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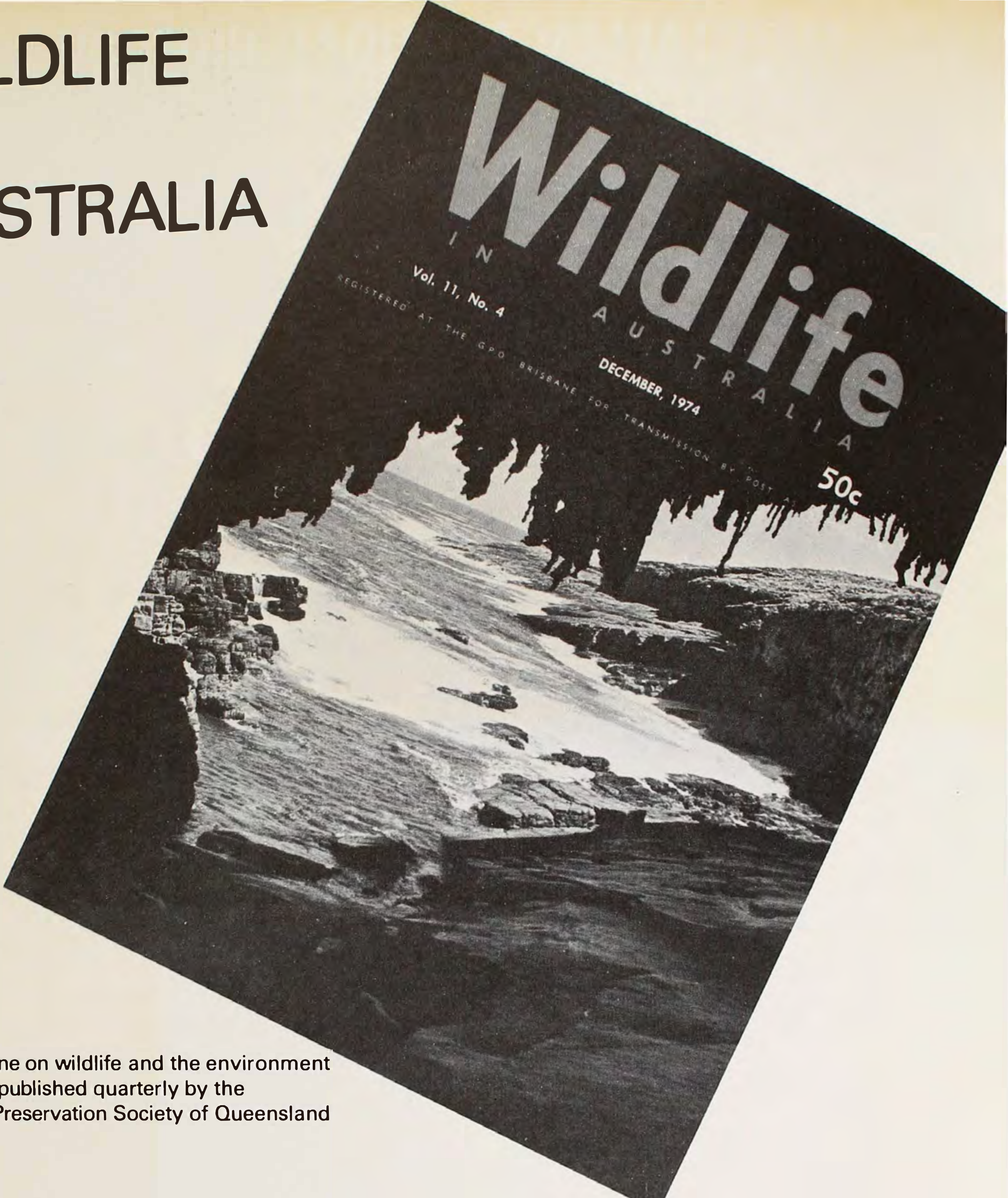

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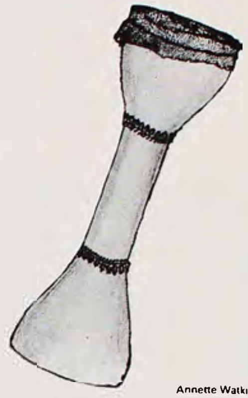

Annette Watkins

COVER: Traditional potters of Papua New Guinea use neither potter's wheel nor kiln. There are variations in firing techniques, but in each method, the pot is in direct contact with the flame. (Photo: Margaret Tuckson)

ABOVE: The *kundu,* a fired clay drum, is unique to the Markham Valley of Papua New Guinea. It is coiled, in the same way as a pot, in two sections which are later joined together.

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A GRAND NATURAL EXPER

THE NADGEE WILDFIRE

BY HARRY F. RECHER, DANIEL LUNNEY AND HAYMO POSAMENTIER

Fire and its use in the management of natural areas must be one of the most contentious environmental issues in Australia. The Australian bush is highly inflammable and although fire is unquestionably part of its natural ecology, naturally-occuring fires are very different from those produced by the modern practice of controlled burning—the deliberate firing of the bush to reduce the amount of litter or 'fuel' in the forest. Controlled burning minimizes the risk of wildfire, but litter removed by these controlled burns

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not only includes the flowering plants whose blossoms contribute so much to the beauty of our forests, it is also an important part of the habitat of ground-dwelling animals.

Little is known of the smaller, and sometimes less attractive, animals of Australia; antechinus and rats are good examples. This is not because these animals are unimportant or uninteresting, but simply because there have not been enough biologists to make the necessary studies. Yet if we are to ensure the survival of Australia's

Nadgee River Plot before the fire showing thick layer of leaf litter and middle-storey vegetation.

Daniel Lunney

Ann Jelinek

rich wildlife, we must be as concerned and knowledgeable about native rats as we are about koalas and kangaroos.

Above: Author (Lunney) weighing *Rattus fuscipes.* Weighing is a routine procedure with each capture. Right: Toe of *Antechinus stuarti* being cut for future identification of the individual. Below: Author (Posamentier) shaking *Rattus fuscipes* into weighing bag as routine trap-clearing procedure.

In 1969, staff of The Australian Museum's Department of Environmental Studies began a study of the small mammals in the Nadgee Nature Reserve, which lies south of Eden on the border of Victoria and New South Wales. The Reserve is bounded on the west by extensive State Forests and on the east by the ocean. As with all Nature Reserves in New South wales, public access is restricted and scientific research is encouraged. Nadgee has a very rich wildlife population and there are extensive heaths, coastal scrubs and wet and dry sclerophyll forests. Nadgee's most important asset, however, may be its small freshwater streams, the only ones in NSW that

Daniel Lunney

are unpolluted and have no introduced fish.

Our study was conceived to help make recommendations on the reservation of natural areas and on their management. Particular concern was felt about the use of controlled fires in National Parks, Nature Reserves and

Daniel Lunney

State Forests, but the information was lacking which was needed to advise on how controlled fire might be used to prevent wildfire and still ensure the survival of the small plants and animals of the forest floor. When we began our work at Nadgee we planned three or four years of observation during which we could get a reasonable idea of the ecology and behaviour of native small mammals, their habitat requirments, and normal fluctuations in population size. These data could then have been used to interpret the results of experiments in which we deliberately burned or otherwise changed the habitat.

Each habitat has its own distinctive fauna and although Australian Museum scientists have collected extensively, studies have concentrated on small mammals and birds. We began at Nadgee by establishing a study plot in forest on the Nadgee River adjacent to a clearing formerly occupied by an old homestead. The trees here are mainly second growth dry sclerophyll—predominantly Silvertop Ash, Bloodwood and Monkey Gum. The forest runs along a ridge that slopes steeply on one side to the Nadgee River and gently on the other to a Paperbark swamp along Wombat Creek. The river side of the forest

HARRY RECHER, Senior Research Scientist at The Australian Museum, is head of the Museum's Department of Environmental Studies.

is regularly scoured by floods.

The Reserve was established in 1957 and the fire history of the area prior to this is not well-known. It is likely that parts of the heaths burnt each year and may have been burnt regularly over thousands of years by the Aboriginal population. A wildfire in 1933 burnt approximately half the area of the Nadgee Reserve including the forest where the Nadgee River plot is located and, in 1965, the heath on which ten of our study plots are located was also burnt. A strict policy of fire supression was then followed. One consequence of this was the invasion of the heaths by shrubs and trees and the decline of some heath birds, notably the Ground Parrot.

By 1972 much of the forest had a well developed understorey and ground vegetation although litter was noticeably patchy. 1971 and 1972 were unusually dry years for southeastern New South Wales. In December

Allan Fox

1972, a chance bolt of lightning gave us a superb opportunity to study the effects of wildfire. The fire ignited under dry conditions in an area of fairly high fuel load. This was the first major fire at Nadgee since 1933. Between sixty and seventy thousand hectares, including almost the entire fifteen thousand hectares of the Reserve, were burnt. Included were the heath and forest habitats in our study areas. All the heaths were reduced to ashes and sixty percent of the canopy was burnt or scorched in forest areas. Ground and understorey vegetation burnt throughout the Reserve and soil litter layers were removed. On the Nadgee River plot, ninety percent of the canopy was scorched, litter and vegetation layers were

H. F. Recher

burnt, and sixty percent of the logs were destroyed. The loss of logs may have a long-term effect on wildlife and is perhaps the most significant change. Rather than disrupt our research, the fire has provided a unique opportunity to study the effects of wildfire on small mammals.

Many animals were killed and the beaches were littered with dead birds. The personnel of the National Parks and Wildlife Service counted more than eight hundred. Parrots, honeyeaters and wrens—generally small birds rather than the larger kookaburras and cur-

Above: Ring-tailed Possum caught by the fire. Left: The heaths were stripped by the fire. Below: The fire was intense behind Jane Spiers beach.

Allan Fox

DANIEL LUNNEY is Research Assistant to Dr. Recher. HAYMO POSAMENTIER is Technical Officer (Scientific) in the Department.

rawongs—were killed. Presumably, large birds were able to fly above the fire and avoid the strong winds it generated. On the heaths and along the roads we found many dead kangaroos and possums. We heard stories of kangaroos leaping off cliffs into the sea in an effort to avoid the fire. With logs and trees still burning fiercely we saw many that had escaped unhurt or with only minor burns.

Clearly many animals, including antechinus and rats, escaped by going underground into holes and wombat burrows. Some escaped by taking cover along streams where the fire was less severe, and others outran the fire or ducked back around it into places already burnt. Though the fire caused great loss of life, many animals survived—enough to recolonise Nadgee. Unburnt patches of vegetation and the banks of streams swarmed with young antechinus. This is understandable since antechinus mate in winter. Hence, the fire came after the young were independent and populations were at a maximum level. In contrast, the two native rats, the Bush Rat and the Swamp Rat, which were found hiding in deep beds of ash in the burnt forest, were all adults. They do not normally begin mating until November and few young, if any, are independent in December.

Australian plants are well adapted to withstand the effects of fire and almost immediately after the fire at Nadgee, sprouts appeared from eucalypts and banksias. With the first rain, seeds germinated. By the following June, the heaths and forest floor were green and some plants were even flowering. In the forest, numerous weeds and grasses responded to the increased light and to the nutrients released by the fire, and by the end of 1973 the forest floor was densely vegetated. Many of these plants were previously uncommon. The Kangaroo Apple (*Solanum aviculare*) for example, formed dense thickets in our study area, but prior to the fire we knew of only one of these plants in the entire Reserve. The lush spring growth of 1973 died back during the heat of summer, but with cooler and wetter conditions in the winter, growth resumed. By the end of 1974, the undergrowth was so thick that walking in the forest was difficult. Wattles that germinated from seed cracked by the fire stood three and four metres high and eucalypts, banksias and other native plants achieved similar growth and have tended to crowd out much of the weedy vegetation. As these plants continue to grow and as the shade from the trees increases, the ground vegetation in the forest will become less dense and the pre-fire situation will be restored.

