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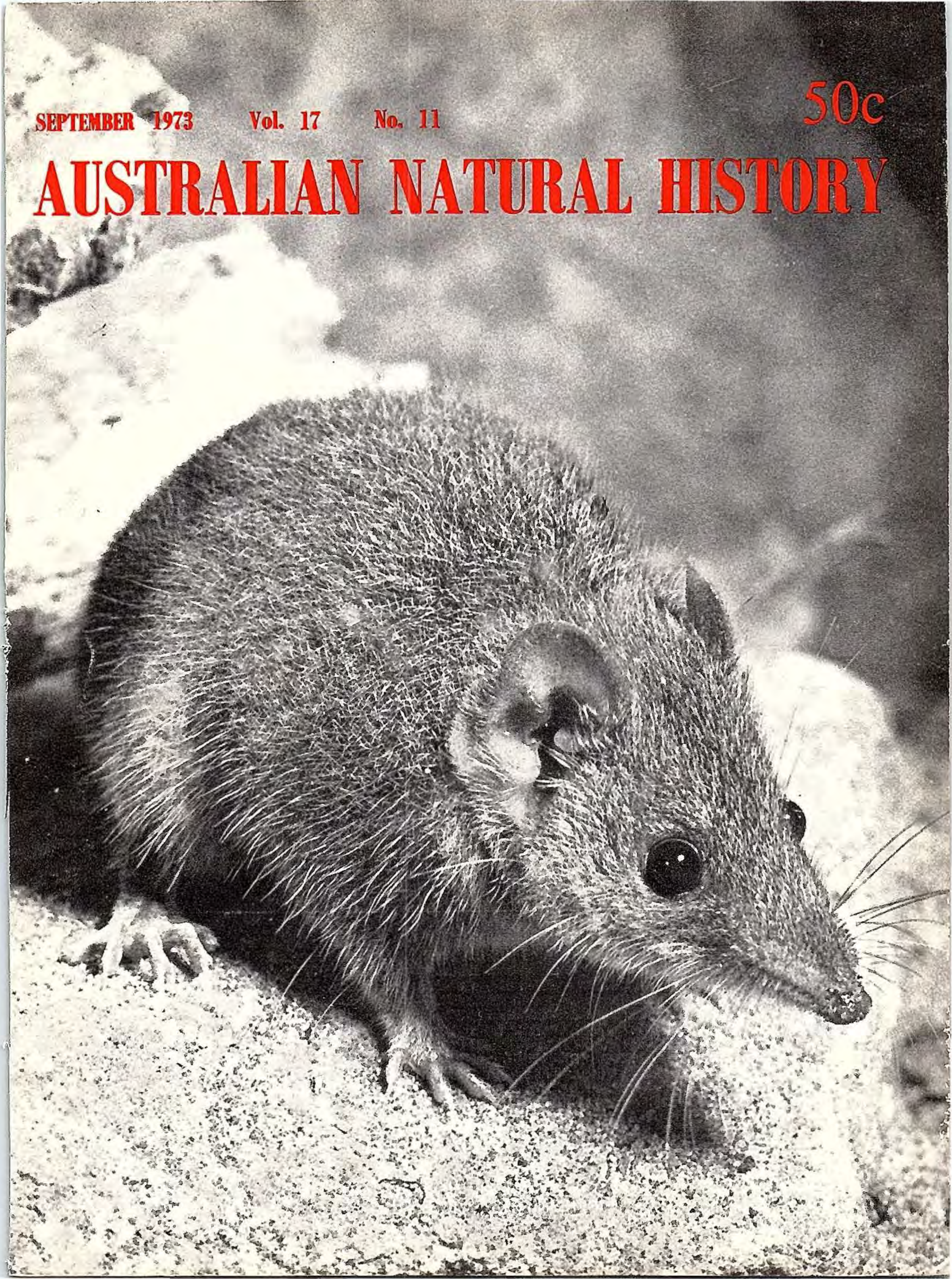
AUSTRALIAN NATURAL HISTORY



AUSTRALIAN NATURAL HISTORY

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● **FRONT COVER:** ***Antechinus stuartii*, commonly called Marsupial Mouse, is the subject of an intensive research programme by the Department of Environmental Studies at the Australian Museum. *Antechinus stuartii*, common in forest habitats throughout southeastern Australia, is especially interesting because each year all the males die within a period of two weeks, leaving behind a population consisting solely of pregnant females. *Antechinus stuartii* is a marsupial, and its only resemblance to a mouse is its small size, from 20 to 40 grams (about five-sevenths of an ounce to about 1½ ounces). It is an eater of insects and other small animals. The Museum's research aims to provide basic ecological information on *Antechinus stuartii* and other small animals so that better ways of managing forests, to ensure the animals' survival, can be recommended. [Photo: Howard Hughes.] BACK COVER: The Wanderer Butterfly (*Danaus plexippus*) suddenly extended its range across the Pacific Ocean from North America in the second half of the nineteenth century. It colonized island after island, reaching Australia about 1870. The prior introduction of suitable plants for its larva enabled it to become established in Australia. [Photo: C. V. Turner.]**

The Diprotodons of Lake Callabonna

By RICHARD H. TEDFORD
Curator of Vertebrate Palaeontology, American Museum of Natural History, New York

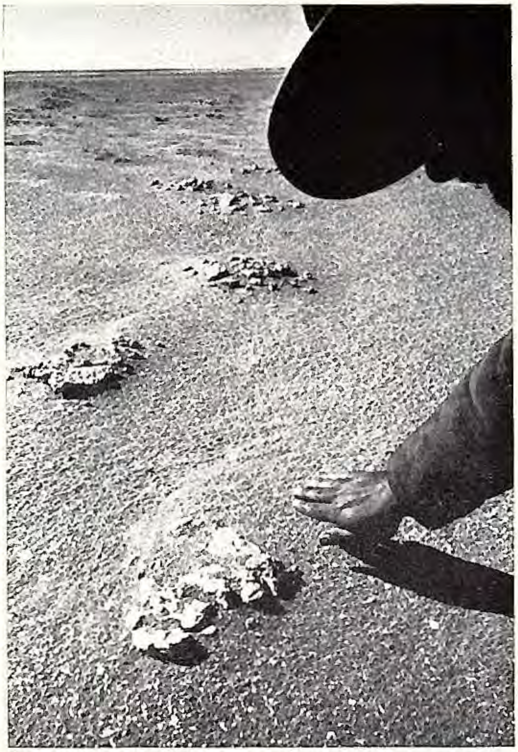
THE heroic exploits of the nineteenth-century explorers of Australia are known to every Australian schoolchild in terms of new land discovered and its potential for settlement. Little attention has been paid to the very large contribution these early explorers made to natural history. Because of their discoveries, however, it was possible, by the 1840's, for John Gould to present to the world, through his magnificent hand-coloured folios, a glimpse of the brilliant and fascinating birds and mammals of the still new colony, and for Sir Richard Owen to announce the discovery of the remains of an equally fascinating extinct fauna of giant marsupials, reptiles, and birds that had inhabited Australia's past.

Owen, of the British Museum of Natural History, was at once the author of the term "dinosaur", the world's leading comparative anatomist, and the major scientific antagonist of Darwin's concept of evolution. For nearly 40 years he alone took on the task of describing the fossil bones from Australia's cave and river deposits. With consummate skill he interpreted the nature of extinct animals that were as strange to the eyes of comparative anatomists as their living counterparts were to the eyes of the first settlers in Australia.

Diprotodon jaw

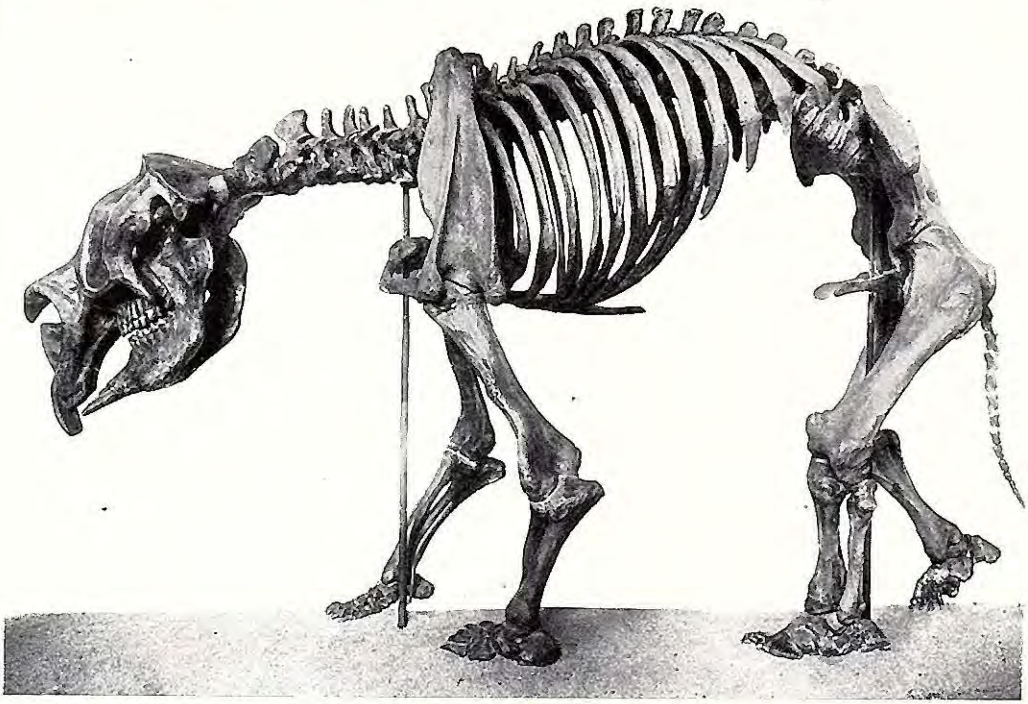
One of the first collections of Australian fossil mammal remains was made in 1830 by Sir Thomas Mitchell, Surveyor-General (and later Governor) of the colony of New South Wales. This collection came from the limestone fissures of the Wellington district, New South Wales. Among the remains, which were made available to Owen, was a fragment of a lower jaw bearing two large, rootless, chisel-like lower incisors. Owen concluded that this was the jaw of a giant marsupial, which he named *Diprotodon* ("two front teeth").

By 1877 Owen had received enough material from Australia, especially from the early settlers of the Darling Downs, south-eastern Queensland, to enable him to reconstruct the skeleton of *Diprotodon*.



One of several *Diprotodon* trackways preserved in hardened, limy mud and etched out on the present lake-surface by the wind. The prints were made in deep mud and do not retain many details of the foot of *Diprotodon*, but impressions of the claws may be seen. The prints are advancing towards the author, whose hand is shown for scale. [Photo: John Mitchell.]

What emerged was a rhinoceros-sized quadruped, standing about $5\frac{1}{2}$ feet at the shoulder, with a massive head. The two tusks of the lower jaw were opposed by two large chisel-like upper incisors, flanked on each side by a pair of smaller incisors. The cheek teeth were double-ridged grinders that would have been effective in shredding vegetation to a suitable form for digestion. This strange beast was made even more mysterious by the failure of the great comparative anatomist to settle on the identification of the boot-bones. Because



Above: The *Diprotodon* skeleton in the American Museum of Natural History, New York. It was mounted from casts, prepared by the South Australian Museum, of a composite skeleton obtained by the 1893 expedition to Lake Callabonna, South Australia. Below: Reconstruction of *Diprotodon*, by Walter Ferguson, from the skeleton shown above. [Photos by courtesy of the American Museum of Natural History.]

Owen was baffled by the feet he illustrated the reconstructed skeleton standing in grass tall enough to hide them from view! The problem of the feet of *Diprotodon* had to wait another 15 years before it was to be solved in a spectacular way at Lake Callabonna in South Australia.

Search for complete skeleton

By the late nineteenth century Owen's reports had raised considerable interest in Australian scientific circles, and the quest for a complete skeleton of *Diprotodon* was actively pursued. The breakthrough came at Lake Callabonna, then called Lake Mulligan, one of the chain of normally dry saltpans that stretch from Lake Frome northward along the foot of the northeastern Flinders Ranges. An Aboriginal stockman on the Ragless brothers' Callabonna Station, a large sheep property just east of the lake, reported numerous large bones in the lake-bed. Examination of these bones by Mr F. B. Ragless so aroused his interest that he notified the South Australian Museum authorities. They in turn employed Mr Henry Hurst to examine the site and report to the Museum Committee. Mr Hurst, a Queensland geologist with experience in searching for fossil vertebrates, reported that the bones were even more numerous than had been thought, and the Museum Committee enthusiastically agreed to support a three-months collecting expedition to the lake; £250 was squeezed from a slender budget for this purpose.

The expedition, which went into the field in March, 1893, was led by Mr Hurst and included his brother George, two excavators (Templeton and Meldrum), and a cook (Mayo). Before heavy rain in June made further work temporarily impossible, Mr Hurst's party had counted 360 individual *Diprotodon* skeletons on the surface in a limited area of a few acres and had removed parts of seventy to eighty of them. In most the feet were preserved, having been pushed deepest into the ancient lake bed as the animals struggled to free themselves from the sticky clays. The feet proved to be strange indeed. Borne on the ends of pillar-like elephantine legs, they consisted of massive interlocking wrist and ankle bones to which, surprisingly, small and weak-looking toe-bones were articulated. It is no wonder that Owen had failed to recognize them!

