SEPTEMBER 1971
Vol. 17
No. 3

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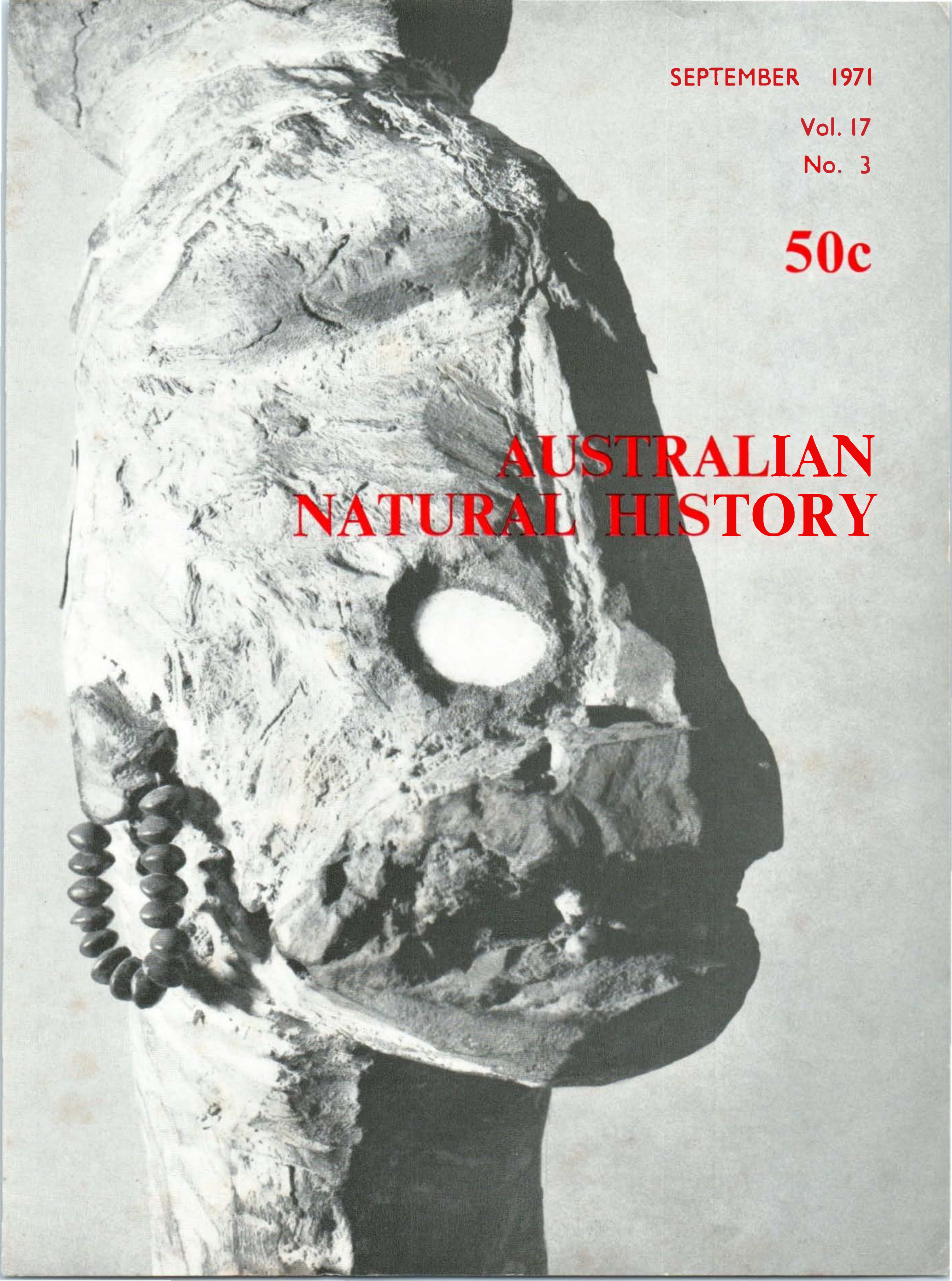
AUSTRALIAN NATURAL HISTORY



AUSTRALIAN NATURAL HISTORY

Published Quarterly by the Australian Museum, College Street, Sydney

Editor: F. H. TALBOT, Ph.D., F.L.S. — Annual subscription, $2.50 posted

Assistant Editor: P. F. COLLIS — Single copy, 50c (62c posted)

VOL. 17, NO. 3 — SEPTEMBER 15, 1971

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● FRONT COVER: The head of this wooden human figure from the Orokolo area, Gulf of Papua, Territory of Papua and New Guinea, is painted in red and white, and has pearl-shell eyes and human teeth set into the jaws. The body and legs are summarily treated, and there are no arms, though they may have been painted on the body originally. Such figures were kept in large men's houses and, representing various spirits, played an important part in ceremonies such as initiation. Rare among the Elema people of Orokolo, these carved figures seem to have been more typical of the peoples to the west, between the Fly and Kikori River deltas. This specimen, acquired in 1916, is on display in the Australian Museum's Melanesian Art Exhibition. It is 28 inches high. BACK COVER: A Common Wombat (*Vombatus ursinus*). These are burrowing, herbivorous and nocturnal marsupials which occur in mountainous forest habitats from southern Queensland, through New South Wales and Victoria to the eastern part of South Australia, and in Tasmania. In contrast to all other marsupials, all their teeth grow continuously from persistent pulps, and in this feature they resemble the rodents. [Photos: C. V. Turner.]

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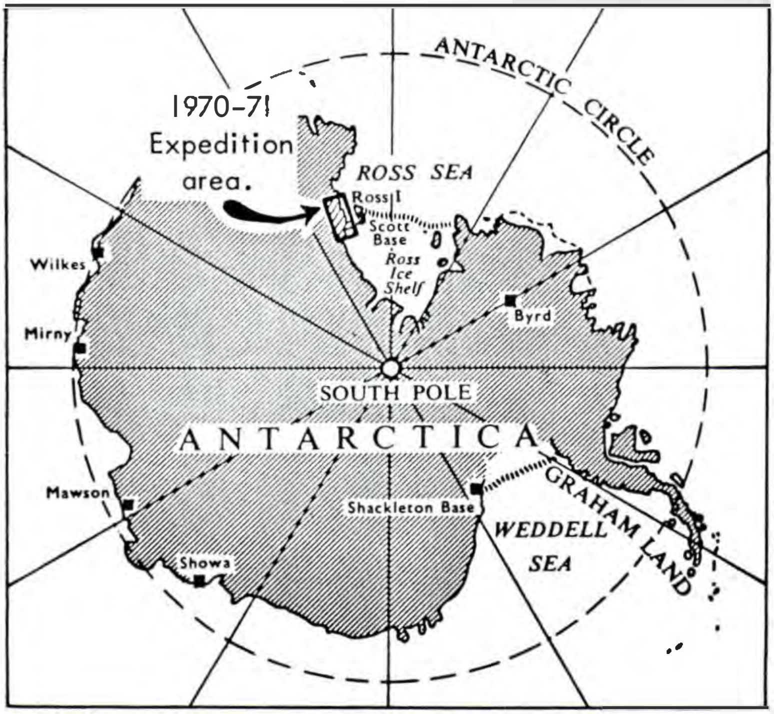


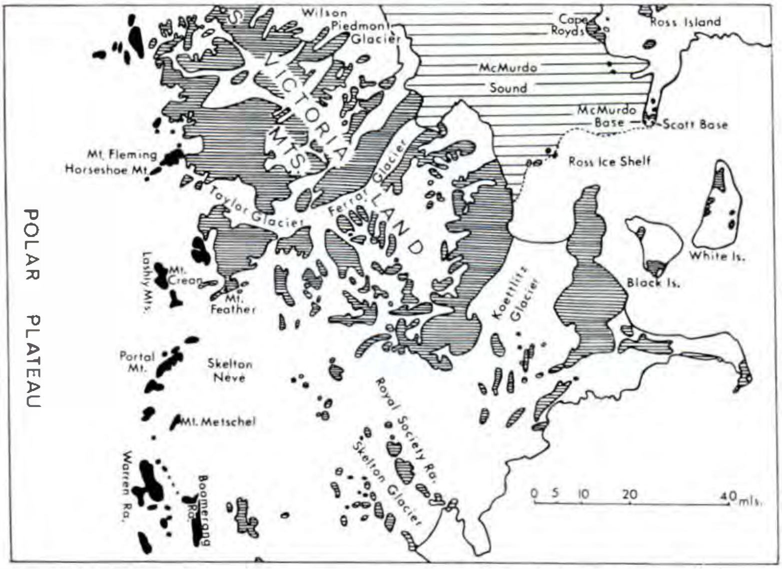
Antarctica, with the New Zealand 1970–71 expedition area indicated. The expedition area is shown in detail in the map on the next page.

Fossil Fish Discoveries in Antarctica

By A. RITCHIE
Curator of Fossils, Australian Museum

ON 17th November, 1970, I stood on an immense snowfield in Southern Victoria Land, Antarctica, with seven fellow geologists, and watched the dwindling shape of a U.S. Navy C-130 Hercules transport plane. After more than a year of planning and many months of preparation we were finally at our destination, ready to begin over 2 months of arduous geological fieldwork in what was to prove one of the most productive scientific expeditions ever sent to this part of Antarctica.

The expedition, Victoria University of Wellington Antarctic Expedition No. 15 (or VUWAE 15 for short), was planned to investigate many different aspects of the geology of Southern Victoria Land, and my particular interest involved a search for the fossilized remains of primitive fish which lived in Antarctica over 350 million years ago during the Devonian period. My field assistant, Mr Gavin Young, from the Bureau of Mineral Resources, Canberra, was also a research worker on fossil fish. The other six members of the party were all New Zealanders, geologists from Victoria University, Wellington, New Zealand, which has been sending annual expeditions to the area since the late 1950s. The leader was Dr Peter Barrett, a post-doctoral Fellow at the University, with several years' experience in U.S. Antarctic teams, and, in 1967, the discoverer of the first fragment of a true land animal in the rocks of Antarctica. Mr Barry Kohn, a Ph.D. student and deputy leader had been a member of VUWAE 13 to the same



Southern Victoria Land, Antarctica. The areas studied by the 1970–71 expedition are shown in solid black.

area in 1968–69. The other members were Mr Rodney Grapes, junior lecturer, Miss Rosemary Askin, Mr John McPherson, and Mr David Reid, all B.Sc. Honours graduates.

Behind us, 110 miles away across the 14,000-feet Royal Society Range, lay McMurdo Sound and the comparative comfort of New Zealand's Scott Base, which had been our home for the previous week. During that week we had managed to visit the historic wooden huts built by Shackleton and Scott, an Adelie penguin rookery, and the nuclear power station which supplies electricity to the nearby large U.S. base, McMurdo Station. Now, for the next 2 months we were to be on our own, on the edge of the Polar plateau at a height of about 6,000 feet, with two-man pyramidal Polar tents for shelter. Double walled for insulation and 7 feet square at the base, these tents are quite comfortable and capable of standing up to ferocious blizzards. For transport we used Polaris motorized toboggans, powered by 10-HP fourstroke engines, to pull our Nansen sledges, heavily laden with food, fuel, personal gear, tents, and, later, all our geological specimens. We had an ample supply of warm clothing, much of it wind-proofed and down-filled.

The area which we were to investigate extended along the western edge of the Transantarctic Mountains for about 120 miles, from the Warren Range in the south to Mt Fleming and other peaks in the north. During the early part of the season the geological programme was greatly hindered by persistent bad weather and by serious mechanical trouble with the toboggans; in the first month there were only 4 days without ground blizzards, whiteouts, or uncomfortably high winds, conditions which made note-taking and fossil extraction somewhat unpleasant. To reach the exposed rocky slopes for fossil remains we had to sledge over extensive areas of snowfield, much of which had an extremely rough surface of sastrugi—sub-parallel, wind-eroded snow ridges up to 3 feet in height. Polaris toboggans are remarkable machines when new, but ours were rather old, and, when faced with such rugged conditions, quickly developed interesting types of metal fatigue and other mechanical problems. Helicopters had to be called in to recover abandoned toboggans, and the Scott Base mechanics worked overtime welding and replacing parts to help keep our geological programme going.

The geology of the area investigated

The geology of the field area was comparatively simple: the oldest rocks exposed were of Devonian age, the Taylor Group, and the upper portion of this group, known as the Aztec Siltstone, contained fossil fish remains at many different horizons. In

The campsite near Mt Metschel, Skelton Névé. Devonian fish-bearing rocks form the lower slopes of the mountain, and are overlain by Permo-Carboniferous glacial deposits and pale yellow sandstones of the Permian Coal Measures. The upper part of the mountain is formed by one enormously thick dolerite sill, intruded into the older sediments in Jurassic times. [Photo: Author.]

post-Devonian times a period of erosion, followed by a widespread period of glaciation, planed down, or even removed entirely, the fish-bearing Devonian sediments. This earlier period of glaciation, in Permo-Carboniferous times about 300–280 million years ago, also affected portions of South America, South Africa, India, and Australia at a time when all of these continents were grouped much more closely together as the former "supercontinent" of Gondwanaland.

