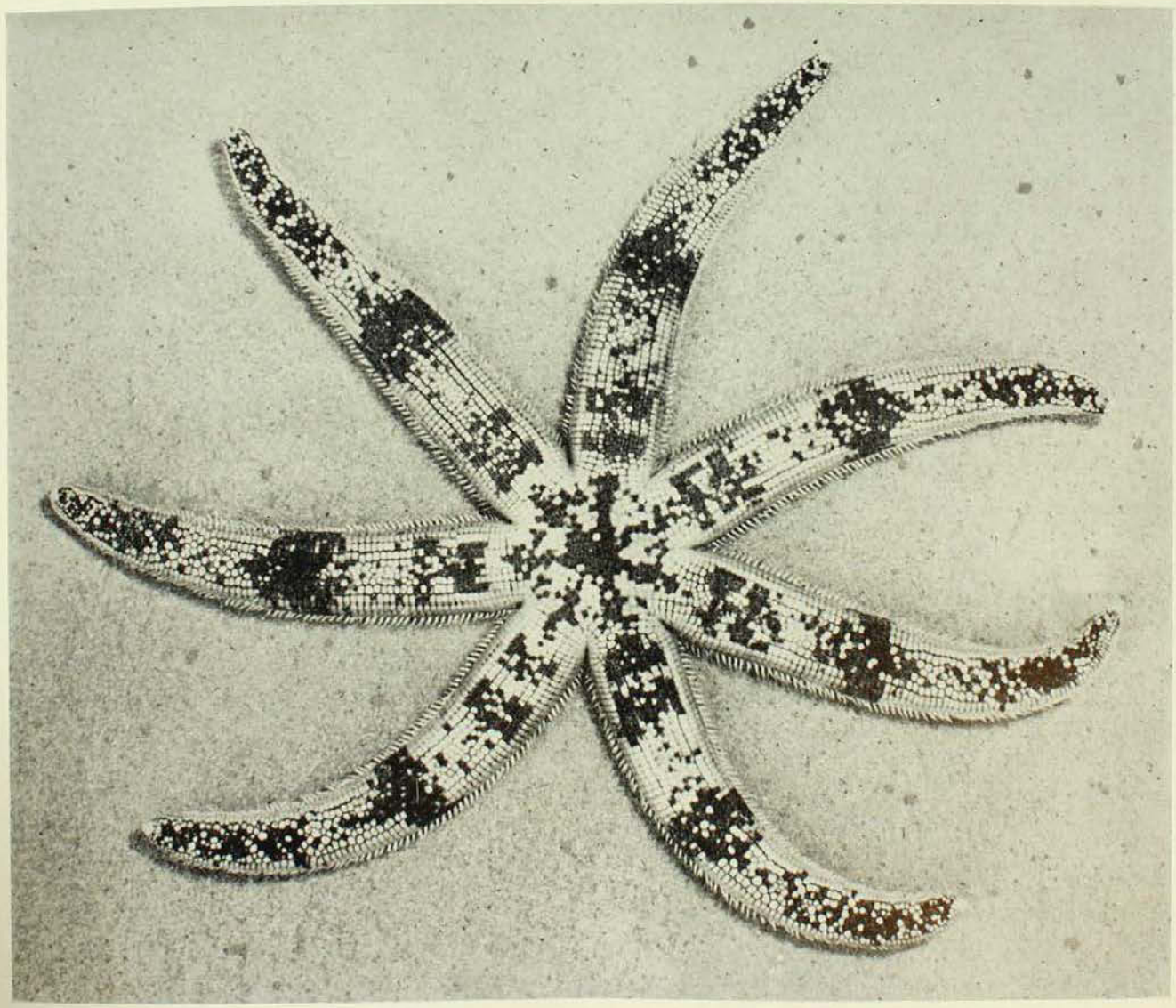
SEPTEMBER 15, 1960

The AUSTRALIAN MUSEUM MAGAZINE

VOL. XIII, No. 7

Price—TWO SHILLINGS



The spectacular sea star *Luidia australiae*, which is found on the bed of the lagoon on Lord Howe Island. It is straw-yellow in colour, with dark greenish-black markings. **(See article, "The Natural History of Lord Howe Island", on page 207.)**

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CONTENTS

• The photo of the Lord Howe Island sea star *Luidia australiae* on our front cover was taken by the Museum's photographer and visual aids officer, Howard Hughes. Sea stars of this species usually fragment when handled, but this specimen (shown about half its natural size) survived preservation.

VOLUME XIII, NUMBER 7 SEPTEMBER 15, 1960

THE AUSTRALIAN MUSEUM MAGAZINE

Published Quarterly by the Australian Museum - - - College Street, Sydney

Editor: J. W. Evans, Sc.D. Annual Subscription, Posted, 10/-

VOL. XIII, No. 7 SEPTEMBER 15, 1960

The Natural History of Lord Howe Island

By ELIZABETH C. POPE

UNTIL 1788, when it was accidentally discovered by Lieutenant Lidgbird Ball on his way from Port Jackson (Sydney) to Norfolk Island, Lord Howe Island was unaffected by man. No inhabitants were seen there then, and no traces have ever been found of the island's occupation by any native Pacific race.

Those first visitors described the island as being a paradise of birds so fearless that they came right up to the sailors and could be knocked over with a stick or caught by hand. There were no indigenous mammals, other than bats, but turtles and fish were to be had for the catching. The island was covered with dense vegetation, and "coconuts and cabbages" were alleged to be plentiful. It is highly probable, however, that the island's graceful *Howea* palms were mistaken for coconut palms, for there is no trace of the latter there to-day and it is unlikely that coconuts could flourish so far south. The evidence of Bowes' diary (1788) shows that the term "cabbages" refers to what the sailors called cabbage trees (? palms) which, when young, were tender enough to eat.

To-day great changes in the fauna and flora are evident. Comparatively few species of birds, other than visiting sea birds, remain where before there were 85 kinds. Turtles no longer visit the beaches to lay eggs, but introduced rats, mice, cats and goats are living in the wild. Domestic animals have been introduced by the settlers, and owls brought to the island to kill the rats turned and preyed on smaller native birds. These changes have upset the balance of nature to such an extent that Lord Howe now represents a classic example of the effect that civilized man has on the balanced, natural community of a small and isolated island.

The late Allan McCulloch's account ("Lord Howe Island—A Naturalist's Paradise" in "The Australian Museum Magazine", Vol. I, No. 2, 1921) paints a splendid word picture of Lord Howe as it was in 1921, when dramatic changes in the bird fauna were going on as a result of the introduction of rats to the island in 1918. In that year the S.S. *Makambo* ran aground near Soldier's Cap Island, and a few rats drifted ashore clinging to fruit cases thrown overboard to lighten ship. They multiplied rapidly and preyed on nesting birds and their eggs to such an extent that McCulloch said, "The quiet of death reigns where all was melody." Some birds that did not fall prey

to the rats succumbed to the attacks of wild domestic cats, some of which were let loose in 1850 by a visiting whaler.

Lord Howe Island To-day

In spite of this tragic reduction in fauna and flora, Lord Howe Island is still a delightful place for naturalists. Its picturesque and somewhat dramatic scenery, in which palms, pandanus trees, tree ferns, banyans and lianas are prominent, makes it one of the most beautiful islands in the world. An added interest is provided by its coral reef—the most southerly one in the world. Fishermen find excellent sport catching game fish (in season), and plenty of blue-fish, double-headed fish, trevally and kingfish are to be had just a little offshore.

There is, however, a much more fascinating part of the island, which may be seen by those willing and able to climb to the plateau on Mount Gower. From the biological point of view, this is by far the most interesting part of the island. Frequent rains and clouds which shroud the top of Mount Gower (2,833 ft.) generally keep the plateau, which is several acres in extent, very moist, so that tree ferns, sedges, low-growing ferns, rare palms and mosses can flourish there. This "moss forest", as the islanders call it, is like a Shangri-la left over from the time when coal measures were being laid down. One can stand in it and imagine what a Carboniferous forest looked like.

Some Animals Of The Moss Forest

It is many years since a biological survey of the high mountain plateau or the Erskine Valley has been attempted, and the time is overdue for another expedition. The last scientist to visit this area (the Director of the Australian Museum) in a few short hours collected two species of peculiar insects called Peloridiids that proved to be not only new to science but also differed from previously known ones enough to be considered a new genus, which was named *Howeria*. No doubt careful collecting would reveal many more such interesting species there. Peloridiids are confined to the damp moss and are incapable of flight, so it is a mystery how they could have reached such

The lagoon on Lord Howe Island, viewed from the high mountains in the south, with North Ridge and the peak of Mt. Eliza in the background.

Photo.—A. R. McCulloch.

an isloated island, for Lord Howe is 300 miles due east of Port Macquarie, New South Wales, 500 miles from Norfolk Island and over 700 miles from New Zealand.

How certain other land animals colonized Lord Howe Island is equally mysterious. The little freshwater crab, *Halicarcinus lacustris*, which lives under stones in the small streams on the island, has managed to ascend the steep sides of the mountains and has established itself in the runnels on the Gower Plateau. The same species also occurs in New Zealand, Norfolk Island and certain land-locked freshwater lakes in Victoria, and in these places is never known to enter the sea.

Another mystery is posed by *Talitrus sylvaticus*, the small land amphipod crustacean which lives in moist leaf litter. It is also found on Mt. Gower and occurs widely in Australia.

The method by which plants reached Lord Howe Island is equally puzzling.

Various authors have advanced different theories to account for the origin of the island's first flora and fauna, and the consensus of opinion seems to be that Lord Howe Island must have had land connections at some time past with New Zealand, Norfolk Island and New Caledonia, as its flora and fauna have closest affinities with theirs. Such connections enable land plants and animals that cannot fly, swim or drift to remote islands, or be introduced by accidental means (as the rats were), to move freely between one area and another and colonize them. Lord Howe Island thus stood at the cross-roads of any such migratory route, and for this reason is of special interest to plant and animal geographers.

Another interesting animal now living only on the southern hills and in the Erskine Valley is the wood-hen (*Tricholimnas sylvestris*), which has its closest relative in the flightless wood-hen of New Caledonia. An account of this and of the interesting extinct White Gallinule (*Porphyrio albus*) may be read in Hindwood's "The Birds of Lord Howe Island" (*The Emu*, Vol. XL, Part I, July, 1940). The wood-hen is unpopular because it makes forays into the lower parts of the island and steals eggs from chicken runs.

Other Land Animals Of Lord Howe

In the forests of the lower areas of the island, the rare, large, elongate shells of the Giant Land Snails (*Placostylus bivaricosus*) may often be seen, but most will be found to be empty, the animal parts having been preyed on by rats. Some say they are extinct, but there are still a few if one knows where to look.

Mr. Ray Missen has managed to keep some in captivity to study their habits, and has supplied the following information: *Placostylus* is active at night, burrowing below the surface of damp sandy soil (but not the soils of volcanic origin), and frequents areas near and under the roots of trees. It emerges irregularly (i.e., not every night) to forage for the dead leaves of certain species of trees, and sometimes climbs the trunks to heights of up to three feet, where it seems to be eating either the lichenous growths or the outer layer of bark.

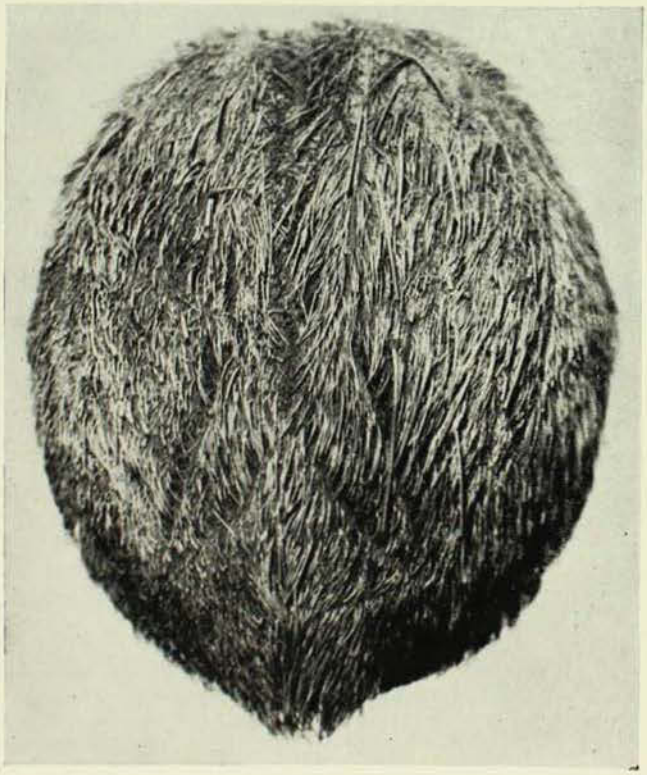
The "moss forest" on top of Mt. Gower is dominated by tree ferns (above). Its floor is covered by an undergrowth of mosses and ferns (below). Primaeval forests from which coal was formed must have looked something like this.

