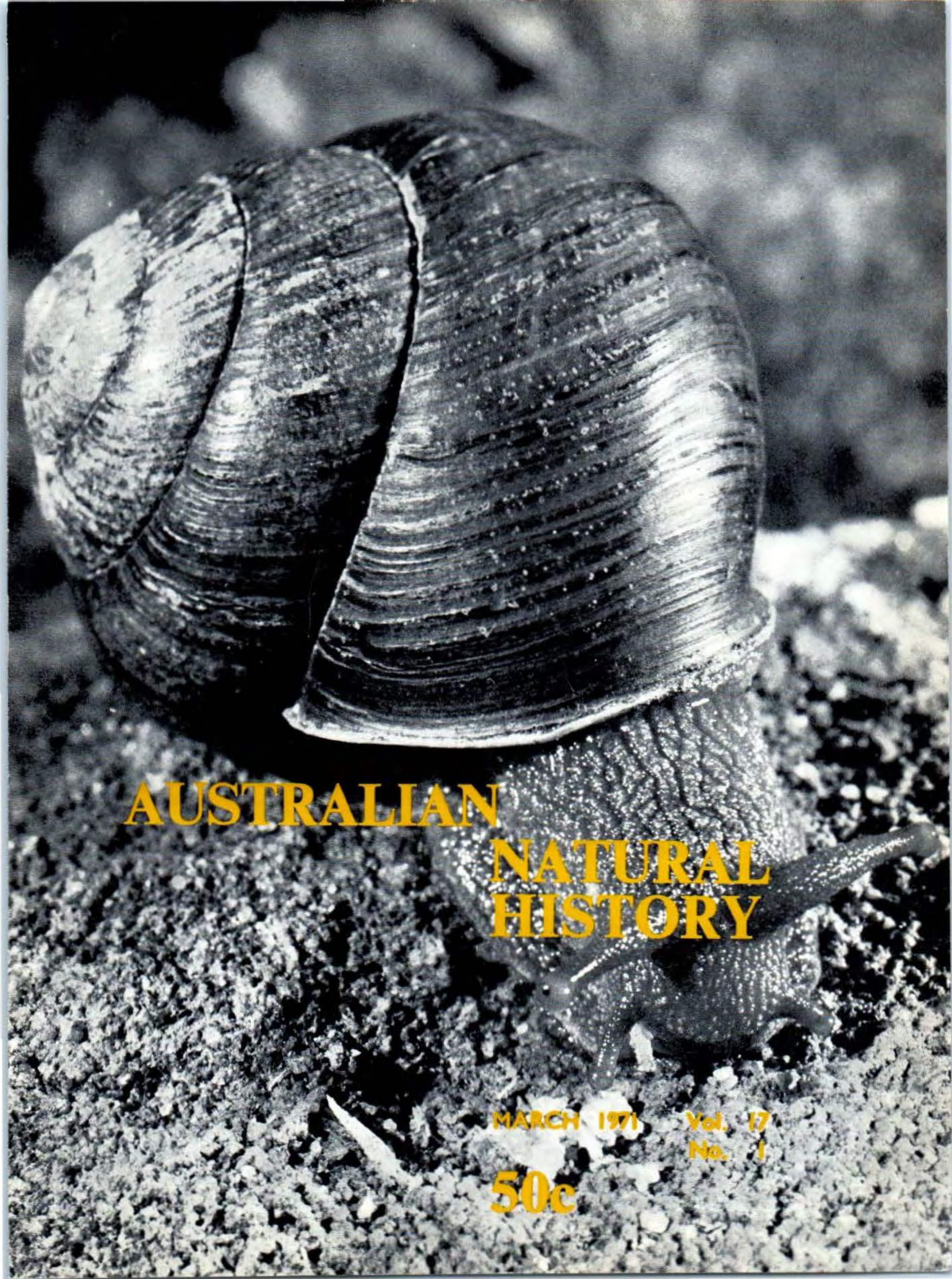
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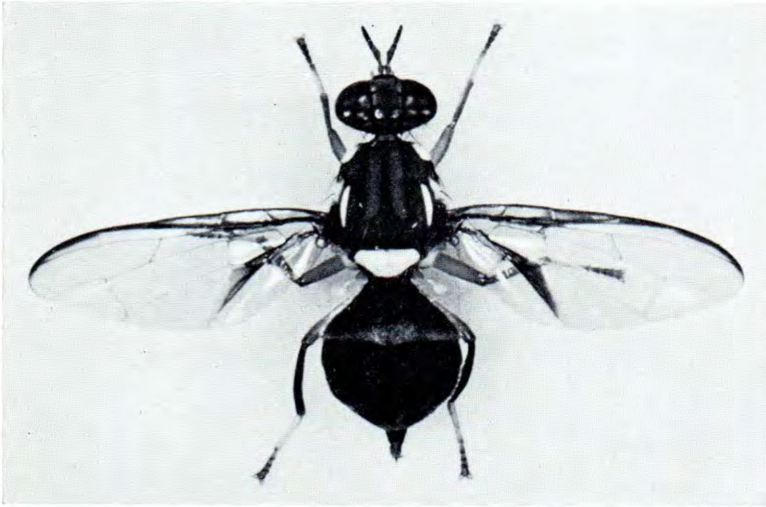
● FRONT COVER: This land snail belongs to the genus *Meridolum*, a group of species found throughout coastal New South Wales. Most of the species are very similar in appearance and have yellowish-brown or reddish-brown shells. They live in damp places—beneath logs, under rocks and in thick leaf litter in native forest. The smallest type of *Meridolum* is about 1·5 cm (about half an inch) wide, but the largest (the one illustrated) reaches 3·5 cm (about 1½ inches). This specimen was found in thick bush south of Sydney. BACK COVER: The family Argiopidae, the orb-weaving spiders, is one of the largest spider groups. Their success is related to their exploitation of the abundant flying insect population as food. The familiar suspended circular snare, commonly seen in open woodland and in gardens, consists of two types of silk—dry, inelastic silk which forms the structural strands radiating from the centre of the web, and an elastic, sticky spiral which makes up the rest of the web and holds and entangles the prey. Hairs and claws on the ends of the spider's legs allow it to move freely on the web without itself becoming entangled. Many orb-weavers consume their web each morning and spin a new one the following night; others, particularly those active by day, use the same web for longer periods, repairing it when necessary. [Photos: C. V. Turner.]



A female Queensland fruit fly. Its general coloration is brown, but the markings on the thorax are bright yellow. These flies are usually about one-third of an inch long—slightly larger than a housefly. [Photo: CSIRO.]

FRUIT FLIES

By M. A. BATEMAN

Officer-in-Charge of the Fruit Fly Ecology Section, Division of Entomology, CSIRO, University of Sydney

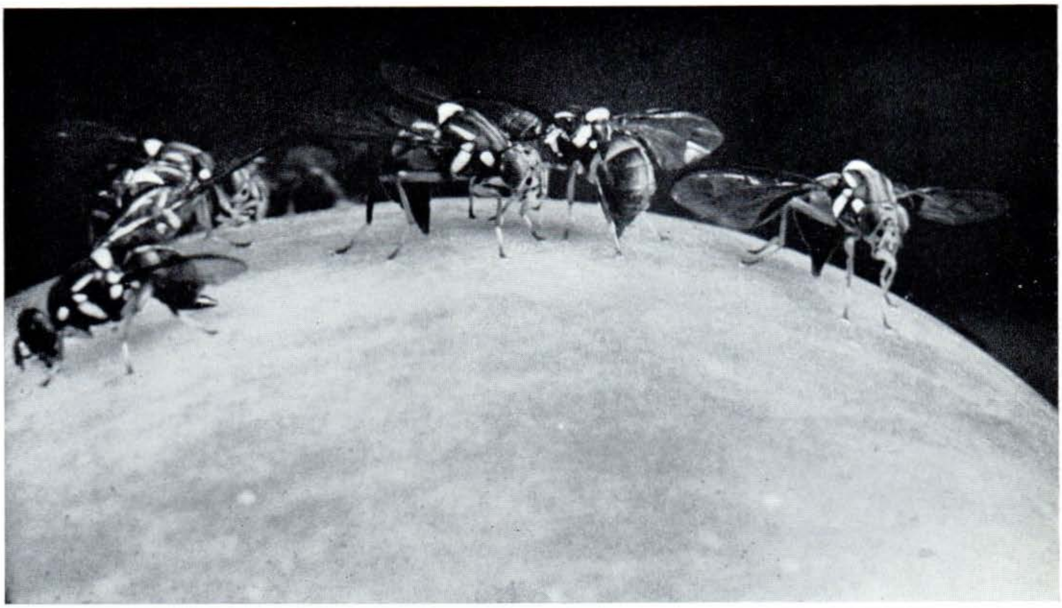
THERE can be few things less pleasant than cutting open (or biting!) an attractive piece of fruit and finding that the inner tissues are brown and putrescent and infested with maggots. Yet this is a very common occurrence in virtually every part of the world where fruit is grown, and almost invariably the insect responsible belongs to the family Tephritidae—the true fruit flies. (Often the term "fruit flies" is loosely applied to the tiny "ferment flies" or "vinegar flies" which swarm around rotting vegetable matter and which have become famous because they are so useful in the study of genetics. These belong to the family Drosophilidae, and, strictly speaking, are not fruit flies at all.)

The family Tephritidae

Representatives of the family Tephritidae are found in almost every country in the world. The vast majority of the hundreds of species are of little interest to mankind because they breed in wild fruits or berries which he does not require for food. But in each continent a few species choose to breed in fruit or vegetables which *are* required by man and these have become very important indeed.

The economically important species of the family fall into two major ecological groups, according to their adaptations to life in the colder or warmer regions of the world. The "cold-temperate" species, as they are often called, are characterized by having only one generation per year, the winter months being spent in diapause (a type of dormancy). The famous Apple Maggot (*Rhagoletis pomonella*), of temperate North America, and the Cherry Fly (*Rhagoletis cerasi*), of temperate Europe and Asia, are the best known members of this group. The other group, the "tropical" species, typically have several generations per year and no obligate diapause—that is, they become active during the winter whenever temperatures are high enough. The best known of this group are the Mediterranean fruit fly (*Ceratitis capitata*), the Oriental fruit fly (*Dacus dorsalis*), and our own Australian pest species, the Queensland fruit fly (*Dacus tryoni*).

The life-histories of the various species of Tephritidae are fairly similar. The adult females are provided with a sharp and rigid ovipositor, which they use to penetrate the skin of a ripening fruit, so that they can



A group of Queensland fruit flies laying eggs into an apple. This photo was taken in the laboratory. In the field, females are extremely aggressive and will not tolerate the presence of other females while they lay eggs. [Photo: CSIRO.]

deposit their eggs just beneath the surface. Tiny larvae hatch from the eggs and proceed to tunnel through the tissues of the host fruit as they feed and grow. Typically they pass through only three instars inside the host before cutting their way out, dropping to the ground, and burrowing an inch or so into the soil to pupate. Inside the pupal case the larva undergoes metamorphosis, and eventually the adult fly bursts the top off the case by hydraulically expanding a curious sac-like structure, called a ptilinum, on the front part of its head. It then proceeds to make its way to the surface. Once there, it expands its wings, again by hydraulic pressure, and is ready to begin life as an adult as soon as its cuticle has hardened.

The pest species owe their importance to the damage done by the larvae as they tunnel through the tissues of their host fruit. This tunnelling is destructive enough in itself, but the damage is usually greatly increased by micro-organisms — yeasts, fungi, and bacteria—which the larvae carry with them and distribute throughout the fruit. When these multiply, the tissues rapidly become brown and rotten. Interestingly, these micro-organisms appear to play an important part in the nutrition of the growing larvae. Adult female fruit flies usually have an elaborate structure called a mycetome associated with the walls of the oviduct, which provides a place where micro-organisms can grow. Its location ensures that each egg is smeared with a culture of them as it passes on its way to the ovipositor. The larvae probably obtain many of their essential nutrients from the micro-organisms injected with them into the host, rather than from the host's tissues. The relationships between the various species of fruit flies and their symbiotic micro-organisms are a fascinating aspect of the ecology of the group, which is as yet virtually unstudied.

Australian fruit flies

Australia has more than fifty species of fruit flies, and before European settlement most of them inhabited the rainforests which covered vast areas of the northern and eastern parts of the continent. As the white man spread further and further northwards he destroyed these rainforests and in their place he planted his own food crops, including imported fruit trees. So with the one hand he destroyed the home and food of the fruit flies, and with the other he provided, for

Premier Congratulates Magazine

The Premier of New South Wales, Mr R. W. Askin, has sent to the President of the Australian Museum's Board of Trustees, Mr W. H. Maze, the following message of congratulation on the 50th anniversary of *Australian Natural History:*

The magazine of the Australian Museum, *Australian Natural History*, celebrates its 50th anniversary in April this year.

The foundation editor was the then Director of the Museum, Dr Charles Anderson, who wrote in the first issue:

"The publications issued by the Australian Museum in the past have consisted of reports, memoirs, records and catalogues, intended principally for scientific readers and specialists in various branches of natural science.

"The Trustees have now decided to make an increased effort to reach a wider public, so that every man and woman in the State, and even children of tender years, may feel that the Museum has a message for them.

"It is with this object in view that the *Australian Museum Magazine* has been established."

