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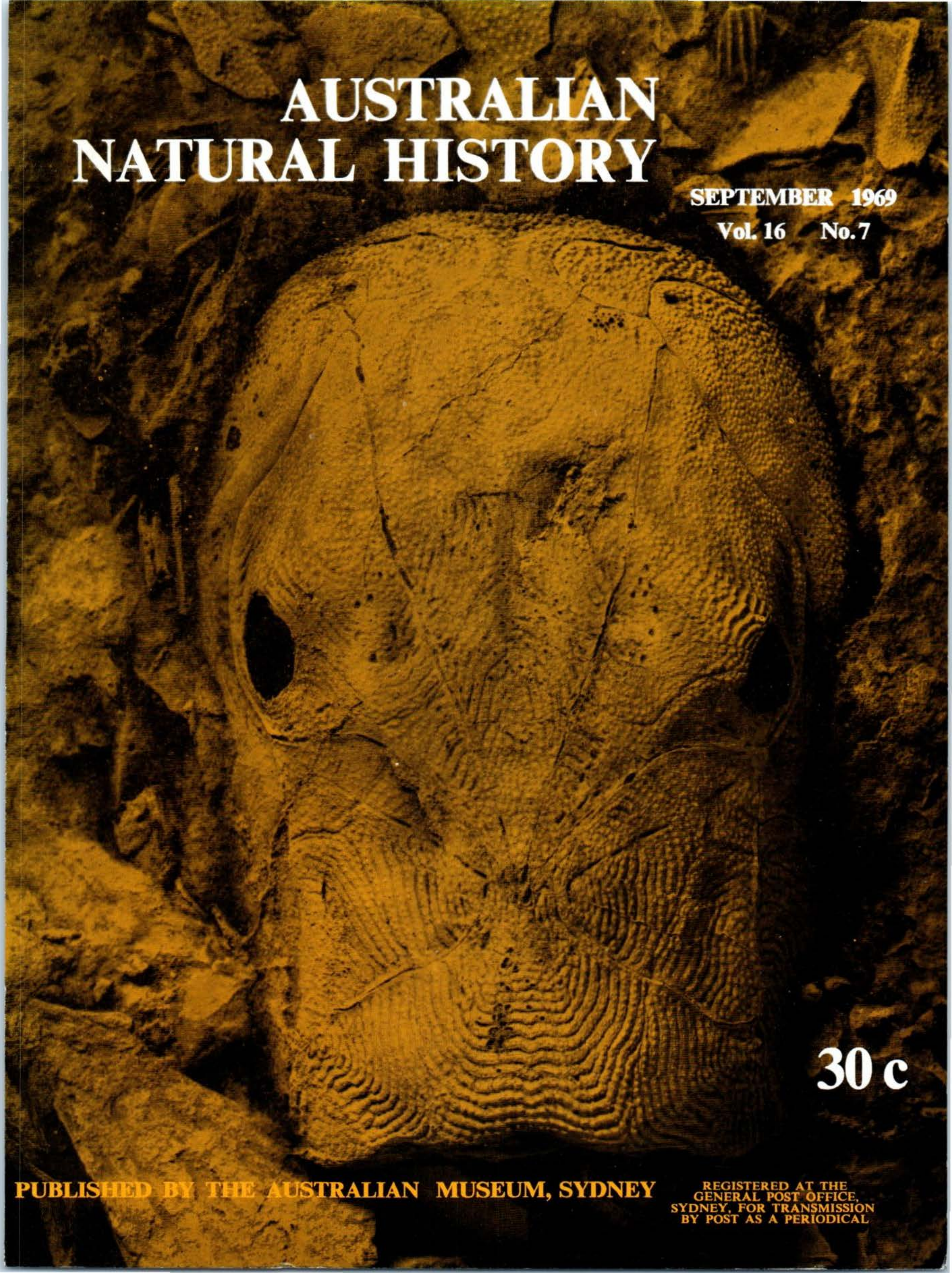

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● **FRONT COVER: An almost complete headshield of a new genus of arthrodiran fish from the Devonian rocks of northwestern New South Wales, found by Dr A. Ritchie and Mr K. Gregg, of the Australian Museum. For a reconstruction of the whole fish see the illustration on page 220. BACK COVER: Newly born scorpions of the species *Urodacus manicatus* cling together on their mother's carapace, well protected in the circle of her venomous sting and powerful claws. Unlike most other arachnids, scorpions bear their young alive. Embryonic development occurs in uterine sacs suspended in the fluid of the body cavity, from which sustenance for the embryo is extracted. As the number of these sacs is fixed at maturity and each can nurture only one embryo, the scorpion's reproductive capacity is very limited, so early protection of the fragile young is important. The young scorpions remain with the mother for 1 to 3 weeks while they undergo their first moult, before dispersing to their solitary existences. [Photos: C. V. Turner.]**

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# *THE WEDGE-TAILED EAGLE*

By M. G. RIDPATH
CSIRO, Division of Wildlife Research, Helena Valley, Western Australia

BECAUSE they are big and because they are carnivores, eagles have always excited man's admiration—and his alarm. The eagle was supposed to embody some martial quality which made it a fit emblem for the Roman legions who conquered our ancestors; and our ancestors were convinced that, like the legionaries, the eagle was a threat, killing their lambs and even their babies, so they have eliminated it from most of Europe.

An eagle feeding on a rotten 'roo carcass on the road is not a noble sight, nor does its obvious avoidance of man suggest daring. But whatever its image, the Wedge-tailed Eagle (*Aquila audax*) does pose stimulating problems in ecology.

Carnivores, including eagles, have to rely for life on sufficient numbers of the right size of prey being available to them. Even though they may have a wide range of diet, they are still at the mercy of the fluctuations of the density of their prey, caused by the erratic climate of most of the continent. Their young take several years to become mature and during this period probably face these dangers even more acutely because of inexperience.

The Wedge-tailed Eagle occurs throughout Australia and Tasmania and extends as far north as southern New Guinea. So far, measurements of populations have never been made, so we do not know how its density may vary between different habitats. Nor do we know whether populations are generally constant in density, declining, or increasing. On the other hand, official records of bounties paid in some States show that quite large numbers have been killed each year. They have often amounted to some thousands. This is because of a widespread belief that eagles take newly-born lambs. For this reason, the Wedge-tailed Eagle has no legal protection in some or all areas of every State, except Tasmania, where it is fully protected throughout. At the same time, the decline of the closely related Golden Eagle (*Aquila chrysaetos*) in Europe and North America, also accused of killing lambs, gives food for thought. The total North American population is reliably estimated to stand now between 8,000 and 10,000, a figure which in some years has been exceeded by the kill of Wedge-tailed Eagles in Australia in 1 year alone! Of course, the introduction of the rabbit and the great increase of carrion, due to open-range sheep and cattle grazing and kangaroo shooting, may have increased the eagle population. Whether these factors offset the effects of this destruction of Wedge-tailed Eagles cannot be decided without many more facts.

A Wedge-tailed Eagle chick, a few days old.

### Investigation in Western Australia

An investigation into the ecology and economic status of the Wedge-tailed Eagle by the Division of Wildlife Research, CSIRO, has been in progress for 2 years. It is taking place in the pastoral zone of Western Australia, where complaints against eagles have often been made. The country is semi-arid with a very variable rainfall,

An unusually low Wedge-tailed Eagle's nest in a Myall tree on the western fringe of the Nullabor Plain, Western Australia.

so there are great yearly variations in vegetation upon which most of the eagle's prey relies. The eagle populations in two separate areas are being studied. One is near Rawlinna, about 250 miles east of Kalgoorlie and adjacent to the western limits of the Nullabor Plain. It has a mean annual rainfall of 7 inches. The vegetation consists of low Mulga (*Acacia aneura*) scrub, giving way to open grassy plains with scattered Myall (*A. sowdeni*). The study area consists of 370 square miles astride the boundary between the grazing country and the unoccupied plain, and includes some of each. The second area consists of 250 square miles near Carnarvon at the mouth of the Gascoyne River, 600 miles north of Perth. It has an 8½-inch annual rainfall. The principal tree is the low Snakewood (*A. eremea*). Both areas are very flat and generally open.

The two study areas are 900 miles apart and have a number of differences. Rawlinna is about 500 miles south of Carnarvon's latitude, and is inland instead of coastal. Whereas the Rawlinna area has only recently been exploited for grazing sheep and is right on the margin of the pastoral country, Carnarvon is in the long-established, and often overgrazed, pastoral region of the Gascoyne. Another important ecological difference is that the rabbit is abundant in the Rawlinna area, but scarce at Carnarvon, which lies close to its northern limit in Western Australia. It is hoped that results from these two areas will give some picture of the eagle's ecology, and also indicate any differences due to differing situation.

The main objectives are to investigate the eagle's movements, breeding, density, longevity, and food, including predation on lambs.

**Extensive search**

Because it is a large predator, the Wedge-tailed Eagle is somewhat sparse on the ground by comparison with smaller species of birds. As a result, the two study areas have had to be extensive, and searching them has to be correspondingly extensive and lengthy. The breeding season normally starts in July at Rawlinna, and from then onwards the area is searched in a landrover. An observer looking for nests sits in a hole in the roof of the vehicle, which moves at a steady 10 m.p.h. in a straight line, 10 miles long. It has been found that the observer can see an eagle's nest up to (and often beyond) 0·4 mile on either side; therefore the transects are repeated parallel to each other every 0·8 mile. The vehicle is driven on an exact compass course, the same for all transects, which

A Wedge-tailed Eagle's nest being examined near Carnarvon, Western Australia.

avoids divergence or convergence, thus ensuring the lines are truly parallel. This gives full coverage. Iron chain, 50 feet long and weighing $1\frac{1}{2}$ cwt, is dragged behind the vehicle, causing a score mark which can be followed on subsequent runs, as the country has few features.

This system ensures that all the nests are found, and their positions are recorded and plotted on a map. They are tagged with a numbered aluminium strip (crows removed even thick aluminium foil, used first), the contents are noted, chicks are banded if present, and a search is made beneath the nest to collect food remains. The latter are identified later by comparison with a reference collection in the laboratory.

Forty-nine occupied nests and 180 old nests have been found during the first two breeding seasons. The normal clutch is two eggs. Single eggs are laid occasionally, but so far only one clutch of three has been found. The breeding season is normally between July and November, but one pair was found breeding at Rawlinna in March, along with sixteen other species of birds, 2 months after heavy cyclonic summer rains. Even the Wedge-tailed Eagle cannot be excluded as a potentially opportunistic breeder in semi-arid country.

**Analysis of prey in nests**

Analysis of the remains of prey from the occupied and old nests shows that rabbits are very extensively eaten at Rawlinna, all nests having some remains of rabbit and most having nothing else. About one in ten nests also had remains of birds or reptiles. At Carnarvon, on the other hand, the food taken was much more varied. Less than a third of the nests had rabbit; three-quarters of the nests had Red Kangaroo (*Megaleia rufa*) or Euro (*Macropus robustus*) remains (mainly joeys) and three-quarters had bird remains, mainly Crows (*Corvus* species) with occasional Galahs (*Cacatua roseicapilla*) and Tawny Frogmouths (*Podargus strigoides*), and even a Brown Quail (*Synoicus ypsilophorus*) and a Diamond Dove (*Geopelia cuneata*): two-thirds of the nests had remains of reptiles, especially Shingle-backs (*Trachysaurus rugosus*) and even quite small species only 5 inches long; and half the nests had the remains of fox (*V. vulpes*) or feral cat.

A Wedge-tailed Eagle's nest, with chicks, in a dead Myall tree.

A few lamb remains were found, but so far it has not been possible to distinguish between the remains of moribund or weakling lambs and those of healthy ones. It is not surprising that some lambs are taken by Wedge-tailed Eagles sometimes. These birds are not only known to take joeys but have occasionally been recorded hunting adult Red and Grey Kangaroos (*Macropus giganteus*) by striking at the head and neck with their talons. During the present investigation they have been seen pursuing adult Euros in a similar way in the Hamersley Ranges. The critical measurements concerning lamb-killing are its actual frequency and the condition of the lambs taken; work on both aspects is in progress.

**Banding**

Seventy-one eagles have been banded in the two study areas. Most have been banded as nestlings, but it has also been possible to trap grown eagles in simple cage traps for banding. Recoveries to date suggest dispersal and subsequent wandering by the young after leaving the nest (up to 300 miles). It is possible to distinguish age, to some extent, by plumage, on the basis of changes observed over 4 years in three captive eagles taken from the nest. Their plumage darkens progressively, but even at 4 years of age has not reached the dark colour of most of those seen breeding. On the other hand, paler eagles can be observed, paired but concentrated in non-breeding flocks during the breeding season. These younger birds may be rather mobile before they reach the age of breeding. They tend to concentrate on any easily available food source, particularly carrion. One flock of eighteen was counted near Rawlinna.