In Southern Victoria Land, as elsewhere in Gondwanaland, the Permo-Carboniferous glaciation was followed by deposition of widespread continental deposits, the coal-bearing sediments of Permian and Triassic times. The Permian Weller Coal Measures contain typical Gondwanaland plants, such as *Glossopteris* and *Gangamopteris* (see Plumstead, 1968, in *Australian Natural History*), and the overlying Triassic sediments of the Lashly Formation contain *Dicroidium*, commonly found in the Sydney Basin and many other sites throughout the southern continents. Dr Peter Barrett and Miss Askin were particularly interested in studying the plant-bearing formations, and recovered a large quantity of well-preserved specimens for detailed examination and stratigraphic correlation.

Spectacular rock formations

The entire sedimentary succession, from Devonian to Triassic, was later shattered and penetrated by the intrusion of molten magma from below; this material, at a temperature of at least 750° C, squeezed up vertical fissures (dykes) and then spread laterally along the sedimentary bedding surfaces at different levels, forcing apart and baking the earlier sediments. These dolerite sills, intruded in Jurassic times around 150 million years ago, now form sheer cliffs of columnar jointed dolerite, up to 2,000 feet high, in the Warren Range and elsewhere in Victoria Land. Rodney Grapes and David Reid spent their time examining and sampling these spectacular rock formations, which resemble, but on a much larger scale, the famous Giant's Causeway of Northern Ireland.

Several members of the team (Barrett, Askin, Kohn, and McPherson) measured detailed geological sections on some eighteen separate peaks and collected numerous samples for later sedimentological and micro-fossil analysis. The writer and Mr Gavin Young concentrated on the search for Devonian fossil fish remains in the Aztec Siltstone, and the most important finds were noted on the sections measured by the others.

Remains of fossil fish have been known from Victoria Land for 60 years, a few scraps having been collected from boulders in a glacial moraine in 1911 by members of Scott's expedition; these were later described by Woodward in 1921. The first specimens to be found in situ were collected by two New Zealand geologists with the Commonwealth Trans-Antarctic Expedition of 1957–59 (Gunn and Warren, 1962) and these were described by White in 1968. Woodward and White showed that the Devonian fish faunas of Southern Victoria Land included spiny-finned acanthodians, primitive armoured placoderms (arthrodires and antiarchs), lobe-finned crossopterygians, and ray-finned actinopterygians—and a few fragments even indicated the presence of primitive sharks. This faunal assemblage, although containing a few genera unique to Antarctica, is not markedly different from the very rich and well-known Devonian fish faunas from other parts of the world.

Victoria University, Wellington, sent their first team, VUWAE 13, into the area in 1968–69 and they collected several hundred pounds of fish-bearing rock, all of which was sent to the Australian Museum for preparation and study. This material, from a widely scattered number of localities, clearly indicated the existence of widespread fish-bearing horizons in the late Devonian sediments of the area. Unfortunately, articulated fish were virtually absent, and most of the pre-1969 material consisted of disarticulated and sometimes waterworn fragments of bone.

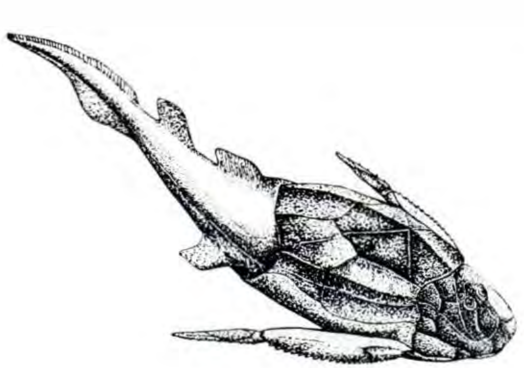
Rock rich in fish debris

Between November 1970 and January 1971 Gavin Young and I discovered fossil fish remains at several levels on some twelve localities and recovered an estimated 2,000 pounds of fossiliferous rock. Although fish remains were usually scattered rather sparsely through the shales and sandstones of the Aztec Siltstone, in a few sites there were localized concentrations so rich in fish debris that it was impossible to walk without stepping on fragments of bone. More commonly our search involved a painstaking examination of large areas of exposed rock on the steep flanks of the mountains. The bulk of the material was disarticulated prior to burial, but we did find many complete bony headshields and well-preserved individual plates from the armour of these ancient fish; articulated specimens were extremely rare, probably because of the environment of deposition in the stream channels, swamps, and lakes of a wide, flat river-plain. A few almost complete specimens were discovered in finely-splitting shales on the eastern flanks of Portal Mountain, sediments laid down during extremely calm conditions.

The bulk of the Devonian fish remains came from the head and trunk armour shields of primitive arctolepid arthrodires, of which only isolated fragments had previously been discovered in Antarctica. The best specimens came from the vicinity of a spectacular serrated ridge, Alligator Ridge, in the northern Boomerang Range, and consisted mainly of flattened trunk shields of scores of individual arctolepids. Strangely enough, the associated headshields were almost entirely absent and the only two specimens we discovered belonging to such fish came from other sites.

Other armoured fish, known as antiarchs, were also quite abundant. They were bizarre-shaped fish with the entire head and front part of the trunk encased in a solid, box-like armour, and the eyes were situated on top of the head, close together in a common opening in the headshield. *Bothriolepis*, the genus found here, had strange armoured pectoral fins articulated to the trunk armour by a ball-and-socket joint.

Exactly how they were used in life is a bit of a puzzle, but there can be no doubt that, in its time, *Bothriolepis* was an extremely successful fish, because its fossilized remains have turned up, often in considerable quantities, in sites as far apart as North America, Greenland, Europe, North Africa, Novaya Zemlya (Russia), China, and many parts of Australia, as well as Antarctica. Since most of these finds were preserved in freshwater continental sediments, the wide distribution pattern was a bit puzzling. The recent discovery of *Bothriolepis* in marine reef deposits in the Kimberleys of Western Australia indicates that some of the bothriolepids lived in marine conditions



A reconstruction of *Bothriolepis*, an armoured antiarch from Upper Devonian sediments of North America, Greenland, Europe, Asia, Australia, and Antarctica. Original length of the fish, 1 to 2 feet. [Drawing by Celia Tanner.]

which would have aided dispersal. Another factor which must have helped was the apparent closer association of the earth's continents before Permian times, 250 million years ago. In Devonian times neither the Atlantic nor Indian Oceans existed, and the present scatter of *Bothriolepis* sites is not quite so startling when plotted on a map of the continents reassembled in their probable pre-drift positions.

Interesting crossopterygians

Not all of the specimens found by VUWAE 15 were easy to collect. VUWAE 13 in 1968 had located a very fine specimen of the lower jaw of a lobe-finned, air-breathing fish known as a crossopterygian. This specimen was firmly stuck on the upper surface of a solid sandstone ledge in the northern Warren Range, and in order to extract it VUWAE 15 had to carry into the isolated locality a portable generator and jackhammer: they were led to the actual fossil by Barry Kohn, who had been a member of the VUWAE 13 team which found it. With some difficulty, in the freezing conditions, the fragile specimen was removed and brought back to Sydney carefully embedded in cotton wool.

These crossopterygian fish are of great interest to vertebrate palaeontologists and everyone else concerned with evolution because they are the group of fish closest to the ancestry of amphibians and all later vertebrates. We were fortunate to find several other specimens of such crossopterygians on other localities. Three more jaws were recovered, one so large that the fish which possessed it must have been at least 7 or 8 feet long. One of the finest of these specimens, collected by the writer on Mt Crean, in the Lashly Mountains, was preserved as a detailed natural mould in a solid block of sandstone, the original bone having been slowly etched away during the hundreds or thousands of years that the fossil had lain exposed to the elements. With modern casting techniques, using latex rubber, we can reproduce the shape of the lost jaw in incredible detail, and the result is an exciting and very important scientific find.

The finest specimen collected during the trip was also a crossopterygian, but one which had originally been buried entire. Erosion had destroyed the tail and rear of the trunk but the remainder of the trunk and the complete head still remained inside the ledge of dark grey siltstone. The jackhammer could not be carried into this site, which involved scaling rather precipitous sandstone and dolerite cliffs, so the extraction of the fish fossil had to be undertaken carefully with old-fashioned hammer and chisel, fortunately with complete success. The head of the fish is flattened in the rock and seen from above with the gill covers spread out symmetrically on either side of the cranial roof. In many respects it is quite close to a form known as *Gyroptychius*, found in the middle Devonian sediments of northern Scotland.

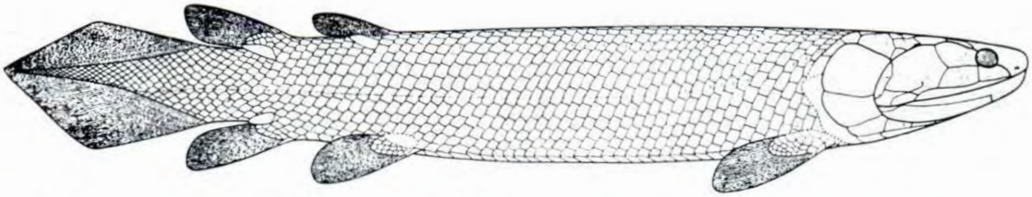
In 1968–69 the VUWAE 13 team had recovered from Mt Fleming a fragment of another type of air-breathing fish. The fragment, about half an inch across, was part of the specialized crushing toothplate of a dipnoan or true lungfish, the first and at that time the only specimen of a lungfish from Antarctica. Hoping to collect more from this site, VUWAE 15 sledged to within 1 mile of the locality, only to be pinned down in our tent by a week of whiteouts and heavy snowfalls which completely blanketed the fish beds—and the access route! Our natural disappointment was tempered by the knowledge that we had earlier found several other specimens of lungfish toothplates at localities much farther south.

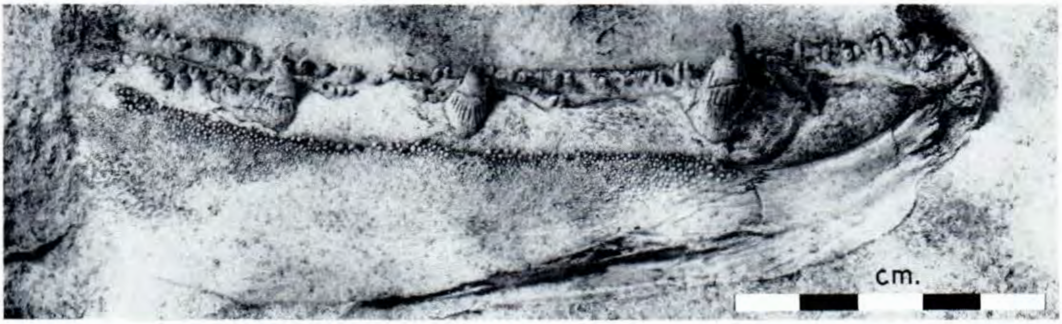
Exciting find

Other discoveries of interest from these sediments of more than 350 million years ago were partially complete specimens of little ray-finned fish, palaeoniscids, members of the Actinopterygii, and some articulated individuals of acanthodians, little spiny-finned fish which died out in Permian times. One exciting find, made by Mr Young at a site in the Lashly Mountains, was a partly articulated specimen of a strange, spine-bearing, shark-like form known as *Gyracanthides*. This genus, which apparently possessed teeth very similar to those found in pleuracanth sharks, has only been recorded from Victoria Land, Antarctica, and from near Mansfield in Victoria, Australia, sites which could not have been so very far apart when these fish were alive. The Antarctic species of *Gyracanthides* from late Devonian times is rather earlier than the Australian species, which is from early Carboniferous sediments.

Although we are obviously interested in the Antarctic Devonian fish faunas for their own sake (and several of the forms we recovered are apparently new to science), we are also interested in comparing the Antarctic Devonian fish faunas with those of other continents. The writer, at the Australian Museum in Sydney, and Mr Young, at the Bureau of Mineral Resources in Canberra, will be occupied for several years preparing and describing the wealth of material now available from the rocks of Antarctica, and it will be exciting if we can establish close faunal correlations between the Devonian fish of Antarctica and southeastern Australia.

The success of this latest expedition organized by the Department of Geology, Victoria University, Wellington, depended to a considerable extent on the support staff at New Zealand's Scott Base and to the transport facilities provided by the U.S.





Above: *Gyroptychius*, an air-breathing, lobe-finned crossopterygian fish of middle to late Devonian times in Europe. Length, 1 to 2 feet. [After Jarvik.] Below: A whitened rubber latex cast of the lower jaw of a similar crossopterygian fish from Mt Crean in the Lashly Mountains of Southern Victoria Land. The photo shows the internal surface of the left side of the jaw with well-developed carnivorous teeth. [Photo: C. V. Turner.]

authorities. Without the very competent Hercules and helicopter aircrews to transport men and materials into, out of, and within the field areas, Antarctic exploration would be much more dangerous and difficult than it is today.

Future collecting prospects

As VUWAE 15 left the Antarctic continent with the largest, most varied, and best preserved collection of ancient fossil fish ever found on that barren continent it was apparent to all of us that we had barely scratched the surface. Future expeditions to the same or similar areas will probably continue to uncover exciting finds of fossil vertebrates for years to come. In many ways the 1970–71 season in Antarctica marks a major step forward in our knowledge of its ancient vertebrate faunas, because while we were excavating our fossil fishes in Southern Victoria Land another expedition, consisting of American geologists and a South African vertebrate palaeontologist, was making even more startling finds in the area around the Beardmore Glacier within a few hundred miles of the South Pole. These scientists have discovered numerous complete skeletons of amphibians and reptiles in rocks of Triassic age, deposited about 200 million years ago. These animals include advanced mammal-like reptiles, forms similar to *Lystrosaurus* and *Thrinaxodon*, which have long been known from sediments of similar age in South Africa and elsewhere, conclusive proof that Antarctica has not always been as isolated as it is today.