New growth on the heaths consists almost entirely of plant species present before the fire. However, species are more widely spread and, two years after the fire, each of our study plots have half again as many plant species as previously. The density of growth is low nonetheless and only the first twenty centimetres has regrown to the conditions that existed before the fire. The slower rate of growth on the heaths and the failure of weedy plants to colonise these habitats suggests that the heaths are much poorer in nutrients than the forests. An old analysis of the Nadgee heath by the Department of Agriculture indeed indicates this and suggests it was the result of too-frequent fire.

Our research at Nadgee consists of three separate, co-ordinated studies. The first is an investigation of the ecology of small mammal populations in dry sclerophyll forest adjacent to the Nadgee River. The Nadgee River plot covers six hectares and, before the fire, it supported populations of two dasyurid marsupials, Stuart's Antechinus (*Antechinus stuarti*) and Swainson's Antechinus (*A. swainsoni*), and two native rodents, the Swamp Rat (*Rattus lutreolus*) and the Bush Rat (*R. fuscipes*). Our studies have concentrated on these four small mammals, although twelve other species of native mammals occur commonly. These are Pygmy, Brush-tailed and Ring-tailed Possums, Swamp Wallabies, Grey Kangaroos, Potoroos, Short-nosed and Long-nosed Bandicoots, Yellow-bellied and Greater Gliders, Dingoes and Wombats. Emphasis has been placed on long-term population changes and the way small mammals use a common environment. Animals are trapped alive, marked by toe-clipping and released.

The second study is designed to provide detailed information on the habitats used by small mammals and the features of the habitat that determine which species of small mammals are present. This work has been confined to heaths and data are available from thirty plots. each plot is a circle thirty-two metres in diameter and small mammals are collected with ordinary rat traps. Among the measurements made on each heath plot are foliage density, leaf litter, diversity of plant species, and extent of bare ground.

Before the fire, the same species occurred in both heathland and forest. Since the fire, the House Mouse (*Mus musculus*), an introduced

Allan Fox

Pre-fire and post-fire aerial views across the two heaths, Impressa Moor and Nadgee Moor with Nadgee beach and Nadgee River in centre of photos.

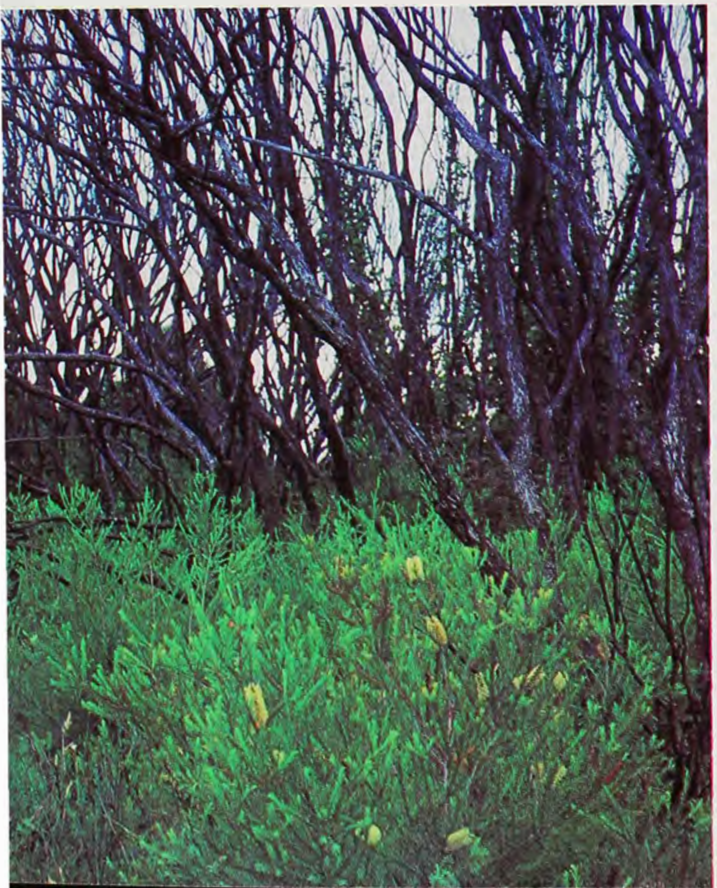
Allan Fox

rodent, has established a population on the heaths and observations have been made on this animal. Regular sampling with live traps has also been conducted since the fire in areas adjacent to or near the Nadgee River plot in places that were not burnt and are thought to have provided refuge for small mammals. Among these refuges is an old farming area on the adjacent river flat where, as the third part of our programme, we are studying a population of the Swamp Rat.

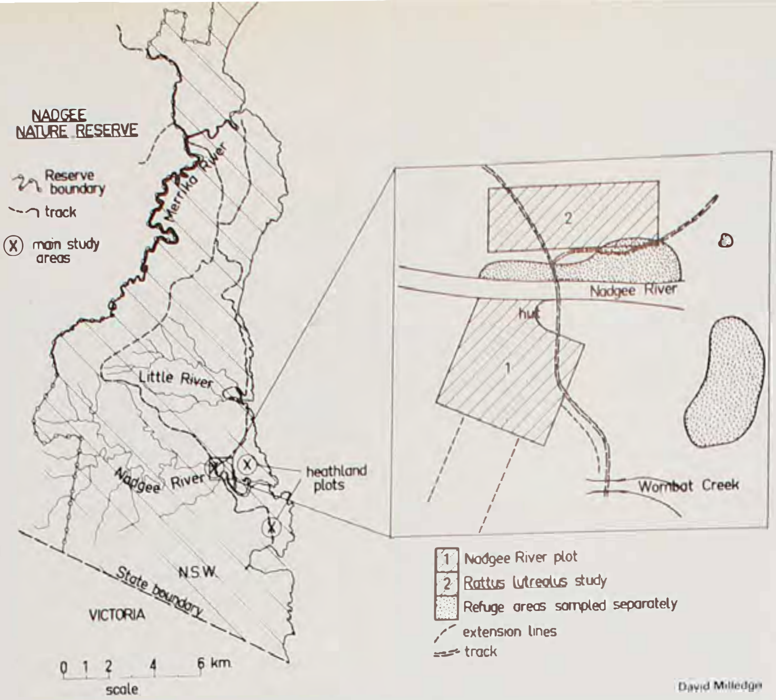
Antechinus are particularly interesting animals in that all the females in a population become ready to mate within a few days of each other and within a fortnight after mating, all the males die! Though most small mammals are short-lived—few live much longer than a year—only antechinus has such a highly synchronised breeding season coupled with the death of all males. At Nadgee, the mating season of Swainson's Antechinus is in late June. All males die by mid-July and females give birth within the first few days of August. These processes occur one month later in Stuart's Antechinus. The timing of the breeding is apparently synchronised with the photoperiod as mating occurs progressively later in the year as one proceeds north from Nadgee. Stuart's Antechinus mates at Nadgee in August, in September near Sydney and in October near Brisbane. As a result, the female is raising her young when food is most plentiful. It is interesting to note that young antechinus are cared for by their mothers for a much longer period (90 days) than the rats (25-30 days). Rats also reproduce over a long period from spring to autumn. At Nadgee, the Bush Rats may have two or more litters a year, and the young of the first litter may even reproduce before the summer is over. Their potential for population increase is, as a result, much greater than that of the antechinus.

We trapped many animals in the forest during January 1973 but found few on the heaths. A few antechinus and rats occurred near the edges of cliffs, where the effects of the fire were less severe, but these soon disappeared, and since the fire few small native mammals have recolonised the heaths. The heath vegetation may not yet be dense enough to support viable populations of the species present before the fire.

Robert Stewart



Regeneration of *Melaleuca armillaris* on northern headland of Nadgee Beach.



David Milledge

The House Mouse, though, now occurs on the heaths in small numbers. After the fire, it began breeding almost at once and its numbers rose rapidly. It seems likely that this animal occurred at Nadgee before the fire and had certainly lived around the ranger's cottage. This mouse has colonised disturbed habitats throughout the world and is particularly good at responding quickly to the changes brought by fire. It disperses rapidly, breeds profusely and thrives on a wide range of foods. It is the only small mammal at Nadgee that breeds throughout the year.

In the forest, the number of small mammals declined during 1973. The Swamp Rat and Swainson's Antechinus disappeared completely and populations of the Bush Rat and Stuart's Antechinus reached very low levels. All however, occurred on unburnt areas nearby and produced young. Other animals also reproduced successfully in either burnt or unburnt areas. With the exception of the Crescent Honeyeater, a forest bird which depends on nectar, all the animals we expected at Nadgee were present though populations were in some cases low. The lush forest vegetation greatly increased the food avilable to kangaroos and wallabies and by the summer of 1973, all females had young. Conditions were favourable for birds which nested two and three times during the spring and summer. Multiple nestings were evident among such insect-eating birds as fantails, warblers and wrens—obviously insects were abundant.

The second year after the fire has seen other changes. Neither antechinus has increased in numbers although both have reproduced successfully. In contrast, rats have greatly increased in abundance and the Bush Rat began breeding earlier in the year than is normal. It has recolonised all the parts of the forest it occupied before the fire and is probably more abundant than ever. Though it does not normally occur in forest, the Swamp Rat has also spread throughout the forest and is now common.

One other small mammal merits mention. Soon after the fire, we trapped the Pygmy Possum (*Cercartetus nanus*) for the first time

Rattus fuscipes, the native Bush Rat.

E. Slater

E. Slater

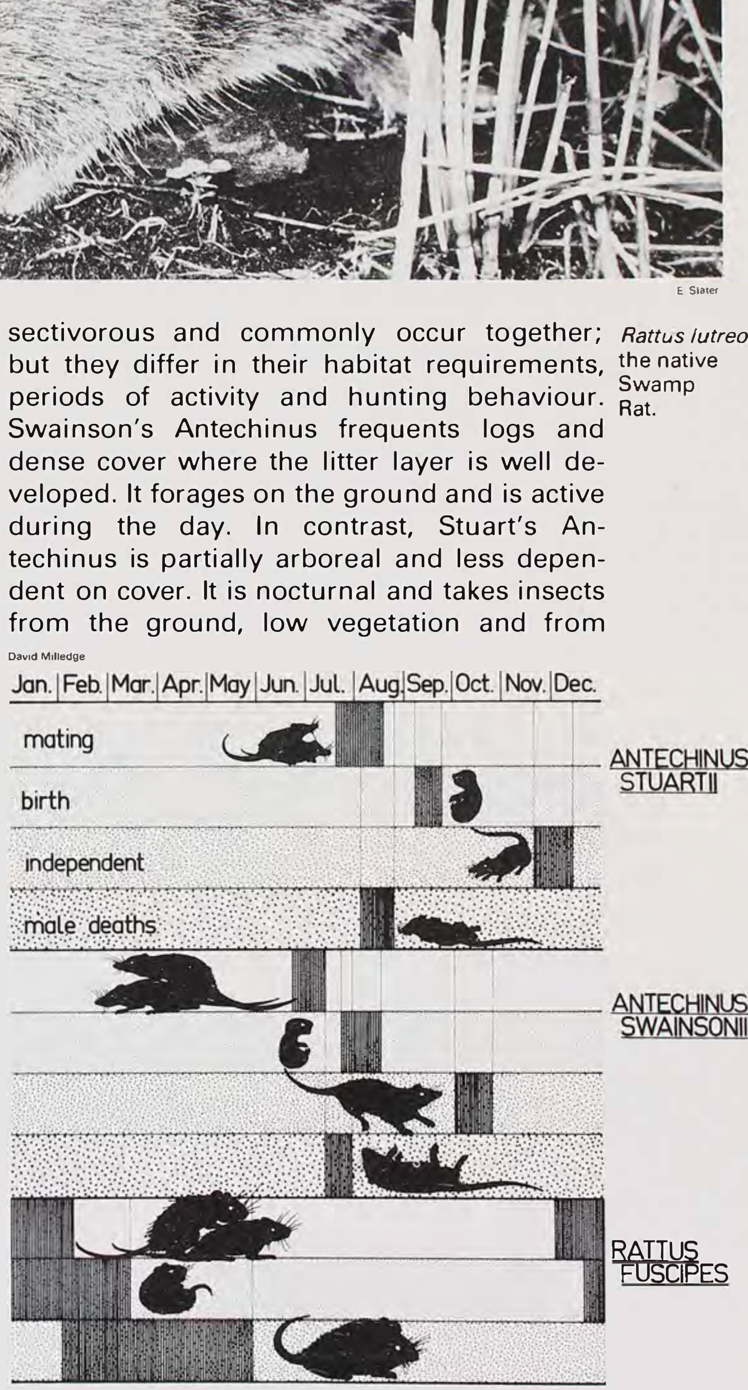
Rattus lutreolus, the native Swamp Rat.

on our forest plot. The Pygmy Possum is primarily insectivorous and is normally arboreal. With the destruction of the forest vegetation, it was forced to forage and move along the ground where our traps are located. As the vegetation has regrown, it has been caught less frequently, an indication that it is spending an increasing proportion of its time in the trees.