Knowing the total area searched and the total number of occupied nests found, it is possible to calculate the density of breeding adults in the different areas. Results to date suggest that at Rawlinna the adult density is greater in the unoccupied portion than in the grazed portion of the study area, though this requires confirmation. Attempts are being made to measure the major food supply, the rabbit, in both portions. The comparatively high density of 16 square miles per pair of adults in the unoccupied portion at Rawlinna, where the diet is mainly rabbit, raises the question of the situation before the introduction of the rabbit. Unless it can be shown that the rabbit replaced an equally abundant and similar-sized diurnal native mammal, it would seem likely that the introduction of the rabbit has increased the eagle population in such areas. It certainly is the mainstay of their presence today.

[*The photos in this article are by Paule Ridpath.*]

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The high tops.

# *ABOVE THE TREE LINE*

By THISTLE Y. HARRIS
Vice-President of the Wildlife Preservation Society of Australia

TRAVELLING across the breadth of the Australian continent, one is impressed with the gradually diminishing height and the change in form of the tall, erect coastal trees to the twisted mallee shrubs further inland, until one finds oneself on a flat plain vegetated solely by hummocky patches of saltbush and bluebush, except along the waterways (often underground) where the River Red Gum (*Eucalyptus camaldulensis*), the one tree that spans the continent, persists. Here increasing aridity is almost entirely responsible for the changing scene.

Ascending from sea-level to the highest altitudes that Australia boasts, a rather similar and equally dramatic change occurs, especially notable at altitudes of from 4,000 feet upwards. Here a single tree species, the Snow Gum (*Eucalyptus niphophila*), dominates; extending to the highest levels of the subalpine zone at 6,000 feet, it diminishes in height with increase in altitude, and shows, by its increasingly gnarled and twisted form, the rigours of the climate. From this point to the summit of the peaks on the mainland, at a little over 7,000 feet, no tall plants can survive and the vegetation of these high moors consists entirely of associations of low-growing shrubs and herbs.

**The extent of the high moors**

The true alpine zone of Australia—from 6,000 feet to a little over 7,100 feet on the mainland—occupies some 2,000 square miles, of which about 1,000 square miles are in southeast New South Wales, about 140 in the

Australian Capital Territory, and about 870 in the Victorian Alps. In Tasmania, where the highest peak is only a little over 5,100 feet, the more southern latitude permits of a similar type of vegetation at a little over 3,000 feet, and this occurs in a number of areas scattered over the island, totalling about 2,500 square miles.

The high-moor vegetation of the mainland appears to have been isolated in the first instance by the Tertiary peneplanation (about 60 million years ago) of the Kosciusko area, part of the great uplift affecting the major portion of the east coast of the continent. The surface of this ancient plain may still be recognized by the strikingly even skyline and the elevated plateaux dissected by waterways cutting deep gorges, especially along the many faults which were formed during this period of disturbance. In Pleistocene times three periods of glaciation (occurring from 1 million to 10,000 years ago and separated by a period of recession in the middle Pleistocene) were followed by drier conditions in early recent times, with a gradual amelioration of climate up to the present day. The existing assemblage of plants occupying the high moors may be regarded as the residuals of a flora which, in Pleistocene times, extended to much lower altitudes, and this, no doubt, accounts for the pockets of what may be regarded as true alpine species at subalpine and montane elevations.

Snow Gum (*Eucalyptus niphophila*) reaches its limit at an altitude of about 6,000 feet.

# *Increase in Price of Magazine*

*As from the issue of December*, 1969, *the price of* Australian Natural History *will be increased to* 50*c a copy* (55*c posted*). *The subscription rate will therefore be* $2.20 *a year, posted.*

*This is the first increase in price since March*, 1961, *despite the fact that the cost of production of the magazine has almost doubled in the last* 6 *years. The Trustees of the Australian Museum now find it impossible to postpone a price increase any longer.*

*The new subscription rate will apply to all new subscriptions and renewals of subscriptions received after* 30*th September*, 1969.

### A specialized flora

Present climate and past history are together responsible for this rather specialized alpine flora.

Low atmospheric pressure accelerates evaporation in summer; winds are high and frequent in both summer and winter and, with no effective windbreaks, plants are cruelly exposed to these. On the other hand, precipitation is high—70 to 100 inches and 130 to 180 rainy days a year. Additional ultraviolet light, snow reflection, and exposed light-coloured rock provide a high light intensity. High temperature ranges are common, not only from season to season, but within very limited periods; it is not uncommon in these parts for a single summer day to range in temperature from 32° to 80° F or even higher. Days are very long in summer and very short in winter. These factors together give a set of climatic conditions existing nowhere else in Australia.

Lake Lilla, Tasmania, with the slopes of Cradle Mountain rising to over 4,000 feet.

**Plant adaptations**

In addition to the peculiar climatic factors, soil conditions in the alpine areas play an important part in controlling plant growth. Low water availability is common; this may be due to a high acid content, to intense cold in the depressed areas, or to dry and shallow soils on the exposed plateaux. However, the nature of the parent rock, and hence the derived soil, appears to have little effect on the vegetation in comparison with climate and water availability.

Plants show varying types of adaptation to these remarkable conditions. Because the ground is covered with snow for at least 1 month continuously per year, and often longer, herbs with definite periods of perennation are common. These remain below the soil and beneath a blanket of snow in the form of underground stems of varying kinds which commence active growth often long before the snow has melted. Rapid development during the period of warmer weather enables such plants to reach maturity and flower usually at the height of the summer. Woody plants of the area, besides adopting perennation methods of seed production, show marked adaptation in the form and nature of their aerial growth. Nanism (dwarfing), tussock formation, and rock-clinging habits provide obvious protection from the effects of wind, cold and changing temperatures; ericoid (heath-like), leathery, spiny, and woolly leaves, common on these plants, also provide some protection against these, as well as reducing water loss.

**The range of plant families**

The high moors contain a range of plant families differing considerably from those which dominate the coastal and inland floras of this continent. The *Acacia* (wattles), family Mimosaceae, of which some 600 species are recorded for Australia, are represented here by a single species, *Acacia alpina;* their close relatives the pea flowers, family Papilionaceae, a feature elsewhere, consist of a mere handful. The myrtles (family Myrtaceae), which, along with the eucalypts, form one of the dominant families of the coast and of the areas immediately below the alpine zone, have very few representatives on the high moors. The family Proteaceae, which is common throughout Australia and which includes the waratah, has only some half-dozen species above the tree line, while the mint bushes (family Labiatae) have only one (on the mainland), and the boronia family, Rutaceae, only a few.

On the other hand, the monocotyledons, especially the orchids, are fairly well represented, while a number of other families, sparsely represented in other parts of Australia, are abundant here. Among these are the buttercups (family Ranunculaceae), with almost a dozen species, and these very abundant; the snapdragon family, Scrophulariaceae, with a number of genera, many of them small and insignificant, but including the widespread and beautiful eyebright, *Euprasia*, with several species; the parsley family, Umbelliferae, with some conspicuous species, such as *Aciphylla glacialis*, and a number of less conspicuous members; the gentian family, Gentianaceae, missing elsewhere in Australia and represented only by a solitary species, *Gentianella diemensis*, but this in great abundance; and the rose family, Rosaceae. The family Rubiaceae and the pimeleas (family Thymeleaceae), also found elsewhere in Australia, make themselves more apparent on the high moors both by number of species and abundance. Two families are common both at this level and elsewhere in Australia—the heath family, Epacridaceae, and the daisy and daisy-bush family, Compositae. The latter, while common in many habitats, particularly of inland and Western Australia, are a marked feature of alpine areas and include a few endemic genera, such as *Ewartia* and *Celmisia*. In Tasmania several species of Epacridaceae are restricted to alpine areas.

**Alpine communities**

The flora of the high moors falls into a number of fairly well defined communities, each with its dominant species but with considerable overlapping of the sub-dominants.

The alpine herbfields, rich in humus, occupy the steep rocky faces, crevices, and ledges of the mountain slopes and plateaux. In the more protected parts the plants are taller and form *tall alpine herbfields*. Several species of Snow Grass, mixed with Wallaby Grass, dominate in some parts, while in others, particularly in the moister areas, the Alpine Pineapple (*Astelia alpina* and *A. dsychocharis*) form a silver carpet a few inches in height. Great sweeps of Snow Daisy (*Celmisia longifolia*) are common, while the magnificent, large, white-flowering buttercup (*Ranunculus anemoneus*) and several small yellow-flowering buttercup species make vivid patterns. Two species of alpine ferns shelter among the many boulders. The low-growing white, yellow-centred everlasting *Helipterum incanum*, with a number of varieties, is a charming addition to this community.

In Tasmania the tall herbfield is notable for its wide variety of colourful heaths with bright, gay fruits; these include species of *Richea*, *Leucopogon*, *Monotoca*, and *Trochocarpa*.

Where less protection is offered the community merges into a *short alpine herbfield*, with a carpet-like covering fed constantly by the waters of the melting snows. In the wetter patches are low-growing buttercups, the small white-flowering *Brachycome stononifera*, *Montia australasica* and a host of other mat plants. In the pools of the swift-flowing streams will be found the marsh marigold (*Caltha intraloba*) and the insectivorous *Drosera arcturi*. In Tasmania

Alpine herbfield on the shore of the Blue Lake, Mount Kosciusko.

this is the home of the cushion bushes of five species within three genera. These amazing plants form continuous hummocks, often several feet in diameter, over the constantly wet moors, and one may pick one's way dry-shod without harm to these resilient plants. In some species the foliage is brilliant green, in others a soft sage-green, and they form a pleasing pattern as they intermingle. Other low-growing plants of this herbfield common to both Tasmania and the mainland include the Sky Lily (*Herporlirion novae zeelandiae*), the charming little Mountain Gentian (*Gentianella diemensis*), and *Stackhousia pulvinaris*, a completely prostrate, yellow-flowering plant which betrays its presence by its delightful and penetrating perfume.

**Fens and bogs**

These are a feature of alpine areas. Fens occur on wet, level, or gently sloping stretches, often along permanent waterways or where water lies for the greater part of the year. The accumulated peat makes a boggy, poorly aerated soil, supporting a vegetation rich in sedges, rushes, tussocky grasses, water millfoil, bullrushes, and a number of species of ground orchids. The mat-like ewartias, sometimes called Australian edelweiss, with their soft foliage, love the fens. The only Australian anemone, *A. crassifolia*, is found in Tasmanian fens.

Bogs occur on constantly wet, often irregular, slopes, and support a richer vegetation than the fens. Spaghnum moss is a feature of them. Trigger plants (*Stylidium graminifolium*) and species of *Epilobium* are common. In Tasmania vast stretches of bog are taken over by the fern *Gleichenia dicarpa*.

**Fjaeldmark and heathlands**

This is a windswept community usually drier than any of the preceding communities and consisting of dwarf flowering plants, with mosses and lichens. While most of the inhabitants are small, erect plants, rosette and mat forming plants also occur. *Veronica densifolia* and ewartias spread themselves over the rocks, while epacrids, *Linum marginale*, *Bossiaea foliosa*, and *Boronia algida* are prominent in mainland fjaeldmark.

Heathlands occupy the rocky banks of watercourses, the shelter of rocky outcrops, glacial moraines, and other protected parts. They have a denser coverage of vegetation than the fjaeldmark and are occupied mainly by small erect shrubs and rock-clinging species. Alpine Mint Bush (*Prostanthera cuneata*) makes a lovely show; the alpine pine *Podocaropus lawrencei* clambers over the rocks; pimeleas and one or two species of phebalium are common. In Tasmania *Boronia rhomboidea* and *B. citriodora* often occur in heathlands in considerable stands.

**The need for conservation**

Alpine areas in Australia occupy only a very small percentage of the total area (0·1 per cent of the mainland, 10 per cent of Tasmania), but they are rich in endemic species and, therefore, are of great scientific interest. They are also very beautiful. (One does not easily forget a good flowering summer on Mount Kosciusko or the Bogong High Plains, or the midsummer brilliance of the wide sweeps of Cradle Mountain.) They have withstood the ravages of the most severe climate this country has ever known; it is hoped that they will be equally successful against the ravages of man.