Photo.—A. R. McCulloch.

Mating of these snails has not been observed. Only one egg was laid in a day, but Mr. Missen has not yet discovered whether this was a daily occurrence or not. Each egg is round, about one-quarter of an inch in diameter, and has rather a hard brittle shell. Up to 18 eggs were observed in one clutch, and in captivity the snails rested above their eggs in the soil. When the young hatch they differ in shape from their parents, being much more like conventional snails. The tall spire does not develop until later.

Thousands of sea birds—wide-awake terns, mutton birds and gannets—nest on Lord Howe Island and the neighbouring Admiralty Islets. On some of the palm-fringed trails (e.g., in the picturesque Valley of the Shadow of Death) it is almost impossible to walk without crashing through the roofs of mutton bird burrows. At night, in the breeding season, the air resounds with the moaning of mutton birds. Red-tailed bosun birds soar near the cliffs of Mt. Gower, Mt. Lidgbird and North Ridge, where they nest.

No snakes occur on the island and the large *Nephila* spiders on their strong golden webs are harmless, so one can walk along tracks or even through the more jungle-like forests without fear of harmful animals. This adds to the island's attraction, for one does not have to be experienced to move about in the forests, off the beaten track.



The fauna of the lagoon floor includes the Heart Urchin (*Breynia australasiae*), often cast up on the beach along with coral fragments, Strawberry Cockles and delicately coloured Codakia shells with their rose-bordered yellow lining. (Natural size.)

Photo.—Howard Hughes.

Reef Fauna

In as short an account as this it is not possible to cover, even briefly, all the land flora and fauna or to describe the fascinating sea life of the island's reefs, which differs so greatly from that of Australian shores in similar latitudes. More tropical than temperate in nature, the fauna of the reefs is rich in sea stars, sea urchins, bêches-de-mer, and their relatives the brittle stars and feather stars, for the seven-mile-long island can boast 58 species. There are about 20 species of coral and large underwater expanses of giant anemones, with attendant anemone fish. Small coloured reef fish including the fantastic butterfly cod, swim among the corals, while crustaceans such as crabs, squillas and pistol prawns hide in the sheltered crevices. Among the molluscs, cowries and colourful clams also show the tropical influence in the marine fauna. All this makes skin-diving and reefing when the tide is low extremely interesting.

While Lord Howe Island has been of great interest to scientists and much has been written about it, only the half has been said. It is indeed a paradise for naturalists.

Back Numbers of Magazine Wanted

A member of the Museum staff wishes to buy five back copies of "The Australian Museum Magazine"—Nos. 1 and 5 of Vol. I and Nos. 1, 7 and 10 of Vol. II. Any reader who can make these available is asked to ring Mr. Mackay at the Museum, 26 6954.

UNDERWATER SABOTEURS

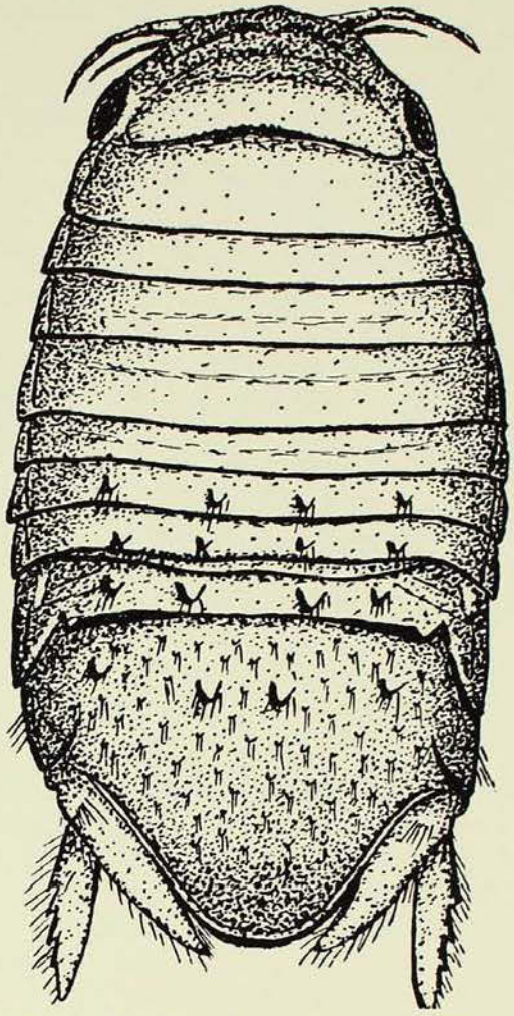
By FRANK McNEILL

MOST casual visitors to the Museum are unaware of the very important research carried out behind the scenes by its staff of zoologists—research that sometimes has a bearing on the economy of the country.

One such programme of research undertaken by the Museum concerned the destructive work of the marine timber borers. The lives and behaviour of these underwater saboteurs—menaces which constantly seek to destroy timber wharves and jetties—were investigated for some years. The borers, which also attack the hulls of timber-built craft, have wreaked their havoc since the dawn of history.

The author's association with the problem of local destructive marine borers began in 1927, when a collaboration was commenced with a marine construction engineer who had a new and refreshing angle on his profession. He had suppressed that inclination, common in his profession, to tear down and build up afresh, and deserved admiration for his unbounded faith in his ability to preserve existing structures, and so eliminate waste. This was, to him, almost a religious creed from which he never wavered. His official duties were concerned with the maintenance of harbour installations owned and controlled by the Port of Sydney authority, the Maritime Services Board. To him can be given the credit for perceiving the one and only practical approach to the eradication, or at least the arrest, of marine borer attacks in the valuable piling of the port—a close observation and an understanding of the causal organisms. As early as 1927 the annual cost of repair and maintenance of piling had reached the then alarming total of £16,000. As in previous years, this figure would have continued to increase with the normal growth of the port.

The problems of marine borer activity are largely concerned with the animals themselves—their identities, their distribution, their habits, their relative destructiveness



A typical Pill-bug borer which when adult is about the size of a garden slater or wood-louse. No kind of timber is immune to its attack.

Drawn by the author.

and their preferences or otherwise for particular types of timber. It was this phase of the research that demanded the aid of the museum zoologist, and from 1927 to 1941 the author was engaged in a close collaboration on the subject. The joint effort bore fruit in the publication of three reports that contain a comprehensive record of the research. No similar reports have appeared that cover so completely the marine borer problems of a single port. The Port of Sydney presented a virgin field for marine borer research, for no observations of a connected nature had ever been attempted there.

To state that success was the outcome of the lengthy observations is not a boastful claim. There are still many older shipping ports in the world where the destructive progress of marine borers has not been

arrested, but our local marine borers have now been checked to a stage where they are no longer a menace to piling. In the vast majority of cases, today's costs are for preservation alone; virtually nothing is expended on replacements.

This is quite an achievement for a maritime port the size of Sydney's, which proved its importance and capacity during the second world war. Its importance may be gauged from the fact that tens of thousands of units of timber piling are required in equipping a major port. Few people who walk over the decking of wharves and jetties ever give a thought to the piling on which this rests—supports which, as far as Sydney's port is concerned, previously had a maximum life in service of barely 30 years. This same piling today is given an indefinite life, or a life as long as needed, and all for the nominal maintenance cost of about seven shillings a year per pile.

Sydney's port authorities have always favoured the old proved and economical timber marine structures. Reinforced fabricated structures of concrete disintegrate far too rapidly through the hydraulic action caused by rust. Forty-five thousand piles is a conservative estimate of those under official jurisdiction; many thousands of others are privately owned. Of course, all the wharves and jetties in the port do not support decking alone. Many also bear roofing, stores, offices, cranes, derricks and massive loading gear. These are the things that cause the rise in the value of piling, so much so that the replacement of a single pile in the Port of Sydney can cost an average of well over £100. On this basis the total cost of replacement would be extremely high, amounting to many millions of pounds when the total cost of superstructures is added.

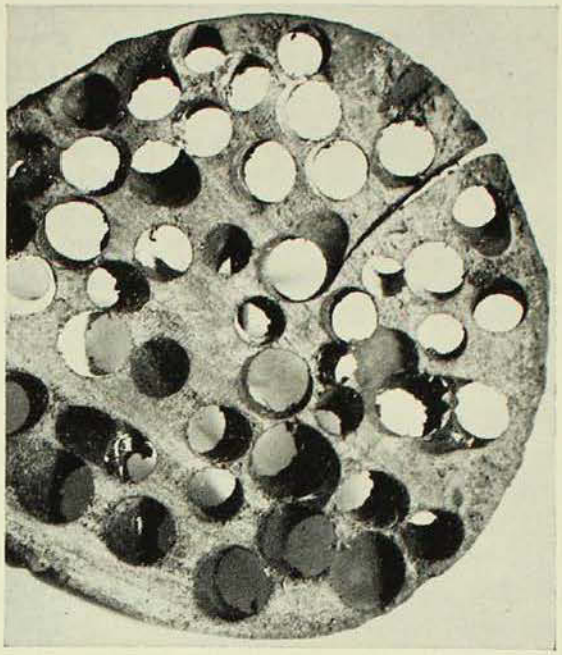
Something can now be told of the destructive borer pests themselves and their vagaries, and of the kind of war that continually has to be waged against them. The campaign is made more difficult by the fact that these destroyers of man-made structures have to be fought in their own domain. They cannot be blamed for being where they are. In the general plan of nature they have lived harmlessly for ages in the wrack drifting about the seas or choking the waters of inlets and the courses of rivers. They thus served a useful purpose, in a sense, as natural scavengers. But man has upset the balance of nature by introducing more abundant and more attractive food and homes for them.

The main types of destructive marine borers are far from being strangers to the zoologist. They have been known for centuries, and are distributed throughout the seas of the world. The really important part of their study is concerned with their varieties and the difference in behaviour of those in separate ports. One of the early conclusions arrived at in the research was that each maritime centre had its own peculiar problems. In other words, the results obtained in one port could not be applied generally to another, even though it was only a few hundred miles away.

The Cobra Borer

Of first importance among destructive timber borers is the worm-like animal which has been named Cobra by the Australian Aborigines; in other countries it is known as Teredo or Ship-worm. Normal examples attain a length of between three and 16 inches, but a few are much longer than this. Cobra borers are actually molluscs, and thus related to mussels, oysters and cockles. They have paired calcareous shells (valves) at the head, or boring end, of the body—complicated contraptions, ornately sculptured, without which a Cobra would be quite harmless. After long and close observation of the method of boring, it is now generally agreed that the paired shells perform this function, probably assisted by some acid exudation.

Cobra borers made probably their greatest attack on human handiwork in the Zuyder Zee, Holland, about 238 years ago. For reasons not understood they suddenly increased their activities (a not uncommon happening), threatened the timber-works of the dykes and almost brought disaster to the whole Dutch nation. The gravity of the destruction stirred local scientists to deep and tireless research, and in three years there appeared in print the first systematic treatise on the pests—a learned contribution in Dutch by Godfrey Snellius. This publication is the foundation on which all similar studies have since been based.



Left: A juvenile Cobra borer (greatly enlarged) exposed in its burrow in a chip of softwood (Oregon fir). One of the pair of shells at the head or boring end of its body is clearly seen. The processes at the tail end act as plugs to seal the minute holes in timber surfaces made by the borers when they first enter as larvae. Above: A thin cross-section of piling, showing the effect of a heavy attack by Cobra borers on non-resistant timber.

Cobra borers begin life as minute free-swimming larvae. In a very short time they settle down to a sedentary life of boring into timber surfaces on which they chance to lodge. Access to the interior is gained by boring a tiny hole. The tail-end then remains at the point of access, while the shell-clad head-end moves deep into the timber as the body thickens and increases in length. The real danger lies in the hidden nature of an attack by thousands of individuals which, without proper methods of protection and control, can well remain undisturbed to the stage when collapse and costly replacement of a timber structure are inevitable.

