. The head is depressed and slightly distinct from the neck, the eyes are rather small. It is leaden-black above and creamy-yellow below. The undersurface of the tail has a black line running its entire length. There is usually a clear line of demarcation between the upper and undersurface colours — dark spotting, if present is minimal. This species occurs along most freshwater streams and dams, feeding upon fish and frogs. The Spotted Water Snake, *Enhydryis punctata*, is a short solidly built species which attains a length of nearly half a metre. It is reddish-brown above with darker spots and blotches on the body and tail; the undersurface is

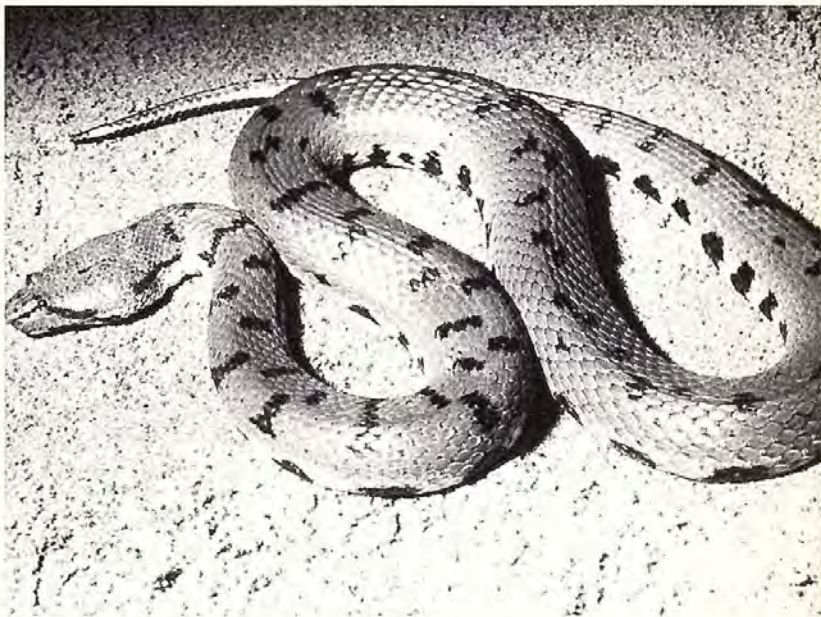
creamish-white. The habits of this species are unknown.

The White-bellied Mangrove Snake, *Fordonia leucobalia*, another robust species, is the most common of the water snakes and is often found in small colonies in mangrove areas. It grows to almost a metre in length and has a small but broad head, only slightly distinct from the neck, and tiny eyes. The colour on its back is variable but most specimens have reticulated wavy black markings on white, or glossy black above, gradually merging on the lower sides with the cream to a white undersurface. The undersurface of the tail is black. Its food consists almost entirely of crabs. It is completely inoffensive by nature even when collected.

Gray's Water Snake, *Myron richardsonii*, is a small moderately built species with slightly ridged scales. It is greyish to olive-brown above with crossbands of black. The undersurface is creamy to yellow, each ventral scale being edged with black. Very little is known of this species habits. It grows to nearly half a metre in length and is reputedly a crab-eater.

The last sub-family, the Boiginae, contains a single member, the venomous (rear-fanged) Red-banded Tree Snake, *Boiga irregularis*. This is a slender species with a broad head quite distinct from the neck, and large yellow eyes with black vertically elliptical pupils. The body markings consist of irregular transverse reddish-brown bands with cream to light brown interspaces and a creamish undersurface. This species is nocturnal, attains a length of two metres, and is aggressive by nature. Although venomous, it is not regarded as dangerous. Small mammals and birds are its food preferences but lizards, frogs and birds' eggs are also consumed. This species is an efficient constrictor and when subduing prey it suffocates the victim by holding it tightly within its strong coils. It produces up to twelve eggs in a clutch and because of its colouration is often referred to as a 'Tiger Snake'.

Most Darwin residents realise the harmless nature of the Colubrid snakes as they are frequently encountered around suburbia. Moreover, people are concerned that



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these species be afforded some kind of legal protection in the near future for at present they are officially classified as 'pests'. Hopefully, proposed changes to the legislation concerning wildlife protection will embrace the Territory's Colubrid snakes. Obviously their respective habitats must also be preserved and as the majority of the Colubrids depend upon the freshwater and mangrove ecosystems for their successful existence, disturbances such as pollution or land reclamation can only have the most adverse effect upon their chances of survival.