In the past, fire and grazing have been their chief enemies from civilization. At the present time these dangers have been partially removed, although the grazing interests still look greedily to the summer pastures. An additional threat is the increasing tourist attraction of the high country and, with an increasing population rapidly gaining increased leisure, this is an accelerating threat. It is not easy to tramp the high moors without trampling down the vulnerable low-growing plants. Australians must be increasingly aware of the responsibility of retaining this interesting and beautiful heritage.

[*Photos by the author.*]

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# ANCIENT FISH OF AUSTRALIA

By ALEXANDER RITCHIE
Curator of Fossils, Australian Museum

THE Devonian period, which lasted from around 400 to 350 million years ago, is often referred to as "the Age of Fishes" because it was a time of unprecedented diversification and experimentation among the water-living vertebrates which we conveniently group as "fish". Simple, armoured, fish-like creatures lacking jaws had long been in existence prior to the Devonian, as is shown by the fact that their fragmentary remains occur in the Middle Ordovician rocks of Colorado, U.S.A., deposited some 480 million years ago. A wide range of these armoured jawless "fish" or ostracoderms has also been collected from Silurian sediments of 450–400 million years ago in North America, Europe, and Asia, but to date only a few isolated scales of these primitive forms have been discovered in Australian Silurian deposits. Fish with well-developed jaws, making possible the capture, manipulation, and chewing of larger food particles, first appear in some abundance in early Devonian times. As most of the important groups of fish are present and clearly-differentiated in Lower Devonian sediments it would seem probable that they originated and diverged during the preceding Silurian Period, but the fossil record is inadequate on this aspect. The only gnathostomes (fish with jaws) definitely known from pre-Devonian sediments are the spiny-finned acanthodians, which range from Upper Silurian to Permian times.

Also commonly found in Devonian sediments are the heavily armoured Placodermi (antiarchs and arthrodires), and more highly developed bony fish or Osteichthyes including the ray-finned Actinopterygii (palaeoniscids) and fleshy-finned Sarcopterygii (lungfish, coelacanths, and rhipidistians). The Chondrichthyes or cartilaginous fish (sharks, rays, etc.) appear rather later in the Devonian and, unlike the others, are not well represented in Australian Devonian sediments.

The evolutionary history of fish during Devonian times is now known in considerable detail, but most of our information has come from a few highly productive areas in the Northern Hemisphere which have long been known and studied. In consequence, many institutions have specialized in vertebrate palaeontological studies, and techniques of preparation have been developed to a fine art. It is to be expected that the most important future discoveries are more likely to be made in the less intensively explored and mapped regions of the continental masses. In fact, during the last decade some of the richest finds have come from Arctic Canada, Asiatic Russia, China, Australia, and Antarctica.

Figure 1.—Distribution of Devonian rocks in Australia. The solid areas indicate surface outcrops, the stippled areas indicate where Devonian rocks have been proved at depth by drilling.

### Resurgence of interest

Despite the size of Australia and the area covered by Devonian sediments (fig. 1) surprisingly few specimens of fossil fish have been recorded, and many of these consist of fragmentary remains or single specimens. Professor E. S. Hills has summarized (1958) Devonian fish discoveries up to the mid-1950's, many of which he himself had described. Since that time there has been a resurgence of interest in Australian Devonian vertebrates which has resulted in the discovery of rich fish-bearing sediments in various parts of the continent, and large collections are currently being prepared and studied both in Australia and in Britain.

When Hills wrote (1958) the oldest known Australian vertebrates occurred in the marine Middle Devonian limestones of southern New South Wales and Victoria. More recently, however, Professor J. W. Warren, Monash University, Victoria, and Dr J. A. Talent have recovered fragmentary bones and teeth of crossopterygian fish (coelacanths and rhipidistians) from calcareous nodules of Lower Devonian age from near Buchan, Victoria. The Middle Devonian limestones of Buchan (Victoria) and Taemas (New South Wales) have yielded a variety of placoderms known as arthrodires, characterized by a movable joint between the head and trunk armour shields. Several have been described by White (1952) and others, but a considerable quantity of additional material was collected along the Murrumbidgee by Mr H. A. Toombs, of the British Museum (Natural History), in 1954. Preparation of this material, involving careful removal of the limestone matrix by dilute acids, is now nearing completion in the British Museum and the material will be described by Dr E. I. White, formerly Keeper of Palaeontology at the British Museum (Natural History).

Fish remains of undoubted Upper Devonian age occur at numerous localities throughout eastern Australia, generally consisting of fragmentary remains of placoderms, notably the antiarch *Bothriolepis* and the aberrant arthrodire *Phyllolepis*. Both occur also in the late Upper Devonian of North America and Eurasia, and *Bothriolepis* has been recorded from Antarctica. Although the majority of the localities (Taggerty and Mansfield, Victoria; Hervey's Range and Forbes, N.S.W.) have produced only disarticulated or fragmentary plates, one site near Canowindra, N.S.W., has provided us with numerous complete individuals. In 1956 roadworking operations uncovered a magnificent slab of Devonian sandstone the entire surface of which was covered with the impressions of well-preserved fish. With one exception the fish are antiarch placoderms, mainly of the genus *Bothriolepis*. Since the bone has weathered away the external impression or natural mould which remains is so detailed that by means of a flexible casting material, such as rubber latex or silicone rubbers, one can obtain perfect replicas of the vanished armour. In places the fins and scale-covered trunks of the fish are also preserved as delicate impressions. Towards the centre of the slab— which is on permanent display in the Hall of Fossils in the Australian Museum—there is a solitary individual of a rather large rhipidistian or fleshy-finned fish, the first complete specimen of its kind ever to be discovered in Australia. This spectacular find will be described by Professor E. S. Hills, of Melbourne.

**Significance recognized**

Although most of the Devonian vertebrate discoveries have come from eastern Australia, fish remains had been reported from the Kimberleys in northwest Australia in the 1940's, but it was not until Mr Toombs visited the area in 1963 that the full significance of the fish-bearing deposits was recognized. The area around Fitzroy Crossing had long been famous for its well-exposed reef deposits of Devonian age, in which all the various facies and environments can be recognized—main reef, fore reef, back reef lagoons and inter-reef basins. These deposits have different suites of fossils related to the original environment, and the inter-reef facies, in particular, has yielded thousands of calcareous nodules containing either the skeleton or armour of a fish or the exoskeleton of a bivalved crustacean. The fish can be accurately dated (from associated marine invertebrates) as of early Upper Devonian (or Frasnian) age. Mr Toombs and Western Australian Museum scientists, collecting in 1963 and 1967, have shown that the Gogo Formation of the Kimberleys contains one of the richest and best-preserved assemblages of Devonian fish ever found. The fine-grained calcareous nodules must be slowly etched away with dilute acids, as in the Murrumbidgee material mentioned above, to reveal the enclosed skeletal remains. With skilful handling, entire headshields of these 350 million year old fish are being extracted from the rock. So perfect is the preservation that the clean and comparatively uncrushed bones reveal even the most minute details under microscopic examination. Although the preparation and study of this material will occupy a team of specialists in Britain for years to come, the nodules

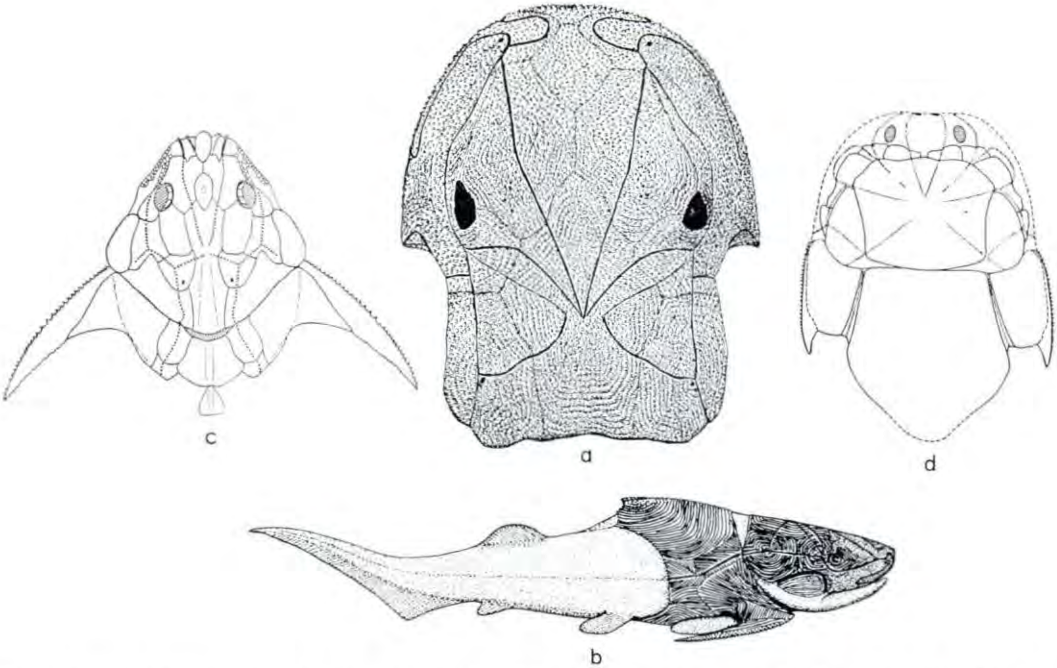


Figure 2.—(a) Reconstruction of the headshield of a new genus of Devonian fish from the Mulga Downs Group, northwestern New South Wales (x five-sixths). The solid lines are grooves for the sensory canals, the faint lines are the boundaries of individual plates forming the headshield. (b) An attempted reconstruction of the whole fish, in lateral view, with the unarmoured parts (not preserved) lightly shaded. (c) The head and trunk armour of *Lunaspis*, a Lower Devonian petalichthyid from Europe, in dorsal view. (d) *Phyllolepis*, a specialized flattened arthrodire from the Upper Devonian of North America, Greenland, Europe, and Australia. The front and lateral margins of the head are unarmoured.

which have been processed to date have yielded a variety of placoderms (both arthrodires and antiarchs), actinopterygians and sarcopterygians (lungfish, rhipidistians, and even a coelacanth). A proportion of this material will eventually be returned to Australia.

**Rich sediments in western N.S.W.**

On the other side of the continent rich fish-bearing sediments have been discovered in the Devonian of western N.S.W. The initial discovery was made by J. Spence in 1956 northwest of Cobar and in 1960–61 Dr E. O. Rayner and Mr H. O. Fletcher, then Curator of Fossils at the Australian Museum, collected a considerable quantity of disarticulated placoderm remains from horizons towards the base of the Mulga Downs Formation. The Mulga Downs Formation, a thick sequence of predominantly sandstone deposits laid down in freshwater lakes and rivers, outcrops intermittently over a very large area both east and west of the River Darling. The underlying beds, the Amphitheatre Group, are marine sediments dated as lower Devonian by the brachiopods, molluscs, and trilobites which they contain. The fish remains provide the only real clue to the age of the Mulga Downs beds, and Dr T. Ørvig, Stockholm, from photographs, provisionally identified antiarchs and arthrodires, some of which appeared to be new. (Fletcher, 1964, pp. 285–286). Many of the plates bore an ornamentation characteristic of a specialized arthrodire called *Phyllolepis* (fig. 2d) which occurs elsewhere in Australia and in Europe and Greenland in association with the antiarch *Bothriolepis;* these "phyllolepid" plates indicated a late Upper Devonian (or Famennian) age for the Mulga Downs Formation. Other fragmentary fish remains were described from the Mulga Downs Formation by Rade (1964) from Mt Jack Station, about 100 miles west of the Dunlops Range localities. Rade identified the arthrodires *Groenlandaspis*, *Holonema*, and *Phyllolepis* and the acanthodian *Striacanthus*, an assemblage which appeared to confirm the late Upper Devonian age suggested by Ørvig.