It is a fitting coincidence that Dr Peter Barrett, leader of our very successful fish-hunting expedition, VUWAE 15, should also have been the scientist who discovered a solitary scrap of bone from a Triassic amphibian jaw in 1967 and thus set off the present extremely successful search for ancient land animals of Antarctica!

FURTHER READING

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BOOK REVIEW

THE INSECTS OF AUSTRALIA, edited by I. M. Mackerras. Melbourne University Press, 1970. 1,029 pages. $19.80.

This is the first important general work on Australian insects since the publication of *Insects of Australia and New Zealand*, by R. J. Tillyard, in 1916. Since then, there has been a 45 per cent increase in the number of known species in this country, and both their classification and their relationships are much better understood.

This new volume embodies the combined talents of thirty authorities on different aspects of entomology, assembled together by the editor, Dr I. M. Mackerras.

The first nine chapters (203 pages) present a general introduction to entomology, designed as essential background material for the chapters that follow. The major part of the book (28 chapters, 826 pages) deals systematically with the orders of insects, and includes workable keys enabling placement, at least to families, of all Australian insects. The value of both parts is greatly enhanced by the magnificent illustrations which are nearly all original (704 blocks in the text and nine coloured plates).

The book is intended primarily as a text book, and is essential for all serious students of Australian insects, but it provides a wealth of information for the keen naturalist. Chapter 5, on general biology, and the section "Biology" for each order are particularly valuable in this respect.

Although most of our knowledge of fossil insects comes from the Northern Hemisphere, chapter 8 includes an up-to-date synopsis of the Australian fossil record and should stimulate "rock hounds" to search for further evidence of the insect fauna of past ages.

Careful reading of the chapters on orders reveals the enormous gaps in our knowledge of some groups, particularly concerning biology, and amateur entomologists might be encouraged to observe life-cycles, host plants, nesting places, etc., and so contribute greatly to our understanding of the fauna.

The book is far too big to be used in any sense as a field guide, but at $19.80 is wonderful value for money and should be on the reference shelf of all keen naturalists.—*Elizabeth M. Exley, Senior Lecturer, Entomology Department, University of Queensland.*

Macquarie University students take a tea break from their ecology course at Myall Lakes. As part of the course, they spent several days studying the heath vegetation there. All three universities in Sydney use Myall Lakes as a classroom. [Photo: Author.]

The Myall Lakes: Tomorrow

By HARRY F. RECHER
Head of the Department of Environmental Studies, Australian Museum

IN the last issue of *Australian Natural History* we took a brief look at what Myall Lakes is like today. In that article Myall Lakes was shown to be an area of great natural beauty and one rich in wildlife which had scarcely changed from the days when A. J. Marshall first visited the region in the early 1930's. But I also hinted at the great and rapid changes taking place, of development, of mining, and of National Park proposals. I asked whether a National Park was necessary, and, if so, how big it should be.

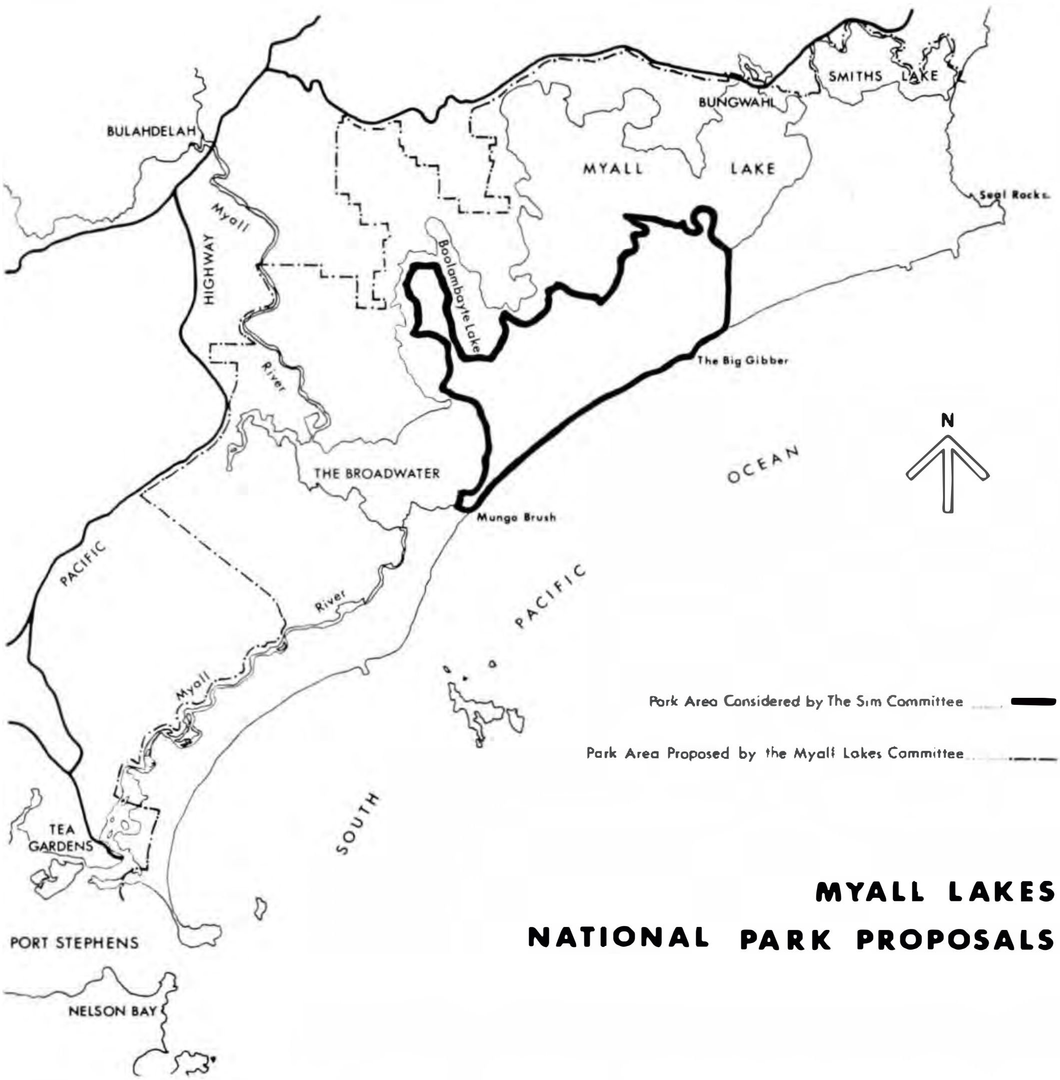
In this article I would like to look into the future and see what Myall Lakes might be like tomorrow. Should the Myall Lakes area be developed? Or is it in the best interests of the country to leave it, as a National Park, in an undisturbed condition? What would our great-grandchildren want? This last is a tough one to answer. We can't account for changes in culture nor can we predict the resource needs of an unknown technology, but we must try to remember that there *is* a future.

The conflict

Currently there are many plans for the use and development of Myall Lakes. Probably this article is a eulogy of Myall Lakes. There is little time left for planning, and less to research the consequences of exploitation. Myall Lakes will probably be one of the tragedies of the 70's, but we should know its story so that we can plan more rationally for the use of other lands.

Many residents of the Myall Lakes area and the Stroud Shire Council would like to see the region developed. To them development means homes, industry, jobs, schools, roads, and hospitals. There is talk of a tourist highway between Tea Gardens and Forster, running between the lakes and the ocean front. According to some residents, this would permit everyone to enjoy the area, and not just hardy bushwalkers. Other residents envision a great city with industries and a population of 1 million. These people do not want a National Park. To them a park is a loss of opportunity—a loss of the opportunity to enjoy the material benefit of an affluent Australia.

The beach sand mining companies would like to go ahead with their mining operations. Their interest in the area is limited. In 20 years they will have completed their mining



MYALL LAKES NATIONAL PARK PROPOSALS

This map of Myall Lakes shows the park proposals of the Sim Committee and the Myall Lakes Committee. The proposal made in this article would extend the park to the west of the Pacific Highway and north of the Bungwahl Road. [Map modified from a Myall Lakes Committee publication.]

operations and departed. The industry puts up a strong case in its favour. There is more than 50 million dollars worth of mineral in the ground at Myall Lakes. Extracted, it will contribute to Australia's overseas balance of trade. For the duration of the mining operation, the industry provides jobs, pays taxes which help support public services, and assists in preparing the region for more intensive and longer-term development. Furthermore, the companies make a sincere and conscientious effort to restore the area after mining. The sands are returned as close to their original contours as possible and, where necessary, they are stabilized with brush and plants. Restored in this manner, the mined area is as suitable for the recreation demands of the vast majority of people as it was before mining.

But conservationists and scientists have not been so easy to please. These groups accept the fact that beach sand mining is in the national interest, but they also feel that it is in the national interest to leave adequate representative samples of the coast in a state unaffected by mining. Myall Lakes is one of the areas they would like to have reserved free of the effect of mining. They contend that the miners cannot restore a mined area to its original condition. The extremely fine dependency of coastal vegetation on subtle environmental factors, as shown by the plants growing on the ridges of the inner barrier system at Myall Lakes, is an example of the kinds of conditions miners could not hope to duplicate. Furthermore, the scientists point out that the extent of mining damage is not restricted to the actual mined area (which may be quite small), but includes ecological effects brought about by road building, drainage channels, and the deliberate or inadvertent introduction of exotic plants. The removal of protecting vegetation and dunes can have fatal effects on vegetation well away from the mining operation by exposing it to wind-carried sea-spray.

This last point may have serious ecological consequences at Myall Lakes. The large dunes near the coast there protect the moorland from coastal winds and salt-spray. This dune area is currently held under mining leases, and presumably will be mined. The clearing of vegetation and the lowering of the dunes by mining will expose the moorland to salt-spray. The consequences of this action cannot be predicted. Nor, with our knowledge of dune stabilization by native vegetation and the current dryness of the climate, can we be certain that the mining companies will be able to stabilize these very high dunes. Before the salt-spray ever affects the moorland, it could be covered by sand. We don't know for certain, but we should have some idea of the consequences of our actions before they are irreparable. We may lose not only the beauty of the high dunes with their forests of *Angophora* and blackbutts, but we may lose important natural areas which, though not mined directly, may be affected by salt-spray and altered patterns of drainage.

The Myall Lakes National Park

Myall Lakes contains good and relatively undisturbed samples of the landforms and habitats which are characteristic of the North Coast of New South Wales. Because of this, the area has been the object of numerous park proposals and is the cornerstone of the parks and reserves system proposed on the North Coast of New South Wales by the National Parks and Wildlife Service. As an indication of its importance, it is the first area on the New South Wales coast outside the Sydney metropolitan region to be approved for National Park status by the State Cabinet. In January 1970, the State Cabinet approved a National Park at Myall Lakes.

The land portion of the park approved lies between the ocean and the east shore of the lakes, and extends from Mungo Brush to just past the Big Gibber (see map). The size of the park (13,000 acres) and its location are essentially the same as those recommended by the Sim Committee in 1968, the National Parks Association in 1961, and the Australian Academy of Sciences. Despite some recent additions of land, it is inadequate. It is too small to provide for the recreation demands which will be placed upon it by the 1 million people who are expected to be living in the nearby Newcastle–Port Stephens area by the year 2000. For example, it is less than half the size of the Royal National Park near Sydney. Royal is one of many parks near Sydney, yet it receives over 2 million visitors per year! This is an impact which is slowly degrading the park. Clearly, the Royal National Park is too small for the use it

Members of a fishing fraternity which makes its headquarters in a picturesque squatters' community at Yagon's Gibber, between The Big Gibber and Seal Rocks. Management plans for Myall Lakes National Park should ensure the survival of this community, which is a most interesting part of the history of the coast. [Photo: Author.]

receives. What use will a National Park at the Myall Lakes receive? After all, it is the *only* National Park proposed for the Newcastle–Port Stephens metropolitan complex. It is also certainly too small for the ecological requirements of many coastal animals, it does not include some of the most interesting (and beautiful) habitats at Myall Lakes, and it does not encompass the lakes themselves. Moreover, beach sand mining will be permitted within the park for 20 years after its formal dedication by Parliament. Such a park will not and cannot retain the character, beauty, and wildlife of the coast as it is today.

The more people we expect in Australia tomorrow, the greater the number and the larger the parks we must reserve today. America failed to do this, and her park system is currently weak in terms of scientific, genetic, and broad conservation values. It is inadequate for recreation demands. In part, this is a distribution problem. The northeast U.S.A. has less than 3 per cent of the reserved parklands, but 24 per cent of the population. Many eastern and heartland environments are not even represented in the system. None of the vast American prairie was ever reserved in its natural state. Hence, current programmes on grassland management and conservation have no datum line for comparison. The United States is finding this an expensive and difficult problem to correct.

In Australia we can expect our greatest population densities to develop along the eastern coast—precisely where they are today. The United Nations suggests that 5 per cent of a nation be reserved as parks and nature reserves. I am not sure how they arrived at that figure, but guidelines of this sort are misleading and can only cause planning difficulties. The amount of land which should be set aside depends upon population size and the state of a nation's technology. Australia, whose population is small but has a great impact on the land, needs to reserve much more of its land than a country with many more people, but where the people are tied to their cities and villages by poverty.