It is still too early to know the full effects of the fire. The destruction of litter and ground vegetation reduced the number of animals the ecosystem could support and many that survived the fire were exposed to increased predation or were unable to find food. It is impossible to separate entirely the effects of fire from the effects of weather. Dry conditions during 1971 and 1972 had reduced the numbers of Swainson's Antechinus and continuing drought has probably compounded the effects of the fire on this animal. Ironically, it has also been affected by flood. In 1973, heavy rains flooded the unburnt areas along the Nadgee River and drowned all know litters there. In general, however, these are short-term problems and with continued regrowth, all animals will return to pre-fire levels.

Each species has shown a different response to the changed habitat. Some differences result from the timing of the fire in relation to the animals' breeding seasons, but the most significant differences are due to the ecology of the animals. The antechinus are insectivorous and commonly occur together; but they differ in their habitat requirements, periods of activity and hunting behaviour. Swainson's Antechinus frequents logs and dense cover where the litter layer is well developed. It forages on the ground and is active during the day. In contrast, Stuart's Antechinus is partially arboreal and less dependent on cover. It is nocturnal and takes insects from the ground, low vegetation and from

David Milledge



W. Clayton

shrubs and trees. From these differences, it is clear that Swainson's Antechinus would be more seriously affected by fire than Stuart's Antechinus, as the fire destroyed the litter layer, ground vegetation and approximately sixty percent of the logs. During 1973, Swainson's Antechinus on the Nadgee River plot weighted up to fifty percent less than in pre-fire years. This indicates that its food was limited. The weight of Stuart's Antechinus did not differ from that of individuals weighed before the fire, as it was able to forage in trees as well as on the ground and could have exploited insect populations that developed on the shoots of eucalypts. Similar opportunities existed for the Pygmy Possum. The loss of cover probably exposed both species of antechinus to increased predation by owls, lizards, feral cats and others, but the effect would have been greatest on Swainson's Antechinus which is active during the day.

A similar comparison can be made for the two rats. The Swamp Rat is a diurnal herbivore dependent on ground vegetation for cover and food, and it could not survide on the study plot long after the fire. The Bush Rat differs in being nocturnal and omnivorous. Hence, it is not as dependent on ground vegetation for food or cover as the Swamp Rat and was able to survive the immediate effects of the fire. Predation and the absence of young animals may have been responsible for the decrease in numbers of the Bush Rat during 1973.

The Nadgee wildfire was a grand natural experiment. It came when we had already learned much about the small mammals of Nadgee and it was as natural a fire as is possible. No one will deny that wildfire poses a threat to human life and property, but as long as we wish to preserve natural areas, we must attempt to duplicate the conditions through which they have evolved. Wildfire is one such condition, and it is clear that infrequent wildfire need not be an ecological disaster. Is it an alternative to controlled burning?

The natural areas that have been set aside in eastern Australia are too small to survive without intensive and careful management. Part of this management will involve the use of or the supression of fire. The wildfire of 1972 burnt the entire Nadgee Nature Reserve

Ann Jelinek

and a large part of the nearby State Forests. Such a fire occuring again in the near future might well cause permanent harm to the Reserve. If Nadgee were to burn this year, many animals such as Swainson's Antechinus which have not fully recovered from the 1972 burn, and many plants which have not yet reached maturity and set seed, could well be eliminated. Others such as the many weeds and the House Mouse could find conditions even more favourable after a second fire. It would probably make little difference if that

Ann Jelinek

fire were a natural one or one set deliberately for park management.

Many ecologists are concerned about the use of fire for management because they feel that insufficient attention has been paid to the effects of fire frequency, time of year of burning, fire intensity and the extent of the area burnt. We have seen how the timing of a fire can affect the breeding success of native small mammals and change the age structure of the population. At Nadgee, the wildfire effectively prevented the native rats from reproducing, but because both sexes survived in unburnt areas and because rats have a high reproductive potential, their populations have recovered quickly. Had the fire occurred in winter, it would have prevented the reproduction of antechinus: unless these animals reproduce successfully every year the population will become extinct!

As forests mature, an increasing amount of nutrients are bound up in large trees, fallen logs and litter. The decomposition of dead plant material releases nutrients slowly, but mature forests are less productive than young, vigorously growing plant communities. They also have fewer kinds of plants and animals—a reflection of the lesser availability of nutrients and of lower productivity. Wildfire massively releases these bound up nutrients and, as seen at Nadgee, there is a tremendous surge of life. Animal and plant populations explode and species diversity increases. In a way, fire is a renewal of the ecosystem.

Antechinus stuarti displaying its arboreal capacity.

But fire also removes nutrients. Some, such as nitrogen, are vaporised by the heat and others are lost by wind and water erosion of the ash and exposed soil. When fires are infrequent, these losses are insignificant. Frequent fire, however, leads to progressive decline in nutrients, loss of soil and reduction of the productivity and diversity of the ecosystem. We can see little difference between fires set deliberately to reduce the fuel load, and wildfire. If either occurs often, the diversity of our natural areas will decline.

What does this mean for Nadgee? Clearly, it is a mistake to allow the entire Reserve to burn at one time. The Reserve is small and many organisms are represented by only a few individuals. Leaving large unburnt areas increases the chances that these animals and plants will survive. The answer, of course, is to use fire in a constructive fashion. Controlled burning can be used to minimize the chances that wildfire will again burn the entire Reserve, but it would be an error to apply fuel reduction techniques in a monotonous and unimaginative way. The use of fire must reflect and enhance the natural diversity of Nadgee. Not only must cool, winter fires be used, but hot fires must be set deliberately during the heat of summer.

Antechinus Swainsoni female with seven young in pouch. Unlike kangaroos, antechinus have open pouches.

The resurgence of life at Nadgee following the wildfire has been exciting to watch. Though more leisurely, it has been like spring following a cold and snowy Northern Hemisphere winter. Though the story is not finished, it is important to see the effects of the wildfire and to understand the ways different animals and plants have responded—important because fire can be destructive; but fire is part of the Australian environment and, if correctly used, can be a powerful tool to ensure the survival of our wildlife.

Assistance from David Hope, Ann Jelinek and Allan Fox is gratefully acknowledged. This work has been supported by grants from the Ian Potter Foundation.

Fully mature male *Antechinus swainsoni* on author Lunney's knee

EMERGENCE OF THE PYGMY ANTECHINUS

BY ROBERT G. B. MORRISON

Pigmy Antechinus are the smallest known marsupials—rather smaller and slighter in build than a house mouse. Adults are about ten centimetres long and young are approximately three millimetres long at birth. They are now accepted by many as having close affinities with the Planigales.

The pair of *Planigale maculatus* that I have been keeping produced a litter of five, but these animals are known to have litters of up to eleven. The growth rate of juveniles probably depends to some extent on the size of the litter. Observations made on this litter, however, agree fairly closely with data from the South Australian Institute of Medical and Veterinary Science where these animals are being bred and studied by Heather Aslin.

This pair mated in early July, 1974 when the female was ten months old. Her pouch became noticeably swollen after the birth of the young some twenty days later. At this stage the male was removed and housed separately, as males and females housed together in captivity have been observed to fight and to kill the young. At about four weeks the young animals could first be seen protruding from the opening of the pouch, which is directed backward in these animals. With larger litters the young are seen a little earlier than this.

At about five weeks, the pouch was very distended and the litter could no longer fit entirely inside it. The young had by this time become furred and could be seen moving their tails and limbs quite vigorously. The mother was still very active, leaving her nest at dusk for food and water, and the exposed young were constantly being dragged along the ground and squeezed against the sides of narrow apertures as the mother moved about. The amount of time she spent cleaning them increased as they became bigger and more exposed. Two main positions for grooming were seen. In one the female could stand on all fours and turn her head back beneath her body and between her forelegs as if about to somersault. Using her tongue she would rapidly groom those parts of the young that could be reached. The other position was used for more extensive grooming: as she sat well back on her haunches, the pouch opening and the young were pushed forward so that they rested on the ground between her back legs. In this position she would clean each baby thoroughly, spending up to half an hour grooming the litter.

This closeup of a female shows the characteristic head shape of Pygmy Antechinus, the very long whiskers and the large ears and eyes.

Although Aslin describes the young as first becoming detached from the teats at twenty-eight days, the young of this small litter remained attached for about six weeks. The mother would then leave her grass nest only very reluctantly, not even emerging for food on some nights. When she did so she was almost always accompanied by two or three young that remained attached to the teats as they were dragged around. Those that stayed in the nest remained hidden from view until they were about seven weeks old. They then became increasingly adventurous, still attaching themselves to the teats at intervals but making excursions from the nest on their own as well as riding on their mother's back by gripping her fur. At about eight weeks they began to eat solid food, becoming progressively independent of the mother from then on.

Although these animals can be housed together, their acceptance of each other probably depends to a large extent on sexual maturity and reproductive state. The mother was removed from the cage after twelve weeks and housed with the male that had fathered the litter. Since then the young, twenty weeks old at the time of writing, have been living together peacefully, sharing a nest of grass that they have constructed in a variety of sites such as hollow logs, beneath pieces of bark, and in dark corners of the cage. They change the position of the nest every few weeks.

Both sexes of this nocturnal species construct nests in which they sleep during the day. In the case of this litter, it is a communal nest, but in cases where the animals fight and

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R. G. B. Morrison

do not nest together, male and female animals have been seen to construct separate saucer-shaped nests of grass, both animals changing the sites of these from time to time.

The reintroduction of the mother to her former mate produced considerable fighting. They were introduced simultaneously into a new 'neutral' cage that had not previously housed an animal. This precaution was taken for fear that the male, which is larger and had lived alone for twelve weeks, might treat the female as a territorial invader and injure her. These fears proved groundless, however, as it was the female who turned aggressor, quickly dominating the male. The form of these encounters is interesting, being highly stereotyped. The dominant animal, which in this case was the female, approached the male with her eyes half shut and her mouth half open. The male adopted a defensive posture by curving his body sideways with his head toward the female, opening his mouth wide and, when the female approached too closely, lifting the closer forepaw. The male's eyes remained fully open. The female was never observed to attack the male from the front but circled around him until she could run in and grip the fur of his back or the base of his tail. This prompted the male to run at very great speed, with the female clinging to him with her teeth, her forepaws on the fur of his back. These brief and very energetic contests are accompanied by a sound, repeated quickly several times, that seems to be made by both animals and sounds like a very high-pitched cricket call. Following these bouts, when the animals have separated, each has exhibited a curious movement with the forepaws in which

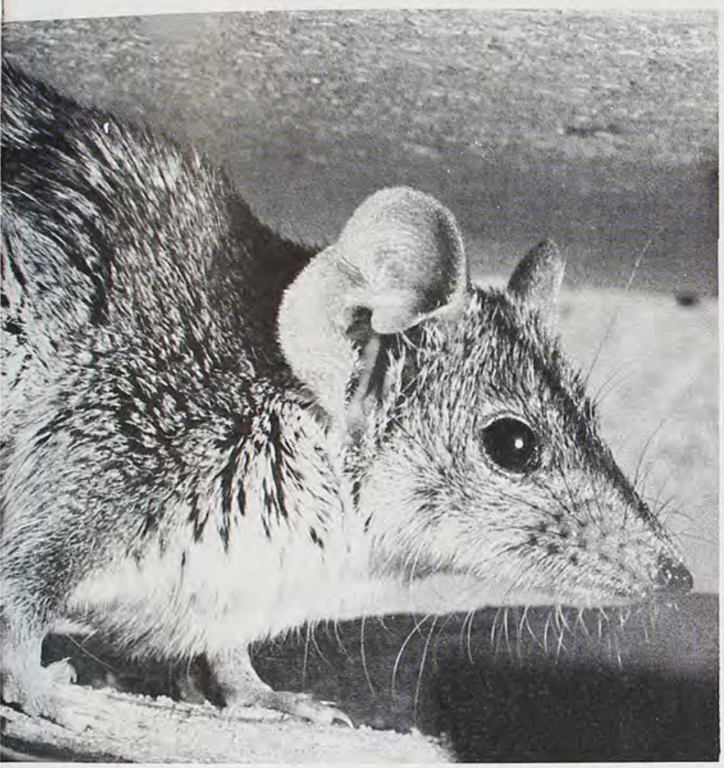
This series of photographs by the author shows sequential stages in the emergence of a litter of *Antechinus maculatus.*

sand is thrown with a quick flicking action both forward and sideways. This action is interspersed with a good deal of rapid grooming. Despite the frequency of these contests, neither animal appears injured in any way.