The Hurst party discovered, and 60 years later we were able to confirm, that many of the *Diprotodon* skeletons bore a crust of lime-cemented clay around portions of the body, especially the feet, which remarkably preserved impressions of the hide, hair, and foot pads of these animals. Similar lime crust around the bodies of the giant emu-like birds and extinct kangaroos also found at Lake Callabonna have provided an unusual opportunity to study the feathers and hides of long-dead animals.

Exciting discoveries

Perhaps one of the most exciting discoveries made by the Hurst party can best be told in the words of its discoverer, George Hurst, writing to his brother Henry in early July while the latter was in Adelaide reporting to the Museum Committee: "As soon as I had dug under the pelvis and into the exact spot where the pouch would be I came on a dear little diprotodon humerus about six inches long. It is evident the large animal is a female and had a picanniny diprotodon in her pouch when she died . . . The claim is very wet and the bones are very difficult to remove but you can depend I will get them all as I think this is the most wonderful discovery ever made in the world."

The Museum Committee and the Director, Sir Edward C. Stirling, were impressed, as was Sir Thomas Elder, whose gift of £50 made possible several more months of excavating. Stirling and his Assistant Director, A. H. C. Zietz, visited the site in August and decided to assume direct control over the excavations, with Zietz in charge. Collecting continued until November when heat, dust, and flies made further work impossible. Stirling's narrative of the 1893 expedition contains a graphic account of the work and gives insight into the conditions that caused the failure of many sheep and cattle properties in the inland around the turn of the century.

In the years that followed, Stirling and Zietz described the 1893 collection, in particular the feet of *Diprotodon*, the skeleton of the giant emu-like bird, *Genyornis*, and the skeleton of the giant wombat, *Phascolonus*. A plaster cast of a composite skeleton of *Diprotodon* was made by the South Australian Museum and used for exchange purposes so that most of the major museums of the world were able to exhibit the skeleton

Aerial view looking north across the surface of Lake Callabonna. The white saline watercourses, waterpools, and dark growth of samphire mark a mound spring area near which the South Australian Museum expedition of 1893 obtained their collection of *Diprotodon* skeletons and other large Ice Age marsupial and bird remains. [Photo: Author.]

of this curious beast. Much, however, remained to be described: the several types of giant kangaroos, the various types of *Diprotodon* suggested by the great size-range among individuals collected, the skull of *Diprotodon*, and the plant and mollusc remains. The richness of the site was apparent, its palaeontological importance was unquestionable, and its geological significance had been hinted at, but no further studies were conducted there.

"Aura of mystery"

An aura of mystery began to surround the original sites. Local property-owners, including the Ragless family, believed that the bones once exposed on the lake floor had been covered by silt and were no longer visible. In 1948 Harold Fletcher, palaeontologist on the Australian Museum's staff, reported in this journal the results of a trip to northwestern New South Wales that included a visit to Lake Callabonna. Mr Fletcher found *Diprotodon* bones there and told how difficult it was to extract them, but it appears that he visited a site many miles from that worked by the 1893 party—a testimonial to the remarkable extent of the *Diprotodon*-bearing beds.

Professor R. A. Stirton, of the University of California, and I first visited Australia as Fulbright Scholars in 1953. Our purpose was to discover, if possible, remains of the fossil marsupials that were the ancestors of *Diprotodon* and other species. Ultimately we hoped to reveal the nature of the earliest marsupials in Australia in order to indicate their origins and subsequent evolutionary diversification. Professor Stirton died in 1965, but some of his students, including myself, are still pursuing these goals.

In 1953 our hosts, members of the South Australian Museum Board, agreed to help us in our search if we would visit Lake Callabonna and try to locate the original excavation sites. If successful we were to determine the most advantageous field methods for extracting the delicate fossils.

After some days we were successful in locating the 1893 camp-site, which, after 60 years, was still plainly marked by bottles, ashes, wooden supports from the drying racks, cooking utensils, and a few pieces of scrap lumber. Nearby, in the saline washes cut into the lake floor, badly weathered *Diprotodon* skeletons were exposed. Almost immediately we located two buried skeletons and other remains of *Diprotodon* by probing through the soft moist clay with steel rods, a method first employed by the 1893 expedition. The only "hard" objects to be encountered within 5 feet of the surface were the bones of extinct animals, and we soon developed the sense of touch necessary to determine whether the probe had hit a bone. Within the first few days we found enough material to keep us fully occupied for the remainder of the time available.

The fragile bones were extracted still encased in their clay matrix by wrapping them with hessian strips soaked in plaster of paris. In this way we eliminated the need to free the bones entirely from the clay in the field, as had been necessary in 1893. Our jacketed specimens could be cleaned of their clay matrix under controlled conditions in the laboratory. This is a time-consuming process, as the bones of these giant animals are surprisingly delicate and so thoroughly permeated with salt water that they may spontaneously crumble upon drying. As a consequence the material has been unusually difficult to prepare and we are still experimenting with various techniques, as each bone seems to require individual treatment.

1970 search

The results of the 1953 visit were very encouraging, and our observations corroborated much that Stirling's report had to say about the deposit, except that we now believe that the amount of fossil material buried there exceeds his estimates many times.

It was apparent to me that this unique site would richly repay further work, so, with the aid of a National Science Foundation Grant, a joint effort was organized in 1970 between the American Museum of Natural History, New York, the Smithsonian Institution, Washington, D.C., and the South Australian Museum. That year was an unusually favourable one for work at Lake Callabonna. Because of a disastrous drought we found we could drive onto nearly any part of the saline clay lake-bed. (The next year the drought broke and our sites were covered by several feet of water!)

We began work at the 1893 site, and, within half an hour, our steel probes had located three *Diprotodon* skeletons. Concurrently with the excavations we explored part of the lake to determine the extent of the fossiliferous ground and to work out the geological history of the deposits exposed on the lake floor and in the surrounding country. Following Stirling's account of the 1893 expedition, we relocated the other fossiliferous sites discovered, but not worked, by the Hurst party.

One of these, 4 miles northeast of the 1893 excavations, proved to be our most productive area. There, where the *Diprotodon*-bearing clays were exposed on the surface by the scouring action of the wind, we were able to locate skeletons of giant kangaroos, wombats, and birds. To the professional eye, chips of weathered bone gave evidence of the presence of a marsupial or bird skeleton beneath the dry clay surface; skeletons of the giant emu-like *Genyornis* were most often indicated by piles of small polished stones that had once been contained in their crops. In all cases the feet of these extinct animals were buried most deeply, indicating that these large-bodied species had been mired in the lake clays, where they had died of starvation or been attacked by predators. We found that the clays, where undisturbed, were thinly laminated and interbedded with ripple-marked fine sand, and that they contained abundant crystalline gypsum—all suggesting deposition in a shallow lake, where the water varied from fresh to brackish and which perhaps occasionally went dry during the seasonal cycle. Scattered fragments of wood, including *Eucalyptus*, and many fruits of the native pine *Callitris* were found with the bones.

Dr Singh, of the Australian National University, also found abundant pollen in the clays, which, along with the wood and fruits, indicated that the shores of the lake once supported a saltbush steppe with scattered wattles and native pines, while the watercourses joining the lake were lined with gum trees. In short, at the time of

A *Diprotodon* skeleton being excavated during work carried out jointly by the American Museum of Natural History, the Smithsonian Institution, and the South Australian Museum in 1970. The animal lies on its belly, facing towards the lower left of the picture, with feet and lower limbs thrust deeply into the churned clay. Its skull and jaws have been removed. The left hind leg can be seen, on the right, in front of Mr Pledge, Curator of Fossils at the South Australian Museum. On the left, Dr Emry, of the Smithsonian Institution, brushes loose matrix from the right elbow joint. [Photo: Author.]

Diprotodon, the Callabonna area had vegetation of a type requiring twice the 5 inches of annual rainfall now "normal" there. Wood from a gum branch discovered in the clays has been found to be more than 40,000 years old and beyond the range of the carbon-14 method of dating. The evidence of higher rainfall suggests that the true age of the deposits may be as much as 70,000 years, when the last major glacial episode of the Pleistocene or Ice Age began. Only small portions of the Australian and Tasmanian "Alps" were glaciated; the rest of the temperate southern part of the continent experienced cooler, wetter, and windier conditions until about 10,000 years ago, when the modern climatic regime began to drive back the valley glaciers from the Australian highlands.

The great quantity of bones at Callabonna did not result from the catastrophic effect of a protracted drought, but rather was a slow accumulation of individuals or small groups of animals that tried to cross those boggy flats during periods of low water. There is dramatic evidence of this in the churned nature of the clay-sand strata around each skeleton, and especially in the presence of recognizable footprints of *Diprotodon*. A combination of deposition and erosion has served to etch out plates of thin limestone carried by the huge feet from the lake floor into the soft clay below, as these Ice Age giants plodded across the lake. This evidence, together with the *Diprotodon* joey, the skin and hair impressions and the bones themselves, gives us a unique picture of *Diprotodon* as a living animal.

The scientific potential of Lake Callabonna still remains largely unexplored. In 1901 the South Australian Government wisely set aside the lake floor as a scientific reserve. Their farsightedness deserves national recognition, for there is no other site like it in the world. Steps should be taken to ensure that Lake Callabonna will remain protected, yet available to all who can properly investigate its unique record of past life.

THE RATIONAL USE OF NATURAL RESOURCES

By STEPHEN S. CLARK
Assistant Curator, Department of Environmental Studies, Australian Museum

THE word "conservation" is heard with ever-increasing frequency these days. One suspects, however, that it means very different things to different people. For some, conservation means preservation. For others, it means "wise use" or the even more impossible goal of "the greatest good for the greatest number over the longest time." Hearing representatives of business and industry speak, one gets the distinct impression that we already practise adequate conservation!

Nevertheless, few thoughtful or sensitive people aware of their surroundings, urban or rural, would deny that we have a great deal to learn about what conservation really means. Rather than proposing yet another definition of conservation here I would like to talk about rational resource use in the hope that this will get us closer to an understanding of what conservation could mean to our society.

It has been recognized in recent years that many of the problems of western man can be traced to his basic attitude toward nature. For us nature is something apart from ourselves, to be exploited ruthlessly and with indifference. The progressive deterioration of our environment is a result of our acting on this implicit belief. Max Nicholson, in his book *The Environment Revolution*, warns that "unless man can make the effort to look at nature and at ourselves with new eyes there is no hope for us on this earth".

The land dictates the best use of resources

"The earth is a great bounty", Ian McHarg says in the opening of his exciting book, *Design with Nature*. Rather than grab all we can get we must begin to understand how this bounty is produced. That man is a part of nature is the basis of ecology. The resources we enjoy, indeed depend upon for survival, participate in self-renewing cycles—and on our present course of action we risk destroying the earth's capacity for renewal.

How can we change our attitude and begin to acquire the necessary understanding? McHarg suggests that we allow nature to dictate to us the resource uses intrinsically suited to particular areas. As a first step, an inventory of the storehouse must be taken. This inventory takes the form of maps of geology, topography, climate, soils, and vegetation. In these and other properties of a given region lies an immense amount of information about the intrinsic suitability or lack of suitability for various land uses. The most important of these uses are: recreation, forestry, agriculture and grazing, mining, and urban development.

Climate, geology, and topography combine to produce soils which may or may not lend themselves to agriculture or grazing and to the presence of vegetation valuable for forestry. Urban development will be restricted by consideration of slope and bedrock geology suitable for foundations. Geology dictates the location of valuable mineral deposits. All of these factors combine to yield areas valuable for recreation.

By superimposing these maps on one another it will be found that certain parts of a region are best suited for a single use or at least lend themselves to a predominant use. Elsewhere we will be less fortunate and several potential uses may overlap. The problem now becomes one of determining compatibility. Certain uses may be highly compatible, such as recreation and forestry, and a single area can be used to great advantage for both. Elsewhere, as with mining and recreation, more difficult problems arise.

A composite map prepared for the Gosford–Wyong area by Mr K. Hueneke, while a student at Macquarie University, is shown in figure 1. Here, present land uses such as urban areas, rural or cleared land, State forests, and present parks and reserves have been mapped. In the original study, natural features including steep slopes, unusual geology and vegetation, and scenic vistas were also indicated. This information has been used to focus on areas of prime recreation value. Although other possibly conflicting forms of land use have not been considered, this study ensures that the recreation potential of these areas will not be overlooked as is so often the case.