Destruction By Martesia

Since the inception of organised study of marine boring pests there has been a regimentation of data on certain accomplices of Cobra borers which contribute their percentage of destruction in different parts of the world. One of these is another kind of mollusc, known as Martesia. It is very closely related to the worm-like Cobra, but it is more like an elongate common mussel in shape. The whitish, paired shells enclosing the body are thick, strong and conspicuously sculptured. Unlike the Cobra borer, the shells enclose the whole of the Martesia animal, but the one thing they have in common is that both begin life as free-swimming larvae.

When numbers of Martesia bore in from the surface of a timber pile they commonly form a ring of destruction. An attack of this kind can penetrate to a depth of two inches in 18 months, equalling approximately the maximum length attained by this particular borer. When the adults die or become loose in their bore holes and drop away their places are taken by newly-settling larvae. In this manner the destruction advances swiftly, stage by stage, until the full diameter of a pile is cut through and a collapse results.

The only known case of destruction by Martesia borers in Port of Sydney waters occurred in the late 1930's, and their depredations were summarily arrested. This one instance proved the necessity for unremitting check and survey of the port area. Luckily, the occurrence was confined to a small pocket in one of the deeper reaches. It was in a position where it could be readily coped with before it spread, unsuspected, to the crowded shipping centres; otherwise, the port authorities might well have had to deal with a disastrous collapse like that experienced not many years ago at San Francisco, when hundreds of people were precipitated into the water. Quite unnoticed, a new and particularly voracious kind of Cobra borer had become established there.

Crustacean Borers

Besides the two kinds of molluscan borers attacking local marine timber structures, there are several virile crustacean types—relations of the common slaters or woodlice of our garden. Like the molluscan borer, Martesia, these particular pests are readily detected; they remain more or less on the outside of timber they are attacking, where their workings are conspicuous. Morever, they are most vulnerable to methods of treatment that have been developed. The smallest of these crustacean destroyers is the tiny Gribble (*Limnoria*), notorious for having rapidly disposed of the timber scaffolding used by the engineer Stevenson in his earliest attempt to build the Bell Rock Lighthouse, off England's east coast. The Gribble breeds in the fine bore-holes of its honeycomb-like workings, and literally infests piling timber in countless thousands. As many as 400 individuals have been counted in a cubic inch of badly attacked timber. This borer's maximum length is rarely more than one-eighth of an inch. At times it is found penetrating deep into heartwood through such faults in piling as limb-scars and knot holes.

Two other crustacean borers occurring locally are known as Pill-bugs (*Sphaeroma*); these and others of their kind are found in all temperate and tropical seas. Pill-bugs are comparable in size to the garden slater or woodlouse. When attacking piling they form large interlacing burrows, and no kind of timber is proof against their ravages. Unlike the tiny related Gribble, Pill-bugs are strong swimmers and move about freely in a crowded area of piling.

Treatment Methods

In the Port of Sydney borer investigations, the behaviour and distribution of all pests were carefully recorded for years in regular routine inspections of 37 control test stations. The methods employed provided data covering the relative intensities of attack and the range of occurrence of the different borers over the widest possible area of the port. With the gradual accumulation of knowledge, methods of treatment were introduced, all emerging from the engineering side of the investigation.

Two of these were of outstanding merit for the originality and inexpensive simplicity of their conception. One was a special tar-plastic compound which sealed off and killed all attacking pests—surface-boring crustaceans as well as the deeper-seated burrowing Cobra and Martesia—when applied in a thin coating, enclosed by mild steel forming, to piling below low-water line.* The other, a more rapidly effective and more easily applied method producing the same result, entails the use of a patented revolutionary floating-collar device, made of mild steel, which opens on hinges and can be closed around piles in the form of a cylinder open at both ends. When a small amount of toxin (inexpensive creosote) is added at the top of the cylinder to float on the water surface, it is able to do its effective work with the down and up movements of the tide. (The latest development in the construction of floating collars is the use of far more durable fibre glass.)

The Australian timber known as turpentine (*Syncarpia laurifolia*) has proved unsurpassed for use locally as a natural resister of Cobra borer attack. Under normal conditions, the 1½ in. to 2 in. deep sapwood is the only part of a turpentine pile penetrated by this kind of pest. The same timber, however, is not resistant to attacks by the crustacean borers. There are

*This tar-plastic treatment was later replaced by a still more effective coating of cement mortar enclosed by "black" iron forming.

recorded cases of Pill-bug attacks reducing 18 in. diameter piling of turpentine to a dangerous stage of collapse in the comparatively short period of 14 years.

Borers A War-time Menace

By the time the more serious operations of the second world war had begun in the south-west Pacific area a great amount of knowledge had been accumulated about marine boring organisms. Concurrently with the last stages of the Port of Sydney investigation, a report had been prepared and published on a similar research for the Port of Brisbane. This had been done in collaboration with an officer of the Queensland Forest Service, and had provided some insight into the nature of the attackers further north towards the tropics.

To the military commanders in the field, combating the ravages of marine borers began to rank high in importance, for the pests presented new and serious problems that had never before been encountered in war. The ubiquitous Cobra borers were well to the fore, and were creating such havoc that specialized help was enlisted. Previously there had been no real need for any substantial knowledge of the marine borers in the near tropical north, but this soon changed. Australian and American scientific liaison officers carried out the work of examining and checking the damage done. Much of the data and specimens gathered from various parts were sent for study and assessment to specialists in the south.

In the rapid military advances, beachheads were hastily established by using any of the natural resources ready to hand. Softwood rain-forest timber was felled for the building of jetties; even the trunks of coconut palms were, on occasions, pressed into service. Some such structures collapsed after as short a life as six to eight weeks. Even jetties constructed of hard mangrove timber lasted no more than seven months. At important points in the advance the timber for use as piling just had to be of proved natural resistance to borer attack, or in some way artificially protected against it. Hence, it was found necessary to bring suitable piling great distances from elsewhere.

In the earliest stages of the conflict the American forces were supplied with quantities of Oregon Fir. This timber arrived in the form of milled and untreated beams or baulks, the cut and squared state making for ease in shipping and building. This untreated timber was totally unsuitable for immersion in sea-water, and had to be protected with sleeves and casings of various kinds.

Any marine construction engineer experienced in the ways of marine timber borers has learnt that some patterns of construction

Built of unsuitable timber, this war-time Naval jetty at Ladava, New Guinea, collapsed less than 16 months after construction because of attacks on its piling by Cobra borers.

are eminently more suited to conditions of intensive attack. Cross and diagonal bracings bolted to piling below the level of high tide are an outmoded design in the bad areas, and have long since been discarded in the Port of Sydney. This was one of the benefits derived from local knowledge which was handed on to Army engineers to be put into practice once the organised settlement of advanced points was begun and closer attention to economy could be given.

Protection Of Landing Barges

Another aspect of the Pacific War was the organised protection ultimately given to landing barges and small craft against marine borers. From the beginning of 1942 these timber-built units were constructed in thousands in Australia alone. At first the feverish organisation could consider only the questions of building and dispatch. Not until later, when things became more settled, was it possible to take stock of the lasting qualities of this equipment. Staggering weaknesses were revealed. The borers destroyed the unprotected softwood (often bond-wood ply) so quickly that the vessels lasted a mere two months and less in service before being jettisoned. Again the services of the civilian specialists were sought by the field commanders. Apart from advice given concerning the transfer of craft to areas of lesser borer-attack when temporarily not in use, proven methods of preservation of hull timbers, involving the use of toxic compounds, were made available, as also were the formulae of several effective sealing compounds.

It is a fallacy that the removal of vessels from salt water to the pure, or near-pure, fresh water of the upper reaches of rivers will kill-off marine borer infestations. Over a short period the practice is certainly effective in killing those borers that belong to the fauna of high-salinity water. The timber hull of a craft, however, just as quickly suffers a new infestation, particularly by a more virile Cobra borer that thrives in all river-waters of low or barely noticeable salinity. Given a long enough spell in such waters, a timber hull will fare worse than if it had not been transferred at all from salt water.

Increase in Price of Magazine

As from the issue of March 15, 1961, the price of "The Australian Museum Magazine" will be increased to 3/- a copy (3/6 posted). The subscription rates (posted) will therefore be 14/- a year and £2/2/- for three years (the full volume).

This has been made essential by rises in the costs of printing, paper and process-engraving in recent years. It is the first increase in the price of the magazine since 1949, except for an extra charge of 1d. per posted copy in December, 1959, when higher postal rates raised the postage on the magazine from 3d. to 5d. It was then decided to bring the posted price to the round figure of 2/6, instead of 2/5, and thus offset, to a very slight extent, the heavy increases in production costs since 1949.

The fact that the price of the magazine has remained practically unchanged for 11 years indicates the Museum Trustees' desire that this educational and authoritative publication, the only one of its kind in Australia, shall be sold at as low a price as possible.

Improvements have been made to the magazine in the past two years, and this policy will be continued wherever practicable.

From the great volume of data gathered in the south-west Pacific area prior to and during the second world war there emerged a special supplement to an Army Engineering textbook of instruction. This served a useful purpose in the training schools of the Services. For probably the first time, the important question of marine borer depredations and their prevention took its place as a war factor of major importance.

[*Photos by courtesy of the Maritime Services Board, Sydney.*]

FRESHWATER CRAYFISHES

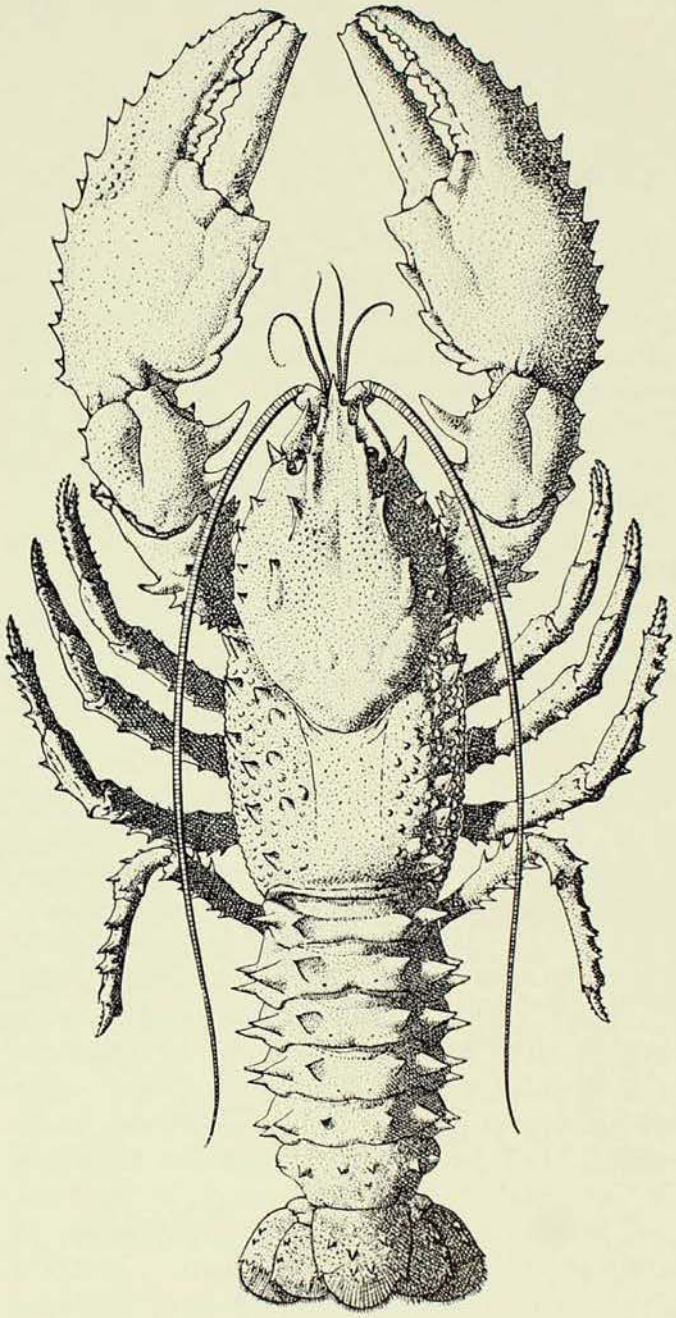
By DONALD D. FRANCOIS

Department of Conservation, Cornell University, Ithaca, New York

THE first crayfish from the fresh waters of the Australian Continent was described in 1794 by Shaw in his *Zoology of New Holland* and, oddly enough, it was not until four years later that a description of the first North American crayfish appeared in print. It is on these two continents that the crayfishes attain their maximum abundance and diversity. Great Britain, for example, has but one species, New Zealand three, and Japan two, while the State of Florida, U.S.A., boasts approximately 42 species and subspecies. Exclusive of Australia and the rest of North America, Florida has more species than the rest of the world. New South Wales also possesses a rich crayfish fauna which, at present, consists of approximately two dozen described forms. As this fauna is studied the number of described species may reach 50 or more.