When deprived of stimuli, animals in captivity seem to become bored, pacing back and forth. This is not only undesirable on humane grounds but also leads to loss of reproductive potential and atypical behavioural patterns. To try to overcome this problem these animals have been housed in large and diversely furnished aquaria fitted with stacks of plywood decks that fit the walls closely and are drilled with series of holes which allow the animals access from one deck to another. These decks greatly increase the floor space available to each animal and each is covered with sand, grass, leaves or bark, to provide adequate material and positions for secluded nesting sites. The clear glass wall of the

aquarium allows observation of activity on any deck and black paper is used to cover the side when observations are complete.

These little creatures are extremely shy, venturing out of cover only with extreme caution. It is interesting, however, to note their reactions to a potential predator. A hand moved close to the glass wall of the aquarium on the same level as the animal provokes only curiosity; the animal comes right up to the glass and sniffs vigorously. The same hand, moved above the animal when it is foraging on the top deck, provokes an immediate alarm reaction, and the animal rushes for cover at top speed. The same sort of reaction is seen in relation to sounds, even if these are quiet. Presumably, danger to this animal in the wild originates largely overhead and their vision,



hearing and sense of smell all seem acute.

Common names for our animals are often unsatisfactory, and the description of this species as the 'pygmy marsupial mouse' is no exception. Describing our marsupial fauna as marsupial forms of placental mammals is a bad habit as it promotes confusion, disguises their unique characteristics and leads to wrong assumptions about their behaviour. As is the case with so many of our native mammals, very little is known of these tiny beasts and most of the information about them has been obtained from captive specimens. A full description of their activities in the wild state is yet another project awaiting the attention of some naturalist.

FURTHER READING

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POTS AND POTTE

The people of Papua New Guinea have, for three thousand years or more, been prolific potters though the potter's wheel is unknown there and in the surrounding Melanesian Islands. Western technology has had some influence on this and other village industries, but traditional pottery-making is still widespread. With more exact knowledge of language groups, it has become increasingly possible to show how the language boundaries coincide with changes in pot styles. There are 750 different languages in Papua New Guinea, so it is not surprising that there is great variety in potters' styles and techniques. Two main techniques are used—coiling and the paddle-and-anvil method—but there are many variations within each.

A coiled pot is built up by joining long rolls of clay. With spiral coiling, a roll of clay is fed spirally onto itself; in ring building one, or in some cases two or three rolls, complete a circle for each layer. The rolls may be as thin as 4mm or as thick as 4cm.

A combination of the coiling and ring-building methods is used in most of the pot-making villages in southeast Papua with some interesting and unique variations occurring from village to village. On northern Goodenough Island, for example, the potters lay down coils of clay in a circle on a board and build them up spirally, gradually working upward to form the base of the pot. At Aibom in the Sepik, the base of the pot is formed from a squeezed-out lump of very soft clay. Thick rolls of clay are then added in rings to form the walls. This is the only known instance of ring building where spiral coiling is not initially used to start the pot.

Paddle-and-anvil describes the technique by which a pot is shaped, thinned and smoothed by the impact of a paddle on the outside of the vessel against an anvil held inside. The anvil is moved firmly toward the paddle with each beat and is, with few exceptions, a smooth spherical or round flat stone. The paddle is always a wooden beater, but not necessarily of paddle shape. Paddle-and-anvil is essentially a finishing technique, mostly involving the final shaping of the pot, but in some cases it only completes the surface or assists the joining of the coils and/or rings.

The beating is carried out at a stage when the pot has been set aside to harden. The base of the pot may be formed in many different ways but is usually made from a soft ball of clay shaped by the hand or, in some cases, pounded open with a long shaped stone. Many of the paddle-and-anvil potters flatten the ball of clay to a disc and then beat it into a dish shape to start the pot. An unusual method is used in the Amphlett Islands where the pot is formed upside-down using slabs of clay which lean inward and are added to by squeezing clay onto the top edge, the final

Photos: Gregory Millen/Australian Museum

MARGARET TUCKSON, an Associate of The Australian Museum, is herself a skilled potter. PATRICIA MAY, an art historian, is presently living in Port Moresby. They have spent several years doing collaborative research on traditional pottery-making in Papua New Guinea and are currently preparing a book presenting the results of their work. Two of Tuckson's research trips were assisted by grants from the Crafts Board of the Australian Council for the Arts.

RS IN PAPUA NEW GUINEA

BY MARGARET TUCKSON AND PATRICIA MAY

shaping and smoothing being done with a paddle. The paddle-and-anvil technique is only used by women except in two areas where men use a paddle to finish the pot's surface. Coiling is used by both men and women.

Generally, the form of the pottery is directly related to the technique used. A common feature of vessels made with the paddle-and-anvil technique is that they are round-bottomed, round-bellied shapes. Coiled pots range from pointed to rounded with a pointed, knobbed or slightly flattened bottom. The decoration also follows a general trend. On paddle-and-anvil pots, it consists of comparatively simple motifs of incised or punctated designs confined to the upper area of the pot. The patterns are applied with simple tools, either bamboo or wooden implements, or fingernails. The Motu people use the serrated edge of shells to mark their pots, and directly after firing splash them with mangrove bark dye. Yabob/Bilbil/Mindiri vessels are covered in the leather-hard stage with a red clay slip. Sio/Gitua pots are decorated more elaborately around the neck and shoulder with applied nubbins and strips as well as with incising. Coiled pots show greater variety in decoration and are often entirely covered with carved designs.

Pots are thoroughly dried before firing and are often hung or kept on racks inside the house for many months. Indoor cooking fires make the houses very smoky and the villagers believe that the smoke strengthens the clay. Traditionally, no kilns are used. In most areas the pots are stacked on a platform of thinly-split timber, sticks, or sago and coconut palm fronds and then covered with more fuel. If the prevailing wind is strong, at the beach for example, extra fuel is stacked on the windward side. In beach villages in the Madang area, *kunai* grass is piled high on top of the pots. When ignited, fires quickly flare and are burnt to ashes within twenty minutes to one hour. Fire temperatures of as high as 918°C have been recorded. No glazes are used. Instead, coatings of vegetable origin such as liquid sago starch and banana skins are splashed or rubbed onto the pot while it is still hot from the fire.

In Papua, the women potters living in coastal or near-coastal regions produce all the pottery. In New Guinea, women produce pottery along the coast and on islands, and inland along the Ramu and Sepik Rivers and their tributaries, in the foothills of the Torricelli and Prince Alexander Mountains, in the Marienberg Hills and on the Sepik Plains. A range of functional vessels are produced: cooking pots, sago storage pots, frying pans, small hanging pots, water carrying and storage pots, eating bowls and serving vessels. Not all types of pots are produced by every group, but they all make cooking pots.

Sago storage jars are confined to the sago-eating societies. In New Guinea, sago storage

The map on the overleaf summarizes present knowledge of pottery-making in Papua New Guinea. It shows pottery-making centres as either villages or language groups, and shows basic techniques and whether the pots are made by men or women.

The pots shown illustrate some of the variations in shape and design that are found in the traditional pottery of Papua New Guinea. 1—Koiwat village, Sawos, Sepik. 2—Tubetube Island, south-east Papua. 3—Abelam (Maprik), Sepik. 4—Rabundogum village, Boiken, Sep


Hus I
LORENGAU
MANUS I
Timoenai
MBuke I
ADMIRALTY ISLANDS
HUMBOLDT BAY
Vanimo
VANIMO
Rawo
Pino
Isi
LEITRE
Taris
Sarai
Sissano
AITAPE
Yakoi
Tumleo I
Tumleo
Raihu
ONE
OLE
LUMI
KOMBIO
YAMBES
SOUTHERN ARAPESH
WEWAK
MENEK
MAPRIK
ABELAM (MAPRIK)
DOIKEN
Kaiep
Terebu
Samap
NUKU
KWANGA
BUNGAIN ?
YANGANG
ABELAM (WOSERA)
BUNA
SAWOS
Chimbian
Kamangaui
ANGORAM
Slei
Koiwat
MAYO
KWOMA
BOSMAN
Sepik R
Chambri Lake
BOGIA
Bonaputa
Suaru
Swagap
NGALA
Aibom
IATMUL
Yaul
Dimiri
Marawat
ADJORA
TANGU ?
YAUL
Keram R
Yuat R
Porapora R
Korak
Tavultae
Bunabun
WANUMA ?
RAO
Ramu R
NAKE
GARUH
SARUGA
MADANG
MAWAN
GAL
Yabob
BAU
Bilbil
BEMAL
HAM
GIRAWA
SUMAU
URIGINA
USINO ?
Mindiri
RAWA
NAHO
NEW GUINEA
AZERA (AMARI)
Sio I
Sinosina
Nambariwa
Gitua
Sialum
AGARABI
AZERA
KAINANTU
KAIAPIT
Markham R
HUON PENINSULA
Watut R
PAPUA
LAEWOMBA
LAE
WATUT
HUON GULF
Lokanu
Lababia
Buso
Siboma
KIKORI
GULF OF PAPUA
Manau ?
Iaudari ?
Mambare R
Gona ?
POPONDETTA
ORO BAY
Sivepe ?
Emo ?
DYKE
Sasembeta ?
Yule I
Boera
Porebada
PORT MORESBY
0 50 100 150 km
0 50 100 miles
AUSTRALIA

TRADITIONAL POTTERY OF PAPUA NEW GUINEA
Hand-formed – completed by paddle and anvil – Women
Spiral coiling – Men
Spiral coiling – Women
Spiral coiling – Men and women make or women make and men decorate
Ring building – Women. Men decorate certain pots
Spiral coiling, completed by ring building – Women
Spiral coiling (or slabs-Amphletts), completed by paddle and anvil – Women
Spiral coiling, completed by paddle and anvil – Men
ABALAM Language groups
(MAPRIK) Dialects
Pot-making villages and small islands
Pot-making areas (specific number of villages not known)
Pot-making industries now defunct
More information needed
Towns, administration centres and missions
NEW IRELAND
NEW BRITAIN
BUKA ISLAND
Malasang
Tung ?
BOUGAINVILLE
NASIOI
SIWAI
BUIN
Chirovai
Vuran
FAURO I
CHOISEUL I
SOLOMON
ISLANDS
ALU I
MONO I
BOUGAINVILLE STRAIT
B.S.I.P.
LAND BAY
GOODENOUGH I
AMPHLETT GROUP
Gumawana I
Nabwageta I
Wamea I
Kwatoita I
Raînu
Oreresan
COLLINGWOOD BAY
FERGUSSON I
CAPE VOGEL
Miadeba
NORMANBY I
EAST CAPE
Dawson I
Mailu I
Bonabona I
MILNE BAY
ENGINEER GROUP
Kaukau
Konemaiaua
Silosilo
Olamamania ?
Tubetube I
Skeleton I
Tewatewa I ?
Kwaralwa I
Panaeati I
Bonarua I ?
Anagusa I
Pananiu I
Ware I
Motorina I ?
Brooker I

Margaret Tuckson

Above: A potter of the Boiken group, Paliama village, Sepik, rolls a clay coil. Right: A woman at Koiwat village, Sepik, bonds the coils of an eating bowl. Elaborate decoration will be carved by a man on the smooth, finished surface.