Conflicting uses in valuable areas

How, then, can we decide what use to make of an area valued for two or more conflicting uses? Simply stated, resource should be used in the manner which results in the greatest increase in the well-being of people. The amount people are willing to pay for different things gives us an idea of how much these things increase well-being. When something is in short supply people may be willing to pay a great deal for it. As supply increases, people become satiated and demand falls off. This is formulated as the economic law of supply and demand (figure 2). When this law is functioning properly it automatically prevents manufacturers from producing more of something than we want. As supply goes up demand

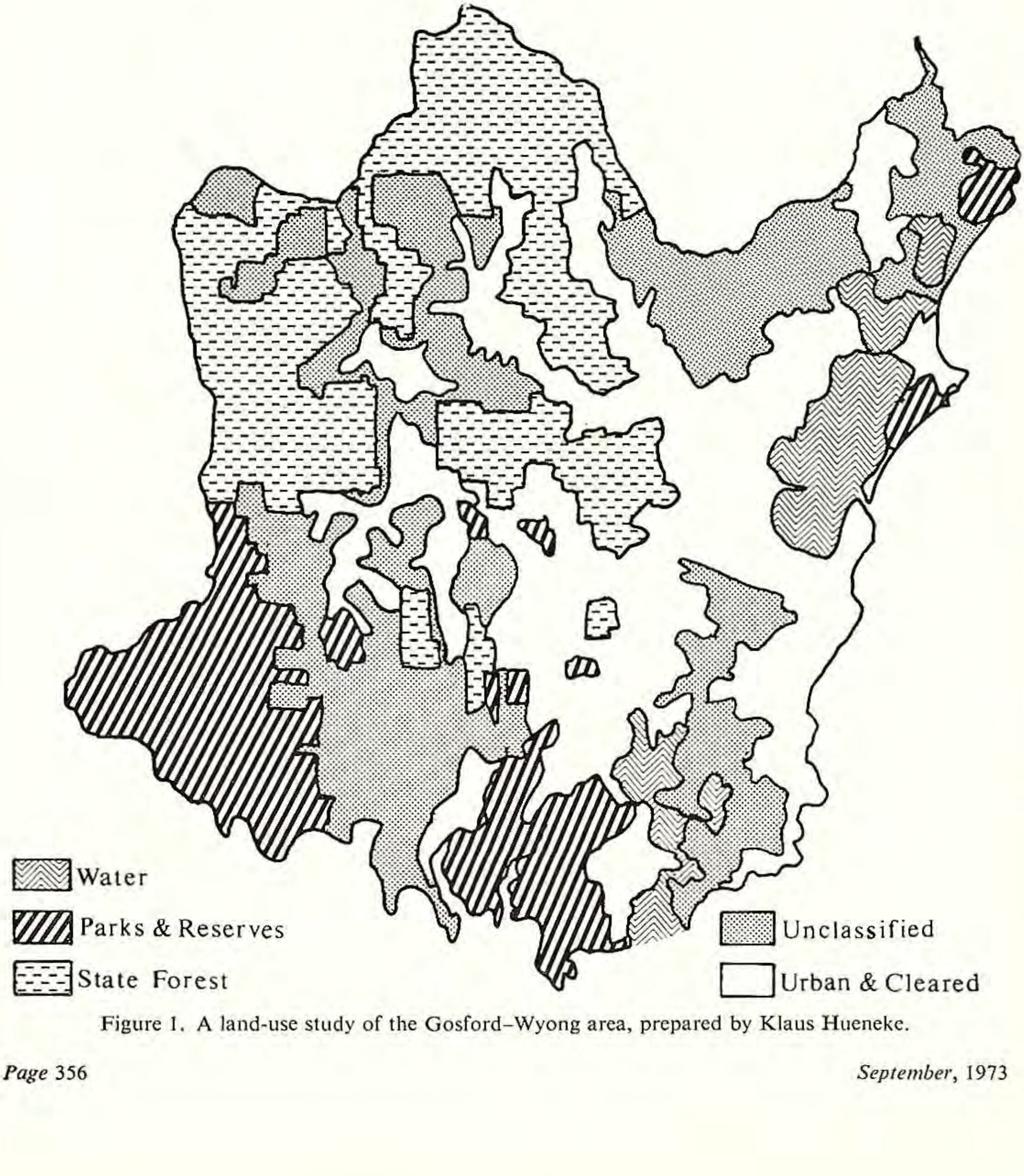


Figure 1. A land-use study of the Gosford–Wyong area, prepared by Klaus Hueneke.

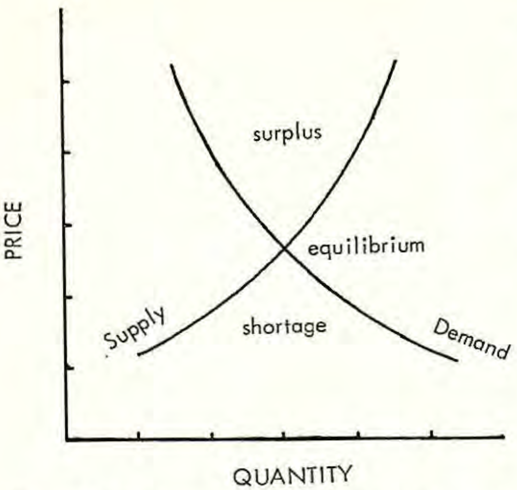


Figure 2. The economic law of supply and demand. [Diagram by the author.]

falls and with it the price people are willing to pay. Eventually a position is reached at which the cost of production plus profit equals the sale price of the item. This is where production stabilizes.

The mining of mineral from an area of land also valuable for recreation provides a good example of how the law of supply and demand may *not* ensure the production of what people desire. In theory, when enough material is produced the cost of production will begin to exceed what we are willing to pay for the mineral, and production will cease. But let us look for a moment at these costs. They should include not only the expense to the company of getting the mineral out of the ground but also the cost to society of damage to the area for future recreation. This value of the area for an alternative use is termed opportunity cost. If this cost is not included, an area may be mined which would have provided a greater increase in well-being if left for recreation.

One way of including this social cost would be to relate the cost of a mining lease over the area in question to that area's value for an alternative use, such as recreation. In this way areas especially valuable for recreation might become too expensive to mine. Under the present system of a constant lease cost we are, in effect, subsidizing mining companies to produce mineral at the expense of recreation and other land uses on which society places a higher value, or which would yield society a greater return.

A most difficult problem in this instance is in deciding the value in monetary terms of a given area as a park. Parks have traditionally fallen into the category of free goods—that is, they are considered to be in abundant supply and freely available to all members of society. Today, however, large parts of Australia have been transformed from complex natural ecosystems to simple managed ones by various types of intensive land use. Natural areas are rapidly shrinking in size and number. To act as though they remain abundant and the property of all will ensure the destruction of even these remnants.

Other resources still considered as free goods include air and water. When population was sparse and industry was in its infancy, water and air could be used freely without reducing their value for the next person. Today, in our densely populated and highly industrialized societies, the quality of the water we use and the air we breathe has declined drastically. As a result, industry has saved large sums in waste treatment at the expense of a public which must breathe polluted air and use polluted water. Such use of free goods resulting in social costs is termed by economists an external diseconomy. If their true value to society had been recognized and companies required to pay to use them, the companies would have sought a means of waste disposal less harmful to society. It is doubtful if any free goods remain in our shrinking world.

Does this mean that everything must have a price? There are several arguments for charging admission to parks. Charges give a basis for estimating their real value to the community. Also, people who benefit from using national parks pay more for them, just as people who own cars pay a larger part of the cost of roads. In addition, fees give some means of regulating the use of the recreation resource. They provide funds for improvement of facilities for accommodating larger numbers of people. By having higher fees during peak seasons and lower ones at other times of the year pressure on the resource is distributed more evenly.

Non-monetary values

McHarg has observed that modern man has "but one explicit model of the world and that is built upon economics." The grave

ACTIONS ASSOCIATED WITH PROPOSED MINING

CHARACTERISTICS OF THE EXISTING ENVIRONMENT	Clearing of Vegetation	Topsoil Stockpiling	Dredging, Recontouring	Roads	Water for Pond		Cover Crops	Exotic Species	Fertilizer	
Soils	-2	-3	-3	-5	-3		+2	+1	+2	-11
Landforms			-5							-5
Groundwater					-4					-4
Mesoclimate			-5							-5
Erosion			-1				+2	+1		+2
Microclimate	-3			-5				-2		-10
Trees	-4	-4	-5	-5	-4		+1		+1	-20
Shrubs, Herbs	-2	-3	-5	-5	-4		+1		+2	-16
Birds	-4		-5	-5	-4		+1	+1	+1	-15
Mammals	-4		-5	-5	-4		+1	+1	+1	-15
Insects	-4	-3	-5	-5	-4		+1	+1	+1	-18
Scientific	-5		-5	-5	-5					-20
Wilderness, Scenic	-4		-4	-5				-2		-15
Intensive Recreation	-1									-1
	-33	-13	-48	-45	-32		+9	+1	+8	

Figure 3. An environmental impact matrix to evaluate the effect of beach sand mining on the environment. [Diagram by the author.]

shortcoming of this model is that things that cannot be valued in monetary terms tend to go undervalued and are therefore not properly allocated to give the greatest increase in social welfare. If we cannot assign a "dollar and cents" value to every resource, we can at least become more aware that social costs or diseconomies are being incurred. One recent technique that has been developed for doing this is environmental impact analysis.

In environmental impact analysis a matrix is prepared in which relevant existing characteristics of the environment are listed along one side and the details of the proposed action, such as mining, across the top. Where some aspect of mining affects a characteristic of the environment a number is entered in the body of the matrix on a scale of 1 to 5. This number is an objective assessment of the magnitude of the effect of the action on the environment. Effect increases from 1 to 5; a negative sign indicates a deleterious effect, a positive sign a desirable or ameliorating one. Such a matrix is subject to the limitation that it will be prepared differently by different workers. However, it does serve the very useful purpose of focussing attention on all aspects of the proposed action and their effect on the environment. These are in a sense costs, even if their value cannot be determined. As further information becomes available, the matrix can be modified and improved upon.

Such a matrix is presented in figure 3 for the effect of beach sand mining on the natural enrivonment. In this matrix the environment affected is presented in four sections: the physical environment, the plant component of the ecosystem, the animal component, and the total environment as perceived by man. The effects on plants may be direct, as in clearing of vegetation, or indirect through alteration of the physical environment. The anticipated effects on animals are mostly indirect and relate to their dependence upon plants in the ecosystem. The effects as perceived by man are also indirect. As far as possible, the actions associated with mining are listed in the order in which they occur.

A further refinement in the use of such matrices is to examine row and column sums. These sums give us in summary form those actions potentially most detrimental and those aspects of the environment most seriously affected. We see here that dredging, recontouring and roads are the most detrimental aspects of mining, and it is here that efforts to minimize effects should be most urgently directed. The living components of the community and the area's scientific and wilderness values are most heavily damaged. Their value for alternative or future uses should be carefully considered.

The three approaches to rational resource use presented here really complement one another. McHarg's methods help us to find areas particularly suited to certain uses. They also help us focus on especially valuable areas lending themselves to more than one use. In resolving conflict between alternative uses in these areas the costs and benefits of each use must be carefully sought and evaluated. Environmental impact analysis serves as an important part of this process by incorporating non-monetary values which might otherwise be ignored.

The goal of rational resource use is to manage the environment so as to best satisfy man's diverse physical, mental, and emotional needs now and in the future. It is a goal worthy of our best efforts and understanding.

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A female "Common Brown" Rat (*Rattus norvegicus*), with young. [Photo: Philip Boucas.]

RATS AS ANIMALS

By S. A. BARNETT
Professor of Zoology, Australian National University, Canberra, A.C.T.

WILD rats are commonly and correctly thought of as pests and carriers of disease. In contrast, laboratory varieties are colleagues of man in many researches. But mammals of the genus *Rattus* are also interesting as animals; and this article deals with them as such.

Only a few of the alleged 300 or so species can be mentioned. Most is known about *R. norvegicus*, the Common Brown Rat of the cooler regions of the Northern Hemisphere. This is the species to which domestic rats also belong. In Australia it is not as common as might be expected. *R. rattus*, variously known as the Ship, Black, House, Roof, or Alexandrine Rat, is similarly widespread, and is common in Australia. It does better than *norvegicus* in hot climates. In general, *norvegicus* burrows (and swims when it needs to); *R. rattus* climbs, and nests above ground.

Some species are hardly larger than mice. Of them, *R. exulans*, a common Pacific rat, has been known to annoy Europeans in Indonesia by nesting in their bamboo furniture. Indigenous Australian species include *R. fuscipes*, the Southern Bush-rat, which lives in sclerophyll forest. Another, *R. villosissimus*, the Long-haired Rat, lives in the arid central regions of Australia and is usually scarce, but occasionally breaks out into vast, destructive "plagues".

Feeding and "intelligence"

The success of rats, especially those that live intimately with man, depends partly on their versatility: they eat anything that we can, and some things that we usually refuse, such as raw cereal grains. In Malaya, various species regularly include snails as a major item of their diet, but sometimes half their diet is insects, especially termites.

Rats are aided in the discovery of all this variety of food by strong exploratory propensities. What is "exploration"? By asking this, at first sight naive, question, experimentalists have opened a region of study important for both psychologists and zoologists. One general finding is that rats are neophilic: that is, they tend (with one important qualification) to approach unfamiliar objects and to enter unfamiliar places; they also readily sample new foods.

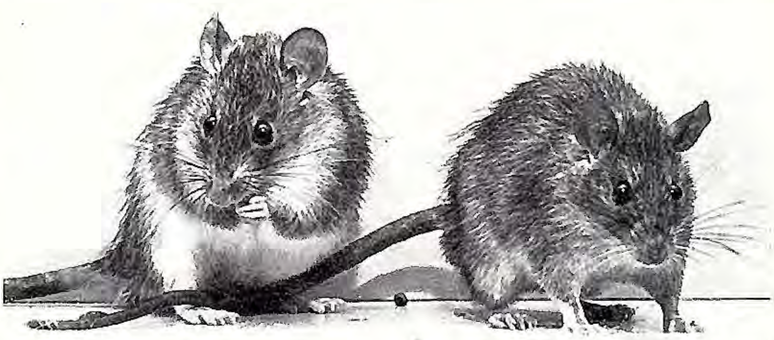
In this way they acquire information about their environment which is stored in their brains and can be used later. Laboratory rats which have been allowed to wander around a maze without incentive or reward can later be trained to run the maze for food more quickly than control rats with no such previous experience. The invisible change which takes place during exploration is important, not only in food-getting, but also in avoiding predators such as hawks: a rat in a familiar environment can run quickly for cover, whereas in strange surroundings it is continually at risk if it exposes itself.