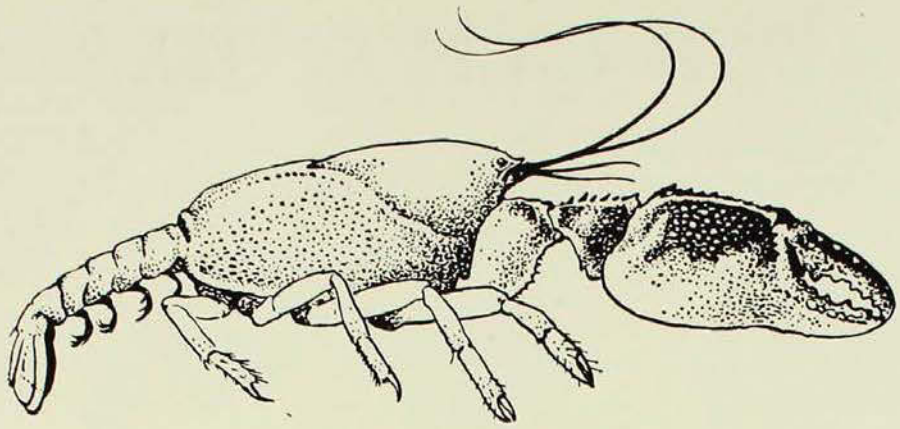
In Australia and North America we find the most specialized forms living in the most unusual ecological situations. In Florida, U.S.A., for example, the monotypic (single species) genus *Troglocambarus* is a small, fragile crayfish with a transparent exoskeleton (outside skeleton, or shell) that lives upside down on the roofs of underground, water-filled, limestone chimneys or caves. They escaped notice in such an inaccessible habitat until just recently, when Professor Horton H. Hobbs, Jnr., discovered and studied them by skin-diving. While *Troglocambarus* lives in subdued light and has functional eyes, many other cave-dwelling crayfishes are quite blind and have little body pigmentation.

The so-called land crayfishes (*Engaeus*) of south-eastern Australia and Tasmania are found in burrows that terminate in large central chambers. They live in "family groups" and are the only crayfishes practising this form of social behaviour. Their burrows usually occur in areas of swampy land, but they are often found in quite firm ground. *Engaeus* can be a serious pest in orchards when they burrow under trees and expose the roots to attack by insects and other pests. They are also responsible for the "crab hole" country found in certain parts of Victoria where this genus is particularly abundant.



The Murray River "Lobster" (*Euastacus armatus*) is noted for its excellence on the dinner table. It is reported to grow to a weight of 6 lb.

After Ellen Clarke.



Left: A typical burrowing crayfish (*Engaeus*) of south-eastern Australia. (Natural size.)

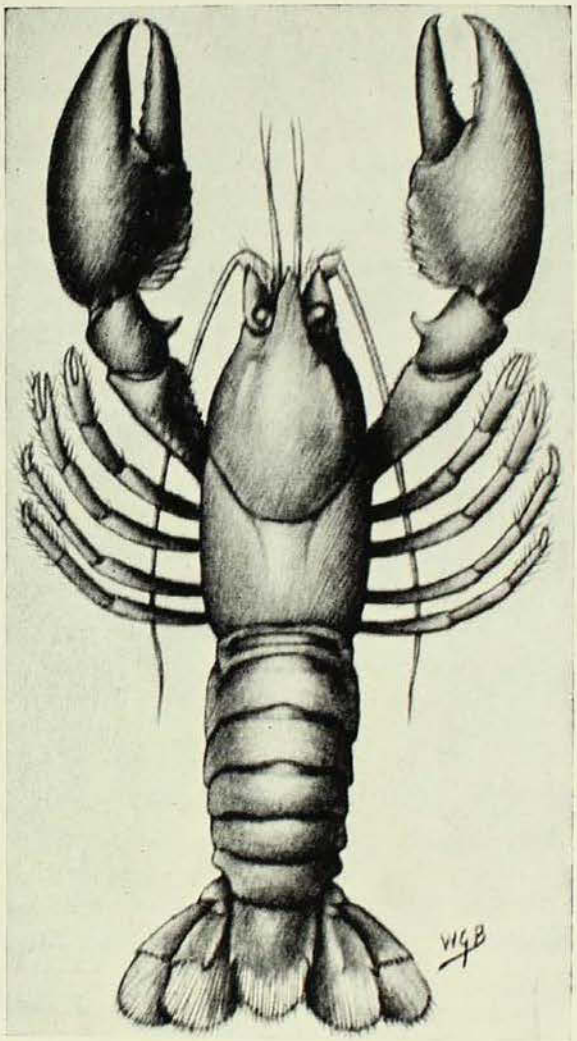
After Ellen Clarke.

Below: Crayfishes of the genus *Cherax* are believed to burrow deep into the floors of inland dams which are drying up, and to emerge again as the dams are refilled by rain. (About two-thirds natural size.)

After Geoffrey Smith.

In western New South Wales, crayfishes of the genus *Cherax* are reported to have appeared in recently-filled dams which had been dry for several years. It is believed that they burrow deep into the floor of the dam when the water recedes, and emerge again as the dam refills with rain water. They might also migrate to a newly-filled dam, for they often leave the water, or their burrows, and travel on land. Although crayfishes have increased their distribution by walking over land, it is questionable if this can explain their appearance in recently filled dams.

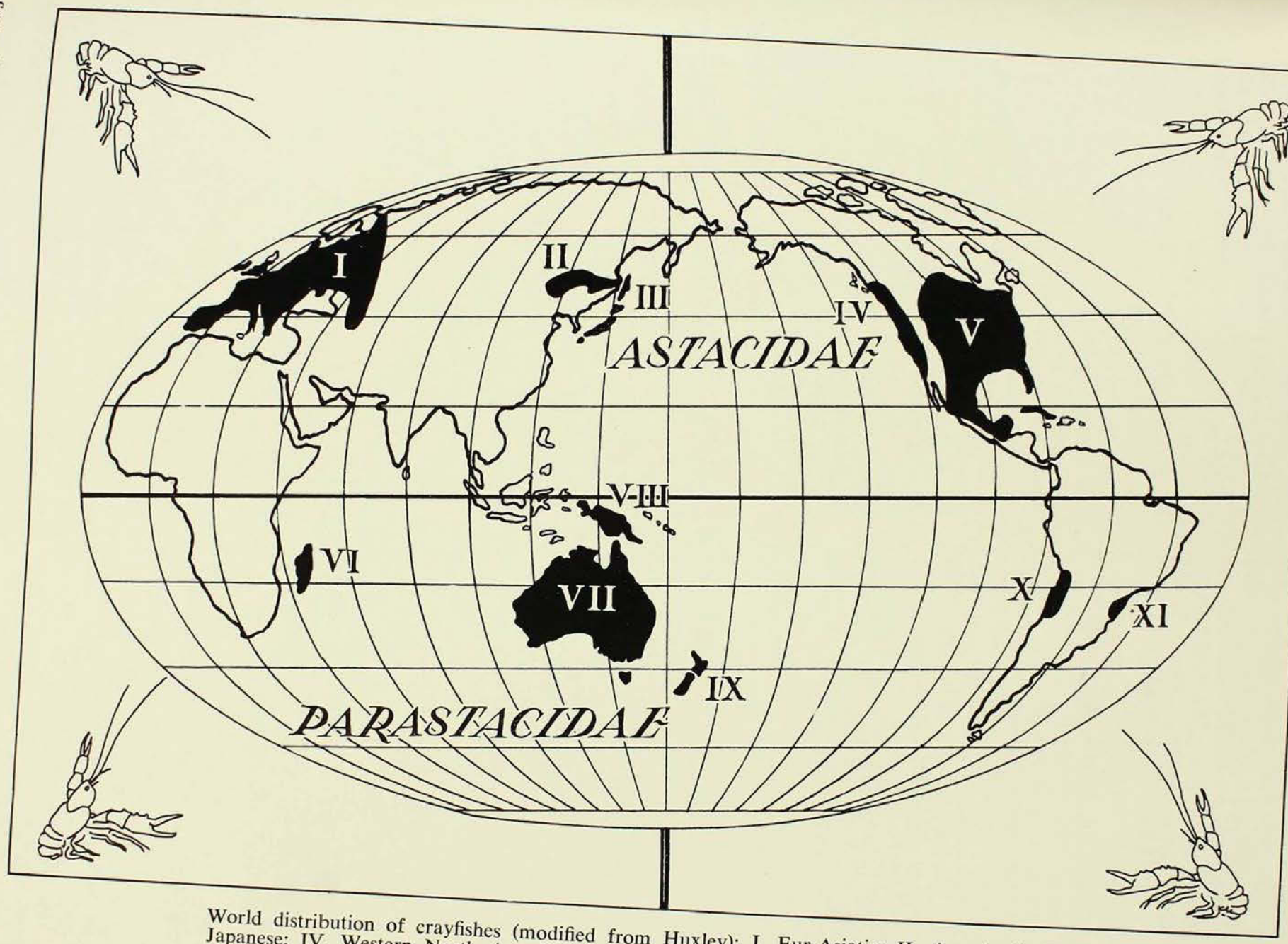
On a rainy, spring night in Columbus, Ohio, U.S.A., the author collected several dozen crayfish which were a considerable distance from their burrows. A large number of these were found crossing an asphalt road. In an area of forest country along the New South Wales-Queensland border crayfish have also been frequently observed making their way overland. Another crayfish occurs in Sydney suburbs on the south headland of Port Jackson, where numbers live in small "soaks" in people's gardens. The stimulus which causes crayfishes to leave their burrows is unknown. Perhaps it is in search of food or a mate, or possibly it is related to a fluctuation of water level in "soaks" and other places where they live. Much more information is needed before this behaviour is understood.



Murray River "Lobster", a weight of six pounds. By comparison, the tiny *Tenuibranchiurus*, of Queensland, does not exceed an inch in length.

8 lb. Crayfish

The largest and the smallest freshwater crayfishes in the world are found on the Australian continent. *Astacopsis gouldi*, of Tasmania, is reported to reach a weight of eight pounds, and *Euastacus armatus*, the Murray River "Lobsters", taken commercially on a small scale, are noted for their excellence on the dinner table. However, a noted gourmet from Canberra, Australian Capital Territory, has rated another freshwater species, *Cherax tenuimanus*, as



World distribution of crayfishes (modified from Huxley): I. Eur-Asiatic; II. Amurland; III. Japanese; IV. Western North American; V. Eastern North American; VI. Mascarene; VII. Australian; VIII. Novoguineaian; IX. Novozealanian; X. Chilian; XI. Brazilian.

Drawn by B. P. Bertram.

the finest flavoured crustacean he has ever tasted. This particular crayfish ranks third in size among the Australian giants and grows to a weight of four or five pounds; the large abdomen or "tail" provides the bulk of this weight. An additional advantage for those handling this animal is the weakness of its pincers, which are incapable of administering a severe nip.

On the island of New Guinea crayfishes form an important item of food for the natives. In the southern United States, particularly Louisiana, the local "crawfish" or "crawdad" is much sought-after as an ingredient for many Creole dishes, notably one named jambalaya. The European crayfishes are also considered a table delicacy. Crayfish farms have been established in France, and in some other parts of Europe crayfishing rights are established and leased in much the same manner as trout-fishing rights.

The tribe Astacidea is composed of three families, Nephropsidae, Astacidae and Parastacidae. The Nephropsidae are marine and are the true lobsters, while the Astacidae and Parastacidae contain the freshwater crayfishes. "Spiny lobsters", or more correctly the marine spiny crayfishes, which are taken commercially off the Australian coast, belong to a quite different crustacean tribe, Scyllaridea. The Astacidae, or Northern hemisphere crayfishes, possess sexual appendages and laminae on their gills; the Parastacidae, or Southern hemisphere crayfishes, lack these structures. The two families also differ more basically from one another in their embryology. Such major family differences and geographical isolation indicate that each of them originally emerged from the sea from different ancestral stock—an astacine-type ancestor in the Northern hemisphere and a parastacine-type in the Southern hemisphere.

World And Continental Distribution

Perhaps the most interesting aspect of the study of crayfishes is their distribution on a world and continental basis. The accompanying map clearly shows that crayfishes are not found continuously in either hemisphere, but have a rather discontinuous distribution. With the exception of New Guinea, the tropics are devoid of crayfishes from about 10 degrees north latitude to about 10 degrees south latitude. Conversely, the large, long-armed, freshwater prawns (*Macrobrachium*), not to be confused with crayfishes, are circumtropical in distribution and attain their maximum expression in the precise areas lacking crayfishes.