Kwoma man at Meno village, Sepik, adjusts a coiled cooking pot for a woman potter. Men make the ceremonial vessels and consider the women second-rate potters. In this incident, the woman got up and walked away.

jars are made by women along the coast at Kaiep/Terebu/Samap, Vanimo, Tumleo, and inland at Aibom, the Sawos villages and the Yuat River villages. The Rao potters of the Ramu Valley are sago-eating people, but instead of using pots, they dry and store their sago in hanging bags of finely split sago palm leaves.

Male potters inland from Madang, the Agarabi men from the eastern highlands and the men of the Watut River Valley produce everyday cooking vessels although very little pottery is still made by the Agarabi. The Azera men of the Markham Valley produce a variety of cooking pots, sorcery pots for making soups and mixing herbs, and a fired clay drum called a *kundu* which is unique in Papua New Guinea. In this region, cooking pots are left with the dead in the burial caves.

In the Sepik area, there are districts where both men and women in the same society make pottery. In general, the women produce the cooking and food preparation pottery and the water jars. Men are responsible for the decoration of some of the vessels made by women and for producing and decorating any ceramics used for ceremonies or rituals. At Aibom, women make large fire-hearths for use in the house. A smaller fire-hearth is made to carry burning embers on the canoes during fishing trips for heating food, repelling mosquitoes and lighting cigarettes.

Margaret Tuckson

Margaret Tuckson

Aibom men model a three-dimensional representation of a human head or a seated figure with a bird perched on its shoulder onto the base of an upside-down pot which has been made by the women. The bird represents the great fish eagle and is a symbol of the men of the village—the fighting force of the clan. The completed pot, placed over the main post on the roof of the *Haus Tamberan*, or Spirit House, is partly decorative and partly of ritual significance. It also protects the end-grain of the post from weathering. In the Maprik area, two or three pots with holes in their bases are lowered over the central roof post of the Spirit House to deflect the rainwater.

Men and women from the Yuat River produce a variety of pottery animals—frogs, tortoises and other curious shapes—which are thought to be only recent in origin and are mostly for sale to tourists. The women from this area make domestic ware as well. In the Mayo/Kwoma area, men model hollow clay heads with eyes and mouth cut out, giving the pottery a very life-like expression. Sometimes a hole is made at the top in which leaves or human hair is placed. At Kwoma, these heads play an important role in rituals associated with yams, the staple root crop of the area. The heads, painted red, yellow and white and often with feathers stuck on the chin, are placed on the 'altar' at yam ceremonies.

A clay wind instrument called an *ochirina,* a round, hollow, fired clay ball with two holes is made by the men of the Wosera and Yuat villages. A sun-dried *ochirina,* often in the shape of a pig's snout, is produced by men from Sina-Sina in the eastern highlands. These are sometimes called pig whistles.

The Motu of the Port Moresby area traditionally made voyages to trade with people in the Papuan Gulf and exchanged newly-made pots for sago. Unfortunately, this is one of the areas where pot-making has virtually stopped because of a breakdown in the trading system. Thousands of pots were once produced annually by eight Motu villages, but only a few women from Boera and Porebada now make

Margaret Tuckson

pottery. The people of the Papuan Gulf no longer need traditional pottery as they can now buy aluminum saucepans from the trade stores, and the Motu no longer eat sago, instead buying rice and other staple foods from the trade stores and in Port Moresby.

Though some groups no longer produce pots because of the increased use of metalware or because of changing social and economic conditions which have affected traditional trade, some industries are thriving and extending the marketing of their pots, either to neighbouring peoples or to collectors and tourists. The Aibom people, the most pro-

Margaret Tuckson

lific potters in the Sepik, still trade pots hundreds of miles up and down the Sepik River. Potters in the Markham Valley are extending their pottery industry because other nearby groups have stopped making pots and the demand for Markham Valley ware has increased. Interestingly, some groups that had stopped using clay pots in favour of the products of Western technology have started using clay vessels again as they prefer the flavour of food cooked in earthenware.

In 1967, the International Labour Organisation employed a pottery expert from Denmark to introduce 'better' techniques on a cottage industry level. At Yabob and Bilbil near Madang, men, who were not traditionally potters, were taught to use potter's wheels and kilns. The women were encouraged to carry on with their paddle-and-anvil method, but to try the simple wood kiln. The women are still producing good pots, but the men's cottage industry has not been very successful.

Perhaps three thousand years' experience has shown that for the potters of Papua New Guinea, their way is better.

Above: A Kaiep village woman, Sepik coast, shapes a pot with paddle and anvil. The pot is rested in a mat-covered hollow in the sand. Left: An Abelam (Worsera) man at Saragum village, Sepik carves a ceremonial cooking pot with a flying fox bone.

Margaret Tuckson

An unusual form of firing at Malu village in inland Madang. The pot is supported on a square framework of fuel. The fire is lit at the top of the framework, 45-60cm above the ground, and the pot slowly sinks as the fire burns.

SEARCHING THE SOUTHERN

SKY

BY A. W. RODGERS

Overleaf: Omega Centauri, a spherical cluster in the Milky Way Galaxy, contains about a million stars and is believed to be some ten thousand million years old. (Photo: Mount Stromlo Observatory)

Astronomy began with the earliest known civilisations—in Mesopotamia, Egypt, Mexico, Peru—and archaeologists have used the level of development of astronomical study as a measure of the sophistication of ancient cultures. In the past, astronomy had a practical role to fulfil. Now physics is applied to optical astronomy to elucidate the origin and evolution of the Universe. Planetary observations, which would have been, even sixty years ago, a major part of optical astronomy, have today been left to space probes. Therefore, what was properly a major interest of astronomers last century has now become the subject of geochemists and geophysicists. The sole remaining link with the practical status of optical astronomy lies in the study of the physics of the phenomena which occur on the turbulent surface of the sun. Through solar winds and through the emission of solar cosmic rays, these phenomena affect many of man's activities—for example, communications—both on Earth and in the regions accessible to manned spacecraft, and solar physicists hope to learn to predict these phenomena.

Mount Stromlo Observatory

This cluster near the Southern Cross contains only several thousand stars and is quite young by the stellar time scale—about ten million years old.

In the past twenty-five years, the development of optical astronomy in Australia and elsewhere has been influenced by work being done by physicists in exploring the sky in other regions of the electromagnetic spectrum available to our detectors. Australia was an early leader in radio astronomy and since then, the spectrum accessible to astronomers has widened to include the far infrared at wavelengths in the sub-millimeter range, the near infrared, (rocket) ultraviolet, x-ray astronomy and recently, gamma-ray astronomy. All these disciplines have interacted and the astronomer now studies celestial objects at many different frequencies in the electromagnetic spectrum.

In the first half of the twentieth century the only initiative in optical astronomy in Australia was taken by the Federal Government in 1923 when they established the Commonwealth Solar Observatory on Mount Stromlo near Canberra. Until 1950 the Observatory worked mainly on problems of solar physics and contributed at an international level. The amount of stellar and galactic astronomy done was small. The largest telescope was 30-inches in aperture and its auxiliary instrumentation was limited. It was built during World War I and subsequently donated to the Commonwealth.

Immediately after World War II, the Director of the Observatory, Dr. R.v.d.R. Woolley, decided to change the mainstream of the Observatory's activities to stellar astronomy and proposed that the Commonwealth purchase a large telescope for this purpose. In 1955 the Observatory acquired a 74-inch aperture reflector, equal in size to a similarly-designed telescope in South Africa. The Observatory also purchased for £300 the scrap remains of the Great Melbourne Telescope of 1868 and by changing the optical design and components and refurbishing some of the telescope drives, extended the working life of this telescope by some twenty years. There are now major defects in the telescope

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bearings, affecting its stability when auxiliary instruments such as spectrographs and photometers are attached, and this is limiting its scientific usefulness.

Professors Twiss and Brown conceived the idea that the correlation of the intensity of light received from each side of a star's apparent disc by well-separated telescopes could be used to measure its apparent diameter. A single-purpose, two-telescope array was set up at Narrabri, NSW by the University of Sydney and has resulted in the measurement of the apparent diameters of thirty bright blue stars in the southern sky.

As early as 1953, three years before the control of the Mount Stromlo Observatory passed to the Australian National University, Dr. Woolley and the ANU physicist, Professor Marcus Oliphant were aware of and planning for the construction of a large telescope in Australia. The aperture envisaged was 200 inches, similar to the magnificent telescope at Mount Palomar in California. The subsequent observatory Director, Professor Bart Bok realised the necessity for choosing the best site in Australia for the new large telescope and for an alternative site for future Mount Stromlo telescopes due to the increasing night-sky light pollution by the city lights of growing Canberra. Over a period of ten years, Dr. A. R. Hogg and the staff of Mount Stromlo Observatory surveyed potential astronomical sites in Western Australia, South Australia, Victoria and NSW checking freedom from cloud, atmospheric stability and accessibility. The Warrumbungle Mountains of northern New South Wales was chosen as the field station for Mount Stromlo and was afterwards adopted as the site of the 150-inch Anglo-Australian Telescope.

In 1968 the dreams of Woolley, Oliphant and Bok were realised when Prime Minister John Gorton agreed to the proposal that a large telescope be built. Unfortunately, the telescope operation and its costs were to be shared with the UK. Whether the extra size of the telescope—150 inches as opposed to 120 inches—available because of the cost sharing is worth the fifty percent of time lost to Australia is quite debatable and there is no question that the telescope, because of its bi-national character, has cost more than it should and has many built in compromises. Still, Australian optical astronomers now have a powerful observational tool, which using, they have the opportunity to maintain their good international reputation. The key to the realisation of this opportunity will be the manner in which the AAT is administered; there must be maximum feedback from the AAT to every university and government research group in Australia. Because it is bi-national, it will be all too easy for the AAT to become isolated as a centre of massive technology from which no one in the rest of Australia benefits.

Astronomy shares with the other environmental sciences, such as geology and meteorology, the inability to make direct experiments upon its subject matter. Experimentation is replaced by surveying or sampling classes of stellar objects for regularities upon which hypotheses can be based, and the role


Mount Stromlo Observatory

The Mount Stromlo Observatory, near Canberra, is the largest in the Southern Hemisphere.


Mount Stromlo Observatory

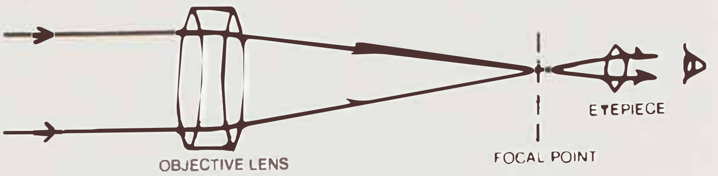
Siding Spring Observatory in the Warrumbungle Mountains of NSW is the field station for Mount Stromlo Observatory and the site of the Anglo-Australian Telescope.

This wide-angle photograph shows the huge complex of gas in the constellation Carinae surrounding an aggregate of young massive stars. 5000 light years distant in a spiral arm of our galaxy. The red colour of the gas is due to the effect of the cominant red radiation of hydrogen arising from the recombination of protons and electrons.

of the 'crucial experiment' is replaced by the observation of stars or objects which run counter to a hypothesis.