In August, 1968, the writer, accompanied by Mr K. Gregg, of the Australian Museum, began an intensive search for fish remains in the area visited by Rayner and Fletcher—the Dunlops Range—and recovered a large quantity of rich, fish-bearing material, including numerous headshields and disarticulated trunk armour units which must represent the remains of many hundreds of individual fish. With the exception of occasional acanthodian spines, most of the fossils are from placoderm fish, disarticulated, current-sorted and preserved as external impressions in the fine-grained sandstones. The arthrodiran genera present are all new to science, and most of them are characterized by a rather long and high trunk armour shield with prominent postero-laterally directed spines on either side. This type of trunk armour is found in a group of arthrodires called the arctolepids, which are most abundant in Lower Devonian sediments, locally common in the Middle Devonian, and rather rare in the early Upper Devonian. The most abundant remains from all the fish-bed exposures in the Mulga Downs Formation belong to a new genus of arthrodire (front cover and fig. 2a, b) whose plates have an ornamentation superficially resembling that of the late Devonian genus, *Phyllolepis*. With much more complete material than was available to Ørvig and Rade, it can now be shown that this form is so distinctive in many features of the head armour, especially, that any relationship with *Phyllolepis* is a distant one. The trunk armour is basically similar to that of the arctolepid arthrodires and especially close to a form known as *Bryantolepis* from the Lower Devonian of North America. While this material was being prepared and studied Miss J. Gilbert-Tomlinson, Federal Bureau of Mineral Resources, made available (1969) some fish remains collected by American Overseas Petroleum geologists to the east of Mt Jack Station, the same general area where Rade obtained his material. A comparison of the Dunlops Range and Mt Jack specimens revealed that both included the same new genera, and possibly even the same species, of arthrodiran fish.

## Additional localities

A second trip to the area in October, 1968, led first to the location of additional and very productive localities in the Dunlops Range and later to the discovery of a considerable quantity of well-preserved fish-remains in the vicinity of Mt Jack. The latter correspond to those described by Rade (1964) but are more complete, revealing that his identifications are incorrect and that the age deduced from them for the Mulga Downs Formation is also suspect.

Figure 3.—Headshield of a small arctolepid arthrodire from the Devonian Mulga Downs Group of northwestern New South Wales (x 2). Dorsal view, showing laterally directed orbits and deeply incised grooves for sensory canals. (For reconstruction of the trunk armour of the same genus, see fig. 4).

One of the most spectacular finds was an entire headshield (front cover and fig. 2a) of the new genus whose remains form the largest proportion of the fossils. The small orbits are laterally directed and the armour displays a distinctive ornamentation of ridges towards the back and small tubercles over the snout and sides. The changes in ornamentation enable one to trace the junctions of the component plates. Most of these bony plates are crossed by one or more deeply incised grooves which once housed the sensory canals in the living animal. Four pairs of these canals converge towards the back of the head and there are long sinuous branches running forwards beneath the orbits and over the snout and cheek areas. The latter canals display a much more highly specialized condition than one normally finds in arthrodires. Despite the similarity of the trunk armour (fig. 2b) to that of the arctolepids, the headshield is so different that this form from N.S.W. must be placed in a new suborder of the Arctolepida. In several respects the structure and pattern of the head resemble those present in petalichthyid arthrodires, a very specialized group of Devonian placoderms (cf. *Lunaspis*, fig. 2c) whose affinities are uncertain. The new genus displays a condition from which the petalichthyid head might have been derived. There still remains the possibility that it was related to the flattened and very specialized *Phyllolepis* (fig. 2d), for which it was at first mistaken. The genus *Phyllolepis* appears rather suddenly in the late Upper Devonian and its derivation is still uncertain. Although it has lost most of the bony plates around the orbits and the margins of the head, the large median plate which forms the bulk of the headshield still preserves four pairs of converging sensory canals, not unlike those in the Mt Jack specimen (fig. 2a). The latter form, which is being described more fully elsewhere (and which will be called *Wuttagoonaspis* gen. nov. after the property on which it was first discovered), provides us with a plausible ancestral condition from which it would not be too difficult to derive the phyllolepid pattern.

Although *Wuttagoonaspis* gen. nov. is of great evolutionary interest its very uniqueness makes it less useful as a stratigraphic indicator—at least until all the other Australian Devonian outcrops have been thoroughly searched. The fact that so many arctolepid or arctolepid-like forms occur in the Mulga Downs Formation suggests that the age is unlikely to be later than the Middle Devonian and may even be as early as late Lower Devonian. The best evidence in support of this view is provided by an interesting little arctolepid arthrodire whose remains occur at Mt Jack and at several of the Dunlops Range localities. They are especially common in blocks of creamy sandstone excavated to form the dam of a water tank on Mt Grenfell station. Headshields are extremely rare (fig. 3) but the trunk armour units are numerous, complete, and essentially uncrushed (fig. 4a–f). They are triangular in section, with a flat base and a sharp dorsal crest, and the postero-lateral corners are furnished with well-developed spinous projections, behind which were attached the small pectoral fins. Nothing comparable has previously been

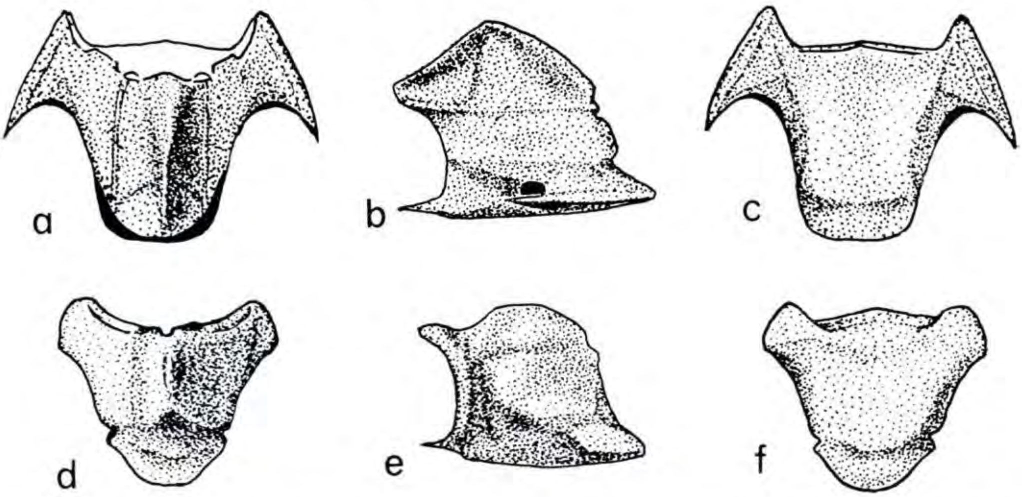


Figure 4.—Dorsal, lateral, and ventral views of the trunk armour of a small arctolepid arthrodire from the Middle (?) Devonian of northwestern New South Wales (x 1). (a–c) reconstruction of external surface. (d–f) internal mould, sediment infilling left after bone has weathered away. (For head armour of the same genus see fig. 3.)

recorded from Australia—or even from the Southern Hemisphere. To find closely related genera we must look to North America, Europe, and Spitsbergen, and there, especially in Spitsbergen, the Lower and early Middle Devonian sediments have produced a wide variety of these small arctolepids. The Spitsbergen genera showing the closest resemblance to the Australian form are *Huginaspis*, *Heterogaspis*, and *Arctolepis*, which occur in the lower part of the Middle Devonian (Eifelian). It seems certain, therefore, that the lower part of the Mulga Downs Formation at least is of a similar age, and not from the late Upper Devonian as had originally been thought.

**Findings of industrial importance**

It follows that there was not a long time-interval between the deposition of the marine Amphitheatre Group (Lower Devonian) and the continental Mulga Downs Formation which followed. Although at first sight such findings may appear to be of minor importance and of interest to a few specialists, this is not the case. Companies seeking natural resources such as oil, natural gas, or mineral deposits require accurate data on the rocks which they are prospecting, and fossils provide such data. Thus it happens that a piece of pure scientific research by Scandinavian palaeontologists in the 1920's on small Devonian fish from Spitsbergen has enabled us, in the 1960's, to accurately date for the first time a very large area of sedimentary deposits in western N.S.W.

Studies on vertebrate and other fossils also provide evidence to support the now widely-accepted theory that the earth's continental masses were once closely associated and that they have drifted to their present positions over a considerable span of geological time. If the southern continents are reassembled as they must have been over 200 million years ago we find that southeast Australia and Victoria Land in Antarctica may have been in close proximity. There is an exciting possibility that the study of vertebrate fossils may help to confirm this in the near future. Devonian fish remains were first collected from Victoria Land in 1911–12 and additional material was recovered by New Zealand members of the Trans-Antarctic Expedition in 1955–58. During the 1968–69 summer season New Zealand field parties returned to the area and succeeded in locating rich deposits of fish remains in situ. Although they had to sledge in and out of the area, they managed to bring back about 500 pounds of fossil material; however, several fine specimens had to be left behind for future parties to extract, through lack of suitable equipment. This material of Devonian vertebrates, recovered at considerable expense and effort, is to be prepared and studied in the Australian Museum, and since it represents by far the richest concentration of vertebrate remains ever discovered in Antarctica the findings will be of vital significance to workers in many fields all over the world, and may lead to accurate correlation between Australian and Antarctic successions.

[*The map and diagrams in this article are by the author; the photo is by C. V. Turner.*]


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# *BOOK REVIEW*

**KU-RING-GAI CHASE NATIONAL PARK, by Douglass Baglin and Barbara Mullins. Horwitz Publications Inc. Pty Ltd, North Sydney. Price $1.**

This excellent booklet serves as a fine introduction to the beauty and natural history of not only Ku-Ring-Gai Chase National Park, but also of the Hawkesbury sandstone country north and south of Sydney. It will serve as a guide to the uninitiated, and is a good choice for introducing the "Australian bush" to friends and relatives overseas. The balance between word and picture is good and the text is sufficiently informative not to insult the reader's intelligence. The photography and printing generally are of high quality—though a couple of the mammal shots look a bit posed. I am particularly impressed by the effectiveness with which natural history subjects have been blended with human activities to provide a graphic picture of this unique park.—H. F. Recher.

# FIRE-STICK FARMING

By RHYS JONES
Research Fellow, Department of Prehistory, Australian National University, Canberra, A.C.T.

IN recent years there has been increasing interest in the effect of man on the Australian environment. Forests have been bulldozed, swamps drained, heaths sown with trace elements, beaches chewed up, and the litter of the mid-twentieth century spread everywhere. That this is deeply affecting the countryside is obvious to all and causes concern to some. G. P. Marsh saw the same thing happening to the face of America during the last century, and doubtless the Roman intelligentsia of the rich provinces of North Africa gave the matter some thought as the wheatfields around their villas turned slowly into desert.

In most discussions a contrast is made between a "natural" environment as opposed to an "artificial" one. We imply that the former represents the climax without the effects of man, and as examples of it we think of bushland around our cities, the national parks, and remote areas. We imagine that the country seen by the first colonists before they ringbarked their first tree was "natural". But was it?

Mannalargenna, an Aborigine from the east coast of Tasmania, holding a burning fire-stick. [Watercolour painting by T. Bock, in the National Library, Canberra.]

**Antiquity of man in Australia**

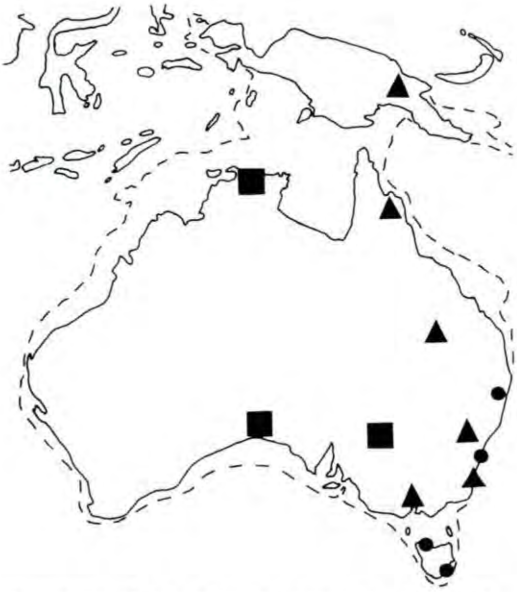
The white man has been on this continent for 200 years in some places and less so in most others. Before he arrived, the continent had been colonized, exploited, and moulded by other men—the Australian Aborigines and their ancestors for tens of thousands of years.

Australian archaeology, in a decade's exciting research, has produced sequences of man's activities back into the Pleistocene in many places. The accompanying map summarizes our present knowledge of man's antiquity in various parts of the continent; it can be seen that by 20,000 to 30,000 years ago he had colonized and extended his range throughout the inland plains of Australia and by 20,000 years ago had reached the southeastern coast.

For a long time there has been a tendency to regard the Aborigines, like most other hunters and gatherers the world over, as passive slaves of the environment, in contrast to the impact of agricultural or industrial man, who is seen as the master of nature, the initiator of ecological change. In recent years, however, the ecological effects of Aboriginal technology have been re-investigated, and work by anthropologists on the living culture and by biologists on the environment suggests that these were enormous. They are still shaping our lives, even in areas where the Aborigines have not roamed free for 100 years.

**Fire and the Aborigines**

Aboriginal man's ecological impact was mostly due to hunting, gathering of plants, and fire. By far the greatest effects were caused by the use of fire.