While no crayfishes are to be found anywhere on the African continent, on nearby Madagascar, with a fauna probably African in origin, the genus *Astacoides* is quite common. This poses the interesting problem of what has happened to the earlier African crayfish fauna. It has been suggested that the severe climatic changes experienced by Africa in the past caused the extinction of its crayfishes. Madagascar, on the other hand, did not undergo the same climatic changes and crayfishes have survived there. In Africa the large river crabs are abundant in the type of ecological situations usually occupied by crayfishes. Similar conditions, with the absence of crayfishes and the presence of crabs, are also found in the Amazon River drainage of South America.

The Northern hemisphere crayfishes can be divided into four groups—the Eur-Asiatic (*Astacus* and *Austropotamobius*); the Amurland (Manchuria, U.S.S.R.) and Japanese (*Cambaroides*); the western North American (*Pacifastacus*); and the eastern North American (*Cambarus, Orconectes, Cambarellus, Procambarus, Paracambarus* and *Troglocambarus*). Strangely enough the crayfishes of western North America are most closely related to the Eur-Asiatic forms and, until recently, all were grouped in the genus *Astacus*. These are the astacoid types, and those of eastern North America are referred to as cambaroid types. The *Cambaroides* of the Amur River basin and Japan are somewhat intermediate between these two types, but are more closely related to the cambaroid forms. If these supposed affinities prove to be valid, they represent a most unusual distribution. For example, a crayfish from California does not have its closest relatives in the United States or eastern Asia, but in England and Europe. Crayfishes are not the only group in which this peculiar distributional relationship has been noted. There are many other plants and animals that exhibit a similar distribution. The Horseshoe Crab (*Limulus*), for

example, is found only on the Atlantic coast of North America and the eastern coast of Asia (Japan, Cochin-China, Borneo).

Generic Relationships Of Parastacidae

The generic relationships of the Parastacidae are not as yet well known. The crayfish fauna of Tasmania (*Astacopsis*, *Geocherax*, *Engaeus* and *Parastacoides*) and of New Guinea (*Cherax*) is obviously derived from Australian stock (*Euastacus*, *Cherax*, *Engaeus*, *Geocherax*, *Euastacoides* and *Tenuibranchiurus*). This is demonstrated by the genera that are common to the islands and the mainland of Australia. Less is known of the Parastacidae from other regions, but superficially *Astacoides* of Madagascar resembles *Euastacus* (Australian), and *Parastacus* of South America resembles *Cherax* (Australian). *Paranephrops* of New Zealand seems to have affinities wth *Cherax* of Australia, but the significance of these resemblances is uncertain.

It is difficult to discuss the Parastacidae without mentioning that they are but another group exhibiting the classic southern distribution common to so many groups of plants and animals (Australia, South America and Africa). It is this pattern of distribution, coupled with the growing fund of geologic and oceanographic evidence, that has recently given new impetus to the much-debated theory of continental drift. This is a theory which joins Australia, South America, Antarctica and Africa into one land mass, "Gondwana Land", with the subsequent drifting apart of the continents to their present location.

The author hopes that this article has given the reader some insight into the many fascinating and complex facets of the study of crayfishes. In conclusion, it will be appropriate to quote the words of Thomas Huxley, brilliant English zoologist of the 19th century, who wrote a successful text, *The Crayfish*, based solely on this group: "Mollusks are far more interesting—bugs sweeter—while the dinner crayfish hath no parallel for intense and absorbing interest in the three kingdoms of nature." (*ex* letter to Jeffery Parker, September 25, 1876).

Premier Opens Museum's New Building

The first part (two storeys) of the Australian Museum's new six-storey wing was officially opened by the Premier of New South Wales, Mr. R. J. Heffron, on August 11. Mr. Heffron, who unveiled a commemorative plaque, was introduced by Mr. Wallace C. Wurth, President of the Museum's Board of Trustees. The Minister for Public Works, Mr. P. N. Ryan, an Official Trustee, and Mr. F. B. Spencer, Crown Trustee, also spoke.

The completion of these first two storeys is one of the outstanding events in the history of the Museum, for it is the first major building addition for half a century and will fulfil the Museum's most urgent need—additional accommodation.

The new two-storey building, which is faced with handsome sandstone, contains curators' offices, laboratories and collections, and has about 16,000 square feet of floor-space. Its features include linoleum-tiled floors, fluorescent lighting, acoustic ceilings and bronze stair-rails and window frames.

A contract for the erection of the other four floors has already been signed. These floors will enable more of the Museum's collections to be displayed to the public, and there will be a public cafeteria on the roof.

This building expansion coincides with the big programme of modernising and reorganising the Museum which is now under way.

The Australian Bird-banding Scheme, 1953-60

By ROBERT CARRICK
Wildlife Survey Section, C.S.I.R.O., Canberra

THE year 1960 seems an appropriate time to take stock of the results of the Australian Bird-banding Scheme, which commenced operations nearly seven years ago.

Limitations of space preclude adequate treatment of all the data, or of the efforts of fully 100 professional and amateur ornithologists who have obtained it. Equally, only passing mention can be made of the history of bird-banding in Australia, which dates back to 1912, and of the State schemes, mainly for ducks, which began in 1951 and which continue to function in Victoria, Western Australia and Queensland. There is also the joint C.S.I.R.O.-Tasmanian Fauna Board scheme for the Short-tailed Shearwater (*Puffinus tenuirostris*) in that State. The interested reader will find full details in the series of reports and papers published since 1954 in "Emu" and since 1956 in "C.S.I.R.O. Wildlife Research."

The Australian Bird-banding Scheme is a service, conducted by the Wildlife Section, C.S.I.R.O., available to Commonwealth, State, university and approved amateur ornithologists who are interested in the scientific study of birds. The individual bird-bander's activity may range from a detailed study of population ecology and behaviour to week-end recreation, which, taken in the mass, makes an important contribution to our accurate knowledge of bird movements. To many, not excluding the professionals, banding is something of a modern sport, which draws its adherents from every walk of life and all ages, for it can be practised with equal value in the back garden with mist-nets and simple wire-netting traps, in swamps where water-fowl breed, on coastal islands among sea-bird colonies, or at sea where the great albatrosses present more exciting hazards.

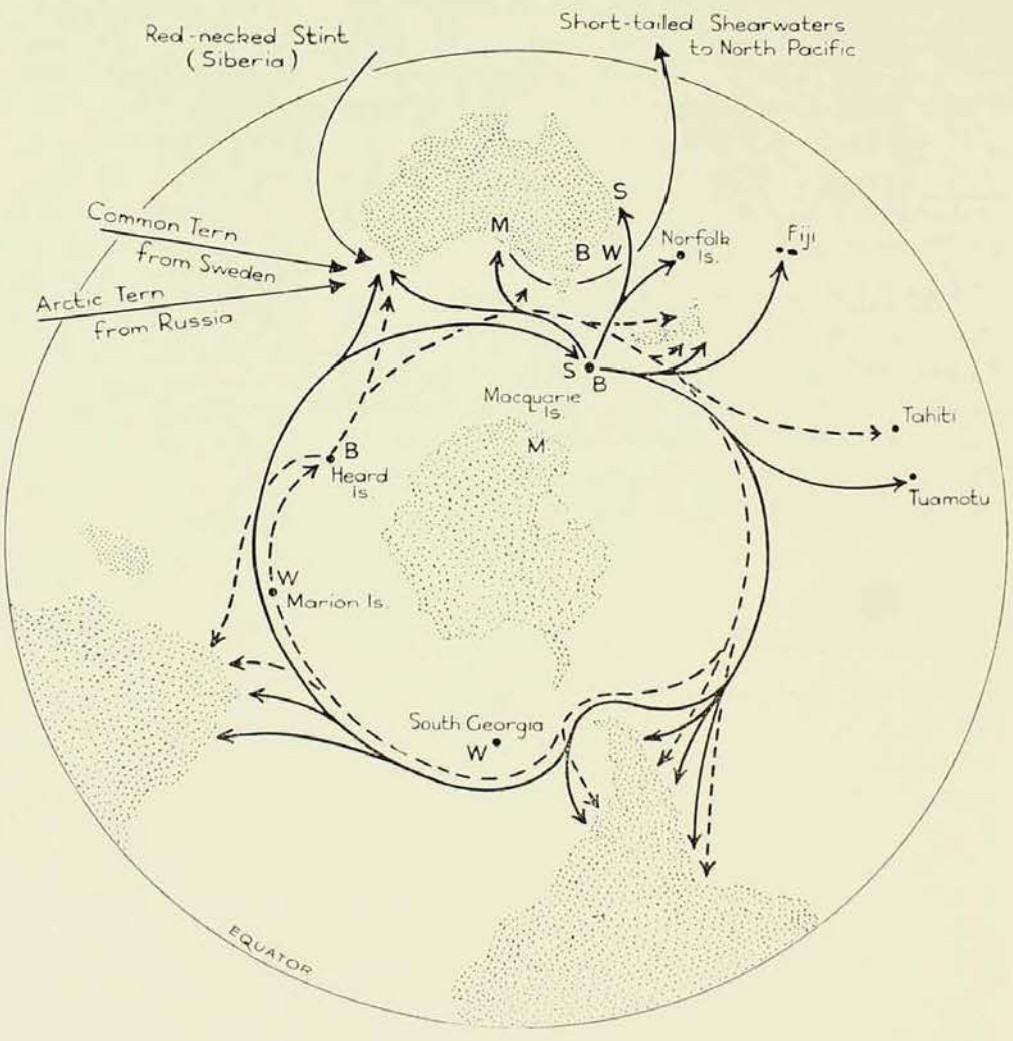
Geographically, the Scheme covers all Australian territory from New Guinea to Antarctica, omitting Queensland, which has not yet decided to participate. To date, most banding has been done in New South Wales, and at this early stage all possible species are being banded, with results that frequently surprise the experts. Up to June, 1960, some 135,000 birds of over 260 species had been banded. The average recovery rate of 10 per cent. compares well with that of other countries, but varies enormously from less than one per cent. in the case of marine petrels and shearwaters and marsh-frequenting ibises to 15 per cent. in the case of ducks shot for sport and 50 per cent. in the case of the sedentary Black-backed Magpie (*Gymnorhina tibicen*), which is readily re-trapped by the banders.

The first bird banded under the Scheme—a fledgling Black-backed Magpie (*Gymnorhina tibicen*), with a numbered aluminium leg-band and single-coloured plastic bands denoting age-group.

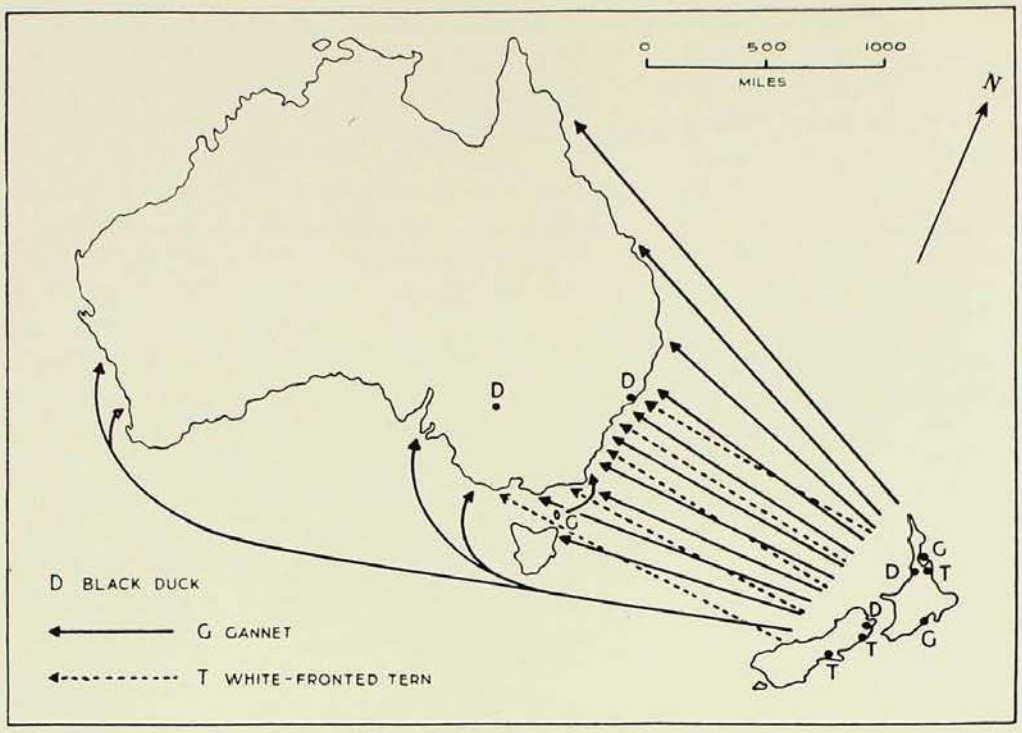
The very first bird banded under the Scheme illustrates this last point, for it was a nestling Black-backed Magpie, band numbered 090-00002, banded by G. M. Dunnet at Gungahlin, Canberra, on October 16, 1953. Its life history, known in detail, is

typical of many of the 562 magpies that have been given different combinations of coloured celluloid bands (in addition to the numbered metal band) for individual recognition in the course of the author's population study of this species. Nestling 00002, now a hen in its seventh year, has been trapped four times since it was first banded, and has been sighted 84 times. It was colour-banded on July 25, 1955, while still in its natal territory, but left the parental group the following month. From April, 1956, until August, 1958, it occupied a treeless non-breeding territory with a cock magpie, just half-a-mile from the nest where it was born. Then in September, 1958, the pair succeeded in taking over a nearby territory almost adjacent to the original one, where the hen parent of 00002 still lives. It was not until 1959 that 00002 nested for the first time. Thus, banding established the survival and sedentary habit of this magpie, its constancy of mate and territory and its failure to breed at two or three years old owing to lack of suitable habitat, as well as other details of its behaviour.