If, however, wild rats of the commensal species, notably *R. norvegicus* and *R. rattus*, were consistently neophilic they would be easy to catch. In fact, they are not: many people have found them so difficult to trap that they have supposed rats to be highly intelligent as well as "wary". In a stable environment wild rats, at least of these two species, adopt regular habits of movement, and nightly use the same pathways from nest to food. If a strange object is placed in the familiar area the result is often a dramatic disappearance of the rats. If the object is a trap or poisoned food, this behaviour gives a misleading impression of intelligence; but it can be as easily induced by a plain box or even a pile of good food. This neophobia undoubtedly protects rats that live in close association with man; but it is not intelligent for it is completely indiscriminate. Recent unpublished work by C. R. Tidemann suggests that it is not displayed by *R. fuscipes*. This species does not live among human beings.

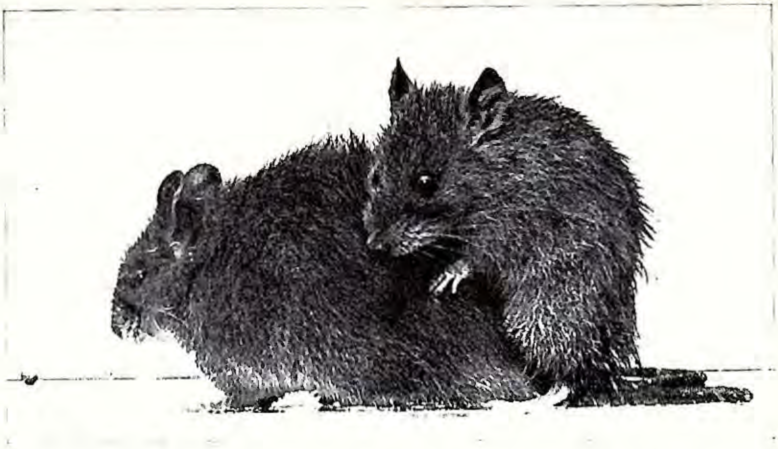
Food selection

Although neophobia is nothing to do with intelligence, the feeding behaviour of rats displays an ability to adapt their behaviour to experience. In general, if rats benefit from eating something, they are likely to continue to eat it, in preference to less favourable foods. This has been shown in many laboratory experiments: rats can select mixtures that contain certain vitamins, for example, or essential inorganic salts.

The obverse is also true: if rats are made ill by a mixture (such as poison bait), and survive, they avoid that mixture afterwards. This apparently simple phenomenon was demonstrated, only after laborious studies, by a group of animal ecologists working at Oxford during the second world war. It has recently been taken up by experimental psychologists. Among their findings is that



The Roof Rat or Ship Rat (*Rattus rattus*), sometimes also called the Black Rat. There are several colour varieties. [Photo: Ivan Fox.]



The Southern Bush Rat (*Rattus fuscipes*). One is grooming the other [Photo: Ivan Fox.]

avoidance of a toxic food may be accompanied by increased exploratory behaviour and sampling of alternative foods.

The ways in which rats adapt their behaviour to their food needs, and to the hazards and opportunities of their environment, are being increasingly revealed as subtle and complex. The findings of detailed experiments turn out to be more fascinating than crude myths that have been current for many decades in popular writings: for instance, that young rats are warned by older ones of the dangers of poison bait. Until very recently there was little evidence of any important social influence on feeding; but now young rats are thought to be influenced by *following* older ones to food. In this way, their food preferences may be affected. The older rats do not pay any special attention to the young that follow.

Rats as social animals

Following by young rats is one aspect of the tendency of members of some species (notably *R. norvegicus* and *rattus*) to herd together in groups. These colonial species, as would be expected, possess a number of social signals that seem to encourage contact or deter conflict. One rat may crawl under another. This behaviour occurs especially in situations in which the rat that crawls under *might* threaten or attack.

Just what are the situations in which conflict may be expected? The answer varies with the species, and perhaps even with different strains. There seems to be no record of normal female *R. norvegicus* threatening or attacking others of their species; but, in West Africa at least, *R. rattus* females sometimes drive strange females away. *R. villosissimus* and *fuscipes* females, too, have proved to be quite combative, at least in the laboratory. These statements refer to encounters outside the nest. *R. norvegicus* females, and no doubt those of other species also, defend a nest with a litter against all comers, by gestures and sounds.

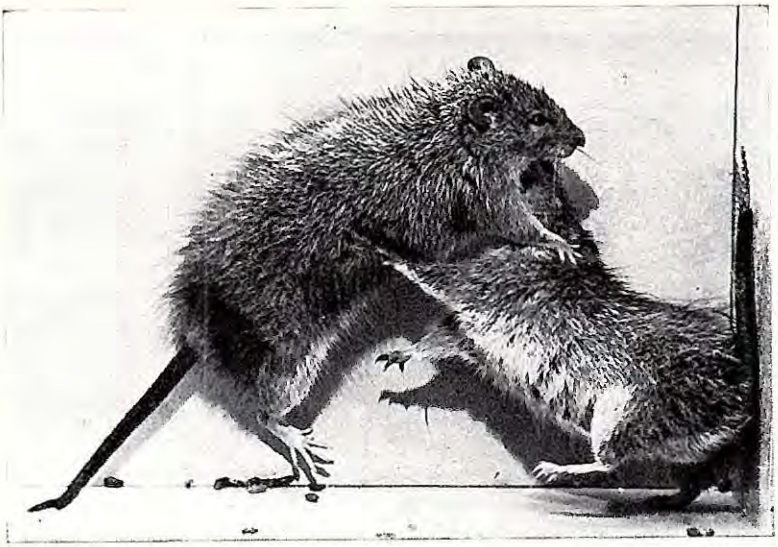
Defence of a nest is a special case of territorial behaviour, defined as defence of a region against members of the same species. The region may be occupied by a single individual, a family, or a much larger group. The most spectacular encounters are those in which a rat in his own territory faces an intruder. *R. norvegicus* and *villosissimus* are then capable of considerable violence.

In the animal kingdom generally, this is rather unusual. The rule is that even intolerant encounters between members of the same species are harmless: they consist of a variety of signals, which may be called "threats"; these induce one individual to withdraw. Even attacks, with biting, among rats commonly fail to lead to severe wounding. In natural conditions they are probably only very brief.

Death from "social stress"

These encounters present a strange anomaly. They seem violent, yet rarely lead to severe wounding. Their outcome varies, but, at the extreme, despite the absence of injury, they can lead to collapse and death of the intruder. Our most detailed knowledge is of *R. norvegicus*; and

The Long-haired Rat (*Rattus villosissimus*). A male (left), marked with black dye for identification, attacks an intruder on his territory. [Photo: Ivan Fox.]



what follows refers mostly to wild rats of that species, not the laboratory varieties. The latter, during tens of generations in captivity, have been successfully, if unconsciously, selected for docility and social apathy.

In natural conditions, and in some artificial environments, if a rat is attacked it simply runs away. But, in experiments, an attacked rat often shows a notable tendency to approach the attacker, as if it were more important to be with another rat than to avoid hostile treatment.

A second possibility is that a rat under persistent attack alters its patterns of social behaviour. First, it keeps out of the way of the attacker; secondly, it loses the propensity to attack intruders on its own territory. A rat in this state may not only survive, but also grow and show all appearances of robust health.

In experiments, however, most rats observed have failed to adapt themselves to continuous persecution. They may die suddenly. If not, they seem to lose their appetite for food; they lose weight; they move about only slowly, and have a bedraggled appearance. Such rats, on post-mortem examination, display a number of pathological changes, including erosions of the inner lining of the stomach and duodenum of a type which, in man, lead to ulcers. Pathological changes have also been observed, in unpublished work, in *R. villosissimus*.

Whether any of these observations will give us a clue to the cause of sudden collapse under attack is still uncertain. One thing they suggest, however, is that wild rats, like their tame laboratory cousins, can now contribute to research on important physiological and medical problems.

Naturalist's Unique Osprey Photo

A particular photo may appeal to a naturalist for a variety of reasons which have no connection with photographic excellence.

My most unusual picture was one of a series I made when working on Pelsart Island in the Abrolhos Group, off Geraldton, Western Australia.

I spent six months on the Island and had the chance of studying nesting ospreys (*Pandion haliaetus*) at ground level, instead of in the tops of tall trees. On these islands the highest trees are low mangroves.

So that I would not disturb the sitting bird I took about a week to prepare my hiding place. I collected a framework of driftwood, and finally added a roof of white canvas. The ground on which I lay was lumps of not particularly comfortable dead coral. For weeks I spent many of my daylight hours in this hide watching the parents carrying out their nesting duties. The chicks were finally successfully fledged.

The large nest structure, some 3 feet in height, was also the home of a King Skink Lizard (*Egernia kingii*) feeding on scraps from the osprey table. Not always on those only, however, because one day it came into my hide, stared at my motionless form, and decided that here was magnificent food. It bit me first on the toe, drawing blood, and when I waved it away it gripped my finger. It finally retreated to search for less active food. In other parts of the island the lizards ate deserted sea birds' eggs and chicks, as well as the fruits of the nitre-bush.

The osprey became accustomed to movements in the hide and developed a tolerance of disturbance, providing I kept most of my body under cover.—*Vincent Serventy.*

Above: The most unusual photo Vincent Serventy has ever taken—an osprey on a nest on Pelsart Island, in the Houtman Abrolhos Group, Western Australia. Below: A King Skink Lizard feeding on scraps left in the nest by the ospreys. At left is a young osprey.

Gilgais, basin-shaped depressions which hold rainwater, occur in many parts of the Cobar area. They are found both singly and in groups, and vary considerably in size. Their diameter varies from 10 to 50 feet or more, and they are up to 2 or 3 feet deep. This gilgai is north of Mount Hope, and, although relatively shallow, holds water for quite a time after rain.

ABORIGINAL WATERHOLES IN THE COBAR AREA

By G. M. CUNNINGHAM
District Soil Conservationist, Condobolin, New South Wales

PRIOR to European settlement, the country between Condobolin, Cobar and Bourke, in western New South Wales, was, in terms of the white man's requirements, virtually waterless. This accounted for the relatively late settlement of the region (except on the fringes) and for the lack of excursions into the area by the early explorers.

There were no perennial streams. Even the fringing Lachlan and Darling Rivers ceased flowing at times, and the Bogan River to the east was invariably reduced to a chain of waterholes.

The creeks rising in the higher country around Bobadah, Nymagee, and Canbelego flowed only for a short time after heavy rains.

In order to occupy this area, the Aborigines were forced to make the best use of the available waters. Some of these waters remained in their natural state, but others had their capacity enlarged by the Aborigines; still further waterholes were constructed where suitable sites existed.

Water sources varied considerably in type. Natural springs, rockpools in the ranges, gilgais in clay soil, small weathered pools on exposed rock shelves, and even hollow tree-trunks, provided sources of water. Some waters were of very small capacity and the water quickly evaporated. Others reputedly never, or only very occasionally, ran dry.

The abundance of game in an area, as well as the ability of the Aborigines to live there, was very closely linked with water supply. When the waters gave out the tribe had to move on.

The sites of the waters were well known to the Aborigines, and white exploring parties often depended on directions to small waterholes for survival in the region.

Many of the waters were used by both Aborigines and native fauna. In some instances waterholes were covered with large stones or logs and branches. This prevented use of the waters by the larger fauna and reduced to a minimum fouling of the water by these animals.

The sites of rockpools are varied, and those used by the Aborigines seem to have varying aspects. In some areas local tradition has it that the enlarged pools and rockholes were constructed on the southern side of rocks where possible. This reduced the time during which the sun shone directly on the waterhole and so lowered evaporation losses.

The major types of waters are discussed below.

Natural rockpools

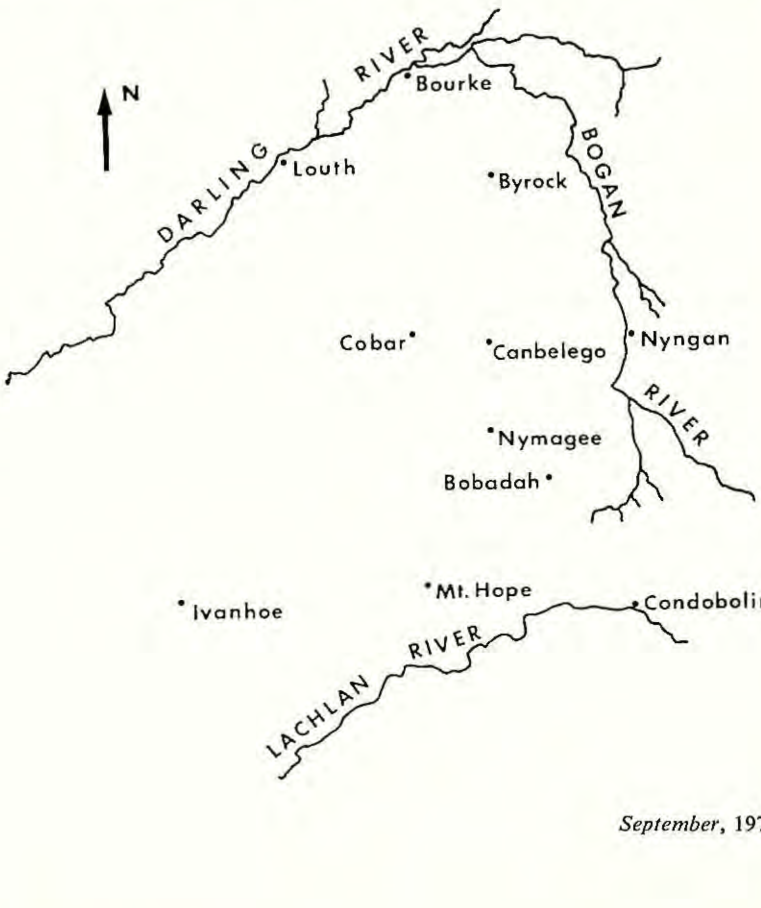
Most of the rockpools occur in drainage lines emanating from rocky hill country. Many are associated with waterfalls and have been carved into the rock by rushing water.