Summary of the present knowledge of man's antiquity in Australasia: squares indicate carbon dates between 21,000 and 30,000 years ago, triangles between 11,000 and 20,000 years ago, and circles between 5,000 and 10,000 years ago. The broken line represents the 100-fathom line which would have been the approximate coastline more than 10,000 years ago. [Map by the author.]

A study of Australian ethnographic literature will show that bushfires were systematically and universally lit by the Aborigines all over the continent. Explorers from Tasman onwards, seeing Australia from the sea, reported that the coastlines were dotted with fires. Peron, in 1802, sailing up the Derwent in southeast Tasmania, said that "wherever we turned our eyes, we beheld the forests on fire". When men explored inland, the entire horizon was often filled with smoke haze from Aboriginal fires, and anthropologists have reported regular seasonal firings over hundreds of thousands of square miles in central and tropical Australia.

**Tasmania**

In Tasmania it was customary for the Aborigines to carry their smouldering firesticks with them, and they set fire to the bush as they walked along. G. A. Robinson, who lived with them for the best part of 5 years, has hundreds of descriptions of their setting fire to the bush, of distant Aboriginal fires, and of large areas of countryside freshly burnt by them.

The ecological effects of these burnings have been studied by Tasmanian botanists, who can only account for the distribution of modern vegetation zones in Tasmania in terms of a long history of intensive Aboriginal fire pressure. Many factors are involved in the distribution, such as soil type and aspect and climatic change, but a long history of firing has reduced the *Notofagus*-dominated rainforest in many places through a mixed eucalypt/rainforest phase to scrub and, eventually, to sedgeland and heath. W. D. Jackson sees the coastal sedgeland of western Tasmania as having been largely formed and extended as a result of constant firing, and as such it is a human artefact.

In eastern Tasmania, firing produced and maintained the open savannah woodland or parkland which greeted the first colonists, with their flocks of sheep. Here and there are extensive, open, treeless areas or "plains" covered with *Poa* grassland. These plains have been formed by repeated firing, and once there was a dense mat of grass on the surface it would have been kept clear not only by man but also by the grazing of macropods, native hens, and other animals.

**Eastern New South Wales**

The savannah woodland, merging into open plains, characteristic of central and western New South Wales, is similar in many ways to that of eastern Tasmania and, again, has been heavily modified by Aboriginal burning. In 1848 Major Thomas Mitchell, the explorer, said with brilliant insight of these park woodlands:

"Fire, grass, kangaroos, and human inhabitants seem all dependant on each other for existence in Australia . . . Fire is necessary to burn the grass and form those open forests, in which we find the large forest kangaroo; the native applies that fire to the grass at certain seasons, in order that a young green crop may subsequently spring up and so attract and enable him to kill or take the kangaroo with nets. In summer, the burning of the long grass also discloses vermin, birds' nests, etc., on which the females and the children who chiefly burn the grass, feed. But for this simple process, the Australian woods had probably contained as thick a jungle as those of New Zealand or America instead of open forests."

**Arnhem Land**

Arnhem Land, like other areas of tropical Australia, has a marked seasonal climate with a wet and a dry season. The Aborigines organized their life according to this pattern, and the firing of the bush during the dry season was a decisive part of their economy. In 1853, a visitor to the short-lived British settlement of Port Essington commented: "About the middle of the dry season, the natives set fire to the grass which is abundant everywhere, and at that time quite dry . . . The conflagration spreads until the whole country as far as the eye can reach, is in a grand and brilliant illumination". The Aborigines still do this, and the role of firing in their total economy has been extensively studied. The fires spread rapidly through the tall dry grass to the bases of the trees, and their ecological effects are maintenance of the open parkland appearance and inhibition of the spread and abundance of non fire-resistant plants.

N.B. Tindale accounts for the presence of patches of eucalypt and open plains in the Cape York rainforest as, again, being due to Aboriginal firing.

**Why did Aborigines burn the bush?**

We can try to answer this question at several levels of sophistication:

● *For fun:* Anthropological friends of mine have asked Aborigines why they were tossing lighted matches into the bush from the back of land-rovers in which they were travelling. The answers have ranged from "it's fun" to "it's custom".

● *Signalling:* In the deserts, fires were used for signalling purposes either between bands or within them, so that the foraging people could know each other's whereabouts. In Tasmania, Aborigines tracked each other for peaceful or warlike purposes by fire spotting, and Robinson records women, abducted by sealers onto offshore islands, signalling to their kinsmen on the mainland by lighting great fires.

● *To clear the ground:* Both in western Tasmanian tea-tree scrub and in Arnhem Land grassland, the best way to clear a path is to set fire to the bush. This removes the undergrowth for easier travelling and also kills snakes and other vermin.

● *Hunting:* In many parts of Australia, a recognized method of hunting was to set fire to the bush and club or spear the animals which broke cover. Foraging over the burnt area also revealed animals such as lizards hiding in holes or burnt to death on the ground.

● *Regeneration of plant food:* After firing, the Australian bush shows remarkable powers of regeneration. Eucalypts throw out new leaves, and grasses grow afresh from the burnt ground. Many of the vegetable foods eaten by the Aborigines are more palatable when young—for example, ferns, bracken, grasses, leaves and shoots of trees. By promoting the regrowth of grasses and young trees, man also provides a food supply for grazing and browsing animals. Aborigines will return to a burnt area after rain in order to hunt the game drawn there by the young plants. This promotion of regrowth through firing is exactly the same process as that practised by modern farmers burning off the stubble in a wheatfield, or by Welsh hill shepherds burning off the mountainside each winter to kill the old bracken. In all cases, whatever the long-term effects may be, the immediate result of burning is to increase the quantity of edible plants for man and his beasts.

● *Extending man's habitat:* It is a thesis of mine that, through firing over thousands of years, Aboriginal man has managed to extend his natural habitat zone. In Tasmania, the climax vegetation along the western coast would be rainforest, which,

The east coast of Tasmania in 1802, showing smoke from Aborigines' bushfires. [Engraving after C. A. Lesueur, from the Nan Kivell Collection, National Library of Australia, Canberra.]

The bush immediately after an Aboriginal fire, northeastern Arnhem Land, 1967. Note the burnt grass, leaving a savannah, park-like distribution of trees. [Photo: Nicholas Peterson.]

according to distribution studies of the Aborigines, was not readily usable by them and was seldom penetrated. By burning, however, aided possibly by post-glacial climatic oscillations, man was able to push back this forest and replace it by sedgeland which is rich in both animal and plant food. In eastern Tasmania, human firing increased the extent of the mosaic pattern of open sclerophyll forest and grassland plains. This is the optimum habitat for some of the macropods, such as the Forester Kangaroo, and the plains provided extra food for the kangaroos, wallabies, emus, and native hens on which the Aborigines fed. Mitchell, in the passage quoted above, clearly understood the symbiotic nature of man, grassland, and kangaroos.

**Increased food supply**

It is interesting that, through firing, man may have increased his food supply and thus probably his population. At the most general level, firing of the bush, in the same way as clearing a forest to create a field, increased the proportion of solar energy per unit area of the ground that man could utilize.

Perhaps we should call what the Aborigines did "fire-stick farming".

Was this deliberate? In some cases, yes; in others, no. Robinson records that a park-like landscape in Tasmania had been formed so as to give cover for the kangaroos. "This has been done by the natives: when burning the underwood, they have beat out the fire in order to form these clumps", he writes. R. Gould reports that Aborigines in the desert are quite clear that burning will attract kangaroos once rain has fallen.

On the other hand some of the effects take thousands of years to become recognizable, and no primitive people could possibly document these processes. However, it is in some ways as irrelevant to me whether or not the ancient Aborigines knew what they were doing as it is to the palaeontologists whether or not the giraffe knew why his neck was growing. If we are interested in the operations of laws of nature, we have to analyse the effects of certain actions or physical changes and see whether they are advantageous or deleterious to the animal or culture involved. Taking a Darwinian line, according to the "principle of the survival of the fittest economy", to "explain" the acceptance and development of a cultural trait we have to show its adaptive value.

Firing, because of its great adaptive value to hunters and gatherers, became an integral part of the economy, and its presence throughout most of the hunting and gathering and agricultural economies of the world implies that it has a high antiquity and great importance in human evolution. Fire was man's first "extra-corporeal muscle". Let us not forget that the power released by the disastrous Hobart bushfire on 7th February, 1967, was equivalent to two atom bombs.

**Results of the removal of Aboriginal fire pressure**

Although fire has been an important factor in Australia for millions of years, natural fires being lit by lightning, etc., the arrival of Aboriginal man increased the fire frequency by an enormous amount. This produced and maintained disequilibriums, with the artificial extension of the range of pyrophytic plants. With the arrival of the Europeans, the Aborigines and their fire-sticks were promptly removed, and the effects of the cessation of regular burning were quickly noticed. Settlers in eastern Tasmania in the 1850's commented that open sclerophyll forest became littered with bark and young shoots, with the grass becoming sour and weak. On the open plains of Surrey Hills in highland north Tasmania, the shepherds were increasingly frustrated by the growth of scrub, which, by 1890, had obliterated most of the open land. The rainforest in Tasmania has spread from its gullies, and large areas of southwestern sedgeland have become covered with high, dense scrub.

In New South Wales, foresters have remarked that the maintenance of eucalypts on many high-quality sites depends on fire; otherwise, it would be replaced by other more tolerant genera. The resurgence of the cypress pine (*Callitris*) in western New South Wales may depend on the reduction of fire frequency. Some animals may have become adapted to a high fire regime and are more rare when this is reduced. It is interesting that Leadbeater's Possum, once thought to be almost extinct in Victoria, increased its numbers after several large fires had provided it with its preferred habitat.

In the dry sclerophyll forests of Tasmania, Jackson calculates, forest litter accumulates at the rate of 3 to 25 cwt per acre per year to a steady level of 30 tons per acre. Fires in these forests with full fuel complements become totally uncontrollable, with vast damage being done to plants, animals, and man. It is ironical that a policy of fire prevention may have brought our bush and forests up to their present dangerous state, and the series of catastrophic fires in recent years may be the result of discontinuing the Aboriginal custom of regular burning. I have been interested in recent weeks to read that a policy of burning-off may be initiated as a new method of forest conservation.

**Fire and conservation**

I am no botanist and would not venture a discussion on the long-term effects on plants and soil of firing or non-firing. However, as an anthropologist, I can state that at the time of ethnographic contact with the Aborigines, and probably for tens of thousands of years before, fires were systematically lit by Aborigines and were an integral part of their economy.

What do we want to conserve? We have a choice. Do we want to conserve the environment as it was in 1788, or do we yearn for an environment without man, as it might have been 30,000 or more years ago?

If the former, then we must do what the Aborigines did and burn at regular intervals under controlled conditions. The days of "fire-stick farming" may not yet be over.

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Excavations in progress at Nebira, Central Papua, last year. The Eriama ridge, where additional sites will be excavated this year, can be seen in the upper left distance. [Photo: Author.]

# *Recent Archaeological Discoveries in Central Papua*

By SUSAN BULMER
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IT has long been known, largely through accidentally found sites and objects, that coastal areas of mainland New Guinea have great archaeological potential. For instance, in 1907 some remarkable village mounds were discovered at Rainu village, near the coast at Collingwood Bay, Northern Papua, during the construction of a mission building. Reports of other sites from many parts of the country have followed, either through the fieldwork of amateur or professional archaeologists or through the interest of various members of the public. The Papua-New Guinea Public Museum and Art Gallery is filing the various site reports for archaeologists to use during their fieldwork, and recently engaged an Australian archaeologist, Mr G. Pretty, to spend some weeks looking into the state of preservation of some of the sites reported. However, detailed fieldwork in lowland archaeology began only last year in two regions: Collingwood Bay, where Mr Brian Egloff, a research scholar at the Australian National University, is now in the field, and in the Port Moresby area, where the author is now resident and engaged in a long-term project of archaeological research.

At this stage it is not possible to answer many specific questions about the prehistoric past of lowland New Guinea, although a number of general remarks can be made. For instance, because radio-carbon dating suggests that some prehistoric sites in northern Australia were occupied over 20,000 years ago, it can be assumed that parts of lowland mainland New Guinea have been settled by humans for a similar period of time. New Guinea and Australia became separated only between 5,000 and 8,000 years ago, when the drowning of Torres Strait is thought to have occurred. The early inhabitants of lowland New Guinea were undoubtedly hunters and collectors of the natural produce of the seashore, forest, and grassland. At a later period, perhaps soon after the drowning of Torres Strait, gardening and pig-raising people settled in parts of coastal New Guinea. Some of these later people were potters, and the various styles of modern pottery suggest that several pottery traditions were brought to New Guinea from different parts of Indonesia and eastern Asia. The variety of pottery present in New Guinea, together with the variations of language and other cultural features, suggest that the immigrants themselves may have come from a number of different areas, but we know too little about the archaeology of New Guinea at present to point to specific places of origin.