Certainly the greatest amount of land for parks and reserves in Australia needs to be set aside on the coast. This is where people live and where they will seek recreation.

This is where the natural environment will be most affected by expanding towns and industry. But this is also where progress in setting aside parklands is the slowest. It is slow because of the conflicting demands for scarce coastal lands—slowness which is tacit permission for short-term commercial exploitation to proceed.

We have many choices at Myall Lakes. We can continue to permit unplanned development and be content with a small National Park. Or we can reconsider and treat the Myall Lakes as part of the growing Newcastle–Port Stephens complex, in which case its greatest use is as a recreation and conservation area. If we accept this, then we must decide what kind of park we should have and what size it should be. There are three levels of choice.

These dunes near The Big Gibber were ravaged by fire 11 months before this photo was taken. As can be seen, there has since been excellent regrowth of native plants, including a spectacular bloom of Flannel Flowers, the white flowers in the foreground. [Photo: Author.]

Three alternative park proposals

In January 1968, the Sim Committee submitted to the Hon. T. L. Lewis, M.L.A., Minister for Lands, a report which, among other things, recommended that a National Park of 13,200 acres be established at Myall Lakes. This would include a 3,000-acre "scientific area" within which mining and prospecting for minerals would not be permitted. Mining would be allowed elsewhere in the proposed park. The park approved by Cabinet in 1970 is based on these recommendations.

The Sim Committee was established in 1965 by Mr Lewis, who was then Minister for Lands and Minister for Mines, to inquire into the conflict between the beach mining industry and conservationists on the North Coast and to propose ways in which these conflicts could be resolved. Unfortunately, the committee only considered areas which had been proposed previously for parks and nature reserves by a variety of conservation organizations. Some of these proposals were made at a time when Australia had a much smaller population and when few people would have predicted the magnitude of growth and development seen in the 1960's. Except in a most limited way, the committee did not investigate the ecology of the areas concerned. Nor could it, by the nature of its charter, consider its proposals with respect to any forms of land use other than beach mining and conservation. It was also restricted to dealing with Crown lands. With these severe limitations, the committee did the best job it could, but, not surprisingly, its recommendations have satisfied no one outside the beach mining industry.

A private study by the Myall Lakes Committee has since called for a park of 96,000 acres at Myall Lakes. This would include some offshore islands, the entire Myall Lakes system, and 30 miles of ocean frontage between Hawks Nest and Seal Rocks. Mining would not be permitted. The area would be retained in its current state, but provision is made in their plan for *all forms* of outdoor recreation. This is an important point. Many persons have got the erroneous impression that a National Park at Myall Lakes will be a wild area, accessible only to a hardy few outdoorsmen and adventurous scientists. In reality, the proposal put forward by the Myall Lakes

Committee is an extremely well-balanced and thought-out plan of management which will provide for effective conservation and yet allow for a maximum diversity of recreational opportunities. In contrast, the current unplanned development of Myall Lakes is rapidly leading to reduction in the quality of the environment and a *loss, not a gain*, in recreational opportunities.

Both the Sim Committee and the Myall Lakes Committee sought scientific advice before making their proposals. However, advice is not a substitute for on-the-spot investigation. We do not really know what size park we must have at Myall Lakes to have a viable ecological system.

The best way to visualize and plan the size of individual reserves is to consider them as islands. Given the continuing increase in Australia's population and technological development, parks and reserves *will* be islands in an urban sea. The fauna and flora of an island are usually a sample of the wildlife from the nearest mainland. The smaller the island, the fewer the organisms which it can support. Large islands have more kinds of organisms because they normally have a greater diversity of habitats and because their large size permits the growth of proportionately larger populations. The larger the population of an organism, the less it is subject to random extinction. We can expect our "islands" parks and reserves to be much like real islands. Though a small park may initially support a diversity of organisms much greater than a similar sized island, that diversity will gradually decrease until it approximates that of the island. To retain maximum diversity we require large "islands".

I personally think that to be completely adequate—to be ecologically viable and to meet the recreation pressure of the people of New South Wales in the year 2000—the park at Myall Lakes should encompass not only the area proposed by the Myall Lakes Committee, but should take in the entire watershed of the Myall River. This could be done by a combination of National Park, State Forest, and permanent zoning regulations which would retain the rural character of the region.

I am talking of a recreation and conservation complex of at least 250,000 acres. There are many orders of magnitude difference between this proposal, the recommendations of the Myall Lakes Committee, and those of the Sim Committee. They are differences which cannot be resolved by discussions around a conference table. Field studies are needed and it is necessary to consider all aspects of land use. It is necessary to know how many Australians will be wanting to use the area 100 and 200 years from now.

These things can be done, but they take time, and perhaps they require discussion on a national level under Commonwealth supervision. The greatest compromise that could be reached would be an agreement to suspend mining and development in the Myall Lakes until the necessary studies have been completed. A small matter of 5 to 10 years. The consequences of our decisions are forever.

FURTHER READING

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BOOK REVIEW

AUSTRALIAN ALPINE LIFE, by John Child. Periwinkle Colour Series, Lansdowne Press, Melbourne, 1970. 112 pages. $1.25.

John Child's *Australian Alpine Life* discusses the origin and structure of alpine habitats, followed by notes and descriptions of the common plants and animals of the region. It is a well-written and well-researched book, although it occasionally ignores some recent studies. Important illustrations are localized and the index is fairly adequate, but some misleading juxtapositioning has been made: for example, the only two members of the frog family Hylidae mentioned are inserted between descriptions of leptodactylid frogs, under the latters' family heading. This book should go a long way toward fulfilling its author's hopes—that it will provide a stimulating introduction to the life of Australia's alpine regions, and, in so doing, foster public enthusiasm for the conservation of these regions.—*H. G. Cogger, Australian Museum*

Botany Bay, looking west, with Bare Island and Congwong Bay in the foreground. [Photo: Author.]

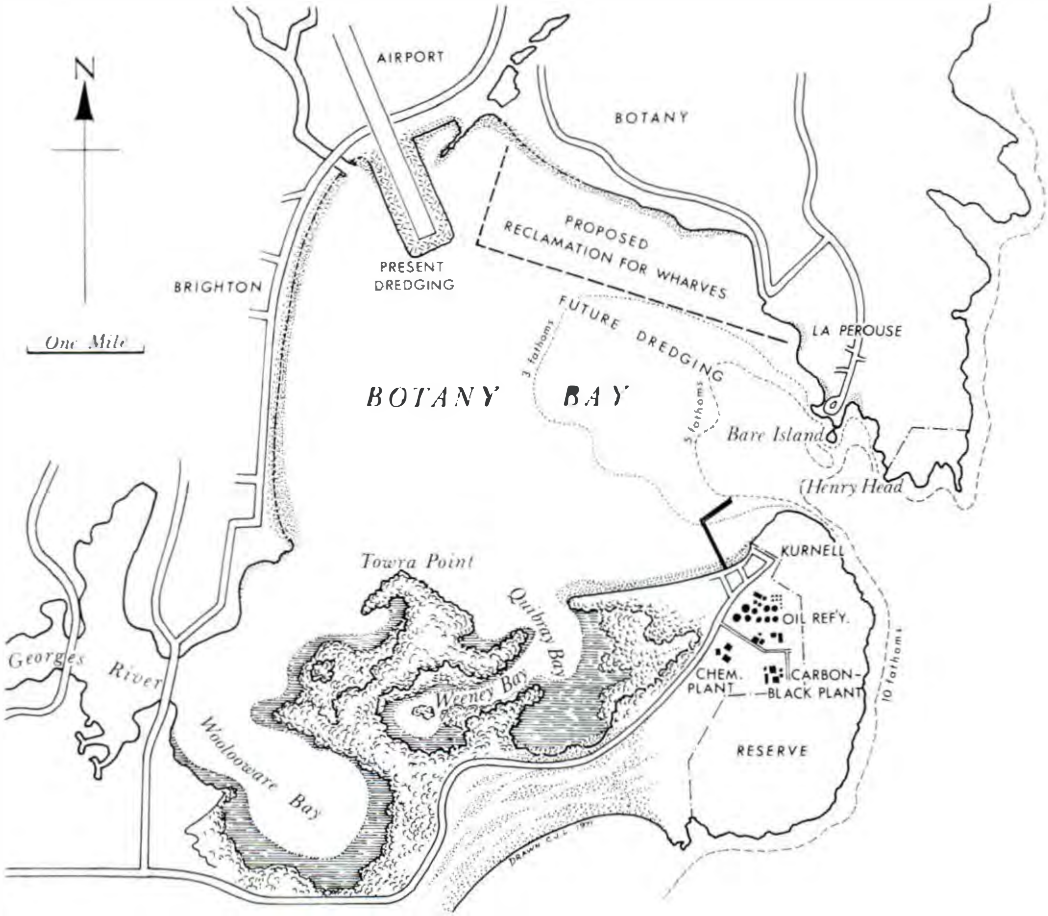
LAMENT FOR BOTANY BAY

By C. J. LAWLER
Secretary of the Underwater Research Group of New South Wales

Mascot Airport's multi-million-dollar runway extensions are rapidly changing the face of Botany Bay—Sydney newspaper.

MANY Sydneysiders do not think too highly of Botany Bay. Mostly, they imagine it as just a wide, sandy bay, bounded almost all around by long narrow beaches. It is thought of as being shallow, treacherous in a storm, and just about raked clear of fish by trawlers. There is no "Bondi" surf along the quiet beaches, and the water seems to be getting browner and browner. The colour of the water is no fault of the bay's, but is rather the result of heavy pollution from two rivers, the Georges and the Cooks. The latter could be better described as a concrete-banked, stormwater canal or, to be really accurate, an open sewer. Both of these rivers are pouring an ever-increasing volume of silt and industrial waste into the quiet waters of the bay. It is for these reasons that the decision to reclaim large areas of the bay for airport extensions and a wharf complex did not give many people much cause for concern.

But this is not the whole picture. The divers of our Underwater Research Group think of Botany Bay in a totally different way. To us, Botany Bay is the bay in the vicinity of Cook's anchorage off La Perouse; the ocean-washed, outer area which Banks explored so thoroughly; Sting Rays Harbour; the rocky cliffs and headlands at Kurnell; the deep bays and promontories along the northern shore; fort-crowned Bare Island and the adjacent bomborah—islands both, but one above and one beneath the sea. The seabed around these areas is rugged, broken, and typified by submerged cliffs and ledges. The water is relatively clear and deep, some parts near the bomborah being over 80 feet deep.



Botany Bay. [Map by the author.]

Then, too, there are the mangroves along the southern shore. The quiet tidal flats at Quibray Bay and Weeney Bay. Acres of mangroves and wetlands that are the nursery areas for countless fish and crustaceans—haunts of seabirds and wading birds that rest and feed here, finding a sanctuary in the trackless mangroves not 10 miles from Sydney's centre.

This is our Botany Bay. Look at a map and you will see that it is nearly half of the whole of Botany Bay. And into this half is packed a profuse and varied array of creatures, from soaring migratory birds to tiny shells creeping across the seabed. There are many species of life, which, if not completely absent from other parts of our Sydney seashores, are by no means common.

Fantastic gardens

Growing on the deep, scattered boulders below Henry Head are fantastic gardens of sponges and sea fans. On some rocks, every square inch of available space is packed with sponges, clumps of coral, ascidians, and bryozoans. This scene is repeated with variations on the other side of the bay, along the Kurnell shore. There the groves of sponges are interspersed with sheets of stony coral and clusters of tunicates.

Around Bare Island there is more variation in the fauna. As well as the inevitable sponges, there are at least two species of soft coral, six species of stony coral, gorgonians, and a great variety of simple and compound ascidians. Living amongst these sessile growths is a fantastic array of mobile creatures. There are tiny purple cowrys which we can find nowhere else in Sydney but on a soft coral that grows along the eastern face of Bare Island. Along the western side of the island there are deep caves. These are the meeting place of numerous Port Jackson Sharks which move into these waters during early spring. The caves are festooned with beautiful orange soft corals, a species rare around Sydney. Another cave on the eastern side is floored with yard-wide sheets of plate coral. In many smaller holes and crevices tiny Banded Coral Shrimps can be seen, waving their long white antennae to attract fish, which they groom and clean. It is in nearby Congwong Bay that some of the first observations of these tropical shrimps were made in Sydney.

Waters fouled

But I have been writing as if all of these animals were still growing and thriving in Botany Bay. Perhaps, more aptly, I should have been using the words "was" and "were". During the last 6 months the once clear waters around the entrance to the bay have become fouled with ton upon ton of brown silt and mud—dredged-up muck that is coming by barge from the airport extension and is being dumped right in the entrance to the bay opposite Bare Island. Great billowing whirlpools of brown mud are swirling around the island and into all the bays near the entrance. What a picture it makes from the air—great discoloured masses of water sweeping in and out of the bay with the tides, flowing around Bare Island, washing the shores of Kurnell, coming out of the bay and fouling the water miles to the south.

Reluctantly we had to remove all these areas from our diving calendar. It is almost impossible to dive and explore in such turbid water, where the visibility at times is measured in inches. Nevertheless, we ached to see what was happening to the fauna, and on several occasions visited Bare Island hoping to find the conditions good enough to dive in. We didn't.