It is an eloquent tribute to past and present editors and staff of the Museum that the magazine has achieved and maintained this objective with such success, and at the same time has established for itself a reputation both here and overseas as a learned journal of the highest standing.

From the average reader's point of view *Australian Natural History*, as the magazine was re-named in 1962, provides pleasurable and informative reading.

In addition, because of the eminence of those who subscribe to its pages, it continues to make increasingly important contributions to scholarship in the field of the natural sciences.

I compliment all those responsible for the production of an excellent magazine occupying a very special place amongst Australians and people overseas interested in the fascinating flora and fauna of this great continent of ours.

My best wishes for the future progress of *Australian Natural History*!

R. W. ASKIN,
Premier and Treasurer of N.S.W.

those species which were adaptable enough to take advantage of it, a sudden abundance of succulent fruit which, we have since found, is quite adequate nutritionally for many of the species. It is surprising that of the fifty-odd species in the rainforests, only one took full advantage of the new opportunities. That was *Dacus tryoni*, the Queensland fruit fly. One other, a closely related but more northerly species named *Dacus neohumeralis*, took reasonable advantage of the situation. Only a few of the remainder made even limited changes in their old habits and adapted themselves to utilize a small amount of the new food provided by man. The majority have stayed in the rainforests and contracted with them, until today many are quite rare.

History of the spread of the Queensland fruit fly

One of the earliest records of maggots in cultivated fruit in Australia was in the early 1850's in the Brisbane area. There are scattered records from other parts of the new Queensland settlements from then until 1889, when the famous entomologist Tryon found the Queensland fruit fly (which was subsequently named after him) severely damaging fruit near Toowoomba, and published a comprehensive description of its activities. After that, reports of infestations came from almost everywhere that settlements were made in Queensland, except in the dry western half of the State.

In New South Wales the history of the occurrence of fruit flies is very poorly documented. One of the earliest reports was in 1893, when the Government Entomologist, A. H. Benson, described what was clearly Queensland fruit fly damaging fruit near the Clarence River in northern New South Wales. In that paper he does not mention the species ever having been seen in the large Sydney and Gosford orchards, although other authors mention that maggots had been found there in earlier times. In 1895, however, Benson clearly reported the presence of fruit fly (almost certainly Queensland fly) in the County of Cumberland, and from then on it was undoubtedly common around Sydney, at least until the turn of the century.

At that point the position again becomes obscure, because of the introduction of the Mediterranean fruit fly (*Ceratitis capitata*) to the Sydney area. This species had been introduced to Western Australia some years earlier (presumably by ships bringing fruit from Africa), and seems to have reached the east coast settlements about 1898. For the next 20 years the majority of records of fruit fly in New South Wales refer to Medfly—not Queensland fly. Medfly spread rapidly into country districts west of the Dividing Range, southwest to the Murrumbidgee Irrigation Area and Albury, and was even recorded from Melbourne and Tasmania. Then, during the 1920's the picture began to change. Medfly began to disappear, and its place was taken increasingly by the Queensland fly. By the middle 1930's Queensland fly was clearly the dominant species. Medfly continued to dwindle, and eventually it completely disappeared. The last one was recorded from Sydney in 1941. We really know very little about why the Medfly disappeared. We simply assume that there was strong competition between it and the Queensland fly, and the penalty for the loser was extinction. The population of Medfly in Western Australia is still thriving, but there it has no competitors.

By the mid-1930's, then, the Queensland fruit fly was established in coastal areas of New South Wales north of Wollongong, and in some inland towns as well, as an extremely destructive pest. Then, in the period 1946–47, there were some further startling developments. Four important events occurred almost simultaneously:

- An extremely active infestation, covering several square miles, was found in the suburbs of Adelaide.
- A large outbreak was found in the suburbs of Melbourne.
- A number of small but widespread infestations were found in East Gippsland, in the northeast corner of Victoria.
- Fruit fly appeared in the Murrumbidgee Irrigation Area for the first time in 8 years.

Perhaps I should say that there were *five* important events at this time, because, at the same time, 5,000 miles away across the Pacific, the Oriental fruit fly (*Dacus dorsalis*) was found to have invaded the Hawaiian islands. Why these developments should have taken place simultaneously is not altogether clear. As far as the spread of *D. dorsalis* was concerned, United States entomologists blamed the war, which resulted in greatly increased movements of people (troops) and food back and forth across the Pacific. Similar circumstances probably helped the spread of *D. tryoni* in Australia, although it is also true that 1946 was an extremely bad year for fruit fly in New South Wales and this must have greatly increased the probability of invasion of the southern States.

The movements of fruit flies—migration and dispersal

As we have seen, fruit flies are quite capable of moving over immense distances—even across oceans. Paradoxically, most of this long-distance travelling is done by the larvae, or maggots, which have neither legs nor wings, and are incapable of moving more than a few yards by their own efforts. The reason is, of course, that they travel in cars and planes and ships, inside the fruit which man likes to take with him wherever he goes.

The adults, the normal migrating or dispersive form, are actually fairly strong flyers. Flights of 30 miles or more (down-wind) have been recorded for certain species between islands in Hawaii. Recently we have learned a good deal more about the movements of the Queensland fruit fly. We have found that young adults have a strong tendency to disperse soon after their emergence from the soil. Adults which have reached sexual maturity, on the other hand, are more likely to settle down, and may remain for weeks in an area such as an orchard where there are ripening fruits available for oviposition. As soon as the fruit begins to dwindle, however, these older adults also disperse, and presumably continue to wander until they locate another area where there is ripening fruit. Fruit flies can move quite rapidly through the dry sclerophyl bushland which is so common in coastal areas of eastern Australia, and movements of marked individuals of up to 15 miles have been recorded. In fact, fruit flies can be found moving through the eucalypt forests in the vicinity of Sydney at any time of the year, and in some seasons, especially late summer and autumn, their numbers are remarkably high.

Limitation of spread

It is important to ask, therefore, what prevents the species from expanding its present distribution far beyond its existing boundaries, either rapidly, by means of larvae transported in fruit, or more slowly, by the dispersive movements of adults. Why does it not invade and become established in the great fruit-growing areas of southern New South Wales, Victoria, and South Australia?

A partial answer to this is that it *has* invaded most of these areas in past years, and still does occasionally, but that the local agricultural authorities have always reacted to these invasions in an extremely aggressive manner. In each place the authorities are constantly alert for signs of new infestations, and as soon as one appears it is attacked with the utmost vigor. So far eradication has always been possible, although the price, in terms of materials and labour, has sometimes been extremely high.

Quarantine stations at State borders, interstate airports and railway stations, etc., probably play a vital role in curtailing the spread of larvae in fruit, but there are no such barriers to the movements of adults, nor to the consequent southwards spread of the species through a gradual expansion of established infestations. This type of spread does not appear to be occurring at present, however, and it may be that the species has come up against some kind of environmental limitation to its southward progression. A look at a map of the species' distribution immediately suggests that temperature may be the limiting factor. The species thrives in the warmer northern regions and fades away to sporadic populations or complete absence in the colder south. Long-term ecological investigations, however, have thrown considerable doubt on this hypothesis. Certainly temperature is important in the determination of both distribution and abundance, but there is another component of the environment which is of more critical importance — moisture. The Queensland fruit fly is vulnerable to desiccation. Pupae in dry soil, new adults emerging through dry soil, and older adults in a dry atmosphere, all have very low probabilities of survival. Moreover, the ability of females to produce offspring is so reduced in dry conditions that populations fail even to maintain their numbers, let alone multiply and spread.

Perhaps this susceptibility to dryness should not surprise us. After all, we presume that the species evolved in the moist rainforests of northern New South Wales and Queensland, where conditions dry enough to lead to the selection of desiccation resistant forms may never occur. We should remember, however, that evolution is a continuing process, and *Dacus tryoni* has already proved itself to be an extremely adaptable species. Environmental dryness may be an effective barrier at present, but we have no guarantee that it will remain so in the future.

FURTHER READING

Christenson, L. D., and Foote, R. H.: "Biology of Fruit Flies." *Annual Review of Entomology*, 5: 171–192, 1960.

May, A. W. S.: "An Investigation of Fruit Flies (Fam. Trypetidae) in Queensland. I. Introduction, Species, Pest Status and Distribution." *Queensland Journal of Agricultural Science*, 20: 1–82, 1963.

BOOK REVIEW

AUSTRALIAN FROGS, by Densey Clyne; Periwinkle Colour Series, Lansdowne Press, Melbourne, 1970; 112 pages; $1.25.

Australian Frogs is an entertaining and stimulating introduction to the identification and study of frogs. Despite the all-embracing title, the book describes only a proportion of the total Australian frog fauna. The coloured illustrations, with one or two exceptions, are of high quality, but the black and white photographs are generally poor. The index is rather inadequate.

It is particularly annoying that, with so many species lacking illustrations, one species has been pictured four times, six species have each been pictured three times, and thirteen species have each been pictured twice. (These figures exclude helpful pairs of photographs showing upper and lower surfaces of the same species). This duplication, if avoided, would have permitted the illustration of an additional 28 species within the book's present size and format.

The introductory chapters on the biology, anatomy, and ecology of frogs are clear and concise. Mrs Clyne is to be congratulated for providing such a useful and readable introduction to the study of Australian anurans.—*H. G. Cogger, Australian Museum.*

"Glory of the Seas" Cone Shell

Conus gloriamaris Chemnitz, from the Solomon Islands. This species is the prized "Glory of the Seas" cone, which has been considered one of the rarest and possibly the most valuable shell in the world. Several living specimens were recently found in the Solomon Islands by Mr W. Gibbons, a diver, and one of them was brought by air to Sydney for these photos, which are believed to be the first ever published of a live *C. gloriamaris*. Above, the animal is seen on its side, with the foot (the long oval-shaped part), head (at the right of the foot, partly obscured by sand), tentacles, and siphon (protruding beyond the shell) clearly visible. The very extensile proboscis can be seen between the tentacles. Below is a closer view of the front end of the animal. The proboscis is seen protruding from its sheath, into which it can be fully retracted. Cone shells feed by poisoning their prey with a dart-shaped tooth held in the tip of the proboscis. Although a few species have been known to cause fatalities in man, it is not known whether this one is dangerous. This species should not be confused with the common Textile Cone, which has a shorter spire and more rounded sides. [Photos: Terry Barlow.]

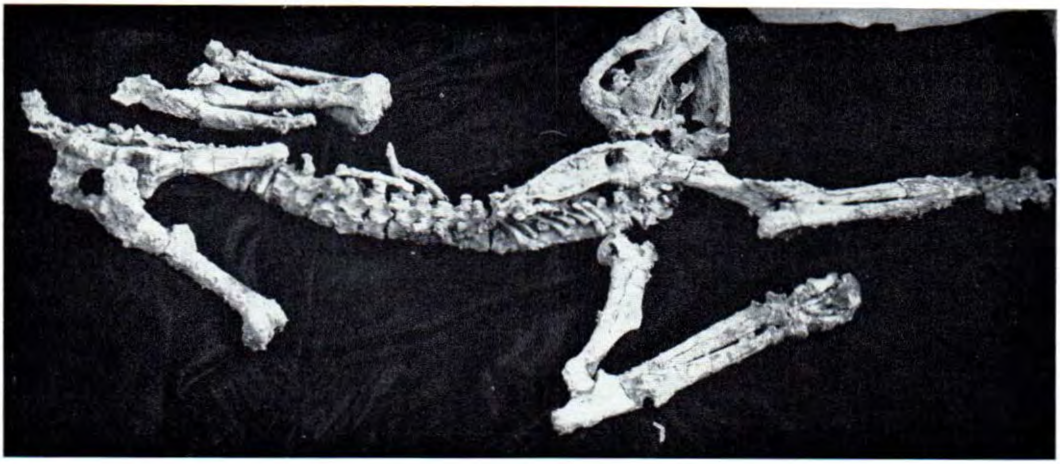


Fig. 1.—The New England *Thylacoleo*. Note the massive skull and powerful forelimbs. [Photo: M Mitchell.]

THYLACOLEO, MARSUPIAL LION OR MARSUPIAL SLOTH?

By EILEEN FINCH
Lecturer in Zoology, University of Western Australia, Perth

IN June, 1966, while engaged on loading loam from the Marshall Ponds Creek loam pit, 10 miles from Moree, New South Wales, Mr John Honnery and Mr Brian Riley noticed what appeared to be a bone embedded in the wall of the pit about 9 feet from the top. Their interest aroused, they carefully scraped away the surrounding soil and exposed a heavily-built skull and lower jaw. This was lifted from the loam, exposing neck vertebrae in the soil beneath it.

The skull they had found was unusual in appearance. It had a short, very broad snout with wide flaring bony arches on either side. At the front of these arches were orbits which, in life, had surrounded the forwardly-looking eyes. Apart from its striking cat-like shape, the most conspicuous feature of the skull was a pair of carnassial, or shearing, teeth on each side of the mouth. Each tooth was a long, sharply-bevelled ridge almost 2 inches in length, which was slightly curved, with its convex surface outwards.

The carnassial teeth in the lower jaw of the fossil lay just inside their two upper counterparts and, in life, would have slid against their inner sides as the mouth closed, in much the same way as the blades of a pair of secateurs ride against each other as they cut.

The science of palaeontology owes much to Mr Honnery and Mr Riley for persisting with their search after they had exposed the skull. It would have been easy, and even satisfying, for them to have triumphantly borne off their initial find instead of spending many hours scraping away at the matrix for further scraps of bone, using the inadequate tools which they had at their disposal. However, they continued until they had unearthed several blocks of matrix containing bone, and then conveyed them to a safe storage place.