#### FURTHER READING

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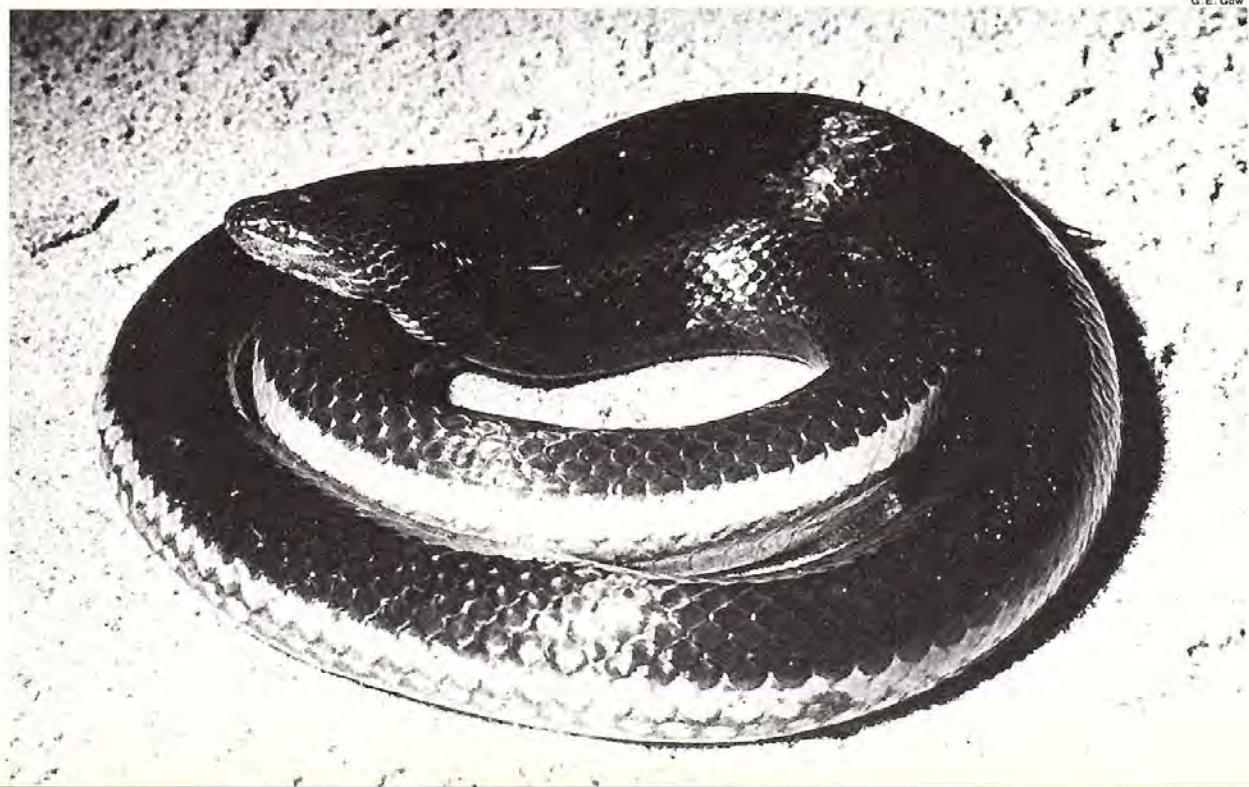
Cogger, H.G. Reptiles and Amphibians of Australia, A.H. and A.W. Reed, Sydney, 1975.

Gow, G.F. Snakes of Australia, Angus and Robertson, Sydney, 1976.

Heatwole, H. Reptile Ecology, University of Queensland Press, 1976.

Porter, K.R. Herpetology, Saunders, Philadelphia, 1972.

The Bockadam, *Cerberus rhynchops*, is a fish-eating species occurring throughout the eastern Indo-Australian Archipelago. It is occasionally found drowned in fishing nets around Darwin but more often discovered partly buried in mud.