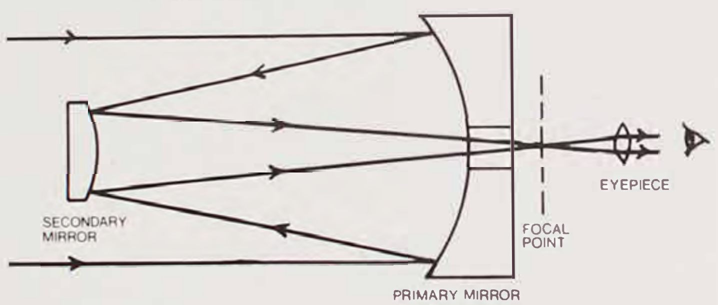
Australian optical astronomy exists in a meteorological climate where, due to cloud cover, limited telescope time is available. This situation does not hold in South Africa or America and explains, in part, the different direction Australian optical astronomy has taken. Where telescope time is abundant there is an incentive to survey a class of star in the heavens; at the very least, one will discover the properties they share. When telescope

REFRACTING TELESCOPE



These diagrams show the light paths in refracting and reflecting telescopes. The size of a refracting telescope is limited by the size of glass lens that can be ground and polished. The aperture of reflecting telescopes can be made larger because transparency of the glass does not matter and the mirror can be supported at its back. When astronomical photographs are taken, the photographic plate is placed at the focal point of the telescope. (Drawings by the author.)

REFLECTING TELESCOPE



The nearest external galaxies to our own are the two Clouds of Magellan. They are observable only from the Southern Hemisphere and can be seen with the naked eye in early summer as faint detached patches of the Milky Way. The photograph shows a part of the Large Magellanic Cloud containing a huge complex of stars, gas and interstellar dust known as 30 Doradus. The gas in the complex has a mass of over one million times that of our Sun. 30 Doradus is 150 thousand light years away.

time is restricted, the long survey approach becomes unviable and it is most profitable to examine closely 'crucial objects' which will support or modify the hypothesis according to know physics. This has, in general, been the role of Australian optical astronomy. The outstanding work on the foundations of radio astronomy carried on in Australia since 1945 has been mainly of the survey kind; as a young subject, the regularities had first to be found. Because optical astronomy in Australia is, in contrast, concerned with detailed studies, the two disciplines have had relatively little impact upon one another. A brief, simplified example of the method used in optical astronomy may illustrate its operation. Stars are often found in aggregates. The first step is to hypothesise that within the aggregate they are of the same age. Two deductions follow. First, they should be homogeneous in composition (formed from the same gas cloud) and their evolutionary status should depend on the rate at which hydrogen has burnt to helium. We know from physics that the burning rate, which is equal to the stars luminosity, depends on the total mass and the central temperature. The second deduction, then, is that the more massive and luminous stars are more evolutionarily advanced than the less massive ones. Surveys show that these deductions, generally, are correct. Exceptions have, however, been noted and it was recently found at Mount Stromlo by Dr. K. Freeman and the author that at least one massive aggregate is not chemically homogeneous. The next step is to hypothesise that in massive aggregates not all stars form at once from a collapsing gas cloud. A new hypothesis taking the total mass of the gas cloud into account must be formulated which will then suggest future crucial observations. It is not only a matter of external influences such as telescope availability, that have determined this emphasis in optical astronomy in Australia. Astronomy is a science with a small number of practitioners and individual influence still counts. Its foundations at Mount Stromlo were laid in the early 1960s by the brilliant astrophysicist Dr. Leonard Searle and have been carried on with the observational analysis of stars with surveyed kinematics by Professor Olin Eggen, currently the Director of the Mount Stromlo and Siding Spring Observatory.

Australian optical astronomers contributed more than their share of technical expertise to the Anglo-Australian Telescope. Professor Sidney Gascoigne played a decisive role in the optical design of this giant telescope, and other Mount Stromlo astronomers defined the star acquisition systems, the guiding systems (to track the star during the course of an observation) and the computer systems used for automated control of the telescope auxiliary instruments such as spectrographs and photometers, and for processing their data outputs. The amount of telescope time (by definition, smaller than one half) available to Australian astronomers will have to be most efficiently used if Australia is to maintain its high international standing in optical astronomy.

If the practice of astronomical research is to enrich our Australian society in the way it has done in the past then the total astronomical

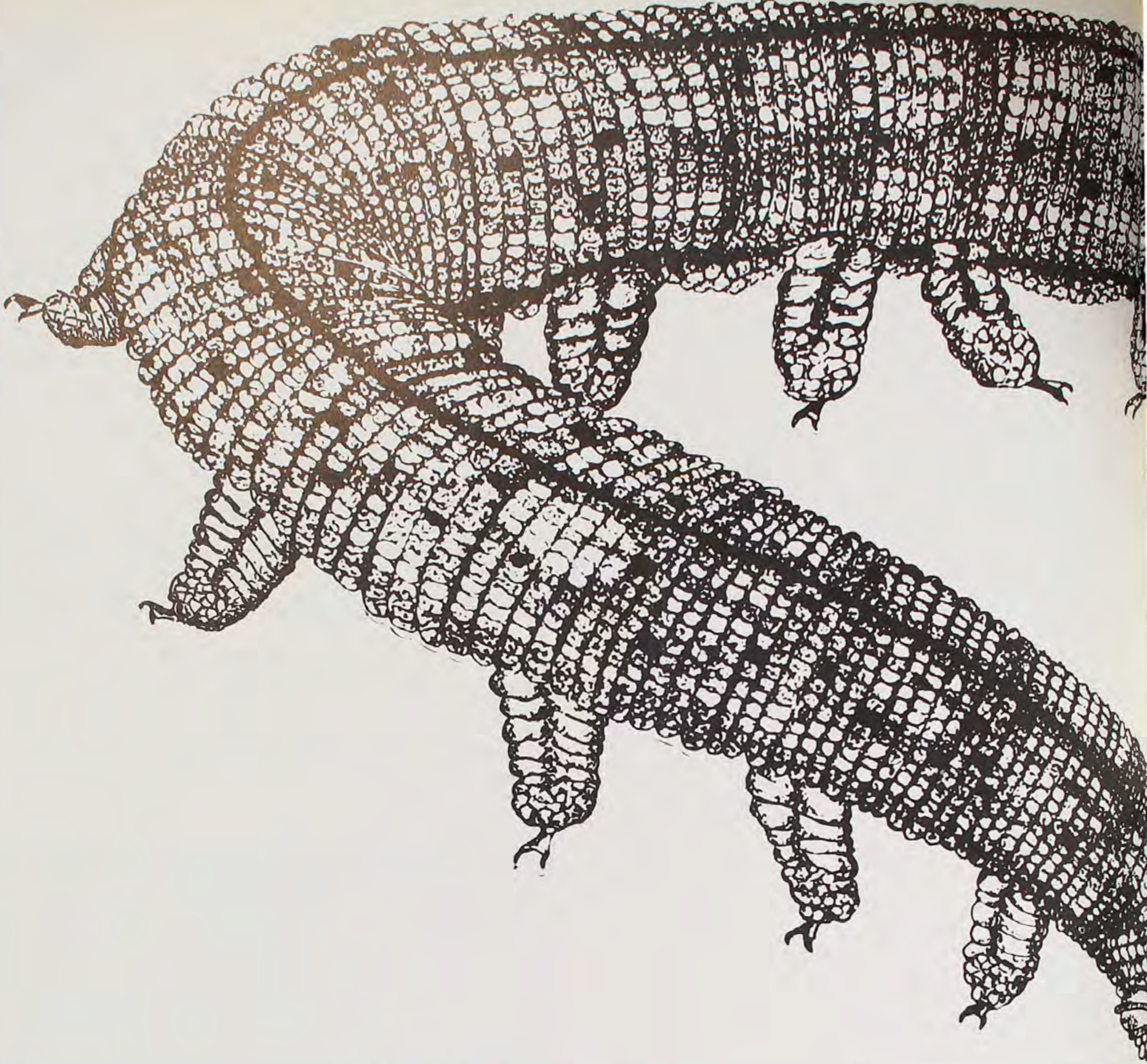
K. Bern and V. Ford/Mount Stromlo Observatory

effort, especially that of Australian radio-astronomers, must continue to be well funded. The large, high-resolution radio telescope arrays in England and Holland are producing radio-astrophysics which has outgrown its survey origins. In so doing, a much more fruitful interaction is occurring there between optical and radio astronomers than is yet possible in Australia. In the optical astronomers' view, the construction of a large-aperture synthesis radio telescope should be among Australia's highest scientific priorities. In this way the value of the large investment in the 150-inch telescope will be enhanced and there will be no opportunity for the hundred-year-old fiasco of the Great Melbourne Reflector to be repeated.

The future of optical astronomy in Australia appears bright, provided that any Australian astronomer has adequate access—based purely on the scientific merit of the research— to the 150-inch telescope. It is also necessary for Australian radio astronomy to be equipped for complementary research. In our universities, there is a first-class system for the training of the physicists, mathematicians and engineers needed in our observatories, and Australian postgraduate students in astronomy have proved themselves to be the most productive in the world. Australian astronomical optics and its mechanical and computer technology is also equal to the world's best. In the future however, we will grow increasingly dependent upon detector technology, which is largely a product of the US military aerospace and night surveillance programs, and on the amount of access we have to the US space-shuttle program.

Thus, the future holds promise for international collaboration beyond the limits of national borders.

Mount Stromlo Observatory



Drawing by the author

From the time of its discovery, Peripatus has been regarded as something of a biological oddity. Because of its unusual combination of anatomical characteristics, its affinities with other invertebrate groups have, in the past, been confusing to say the least. Consequently, the peripatids have been variously included in most of the higher invertebrate groups over the past two hundred years. More recently, Peripatus has been labelled as the 'missing link' between the segmented worms (Annelida) and the jointed-legged invertebrates (Arthropoda).

Regrettably, the fossil record tells us little about this controversial animal as only one undisputed and well-preserved fossil specimen is known. This is *Aysheaia pedunculata* from the Middle Cambrian deposits of British Columbia. The structure of *Aysheaia* does indicate however, that peripatids have changed comparatively little over their known 550 million years of existence. Peripatus has now been placed in the phylum Onychophora, thus separating it taxonomically from all other groups. The phylum includes some seventy-five described species from Africa, Asia, Central and South America, and Australasia. The common name 'Peripatus' is derived from one of the South African genera. The five described Australian species are included in the genus *Peripatoides* and are named as *P. oviparus, P. insignis, P. leuckartii, P. occiden-*

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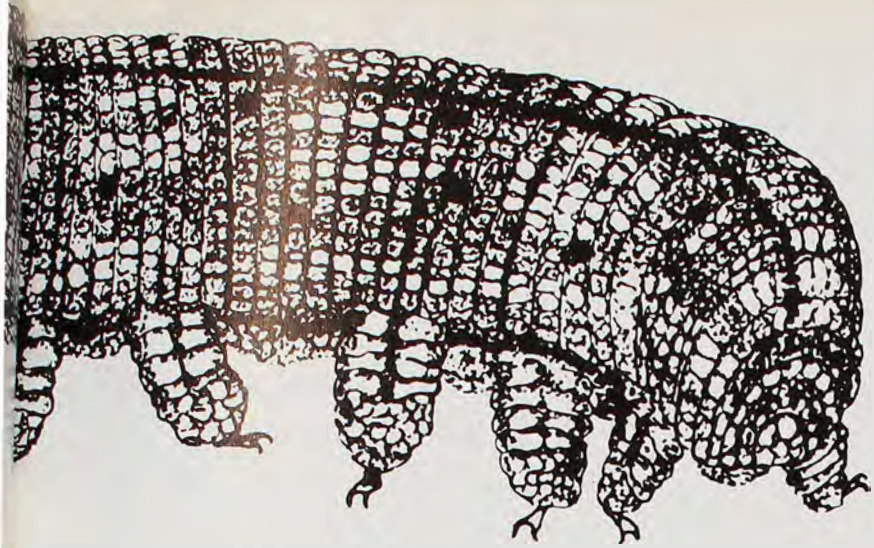


THE RIDDLE OF PERIPATUS

BY ROBERT HARDIE

talis and *P. gilesii*. The Australian forms occur mainly on the eastern coastal fringe, in Tasmania and in southwest of Western Australia.