News of the find soon reached Mr John de Bavay, of the University of New England, N.S.W., who investigated the site and the material which had been collected. He had no difficulty in identifying the skull as being that of *Thylacoleo*, a marsupial which was not directly related to the familiar African lion, but, as it shows a superficial skeletal resemblance to the "King of Beasts", is often referred to as a "marsupial lion". He immediately realized its unique importance and, not being a palaeontologist himself, he sent it to Dr D. Ride, Director of the Western Australian Museum, Perth, with the request that it should be studied and eventually returned to New South Wales for exhibition in the Australian Museum, Sydney.

When the find was examined in Perth we discovered that the bones included not only the large *Thylacoleo*, which had been found first, but also the fragmentary remains of several other undoubtedly herbivorous species of fossil marsupial, such as the giant wombat and the giant kangaroo. Could this find represent a "marsupial lion" and the remains of its meals?

First discovery

Before we can answer this question and understand the excitement of the find it is necessary to know something about the speculation centred around *Thylacoleo* ever since its first discovery at Lake Colongulac, Victoria, by William Adeney about 1846 and its subsequent description by the great English anatomist, Sir Richard Owen, in 1858. Because of the existence of giant fossil herbivorous marsupials which Owen had earlier described, he predicted that large extinct carnivorous marsupials must also have existed in Australia and, on the discovery of the remains of *Thylacoleo*, he claimed that they represented "a marsupial beast of prey, rivalling the lion or tiger in size, and equal to cope with the diprotodon and nototherium." (*The Leeds Mercury*, Thursday, September 30th, 1858, page 4).

Soon after he put forward this theory, opposition grew and the opinion was expressed by leading anatomists, including Professor W. H. Flower, that *Thylacoleo* was an herbivorous animal.

Although, since Owen's description, numerous separate fragments of *Thylacoleo* have been found, including some pretty complete skulls, no material has been described which is adequate to settle the question.

Early arguments

All the early arguments were based on the skull. The massive head, wide cheek arches, and carnassial teeth suggested a carnivorous habit to Owen, but his opponents pointed out that *Thylacoleo* had puny little canine teeth which could never have been used for attacking and gripping living prey. By the same token, the lower incisors were said to have been incapable of tearing flesh from bones because of their forwardly-directed and procumbent position. On the other hand the suggestions which were made of an herbivorous habit seemed to be just as untenable because the molar teeth are

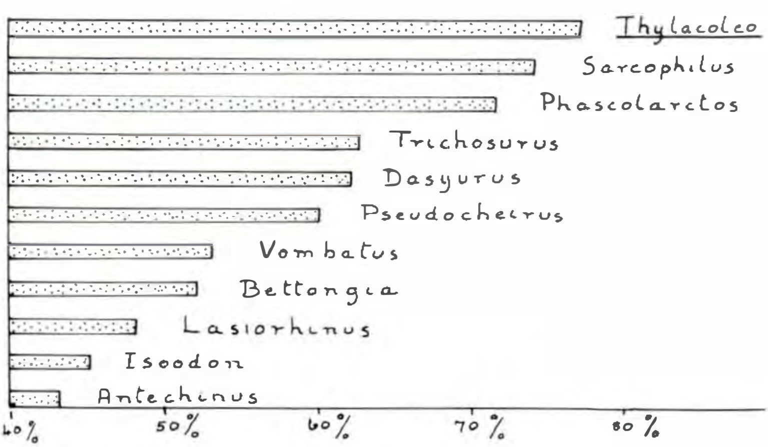


Fig. 2.—Ratio of length of forelimb to length of vertebral column (excluding the sacrum and tail) for a number of marsupials. [Diagram by the author.]

so reduced in size and number as to be quite useless as grinding organs which are so necessary for breaking up fibrous food. Various proposals were made for highly specialized diets which might overcome this argument: a former Director of the Australian Museum, Dr C. Anderson, suggested that *Thylacoleo* might have lived on the fruits of members of the cucumber family, while the great American palaeontologist of the nineteenth century, Professor E. D. Cope, considered that it might have subsisted on eggs (perhaps those of the crocodile). Mr E. D. Gill, Deputy Director of the National Museum of Victoria, has more recently questioned whether these foods would have been hard enough to necessitate the use of powerful shearing teeth and, moreover, has noted that neither the crocodile nor members of the cucumber family were to be found over the whole range inhabited by the "marsupial lion", which extended from Queensland to south-western Australia and Tasmania.

Although fragments of skeletons had been found in deposits which contained pieces of *Thylacoleo* skull or teeth, until recently no skeletons were known which could undoubtedly be associated with skulls of the "marsupial lion" (for mention of another skeleton which has been recently discovered but not yet described, see B. Daily, *Australian Museum Magazine*, vol. 13, pages 163–166), so no conclusions could be drawn from the post-cranial characteristics of the animal which might settle the question of its habits.

Exciting find

My excitement can therefore be imagined when, on preparing the fossil sent to Perth from New England, I found that it comprised an almost complete animal about 4 feet long. Although the fossil was badly broken, it could easily be proved that all parts belonged to the same individual because limb girdles were still attached to the vertebral column and, where breaks occurred in the limbs, they were in the middle of long bones, the ends of which were still articulated with the girdles. Fragments of the vertebrae of the neck were still attached to the skull and the broken pieces of long bones matched exactly when placed together. Only the hind feet and the tip of the tail are missing.

Much work has still to be done before the skeleton can be fully interpreted. So far, evidence of the life and habits of the "marsupial lion" is available from the forefeet, which are now freed from their encrusting matrix, and from the proportions of the limbs.

The forefeet are comparatively long and narrow and show close resemblance to the common Brush Possum (*Trichosurus*). However, the digits lie parallel to one another and the "thumb" is almost as long as the fingers. It is very strong and bears at its tip a hooked distal phalanx which supported a large, hooded, lion-like claw. There is evidence of a second, and possibly a third, claw on digits two and three, but it is impossible to determine whether digits four and five were clawed because preservation of this part of the fossil is poor. The impression gained from this structure is of a strong and heavy paw in which the digits could not be widely separated and which was therefore probably used as a single entity.

Limb lengths

Measurements of relative limb lengths expressed as a ratio of the length of the forelimb to that of the hind limb show that the limbs of *Thylacoleo* are approximately equal. By comparison with other mammals this would imply a cursorial, or running, method of locomotion rather than a jumping or burrowing type. Also, if the length of the forelimb is compared with that of the vertebral column (excluding the sacrum and tail) as is shown in fig. 2 for several marsupials, it is quite clear that *Thylacoleo* has a very long arm for its body size. The arm of the Tasmanian Devil (*Sarcophilus*) is similarly elongated, and this limb is certainly used to strike at prey and to drag it back towards the jaws. Climbing members of the possum tribe, such as the Koala (*Phascolarctos*) and the Brush-tailed Possum (*Trichosurus*), have fairly long forelimbs in contrast to the comparatively short arms of the burrowing Wombats (*Vombatus* and *Lasiorhinus*) and of the quadrupedal marsupials which jump (such as *Isoodon*). However, the climbing forms with long forelimbs have mobile digits on the forepaws which give the animal a firm grasp of the branch of a tree.

Fig. 3.—Skull of a lion, showing the teeth, shape of the lower jaw and wide bony cheek arches of a carnivore. [Photo: M. Mitchell.]

Mechanism of jaw movements

To add to the evidence of carnivorous habit which we get from the skeleton, recent studies on the mechanism of jaw movements in mammals will help us to interpret the structure of the skull rather more profitably than was possible in the past.

When an animal chews, the force exerted by the jaw muscles is used both to move the jaw and cut the food. The bite-force acts at the point where the most powerful chewing takes place and the skull is normally strengthened in this region. In *Thylacoleo* the anterior end of the cheek bone is thickened to form a buttress to absorb much of this force and, at the same time, the bar of bone behind the orbit of the eye further strengthens the same region. It is probably of great significance that the only two marsupials known which have complete bony bars behind the eye are *Thylacoleo* and *Thylacosmilus*, the South American Marsupial Sabre-tooth! It is notable that in *Thylacoleo* the carnassial premolars lie just below the buttress, indicating that the maximum bite-force is exerted in this region of the jaw and the stress is then distributed upwards onto the roof of the skull.

Further evidence suggesting that the shearing action of the carnassial teeth is the main means of taking food into the mouth lies in the shape of the lower jaw, or mandible, and the direction in which this mandible is free to move. In carnivores in general, as in the lion (fig. 3), the jaw joint about which movements of the lower jaw occur lies approximately on the same level as the lower teeth, while in herbivores, such as sheep, this joint is developed above the tooth-row in a vertical extension of the jaw. The jaw joint of *Thylacoleo* is very similar to that of the true lion. At the same time, in carnivores, the condyle of the mandible is a rounded roller-bearing which fits into a deep cylindrical cavity on the skull, an arrangement which limits the mobility of the jaw to the up-and-down movement necessary if the teeth are to slice food. However, such a jaw hinge restricts the sliding movements which in herbivores are the essential components of the chewing action needed in grinding up plant food.

Finally, the cheek arch is very wide and there are very well developed ridges along the upper posterior border of the skull to provide large areas for attachment of the voluminous jaw-elevating muscles, the deep masseter, and the temporalis, which provide the force of the bite.

Mental picture of original animal

Taking these things into account, I find it easy to picture the fossil skeleton I am studying as an animal the size of a leopard with comparatively long limbs for its size and a large, heavy head supported on a thick, muscular neck. The head was short and wide with powerful jaw muscles and

Fig. 4 (above): Skull of *Thylacoleo* as seen from above. Note the short broad snout, wide cheek arches, and complete bar of bone behind each eye orbit. Fig. 5 (below): The lower jaw and part of the right side of the skull of *Thylacoleo.* The procumbent lower incisor and carnassial teeth are clearly seen. [Photos: M. Mitchell.]

forward-looking eyes. The paws were strong, heavily clawed, and probably used in striking prey and for tearing it. The pointed and strong incisors and sharp shearing premolars, operated by great muscles, would have had little difficulty in cutting through flesh. There is little doubt in my mind that the "marsupial lion" was truly lion-like in its feeding habits.

Among the lumps of matrix containing parts of the skeleton of *Thylacoleo* was one which, after preliminary washing, revealed two small, unworn teeth. Careful investigation brought to light an ill-preserved, crushed skull of what can only be a pouch joey of the large *Thylacoleo*. The right upper jaw is complete, but the premaxillary region of the left upper jaw is missing. The lower jaws have been crushed obliquely against the skull, which was probably still largely soft and cartilaginous when the animal was alive.

The joey was so young that only the two upper and one lower incisors on each side of the mouth had erupted; the other teeth were still embedded in the bone. But the most exciting feature of the teeth was the last premolar tooth, or sectorial, in each jaw. Unexpectedly, it is almost of the same size and shape as the carnassial tooth of the adult, in spite of the fact that it has not yet erupted from the jaw. This raised the question as to whether *Thylacoleo* had milk-teeth or not. In most marsupials the last premolar of the dental series (in this case the sectorial tooth) has a milk predecessor which erupts and comes into use before the permanent tooth. In this joey there is no sign of a milk-tooth and the permanent tooth is beginning to erupt.

Unanswered questions

And what of the fragments of other marsupials found in the deposit as well? It is too early to say much about them, beyond that the bones are the merest fragments and are all broken.

In all, the deposit is full of questions and, we hope, answers too. Further study of the jaw of the pouch young may reveal answers to the problems of the erupting dentition of *Thylacoleo* while the skeleton, when interpreted in the light of careful investigation of the muscular systems and associated skeletal features of a wide range of marsupials, will provide more useful clues as to the locomotion and habits of one of Australia's largest and most problematical extinct marsupials.

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MUSEUMS' EXPEDITION TO PAPUA-NEW GUINEA

By STEPHEN ROOKE
Journalist and Broadcaster, Sydney

THE British Museum, the U.S. National Museum, and the Australian Museum made a combined biological collecting expedition to Papua-New Guinea from 20th May to 26th June, 1970.

I joined the expedition in Madang on 1st June to be observer, do some marine photography, assist with the diving and collecting, and cook some indigenous vegetables, including yams and taro, so they would marry successfully with tinned bully beef. Also, in some quixotic way, to attempt to maintain esculent logistics and sustain gastronomic morale during the week the expedition camped out on a coral island, under swaying coconut palms.

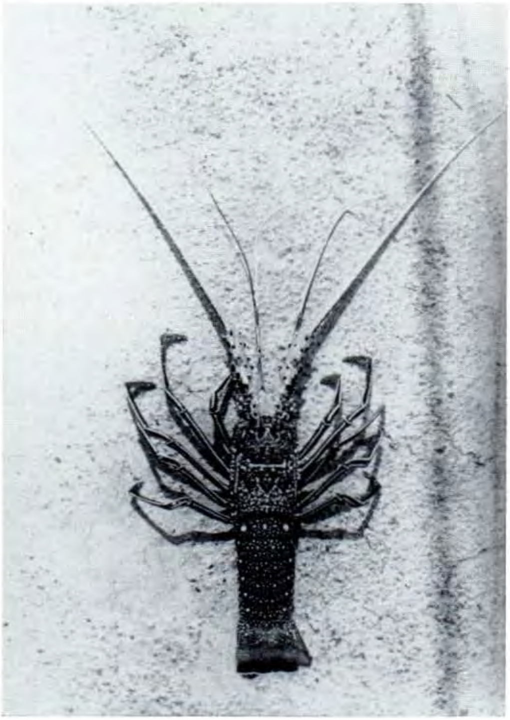
The idea of a combined museums expedition was formulated and co-ordinated by Dr Frank Talbot, Director of the Australian Museum. As a result, representatives of the British Museum and the U.S. National Museum pooled resources with scientists from the Australian Museum to participate in a joint collecting trip to Papua-New Guinea which may be the first of a planned series of combined expeditions to the Indo-Pacific area.