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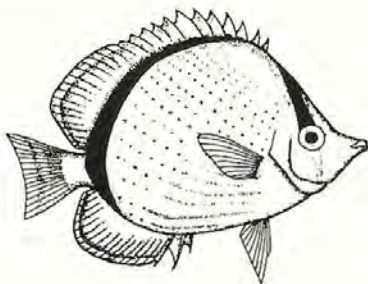
Macleay's Water Snake, *Enhydryis polylepis*, inhabits freshwater streams throughout the tropical Australian coast. It is an inoffensive species, feeding mainly on fish and frogs. Large colonies often exist in waterholes and streams.

## THREE APPROACHES

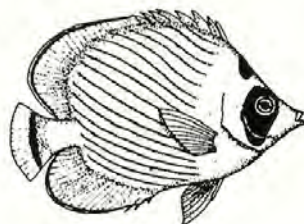
A FIELD GUIDE TO THE REEF FISHES OF TROPICAL AUSTRALIA AND THE INDO-PACIFIC REGION, by R.H. Carcasson, *Collins, Sydney, 1977, 320 pages, illustrated, \$14.95.*

This Field Guide includes eighteen hundred species of fishes and includes illustrations of a third of the species, three hundred and eighty-nine species illustrated in colour from paintings of reef fishes. The colour illustrations are grouped together while the black and white figures are placed in the text with the appropriate species. Descriptions are given to help identify the family in which a particular species may belong. In some cases a brief description is given for a species but many are simply listed, giving general habitat and geographical distribution. The book is small and easy to carry into the field.

For a field guide to be successful it must be reasonably accurate, it must include sufficient illustrations for the area it covers and an amateur must be able to identify fishes from the guide. Previously only one book, *Coastal Fishes of Japan, Masuda, Araga, and Yoshino, 1975, Tokai University Press*, has been a successful field guide for identification of Indo-Pacific fishes. The book treats twelve hundred species, all of which are illustrated. A large percentage of the species treated occur on coral reefs.



*C. selene*



*Chaetodon adiergastos*

Field guides have been highly successful for birds for several reasons. The taxonomy of the eighty five hundred species of birds is relatively well known and guides treat very limited geographical regions, conse-

quently only a few hundred species are included. Unfortunately, field guides for fishes are rarely successful, partly because fish taxonomy is not well known and also because authors often attempt to cover too many species.



Spotted Seahorse



*Ophichthus polyophthalmus*

Of the twenty thousand species of fishes, about six thousand occur in the Indo-Pacific and over half of these are found on coral reefs. Taxonomic problems have been resolved for only about half of the species. Over fifteen hundred species of fishes have been collected from the Great Barrier Reef, including many previously unknown species. In the past fifteen years, considerable scientific research has been carried out on Indo-Pacific coral reef fishes. Unfortunately much of the information obtained from these studies is available only in scientific publications. The author of the Field Guide has apparently relied mostly on other popular literature, much of which is now out of date. The book was prepared a few years ago and does not include information from recent publications such as *Damselfishes of the South Seas*, G. Allen, TFH Publications, 1975. Allen's work deals with all species known from the Great Barrier Reef and brings the taxonomic and biological information up to date. To produce a comprehensive field guide for Indo-Pacific coral reef fishes is a monumental task that a specialist would not even attempt.

While the Field Guide is useful in placing fish in their correct group, such as family, it has several disadvantages. About fifteen percent of the species included



are estuarine or oceanic fishes rarely seen around reefs. While many of the common reef fishes such as the reef shark are not included. The quality of the illustrations is fair but there are too few. The brief descriptions given for the species not illustrated are generally inadequate to allow identification. In many groups, such as wrasses and parrot fishes, juveniles and adult males and females all have different colour patterns. Because of this variation and the great diversity of fishes on coral reefs, an amateur will be able to identify only a few species. Despite this, the book should be useful in grouping fishes in their respective families etc.—D. F. Hoese, Assistant Curator of Fishes, *The Australian Museum*.

BRELLA, *The Story of a Young Fruit Bat*, by Josephine Croser; Nelson, Melbourne & Sydney, 1976; 101 pages, illustrated, \$5.95.