By virtue of their situation in watercourses, these pools are usually in sheltered positions and are not subject to direct sunlight and wind over the whole day. Their size varies considerably. Pools may reach 40 or 50 feet in diameter and may be 3 to 6 feet deep or more.

The rushing waters which quickly materialize in this rocky country after heavy rains provide most of the water stored in natural rockpools. Seepage through the rock beds of the hills no doubt also contributes to the maintenance of their capacity between rains.

Sadly, many of these pools appear to be silting up following grazing of their catchments by sheep and feral goats. As a consequence, many now hold only a fraction of their original capacity.

In addition to the major rockpools, small shallow natural pools occur throughout the area. Most of these occur in granite country on exposed rocks, and are usually only a few inches deep (see photo on the next page.) Their storage capacity is small, and because of their exposure to wind and the sun these waters quickly dry up. Despite this, they are a source of water often many miles from a more permanent site and no doubt assisted travelling Aborigines in the days immediately following rain.



The area between Bourke, Cobar and Condobolin which is discussed in this article.

A series of small natural pools on an exposed rock shelf in the Nymagee area. These pools are between 2 and 4 feet in diameter and 2 to 4 inches deep when full. The bare rock surface provides an excellent catchment.

An advantage of these small holes is that they usually have a hard rock catchment, and so fill easily with small showers. Such rains would contribute little to storage in the larger rockpools and gilgais, as most of the moisture would be absorbed by the soil of their catchment areas.

Artificially deepened waterholes

These are the pools which are partly natural and partly man-made. In capacity they are generally much smaller than the large natural rockpools.

Waterholes up to 14 feet long and 5 feet wide, with a depth of at least 3 feet, exist in the area under review. Most of the artificially deepened waterholes, however, are smaller, as shown in the photo on page 369.

Although the exact method of construction of these rockholes is not known, many have the appearance of having been chipped out. Even so, the lips of the rockholes and their internal walls are usually quite smooth.

Mostly, these artificial rockholes are located along a line of weakness or crack in the rock.

At times, a number of small holes are seen near one or two larger holes, indicating that a number of attempts have been made to construct a rockhole. These were either abandoned or were only in the early stage of development when the tribes of this area left.

Bare rock surfaces act as catchments for these waterholes. In most cases the waterhole is situated in a low spot or along a drainage path on the rock.

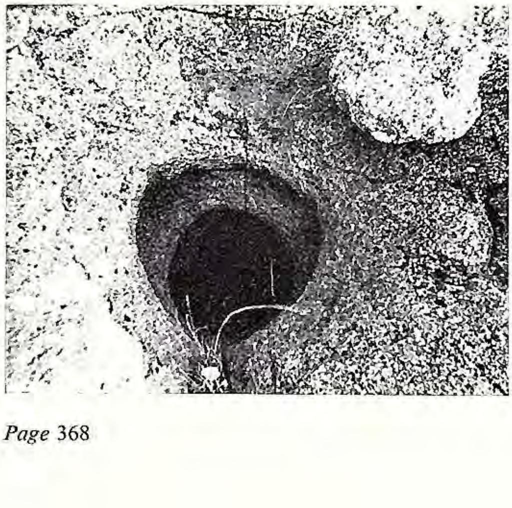
Rock shelves and large exposed granite rocks are the usual sites for these waterholes. These locations were visited at intervals by the Aborigines, and the stored water was utilized in part or fully before the group left. According to local lore, a fire was lit in the larger waterholes if they were emptied. This was done shortly before the Aborigines departed. Fire caused rock from the sides to crack away, and so storage was increased. The next visitors cleaned the broken rock from the waterhole and, if it was emptied, repeated the process. In this way storages were gradually widened and deepened.

With the smaller waterholes the process by which the artificial section (see photo on page 369) was deepened is unknown. It may have been by percussion only or by a combination of fire and percussion. A similar process of utilizing the water and then deepening the hole was probably employed by those using these smaller waters.

Artificial rockholes

The sites of these waterholes are usually level or slightly sloping rock faces. Chosen

Above: A number of attempts to form a waterhole appear to have been made along a crack which forms a drainage path between two higher sections of a granite boulder. Below: A close-up of the artificial rockhole which is seen at the bottom of the photo above. This rockhole, which is in the Mount Hope district, was made along a fine crack in the rock. It is about 30 inches deep and 15 inches wide at the top. The stone beside it was used to cover it to prevent access by native fauna.



rock types vary, but granitic sites were quite popular. At times, however, nearby rock projections appear to have been chipped away by the Aborigines to form "catch drains" or pathways for water to enter the rockhole.

Rockholes of this type may be up to 15 inches in diameter and as deep as 30 inches.

Artificially shaped stones usually cover these rockholes.

Gilgais

Gilgais are not abundant in this country, but they are widespread. Some appear to have a poor water-holding ability, but others hold water for long periods and support a water-loving vegetation.

Gilgais may be 10 to 50 feet in diameter and up to 2 feet or so deep.

The occurrence of Aboriginal grinding stones and other tools around some gilgais indicates that they were used as sources of water for short periods, at least.

Other sources of water

As mentioned previously, springs on hillsides were used by the Aborigines. These usually fed small pools, which were often fouled by native fauna.

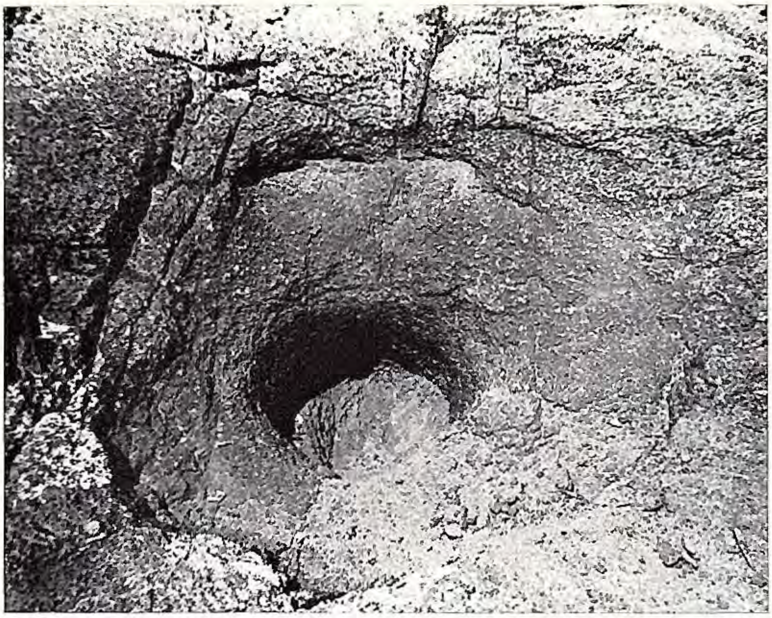
In other situations, where water was unavailable from other sources, the roots of certain trees were utilized. The roots were exposed, cut into lengths, and then stood upright in a container. Under gravity, the sap ran out and the collected liquid was used as a drink.

Hollow, living trees which held water inside their trunks were a source of water for the Aborigines of the belah-rosewood country between Cobar and Ivanhoe.

Rainwater was channelled by the branches into holes in the forks of these trees—usually belahs (*Casuarina cristata*). The rosewood is *Heterodendrum oleifolium*.

The stored water was extracted by a sucking action, using long, hollow plant stems as straws.

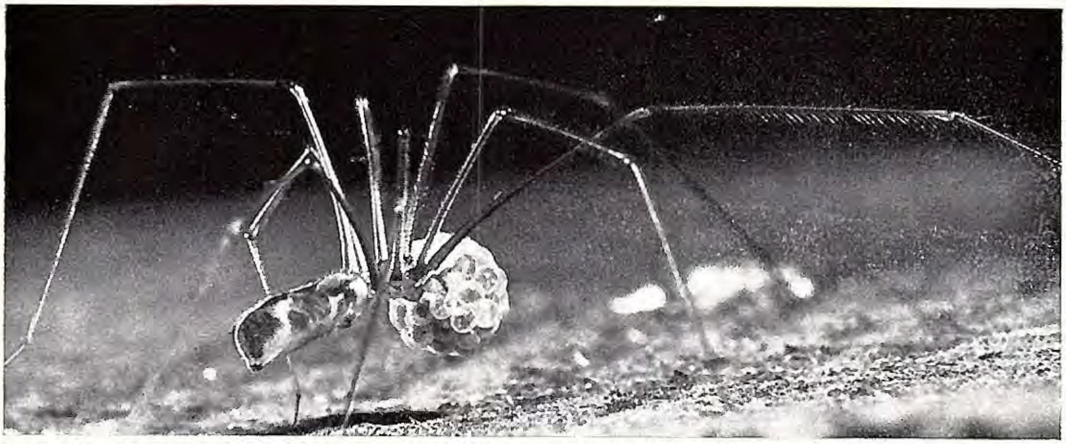
The locations of these water trees were apparently well known to the local inhabitants, who made good use of them.



A close-up view of a rockpool which, apparently, had been artificially deepened. The central section is about 5 or 6 inches deeper than the remainder, and is centred on a crack in the rock. (Artificially deepened parts of rockholes are usually associated with a crack in the rock). This rockpool is in the Mount Hope district.

By using natural water storages and developing others by the primitive means of chipping and firing, the Aborigines mastered the inhospitable environment of the region—a region which was one of the last occupied for pastoral settlement in New South Wales because of this very reason. Only after the discovery of minerals and the construction of large artificial water storages did European settlement of the area gain impetus and lead to permanent occupation of the area for pastoral purposes.

[*The map and photos in this article are by the author.*]



Spiders of the family Pholcidae (Daddy-Long-Legs or Cellar Spiders) are unusual among web-spinning spiders because of the protection they give to their eggs. The female spins a few strands of silk around the egg-batch and then holds it in her jaws until the spiderlings hatch. The Daddy-Long-Legs in the photo is *Pholcus phalangioides*, a worldwide species commonly associated with man. [Photo: Anthony Healy.]

3,000 YEARS OF TRADE IN NEW GUINEA OBSIDIAN

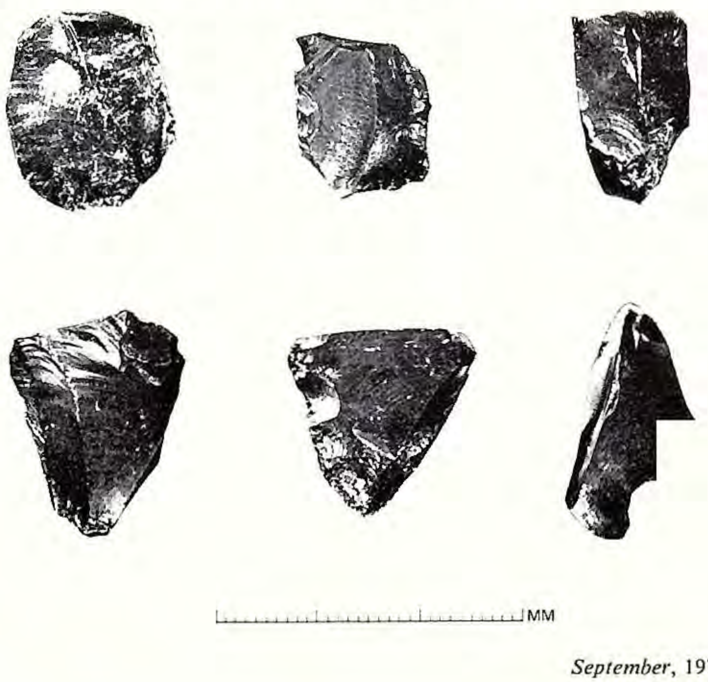
By WALLACE AMBROSE

Research Officer, Prehistory Department, Research School of Pacific Studies, Australian National University, Canberra, A.C.T.