Regardless of its accuracy, the 'missing-link' reputation of Peripatus is understandable once the animal's peculiarities are taken into account. To obtain some idea of what a peripatid looks like, think of a squat, velvet-covered earthworm about five centimetres long, then add fifteen pairs of stumpy legs and a pair of soft, flexible antennae with a small, beady eye at the base of each. The body shows superficial, wormlike segmentation and, internally, has features of both the annelids and arthropods. Peripatus has a simple bi-lobed brain to which are connected two long ventral nerve cords that run for the whole length of the body. The excretory organs are arranged segmentally down both sides of the

Sketch of the east-coast peripatus (*P. leuckartii*) showing the external features of the group. The body length of this individual, excluding antennae, is 23mm..

Robert Hardie

The colour patterns among peripatids are highly variable—even within a species or a single lot of young. The species shown is *P. leuckartii.*

body wall and the main body cavity is filled with a circulatory fluid called haemolymph. The thin-walled, tubular heart lies above the straight intestine and serves to circulate and maintain the pressure of the haemolymph. Among peripatids, there are distinct male and female individuals. The reproductive system of the male consists of a single testis, connected to the genital aperture by a long sperm duct. The single ovary of the female has a pair of oviducts connecting it with the outside. Both systems have one or more pairs of accessory glands.

While the eyes are similar to those of a predaceous polychaete worm and the casual, ambling gait is much like that of a millipede, Peripatus has many features peculiar to itself. The soft, dry skin is densely covered with tiny papillae, which give the animal its velvety appearance. The colour patterns formed by the papillae are often elaborate and tend to be highly variable within a single population, or even a single lot of young. This characteristic alone has caused much confusion to biologists involved in the classification of some peripatid groups. The legs, which range from fourteen to sixteen pairs in Australian species, are not jointed, but are tubular extensions of the muscular body wall. Like the antennae, the legs can be moved in any direction by the action of muscles working against the internal pressure of the haemolymph, the combined action forming a sort of hydrostatic skeleton. Each of the legs ends in a small, triangular foot, complete with two strongly curved claws. Peripatus breathes by means of a number of fine respiratory tubes, or tracheae, which open to the surface of the body in small pits.

The nature of the peripatid respiratory system exerts a strong influence over the sorts of places in which these animals can live. The tracheal tubes which transport oxygen directly from the atmosphere to the internal tissues are similar to those of insects, but with one important difference. The tracheae of insects have closing devices, or spiracles, over their external openings to prevent the loss of vital body-water to the atmosphere. Spiracles are not present in Peripatus, so if the animal is exposed to hot, dry conditions, it will quickly dessicate and die. Therefore, at least theoretically, Peripatus is restricted to areas where the humidity is high and the risk of dessication is minimized. As an added precaution, peripatids are largely nocturnal, seeking food at night when the air is cool and moist, and remaining under rocks and logs during the daylight hours. It is to be expected then, that the peripatids are found mainly in the warmer, tropical and sub-tropical parts of the world.

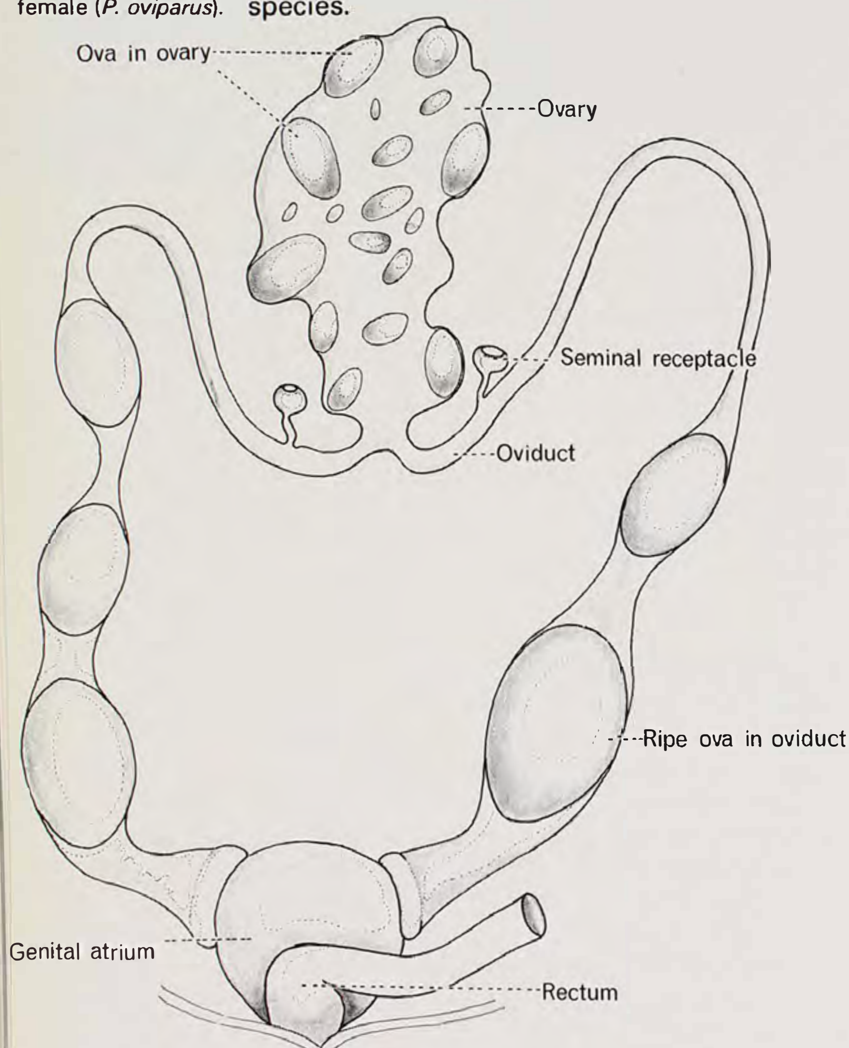
With regard to the distribution of the Oncychophora, there are some interesting exceptions. In South Africa, Australia and New Zealand, Peripatus is found in some very cold regions. For example in Australia, specimens have been found above 2,000 metres in the Mt. Kosciusko area and above 1,700 metres on the New England Tableland. In such areas, the winters are exceptionally severe with heavy frosts and snow, and the summers are often hot and dry, particularly in the New England region. In the coldest part of winter, there are records of peripatids active when the air temperature is below freezing and the temperature beneath rocks where Peripatus lives is as low as 4°C. At these temperatures, most 'cold-blooded', or poikilothermic, animals are either very sluggish, completely inactive, or dead. At the other extreme, peripatids have been found alive under drought conditions when the humidity is very low and the air and ground temperatures are around 38°C. How does Peripatus, an animal which to all purposes is adapted to moderately high temperatures and high humidity, survive such harsh conditions? Part of the answer is that some Australian species are able to crawl into fine crevices and slow down all body processes, becoming torpid for up to three months. Thus, under dry conditions, food reserves and precious body-water are used sparingly to keep the animal alive. It is also possible that water may be generated by the chemical breakdown of some of the body tissues. When rain wets the ground, Peripatus revives and returns to normal activity. In addition to this state of torpidity, the posture adopted by Peripatus in its place of hiding ensures that as much of the body surface as possible is in contact with the solid substrate. This means that many of the tracheal openings are sealed off from the atmosphere and unnecessary loss of water is dramatically cut down. The means by which Peripatus can remain active under extremely cold conditions has not been completely worked out, but it is possibly related to an increase in the concentration of certain chemicals in the body fluid.

Another, more behavioural, aspect of survival is connected with the fact that peripatids are very sensitive to daylight and will always tend to move rapidly back under cover when exposed. Also, in the presence of daylight, a reaction is initiated that causes these animals to 'need' much body/surface contact. Thus, during the daylight hours when the risk of dessication is highest, both the tendency to move away from light and to make as much contact with the substrate as possible, will ensure that the animal is in the most moist part of the habitat—in a crevice of some sort.

Another unusual aspect of the Australian Oncychophora is the method of reproduction of some species. Although in some ways unusual, the life cycle of peripatids is fairly simple. The only verified means of sperm transference in this group is the deposition of packets of sperm, or spermatophores, by the male onto the outer body wall of the female. Where the spermatophore is deposited, changes take place in the structure of the body wall which enable the sperm to penetrate into the haemolymph. The sperm then travels through the haemolymph to a pair of small storage sacs near the ovary; this journey through the body fluid is probably assisted by specialised haemolymph cells. As the ripe eggs are released from the ovary, they are fertilised by sperm from the storage sacs. In most species, the eggs then remain in the main reproductive tube, or uterus, and the young undergo embryonic development in-

side the female parent. When development has reached a set stage, the young are born alive as miniature adults; this is termed viviparous development. In some Australian species, this development can take as long as thirty weeks. The young, which are about five millimetres long at birth, grow by shedding the outer skin (moulting) at regular intervals. After about eighteen months, growth is complete and the animal is mature. There are three known species in the world which employ an alternative system—they lay eggs that have a tough, sculptured 'shell', or chorion. These species are *P. oviparus* and *P. insignis* (Syn, *Ooperipatus oviparus* and *O. insignis*) from Australia, and *P. viridimaculatus* (Syn, *O. viridimaculatus*) from New Zealand. The females of these species have an egg-laying tube, or ovipositor, arising from between the last pair of legs. Following fertilisation, the eggs do not remain within the uterus but are laid via the ovipositor in the leaf litter and left to hatch; this is termed oviparous development. After hatching, the young grow in the same way as the viviparous species.

Dorsal view of reproductive system of oviparous female (*P. oviparus*).



Two particular aspects of reproduction are of special interest. Firstly, the number of young produced per batch varies considerably from north to south. The females from the north of Queensland have produced up to seventy-six young over a period of three days, while the southern forms from NSW and Victoria usually produce only fifteen or so young per batch. While this can be explained partly by the difference in size of the adults, northern forms being around eight centimetres long and the southern ones about three to four centimetres, this great difference in numbers of young produced by the same species is unusual. The young in both cases are about the same size.

Secondly, although a given number of young are produced, there may be many more incompletely developed young retained in the oviduct. In connection with this, the young which appear to be developed almost to the point of birth can be retained within the parent if external conditions are unfavourable—if it is too wet or too dry. Thus, it seems that some sort of biochemical mechanism can be brought into action to decelerate or accelerate the development of embryos. The precise nature of this mechanism has not yet been determined.

Peripatus is a nocturnal hunter, and feeds on a range of small invertebrates such as springtails, termites, insect larvae and nymphs. A number of specimens have also been observed to feed on larger, dead insects and even rotten meat. The amount of liquid in the diet is important for, as the skin of peripatids is impermeable, any body-water which is lost must be replaced orally, either in food or by sucking on damp moss or wood.

The method of food capture used by Peripatus is unique. On either side of the soft, circular mouth are two small protruding structures called oral papillae. Within the body is a pair of elongate, multi-branched slime ducts which produce large quantities of viscid mucous. These ducts open to the outside via the oral papillae. When confronted by a possible meal, Peripatus raises its head and, with the oral papillae pointing towards the prey, quickly contracts the muscles of the body wall and emits two streams of the sticky secretion from the papillae. On contact with the air, the substance thickens and falls over the victim like a net, holding it helpless. The peripatid then moves in and by means of two pairs of small chitinous jaws within the mouth, cuts a hole in the body wall and sucks the prey dry.

The sucking process is made possible by the close application of the mouth to the body of the prey, thus forming a seal, and the rhythmic contraction of the pharangeal muscles. Soon, nothing is left of the victim but a hollow shell.

The jets of sticky fluid employed in food capture are also used for defence, acting as a deterant to other predators such as ants or assassin bugs. The holding power of the hardened secretion is unbelievably strong.