Virtually all native mammals are protected in Australia and in this regard this continent differs markedly from many others in which protection is afforded only to a minority of larger important game animals or fur bearers. Even common small mammals such as rodents and bats enjoy protective legislation here. While this situation is most admirable and worthy of emulation by other countries, it has one major disadvantage. Children who are keen and budding naturalists and who would delight in keeping some of the more common native mammals as pets, are unable to do so because of the Fauna Protection regulations.

One group of native mammals which occurs in plentiful numbers and which is not protected because of its potential for economic damage contains the flying foxes or fruit bats of the genus *Pteropus* which is represented by four species in Australia. These animals can make fascinating and interesting pets which could provide children with much enjoyment and delight.

'Brella' is a fictional account for children of the discovery and rearing of an orphan flying fox by a boy and his sister. The story is narrated with feeling and appreciation of natural phenomena without falling into the pitfall of sentimentality. It could help to arouse a latent interest in natural history and provide some stimulation towards continued study of the subject, in some children.

Although there is a slight tendency towards anthropomorphism on some occasions, this is not of a very serious nature, and the general information given regarding the natural history of flying foxes is reasonably accurate. It is a great pity that the account of the development of the behaviour of this bat is terminated by its banishment to a fauna reserve at the very point where it is just learning to fly. A continuation of these observations beyond this

point would have proved most instructive and interesting.

The book is well produced and illustrated with line drawings which are reasonably accurate. The price of \$5.95 for a childrens book of about 100 pages seems somewhat excessive. — B. J. Marlow, Curator of Mammals, *The Australian Museum*.

THE CONSERVATIONIST 76 *National Parks and Wildlife Service (NSW), Sydney, 1976; 24 pages, illustrated, \$1.50.*

"This book is about the work of the National Parks and Wildlife Service in its attempts to conserve all that is natural, beautiful and memorable in New South Wales." The quote is from the title page of *The Conservationist*, the new and presumably annual publication of the National Parks and Wildlife Service, (NSW). *The Conservationist* is beautifully produced with some superb photographs of wildlife, but it is not an in depth account of the park service and its role as a conservation organization. In fact, it is the annual report of the Service, conveniently designed in such a way that when twenty pages of information on research, park management finance and administration are deleted, you have a twenty-four page booklet filled with pretty pictures.

There is nothing wrong with a well presented annual report. In the continuing quest for funds within the Public Service, annual reports have become part of the bureaucrat's public relations arsenal for obtaining even larger budgets. But is a flashy annual report the best way for the parks service to be spending its money. The service publishes an excellent journal, *Parks and Wildlife*, and produces good educational material on conservation and wildlife for teachers, farmers and others interested in learning about Australia's wildlife resources and how these might be conserved. Yet *Parks and Wildlife* has appeared only irregularly and education publications generally seem to have been hampered by a lack of funds. *The Conservationist* is not a meaningful statement about conservation. The information it presents is already available in more detail in other publications.

*The Conservationist* is an expensive publication and to the extent that it diverted funds and skilled staff from other publications has done a disservice to conservation in New South Wales. *The Conservationist* costs \$1.50, but I can not recommend its purchase. If you must have a copy, I suggest you obtain the Annual Report for 1975-76 of the National Parks and Wildlife Service (NSW).— H. F. Recher, Department of Environmental Studies, *The Australian Museum*.

# LETTERS

## NATIONAL PARK ALTERNATIVES — ARE THEY PRACTICAL ?

Dear Editor:

In his article "An Ecologist's View — The Failure of our National Parks System" (ANH Vol. 18 (11), Dr. Harry Recher says that he cannot see a practical way to create a national parks system in Australia which will achieve the goals he sets as an ecologist and at the same time conform to the political and economic realities of Australian Society.

He then goes on to outline an alternative 'dynamic' system of conservation, dispensing with fixed boundaries and the '19th Century conservation attitudes' which he believes to be bound up with national parks.

I agree with Dr. Recher that national parks as they are now known are unlikely ever to achieve all the goals that ecologists set for them, but to suggest as a *practical* alternative the dismantling of entrenched Australian political, legal and social structures such as the rights of States, the concept of private property and the security of human settlement, is stretching things just a bit.