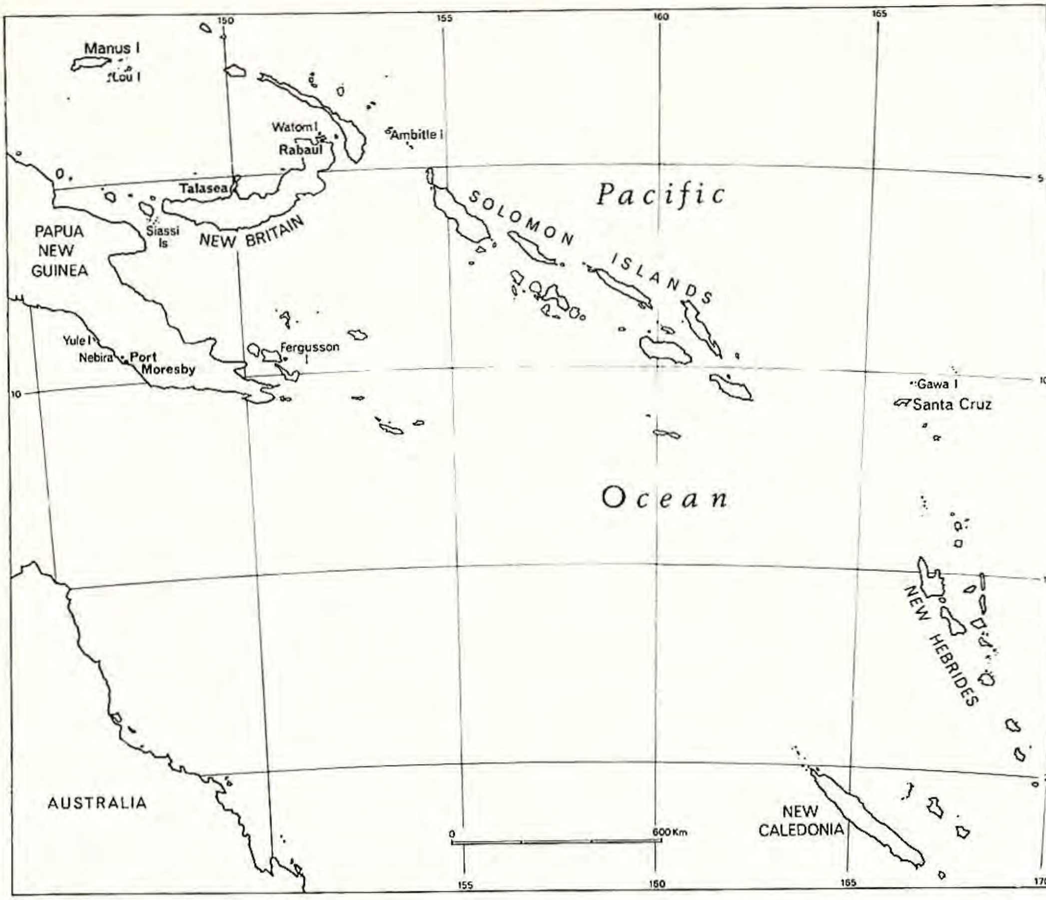
OBSIDIAN, a natural volcanic glass, is very rare in Australia but is relatively common in other countries bordering the Pacific Ocean. In a great arc of volcanic centres stretching from New Zealand in the south, to Japan in the west, and the west coast of the American continent in the north and east, obsidian is found, usually as relatively minor isolated exposures within far larger silica-rich crystalline volcanic rock masses.

In this large circum-Pacific region obsidian has found a ready use with prehistoric groups. Whenever a razor-sharp blade was needed a piece could be struck from a larger block, which might have been quarried and carried some distance from its place of origin. Some sources would yield large blocks unblemished by cracks, flow bands, bubbles or crystallized zones. These better-quality sources would be the ones which people would seek out and exploit, so that a quarry of good material would be highly valued, become widely known, and provide an important item of trade or exchange.

Coastal trading or exchange systems were well developed and widespread in recent Papua New Guinea history. Obsidian has been included in this trade from the three major known sources—Lau and Pam Island off Manus Island in the Admiralty Group, Talasea in the Willaumez Peninsula of New Britain, and Fergusson and Dobu Islands off the eastern tip of Papua. The Talasea source gives some of the best quality obsidian, without flaws and producing large sharp flakes. It was being traded widely up to recent times by seafaring Siassi Islands middlemen from the western tip of New Britain to distant places along the north coast of New Guinea and the Huon Peninsula. It has also found its way around the New Britain coast to the eastern extremity at Rabaul. Although there is a minor source of



Small flakes of obsidian used as simple cutting or scraping tools from the Ambitle Island site. This obsidian was brought from Talasea and Lau Island to Ambitle Island more than 2,000 years ago. [Photo: D. Markovic.]



Location of places referred to in the text. From this an idea of the extent of prehistoric voyaging can be gained. [Map by W. Mumford.]

obsidian at Rabaul it is of inferior quality for flaking and people still use the preferred Talasea material.

Chemical composition

The chemical composition of rhyolitic obsidians from different sources does not vary greatly in major components, such as silica, aluminium, potassium, and sodium. On the other hand, the minor and trace elements often show wide variations between one source and another. Though the compositional variation between different sources may be large, the variation of minor elements within a source is usually very small. Therefore the relative chemical homogeneity of each separate source allows it to be matched with a fair degree of certainty with an unknown piece of obsidian which may have been carried far away from its original source. In the present case the elements used for comparison of sources are strontium, zirconium, barium, copper, manganese, magnesium, iron, titanium, and calcium.

This ability to match an unknown artefact to one of the known raw material sources, by chemical analysis, is a very useful aid for archaeologists dealing with questions of prehistoric contacts between groups and their possible exchange and trade networks. When obsidian is recovered from a site archaeologists will, therefore, be interested to know from where it came, particularly because the possible sources are so few.

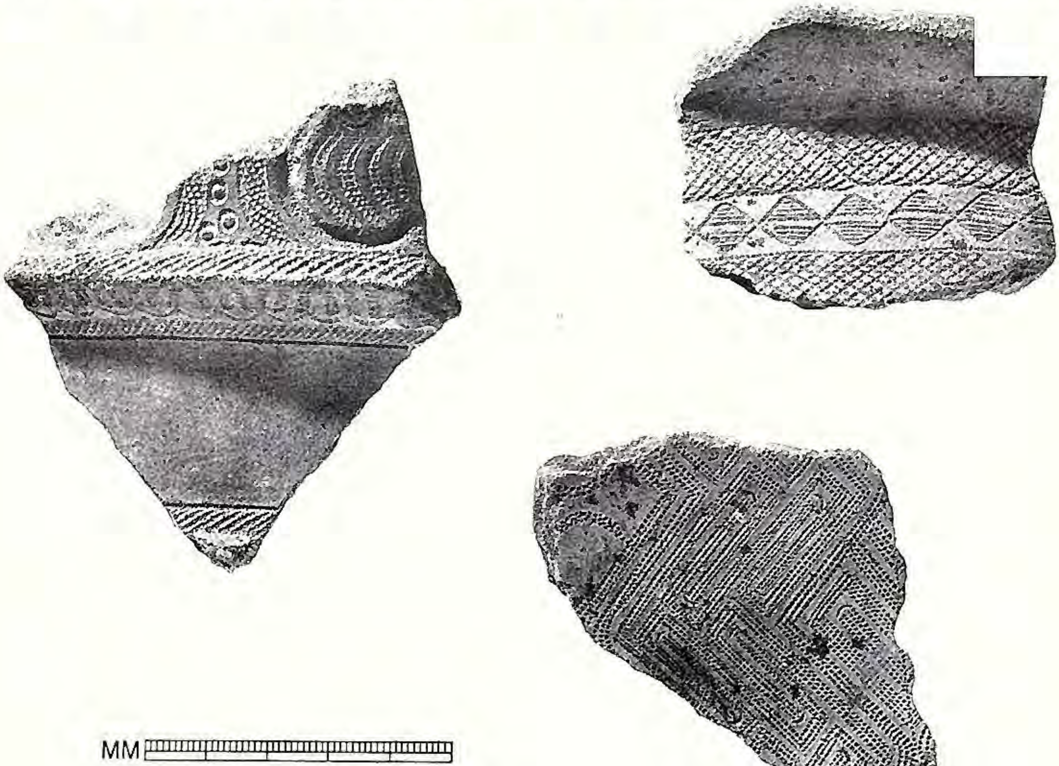
The first work on matching obsidian from archaeological sites to the known quarry sources in Papua New Guinea, by spectrochemical means, showed that flakes from the Watom Island site had been brought from Talasea about 2,500 years ago.

Lapita ware

The fact that there are small obsidian artefacts on Watom Island which have been dated between 2,000 and 3,000 years ago is not in itself very remarkable. What is more important is their association with a distinctively ornamented pottery that is now recognized as the earliest in the region. There exists a striking similarity between the Watom Island pottery and that from sites in the New Hebrides, New Caledonia, Fiji, and and Tonga. With the recognition of this similarity of pottery, archaeologists were quick to suggest early links by a community of culture throughout the region. Much effort has been spent by many archaeologists in trying to establish a clearer picture of the life and range of contacts of the prehistoric groups responsible for this pottery. The ware itself has now been named Lapita, after the name of an archaeological site in New Caledonia where it has been found in abundance and was first extensively described.

The importance of obsidian, in our understanding of the Lapita sites, is the way in which artefacts made from it can be correlated with the original source of the raw material. In this way it is possible to build up a picture of the realm of contacts, the possible influences, and generally the extent of the region which could have been exploited for other raw materials and products.

Prehistoric sites recently excavated on two very small islands, one at Ambitle off the southeastern corner of New Ireland, and the



Fragments of Lapita ware from excavations on Ambitle Island, off New Ireland. The ornate geometric pattern was produced by repeatedly impressing a dentate stamp into the vessel before it was fired. Working with a small number of basic decorative elements, the potters produced a very wide range of complex designs. [Photo: D. Markovic.]

other at Gawa in the Santa Cruz group in the southernmost Solomon Islands, have also produced pottery with a distinctive and rather ornate Lapita decorative treatment.

The obsidian on the Ambitle Island site appears to be from two sources. A comparison of the nine elements determined by emission spectrography shows that one of the two obsidian types is from the important Talasea source. Though it is not possible to match the second type of obsidian from Ambitle with any of the known sources with certainty, a comparison of nine major elements suggests the second type is from the Lau-Pam source. The distance from Talasea to Ambitle is not much further than the distance of the historically recorded transport of obsidian from Talasea to the New Guinea mainland—that is, about 500 kilometres, (about 300 miles). The distance from Lau to Ambitle is rather longer at about 750 kilometres (about 450 miles). This requires sailing over about 200 kilometres (about 120 miles) of open sea at one stage of the voyage.

The Gawa site also has obsidian and Lapita pottery together, while, again, the age is within the same period as the other related pottery sites—that is, up to about 1000 B.C. The analysis of the Gawa obsidian shows it to have come from the Talasea source, a fact which, in this case, required the remarkably long transport of about 2,000 kilometres, most of which distance would have been by sea.

Seafaring skills

That such long-distance travel was not an isolated feat of endurance but well within the capacity of skilled seafarers seems clear; the ability to sail such journeys, often on wide stretches of open sea, implies that the sophisticated technology necessary for building and sailing ocean-going craft was well developed by the first millenium B.C. in island Melanesia.

Who the distributors of the obsidian were, or where their sailing skills and their technology for making the ornate Lapita ware were first developed, has not yet been discovered. It does seem certain, however, that by gradual cultural change the seafarers of about 500 B.C. in the western Pacific had rather more restricted contacts at their easternmost landfalls in Fiji, Tonga, and Samoa. It is now generally believed that in this area the people who later became recognizably Polynesian in language, customs, and technology were to emerge. Even so, the outstanding ability of Polynesian fishermen and sailors continued long enough to be recorded in recent history.

Early contacts between seafarers bringing new materials, products and way of life, and earlier groups who were essentially land-based, is also found at two sites near Port Moresby, where obsidian has been recovered associated with pottery which has some family resemblance to the Lapita ware. The sites have been dated by radiocarbon analysis to around the second century A.D. The spectrochemical analysis of the odsidians from these mainland sites at Nebira near Port Moresby and Apere Vanuna, near Yule Island, shows that they came from the Fergusson Island source, which is about 600 kilometres away by sea.

In the mainland coastal Papua New Guinea sites there is clear evidence that the associated pottery and obsidian are relative latecomers in the prehistory of the region, having been brought there by people who were familiar with voyaging long distances and who were able to acquire some access to resources probably owned by different groups whose livelihood did not depend on the sea.

The nature of the contacts between the groups who burst on the scene in coastal areas of Melanesia nearly 3,000 years ago, and who managed to preserve long-range contacts for several hundred years, will be complex. But the extent of the early contacts can be delineated by finding the sources of the raw materials, such as obsidian, pottery clays, and rocks, which have been brought to the new settlements from distant places.

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NEW BOOKS REVIEWED

BASS STRAIT BIRDS

BIRDS IN BASS STRAIT, by Ken Simpson. A. H. & A. W. Reed Pty Ltd, Sydney, 1972. Board covers, 112 pages, 4 maps, 70 coloured and 27 black and white photos. $4.95.

This book has been sponsored by the Oil and Gas Division of the Broken Hill Pty Co. Ltd. It is the first, we are told, of several titles on selected Australian subjects initiated by the sponsor. If the quality of the other books in the series compares with this one, they will be well worth waiting for.

This is a most delightful book, not only for ornithologists but for all people interested in the sea or seashores or wild places generally.

Ken Simpson has been a bird-watcher all his life. He joined the Bird Observers' Club when 11 years of age. He has always been particularly interested in sea birds, and this book contains many personal observations and facts that he has accumulated.

The text is an up-to-date, authoritative account of the birds of Bass Strait. It is divided into six sections, which deal with the breeding sea birds; the resident sea birds that breed in freshwater areas; regular summer and winter migrants to the Strait; rare visitors, and, finally, those land and shore birds such as waders, sea-eagles and Cape Barren Geese that make up the regular fauna of the Bass Strait islands.

Two pleasing features of the text are the references for further reading on every species dealt with, and the suggestions on how to correctly identify each bird. Details are even provided to help one identify some of the sub-specific races of certain albatrosses. Descriptions of immature plumages are also given. The text provides entertainment, too. It is full of enjoyable anecdotes about people and places associated with the author's bird-watching activities. While bird-watchers are often the butt of many jokes, it is a good writer who can turn his experiences into an entertaining story.

The ninety-seven photographs, mostly coloured, illustrating fifty-four species, are the best series yet published on sea birds in Australia. The photographs are used discerningly to illustrate the birds and their habitats, as well as being useful for the identification of immature and sub-species plumage differences. The major credit goes to Bill Burlace for his action shots of sea birds. Burlace, along with other Sydneysiders, regularly goes to sea in a small boat up to 20 miles offshore to photograph and observe sea birds, and his efforts have been well rewarded. (Photographs of the heads of prions and the New Zealand crested penguins also provide good identification aids.)