Beyond these sorts of general statements, remarks at present must be limited to a restricted range of evidence and to the small areas in which work is now in progress. In this article we will be concerned with the new evidence coming to hand about the prehistory of the Port Moresby area.

### Armchair archaeology

The Port Moresby area is rich in written records about the local people and their way of life from the 1870's, when the first missionaries settled there. These throw considerable light on the most recent prehistoric peoples, although the effects of European contact must be untangled from the record. A number of villages of people speaking a single language, Motu, were found along the coast between Manumanu, some 45 miles to the west of Port Moresby, to Kapakapa, about 40 miles to the east. These people were fishermen and traders, living in pile houses on the beach or some distance out in protected lagoons. The inland people, the Koita, spoke an unrelated language and lived either in hamlets in the coastal hills or in coastal villages, either with the Motu people or in their own communities. The Koita occupied the lowlands from the beach to the Laloki River, dwelling inland mainly in the hunting season.

The anthropological and historical records of the Motu and Koita people give general and specific clues to the archaeologist in material culture, such as ornaments, tools, and weapons, and in the search for prehistoric sites. There are also other approaches which give clues to the prehistoric past; the study of land forms and change, vegetation, and animal life, for instance, are essential to understanding the remains left by prehistoric peoples.

In the case of the Port Moresby area, the coastal plains are not tropical, but mainly short-grass savannah country, meaning that hunting peoples could make a living there, particularly when sufficient lowland forest was available for food collecting. Only remnant patches of forest exist now, on steep slopes or by river courses. Gardening in the usual range of Oceanian crops is out of the question for much of the year. As a result of the accident of the direction of the prevailing winds being parallel with the mountain ranges, the area receives very little rainfall in comparison with most of New Guinea, and most of the rainfall is in the season from December to through April. During the wet season good crops can be grown, but, except in small pockets in the coastal hills with good ground water and near the permanent watercourses, during the rest of the year staple goods must be obtained through trade. Rich fishing and seafood collecting were available for much of the year along the coast at Port Moresby, and for a 2-month or 3-month season the Koita hunted and smoked large quantities of wallaby, which they traded to the Motu and other neighbours.

The Motu filled this unusual ecological niche by specializing in the manufacture of pottery and small shell-bead valuables. During the wet season the Motu men travelled in many-hulled canoes to trade with peoples of the Papuan Gulf, exchanging pots and other goods for huge quantities of sago with which to return to the Port Moresby area.

### Surveying archaeological sites

In order to move back in time and discover something about the earlier peoples of the


Plate A.—Surface finds from Nebira, Central Papua. Pottery sherds with red slip and burnished surface. The incised decoration is filled in with lime. [Photo: C. Schollum.]

Port Moresby area, and to make some informed guesses about the past history of the Motu and Koita peoples, it is necessary to look into the evidence in the ground of their settlement. If there has been settlement of a fairly large community, such as has occurred on some beaches in Central Papua, a site may consist of a thick accumulation of broken pottery and other domestic rubbish which is obvious to almost any eyes. If settlement was in smaller numbers, or if the residence sites were relocated frequently, the accumulation may be smaller in volume, but is certainly not less important in reconstructing the prehistoric past. If the dwelling has been confined to a small space, such as under a rock overhang, the rubbish left by human occupation may be deeper than when a dwelling is in the open.

The discovery of archaeological sites is often a matter of sheer luck, but it isn't usually the archaeologist that has the luck; excavation for a house site, clearing for a road, or even mining and quarrying work, commonly lead to the discovery of prehistoric sites. For this reason archaeologists are greatly dependent on people who know the land better, either New Guineans or expatriates from other countries who happen to have lived there longer or been around more. For instance, Mr W. E. Tomasetti, a former officer in the Department of District Services for many years, and now Dean of Students at the University of Papua and New Guinea, is one of New Guinea's most active amateur archaeologists. As an officer in a number of Districts he learned of many remarkable archaeological sites and referred them to interested archaeologists. These sites include Kiowa (Eastern Highlands District), excavated by the author in 1960; Kosipe (Central District), excavated by Dr J. P. White, now of the Australian Museum; and Nebira (Central Papua), where the author is now working.

The other way to find sites, generally a technique which has to supplement the first accidentally discovered sites or objects, is to systematically comb a particular area of land, using all cultural and geographical clues to record as large a number and as wide a range of sites and information as possible. This can give some indication of how representative single sites or finds are. At the present state of the survey of the Port Moresby area, for operational purposes an area of about 24 square miles, about 50 sites have been visited or recorded, although many more have yet to be looked into. A number of Port Moresby residents have given assistance in assembling this site information, not only searching their memories but also reporting new observations. I am particularly grateful in this respect to Mr Roy McKay, Preparator-in-Charge at the Papua-New Guinea Museum, who has taken a great interest in prehistoric sites and finds.

Two specific survey projects are planned for 1969: the combing of the coastal hills for further sites, and further exploration in the vicinity of the inland lowland Laloki River. These are two areas where historical accounts indicate very little settlement in the late 19th century, although a substantial number of prehistoric settlement sites have already been found.

**Pottery collections**

One of the commonest elements of the rubbish tips of prehistoric settlements in Central Papua is broken pottery. This is good fortune in terms of general Pacific archaeology, for other objects made of durable materials are far less common in open sites, although stone and bone rubbish is sometimes of great proportions in rock shelter camps. Although pottery cannot in itself provide much information about daily life in prehistoric times (unless, of course, its decoration includes scenes of daily life, which is not the case in Pacific pottery), it is very useful in comparing or linking peoples of different areas, as well as in measuring change within a particular people, for pottery decoration styles and shapes change over time and between communities. It is also easy to spot potsherds on the ground, once one's eyes are focussed to this task, and this can lead to the discovery of many new dwelling sites.

As was mentioned above, the Motu-speaking peoples of the Port Moresby area made their living largely through pottery manufacture. The main form of pot, an undecorated globular pot with a wide everted "collar" rim, was the form traded to the Gulf peoples. This pot was used both for cooking and for storage of water and sago. From the historical records the rim varied from a rolled form to vertical spouts, but the general form was very consistent. For serving food, the Motu also made open round bowls of various sizes, which commonly had a thickened outer rim with a narrow band of incised geometric designs.

It soon became apparent during field surveying that a far greater range of pot shapes and decoration than had been reported for the Motu potters was present on many sites around Port Moresby. Large collections from various sites have been made, and the collection is continuing, the intention being to see if a similar range of pots was in use throughout the district or if different communities used a different range. Some of the newly recorded kinds of decoration are shown in plates A–C. One painted sherd, a striped piece similar to the two in the lower right hand corner of plate B, has previously been reported from Daugo Island, and Mr Ronald Lampert, of the Australian National University, has collected sherds similar to those in plate A from the same location. Other sherds, not illustrated here, are similar to a collection made at Rainu, Collingwood Bay, and reported by Seligmann and Joyce (see reading list below). A number of studies of prehistoric and modern pottery from New Guinea are now being made by archaeologists from the Australian National University, and the findings of their studies should cast some light on the position of the pottery of Central Papua.

**Excavations**

Largely as a result of the rich collections of pottery and an initial survey of the historical literature, excavations were begun at Nebira, a large open settlement site near the Laloki River, about 8 miles from the sea. This site, known in some local traditions as the location of Koma, the foundation village of the Eastern Koita people (see C. G. Seligmann, page 41 in the book mentioned in the reading list below), covers most of a hill of about 21 acres and over 400 feet high.


Plate B.—Surface finds from a site near Boera village, Central Papua: red-painted decoration on flaring "collar" rims. [Photo: C. Schollum.]


Plate C.—These pottery sherds, with dentate stamp decoration in geometric patterns, are surface finds from Nebira, Central Papua. [Photo: C. Schollum.]

Much of the hill is heavily eroded, and quarrying for metal is proceeding at one end, but much of the site is available for archaeological investigation, including a deep stratified scree slope at the base of the hill. Fortunately, quarrying is not likely to affect much of the suitable portions of the site for some time.

During the 1968 season grid excavations were begun in a saddle area between the two main peaks of the hill, about 300 feet above the river. The finds include the remains of a pile house with associated burials, two midden layers into which further burials were dug, and a final, most recent, midden layer containing mainly Motu-type pots. This deposit was covered with stratified sandy soil identical to the soil at present found with the short-grass vegetation at Nebira, indicating a considerable period since the site was last occupied. The two early midden layers contain a range of pottery quite different from the recent Motu, including painted pottery and incised ware similar to that illustrated in plates A and B. However, most of the finds from the first season's excavations have not been cleaned and processed, and therefore no firm conclusions can yet be drawn. The earlier midden layers also contain shell and bone refuse and a rich chert tool industry. Associated with some of the burials are ornaments—incised long-bone beads, shells, pig tusks, and dog's teeth.

During 1969 excavations will continue at Nebira and trial excavations will be begun at rock-shelters on a nearby lowland ridge, Eriama. There are also open settlement areas at Eriama, in proximity to these rock-shelters, which contain a similar range of pottery to that found at Nebira. It is hoped that these shelter sites may provide a different range of finds to be associated with or contrasted to those from the open settlements. Finally, it is hoped to investigate a site on the nearby river flats, probably during the 1970 season.

Many questions can now be asked, but not yet answered. For instance, does the similarity of the early pottery in Port Moresby and Collingwood Bay mean that these two areas were occupied by related peoples, or was one area settled from the other? Who were the earlier people living in the Port Moresby area? Were they just Motu people making a different kind of pottery, or were they another earlier people? Who were the people living inland near the Laloki River? Were they ancestors of the Koita peoples, and were they potters?

If the present programme of archaeological work in the Port Moresby area can be carried out, some sequence of the prehistoric settlement in this small area may be understood. But New Guinea is a vast country, and it is to be hoped that many more archaeologists will become interested in the lowland area and that many more members of the public will assist them by collecting information about suitable sites and interesting finds. The task of unravelling New Guinea's lowland prehistory is an enormous one.

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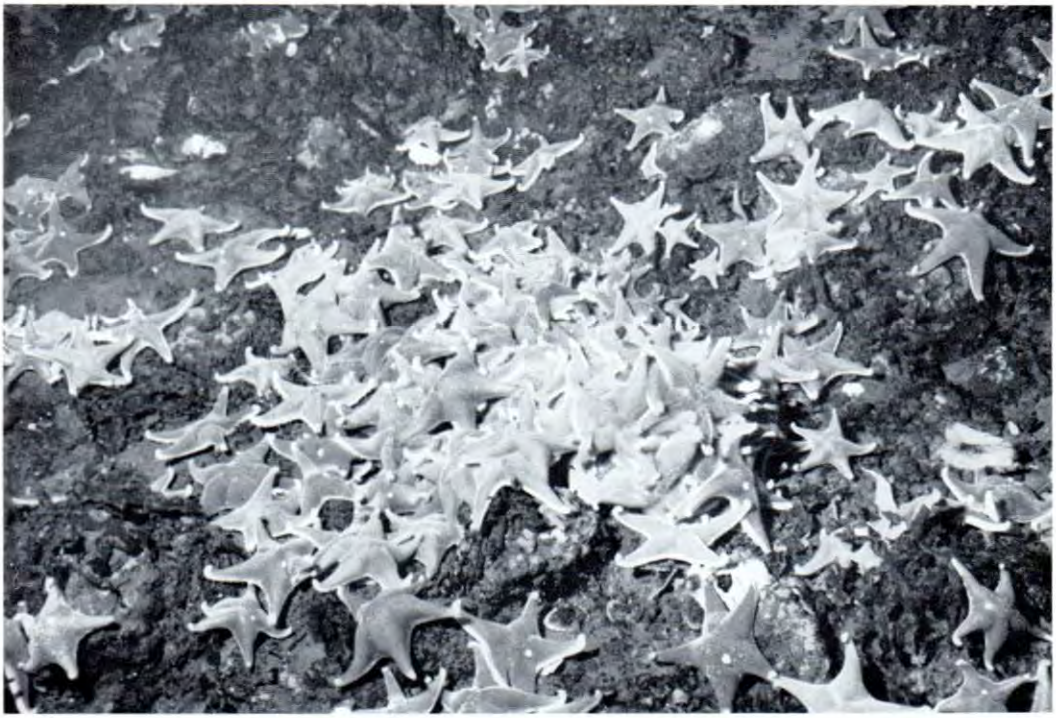

Specimens of the sea star *Odontaster validus* on the sea floor at Cape Evans, McMurdo Sound, Antarctica. According to the photographer, one animal in the middle of the large clump of stars was feeding on a small heart urchin, *Abatus;* apparently the other stars were attracted by materials escaping from the partly digested heart urchin. A sea urchin, *Sterechinus neumayeri*, can be seen rather faintly in the top left-hand corner. [Photographed at 75 feet on 28th November, 1967, by Paul K. Dayton.]