Visiting scientist dismayed

Then, in December 1970, a Japanese scientist, Dr Masashi Yamaguchi, arrived in Sydney hoping to see some of our temperate corals. Unfortunately, there is nowhere else in Sydney that we know of other than Bare Island where both the shallow-water coral *Plesiastria urvillei* and the usually deeper-living *Coscinaraea mcneilli* occur in close proximity. There were also, in the vicinity, two other corals, *Balanophyllia* and *Astrangia*, the former being not particularly common in shallow water, either. Add to this the fact that the area where all these corals were to be found, La Perouse Point, was easily reached and divable in almost any weather conditions. There was only one thing wrong—the water itself.

Underwater Research Group diver Neville Coleman explores and photographs the sea bed off Bare Island. Surrounded by many sponge colonies is a large Magnificent Volute (*Cymbiolena magnifica*). [Photo: W. Deas.]

This would be the test, then. We would have to dive in the filth, find the corals, and, incidentally, see how they had fared during their 6 months in the muck. The morning we arrived at Bare Island was a typical one, typical of the previous 6 months, that is. Yellow-brown water lapped over our fins as we stood on the edge of the shore. The wavelets were creamy-brown and it was impossible to see our feet in knee-deep water. Dr Yamaguchi was rather dismayed at the liquid mud I proposed diving into. Not being particularly experienced with scuba equipment, he decided to wait on shore. I would be accompanied by Ken O'Gower, Associate Professor of Biological Sciences at the University of New South Wales, who was used to diving in sewage-fouled water off Bondi studying Port Jackson Sharks. I felt sure I could guide him to the coral, even in zero visibility.

The first 20 feet was almost impossible; only by feeling our way down through the *Ecklonia* kelp holdfasts could we keep any sort of orientation. Luckily, below this depth the water was a little clearer and we could see for about 6 feet or so. We were suffused in a pale-brown glow, so different from the usual green or blue tinge associated with ocean water. In these "sparkling" conditions we soon found our coral—the whitened skeletons of the coral, that is. Some colonies were at least 50 per cent dead, others only about 20 per cent. I would estimate that an average of 25 per cent of each colony of *Coscinaraea mcneilli* we saw was dead. All the corals were covered with a deposition of fine silt, probably the smothering agent. If, in 6 months, a third of the coral at La Perouse Point is dead, can we assume that, at the same rate of fouling. one more year will see it all dead?

"Terrible picture"

This terrible picture stirred us to investigate further. The water remained dirty, but we decided to see for ourselves what effects the pollution was having around Bare Island itself. Conditions should be a little better, as the island is closer to the influence of the ocean and more easily scoured by tidal action. By late February the dredging had slackened and the colour of the water around the island looked reasonable—from the surface.

During the first week of March 1971, we dived right around the steep, cliff-like edge of the submerged rock shelf on the eastern side of Bare Island. Visibility below the surface was about 6 feet. This was far below what we would normally expect; the average visibility a year ago in this area would have been about 25 feet. Consequently, at a depth of 35 feet the level of illumination was very much reduced. I would estimate it at equivalent to that at a depth of 100 feet of water in normally dirty conditions—i.e., visibility less than 20 feet. What effect this would have on light-dependant species is not difficult to imagine.

In this area most of the animals are growing well clear of the bottom, on boulders or up on the cliff face itself. They appeared to be little affected by the pollution so far, except

An underwater photo of a Banded Coral Shrimp (*Stenopus hispidus*). These shrimps are found in crevices and holes around the shores of outer Botany Bay. [Photo: W. Deas.]

that most of them were covered with what we divers think of as dust. At the limit of our dive we came to the large cave with the spectacular sheets of plate coral, a feature of the area. These plates are growing at a steep angle and are at least 5 feet above the sea-bed. This has effectively kept them clear of the fine silt that is so quickly killing the same species at La Perouse Point. Not so another large plate coral, growing some yards away, close against the base of the cliff and in a horizontal plane. This coral had a dead, bleached margin about an inch wide right around the edge of the colony, where drifts of silt had actually covered the colony.

In the same murky conditions we had a brief look at a similar cliff formation that runs up into Congwong Bay. There is less tidal scour here, and we could definitely see an increase in the fine silt cover on all sessile animals. One small cave had well over 5 inches of very fine silt on its floor, covering colonies of sponges and small clumps of *Astrangia* coral.

There are other areas that we have not been able to visit, simply because the water is too dirty. With our landmarks and routes obscured, it would be difficult to find our way to some of the more outlying reefs, with their gardens of sponges and soft corals, many of them growing in a vulnerable position close to the sea-bed.

What of the future?

This is the position at present, after only 6 months of relatively minor dredging. What will happen when reclamation and port dredging commence? How will these unique areas look, after several years' "rain" of mud and sediment? And when Botany Bay becomes a port will it all become as Darling Harbour and Walsh Bay, black cesspools of accumulated oil, grease, excrement, and waste? The oil-spills around the tanker terminal at Kurnell will be nothing compared to the wastes from a million tons of shipping.

We will have at last completed the rape of the few remaining virgin areas close to Sydney. The shores of Botany Bay have already been drastically destroyed and changed in our 200-year occupation. Gone are the forests and birds of Kurnell Peninsula, leaving barren sand-dunes in their place. The sand-dunes themselves are now disappearing into the maws of a thousand trucks. Gone are the sand-flats along the Botany shore, where great flocks of migrating birds stopped on their thousand-mile journeys. Gone are the great white gums at La Perouse, against which Bare Island used to stand out treeless before the forested headlands.

Now we destroy the only parts that have remained inviolate since Cook's day and a thousand years before that. The sponges and corals and all the rest were probably growing there when Rome was a village. Those very plates of coral we looked at would have been big when men were first setting out for the South Seas. Now they are all due for the slow choke on civilization's excrement. So passes Botany Bay.

FURTHER READING

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"Pair Association in the Banded Coral Shrimp", by J. C. Yaldwyn, *Australian Natural History*, Vol. 14, No. 9, March 1964.

"The Bird Habitats of Botany Bay", by Arnold R. McGill, *Australian Museum Magazine*, Vol. 13, No. 6, June 1960.

BOOK REVIEW

THE DARK AUSTRALIANS, by Douglass Baglin and David R. Moore. Australia and New Zealand Book Co. Pty Ltd, Sydney, 1970. 136 pages, including 226 plates, many in colour. $12.50.

This is a delightful book, a credit to authors and publishers alike: dust-jacket, cloth cover, end-papers, type-face, size of page (about 9 inches x 11 inches), layout of contents, and the excellent plates of both colour and black and white photos taken by Douglass Baglin, all contribute to the very high quality of the production.

Even more important is the impression made by the obvious co-operation of, or rather the duo-composition by, photographer and writer. It is not a case of finding illustrations for a story, nor of getting a text to go with a series of photographs. Text and photographs are part of a single harmonious composition. The pictures take up most of the relevant space, about 104 pages, while the running text totals about 15 pages (about 7,500 words). But the latter, by David Moore, must be read with the pictures and their captions, and the pictures studied as part of the text.

The plan of the text is very appropriate for this type of book with a popular appeal. The context is set by an introduction to Aboriginal mythology and beliefs, related by word and picture to the country itself; only then follows the past and the old or traditional life, to be concluded by (i) an account of Aborigines' experience of contact and discrimination, and (ii) by an appeal for "the future that must be". Mr Moore has done the difficult task of providing in 7,500 words the textual theme of the composition. This brevity has involved generalizing, which does lead, perhaps inevitably, to some bald assertions, but this does not detract from the over-all impression of art, involvement, and sincerity. *The Dark Australians* is a good book.—*A. P. Elkin, The University of Sydney.*

The city of Sydney seen dimly, in the background, through an early-afternoon smog. [Photo: C. V. Turner.]

OUR AIR

By EDWARD LINACRE
Associate Professor of Climatology, Macquarie University, Sydney

WE cannot really talk about "our air" as though it belongs to us, in the sense that we may do with it what we like. We can only borrow it—for breathing and combustion—and benefit from its effects, as wind, on rainfall, windmills, and so on. It remains afterwards. We do not destroy the air, we simply change it, usually leaving it grubbier than we found it.

Man is not entirely responsible for the material in the atmosphere. Dust lifted up by the wind (maybe increased by man's disturbance of the ground-cover by agriculture), salt-spray blown from the shore, smoke from bushfires started by lightning, plant pollen, volcanic eruptions—these form the background to man's influence on the air's cleanliness. In the past these natural processes leading to dust in the air have been matched by the natural cleansing of gravitational fall-out and the rinsing effect of rain. Unfortunately, such remedial processes do not immediately offset rapid increases of pollution, which therefore lead to locally high values of pollution concentration.

Three scales of air pollution

At this point it is worth distinguishing the scales of pollution. We are obviously discussing different things when considering the airborne particles in the lungs of a cigarette smoker, the turbidity of the air over Sydney, and the gradually increasing dirtiness of the atmosphere of the entire world. Thus there are three scales of air pollution—personal, regional, and global. In each of them, it is the concentration that matters, not the total amount. What one smoker produces is trivial in quantity, but is concentrated into a relatively small volume of air that he breathes, so the concentration is high at the point where he is sensitive. The same applies to a factory in a valley.

The table (after Lave and Seskin) at the end of this article shows the interaction of personal and regional pollution in terms of the incidence of lung cancer, and the literature on the effects of personal pollution is extensive. For the rest of this article, attention will be focussed on regional pollution, with some remarks on global pollution at the end.

In regional pollution we are concerned partly with solid particles of dust, and liquid droplets from sprays or condensed vapours, or water droplets containing dissolved contaminants. For instance, sulphur dioxide created by burning sulphurous fuels will dissolve in rain to form drops of weak acid. Solid and liquid of a size so small that they never settle out of the air are known as aerosols. The air also contains gaseous pollution.

Once again one has to remember the natural context. Enormous amounts of methane are evolved by the world's swamps, carbon dioxide from the oxidation of peat and from bush fires, hydrocarbon volatiles from plants. However, these are so widespread that their effect on the concentration anywhere is slight, whereas the congregation of man's activity into cities appreciably affects the regional climate there.

It is convenient to simplify discussion of urban air pollution by considering two extreme examples—London and Los Angeles. Roughly speaking, London's pollution is mainly solid dirt, or was until recently, while Los Angeles is the exemplar of gas pollution. Here we define pollution, according to the Los Angeles regulations, as air contaminants which cause "injury, detriment, nuisance or annoyance", or which endanger the "comfort, repose, health or safety" of any considerable number of people.

London's disastrous fog

The potency of London's pollution was strikingly demonstrated in 1952 when a four-day fog, precipitated and acidified by chimney smoke, killed several thousand people and damaged the health of countless more. As a consequence, legislation prohibiting the use of smoky fuels in London was introduced in 1956; it has reduced dust-deposition rates by 40 per cent in 8 years, dramatically improved the city's appearance, noticeably increased the amount of sunshine reaching the ground, and halved the frequency of fogs. This is certain to reduce deaths due to respiratory weakness: in a comparison of the variations of bronchitis deaths in Britain in 53 different boroughs, Lave and Seskin found that 39 per cent of the variation of mortality rates was associated with the differences of dust deposition. In addition, less dust in the air improves visibility: when the dust deposition rate at Columbus (Ohio), U.S.A., was lowered from 35 to 22 tons per mile^2 per month, the distance of clear visibility increased from 4·3 to become 6·2 miles.

In parts of Wollongong, New South Wales, the deposition rates are still 70 tons per mile^2 per month (compared with 3 in rural areas and 87 in Tokyo), but the rates in N.S.W. generally are decreasing, e.g., from 22 in 1954 to 15 in 1967 in Sydney despite a great increase of annual fuel consumption. This greater consumption doubled the sulphur dioxide content of the air in Sydney. But the solid-particle pollution of the air is being steadily reduced as the result of enforcement of the 1961 Clean Air Act, and the expensive installation of improved flue-gas cleaning equipment.

The high cost of remedying this kind of air pollution when due to industry raises the question of who pays. In U.S.A. it is reckoned that the average cost of pollution is $50 a year for each member of the public. In Australia the increase of the height of a chimney to reduce ground-level pollution concentrations may cost an industrialist $700 per foot, and the gas cleaning equipment at the Hazelwood power station cost $9 million. So payment is made either by the *local* public in pollution costs, or by the *widespread* customers of industries whose production costs are raised by anti-pollution measures. A compromise reached in U.S.A. is for the general community to subsidize industry waste-treatment installations.

As regards pollution by sulphur dioxide. Australia is a lucky country in having solid. oil, and gas fuels available with sulphur contents of less than 1 per cent, whereas Middle East oil may contain 6 per cent. This decade, Australia should be almost independent of fuel imports. The concentrations of sulphur dioxide in Sydney are typically only 0·02 ppm (parts per million), whereas in New York they can be 0·24 ppm, and in London were up to 1·34 ppm during the 1952 disaster.

The problems of Los Angeles are less easily solved, as they arise from the combination of two factors—the affluence which leads to numerous cars, and the local meteorological conditions. Chimneys are less important than in London because Los Angeles is warmer, being at a lower latitude—about that of Sydney. The air is not as damp, so wet fogs are less likely. Instead, there is smog due primarily to car exhausts.