The absolute ecological management of Australia would probably require the elimination of nine-tenths of its human population, with flood, fire, storm, disaster and other natural processes keeping those remaining in check and on the run. Much less extreme forms of ecological management as suggested by Dr. Recher are very attractive to me but would still require a major social revolution to give them effect. The system of dynamic zones of management put forward would at times play havoc with local economies. The abandonment of a sizeable town with much of its capital investment might be required to meet some goal of ecological management in a forest or estuary on which the town was dependent. Government bureaucracies would have to rid themselves of their rigid attitudes and all their empire builders. Landholders would have to forget about pride of ownership, local attachment and other archaic sentiments.

Viewing this ecologist's dream through the slightly cracked green tint glasses of the active conservationist produces effects reminiscent of a kaleidoscope — the image is very nice to behold, but who in 1977 could call it practical?

*Peter Prineas  
Mosman, NSW*

### THE AUTHOR REPLIES:

Prineas and I agree on the objectives of conservation which have led to the establishment of national parks in Australia. We also agree that the parks system by itself

can not achieve the objective we've defined for it. Where we seem to disagree is on the means of correcting the deficiencies. Prineas, like most persons concerned about their environment, would like to see the continued dedication of parks and reserves with perhaps such objectives as reserving 5% of Australia in national parks or in sampling all major ecosystems. I have argued that at best, such a system of reserves is only a temporary expedient: the lesser of many evils. We need to evolve a system of land management in which the conservation of ecosystems, wildlife and wilderness is valued as highly as other human activities. To achieve this, we need to dispense with formal and environmentally unrealistic boundaries and will have to modify our attitudes towards the 'ownership' of land. I envision a system of social evolution during which the growth and development of the community is adapted to the Australian environment. I do not believe that this requires the elimination of nine-tenths of the population and a return to an aboriginal existence, but it does require the rejection of our present (environmentally insane) dedication to an ever increasing GNP and (ever increasing) material possessions.

My suggestions are idealistic, but they are not impractical. I am not the only one to have suggested the elimination of state boundaries nor am I the only one who is unhappy with the consequences of private ownership of land where the owner acts in its own interest and not as a custodian for the community. The American Congress has come close to passing legislation which in effect defines the owner of land as a tenant and requires the land to be passed on to the next tenant in a good condition.

If we can accept (and Prineas has) that our system of national parks is deficient and will in the long run fail, then we should seriously discuss alternatives. I have suggested an alternative: but I have not proposed ditching the existing parks system nor have I said that we should cease adding to it. Our parks may not be very good, but at this stage they are all we have. As outlined in my article, we could immediately begin to improve the national parks system by applying our existing knowledge of ecology and the requirements of wildlife to the selection of parks and to their management. We will not improve on the situation unless there is a lot more discussion of the deficiencies and the alternatives. Prineas might begin by purchasing a new pair of green tinted glasses: if he did, he might see that there have been significant changes in the attitude of the community to conservation and a much wider range of options are available for the retention of environmental quality.

*Harry F. Recher*



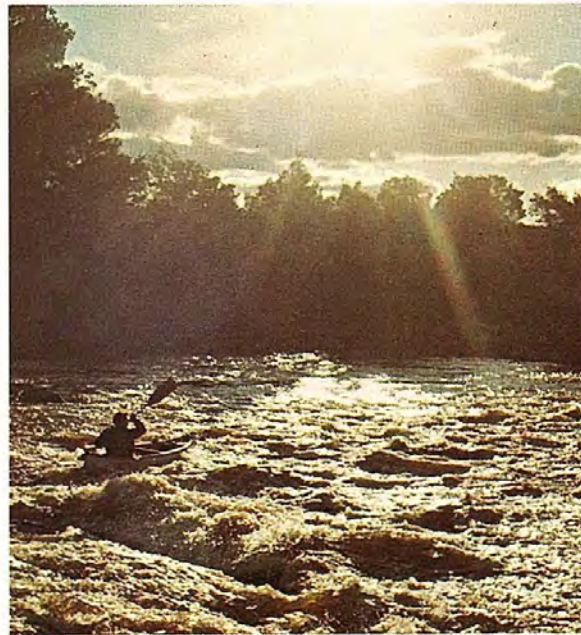
K. Gillett



I. Dunlop / Film Australia



E. Swater



These photographs are from *The Conservationist* Annual Report 1976 of the National Parks and Wildlife Service.

M. Thompson



K. Gillett