Banding is an essential tool in detailed studies of bird behaviour, life-history and ecology, because individual identification brings to light important facts that would otherwise remain obscure, and places such research on a high level of accuracy. A study of the Superb Blue Wren (*Malurus cyaneus*) by I. C. Rowley has demonstrated territorial social groups in that species too, as well as the interesting communal habit whereby non-breeding wrens assist in feeding the young and earlier broods may also feed those hatched later in the same season. H. J. Frith has traced the breeding histories of individual Mallee Fowl (*Leipoa ocellata*) by means of colour-banded birds; Antarctic biologists have demonstrated that each pair



Australia and the global movements of birds, as shown by banding: A Common Tern (*Sterna h. hirundo*) and an Arctic Tern (*S. macrura*), banded in Sweden and north-west Russia, were recovered near Perth. Eight Short-tailed Shearwaters (*Puffinus tenuirostris*) from South Australia and Tasmania have been recovered in north Pacific waters. One hundred and twenty-six young Giant Petrels (*Macronectes giganteus*) from Heard and Macquarie Islands have made long circumpolar journeys and almost reached the Equator. **W.** Two Wandering Albatrosses (*Diomedea exulans*), caught off the New South Wales coast in winter, have been found in colonies at South Georgia and Marion Island. **B.** Two Black-browed Albatrosses (*Diomedea melanophris*) from Heard and Macquarie Islands reached New South Wales waters. **S.** Six Southern Skuas (*Catharacta skua lonnbergi*) from Macquarie Island winter as far north as Queensland. **M.** A McCormick's Skua (*C. s. maccormicki*) from Wilkes Station was found on Yorke Peninsula, South Australia.



Trans-Tasman movements of birds, as shown by banding: 155 gannets (*Sula serrator*) (unbroken arrows), banded (G) as nestlings in New Zealand, have been recovered around the eastern and southern coasts of Australia from northern Queensland to the south of Western Australia. Most are first-year birds, but the oldest was in its fifth year. Four young gannets, banded at Cat Island, Tasmania, were recovered in their fourth winter near Eden, N.S.W. Twelve White-fronted Terns (*Sterna striata*) (dotted arrows), banded as nestlings (T) in New Zealand, have been found on the Australian coast from the Sydney region to Lorne, Vic. Two Black Ducks (*Anas superciliosa*) (D) have reached Australia from New Zealand; one coming from Blenheim to Menindee was 6 years old, the other, from Auckland to Newcastle, 3 years.

of Wandering Albatrosses (*Diomedea exulans*) breeds every second year at the same site; J. B. Hood trapped a two-year-old Fairy Tern (*Sterna nereis*) on its nest only 300 yards from its birthplace; and R. A. Tilt found a one-year-old Yellow-tailed Thornbill (*Acanthiza chrysorrhoa*) nesting in the tree in which it was born.

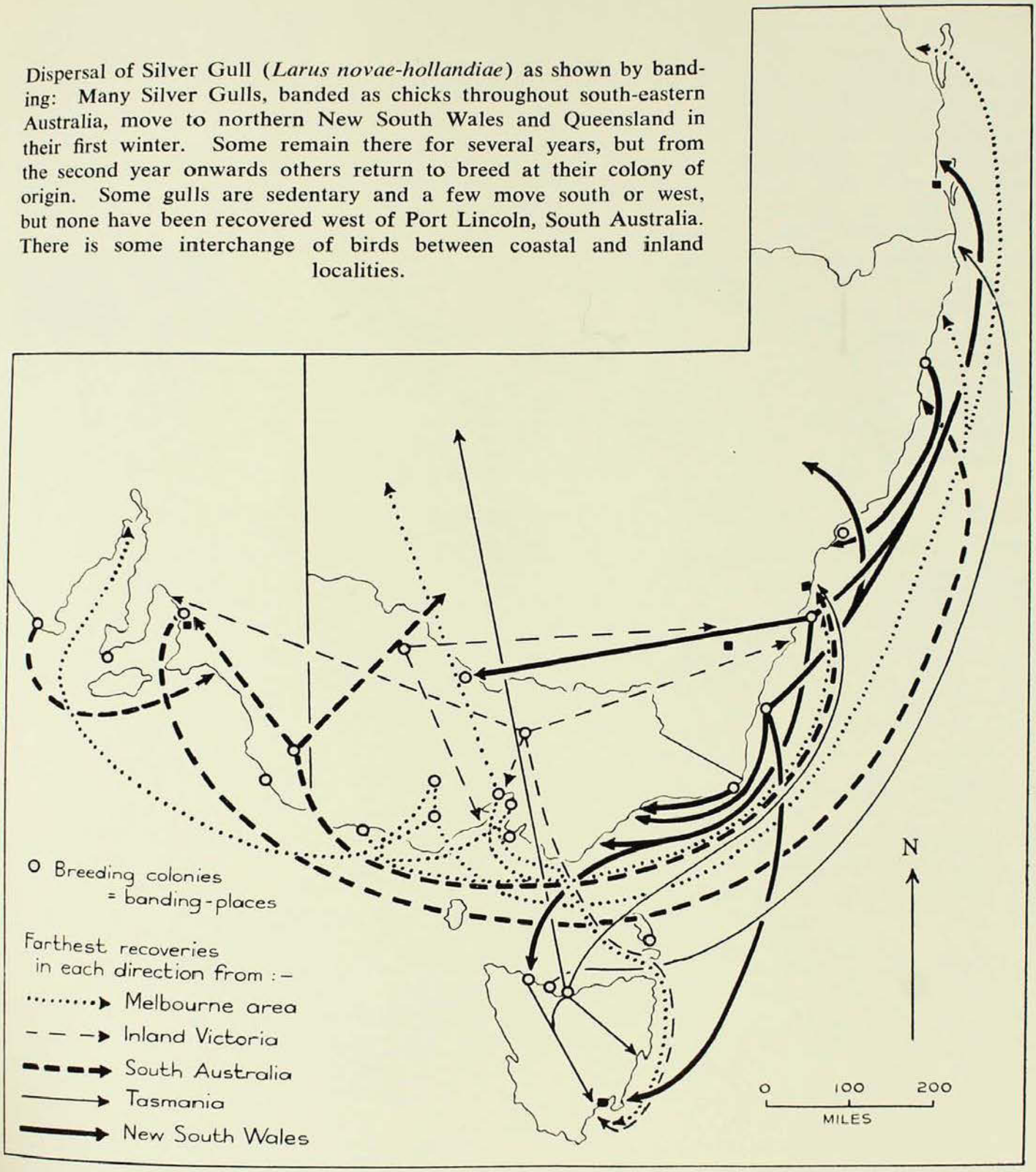
The Scheme is yet young to consider longevity records, but these are on the way, as shown by the magpie cited above and by J. B. Hood's adult White-plumed Honeyeater (*Meliphaga penicillata*), banded in April, 1956, and re-trapped nine times in all seasons at the same place up to April, 1959.

Bird Migrations

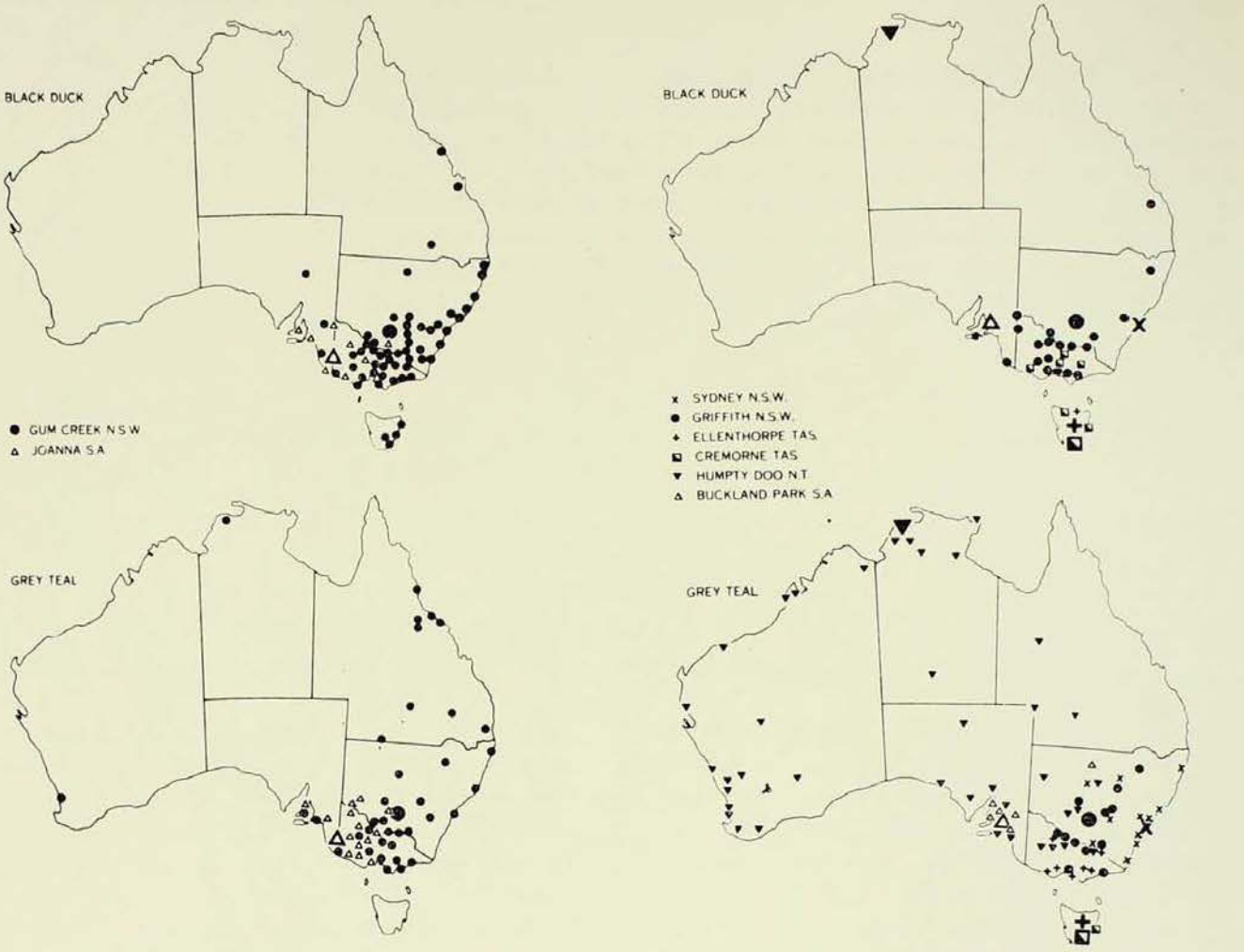
Data on bird migrations and dispersal are the expected fruits of a banding scheme, and the results of this nature to date are encouraging. On the global scale there are the extensive movements around the Southern Ocean and into warmer seas of young Giant Petrels (*Macronectes giganteus*), banded mainly by D. P. Sweetensen at Heard Island, and by M. Taylor, S. E. Csordas, K. Keith and M. P. Hines at Macquarie Island. Recent recoveries at South Georgia and Marion Island of Wandering Albatrosses, banded at sea off the New South Wales coast by J. D. Gibson and A. R. Sefton at Thirroul and by S. G. Lane, C. B. Campion, M. D. Murray and others near Sydney, augur well for the future of this project. Confirmation has been obtained of the transequatorial migration of the Short-tailed Shearwater, 25,034 of which have now been banded by D. L. Serventy in Tasmania and South Australia. D. Macdonald and R. H. Green succeeded, after two unsuccessful attempts, in landing on Albatross Rock in Bass Strait and banding over 300 young White-capped Albatrosses (*Diomedea cauta*), a feat that should be rewarded by some interesting results. Likewise, the successful trapping and banding of 925 waders by D. L. Serventy and others must lead to more recoveries of Australian bands in the northern hemisphere. Trans-Tasman migration by Gannets (*Sula serrator*), White-fronted Terns (*Sterna striata*) and two Black Ducks (*Anas superciliosa*) from New Zealand has been one-way traffic to date, but a banded Crested Tern (*Sterna bergii*) seen in the South Island was almost certainly of Australian origin.