Car exhausts

The undesirable gases in car exhausts are carbon monoxide, nitrogen oxides and unburnt hydrocarbons. There are also poisonous fumes from the lead added to petrol to increase the octane rating. Similar gases are discharged by airplane exhausts, but are probably negligible except in the stratosphere, where the air's stability may allow gradual accumulation. The fumes from the sixteen active airports at Los Angeles account for only 1·6 per cent of the total air pollution there. Diesel engines produce less gaseous pollution, even though maladjusted engines may emit a smelly smoke.

Carbon monoxide

Exhaust gases of cars contain up to 10 per cent of carbon monoxide, due to incomplete combustion. The amount might be reduced by an exhaust manifold air injection, catalytic devices on the exhaust pipe, proper carburettor setting, water injection, preheat of air into the carburettor, or the use of liquid propane as the fuel. Even a more rapid traffic flow slightly reduces the carbon monoxide production, as the engines work more efficiently. It seems probable that a worthwhile reduction will come from the present activity in Detroit and elsewhere to reduce the pollution from each car, at least as regards the monoxide and hydrocarbon. But this may well be offset by the increase in the number of cars. Complementary ways of reducing urban pollution by cars would be urban decentralization, the development of electric or steam cars, even higher city-parking tolls, and better public transport.

Carbon monoxide is noxious. It induces dizziness at levels of 100 parts per million, only just above that which has occasionally been measured in Sydney's streets. It also affects the lungs and visual acuity, and makes heart attacks fatal.

The nitrogen oxide reacts with the hydrocarbons in the presence of the ultraviolet light in bright sunlight to form PAN (i.e., peroxyl-acetyl nitrate) and ozone, which latter is poisonous, being highly oxidizing. The lung tissues and blood are damaged: in California the death rate from emphysema quadrupled during 1950–57. It is reckoned that the maximum amount of ozone acceptable for 8 hours a day is 0·1 ppm, and a warning is issued at Los Angeles if the ozone level exceeds 0·5 ppm, the daily maximum there commonly reaching 0·4 ppm. The figure for Sydney is only 0·03 ppm, but measurements in Melbourne have shown up to 0·1 ppm. The polluted air affects plants.

The effect of the hydrocarbon emission and the photochemically-formed PAN is to produce the brown haze, a miasma which covers Los Angeles like a pall, affecting eyes and lungs and making it necessary for aircraft to land by instruments, even on the clearest day. About two-thirds of Los Angeles people suffer from eye irritation.

The smog of Los Angeles was first a matter of public concern in 1945. Since 1966 there has been legal control of automobile exhaust gases, which has reduced the emission of unburnt petrol by about a third. The American car manufacturers hope that by 1975 they will have lowered the concentrations of exhaust-gas hydrocarbons from the 900 ppm of an uncontrolled car to 50 ppm, 3·5 per cent carbon monoxides to 0·5 per cent, and 1500 ppm of nitrogen oxides to 250 ppm. In the meantime, and almost certainly thereafter, at Los Angeles at least, it is necessary to operate an elaborate pollution warning system, with graded alerts. On the first alert, open fires are totally prohibited, the public are urged to pool their transport, and so on. If forecast concentrations reach the levels justifying the third alert (e.g., 0·03 per cent of carbon monoxide), then the State Governor declares an emergency and industries may be shut down.

Position in Sydney

The position in Sydney is not yet so bad, as the number of cars in Sydney is less than half of Los Angeles' 3·5 million, and the cars have much smaller engines. But the growth of Sydney's population and affluence means more and bigger cars, and a Los Angeles situation is forecast within one or two decades. Already there is an obvious pollution cloud over the city on many weekday mornings after a clear night; recent experiments on the tracking of low-level balloons over Sydney were spoilt by losing sight of them in the haze. The current setting up of a State Pollution Control Commission is greatly to be welcomed.

It was mentioned that Los Angeles' problem is twofold, and that the second factor is the meteorology there. This cannot be altered in the way that pollution production can be regulated, but it can be allowed for, once the situation is understood. Too late in the growth of Los Angeles it is realized that the region has a tendency to stagnant air in which the pollution simply accumulates. In Sydney we benefit from useful sea-breeze ventilation during the day, and a prevailing offshore wind. Nevertheless, it is still worthwhile to consider what the effects will be of locating future growth inland—i.e., upwind of the main city area. Regional planning should take into account the meteorology as well as topography. Unfortunately, not enough is known about Sydney's regional climate. To help remedy this, a group of research workers at Macquarie University is investigating the region's ventilation characteristics.

On a wider scale, what about the combined effects of the pollution from individual regions on the atmosphere of the globe as a whole? What effects may we expect from the global increase of turbidity (Bryson reports a doubling in 6 years *outside* U.S. cities) and from the increase of carbon dioxide content by several per cent over the last century (Strauss reports an increase of 0·06 ppm per month, i.e., 1 per cent every 5 years). Do these changes relate to the recent temperature increase of about 0·5° C over 60 years? Possibly. As regards the carbon dioxide effect, there are two schools of thought. On the one hand it is suggested that the increased concentration results from the higher oxidation rates of the world's peat bogs, caused by higher temperatures. But this does not *explain* the temperature rise, which more usually is held to result from the man-made carbon dioxide increase. This gas transmits sunlight to the ground but obscures the radiation of the earth's heat to the sky. The opposite, a cooling effect, may be expected to follow from a rise of turbidity, which could increase the atmosphere's reflectivity, so that sunlight is prevented from warming the earth. On the whole, the absence of any marked trend over recent decades, either cooling or warming, may result from a balance at present between the effects of the dust and the carbon dioxide.

In the future the balance may tilt one way or the other, triggering a change of the world's climates towards another Ice Age or a time of great heat (and a melting of the ice caps and, thus, a flooding of our coastal cities). We forget how unstable our climate is: only a few hundred years ago the Thames at London used to freeze in winter. The urgent task is to reduce the creation of pollution as far as possible, and, by an understanding of local meteorology, to reduce the effects of what proves unavoidable.

TABLE

Lung cancer mortality rates (annual deaths per 100,000 population):

	Smokers	Non-smokers
Urban	100	16
Rural	50	5

FURTHER READING

The literature is enormous. The layman would find particularly helpful *The* 1969 *Report of the Australian Senate Select Committee on Air Pollution*, obtainable from Federal Parliament House. Other recommended reviews are:

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ARACHNIDS

By MICHAEL GRAY
Arachnologist, Australian Museum

SOME 60,000 species of spiders, scorpions, whip scorpions, pseudoscorpions, harvestmen, mites, and some other less familiar orders constitute the class Arachnida. Together with their marine relatives, the horseshoe crabs of Asian and American waters, they make up the Chelicerata, a group characterized by the possession of biting jaws or chelicerae, segmentally homologous with the insect antenna and quite distinct from the chewing mandibles of the insects, millipedes, and crustaceans.

Arachnids are probably the oldest of all Recent terrestrial animals, with representatives going back to Silurian times, over 350 million years ago. Typically they are cryptic predators occupying relatively stable niches such as are found in forest litter, under rocks and logs, and in soil. They are common elements in the fauna of tropical and subtropical regions, but are also abundantly represented outside these regions, notably by harvestmen, pseudoscorpions, mites and spiders (see list of arachnid orders on the next page). The very abundant mites and spiders show ecological diversity equivalent to that of the insects and occupy a correspondingly wide range of terrestrial habitats. In addition, they have secondarily invaded the aquatic environment.

Form and function

Arachnids are diverse in form but show a similar basic organization. The anterior cephalothorax (fused head and thorax) is protected above by a smooth, hard carapace and bears the appendages—the biting jaws, the tactile, grasping or leg-like pedipalps, and four pairs of walking legs. The softer abdomen contains the heart, digestive caeca and gonads and lacks appendages in most forms. Exceptions are the scorpions, which have a pair of ventral comb-like pectines of uncertain function (vibration, chemical or soil texture receptors have been suggested), and the spiders with their paired silk-producing spinnerets.

Reduction or loss of abdominal segments is an important specialization. The mites and most spiders have lost all sign of external segmentation, the abdomen forming an extensible sac for food and egg storage. In spiders loss of posterior segments has caused migration of the spinnerets from a mid-ventral to a terminal abdominal position, where their manipulation in silk-weaving is more efficient. Constriction of the first segment of the abdomen to a waist or pedicel characterizes several orders (figures 2, 3, 4). This allows the precise turning and lifting of the abdomen required in such actions as the directing of the defensive abdominal acid spray of the thelyphonid whip scorpions (with a range of up to 3 feet) and of the spinnerets of spiders. The scorpions, with a broadly joined cephalothorax and abdomen, achieve a similar ability to direct the terminal sting by elongation of the last five abdominal segments into a flexible tail (figure 1).

Fig. 1. Scorpion—clawed, grasping pedipalps and flexible tail with terminal sting. [Photo: Howard Hughes.]

Arachnid appendages, particularly the first three pairs (jaws, pedipalps, first legs), have undergone a variety of adaptive changes related to feeding, defence, and reproductive behaviour. The jaws are commonly chelate, but in whip scorpions and spiders they are reduced to single-hinged fangs. In the spiders a poison gland opens on each fang. The pseudoscorpions and scorpions are the only other arachnids possessing poison glands, but these are placed, respectively, in the pedipalp claw and in the last joint of the tail. In the ticks (a group within the Acarina or mites) the mouth-parts are elongated and toothed to form piercing organs by means of which salivary secretions (often toxic, as with the dog paralysis tick) can be injected into the host dermal tissues to digest them for ingestion in liquid form.

The pedipalp is a mainly locomotory-sensory appendage in forms having relatively robust jaws, such as solifugids, mites, spiders, and some harvestmen. The weaker-jawed pseudoscorpions, scorpions, and whip scorpions possess enlarged, raptorial pedipalps which take over the varied prey-catching, defence, and digging functions performed by the jaws in other orders. Concomitantly with this in the whip scorpions the first pair of legs are greatly attenuated and are carried forward of the body as sensory appendages. Solifugids have a suctorial disc on the tip of each pedipalp which is used in negotiating rocks and similar obstacles (figure 6). Male spiders show a peculiar elaboration of the claw of the pedipalp into a bulb-like copulatory organ. Sperm is stored in a basal, expanded reservoir until mating, when it is ejected via a thin apical duct which is inserted into the female opening.

Behaviour

Avoidance of environmental fluctuations rather than tolerance characterizes arachnid behaviour in relation to physical factors. Most arachnids are moisture-dependent, light-shunning, nocturnally active animals. Many of the spiders, mites, and whip scorpions live as vagrants with no permanent refuge site. Such animals simply live under rocks or logs or in forest litter while conditions of temperature, humidity and

MAJOR ORDERS OF ARACHNIDS

ORDER	COMMON NAME	DISTRIBUTION	TYPICAL HABITATS
Scorpiones ..	Scorpions	Tropical-subtropical, particularly in drier regions.	Under stones, bark, logs, and in burrows.
Thelyphonida ..	Whip scorpions ..	Tropical in warm, humid regions.	Under stones, bark, litter, and in burrows.
Phrynichida ..	Tailless whip scorpions.	Tropical-subtropical, in humid regions.	Under stones, bark, logs, litter, and in caves.
Palpigradi ..	Micro whip scorpions	Tropical-temperate. Probably common, but small and cryptic.	Humid habitats under stones and in soil.
Araneae	Spiders	World	Various—Moist, dry, exposed, cryptic. In caves. Some aquatic.
Ricinulei.. ..	....	Tropical. Rare. No Australian representatives yet found.	In litter, under logs, and in caves.
Pseudoscorpiones	False scorpions ..	World	Humid crevice dwellers—under rocks, bark, moss, litter, and in caves.
Solifugae ..	Wind scorpions ..	Tropical-subtropical, particularly in drier regions. No Australian representatives.	Usually in burrows under rocks or logs.
Opiliones ..	Harvestmen	World	In litter; under logs, rocks, and bark; on foliage and in caves.
Acari	Mites and ticks ..	World	Various — terrestrial and aquatic. Some parasitic.

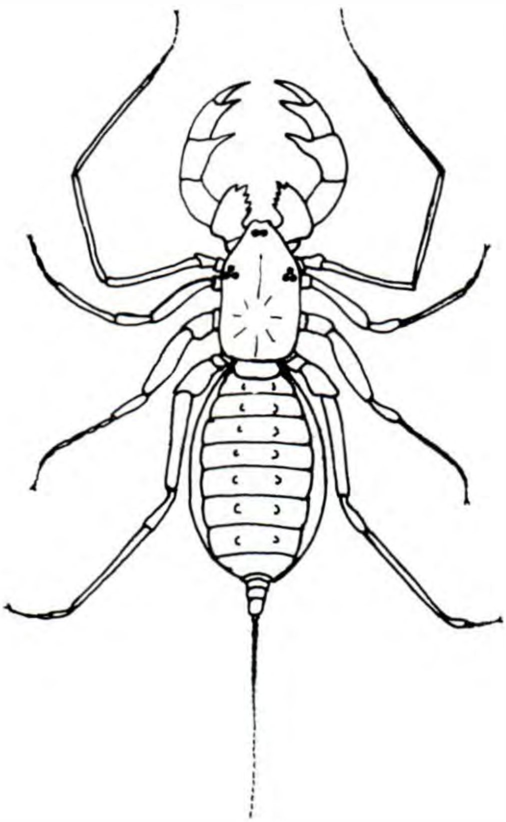


Fig. 2. Whipscorpion—slender sensory tail and spined, grasping pedipalps. [Drawing by the author, after Kaestner.]

food availability are suitable, but, with the coming of a prolonged dry spell or a falling-off of food supply, search responses will be initiated until a suitable habitat is reached once more.