The purpose of this expedition was to collect as many species as possible of fish and invertebrates from a variety of habitats in the Territory. By obtaining a large series of comparative material the collection will be absolutely necessary for future taxonomic studies, comparisons with Australian species, and further systematic studies in other parts of the world.

It was agreed by the scientists that they would prepare the collected material in the field, divide the "loot", and dispatch the specimens to their respective institutions to be sorted and preserved for future research.

Impressive scenery

I arrived in Madang on 1st June, after flying from Australia across the Coral Sea.



A Coral or Painted Crayfish (*Panulirus longipes*), from Kiriwina Island, in the Trobriand group. These crayfish are brownish or purplish, ornamented with pale spots and stripes, and the legs are purple, streaked with white. They grow to more than 12 inches in length, and large specimens weigh up to 8 pounds. [Photo: Author.]

Skimming down from the clouds, I viewed Madang's harbour with its turquoise necklets of coral islands, surrounded by a mantle of jungle-clad mountains. Below me was the town of Madang, the picturesque staging ground to the highlands. The plummeting gorges, moon-like landscapes, awe-inspiring mountains, brown curving rivers, and nests of matchbox villages project what must be some of the most interesting geography in the world.

On arrival I was picked up at the airport by Dr Winston Ponder, Mr Barry Goldman, and Mr Phil Colman, all from the Australian Museum, and driven to comfortable quarters, on loan from the Institute of Human Biology, which the expedition was using as a base in Madang.

Collecting at night

Almost immediately after arrival, I joined the group in a night collecting trip in Madang Harbour. After driving out into the tropical night, past tall coconut palms and rain trees, into a riot of coloured poinciana, hibiscus, and bougainvillea, we were soon wading waist-deep in the tepid waters of Madang Harbour. Under a flaring incandescent pressure lamp, and with nets poised, we looked cautiously for stonefish, molluscs, and garfish.

American ichthyologist

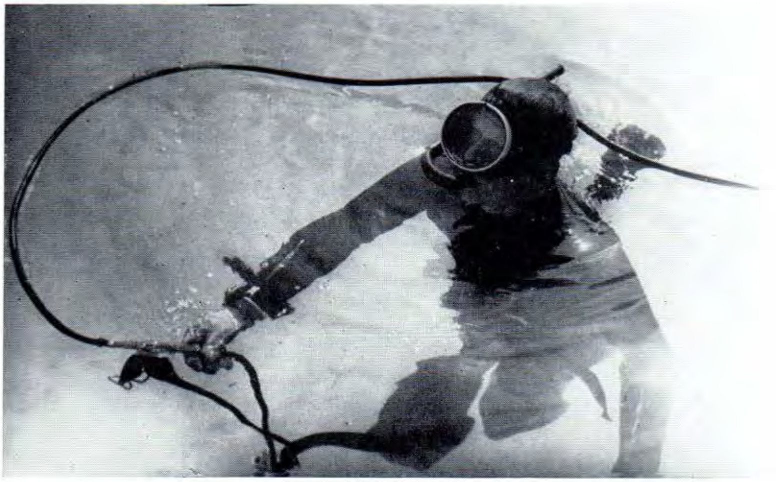
It was on collecting trips like this that I got to know Dr Bruce Collette, representative of the U.S. National Museum. He told me he was born and educated in the U.S.A. and was a graduate of Cornell University. Later he joined the U.S. Bureau of Commercial Fisheries, particularly the section called the National Center for Systematics, located in the U.S. National Museum, which is part of the Smithsonian Institution. His participation in the joint expedition was part of his year's sabbatical leave at the Australian Museum.

Both the Papua-New Guinea trip and the sabbatical were planned around his world-wide revisions of several groups of fish, especially the garfish (Hemirhamphidae), that family which is known commonly in the U.S.A. as half-beaks. Another of his specializations was longtoms (Belonidae) or needlefish. His other choice of scientific study centred around the family Scombridae, known generally as mackerels and tunas.

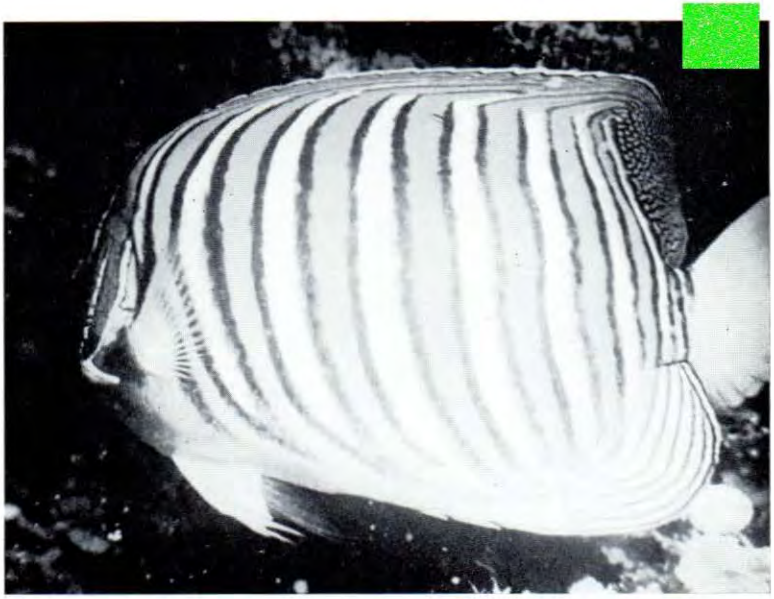
Fish poison

Dr Collette is sure the general area around New Guinea is a centre of fish distribution and could contain a greater number of species of some fish than almost any other place in the world. Large collections of fish were certainly made on this trip, mainly by making poison stations. This is a marine collecting technique using a type of fish poison which stuns and kills fish, allowing divers to collect in hand nets large numbers of specimens around the poisoned area.

The technique was adapted from natives, who have used this method for centuries to catch fish for food. They obtained the poison by crushing the leaves and bark of trees which contained it. The poison only works on fish, and appears to have no effect on warm-blooded animals, including humans, exposed to it in a solution of sea-water. Little, if any, long-term damage is done to fish populations in areas where poison has been used, and regeneration appears to be relatively short-term.



Dr Bruce Collette using hookah gear off the yacht *Finisterre*. [Photo: Author.]



A Blue-banded Angel Fish (*Pygoplites diacanthus*), off a reef at the northern end of Kiriwina Island. These fish reach a length of 9 inches. They are yellow, with light-blue vertical stripes broadly edged with black. [Photo: Author.]

After collecting around Madang until 4th June, preparations were made to load all the gear on to the charter aircraft which was to take the expedition to the next operations base at Losuia, on the island of Kiriwina, the main island in the Trobriand group.

It was a formidable task, loading the immense amount of scientific gear on to the aircraft from its storage base, provided by the Department of Agriculture, Stock and Fisheries, close to the water. This equipment included a heavy diving compressor, a motor-driven generator, a number of 30 gallon drums, and a large quantity of plastic polydrums, some already filled with specimens collected.

Trobriand Islands

The Trobriand group of islands lie 100 miles off the northeast coast of Papua, and 150 miles north of Samarai. They are real coral islands; some of them are low-lying, while others form coral cliffs rising to heights of up to 300 feet.

There are a Government station and hospital at Losuia, on Kiriwina. Apart from the administrative centre, the hospital, several stores, a post office, and the missions, the rest of the island is divided up into separate villages, containing a native population of about 1,100. The islands are an official control health area, and extensive campaigns have been introduced to reduce malaria, TB, and yaws. Today blackwater fever is rarely heard of.

From the moment you arrive it is obvious that the Trobriand Islanders are a most friendly people. In their appearance and customs they seem to be different to others in the Territory.

For generations the hospitality of the gregarious Trobrianders was legendary to scores of ships which anchored off their shores. Today the people of Kiriwina are still friendly; however, some are slowly becoming sophisticated as more and more contact is made with Europeans, who come in on regular flights from Port Moresby to stay on the island for limited periods.

Natives' carvings

Carving has been a tradition with the Trobriand Islanders, especially their beautifully decorated canoe prows, lime pots, and spatulas. Today's tourists eagerly buy carved ornate walking sticks, bowls, pigs, and massive chunky tables, which form the bulk of carvings offered.

The main language is Kiriwini, with English usually spoken only by those who have been to school. Gardening is still the main occupation of the islanders, with yams their staple diet, supplemented by taro, fish, and bananas.

Kiriwina is 37 miles long and 12 miles wide. The northern and eastern sides of the island are fringed by a coral reef. On the northwest side, near Kaibola village, is a large bay, which proved to be an excellent collecting spot for the expedition. A seine net was used along the beach for collecting, and poison stations were set up out on the reef.

While swiming over the edge of the reef, we saw fish of all sizes and colours in depths of water under 30 feet. Visibility was good and several large reef sharks, swimming close by, appeared too well-fed to be interested in the anatomy of intruding marine biologists and a slightly apprehensive photographer.

Prehistoric monoliths

On Kiriwina there still stand strange prehistoric monoliths, evidence of some race which the present islanders claim to have no knowledge of; the islanders refer to the monoliths as belonging to men who have gone before.

These huge ancient coral slabs, set in an east-west orientation, with some blocks at least weighing several tons and transported 6 miles from their place of origin on the shore, still remain an enigma to scientists. Speculation can only be made as to who might have erected them and what their purpose was.

It was the same with burial caves I looked at on the island. Inside these eerie limestone caves were ancient earthenware pots and remains of skeletons lying about and stacked into crevices, with hollow skulls grimacing out of what could be described as subterranean charnel depositories or limestone burial vaults.

Whatever their origin was, both the stones and the burial caves are linked in some mysterious way with some early culture which existed on Kiriwina and whose history still lies buried in the past.

Originally it was planned that the expedition would spend a week on the remote Lucancay Islands and reefs about 10 to 60 miles off the northern end of Kiriwina Island. However, shipping transport was hard to arrange with the amount of scientific equipment we had, and a compromise was made by the leader of the party, Dr Winston Ponder, who solved the problem by chartering a 72-foot work yacht, the *Finisterre*, to explore areas of reef off the nearby islands and do some dredging for molluscs in greater depths than we could safely dive with our hookah gear.

Kuia Island

Later, the expedition put ashore on the island of Kuia, in the Trobriand group, with arrangements made for the Government launch from Kiriwina to pick us up in a week's time.

It was a low-lying coral island, with abundant coconut palms, thick tropical vegetation, and a native village and community. The experience of camping close to the islanders was stimulating and beneficial to us, as we could barter for food and enlist the natives to bring in shells, fish, snakes, and lizards for our communal collection.

During the week on Kuia, Mr Geoff Palmer, from the British Museum, who had been working long hours every day, sorting and classifying specimens, developed a septic tropical ulcer on his leg, from coral poisoning, and had to be taken back to Losuia, on Kiriwina, in a sailing canoe, for medical treatment.

Fish research

Watching the collection of marine specimens grow, I talked to Mr Barry Goldman, from the Australian Museum, about his research into coral reef fish on One Tree Island, on the Great Barrier Reef, Australia. I was interested to find out that there were comparisons between the fish fauna of the Barrier Reef area and those in Papua-New Guinea, but Mr Goldman said that exact comparisons could not be made unless one sampled the habitat quantitatively. However, he thought it possible that certain assumptions could be made from previous knowledge gained of fish species' distributions and of the behaviour of most reef fish.

Members of the expedition preparing to leave Kiriwina Island. [Photo: Author.]

Mr Goldman feels the theoretical work he is engaged in may have applications to possible coral reef fishery management at some later stage. He believes this branch of research is important, considering that, on many of the islands in Papua-New Guinea, the primary source of protein is the fish supply.

On Kuia, it was interesting to observe the social anthropology of an island group which makes little contact with Europeans, except occasional visits from patrol officers and visiting medical research teams and the rare appearance of a cruising yacht.

I acquired a magnificent flaked green granite axe, which had been used as barter in the Kula Trading Ring, made famous by the anthropologist Malinowski. This is basically a ceremonial exchange cycle of various items between the different islands, which the Trobriand Islanders take part in.

In one way I was reluctant to leave Kuia. However, we returned for a brief moment of luxury to Mr Wong's Hotel Trobriands on Kiriwina, and then flew to Port Moresby, the last leg of our scientific odyssey.

Fine collection of molluscs

There, in the capital and administrative centre of the Territory, Dr Ponder and Mr Colman, mollusc specialists, made a fine collection of molluscs, aided by the expert local knowledge of the president of the Port Moresby Malacological Society, Mr Alan Hinton.

Unfortunately the weather remained unstable right till the end of the expedition, making fish collection difficult.

Assessing the trip in retrospect, a fine collection was made and the effort appeared to be well worth the joint co-operation of the men from the British, American, and Australian museums.