# *Antarctic Sea Star*

**By JOHN S. PEARSE**

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ANYONE who peers out over the shallow sea floor of McMurdo Sound, Antarctica, either through cracks and holes in the sea ice or while diving, is bound to be impressed by the abundance of small reddish sea stars. They are everywhere. Meat-baited traps invariably collect large numbers of these little animals. René Koehler, who had many specimens in his collections from the First French Antarctic Expedition, described them in 1906 as *Odontaster validus*. They have been present, often in very large numbers, in the collections of virtually every other expedition to the Antarctic. Certainly they are among the most abundant animals in shallow Antarctic seas. This article summarizes what is known at present of this characteristic animal of the Antarctic coasts as revealed mainly by studies in McMurdo Sound.

### Systematics and distribution

*O. validus* belongs to a small (5 genera, 26 species) phanerozonid family, Odontasteridae, that is characterized by the presence of prominent "teeth" (hence the family name) around the mouth. The family is found mainly in colder waters of the Southern

Hemisphere. All seven species of the genus *Acondontaster* are found in Antarctic waters and only one (or two) of these also occurs northward off southern South America. Two species of the genus *Asterodon* occur off southern South America, while three others occur off New Zealand. The single species of the genus *Eurygonias* also occurs off New Zealand. *Odontaster* is the largest genus and has a much wider distribution. *O. validus* is restricted to the Antarctic, while a second species is Antarctic and sub-antarctic in occurrence. A single species each occurs off southern South America, South Africa, and New Zealand, while another is known from a single south Atlantic abyssal record. In the Northern Hemisphere, one species of *Odontaster* occurs at bathyl depths off western North America, three others occur off eastern North America, and a fourth occurs off Europe. A final rare species of questionable status, *Hoplaster spinosus*, has been taken from the abyssal floor of the Bay of Biscay.

The disjunct distribution of the Southern and Northern Hemisphere species of *Odontaster* is puzzling. Moreover, if a fossil of Jurassic Age is a specimen of *Odontaster*, as reported by Professor H. B. Fell, it is remarkable that such an old genus could be so successful in cold southern waters while being completely absent from the Arctic.

*O. validus* ranges around the Antarctic continent and extends as far north as South Georgia and Bouvet Islands. It has not been recorded from the Falkland Islands nor the Patagonian Shelf. Such a distribution suggests that it is highly stenothermal and is restricted to water temperatures between about —2° and +2° C. Its vertical distribution extends from the water's edge to at least 914 metres depth.

**Anatomy**

*O. validus* is a "cushion" star and, as such, has a thin, soft integument with relatively widely scattered small ossicles. It is not a large sea star, averaging about 25 grammes wet weight and 70 millimetres arm-length. The abactinal (aboral) ossicles carry clusters of spines on small stalks (paxillae) that give the star a soft velvety appearance. A single white madreporite is conspicuous. The small inconspicuous marginal ossicles are unusual for a phanerozonid sea star. Almost all

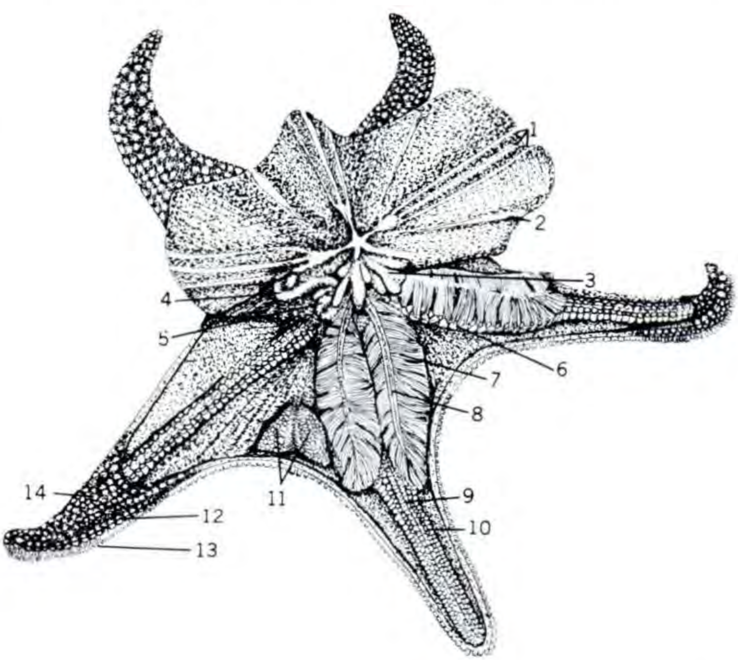


Diagram of anatomy of *O. validus*. The abactinal body wall has been folded back and the gonads of the left and right interradii and the pyloric caeca of the left radius removed. (1) radial muscles and mesentery attachments. (2) Interradial mesentery attachment. (3) Intestinal caeca. (4) Stone canal. (5) Cardiac stomach pouch on capitula of first ambulacral ossicle. (6) Tiedemann's pouch. (7) Folds of pyloric caecum. (8) Median duct of pyloric caecum and radial mesentery attachments. (9) Ambulacral ossicles. (10) Twin ampullae of tubefeet. (11) Gonads. (12) Marginal ossicles. (13) Actinal spines. (14) Abactinal paxillae. [Drawn by Kathleen T. Pearse.]

specimens of *O. validus* have five short arms that are joined broadly at the base to give a "bat" star appearance. Rarely, four-armed or six-armed specimens turn up in collections, these apparently being growth abnormalities rather than results of injury. Regeneration of arms, in fact, does not seem to occur.

The internal anatomy of *O. validus* is similar to that of other sea stars (see diagram). The eversible cardiac stomach is anchored by stout cords to unusually large capitula of the first ambulacrals. Simple folded pyloric caeca have well developed Tiedemann's pouches along their oral sides. The intestinal (rectal) caeca are also well developed. These two structures, Tiedemann's pouches and intestinal caeca, seem to be best developed in sea stars that employ a ciliary-mucoid type of feeding. A pair of lobular gonads are located in the angles between each arm, and separate gonoducts connect each gonad to gonopores located on the edge of the abactinal surface. The thin abactinal body wall is strengthened by prominent muscle bundles that radiate from a central point near the anus.

**Food, feeding, and nutrient stores**

Specimens of *O. validus* seem to be rather unselective omnivores that feed mainly on bottom detritus. Their attraction to seal, beef, or fish meat in traps suggests that they can also be scavengers. Moreover, specimens have been collected with their cardiac stomachs everted around sea urchins, amphipods, and shrimp. They also often clump around, and feed upon, seal faeces, making one wonder what they would not eat!

Detritus and small invertebrates such as crustaceans and snails are commonly found in their stomachs. In the summer numerous diatoms are also often present in their stomachs. These small food materials are almost always enmeshed in masses of mucus. The mucus is probably secreted by the everted cardiac stomach where it can entangle small food particles. The mucus-food mass then passes through the mouth and into the pyloric caeca along the Tiedemann's pouches to be sorted and digested.

The pyloric caeca are the main digestive and nutrient storage organs of sea stars. On a dry weight basis, pyloric caecal lipid and carbohydrate content in *O. validus* ranges from about 15-25 per cent and 2-12 per cent, respectively. In areas of high plant production, such as at Cape Evans in McMurdo Sound, the pyloric caeca nearly double their size during the summer when they accumulate these stores. Carbohydrate content (mainly polysaccharide), in particular, increases by nearly 500 per cent. Accompanying these increases, there is an accumulation of chlorophyll derivatives that give the pyloric caeca a deep-green tinge. The size of the pyloric caeca, and the amount of their accumulated stores, decrease during the winter after diatom production has ceased.

Little seasonal change occurs in pyloric caeca size or composition in areas where summer benthic diatom production is relatively low, such as near the ice-locked southern end of McMurdo Sound. Moreover, there is little trace of green chlorophyll derivatives in the pyloric caeca. Animals in these areas have a pale coloration in marked contrast to the deep red and orange colours of the animals feeding on heavy diatom concentrations. The red and orange colours are likely to be due to carotinoids of plant origin. Specimens of *O. validus* have never been collected from under the permanent ice cover of the Ross Ice Shelf south of McMurdo Sound; perhaps some plant food is necessary for the maintenance of the populations.

**Reproduction**

The sexes of *O. validus* are separate. Spawning occurs only during the winter months between late May and mid-September in McMurdo Sound. Spawn-out seems to be gradual because the gonads slowly decrease in size. Gametogenesis begins some 18 months to 2 years prior to spawning, and the gametogenic cycles overlap so that gametes destined to be spawned for two or three successive annual spawning periods can always be found in the gonads. In full-grown females two or three discrete size classes of oocytes, representing year classes, are always present.

The beginning of oocyte growth occurs primarily in the summer months, and, during the first year of oogenesis, many more oocytes are formed than actually complete growth. About 20 per cent of the oocytes grow rapidly to full size during the second year, while the remainder disintegrate. The ovaries (and testes) of *O. validus*, unlike those of sea urchins and some other sea stars, contain very few non-gametogenic "nurse" cells; apparently many oocytes act as nutrient cells for other growing oocytes.

The sizes of the gonads vary seasonally, increasing during the summer when gametogenesis seems most active, and decreasing during the winter spawn-out period. The gonads, like the pyloric caeca, are usually much larger in areas of high diatom production than in areas of lower production (Cape Evans as contrasted with McMurdo Station in McMurdo Sound), so that the amount of gametes produced seems directly proportional to the abundance of food.

Although total gamete production is related to the amount of food present, the timing of both gametogenesis and spawning is very similar among different populations in McMurdo Sound. Moreover, oocyte size classes in gonadal samples taken from the Balleny Islands (66° S.), Robertson Bay (71° S.), and Hallet Station (72° S.) are nearly identical to comparable samples taken from McMurdo Sound (77° S.). This similarity over such a wide latitudinal range suggests that gametogenesis and spawning are synchronized in the species throughout its Antarctic distribution. Seasonal fluctuations of light and temperature differ markedly in these different areas, making it unlikely that such factors are important for synchronization. (The sun never sets for more than a day at the Balleny Islands, while it is below the horizon for 2½ months at McMurdo Sound.) The one seasonal change that seems to be similar in time throughout Antarctic waters is the period of phytoproduction; blooms occur fairly suddenly during the mid-summer months of November or December. Perhaps the marked seasonality of phytoproduction somehow directly synchronizes gamete production.

**Development**

As in most other sea stars, eggs and sperm are released free in the sea where fertilization takes place. Early embryology proceeds through stages that are typical of sea stars with "indirect" development. The eggs are about 0·1 millimetre in diameter and divide completely and equally to form a much convoluted hollow ball of cells. After about 7 days this convoluted blastula rounds out into a spherical blastula (coeloblastula), the fertilization membrane breaks down, and the embryo swims free. Gastrulation and later developmental stages proceed slowly; it is not until the second month after fertilization that a feeding early bipinnaria stage is reached. Further developmental stages are unknown.

The slow rate of early development is particularly notable. In fast developing sea stars, such as *Luidia savignyi* of the Red Sea (at about 30° C), gastrulation occurs in less than a day after fertilization and the bipinnaria is formed by the second day. Gastrulation occurs in the previously known slowest developing sea star, *Porania pulvillus* of Scotland (about 15° C), in 3 to 4 days after fertilization, and the bipinnaria develops in 7 to 10 days. Not only is the developmental rate of *O. validus* not temperature adapted, but the time to reach the bipinnaria is exceptionally slow. The slow rate of development of *O. validus* places the feeding larvae in the early summer when plant food is available, even though spawning occurs in mid-winter.