Burrowing is another very common way of avoiding climatic stress. The burrow also provides a refuge from predators and a vantage point from which to ambush passing prey animals. In general, arachnids regulate their activities so that excursions into exposed areas (for food and mate-seeking) are confined to the cooler, humid night. However, some burrow dwellers are also active day-feeders if surface temperatures are not too high, since the burrow provides a cooler, moist refuge to which they can retreat periodically.

All arachnids can function adequately within certain environmental limits beyond which avoidance behaviour is initiated. However, these operational limits vary greatly from species to species and sometimes even within species. Desert-dwelling scorpions and solifugids have a wider range of temperature tolerance than forest-dwelling species. Diurnally active orb weaving spiders have thicker cuticles and lower rates of water loss than nocturnally active forms. In a web suspended several feet above the ground air currents reduce the problems of overheating, particularly when combined with the cooling effects of obligatory water loss across the cuticle.

The survival limits of some species can be extended by short-term regulatory behaviour such as stilting, the response of scorpions and some spiders to increasing body temperature. The body is lifted clear of the substratum, so allowing better air circulation and a greater rate of heat loss than in the "belly down" position. A longer-term response is shown by trapdoor spiders, which seal down the lids of their burrows with the onset of drier summer conditions so that the risk of acute burrow air dehydration is reduced. The burrow is not reopened until the first storms of late summer-autumn, when the young which hatched during the summer period are released. Many spiders, including mygalomorphs such as the funnel-webs, are capable of surviving the very cold winter

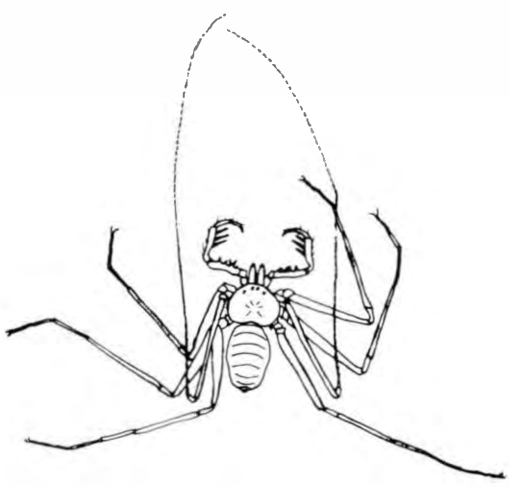


Fig. 3. Tailless whipscorpion—extremely elongate sensory first legs and spined, grasping pedipalps. [Drawing by the author, after Kaestner.]

conditions of subalpine regions in a state of inactivity or torpor. Whether this condition is a physiological response or simply a passive depression of metabolic activity with falling temperature is not certain.

Such "long-term" regulatory behaviour patterns are common in those arachnids of temperate and arid regions having life-cycles of more than 1 year. Many such species live for 1·5 to 3 years, the young overwintering before maturing. Others, notably scorpions and mygalomorph spiders, live much longer (a South American tarantula was kept in captivity for 18 years, a span probably never attained in nature, however), but many of these are distributed in tropical-subtropical areas where the more stable physical environment and constancy of food supply favour development of longer-lived (and larger) forms.

All arachnids are carnivorous, with the notable exceptions of certain plant-feeding mites and some harvestmen which feed on detrital material. The mites also include

Fig. 4. An Orb-weaving Spider, in the head-down position which builders of suspended webs commonly adopt. The abdomen is unsegmented and sac-like. [Photo: Howard Hughes.]

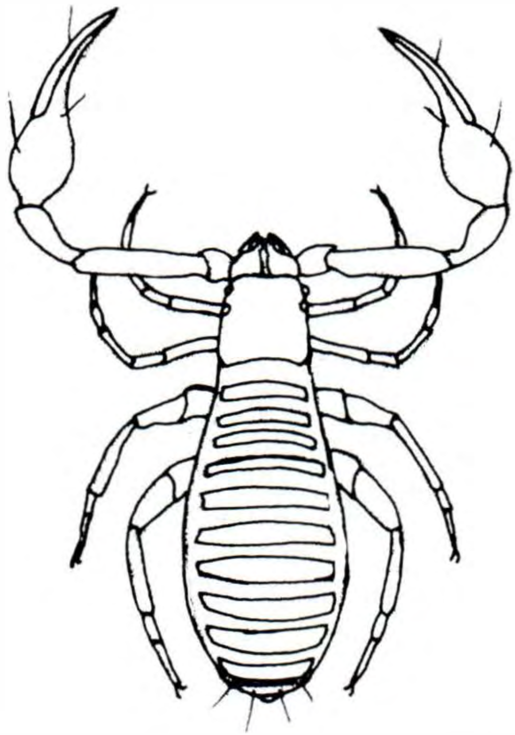


Fig. 5. False scorpion---clawed jaws and pedipalps and flattened body. [Drawing by the author, after Savory.]

the only parasitic forms, which often have complicated life-histories involving vertebrate or invertebrate intermediate hosts, sometimes species specific, on which they must feed to complete the phases of their life-cycle. An unusual feature of the life-cycle of the mites and of the rare Ricinulei is that both include a six-legged larval stage in contrast to the direct development of all other arachnids.

Prey capture

Prey-catching involves hunting, ambushing (lying in wait), or snaring behaviour, with the touch and vibration senses being the most important in prey location. However, in many of the spiders the eyes are well developed for this purpose. Jumping spiders have particularly well-developed vision, and, in addition, they can swivel the retina by muscle action to follow prey movement without moving the body. Vision is also good in the web-building dinopid spiders. They construct a small net web, which is held by the front legs. When prey, such as a moth, moves into the visual range of the enormous anterior median eyes the spider stretches out the net and launches itself over the moth, entangling it in the web. The lycosid or wolf spiders have enlarged posterior eyes placed so as to give them good perception of movement in several directions; in addition, these spiders (which often hunt by day) can use the eyes to navigate by sun position and polarized sky light.

The trapdoor spiders provide a good example of the "ambush" technique of prey capture. The spider sits with its front legs on the burrow rim, the lid just lifted, and leaps out to grasp prey animals which wander close enough to be taken without the spider having to emerge fully from the burrow. In arid regions where less food is available trapdoor spiders often increase their effective prey-catching range by attaching leaves or twigs around the burrow rim as trip lines: in such cases the spider will leave the burrow fully to take prey at the ends of the trip lines as much as a foot from the burrow itself. Spiders showing this sort of feeding behaviour usually construct a very light leaf-litter trapdoor which can be quickly flung open and which stands open when the spider leaves the burrow, so providing for a rapid retreat if necessary; this contrasts with the heavy soil-door of trapdoor spiders which never emerge fully from the burrow to feed.

Web snares of spiders are the most obvious of arachnid feeding specializations. Of the variety of webs in use by Recent species four main types can be recognized; these probably represent an evolutionary progression. The simplest type of web consists of trip threads radiating from a silk-lined ground retreat. From this has evolved the more closely-woven sheet web which spreads out horizontally from the retreat funnel, the spider running on top of the sheet. A further stage is seen in spiders which have left the ground to live in foliage, and here it is easier to run on the lower surface of the tangle or sheet web spun in such locations. From the suspended web amongst foliage the symmetrical orb web has probably been derived by successive simplification of a more randomly arranged type of web.

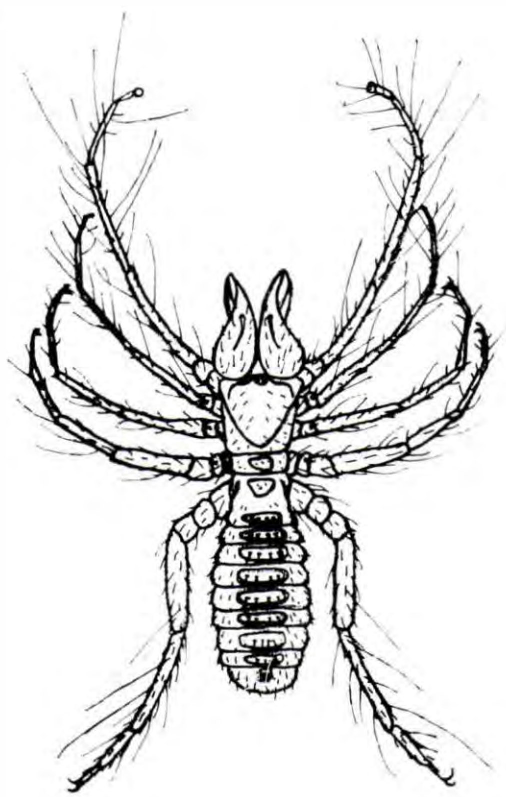


Fig. 6. Wind scorpion—powerful clawed jaws and leg-like pedipalps with terminal suckers. [Drawing by the author, after Savory.]

Other arachnids rely on making physical contact with their prey while actively hunting. The stinging tail of the scorpion is not universally used in disabling prey. In some forms it is much reduced, while the pedipalpal claws are large and powerfully developed to deal with both prey-catching and defence. The long-legged harvestman, after contacting its prey with the attenuated second legs (figure 7), surrounds it with a palisade of legs and grasps it in the pedipalpal claws. The chelicerae then tear open the body wall of the prey and pass the soft internal tissues to the mouth. If the prey animal moves the harvestman bounces up and down on it like a pile-driver until it is subdued.

Arachnids can survive for considerable periods without feeding. Scorpions have survived for over a year when supplied only with moisture: male mygalomorph

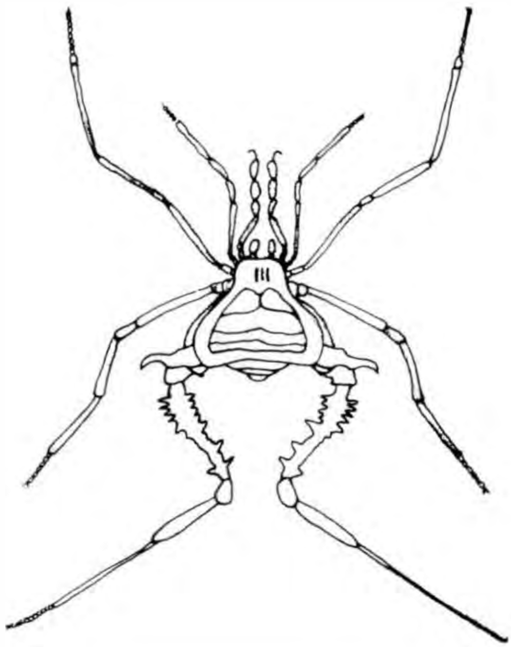


Fig. 7. Harvestman—long legs and short, stocky body. [Drawing by the author, after Savory.]

spiders leave their refuges on reaching maturity to wander in search of females and can survive for over 3 months without food. Arachnids have the ability to store considerable amounts of food in the distensible abdomen, a feature particularly well developed in the parasitic ticks, so that when food is available in quantity maximum use can be made of it.

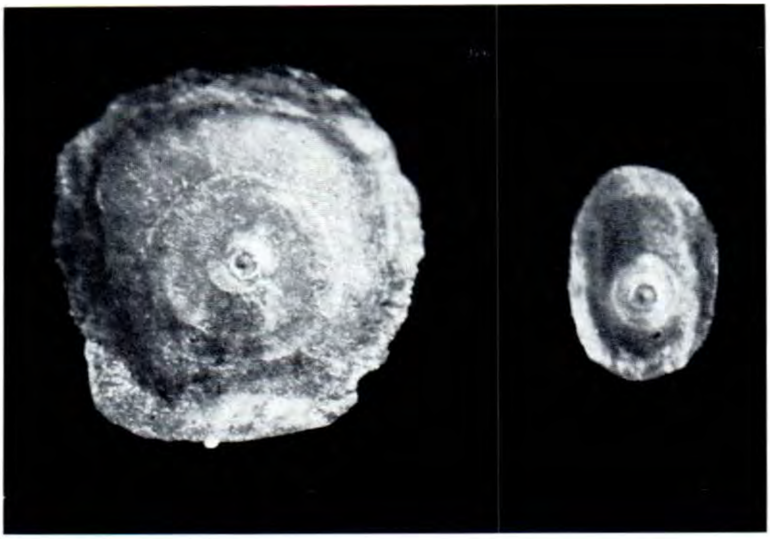
Reproduction

As with feeding behaviour, reproductive behaviour shows much variation in arachnids. In most groups some form of preliminary courtship activity occurs prior to mating so as to establish recognition between the mating partners and to increase female receptivity. Elaborate signals and movements are used by the visually-efficient jumping and wolf spiders, while web-building spiders utilize a special code of tapping on the web to establish the male as a mate rather than a meal.

Sperm transfer is achieved in several ways. The commonest method, seen in whip scorpions, scorpions, solifugids, pseudoscorpions, and many mites, is indirect transfer by means of a spermatophore or sperm capsule. After a preliminary courtship sequence the male deposits the spermatophore, capsule uppermost, on the ground. He then grasps the female by the pedipalps and guides her over the spermatophore so that the capsule is lodged inside the genital orifice. This differs in the solifugids, where the male, after deposition, picks up the spermatophore in its jaws and pushes it directly into the female orifice. Some of the pseudoscorpions go to the other extreme and mate without ever seeing each other. The male simply deposits a spermatophore in a suitable site and then wanders off trailing silk threads from silk glands in its jaws. If a female comes into contact with these threads she will follow them to the spermatophore, which is then taken into the genital opening. The silk secretion is also used to line a soil brood chamber in which the eggs are incubated.