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This Port Jackson Shark has just been tagged in one of the resting sites used by this species. [Photo: Author.]

Underwater Studies on the Port Jackson Shark

By A. K. O'GOWER
School of Zoology, University of New South Wales, Kensington, Sydney

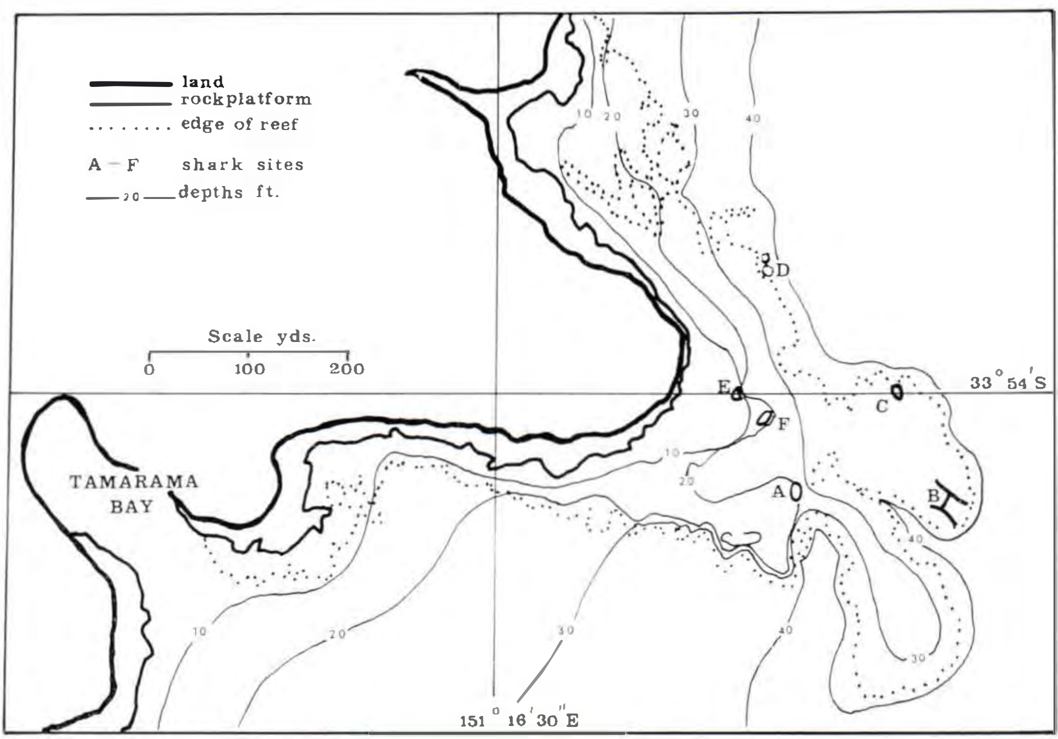
WE know that female Port Jackson Sharks (*Heterodontus portus jacksoni*) migrate from deeper waters to the shallow inshore reefs in the winter to deposit eggs at the mouths of estuaries, and then return to deeper waters in spring. We know they also migrate considerable distances along the coast. We know they frequent certain specific sites on the shallow inshore reefs, year after year, and can return to those exact sites if "transplanted". We know what they eat and when they eat it, and we know the specific requirements for oviposition. All of these data have been collected by donning scuba diving gear and observing the sharks in their natural environment.

Why study the Port Jackson Shark? Oceanic and deep-water sharks are usually inaccessible, and if accessible are not easily studied. Thus, all of our information of them has been obtained either from catch records or from observation of sharks in captivity. The shallow-water species are either large active predators or are in small numbers. The Port Jackson Shark, on the other hand, is small, harmless and of no commercial importance, and occurs in relatively large numbers on the inshore reefs at certain times of the year. This species therefore presents an ideal opportunity for studying a demersal shark in its natural environment.

An underwater survey and tagging programme was initiated in 1962, using collar tags applied to the caudal peduncle (just before the tail) of sharks in situ. One hundred and four surveys were made on a small sublittoral reef of approximately 40 acres at South Bondi, near Sydney, over a 3-year period. Regular visits to the reef were not always possible because of rough seas, and the surveys were finally abandoned because of the frequent extremely low visibility caused by the introduction of a new sewerage treatment plant at the North Bondi sewerage outfall. Despite these difficulties, the programme yielded extremely interesting data on the behaviour of the Port Jackson Shark.

Of all the 300-odd Port Jackson Sharks observed on the reef at South Bondi more than 98 per cent were found sheltering at one of six sites (A to F in map below). The numbers of sharks counted on the reef during any one survey ranged from nil to 28, while each of the sites A to F had counts ranging up to the respective maxima of 16, 15, 10, 13, 16, and 8. Consequently the potential "shelter accommodation" provided by the six sites always exceeded the maximum number of sharks observed on the reef at any one time. All of the six sites were caves or trenches and were characterized by their difficulty of access both from above and from the sides. Although the reef contained very many "potential resting sites of similar quality", very rarely were sharks observed resting elsewhere than at one of these six specific localities. Sequential observations, days and even years apart, on sharks resting at different sites on the reef, on sharks deliberately disturbed and followed from site to site to site, and the returns of "transplants" from distances of 2 kilometres (about 1¼ miles) within Sydney Harbour, all indicate that the Port Jackson Shark must remember the location of specific resting sites on different reefs.

The estimated number of sharks seen on the reef at South Bondi was 300, and of these 158 were tagged. Of the tagged sharks 69 were subsequently identified in resightings, and this number represents about half of the tagged population. The longest recorded interval between tagging and resighting was 3½ years, and, although the majority of resightings occurred within a month of tagging, most of the remainder were recovered after 4 or more months. Observations on the occurrence of tagged sharks at each of the



Location of resting sites of the Port Jackson Shark on the inshore reef at South Bondi, near Sydney. [Map by the author].

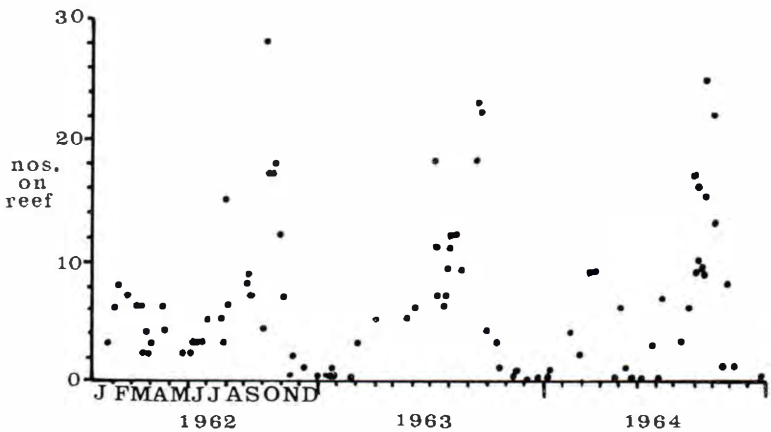
six resting sites indicated no individual preferences for specific sites on the reef. The reef may therefore be regarded as home territory for all members of this local population. However, there appeared to be a distinct movement of sharks into the cave at site E, both from other sites on the reef and from elsewhere, just prior to their spring migration.

Continuous observations on the South Bondi reef showed there was a consistent annual cycle of changes in density of sharks over the 3 years. Numbers were low from November to June, building up to a peak in July to August, declining but to build up to a second peak over September to October (chart below). There was obviously a strong correlation between high reef densities and the breeding season, while the decline in numbers of sharks between the bimodal peaks of high density was correlated with oviposition. That oviposition was occuring during this period was determined both by palpating resting females (for the spiral flanges of the eggs may be felt and even seen through the skin) and by examining oviposition sites for recently deposited eggs. The eggs of the Port Jackson Shark have a double spiral and were frequently found wedged between rocks on shallow reefs near the mouths of estuaries and harbours at depths of up to 5 metres (about 16½ feet). The location and orientation of the eggs within the cracks and crevices between rocks indicate an active placement by females, and, as female sharks have frequently been observed carrying eggs in their mouths, it is presumed that egg deposition is accomplished by oral manipulation of the extruded egg. The incubation period is from 9 to 12 months. From the available data it is proposed that the life-cycle of the Port Jackson Shark is as follows:

The Port Jackson Shark has a well-defined breeding season, which starts with the influx of mature females, accompanied by some males, on to inshore reefs in late July and early August. Mating probably occurs at this time. Breeding females shelter on these inshore reefs during the reproductive season, but most mature males remain in deeper water throughout this period. Females deposit from to 10 to 16 eggs, mainly in August and September, on shallow sheltered reefs in depths of a few metres, where they are anchored in rock fissures.

Young sharks emerge from the eggs after approximately 1 year and move into nearby nursery grounds in bays and estuaries. Some juveniles may migrate into deeper water, particularly during summer, but they tend to remain on the nursery grounds for several years in mixed groups of males and females. At the onset of sexual maturation juveniles move into deeper water and segregate into male and female groups to form a separate adolescent population. After several years of adolescence, these sharks join the adult population.

Adult males depart from inshore waters towards the end of the breeding season and probably move into deeper water. The breeding season ends with the departure of



Seasonal variations in densities of Port Jackson Sharks on the inshore reef at South Bondi. The letters indicate the months. [Chart by the author.]

Egg of a Port Jackson Shark. Note the spiral flanges, which serve as an anchor. The eggs must be "unscrewed" to free them from the oviposition sites in rock crevices. [Photo: Elizabeth Westcott.]

females from inshore reefs in late September or October. Some migrating adults may simply move offshore into deeper, cooler waters, but others migrate southwards along the coast. A post-migratory return to shallow reefs can occur as early as March or April, but sharks do not stay inshore at this time of the year and numbers remain low until the beginning of the breeding season.

Although only four sharks were resighted outside the Sydney area, this must be regarded as a reasonable proportion for distant recaptures, particularly as this species would only be caught accidentally by professional fishermen. The movement of these sharks, from Sydney to Newcastle and to Eden, indicates that a considerable latitudinal migration is involved, and, with a period of 223 days between tagging and recapture over a distance of 400 kilometres, the speed of migration must exceed 1·8 kilometres per day. It could be proposed, therefore, that the Port Jackson Shark can remember literally hundreds of resting sites along the coastline and can return to specific localities on small reefs, after absences which can be measured in months or years and distances which can be measured in hundreds of kilometres, with as great an accuracy as a salmon shows when returning to its native stream—but, unlike the salmon, the Port Jackson Shark can find many localities.

Not only is the Port Jackson Shark unusually morphologically and physiologically well-adapted to its habitat and niche, but its migratory and resting behaviour are well adapted against predation by large sharks, while it possesses a unique ability to remember and to find highly specific localities over large distances. All of these characteristics make this shark uniquely suited for further behaviour studies, particularly those associated with migration, navigation, and site recognition.

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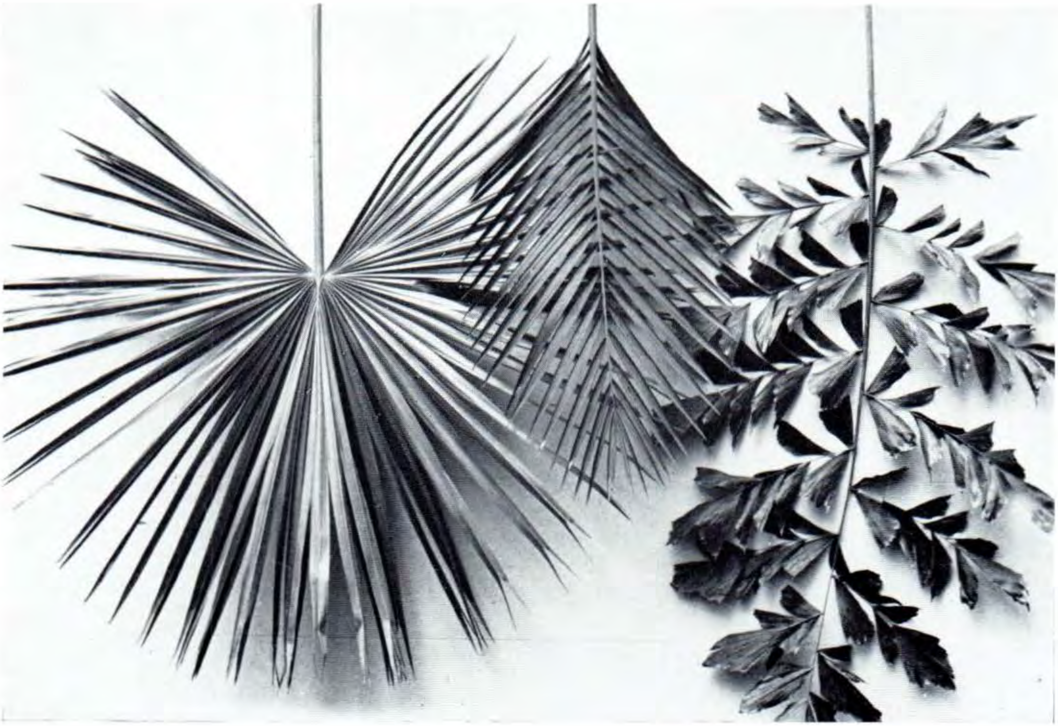
BOOK REVIEW

AUSTRALIAN DESERT LIFE, by Keith Davey; Periwinkle Colour Series, Lansdowne Press, Melbourne, 1970; 112 pages; $1.25.