The taxonomy, or classification of the Australian peripatids has been the subject of a number of scientific papers but little attention has been paid to the group since 1922. Even today there are problems associated with the description of new and already existing species. The current approach to classification is based largely on measurement of the characteristics of a number of individuals. This ensures that the range of variation within a species has been taken into consideration. However, Peripatus is soft-bodied and has only claws and jaws as hard parts; accurate measurement is therefore extremely difficult. Almost every other characteristic, including width, length, colour, number of antennae segments and so on is so variable as to be of little or no taxonomic value.

The present situation is, then, that only five valid species have been described from Australia, and the basis of these descriptions rests on the number of pairs of legs, whether the animal is oviparous or viviparous and, to a lesser extent, the locality from which it was collected.

The simple key below will assist in the identification of Australian species:

14 pairs of legs .... PERIPATOIDES INSIGNIS

15 pairs of legs
ovipositor present in female ...... P. OVIPARUS

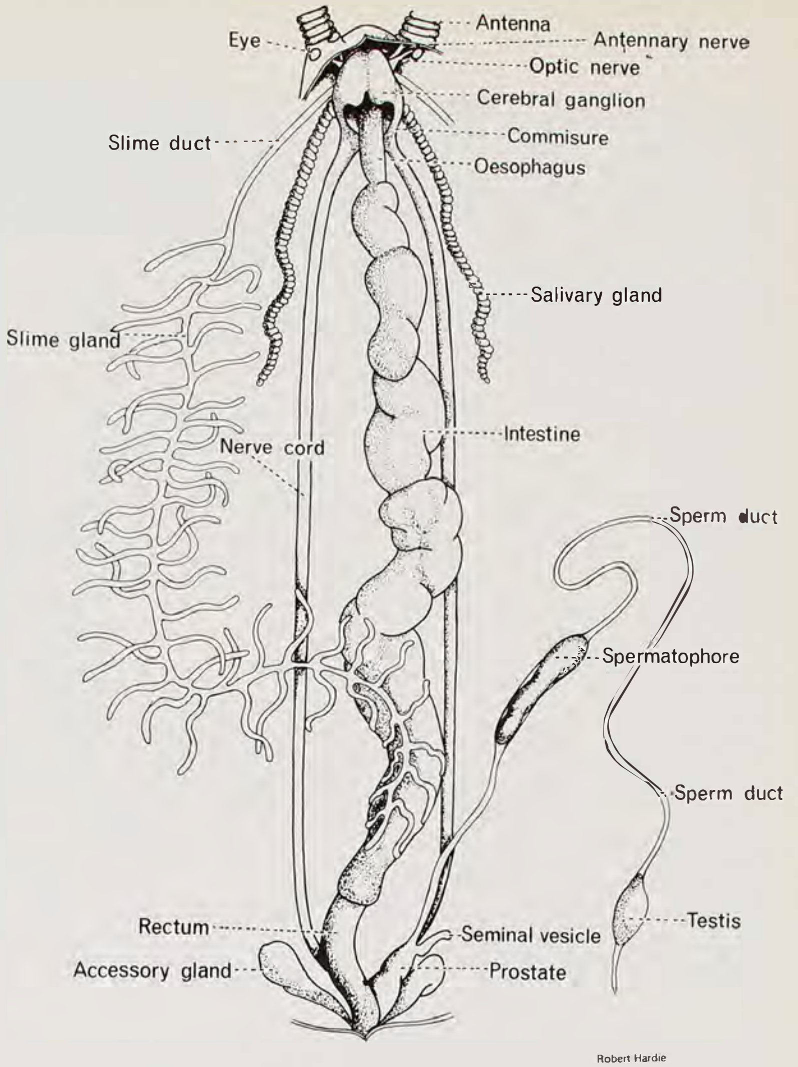
15 pairs of legs
ovipositor absent in female
locality—eastern Australia ...... P. LEUCKARTII

15 pairs of legs
ovipositor absent in female
locality—southwest Western Australia .... P. OCCIDENTALIS

16 pairs of legs .... P. GILESII

If you happen to find only a male of *P. oviparus* or *P. leuckartii*, good luck!

The question which ultimately arises regarding Peripatus is: why do the problems surrounding this animal still exist? Concerning origins and affinities, there is little fossil evidence to help out. The anatomical characteristics are divided between the annelids, arthropods and Peripatus itself. As *Ayshaeia*, 550 million years old, looks much like the modern onychophoran, it might be argued that the peripatid stock arose from similar, or the same stock that gave rise to the modern annelids and arthropods, but separated from the main line sometime in the Cambrian and continued on a solitary and undemanding track to the present day. Few obstacles were presented; the animal was apparently well adapted and had little need to modity its basic form to any great degree.



Dorsal view of alimentary canal and male reproductive system.

Concerning the problems of classification, the answer is almost the same. As only very minor anatomical changes were required, particularly once the animal was established in a home base, such as Australia, good taxonomic characteristics have just not developed.

The problems mentioned may be more fully understood once detailed biochemical analyses have been carried out on a comparative basis. Until such time, Peripatus will undoubtedly carry on, just being what it is.

John Turnbull

THE FIGHT FOR THE FORESTS

REVIEWED BY STEPHEN S. CLARK

THE FIGHT FOR THE FORESTS by R. and V. Routley, *(Second Edition) Research School of Social Sciences, Australian National University, Canberra, 1974; 407 pages, illus., $4.95.*

The Fight for the Forests is a landmark in the growing literature on Australian resources and how they should be used. It represents the type of analysis of alternatives which should be undertaken before any major resource use is planned. Unlike environmental impact studies, which so often degenerate into a justification of a particular project in a particular area, this document considers the whole range of alternatives for our forests and the economic, social, and environmental costs and benefits of each.

In this time of rapidly increasing world population, one of the most important questions any society can ask is 'what are the most appropriate uses of the resources at its disposal'. It is of crucial importance to realise that this is ultimately a question of values, and it is the right and obligation of every citizen to participate in the formulation of an answer. Scientists and technicians can provide much helpful information on alternatives and their implications in the short and long term but, in the end, it is for society as a whole (hopefully on the basis of informed opinion) to decide how it will use scarce and valuable resources.

Australian forests are such a resource. For climatic reasons, Australia has never been extensively forested. Now only four and a half percent of the continental land area remains under forest cover; about a third of the land forested when European man arrived. At the same time, forests lend themselves to a variety of uses including timber and wood product production, watershed protection, soil conservation, recreation, wildlife conservation, and landscape aesthetics.

These uses are not necessarily incompatible. For example, selective cutting of timber, and recreation may be practised on the same area. The concept of multiple use is a sound and useful one but its proper implementation depends on a detailed understanding of the community needs which can be met by forests and the ways in which use for one purpose can affect use for other purposes.

Australia is embarked on a programme of intensive forestry in which large areas of remaining eucalypt forest are to be converted to pine plantation or harvested for woodchips. The Routley's book is a critical evaluation of the justifications given for undertaking such a programme, and the implications for the environment and alternative uses of forests.

Australian self-sufficiency in wood production, and balance of trade considerations are usually given as the major justifications for a programme of intensive forestry. Crucial to the thesis presented in the book is the fact that Australian forestry has never been a profitable activity. According to the Routleys most state forestry authorities have operated at substantial losses and figures are presented to indicate that this is likely to continue to be the case for more intensive forestry practices such as establishing pine plantations and harvesting for woodchips. This might be justifiable if multiple-use (the Routleys suggest the term multiple-value) management were practised, but as wood production is, at the moment, the over-riding consideration in forest management, the Routleys conclude that: "Forestry losses . . . can only be explained on the hypothesis that forest services are prepared to treat the forests not as a public resource to be exploited with restraint for total public benefit but as a cheap or even loss-making source of raw material for private industry."

It is argued that Australia's need for wood products will become increasingly urgent in the future; however, the population figures projected by forestry interests represent only the highest of a series of possible projections, and projected consumption figures depend

Not a battle-field, a view of the Eden woodchip project. Such woodchip projects have been described by government officials as 'preserving and improving the environment'. This project will 'improve' over half a million acres of coastal forest

The Greater Glider (*Schoinobates volans*), which is capable of gliding as far as 180 feet, is regularly distributed throughout eastern Australia in montane forest. A hollow tree dweller, it is virtually eliminated by clear-felling.

This stand of Messmate (*Eucalyptus obliqua*) in the Tallaganda State Forest is soon to be bulldozed to make way for a pine plantation. This fine forest has, in its present form, a high value for recreation, aesthetic and other purposes in an area of rapid population growth.

Conservation activity, Bondo State Forest. The pine program has actually been hailed as a fine example of conservation—'conservation of softwoods'.

upon heavily encouraging public use of wood and paper products through advertising. In effect, the Routleys contend, we are subsidizing private industries' production of something they must convince us we need and, in the scramble to increase timber production, they are making impossible a variety of valuable alternative uses for our forests. As the Routleys sum up: "What is good for the timber industry, sawmilling and paper companies is not necessarily good for Australia. While softwoods can be imported, the values being destroyed with native forests cannot." Once the cost of ignoring alternatives is fully appreciated, the ventures are seen as economically unsound and environmentally disastrous.

Forests are a potentially renewable resource, though this is certainly not the case in all forms of exploitation. Indeed, great skill and care must be exercised for it to be true at all. Forests, like all ecosystems, are complex, dynamic entities in which an impact on one or a few components is likely to have ramifications throughout the system. Disruption or disturbance may be temporary, the system returning to its previous state; or degradation may be progressive and irreversible. Such evidence as exists in Australia and overseas indicates that the latter is a very real possibility in the case of the most intensive forestry practices now being planned.

Clearcutting to establish a pine plantation or to harvest for woodchips carries with it serious environmental problems. Heavy rain while the soil surface is unprotected by vegetation may result in extensive loss of surface soil and valuable nutrients. Consequent siltation and enrichment of coastal waters carries the problem still further afield. Pines themselves lead to further progressive changes in the soil such as increased leaching of nutrients and soil impermeability, thus increasing impoverishment and soil losses through erosion. Attempts to correct this situation through the use of fertilizers will cause even more pollution of aquatic ecosystems; just one example of how disturbance can spread.

The replacement of mixed eucalypt forest by a monoculture of pine or a single native species favoured for woodchip production has further biological consequences. Many species of understorey plants may be eliminated, especially under pines (or where actively discouraged to prevent competition). Birds, mammals, and other less obvious animals dependent on these and on a variety of tree species for food and shelter may eventually disappear. Reserves and corridors have been provided, but without prior survey the adequacy of these, or even knowledge of which animals are endangered, is more speculation than established fact.

Some species may be favoured for a time by the new set of environmental conditions. These may even reach pest proportions (a very real possibility for some insects) and require control measures—further indication that an unstable situation has been produced. *Phytophthora cinnamoni,* a root-rot fungus that attacks many native plants, presents an especially alarming prospect. Its spread is favoured by intensive management practices such as roading (and increased surface runoff) and it could result in the devastation of eucalypt stands over large areas. Fire presents still another hazard. Young, even-aged stands are particularly susceptible to mortality from fire. If this occurred before they reach reproductive age no viable seed for regeneration would be available.

The question of national parks versus intensive forestry is dealt with at length in the final chapter. Arguments about the insufficiency of Australia's wood supplies are far from convincing and the inadequacy of Australia's national parks, both as public recreation areas and as reserves for flora and fauna, must be recognised. True multiple-value managment would provide for this type of alternative use and would, as the Routleys contend, be more socially responsible and environmentally advantageous as well as economically sensible.

Though we have a long way to go, the means exist for the realisation of true multiple-value use of our forests. In this regard, Chapter Eight is the most valuable part of the book, for it presents a detailed cost/benefit analysis of alternative uses of forest areas, taking into account all values—not just wood production values. While this is a necessary condition for sound resource-use planning it is not, of itself, a sufficient one. Forests must come to be regarded as 'for the people' in the broadest and most constructive sense. For this to happen people must realise the role they have in determining the future of their forests. *The Fight for the Forests* has made a valuable contribution toward making us aware of what needs to be done. — *Stephen S. Clark, Department of Environmental Studies, The Australian Museum.*

Photos: Courtesy of Australian National University Press, Publisher

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