Male spiders spin a small horizontal web onto which a drop of sperm is deposited from the abdominal genital opening. The copulatory organs on the pedipalps, referred to above, are then dipped alternately into the drop, and, as body fluid filling the reservoir of the palp is actively re-absorbed, so the sperm fluid is automatically taken up to replace it. During mating the tip of the palp is inserted into the female opening and the sperm is expelled by hydrostatic pressure.

Different again are the harvestmen in which, without any preliminaries, the animals come together and mating occurs directly by means of an extrusible penis. Many mites also mate directly in this way. It seems possible that one group of arachnids, the small Palpigradi, may prove to be parthenogenetic, i.e., able to produce fertile eggs without mating, but this is only conjectural at present.



The male and female of citrus red scale (*Aonidiella aurantii*) have different forms of scale covering. The rounded scale covers a female, the elongate scale a male. [Photo: CSIRO Division of Entomology]. The photos on the next page show citrus red scale insects without their scale coverings.

Scale Insects

By G. J. SNOWBALL
Division of Entomology, CSIRO, Biological Control Station, Sydney

SCALE insects and their relatives form a large and important section of the insect fauna of the world, some 6,000 species having been described, including about 600 from Australia.

The common name refers to the thin, flat, hard covering, separate from the body, developed by the individuals of many species, but there are many variations of this feature within the group and the external appearance can vary enormously. The covering may be in the form of a secretion closely adhering to the body wall, and may be thick or thin, hard or soft, glassy, waxy, or cottony. Even within the same species, the covering can differ considerably in colour and shape, according to age, the nature of the food plant, and various physical factors of the environment. In many species there is no covering and the body wall of the insect may be thin or thickened in various ways. In some species, the insects become enclosed in masses of host-plant tissue known as "galls". The form of the gall is often strongly characteristic of the species of insect which stimulated its production.

Soft and hard scales

Two of the most important groups of scale insects, partly because some are pests of economic plants, are the soft scales (family Coccidae) and the hard or armoured scales (family Diaspididae). In the soft scales, e.g., wax scales, the body covering, if present, is always closely associated with the body wall; in the hard scales, e.g., red scale, the covering is usually scale-like and is detached from the body wall at least during part of the life of the insect.

The external appearance provides only a broad guide in distinguishing between species of scales. An exact identification requires the examination under the microscope of the anatomical features of properly prepared specimens: for example, the presence of two small structures in the body wall distinguishes red scale of citrus from the closely related yellow scale in which they are absent. Until this discriminatory characteristic was recognized in 1936, there were frequent instances of one species being mis-identified as the other.

Scale insects, in common with the aphids and the other bugs to which they are related, have a characteristic feeding apparatus, a sucking tube formed by the longitudinal interlocking of four elongated bristles. The tube is supported by a conical structure, from which it is exserted to penetrate the food substrate during feeding. Scale insects, like aphids, feed only on plant sap.

Life-history

Although the details of the life-history of scale insects vary greatly, there is a more or less common pattern. There may be one generation per year, as in the white wax scale around Sydney, or up to five, as in the red scale, the rate of development of the individual scales being greatly increased with higher temperature, within certain limits.

Adults of citrus red scale removed from scale covering. The male (above) has a single pair of wings. The female (below) is wingless. [Photos: CSIRO Division of Entomology.]

The newly-born scale insects, or "crawlers", of different species are quite similar but the resemblance lessens during later development, especially in the female sex.

During development the female may go through three or four instars (= stages), depending on the species. In the majority of species, the female ultimately loses the power of locomotion and becomes fixed to the surface of the food plant. The adult female is always wingless and, apart from its ability to reproduce, retains many of the characteristics of the immature stages which precede it. In many species, there is a considerable increase in body-size during the adult female stage, some females of white wax scale increasing their body length six-fold.

Males undergo more striking changes during development than females. There are five or six instars, depending on the species. The adult male is a highly specialized, freely-moving insect, usually possessing a single pair of wings. In truly biparental species, e.g., red scale, males are necessary for reproduction, while in other species, such as Chinese wax scale, they occur but are unnecessary since unfertilized females can reproduce. In still other species, e.g., white wax scale, males are not produced at all. In the species which are biparental a delay in fertilization can result in a considerable extension of the life of the female scale. Under laboratory conditions a female red scale which is fertilized at the usual time, about 36 days after birth, can live about 96 days in all, but one which remains unfertilized may live 197 days or more.

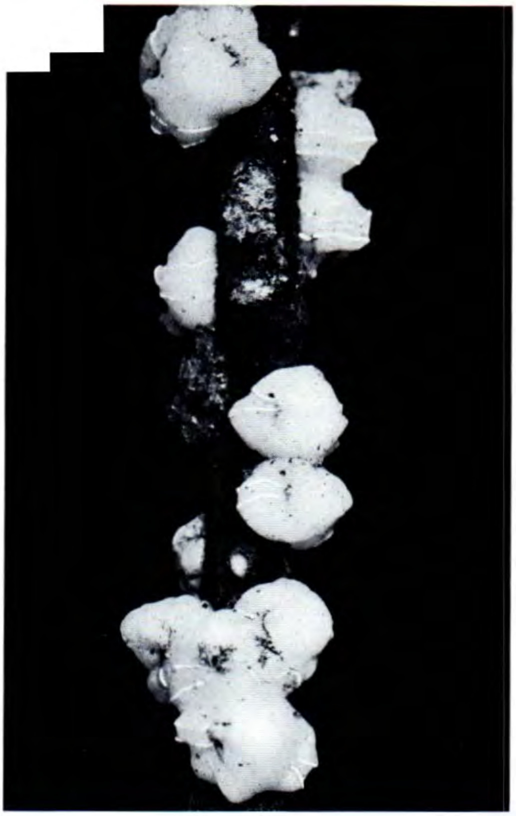
The adult female may lay eggs which take some time to hatch, as in the white wax scale, or the eggs may hatch virtually as they are deposited, as in the soft brown scale, or living young may be produced, as in the red scale. The production of progeny is high, ranging from 50 to 150 per female for the red scale to 11,000 in an African species of wax scale.

In some species of wax scales, the stopping of the food supply—for example, through the cutting-off of a supporting twig—stimulates the production of eggs, even by very small scales. This behaviour can be utilized to obtain scale eggs in laboratory culture at times when they are not normally available. With hard scales, starvation does not act as a stimulus to production of progeny.

Honey-dew

A biological characteristic of soft scales is that, like aphids, they excrete, often in copious quantities, a sugary liquid derived from plant sap, known as "honey-dew". Because of this behaviour, soft scales may contribute indirectly to an upsurge in the population of hard scales on the same tree. The honey-dew often attracts ants, which feed on it. The comings and goings of the ants can interfere with egg-laying by small wasps which are natural enemies of the hard scales, allowing more hard scales to survive and reproduce. The effect is indirect because the hard scales do not produce honey-dew, and the ants display no direct interest either in them or their wasp enemies. Increases of red scale induced by ant activity have been observed in South Africa and California, but there have been no clear-cut demonstrations of them occurring in Australia.

Many species of soft scales are fairly benign in their effects on plants, the damage being caused by loss of plant sap and by blackening of leaves and fruits from the growth of sooty mould fungi on the honey-dew secreted. On the other hand, some hard scales, such as the red scale on citrus and the San José scale on deciduous fruits, can cause the death of plant tissue and seriously injure trees if the insects are numerous. It is probable that in these species, the scales secrete a toxic saliva.



The white wax scale (*Gascardia destructor*) is covered by a thick layer of soft, moist, white wax. [Photo: CSIRO Division of Entomology.]

Density of infestation

Scale insects characteristically show considerable variations in density of infestation. In some cases these variations are clearly associated with the activities of natural enemies. The soft brown scale of citrus frequently reaches large numbers on portions of some trees, but such concentrations are soon reduced by attacks by parasitic wasps. Differences in climatic conditions also influence scale density. With red scale in the coastal areas of New South Wales, young citrus trees tend to be more heavily infested, the infestation diminishing with the age of the tree, and this appears to be because the more open foliage of the younger trees provides the higher illumination preferred by the red scale.

In the inland areas of New South Wales, the situation is reversed, the older trees being more subject to infestation. Apparently the scales are better protected by the increased amount of foliage in older trees from the lethal effects of high daytime temperatures which can occur in these areas. The abundance of scale insects is also considerably influenced by the kind of plant host infested and by its interactions with other environmental components, but very little is known of the mechanisms involved. In unsprayed orchards orange trees heavily infested with white wax scales may occur within a few yards of lemons with only scattered infestations, and *vice versa*. In New South Wales, oleander is rarely infested with white wax, except in isolated instances, although those individuals which occur on it are normal in development. In the coastal areas of southern Queensland, it is a major host and becomes heavily infested.

Biological paradox

As with most insects, scales represent a biological paradox in that their biological endowment is a mixture of strengths and weaknesses. The individual insects are easily damaged mechanically, and, in the early stages at least, have limited ability to withstand physiological stresses resulting from excessive heat, cold, or dryness. Their mobility from their own efforts is limited so that they are vulnerable to adverse changes in their immediate environment and to the attacks of natural enemies. They have no powers of searching for food, being dependent on chance encounters with food plants should those utilized by their parents become unavailable. Because of these features, mortalities take heavy toll of the individuals. Nevertheless, these losses are offset by high rates of reproduction, and scale insects are successful as species in the sense that they have persisted as entities over the very long periods of time since they were evolved and are still represented, in many cases, by large numbers of individuals.

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MEET OUR CONTRIBUTORS . . .

MICHAEL GRAY is an M.Sc. graduate of the University of Western Australia. He took up the position of Arachnologist and Assistant Curator in the Australian Museum's Department of Entomology and Arachnology in mid-1969. His main interests are the systematics and biology of the mygalomorph and sparassid spiders.

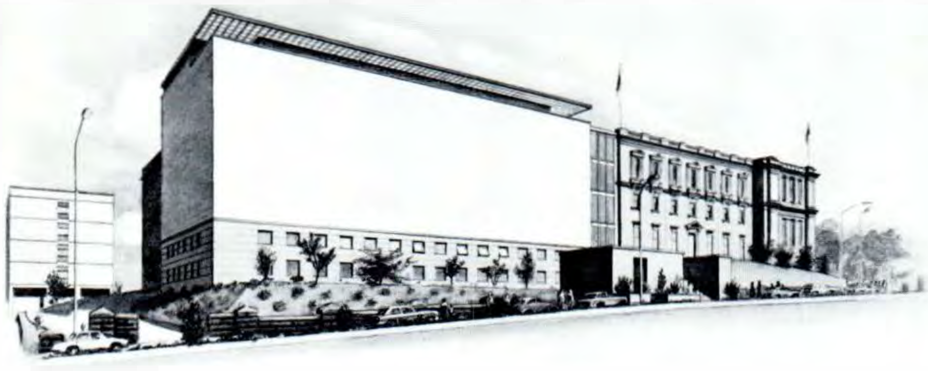
C. J. LAWLER is the secretary of the Underwater Research Group of New South Wales, and has had extensive diving experience around the N.S.W. coast. He was made an Honorary Associate of the Australian Museum in 1970. He is co-author, with fellow Underwater Research Group member Walter Deas, of the book *Beneath Australian Seas*, and has published many articles dealing with marine animals as encountered by the scuba diver. He is at present writing the text of a book illustrated by fellow diver-photographers Walt Deas and Ben Cropp.

EDWARD THORNTON LINACRE, a Fellow of the Institute of Physics, has been Associate Professor of Climatology at Macquarie University, Sydney, since 1969. He trained at Edinburgh and London Universities, and gained his Ph.D. for a study of water evaporation factors while with the CSIRO Division of Irrigation Research from 1960 to 1969. During the latter part of that period he was Principal Research Scientist.

HARRY F. RECHER, head of the Department of Environmental Studies at the Australian Museum, was born in the U.S.A. and received his doctorate in biology from Stanford University. He came to Australia in 1967 as a Lecturer in Biology at the University of Sydney, and joined the staff of the Australian Museum in 1968. Since then he has done much research, including biological surveys of the New South Wales coast and Lord Howe Island.

ALEX RITCHIE, Curator of Fossils at the Australian Museum since February 1968, was born and educated in Scotland (B.Sc. and Ph.D., Edinburgh, 1959 and 1963). He lectured on geology and palaeontology at Edinburgh University (1960–63) and Sheffield University (1963–67), and is currently a part-time lecturer at Macquarie University, Sydney, presenting an annual course on vertebrate palaeontology. His earlier research involved Silurian and Devonian vertebrate and arthropod faunas of Britain and Norway and Carboniferous fish from Spain. Dr Ritchie has since collected, and is studying, Devonian fish faunas from many parts of Australia and from Victoria Land, Antarctica.

G. J. SNOWBALL is a science graduate of the University of Western Australia. In 1946 he joined the CSIRO Division of Entomology. He has worked on the ecology of cattle tick, on a biological control project against Queensland fruit fly, and, since 1965, on the biological control of white wax scale. Currently, he is also studying the natural enemies of armoured scales of citrus.



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