About 70 per cent of the Australian continent is loosely classed as arid, yet Keith Davey's *Australian Desert Life* is the only popular book currently available which attempts to provide an introduction to the plant and animal life of this vast region. For this reason alone the book should be welcomed, especially by students, teachers, and visitors to our desert areas.

Although one sympathizes with the author in his efforts to fit so much information into so small a space, some of his generalizations are likely to prove misleading. There are many typographic errors and mis-spelt scientific names, while in some cases his common and associated scientific names refer to different species. Few of the illustrations are localized, thus reducing their impact and value as examples, while some are misidentified. Discussion of general desert ecology, including the effects of man and his introduced animals, is inadequate.

Despite these criticisms, all of which can be rectified in future editions, *Australian Desert Life* is very readable and fills a long-standing gap in Australian natural history publications.—*H. G. Cogger, Australian Museum.*



The three main types of palm leaves (from left): the fan-leaf of *Livistona australis*, the feather-leaf of *Laccospadix australasicus*, and the bipinnate leaf of *Caryota rumphiana*. [Photo: Author.]

AUSTRALIAN PALMS

By A. N. RODD
Botanist, National Herbarium of New South Wales,
Royal Botanic Gardens, Sydney

AUSTRALIA has little to boast about in its palms. Unlike some of our other plant groups, such as the eucalypts, banksias, and grass-trees, palms are not a unique feature of Australian vegetation: far from that being the case, the forty or so species of Australian palms are merely outlying representatives of a vast and highly diverse plant family centred in the tropics. The great majority of our palms belong to genera which have achieved greater diversification outside Australia than within it, and even the two or three endemic genera do not display any particularly striking adaptations which would distinguish them sharply from related non-endemics.

After such a deflating introduction, let us proceed to look at just what Australia has in the way of palms. But perhaps it would be wise to establish first just what constitutes a palm—to find out something about the structure of this remarkable group of plants and their position in the plant kingdom, also something of the classification of palms.

Distinguishing features

Palms are typically tall-growing plants with straight, unbranched, apparently woody stems. The stem terminates in a crown of massive leaves, each leaf consisting of a long, stiff stalk or mid-rib to which are attached many narrow segments, or leaflets, usually rather parchment-like in texture, and invariably folded into a V where they join the mid-rib. These leaflets may be arranged in two rows along either side of the mid-rib, making a leaf shaped like a bird's feather, or they may all arise from the apex of the leaf-stalk, the leaf thus being shaped more like a fan. We shall distinguish palms showing these different arrangements as "feather-leaved" and "fan-leaved" palms.

The flowers of palms are borne in considerable numbers on large, usually much-branched inflorescences. Inflorescences may emerge from the stem below the leaves, or among the leaves, or in some groups of palms they may appear at the very apex of the stem, terminating its growth. The whole inflorescence, and often its individual branches also, is sheathed in the bud stage by large bracts sometimes known as "spathes".

The palm flower in its primitive form has three sepals, three petals, six or more stamens and a three-celled ovary, each cell containing one ovule. However, evolution has given rise to numerous variations on this basic pattern, mainly involving reduction in number, or suppression, of parts of the flower. In many cases the organs of the two sexes, i.e., the stamens and the ovaries, are on separate plants, or on separate flowers on the one plant, rather than both in the one flower. The fruits of the majority of palms have only a single seed, even though in many of these the ovary has three ovules; usually two of the three fail to develop into seeds.

Position in the plant kingdom

Palms are flowering plants belonging to the subclass Monocotyledoneae, or Monocots for short. This is one of the two great subdivisions of flowering plants, containing also the grasses, sedges, lilies, and orchids (to name just a few of the most important Monocot groups). Palms comprise the family Palmae (alternatively called Arecaceae), which is the only family of the order traditionally called Principes ("princes" among plants). Their affinities among the Monocots are believed to be with the order Arales, comprising the large and chiefly tropical Arum family (Araceae) and the humble duckweeds (Lemnaceae), and possibly also with the order Pandanales, comprising the pandanuses or screw-pines. The Palmae consist of about 2,600 known species, divided among about 230 genera. They are found only between the latitudes 44° N. and 44° S., but as a group they are overwhelmingly tropical. The temperate palms, apart from being few in numbers of species, show a very limited representation of the richness and diversity of tropical palm life.

Structure of stem

Palms include among their ranks the largest known Monocots. The Andean Wax Palm reaches almost 200 feet in height, and a quite average-sized palm would be larger than almost any other Monocot. Now the structural elements in Monocots have evolved along quite different lines to those of the Dicots (the Dicotyledoneae comprise the other great subdivision of the flowering plants and include most of the trees and shrubs we are familiar with); consequently, palms have not been able to employ the excellent mechanical properties of that homogeneously dense and rigid honeycomb of thickened cell walls called *wood*, which forms the bulk of the trunk in Dicot trees (and also in conifers) and which has the added property of increasing in cross-section by addition of layers to the outside of the trunk as the tree grows taller. Monocots appear never to have evolved the ability to produce wood. Instead, their stems consist of numerous fine strands of conducting and supporting tissue embedded in a matrix of spongy ground tissue, the whole arrangement being laid down by the growing apex of the plant with no later increase in bulk of structural tissues. In most tall palms this type of structure has been carried to a high degree of refinement, the fibrous supporting tissues forming a dense array of steely-hard, cable-like strands, concentrated particularly toward the outer periphery of the stem cylinder. In structural concept there is a great similarity between a palm stem and a pre-stressed, steel-reinforced concrete pillar!

Classification of palms

Apart from species and genera, the palm family can be divided into a number of readily recognizable subfamilies. Space does not allow me fully to enumerate these, but

An arecoid palm, *Rhopalostylis baueri*, endemic to Norfolk Island, showing the "crownshaft" of sheathing leaf bases and the encircling scars they leave on the stem when the leaf falls. Flowering and fruiting inflorescences are present, as also is the large bract, or "spathe", which encloses the former when in bud. [Photo: Author.]

there is one convenient generalization which can be made for Australian palms—viz., most feather-leaved palms belong to the subfamily Arecoideae (arecoid palms), while virtually all those with fan-leaves belong to the subfamily Coryphoideae (coryphoid palms).

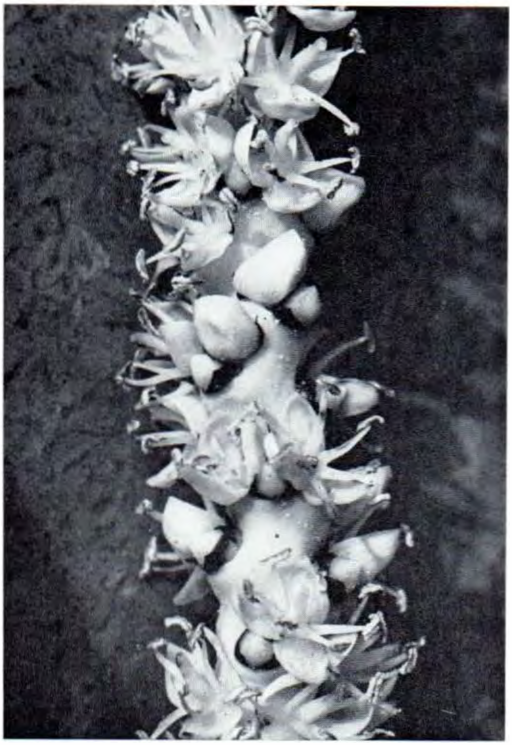
Other features of palm classification will be discussed in the enumeration of Australian palm genera which follows:

Subfamily Arecoideae

This is the largest subfamily of the Palmae and the most important in Australia, at least in numbers of genera and species. Arecoid palms, as mentioned above, are all feather-leaved; they are also characterized by their slender, smooth stems, which in some species branch at ground level to form clusters and in many genera are topped by what is known as a *crownshaft* of tightly-furled sheathing leaf-bases. The leaflets are invariably *reduplicate*, i.e., folded into an inverted V where they join onto the mid-rib. The inflorescence may be compound with numerous branches (e.g., *Archontophoenix*) or it may be reduced to a single unbranched spike (e.g., *Linospadix*, *Laccospadix*). The only noticeable sheathing bracts are those enclosing the whole inflorescence in bud, there being none sheathing individual branches.

The Australian arecoid genera are:

Archontophoenix.—This genus is endemic to the east coast of Australia. These are tall, graceful palms, common in sheltered gullies and on riverbanks of the coastal plain and foothills, often in slightly swampy situations. Of the two species recognized, the more southern one, *A. cunninghamii*, occurs as far south as the vicinity of Bateman's Bay, 160 miles south of Sydney; this is the Bangalow Palm of New South Wales, or Piccabeen



Part of a *Rhopalostylis* inflorescence. Each small flower has three sepals (dark in the photo), three fleshy boat-shaped petals, six stamens, and a cylindrical fleshy ovary. [Photo: Author.]

Palm of south Queensland. The other species, *A. alexandrae*, occurs in north Queensland only. It is extremely abundant on the narrow coastal plain between Townsville and Cairns.

Areca.—There is only one Australian species of this genus—*A. alicae*, occurring in the Atherton Tableland foothills: the genus is moderately large, with species in southeast Asia, the Malaysian region, and New Guinea. One of these, *A. catechu*, is famous as the source of betel nuts, widely used as an expectorant and mild narcotic in tropical Asia.

Carpentaria.—An endemic genus, as understood at present. The only species, *C. accuminata*, was described from poor specimens collected on the shores of the gulf whose name it bears. Closer study of better material may show it to belong to another genus.

Gulubia.—One species, *G. costata*, from Cape York, of this genus, which also has species in Indonesia, the Philippines, and New Guinea. There has been some dispute as to whether our species should more correctly be placed in *Hydriastele.*

Hydriastele.—Two species from lowland north Queensland or possibly just one variable species. There are others in New Guinea.

Kentia.—A single species, *K. ramsayi*, of this otherwise New Guinea genus is known from Arnhem Land, where it grows on rocky sandstone hills.

Laccospadix.—A genus with one species in northeastern Australia and one in New Guinea. *L. australasicus* is an attractive small palm of clustering habit found in rainforest undergrowth at altitudes of 2,000–4,000 feet on the Atherton Tableland.

Linospadix.—A genus of about seven species of dwarf rainforest palms from eastern Australia, and at least another five from New Guinea. All except one of our species are confined to north Queensland, where they are a common feature of the shrub layer of the "scrubs" in the highest rainfall areas. The exception is the Walking-stick Palm (*L. monostachyus*), which inhabits rainforests as far south as the Taree district in N.S.W. *Linospadix* species have very slender stems, hardly thicker than a pencil in some species, and clustering in most. The small leaves have very few leaflets, and the unbranched, arching inflorescences can be strikingly beautiful in fruit, with their chains of brilliant coral-red drupes.

Normanbya.—An endemic genus of a single species, *N. normanbyi*, occurring only in lowland rainforest north of the Dainstree River in north Queensland. A tall, very handsome palm with broad, jagged-tipped leaflets and large, dull-crimson fruits.

Orania.—A genus widespread in the Malaysian region, represented in Australia by one species, *O. appendiculata*, of northeast Queensland. A stout-trunked palm with long, heavy leaves, it occurs at medium altitudes in rainforest, mainly in openings where light can penetrate.

Ptychosperma.—A fairly large genus occurring mainly in the New Guinea-Solomon Islands region, with two or possibly three species in Australia. One is found near Darwin; the other one (or perhaps two: our present knowledge of these, as of most native palms, is too fragmentary to permit of informed decision) on rainforest margins from Cape York to near Rockhampton. They are medium to smallish-sized palms with leaves of rather few leaflets.

Subfamily Coryphoideae

The coryphoid palms are represented in Australia by three genera only, but one of these, *Livistona*, probably accounts for the majority of palm trees on the continent. As already noted, coryphoid palms are fan-leaved, the leaf-stalks are often spined or toothed along their margins, and the folding of the leaf segments is always *induplicate* (i.e., they form an upright V in section). Trunks are more rough-textured than those of arecoids and show a tendency to retain the old dead leaf-bases. The inflorescences are long and much-branched, usually with conspicuous sheathing bracts around the branches as well as the main axis.

The Australian coryphoid genera are:

Corypha.—A genus of six to eight species of massive palms, distributed through India, southeast Asia, and the Malay Archipelago. They are remarkable for their gigantic terminal inflorescences, the appearance of which heralds the death of the palm. *C. elata*, known mainly from the drier parts of Malaya, Indonesia, and the Philippines, is recorded from two or three localities in Arnhem Land and the Gulf country of Queensland. It inhabits savannah country, usually along river banks, and may possibly have been introduced to Australia by pre-European Malay traders.

Licuala.—A large Asian and Malaysian genus with one species, *L. muelleri*, native to north Queensland between Townsville and Cape York. This is a most striking and beautiful palm, as its large fan-leaves are almost perfectly circular in outline and divided into only a few segments of varying width. It inhabits swampy coastal lowlands, often forming pure dense stands.

Livistona.—Another large genus with an overall distribution very similar to that of *Licuala*, it has evolved a greater number of species in Australia than any other genus of palms, the number generally being estimated at about eleven. They are palms of varying stature, though all have leaves deeply divided into fairly narrow segments. The species best known to most Australians is *L. australis* which is the familiar Cabbage Palm of the N.S.W. coast. There are some fine stands of this palm very close to Sydney, for example at Bilgola and Mona Vale, and Palm Beach presumably derives its name from the occurrence of it there. Its natural range is from south Queensland to far-eastern Victoria, thus making it the southernmost of all Australian palm species.