Four maps are used to indicate ocean currents, the location of islands, and the probable paths of the migrant sea and shore birds that visit the Strait.

The last chapters provide useful information about land bird migration across the Strait, sea bird research, beachcombing for dead sea birds, specimen preservation, and sea bird photography. Finally, a list of bird societies and clubs is provided. However, the information on New South Wales is inaccurate. It is the New South Wales Field Ornithologists' Club that is based in Sydney, not a branch of the Royal Australian Ornithologists' Union, while the Bird Banders' Association is an Australia-wide organization whose membership is open to all. Banders must, of course, be licensed by their State wildlife authority and the CSIRO Division of Wildlife Research.

Birds in Bass Strait is recommended reading for all persons interested in natural history.—*Alan K. Morris, of the National Parks and Wildlife Service.*

FOR BEGINNERS

BIRDS FOR BEGINNERS, by Olive Seymour; Jacaranda Press, Brisbane, 1972; 96 pages of text and coloured and black-and-white drawings; price, $4.50.

This book, as the title says, is for beginners; it is recommended, as it achieves this object well.

The first thirty-four pages tell where to look for birds, how to make notes, how to use field-glasses, and give information on nests and eggs, camouflage, bird voices, how to attract birds to your garden, and on migration. At the end of this section is a reference section, where all the main orders and groups of Australian land-based birds are described by size and calls and other useful characteristics. A total of 187 species are listed, and an observer should usually be able to place any bird he sees into its correct group; if it is one of the passerine families not listed he should be able, from his training in note-taking and his knowledge that it is not one of the groups represented, either to find it in a larger text book or send a description to his State Museum, enabling the latter to give or suggest identification, as advised in the book.

It is hoped that this book will encourage people to become bird observers with accurate notes and thus increase our knowledge of birds in Australia.—*H. J. de S. Disney, Curator of Birds, Australian Museum.*

A cicada, *Psaltoda argentata*, singing on a branch of a shrub. The insect stands up so that no part of its body touches the branch—probably to prevent damping of the sound produced. Also, the abdomen is raised and extended, the extension being so great that the intersegmental membranes (the pale rings seen on the abdomen in the photo) are plainly visible. In the resting position, this insect's body-length is 3 to 3.5 centimetres ($1\frac{1}{8}$ to $1\frac{3}{8}$ inches); its predominant colour is black with a conspicuous silvery patch on the side of the abdomen. This photo was obtained with a 200 millimetre telephoto lens and a 20 millimetre extension ring on a standard reflex camera. [Photo: Author.]

Sound Production in Cicadas

By DAVID YOUNG

Research Fellow, Research School of Biological Sciences, Australian National University, Canberra, A.C.T.

THE shrilling of cicadas is a familiar summer sound in the warmer parts of Australia. There can be few people brought up in Australia who are not acquainted with the noise made by these notorious insects. Entomologists classify typical cicadas as a single family of insects (Cicadidae) belonging to the order of bugs (Hemiptera). Most cicadas are found in the tropics and subtropics around the world and some extend into temperate regions.

No other family of insects has evolved such a distinct and specialized means of producing sound. It is only the males that produce the sound. The broad outline of this mechanism has been known for many years, but it is only recently that electronic recording and display apparatus has enabled detailed studies to be made of the physiological mechanisms involved and of the physical qualities of the sound itself. These studies were begun some years ago in other countries and so I became interested in looking at Australian cicadas. The Australian cicadas have proved particularly interesting so far in revealing new variations on the basic mechanism and in the presence of some highly specialized and unusual forms.

My own studies have centred on the species available on the northern New South Wales coast. This is a good area for regularly collecting a number of interesting species. It has been possible to experiment on freshly collected cicadas through the use of a mobile laboratory, which Mr K. Underwood has enabled us to site at his property, Marbuk Park, Port Macquarie.

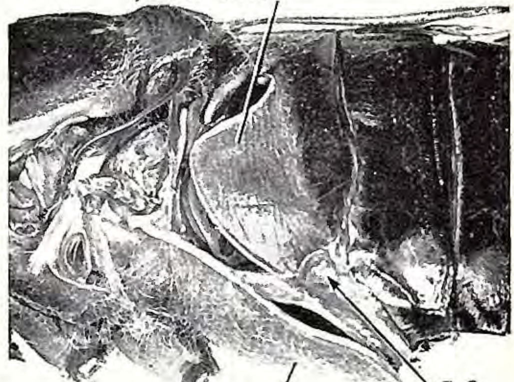
Sound-producing mechanism

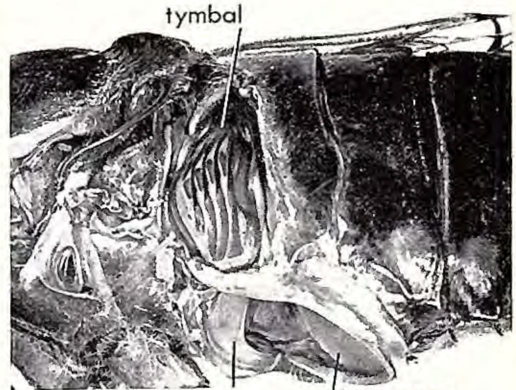
The basic sound-producing mechanism consists of a pair of ribbed cuticular membranes, the tymbals, which are situated on what appears to be the first abdominal segment. The tymbal membrane bears several long ribs, alternating with short ribs arranged in a line. Internally the upper part of each tymbal is attached by a short tendon (or apodeme) to a large tymbal muscle. The contraction of this muscle causes the tymbal to buckle inwards, and relaxation of the muscle allows the tymbal to pop back to its original position. The tymbal buckles along the line of short ribs. A pulse of sound is produced by the damped vibration of the tymbal when it pops in, and sometimes when it pops out, and the frequency of the sound is determined by the natural period of vibration of the tymbal. The basic characteristics of the sound result from a combination of the sound frequency, the pulse repetition frequency, and the structure of the individual pulses. Variations in the pulse amplitude (i.e., loudness) and in the temporal grouping of the pulses produce the more detailed patterning of the song. The combination of these characteristics is constant and distinct for each species of cicada so that different species can be recognized by their songs.

Distinguishing one song from another

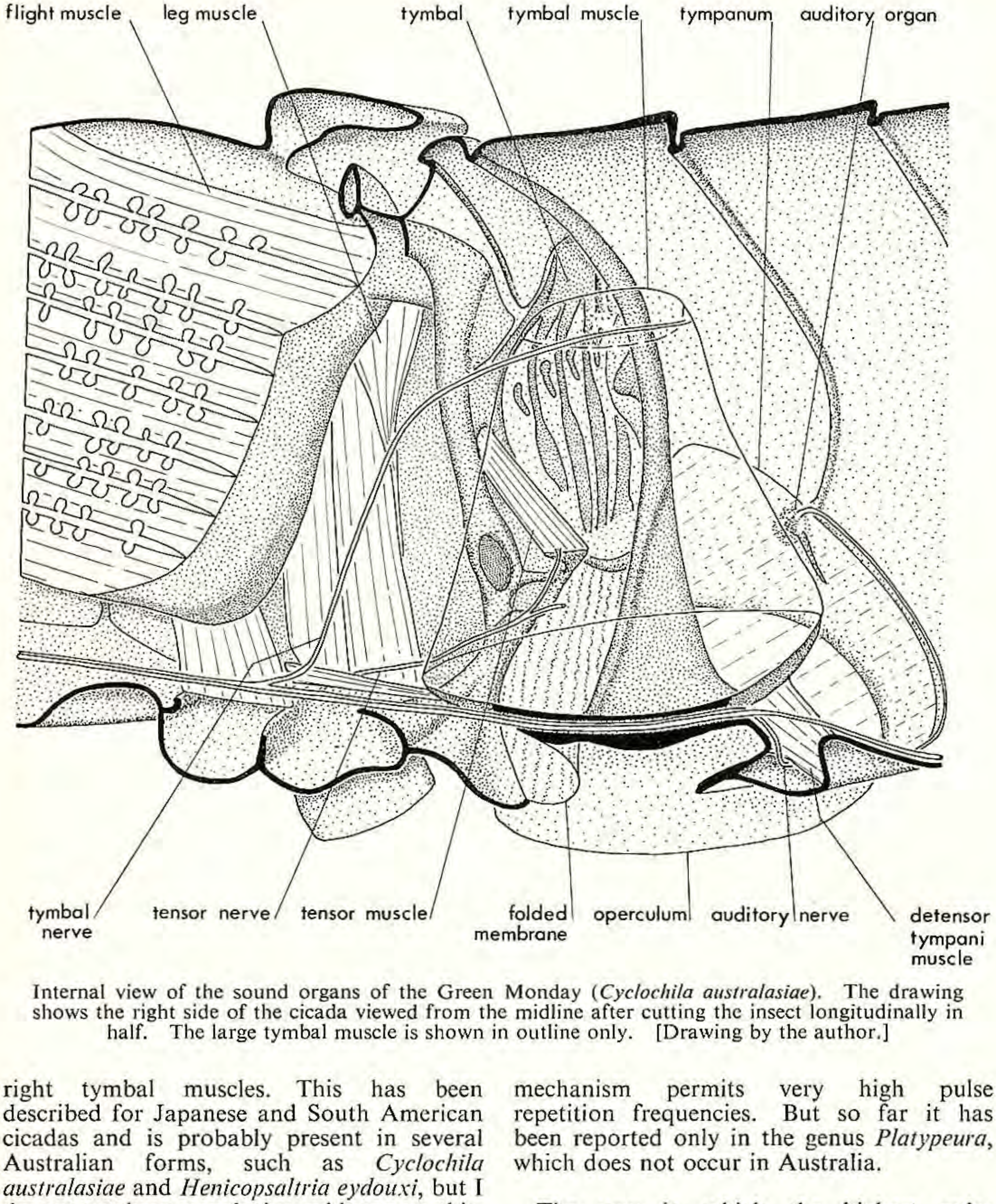
With a little practice the songs of the different species can be distinguished by ear, even from a passing car. To some extent the physical qualities of the song can be predicted by listening to it carefully. As with all sounds, a harsh note reflects a high harmonic content and a purer note a low harmonic content. Since the human ear takes some time to assess the pitch of a sound, the sound frequency will only be heard clearly where the pulse duration is long. Where it is short, the pulse repetition frequency will be more strongly evident. Again, where the sound pulses are grouped, the ear tends to hear a mixture of the pulse and grouped pulse frequencies, so giving a rasping quality to the sound.

These various qualities of cicada songs result from a number of variations on the basic mechanism described above. One of the qualities which varies most is the pulse repetition frequency, and this is achieved in several ways. In most cicadas a single nerve impulse causes a single, rapid contraction of the tymbal muscle. Rather low pulse repetition frequencies result where the left and right tymbal muscles contract simultaneously and only the inward pop produces a sound pulse. So far this situation has been reported only in Australian cicadas such as *Arunta perulata* and *Cystosoma saundersii*. The lowest pulse repetition frequency reported for any cicada is that of *Cystosoma* at 40 per second. Higher pulse repetition frequencies are usual in most cicadas, and one way in which this is achieved is by alternating the contractions of the left and





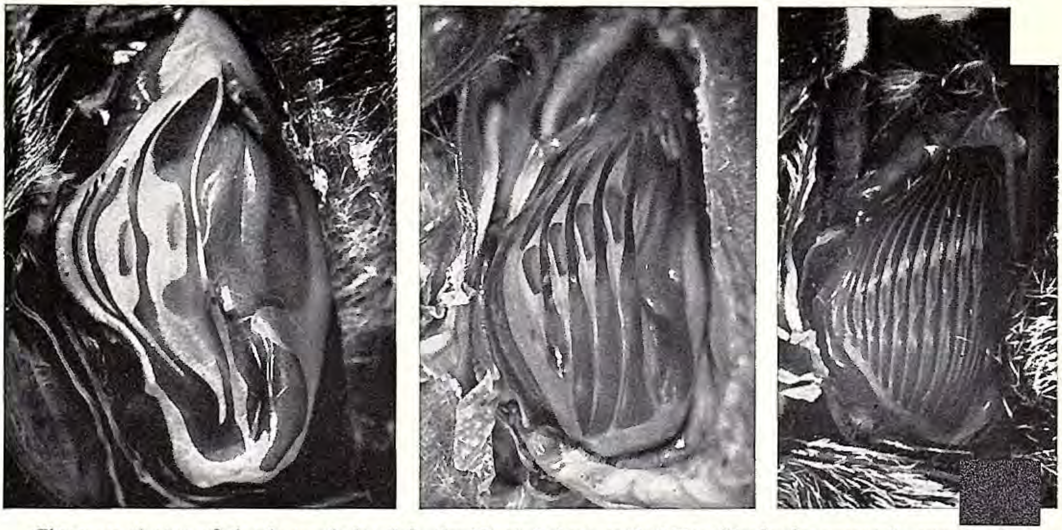
The sound organs of the Green Monday (*Cyclochila australasiae*). The insect is viewed from the left side with the left wings removed. Above: the structures visible in the intact insect, including the auditory capsule (a.c.). Below: the same insect with the tymbal cover and operculum removed to show the specialized cuticular membranes. [Photos: B. Parr.]