When the Scheme was launched in 1953 Australian ornithologists had little experience of trapping and banding birds, and few people were aware of the significance of bands on wild birds. In order to train banders and demonstrate the value of co-operative effort, as well as to test the re-

Dispersal of Silver Gull (*Larus novae-hollandiae*) as shown by banding: Many Silver Gulls, banded as chicks throughout south-eastern Australia, move to northern New South Wales and Queensland in their first winter. Some remain there for several years, but from the second year onwards others return to breed at their colony of origin. Some gulls are sedentary and a few move south or west, but none have been recovered west of Port Lincoln, South Australia. There is some interchange of birds between coastal and inland localities.



covery rate, the author organized the banding of large numbers of young Silver Gulls (*Larus novae-hollandiae*) and Crested Terns. The former species, with nearly 38,000 birds banded, easily tops the list, and the number of Crested Terns banded is almost 11,000; the numbers recovered are over 900 and 400 respectively. This would not have been possible without the co-operation of M. D. Murray in New South Wales, A. G. Brown and P. Reilly in Victoria, R. H. Green and D. Macdonald in Tasmania, and the late W. C. Johnston and J. B. Hood in South Australia—to name only the more prolific banders of gulls and terns.



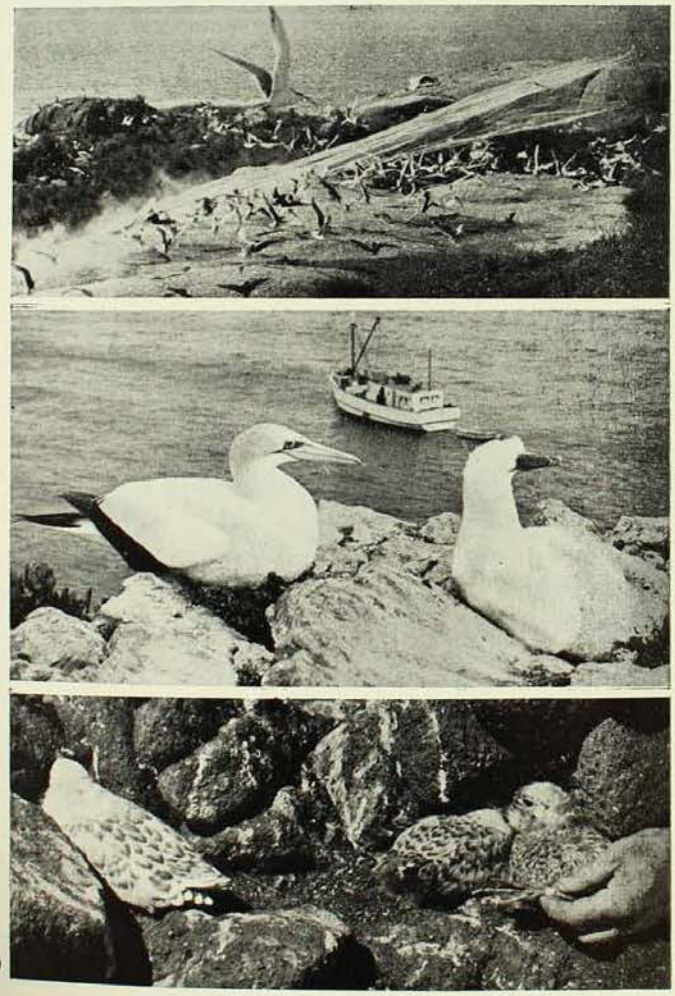
(*a*) Dispersal from breeding-places (*b*) Dispersal from concentration areas

Movements of Black Duck (*Anas superciliosa*) and Grey Teal (*Anas gibberifrons*) throughout Australia during 1957 and early 1958: Extensive breeding of ducks during 1955 and 1956 was followed by drought conditions throughout inland, and finally coastal, regions. Black Duck and Grey Teal banded at two breeding-places (*a*) concentrated on permanent local swamps and also dispersed farther afield to wetter coastal areas. Grey Teal moved farthest and reached all coasts, including Northern Territory and Western Australia. As these coastal refuge areas (*b*) dried up the ducks in them were banded, and further widespread dispersal, especially by Grey Teal, occurred. They performed transcontinental journeys to all parts of the Australian mainland in search of suitable water conditions, and the scatter of Grey Teal banded at Darwin is particularly impressive.

Silver Gull's Northward Movement

The necessity for banding in order to establish movements within the geographical area permanently occupied by a species is well illustrated by these results. The Silver Gull has shown, in the main, an orderly northward movement in winter and an almost complete tendency of the young to breed at their natal colonies, even when this involves passing through others, as in the case of Montagu Island gulls returning from winter quarters north of Five Islands. Crested Terns, on the other hand, disperse more indiscriminately and even adults may change their breeding location from year to year. The extensive duck-banding carried out by H. J. Frith and others reveals very erratic movements, and the comparative findings for different waterfowl species, especially the far-flung nomadism of the Grey Teal (*Anas gibberifrons*), are of

great scientific interest as well as being part of the essential foundation on which conservation of these sporting species must depend. Similar movements of Straw-necked Ibis (*Threskiornis spinicollis*) and White Ibis (*T. molucca*) have been shown; several banded by the author at the Macquarie Marshes in central New South Wales were speared by natives in Cape York and Arnhem Land, while one went south to Deniliquin, on the Murray River; a Straw-necked Ibis banded by K. G. Simpson at Port Fairy, Victoria, was found in Queensland, and others banded by P. J. Fuller and J. R. Ford north of Perth, Western Australia, have travelled several hundred miles north, sometimes in a few weeks. Members of the Bird Observers' Club, Melbourne, led by W. R. Wheeler, have banded 2,329 young White-faced Storm-petrels (*Pelagodroma marina*) at Mud Island, Port Phillip Bay.



Top: A rocket-net being shot over Crested Terns (*Sterna bergii*) and Silver Gulls (*Larus novae-hollandiae*) at Montagu Island, New South Wales. Centre: Gannet (*Sula serrator*) at Horuhoru, Hauraki Gulf, New Zealand. Bottom: Young Silver Gulls are not banded until well feathered, and, to avoid straying and attack by neighbours, they are not picked up.

Several isolated recoveries provide pointers to bird movements in Australia that can only be guessed at present. At Antill Ponds, Tasmania, R. H. Green banded a Swamp Harrier (*Circus approximans*), which reached the north-eastern corner of New South Wales, and a Starling (*Sturnus vulgaris*), which surprisingly turned up in a Brisbane garden within a month, and in October at that. An Eastern Silver-eye (*Zosterops lateralis*), recovered by a cat in Launceston, Tasmania, in January after being banded by S. G. Lane in Sydney the previous June, is the first proof of the suspected north-south migration of this species.

Trapping Methods

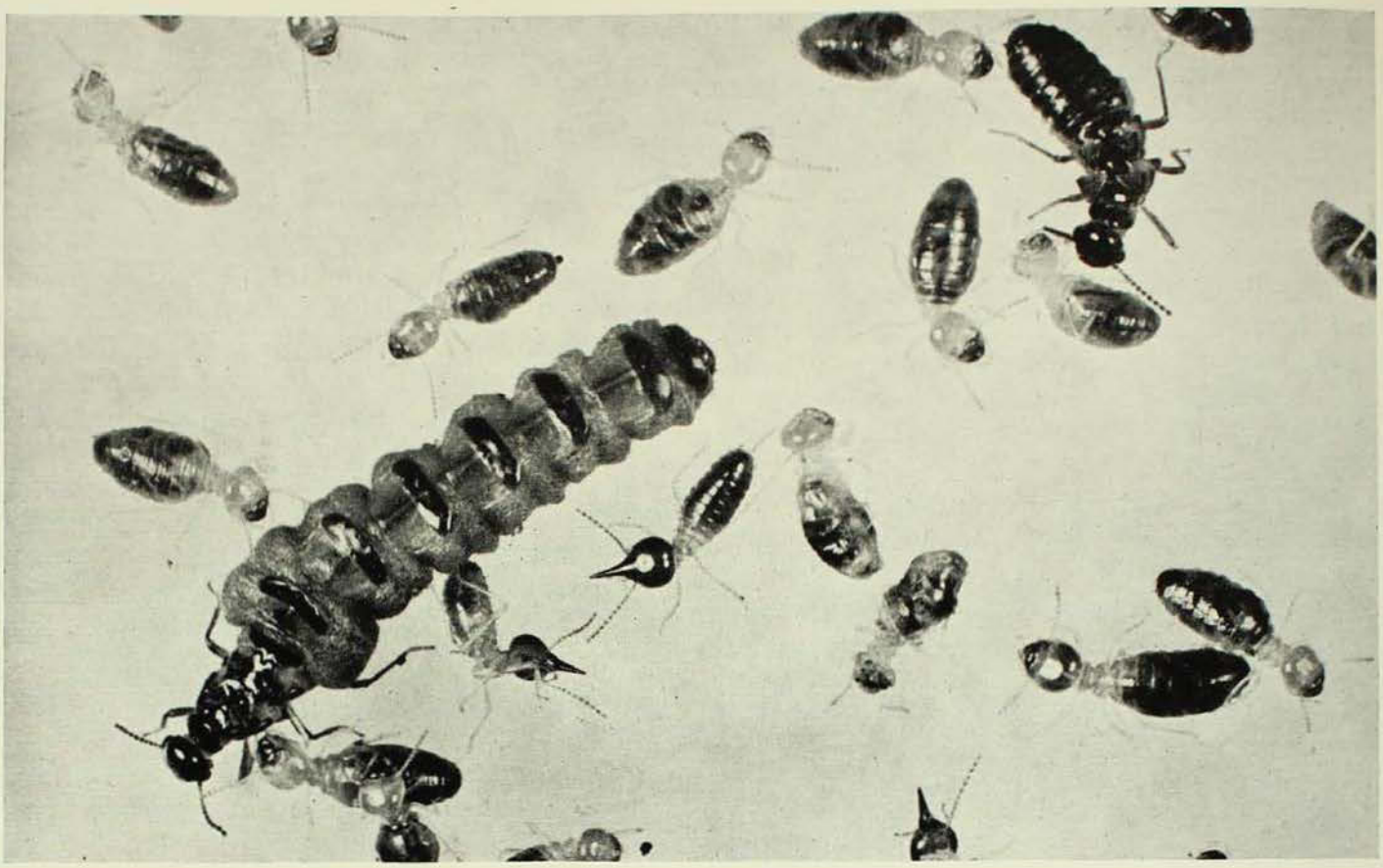
Trapping methods include hand nets, mist-nets, clap-nets, many varieties of wire-netting cages with simple funnel entrances or ingenious drop-doors, and even powerful rocket-nets carried by projectiles fired from mortars. Mist-netting with fine, almost invisible, black nylon nets stretched across flyways is becoming something of an art and is largely responsible for the more impressive totals of species and individuals by several keen banders, notably J. B. Hood, S. G. Lane and C. B. Campion, N. J. Favaloro, R. H. Green, and J. McKean. The last-named, with L. O'Connor, has recently extended the Scheme's operations to Lord Howe Island.

The Australian Bird-banding Scheme has already made a significant contribution to our knowledge of the movements and habits of many birds, and the widespread interest shown by the Australian public ensures that the increasing efforts of the ornithologists will be proportionately rewarded.