Another well known *Livistona* is *L. mariae*, the palm for which Palm Valley, in the Macdonnell Ranges of Central Australia, is famous. The few known occurrences of this distinctive species in these oasis valleys can only be taken as evidence of a wider distribution in former times, and thus, presumably, of a wetter climate over the whole region. Another *Livistona* species has a similar isolated occurrence in the Carnarvon Ranges of inland Queensland.

Other *Livistonas* are found right around the northern half of Australia's coastline, from the Hamersley Ranges in Western Australia to the central Queensland coast. The traveller to Darwin by road will see thousands of plants of the small *L. humilis*, the most widespread and numerous species, once he gets north of about Katherine. One species, collected by Robert Brown (the eminent botanist who accompanied Flinders on his circumnavigation of Australia) on one of the islands of the Gulf of Carpentaria, has not been found since by botanists!

Palms of other subfamilies

Calamus.—A very large Old World genus of climbing palms, or "rattans", *Calamus* belongs to the subfamily Lepidocaryoideae, distinguished by fruits covered in tightly appressed scales, like lizard skin. This genus is represented in Australia by at least four species in north Queensland and one, *C. muelleri*, in south Queensland and N.S.W. In this country they are known as Lawyer Vines, presumably on the analogy expressed by: "once let yourself into their clutches and you'll never get out". Although this may be a baseless slander of the legal

Livistona loriphylla, on limestone outcrops above Katherine Gorge, Northern Territory. This distinctive species has leaves divided virtually to the base, and it is perhaps the only *Livistona* which branches into several trunks. [Photo: R. G. Coveny.]

profession, it certainly describes well the plight of anyone who becomes tangled with the long, barbed appendages of *Calamus* leaves: each movement causes the clothes or skin to engage with further needle-sharp hooks, and finally the victim may be able to free himself only by forcefully tearing them out of his flesh and clothes!

Lawyer Vines are mostly dwellers of dense rainforest, in which they get sufficient light to grow by climbing into the crowns of tall trees. Other, self-supporting, palms are unable to compete in such situations, as they cannot grow tall enough or rapidly enough to get up into the forest canopy. The hooked appendages mentioned above are not adaptations for catching humans or other animals, but rather the means by which the palm climbs, catching onto leaves, twigs or branches of surrounding trees.

Caryota and *Arenga*.—These genera, each represented in north Queensland by a single non-endemic species, are members of the small subfamily Caryotoideae. This subfamily is characterized by its remarkable mode of flower production, by its three-seeded juicy fruits containing irritant crystals, and by the unusual structure of the leaves. *Caryota* is further remarkable in that it is the only genus of palms with bipinnate leaves, i.e., the leaflets are themselves divided into leaflets. These ultimate leaflets have a characteristic triangular shape, from which palms of this genus get the name Fishtail Palms. Both *Caryota* and *Arenga* are genera of a few species, and have similar distributions in southeast Asia and the Malaysian region.

Nypa.—This tropical Asian mangrove palm occurs in Australia only in the northern half of Cape York Peninsula, and has thus been encountered by very few Australians. With only a single species, *N. fruticans*, the genus differs so much from all other palms that some botanists prefer to exclude it from the family Palmae altogether. At present it is known only from equatorial regions of Asia and Australasia, but numerous finds of fossil seeds show it to have existed in virtually identical form in northern Europe in the early Tertiary period, about 60 million years ago!

It is a massive, almost trunkless, feather-leaved palm, the leaves standing almost vertical and up to 25 feet long. It forms pure stands on the tidal mud-flats of brackish estuaries. The fruits are borne in large globular heads, more like the fruit-clusters of pandanuses than of other palms.

Borassus, *Cocos*.—These genera, belonging to the subfamilies Borassoideae and Cocoideae respectively, are known to occur in a semi-wild state in northern Australia, but are probably not truly native. *Borassus flabellifer*, the Palmyra Palm of India, is a large fan-leaved palm of which the sugary sap is fermented to make palm toddy. *Cocos nucifera* is the familiar coconut palm of travel posters (usually atrociously drawn!). Its original home is believed to have been somewhere among the Indian Ocean islands, though nearly all other cocoid palms are South or Central American.

From this brief enumeration of Australian palm genera, one fact becomes apparent, namely, that our knowledge of our native palms is abysmally poor. Soundly based decisions about the correct status of most species and many of the genera cannot be made unless we undertake detailed fieldwork to determine patterns of variation within and between populations. A much better knowledge of related palms in New Guinea and Indonesia is also essential.

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BIOGEOCHEMICAL CYCLES AND MAN

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

THAT change pervades life and environment and the relationships between them was instinctively grasped by early man. Indeed, the endless succession of days and nights, the waxing and waning of the moon, and the birth, life, death, and renewal of the seasons are the milieu in which he evolved from his earliest beginnings. Primitive man strained his eyes and imagination in order to perceive some predictive elements in this never ending flux of events. The astrologers rightly guessed the impact of the solar system upon their well-being but, not confining themselves to physical reality, were swept off into the realm of omens and prognostications. The mythology of Greece and Rome was a personification of ever-changing forces influencing man's fate and, therefore, in need of being ordered. Many centuries have passed since these early beginnings, but it is still fundamental to the pursuit of science that things will occur again as they have in the past.

Regularly recurring sequences of events, or cycles, as they are termed, are really the dynamic aspect of the order we perceive in a crystal. They represent an ordering in time as contrasted to a static spatial ordering. It is noteworthy that this regular change in time is not always readily apparent to man. Where the rate of change is slow and the time necessary for completion of a cycle long relative to man's life-span, the cycle may go undetected. The same may be true if a cycle initiates and completes itself over large distances. Thus, it was not until the nineteenth century that the dynamic foundation to geological thinking was laid. Prior to that time mountains and valleys were perceived as having been sculpted in the distant past to remain unchanged up to the present. Only with great difficulty did man make the conceptual leap to the grandeur of uplifted mountains, erosion, deposition, burial, and again uplift in steady, if imperceptibly slow, procession.

With the advent of life on this earth and its slow struggle upward through geological time, still other cycles were initiated and

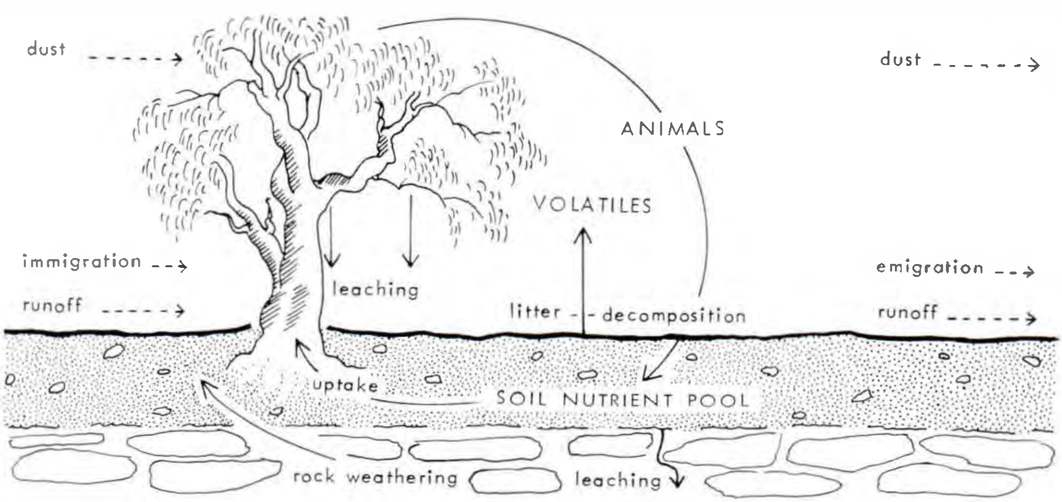

Diagram I: The nutrient cycle. [Drawn by Janet Boddy.]

modified in the never-ending process of mutual adjustment between life and environment. It is hardly surprising that these cycles most deeply involve those elements and substances life is fundamentally dependent upon. They are often referred to as biogeochemical cycles stressing the interaction of the living and non-living components of the biosphere. More dramatically, but hardly less truthfully, they have been termed life support systems.

Importance of understanding cycles

While it is sometimes debated whether or not man has conquered nature, it is not questioned that he is by far the dominant form of life and that he is having a profound and often detrimental influence upon his environment. It is suggested here that many of man's so-called environmental degradation problems may be traced to accidental interference with the biogeochemical cycles which function in the thin life-supporting film of air, water, and land at the surface of the earth. If we are to persist here on this earth, it is imperative that we come to understand and respect the functioning of these cycles.

There are very few places on the surface of the earth that do not, or did not at one time, support a community of plant and animal life. As diverse as these communities are in their overall appearance or in the kinds of organisms making them up, they are basically similar in the way they obtain, use, and reuse the chemical nutrient elements. Ninety-five per cent of the mass of all protoplasm is made up of oxygen, carbon, hydrogen, nitrogen, and phosphorus. As shown in diagram I, the soil represents a reserve pool of these and other essential elements subject to losses through leaching and additions through rock weathering. From this pool plants draw up the nutrients they need and, with the energy of incoming solar radiation, incorporate them into living protoplasm through the processes of photosynthesis and respiration. Where vegetation is persistent it represents a second nutrient pool from which elements are returned to the soil surface via rainwater leaching and leaves and other litter. Animals are also a part of the cycle, for they depend upon the plants for compounds they cannot synthesize themselves. The litter that has fallen to the forest floor, and ultimately the animal life, decomposes and returns the original elements to the soil pool, thus completing the cycle.

The cycle shown in the diagram is nearly closed. That is, there is a finite and nearly constant amount of material being circulated between the soil and vegetation pools. Admittedly, there are additions and losses in dust and erosion runoff. Animals enter and leave the area no matter how carefully it is delineated, but it is a good assumption that these changes tend to cancel themselves out in the undisturbed community.

Man simplifies nature

Generally speaking, man simplifies nature in order to increase its output of things he needs or deems of value. The large areas of tropical rainforest in the equatorial regions of the world provide an excellent example of this. For many years man has been deeply impressed with the luxuriance of this type of vegetation and surmised that the soil which could grow such a profusion of different plants would be excellent for his crops. In fact, we now know that the majority of nutrients in tropical forests are contained in the vegetation rather than the soil, which is rather poor in nutrients. Also, it is known that the system is a very dynamic one. Decomposition proceeds rapidly at the high temperatures of the tropics and nutrients are taken up again quickly by the continually growing vegetation. When man clears the natural vegetation for agriculture, as is being done with thousands of acres today, it can readily be seen that he removes most of the system's nutrient capital and completely stops its functioning (see photo). As G. Milne, soil scientist working in Africa, so aptly put it: "The entire mobile stocks are put into liquidation and, as is usual at a forced sale, they go at give-away prices and the advantage reaped is nothing like commensurate with their value". Burning is the commonly practised means of clearing and when this is complete all of the elements except nitrogen (escaping as a gas) are present in the ash on the ground surface. The heavy tropical rains take their toll. With no uptake to balance the inevitable downward trend of leaching, nutrients are soon moved out of reach of the roots of any plants beginning their growth. Two or at the very best three

The clearing of tropical rainforest for agriculture in the lowlands of Costa Rica, Central America. [Photo: Carol Anne Clark.]

crops are all that can be expected from this soil which once sustained tons of living matter.

Hydrologic cycle

In order to follow the nutrients lost to the immediate system a second cycle, much larger and less well defined, must be considered. While we have not made a special effort to discuss energy, we have seen the fundamental importance of the sun's radiation for the synthesis of living material in plants. This energy also drives the earth's atmospheric circulation patterns which distribute water, a second basic requirement of life. The rate of rain falling on the land surface is a varied one (diagram 2). That which strikes the vegetation cover may be evaporated off leaf surfaces immediately. Water reaching the ground percolates into the soil or, if falling faster than the capacity of the soil to absorb it, runs off into rills and drainage channels of ever-increasing size until ultimately the ocean is reached. Plants take up water from the soil and, in the process of transpiration, evaporate it back into the atmosphere at the leaf surfaces. Water which the soil cannot hold travels downward to the water table and from there eventually finds its way into the ocean, where large-scale evaporation replenishes atmospheric moisture.

Man has probably had little detrimental effect on this so-called hydrologic cycle on a world-wide scale. Contrary to popular belief, clearing or revegetating an area does not measurably affect its climate. It has been suggested that the cooling trend in the world's temperature since 1940 (which means less energy to drive atmospheric circulation) may be due to increasing air pollution. It remains to be demonstrated if this is in fact the case and if the cooling trend is a significant departure from normal long-term fluctuations.