Internal view of the sound organs of the Green Monday (*Cyclochila australasiae*). The drawing shows the right side of the cicada viewed from the midline after cutting the insect longitudinally in half. The large tymbal muscle is shown in outline only. [Drawing by the author.]

right tymbal muscles. This has been described for Japanese and South American cicadas and is probably present in several Australian forms, such as *Cyclochila australasiae* and *Henicopsaltria eydouxi*, but I do not yet have conclusive evidence on this. A further increase in pulse repetition frequency is achieved in some by having both the in and out pops of the tymbal producing sound pulses. This occurs in *Psaltoda harrisii*, for example. In some cicadas a single nerve impulse results in several contractions of the tymbal muscle, and this mechanism permits very high pulse repetition frequencies. But so far it has been reported only in the genus *Platypeura*, which does not occur in Australia.

The way in which the highest pulse repetition frequencies are obtained involves the tymbals with the most highly developed ribs. In the Floury Miller Cicada (*Abricta curvicosta*) the tymbal membrane bears about twelve long ribs, which are strongly raised above the level of the membrane and are closely parallel to each other. Consequently,



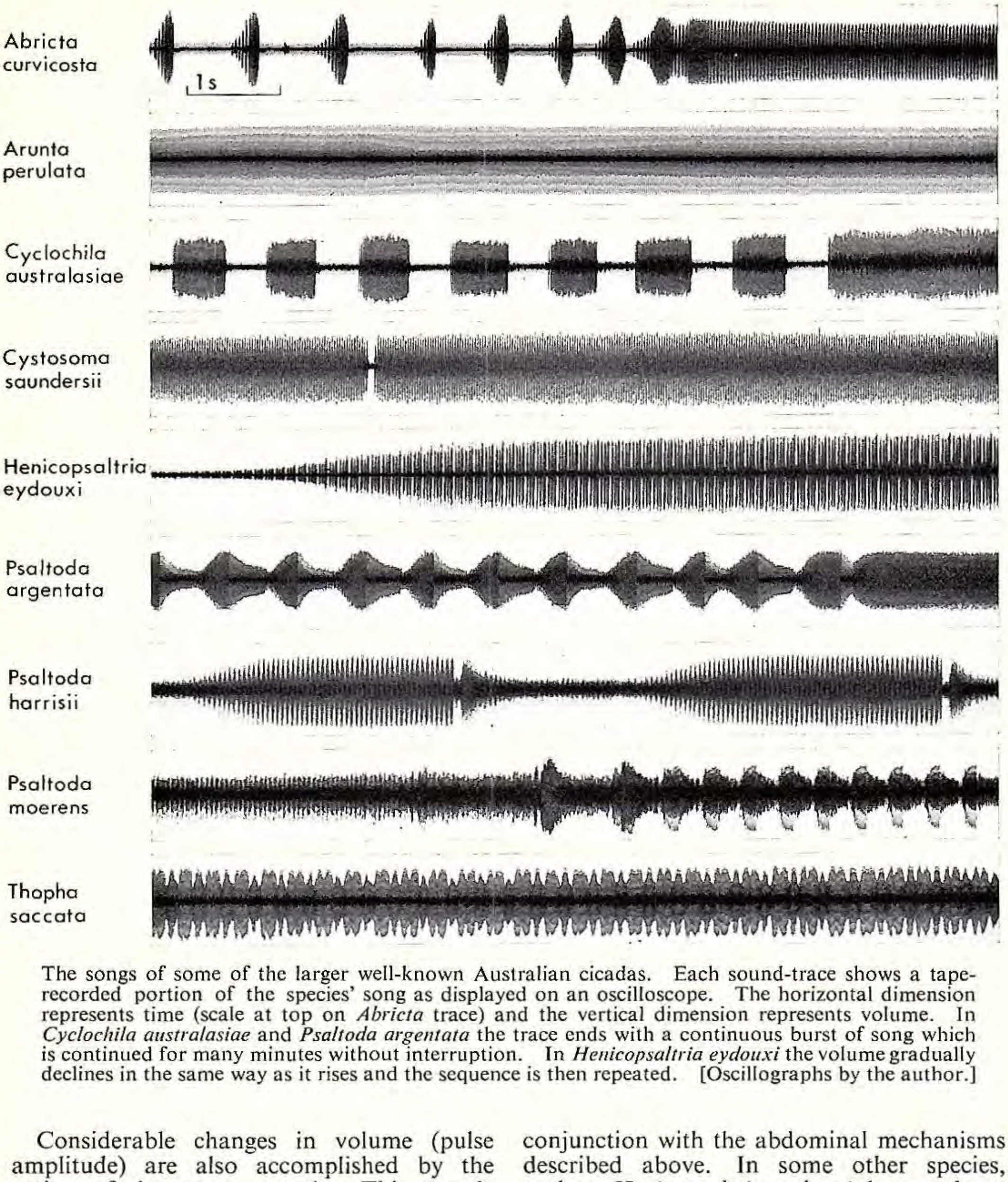
Close-up photos of cicada tymbals: left, the Black Prince or Red Eye (*Psaltoda moerens*); centre, the Green Monday (*Cyclochila australasiae*); right, the Floury Miller (*Abricta curvicosta*). Note especially the differences in the shape and arrangement of the long ribs on the tymbal membrane and presence of the small ribs arranged in a line. [Photos: B. Parr.]

when the tymbal buckles inward, the individual ribs buckle in orderly succession and each produces a separate pulse of sound. In this way, a single inward movement of the tymbal results in several sound pulses. In *Abricta* the pulse repetition frequency is over 1,000 per second. This tymbal mechanism is also found in the famous American periodical cicada, *Magicicada*.

Much yet to be learned

Much remains to be discovered about how the physical properties of the tymbal influence the quality of sound produced. This is especially true of the role played by the ribs, which are present in all the tymbals I have examined. In several genera, such as *Arunta*, *Cyclochila*, and *Cystosoma*, the long ribs of the tymbal are regular in shape and parallel to each other, though not strongly raised nor so closely parallel as in the tymbals of *Abricta*. In other genera, such as *Psaltoda* and many overseas genera, the long ribs are not regular in shape nor arranged parallel to each other. One possible significance for these variations may be that the tymbals with parallel ribs produce sound pulses with few harmonics and the tymbals with ribs not parallel produce sound pulses with many harmonics. However, the exact physical mechanisms of tymbal action are currently being studied by my colleague, Dr Harald Nocke, and this study promises to extend and revise our current concepts considerably.

In addition to the factors involved directly in the buckling of the tymbal, other accessory mechanisms have an important influence on the properties of the sound produced. One of these involves the tracheal system of the insects. The sound muscles of cicadas are enveloped in expansions of the tracheal system and these expansions extend into the abdomen to form what is in effect a single, large air chamber. Often this occupies most of the abdomen, and the vital organs of digestion, excretion, and reproduction are all pushed into a corner. The air chamber serves not only to reduce the damping of the sound pulses but also positively acts, in many species, to increase the volume of sound emitted. During the songs of several species, volume changes are accomplished by altering the effectiveness of this air chamber, either by changing the shape of the abdomen or by varying the gap between the opercula and the tympana, or both at once. For example, in *Abricta* and *Psaltoda* sudden increases in volume can be seen to be accompanied by a rapid raising and extension of the abdomen.



The songs of some of the larger well-known Australian cicadas. Each sound-trace shows a tape-recorded portion of the species' song as displayed on an oscilloscope. The horizontal dimension represents time (scale at top on *Abricta* trace) and the vertical dimension represents volume. In *Cyclochila australasiae* and *Psaltoda argentata* the trace ends with a continuous burst of song which is continued for many minutes without interruption. In *Henicopsaltria eydouxi* the volume gradually declines in the same way as it rises and the sequence is then repeated. [Oscillographs by the author.]

Considerable changes in volume (pulse amplitude) are also accomplished by the action of the tensor muscle. This muscle inserts on the side of the tymbal and its contraction increases the resting tension of the tymbal (rather like tightening a drum), so resulting in louder sound pulses when the tymbal buckles in. The tensor muscle is very large in those species which show sudden volume changes in their song (e.g., *Psaltoda moerens*), and in these cases it works in conjunction with the abdominal mechanisms described above. In some other species, such as *Henicopsaltria eydouxi*, large volume changes appear to be accomplished almost entirely with the tensor muscle since no abdominal movement can be seen during the song. Thus in *Henicopsaltria* also the tensor muscle is very large but in species such as *Cyclochila* and *Cystosoma*, which show little or no volume variation, it is much smaller.

Cicadas can, of course, hear the sounds produced by other cicadas. The sound is received by a large membrane, the tympanum, which is normally concealed by the operculum. A short tendon connects the tympanum to the auditory organ, which is located in the auditory capsule on the abdominal wall. However, the tympanum is creased during sound production by the action of a special muscle, the detensor tympani, and so the singing cicada is not deafened by its own song.

In conclusion, recent research is gradually showing that cicadas have a most intricate system for producing their distinctive calls. It can be seen that the basic mechanism of nerve, muscle and tymbal is subject to a number of important variations in the different genera studied. In addition, the accessory mechanisms make an essential contribution to the loudness and variety of cicada songs. Although the study of this system involves complex apparatus, there are many important aspects which can be studied without any apparatus at all. This is an area where the amateur naturalist can make a valuable contribution to our overall understanding of the singing behaviour of cicadas. For the little that we know about sound production should not be allowed to conceal our almost total ignorance of other aspects of cicada biology.

MEET OUR CONTRIBUTORS . . .

WALLACE AMBROSE, Research Officer in the Prehistory Department, Research School of Pacific Studies, Australian National University, Canberra, has worked in the Prehistory Department since coming to Canberra from New Zealand 10 years ago. His present interests are in the improvement of a dating technique based on the natural hydration of obsidian and the application of this system to archaeological sites lacking other means of dating. He is also interested in the preservation of swamp-degraded wood from excavations. He is a member of the International Committee of Museums working group on wood preservation.

S. A. BARNETT is Professor and Head of the Department of Zoology, Australian National University, Canberra. He read zoology at Oxford. During and after the war he was head of a British Government research unit on rodent pests. For 20 years before emigrating to Australia he worked in Glasgow University on "social stress" among wild rats, and on the effects of "cold stress" on mice. He is continuing his work on wild rodents in Australia. He also directs research on the exploratory behaviour of small mammals in an artificial, automated environment designed in his Glasgow laboratory. He is author of *The Human Species*, now in its fifth edition; *"Instinct" and "Intelligence"*, now in its second edition; and *The Rat: A Study in Behaviour*.

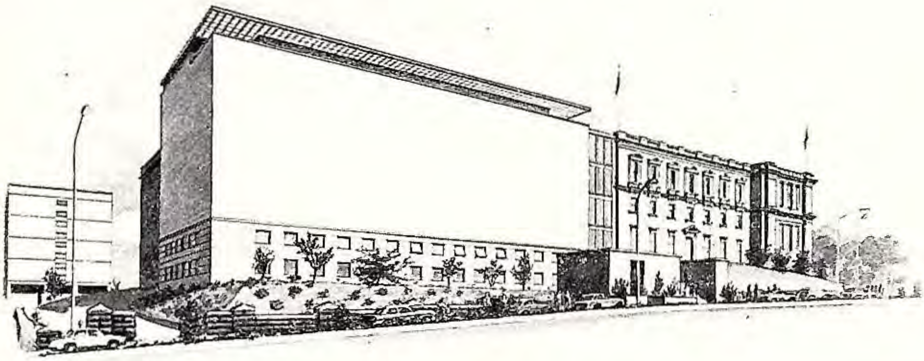
STEPHEN S. CLARK, Assistant Curator in the Australian Museum's Department of Environmental Studies, came to the Museum from the United States, where he received a B.A. in geology from Harvard University and an M.Sc. in Resource Planning and Conservation from the University of Michigan. While an undergraduate he spent summers in the field in Montana, Maine, and Greenland. Graduate work in ecology included seven months of field study and research with the Organization for Tropical Studies in Costa Rica. His present interests include the ecological effects of beach-sand mining and resource management.

G. M. CUNNINGHAM is District Soil Conservationist in charge of Soil Conservation Service activities in western New South Wales. He is a graduate in Agriculture (B.Sc. Agr.) of the University of Sydney, and, since graduation in 1963, has been stationed at Nyngan and Condobolin. His work has taken him over much of western New South Wales, as well as parts of Central Australia, Western Australia, and Queensland. A deep interest in the history of the Aborigines who formerly inhabited inland Australia has led him to many interesting sites, including some which are otherwise virtually unknown.

VINCENT SERVENTY is a Western Australian naturalist and author, now living in Sydney. His early professional career was spent mainly in science education after obtaining his degrees at the University of Western Australia. He is chairman of the Nature Conservation Council of New South Wales, president of the Wildlife Preservation Society of Australia, editor of *Wildlife in Australia* and conservation representative on the National Parks and Wildlife Advisory Council of New South Wales and on the council of the Gould League.

RICHARD HALL TEDFORD, a Californian, first became acquainted with Australia 20 years ago, when he and the late R. A. Stirton, both at the University of California, came to this country as Fulbright scholars to search for a history of the unique mammal fauna of Australia. This work has been so exciting and successful that Dr Tedford has returned to Australia ten times during the past two decades. He married Elizabeth Henderson, of Ardrossan, South Australia, in 1954. They now live in the New York area.

DAVID YOUNG is a research Fellow in the Neurobiology Department, Research School of Biological Sciences, Australian National University, Canberra. He works on the motor and sensory systems of insects. His main subject is the specificity and regeneration of nerve connections in cockroaches, but in the summer he turns his attention to cicadas. Dr Young has a degree in zoology from Oxford and a Ph.D from Cardiff.



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