The behaviour of the embryos and larvae is also unusual; they remain close to the bottom of culture dishes. Moreover, they have never been collected in the plankton. Such behaviour suggests that they are mainly demersal in habit, and feed and develop while swimming close to the bottom. The feeding plutei larvae of the common Antarctic sea urchin, *Sterechinus neumayeri*, also probably are demersal. In polar seas, such as the Antarctic, a pelagic larval habit apparently is hazardous because of ice and low surface salinities, and many other less common echinoderms brood their larvae, thus keeping them completely out of the plankton. Feeding demersal larvae that have long developmental times probably represent an adaptive "compromise" that keeps larvae out of hazardous pelagic conditions but allows for wide dispersal. In accordance with such a hypothesis, *O. validus* and *S. neumayeri* are both among the most widespread and common of the Antarctic echinoderms.

### Growth and age

Oogenesis begins when specimens of *O. validus* are about 3-5 grammes wet weight, and spawning first occurs when about 5-8 grammes wet weight is reached. Because oogenesis requires nearly 2 years for completion, *O. validus* may grow at the rate of only 1-2 grammes per year and are somewhere between 3 and 6 years old at their first spawning. The majority of specimens collected from McMurdo Sound weighed about 25-30 grammes indicating an average age of perhaps 20 years. Some specimens, however, weighed nearly 100 grammes, and may have been between 50 and 100 years old. These age estimates are based on the assumption that growth is constant and linear in time. It almost certainly is not; in other sea stars that have been studied, growth nearly ceases after "full" size is reached but the animals continue to live and produce gametes for many succeeding years. It is probable that many specimens of *O. validus* surpass 100 years of age and the turnover of individuals in a population is very low.

### General ecological considerations

*O. validus* is found mainly from the shoreline down to about 50 metres depth on the west coast of Ross Island in McMurdo Sound. From the shore to about 20 metres, the bottom is relatively barren and consists of basaltic gravel and boulders. Common large animals occurring in this area with *O. validus* include sea urchins (*Sterechinus neumayeri*), giant isopods (*Glyptonotus antarcticus*), large ribbon worms (*Lineus corrugatus*), and fish (*Trematomus bernacchii*). At Cape Evans, snails (*Neobuccium eatoni*) and leafy red algae (*Iridaea* and *Phyllophore*) are also abundant. Below about 50 metres, the fauna becomes much more diverse and consists mainly of large silicious sponges, alcyonarians, ectoprocts, tubicolous polychaetes, and associated infauna.

The shallow coastal area down to about 15-20 metres is a particularly unstable environment. Considerable freshwater runoff often occurs during the summer months. Perhaps indicating adaptation to occasional periods of dilution, specimens of *O. validus* survive and show little volume increase when kept in sea-water diluted 50 per cent with fresh water for over 24 hours.

During the late summer and winter, icebergs and storm-tossed icefloes scour the shallow sea bottom. Moreover, large masses of anchor ice form on the shallow bottom during the winter and are released to float to the undersurface of the floating sea ice in the early summer. Animals in the area, including *O. validus*, occasionally are trapped in these rising masses of ice crystals and frozen into the sea ice above.

*O. validus* seems to be remarkably free of both predators and commensals. The only commensals so far found are several species of ciliates occurring in the stomachs of about 5-15 per cent of the animals. I never found any predation on *O. validus*, although a photograph in the March-April, 1968, issue of the *U.S. Antarctic Journal* shows a specimen of *O. validus* being attacked by a sea anemone. *O. validus* therefore seems to be a species near a top trophic level in the relatively simple environment of the shallow Antarctic seas. Comparative studies in McMurdo Sound suggest that population size is regulated partly through the effect of food abundance on gamete production. Much more could profitably be studied on this relationship between food abundance and gamete production, as well as on growth rate, turnover, synchronization of reproduction, and larval ecology.

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# BOOK REVIEWS

**FIELD GUIDE TO THE ALPINE PLANTS OF NEW ZEALAND, by J. T. Salmon. A. H. & A. W. Reed Pty, Sydney, 1968; 327 pages, 477 coloured plates, 2 maps. Price, $5.60.**

Anyone who buys this attractive little book to enjoy the pictures is unlikely to be disappointed, though he will occasionally be misled by a plate that is larger than life. But Professor Salmon does not yield too often to this temptation. Most of his colour-photographs do not exaggerate at all, and, in any case, there are measurements in the text beneath. Australians may conclude that there is nothing that surpasses their own alpine eyebrights for colour, or alpine buttercup and helipterum for distinction, but they must admit that the relatively extensive alpine area of New Zealand offers variety. Admittedly, in most genera the pollinators have favoured a gleaming white, but the fruits have all the colours that the flowers lack, and stems and foliage are often hoary or tawny, even brilliant red. Many of these pictures show how perfectly the habit fits the setting.

As a look-and-say manual for identification this book, with its ecological classification, should also succeed very well, and it may well give New Zealanders sufficient knowledge to create a demand for something more technical. The brief descriptions here make little attempt to emphasize key characteristics. You will not learn to tell a pentachondra berry by its pips, or that "rock snowberry" bears a completely dry fruit.

This brings up the question of popular names. Professor Salmon is convinced that there must always be one. But it is only for the commonest plants that they acquire precision. Even he cannot decide whether *Dacrydium bidwillii* should be "bog" (page 316) or "mountain" (page 74) pine, and why use "mountain totara" for *Podocarpus nivalis* when *P. hallii* has almost as good a claim, and snow totara would be unambiguous? There is surely little advantage in the longer Maori names (hunangamoho, panakenake) or in "north-west Nelson gentian" and the like, but "speargrass", "woollyhead", even "Haast's carrot" may help the layman to begin to know one plant from another. The book as a whole will certainly do so, and it will please the more sophisticated much more than it will annoy them.—*G. T. S. Baylis.*

**A TREASURY OF AUSTRALIAN WILDLIFE, edited by D. F. McMichael; Ure Smith. Price, $7.95.**

For 48 years the Australian Museum has produced its quarterly magazine. During this time the articles have ranged over many interesting items of the Australian environment, particularly its fauna. For teachers in particular, it often provided the only up-to-date information on many aspects of zoology. However, back numbers are not easy to obtain, so with this in mind a cross-section of the articles has been published in book form. The editor, Dr D. F. McMichael, had the problem of making the best sampling of the riches available. It must have been a difficult task deciding what had to be left out.

A glance at the contents pages shows that with the mammals a good coverage has been managed. The birds, with their greater number of species and diversity, only feature a few groups. The reptiles have a more adequate coverage. With the invertebrates it was a matter of sampling those major groups in which most people are interested.

However, to remedy these deficiencies the editor has, in each section, added a summary packed with information to serve as an introduction. Also, in all the articles the information has been brought up-to-date by the addition of material obtained since the article was first written. The illustrations, in both black and white and colour, are superb and enhance the text. The result is a satisfying piece of work.

There are a few weaknesses in the book. I found the glossy paper, though giving high quality in the pictures, makes for slightly less easy reading. Also, the captions for the colour blocks have been run together in a most confusing way, though there was ample space for these to be spread out. In addition, the lack of an index makes finding information difficult, though the contents page does indicate the broad areas of interest. In a second edition—and a work of this value should soon achieve this—an index should be added.

In conclusion, it is a book which can be recommended for all primary and secondary school libraries, as well as the library of the naturalist. The layman will also find the articles in general easy and enthralling reading.

It is to be hoped that in the years to come more of the best articles in the magazine *Australian Natural History* will be published in this way—*Vincent Serventy.*

**FLOWERS AND PLANTS OF VICTORIA, by Cochrane, Furher, Rotherham, and Willis. A. H. and A. W. Reed, Sydney, 1968; 216 pages. Price, $9.95.**

There are many books in print about Australian plants, most covering only a very limited section of the flora or only a limited area of any one State. However, this publication deals with all the ecological areas of Victoria and a large proportion of the flora of each area. The areas covered are: heathlands, Grampians, Mallee, salt-marshes, detached granite hills and outcrops, rocky gorges and escarpments, basalt plains, swamps, streams, river banks, coastal dunes and cliffs, box and ironbark forests of the goldfields, stringybark and peppermint forests, mountain forests, fern-gullies, East Gippsland and alpine areas.

Probably the most striking aspect of the whole book is the quality of the colour plates. Obviously, the original transparencies must have been as excellent for them to have printed so well. This is to the credit of the photographers. Details of plants, including flower structure, are clearly shown in many of the plates, a factor which adds to the value of this book for both amateur and professional botanists.

The division of the State into broad ecological areas with a coverage of each area photographically is a much better method of presenting the flora of a State than by a purely taxonomic arrangement, which often only confuses the amateur instead of instructing—and instruction should be the prime purpose of a publication of this nature.

The descriptions and general information about each species illustrated are well compiled and presented, due, of course, to the extensive knowledge and field experience of the author, J. H. Willis. There are a few additions which could be made to the range of occurrence of some species, e.g., *Leptomeria aphylla* (plate 87) also occurs in New South Wales and Western Australia.

There are one or two aspects of layout and presentation which, in my opinion, could be improved. The use of the common names of the plants in two places is unnecessary; repeating the plate number preceding the botanical name would have been sufficient. This alteration would allow space for inclusion of an approximate magnification factor under each plate. The use of phrases such as "about natural size", "twice natural size", or just "IX", "2X", "½X" etc. would add much to the value of the book, particularly for use by amateurs, without adding to the cost of publication.

The text which precedes and follows the section of plates (as distinct from the description of the plates) is quite well written and informative, but is somewhat rambling, a problem always associated with general descriptions of areas of vegetation. I would have preferred more use of botanical names in this text instead of common names. Although reference is made to the particular plate where the botanical name can be looked up, I consider that the use of scientific names is more precise and effectual.

The few aspects of the book which I have criticized are relatively minor and in no way detract from my earlier statement that this is an excellent and useful publication. I hope to see similar publications for other States in the near future.—*D. F. Blaxell.*

# *MEET OUR CONTRIBUTORS . . .*

SUSAN BULMER is affiliated with the Department of Anthropology and Sociology at the University of Papua and New Guinea, Waigani, and during March, 1969, she was also a temporary Lecturer in Prehistory. She first took up studies in prehistory while a Fulbright Scholar at the University of Auckland, New Zealand. In 1959 and 1960 she carried out the first field survey of sites and archaeological excavations in the Australian New Guinea Highlands.

THISTLE Y. HARRIS (Mrs Thistle Y. Stead), B.Sc. (Syd.), M.Ed. (Melb.), was formerly Lecturer in Biological Science at Sydney Teachers College. She is Vice-President of the Wildlife Preservation Society of Australia and the Wildlife Research Foundation of Australia, and is a Councillor of the Nature Conservation Council and the Australian Conservation Foundation. She is editor of *Naturecraft in Australia*, and is the author of a number of publications, including *Wildflowers of Australia*, *Australian Plants for the Garden*, *Eastern Australian Wildflowers*, *Australian Plant Life*, and *Alpine Plants of Australia* (in press).

RHYS JONES was born and bred in Wales. He received a university education in England, where he read natural sciences and palaeolithic archaeology. He became a teacher of prehistory at the University of Sydney, and is now a Research Fellow in the Department of Prehistory, Australian National University, Canberra. Most of his fieldwork has been carried out in Tasmania, where he has excavated some archaeological sites. He has a general interest in human ecology and evolution.

JOHN S. PEARSE lived and worked at McMurdo Station, Antarctica, from November, 1960, to January, 1962. After receiving a doctoral degree from Stanford University, U.S.A., in 1965, based on his work on *O. validus*, he joined the American University in Cairo, Egypt, as an Assistant Professor. Work on reproduction of marine animals was continued in Egypt with studies on tropical species in the Red Sea and Gulf of Suez. He left Egypt after the 1967 Arab-Israeli war to teach at Stanford University and Oregon State University, U.S.A. He is at present doing research on the regulation of reproduction in common sea urchins in Californian kelp beds.

M. G. RIDPATH read zoology at University College, London, and graduated in 1952. He then joined the British Ministry of Agriculture, where he carried out research on the ecology and control of various birds of economic importance, especially pigeons. He came to Australia in 1959 to become a member of the Division of Wildlife Research, CSIRO. He has been engaged in research on the ecology, economic importance, and conservation interest of two birds—firstly the flightless Native Hen in Tasmania, and now the Wedge-tailed Eagle in Western Australia.

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 in the University of Edinburgh (1960–63) and the University of Sheffield (1963–67). He has worked on some of the earliest known vertebrates from the Silurian and Devonian of Scotland and Norway, and on the eurypterid arthropods occurring with them. Field projects have ranged from mapping in Arctic Norway to a fish-collecting dig in the depths of a defunct oil-shale mine in southern Spain. In Australia Dr Ritchie has continued collecting and studying Devonian fish, from western New South Wales initially, and hopes to extend these studies to other parts of Australia and to Antarctica.

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