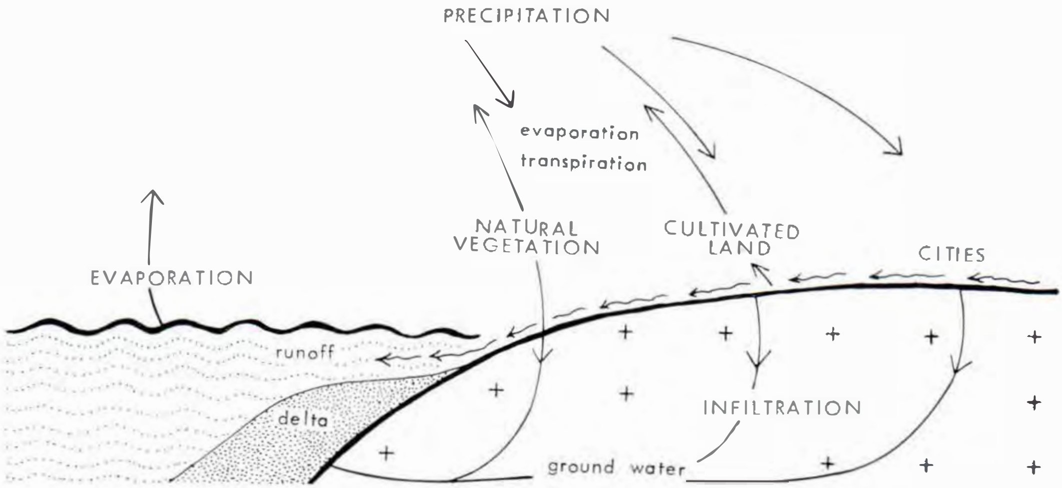

Diagram 2: The hydrologic cycle. [Drawn by Janet Boddy.]

On the other hand, particulate matter in the air above cities and convection currents arising from city heat sources have measurably increased precipitation in their vicinity.

By contrast man has considerably affected the hydrologic cycle locally. It is estimated that on an average 30 inches of rain fall in the United States yearly. Of this $21\frac{1}{2}$ are returned to the atmosphere directly in transpiration and evaporation. The remaining $8\frac{1}{2}$ inches go into runoff and underground flow. The effect of vegetation on these fractions is very marked. In addition to its interception and transpiration functions it also acts to increase soil permeability and surface irregularities reducing runoff. In experimental watersheds in the United States removal of vegetation has increased runoff by 65 per cent in the first year. When such areas are reforested, peak flood flows are reduced by as much as 90 per cent. Thus man's treatment of the vegetation of an area obviously greatly affects the amount of water that can be husbanded for a multitude of uses, if not the total amount which actually falls.

Not only has man been ingenious in reducing the amount of water available to him, but he has also been able to render large amounts of available water unusable by polluting with a wide range of chemicals used in agriculture, with by-products of industrial processes, and with residential sewage. Man uses and reuses runoff many times before it reaches the oceans. Until recently, with small-scale industry and scattered population, he relied upon his neighbour upstream to return the water used in a form the stream could purify before it reached him further down. Now the volumes and kinds of waste added to our rivers are beyond their capacity to purify, and adequate supplies of pure water are a serious problem.

To return for a moment to nutrient cycles, increased runoff often results in severe erosion and removal of valuable nutrients from the surface in addition to those leached downward. These nutrients are carried along with the water in its cycle until a reduction in current velocity causes their deposition, usually at the mouths of rivers. The deltas of all the major river systems of the world contain millions of tons of elements essential to life, elements badly needed to grow food for a burgeoning world population.

DDT concentration

Man's lack of understanding of biogeochemical cycles has resulted not only in their destruction and malfunction but also in their following their normal pattern to his detriment. To take a single example, it is now known that the extensively used pesticide DDT is not only passed along from level to level in the food web of the living community, but also becomes successively more concentrated. G. M. Woodwell, ecologist at the Brookhaven National Laboratory, New York, and his co-workers, studied this phenomenon in a salt marsh near Long Island that had been sprayed with DDT for 20 years to control mosquitoes. They discovered that the salt marsh sediments contained, in addition to the normal nutrients taken up by plants, 32 pounds per acre of DDT. The plankton at the base of the food chain contained 0·04 parts per million of the chemical, and this increased to 1·0 p.p.m. in the minnows feeding upon them and to 75 p.p.m. in fish-eating birds, a final concentration of over 1,000-fold. While such concentrations may not be lethal, they are known to be harmful to animal populations, including, potentially at least, man himself.

Oxygen supplies

The atmosphere in constant movement over the earth's surface, and the oceans as well, contain both oxygen and carbon dioxide; however, this was not always the case. The fossil fuels deposited as plant remains in earlier geological periods represent unoxidized products of photosynthesis. As such they have contributed to a net gain in the oxygen of the atmosphere and oceans. If total reserves of fossil fuels are estimated and back calculation is made to the amount of oxygen produced, the value determined is more than sufficient to account for the oxygen present in air and water today.

Oxygen is produced by the photosynthetic activity of the plant life both in the oceans and on land. From both sources it enters the atmosphere and from there is taken up in respiration, decay, and combustion of fossil fuels. The carbon dioxide released in these activities is returned to the atmosphere for use by plants. There is an elegant simplicity about the complementary activity of plants and animals in exchanging carbon dioxide and oxygen, but the simplicity of this cycle does not ensure its stability. It has been determined, for example, that due to widespread clearing of land and combustion of fossil fuels today's oxygen consumption exceeds the amount supplied by terrestrial vegetation. The difference is made up by the world's oceans, which means we are dependent upon them in a way not often realized. If, in fact, the oxygen reservoir of the oceans and atmosphere is due to noncombusted fossil fuels of the earth's crust, then it is academic to concern ourselves with the exhaustion of coal, gas, and oil reserves. Long before their depletion is complete our atmosphere will no longer support life.

There is still, of course, sufficient oxygen in the atmosphere for us to breathe (in most places! Shops in Tokyo have vending machines which dispense it.). But, as with water, man has added to it in ways making it detrimental to his health and longevity. Automobiles and industry pour tons of particulate matter, carbon monoxide, nitrogen oxides, sulphur oxides, and hydrocarbons into the air above cities. In these areas a higher-than-normal death toll is usually correlated with days of abnormally high pollution levels and the incidence of respiratory diseases is significantly higher.

Rubbish problem

True to the precedent set by earlier forms of life, man has been instrumental in creating a new form of cycle, albeit an incomplete one at present. The solid wastes of our technological age are accumulating at a rate that has urban man seriously wondering where on earth he is going to put them. In the United States alone he finds himself at the end of each year with 350 million tons of residential and industrial rubbish and sewage. Added to this are agricultural and mining refuse reckoned in billions of tons, and 15 million tons of scrap automobiles. Disposal areas are now filled with deposits of geological magnitude, and the supply of suitable sites is nearly exhausted. It is apparent that somehow a way must be found to complete this cycle by reducing the products synthesized back into basic elements suitable for reuse. The atomic fusion reaction now in an experimental stage provides the greatest hope of achieving this end. If control of the reaction is achieved, it could be used to process tremendous volumes of all types of solid waste, vaporizing and ionizing them to make recovery of constituent elements for reutilization possible.

The fusion reaction provides an excellent example of the type of innovative and understanding approach man must make toward the dynamic environment discussed here. It would close the cycle man has initiated without producing harmful radioactive by-products which could enter biogeochemical cycles. Its fuel, deuterium, unlike coal and oil, is unlimited. The far-reaching importance of this possibility could only be grasped in our increasingly more finite world in which cycles of use and reuse are ever tightening. In the future, for whatever we use, synthesize, or manufacture we must ask: how and by what pathways will this return to the form with which we began? What mischief or good is it likely to do along the way?

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MEET OUR CONTRIBUTORS . . .

ALAN BATEMAN is a Principal Research Scientist in the CSIRO, and is Officer-in-Charge of the Fruit Fly Ecology section of the CSIRO's Division of Entomology. He graduated B.Sc. with First Class Honours in Zoology, and later Ph.D., from the University of Sydney. He joined the CSIRO in 1957, but remained at the Zoology Department at the University of Sydney as a member of the Joint CSIRO-University Unit of Animal Ecology, with Professor L. C. Birch. He initiated the Division's experiment station at Wilton, New South Wales, in 1960, and has been involved in field and laboratory studies of the ecology of fruit flies since that time, except for a stay of about 15 months in England, mainly at the Imperial College, University of London.

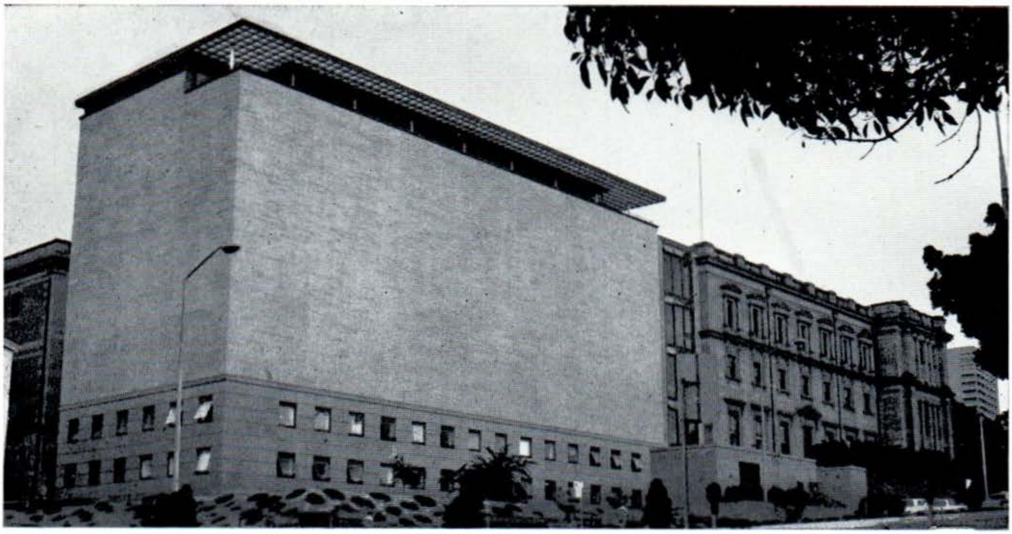
STEPHEN S. CLARK, Assistant Curator in the Australian Museum's Department of Environmental Studies, came to the Museum from the United States, where he received a B.A. in geology from Harvard University and an M.Sc. in Resource Planning and Conservation from the University of Michigan. While an undergraduate, he spent summers in the field in Montana, Maine, and Greenland. Since beginning a graduate programme at Michigan in 1965 he has concentrated on course work in ecology, including 7 months of field study and research with the Organization for Tropical Studies in Costa Rica. His interests include eco-system function and the relation of man to his environment.

EILEEN FINCH is a Lecturer in Zoology at the University of Western Australia, Perth. She was educated in Cornwall, England, and gained matriculation to London University at the age of 14. She came to Western Australia with her family when her father, a mining engineer, accepted a position on the goldfields. Mrs Finch graduated B.Sc. from the University of Western Australia with a zoology major. She worked on anuran systematics for her M.Sc. She has been Chief Examiner in School Leaving Biology for several years.

A. K. O'GOWER, of the School of Zoology, University of New South Wales, is particularly interested in the ecology of littoral and benthic molluscs, but while supervising Dr R. H. MacLaughlin's research on the ecology of the Port Jackson Shark, he has also become interested in sharks and is currently searching for blood enzyme polymorphisms in this shark. The underwater studies reported in this issue were made jointly by Dr MacLaughlin and Professor O'Gower in front of the latter's home at Tamarama Bay, near Sydney. Professor O'Gower is at present Acting Head of the School of Zoology, University of N.S.W. Dr MacLaughlin was formerly Lecturer at that School, and is now in the Department of Biological Sciences, Sir George Williams University, Montreal, Canada.

A. N. RODD was recently appointed as a botanist at the National Herbarium of New South Wales, where he formerly held the position of Botanical Assistant for 6 years. He is a graduate of Sydney University. His work involves identification of cultivated ornamental plants and research into their nomenclature, and this has led to him developing a strong interest in the systematics and geography of flowering plants on a world-wide basis.

STEPHEN ROOKE completed his secondary education in New South Wales, and then studied singing and music at the Sydney Conservatorium of Music. After working in theatre as a writer and director, he became a journalist and broadcaster, with interests ranging from music, theatre, and travel to marine history, archaeology, and underwater photography. He has also written for radio and television. At present he is working on a book about Australian shipwrecks.



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6–8 College Street, Sydney, N.S.W. 2000; telephone, 26 6954; P.O. Box A285, Sydney South, N.S.W. 2000; telegraphic address: Museum

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D. J. G. GRIFFIN, M.Sc., Ph.D., Curator of Crustaceans and Coelenterates.
D. HOESE, B.Sc., Assistant Curator of Fishes.
PATRICIA A. HUTCHINGS, B.Sc., Ph.D., Assistant Curator of Marine Invertebrates.
D. K. McALPINE, M.Sc., Ph.D., D.I.C., F.R.E.S., Assistant Curator of Insects and Arachnids.
B. J. MARLOW, B.Sc., Curator of Mammals.
D. R. MOORE, M.A., Dip.Anthrop., Curator of Anthropology.
J. R. PAXTON, M.Sc., Ph.D., Curator of Fishes.
W. F. PONDER, M.Sc., Ph.D., Curator of Molluscs.
ELIZABETH C. POPE, M.Sc., Curator of Worms and Echinoderms.
H. F. RECHER, Ph.D., Curator, Department of Environmental Studies
A. RITCHIE, Ph.D., Curator of Fossils.
C. N. SMITHERS, M.Sc., Ph.D., Curator of Insects and Arachnids.
Vacant: Assistant Curatorship of Anthropology.

EDUCATION OFFICER:
PATRICIA M. McDONALD, B.Sc., M.Ed.

V. C. N. BLIGHT, GOVERNMENT PRINTER, SYDNEY