[*Maps and photos by Wildlife Survey Section, C.S.I.R.O.*]

Shark Attacks

Details of shark attacks in Australia have been compiled at the Australian Museum for a world-wide survey being made by the Smithsonian Institution, Washington, U.S.A. The survey will facilitate research into the reasons for shark attacks.



King, queen, workers and soldiers of *Nasutitermes fumigatus*. The soldiers protect the colony by ejecting, from their pear-shaped heads, a fluid which is toxic to potential invaders, such as ants.

Photo.—D. Wilson.

SOME ASPECTS OF THE LIFE OF THE TERMITE

By F. J. GAY

Division of Entomology, C.S.I.R.O., Canberra

TERMITES, or white ants as they are frequently called, are widespread throughout the tropical, sub-tropical and temperate regions of the world. Australia is no exception to this pattern, and, apart from the high alpine country in the south-eastern corner of the continent, termites are abundantly present in all States. To date more than 150 species have been described from the mainland, most of them occurring in northern Australia and the south-western corner of Western Australia.

The common name "white ants", which is applied to these insects, is misleading for they are seldom white and they constitute a separate and distinct order (Isoptera) from that in which the true ants occur (Hymenoptera). Although termites possess a social organisation which resembles that of the true ants in many ways, the morphological features of the order indicate a close affinity with the Orthoptera, and more specifically with the cockroaches. In fact the most primitive living termite, the Australian species *Mastotermes darwiniensis*, possesses a wing venation and wing shape which are characteristically blattoid (cockroach-like); in addition, this species is unique among termites in laying its eggs in capsules or pods, very reminiscent of cockroach oothecae (egg-cases).

There appears to be little doubt that cockroaches and termites arose from a common ancestral stock, and from the fossil record it seems that termites established themselves as a distinct group prior to the Tertiary period and possibly as early as the Permian. Since that time a rich and varied termite fauna has evolved, so that today there are more than 2,000 recorded living species throughout the world, all of which exhibit social organizations of varying degrees of complexity.

Caste System

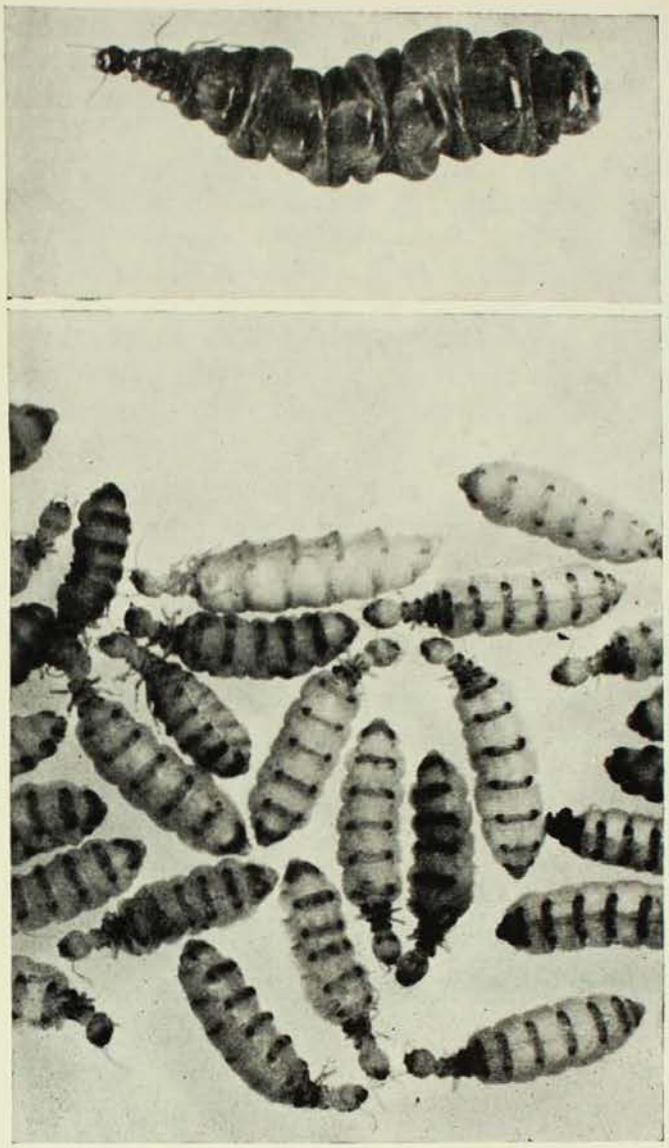
The basic feature of termite life is this development of social integration founded on a caste system, in which certain members of the colony group are specialized to perform particular tasks. Fundamentally, every termite colony consists of—

- A small reproductive group, generally a single male and female known as the primary king and queen, but occasionally many males and females which are referred to as substitute or neoteinic reproductives.

- The workers, which are of both sexes, and have non-functional reproductive organs. Their activities include building and repairing the nest, constructing tunnels or runways to food sources, feeding the king, queen, soldiers and immature forms, and tending the eggs.

- The soldiers, which also are of both sexes but with atrophied reproductive organs. The function of this caste is defensive, and is mainly concerned with guarding the nest or galleries against the invasion of such enemies as ants.

The first stage in the development of a new termite colony can be considered as beginning with a flight of winged males and females from an old-established colony. These colonizing flights usually take place just before or just after rain, thus ensuring moist conditions for colony foundation. After a relatively short flight (for termites are not strong fliers) the winged males and females settle on the ground and very soon shed their wings, which have fulfilled their dispersal function and are now merely an encumbrance. Males seek out a companion



A primary queen (above) and a group of substitute or neoteinic queens of *Coptotermes lacteus*.

Photo.—D. Wilson.

female, and are assisted in this by the female's habit of elevating the abdomen and emitting a scent which attracts the males. When a male has established contact with a female the pair moves off in tandem formation, with the female leading, to seek out a suitable site for the initial cell of the new colony. This usually consists of a piece of dead wood, partially buried or in contact with the soil. The pair proceed to excavate a small cell in the wood or in the soil adjacent and only when they are safely established within this cell does mating take place.

The first eggs of the young royal pair are deposited after an interval of one to two weeks, and hatching begins about four or

five weeks later. Throughout the incubation period the eggs are cleaned and restacked regularly because the high humidity within the cell favours the growth of fungi which can adversely affect egg development. The necessity for this egg cleaning and stacking persists throughout the life of the colony, and becomes a task of some magnitude when it is realized that in mature colonies of some Australian species there may be upwards of 100,000 eggs present at one time.

The initial batch of eggs is always small, and rarely exceeds 20. These are laid over a period of two or three weeks, and oviposition then ceases for several months. As the young termites hatch they are fed by the king and queen, but when they reach maturity they feed themselves; ultimately, they take over the task of feeding the royal pair and extending the size of the initial cell to accommodate their activities.

Colony growth appears to be quite slow in the Australian species that have been studied. Three years after founding, the population of incipient colonies may not be more than 80-100 individuals, and it is probably almost 20 years before the colony attains maturity, at which time it may contain up to two million individuals.

The reproductive activity of the queen changes from the original condition, in which she lays a small batch of eggs perhaps twice a year, to an eventual one in which she lays almost continuously and may produce as many as 3,000 eggs a day. This remarkable increase in egg production is accompanied by a marked morphological change in the queen's abdomen, which becomes greatly enlarged to accommodate the enormous ovaries. She becomes very restricted in her movements within the colony, and is virtually an egg-producting machine, continually tended by workers who groom her body, supply her with food and remove the eggs to storage chambers as fast as they are laid. Throughout the reproductive life of the queen she is periodically fertilized by the king, who remains in close association with her.

Reference has already been made to the possible occurrence of a group of substitute or neoteinic reproductives in a termite colony. These forms, which are developed from immature reproductive nymphs within a colony when the primary reproductives die or are killed, have a much lower reproductive potential than the primary forms. In order to maintain the colony population at normal level several neoteinics are produced at the one time, and in at least one species (*Amitermes laurensis*) several hundred neoteinic queens may be present in a single nest. Not all of our Australian species are capable of producing neoteinic reproductives, but, in those species which are, neoteny confers potential immortality on each colony. Where neoteny does not occur, the life of the colony is determined by the life of the primary king or queen, for when either one of this pair dies the colony will gradually decline and eventually die. Nevertheless, the life of such colonies is surprisingly long, and studies of *Nasutitermes exitiosus* suggests that kings and queens of this species probably live 50 years. The longevity of other castes is also unexpectedly great when compared with that of other and seemingly hardier insects. Workers and soldiers of *N. exitiosus* have been kept alive in the laboratory for more than two years, and the same castes of *Coptotermes acinaciformis* for just over four years.

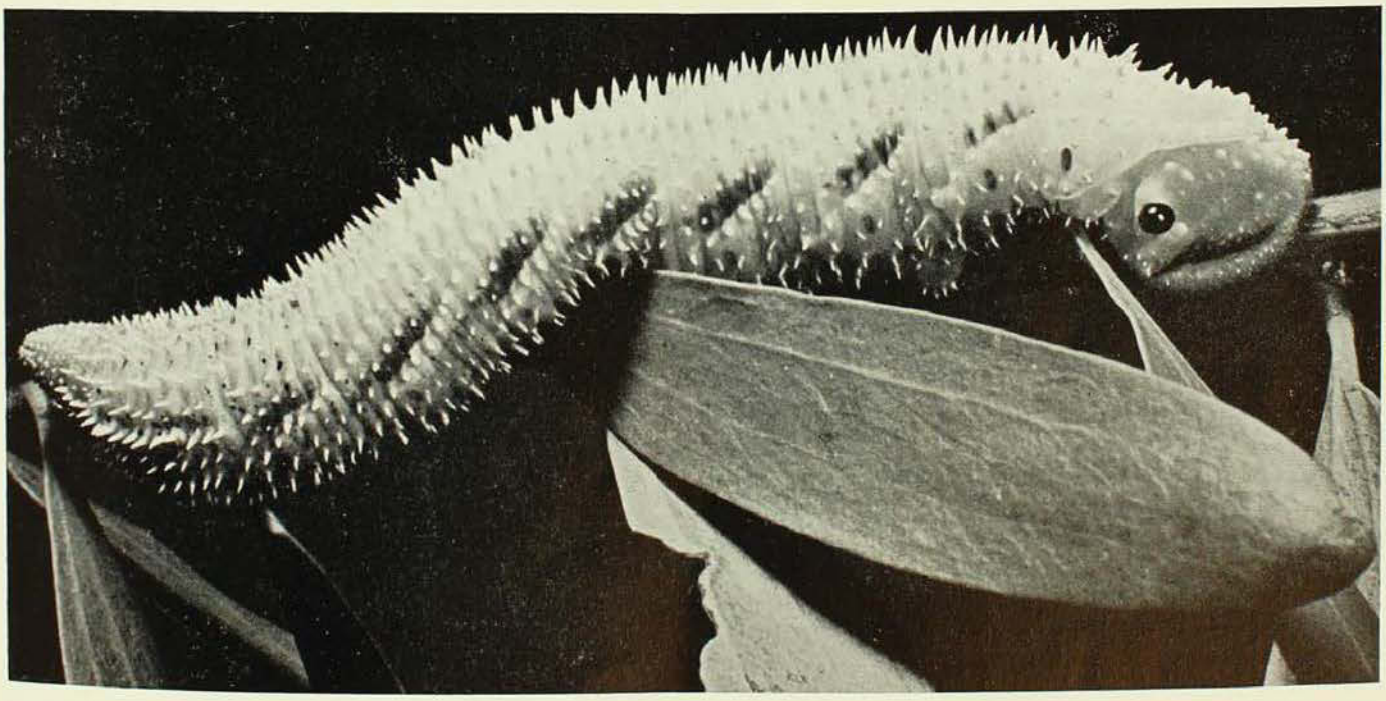
Subterranean Chambers

While termites may nest in systems of subterranean chambers and galleries or in the branches and trunks of trees, the best-known nests are the conspicuous and often characteristic termitaria which they build above ground. These structures, which are built of a mixture of earthy and woody materials, vary from species to species in the relative amounts of the two components and in their internal organization. Broadly speaking, the termitarium is an aggregation of chambers and passages enclosed by a continuous outer covering of earthy, clayey or carton-like material. It is the vital centre of the colony, housing the king and queen, eggs, immature stages and the winged reproductives prior to their colonizing flight. Daily and seasonal fluctuations in environmental temperature are buffered by the termitarium, and the resulting equable temperature within the mound, together with a constant high humidity, produce ideal conditions for the development of the eggs and immature stages.

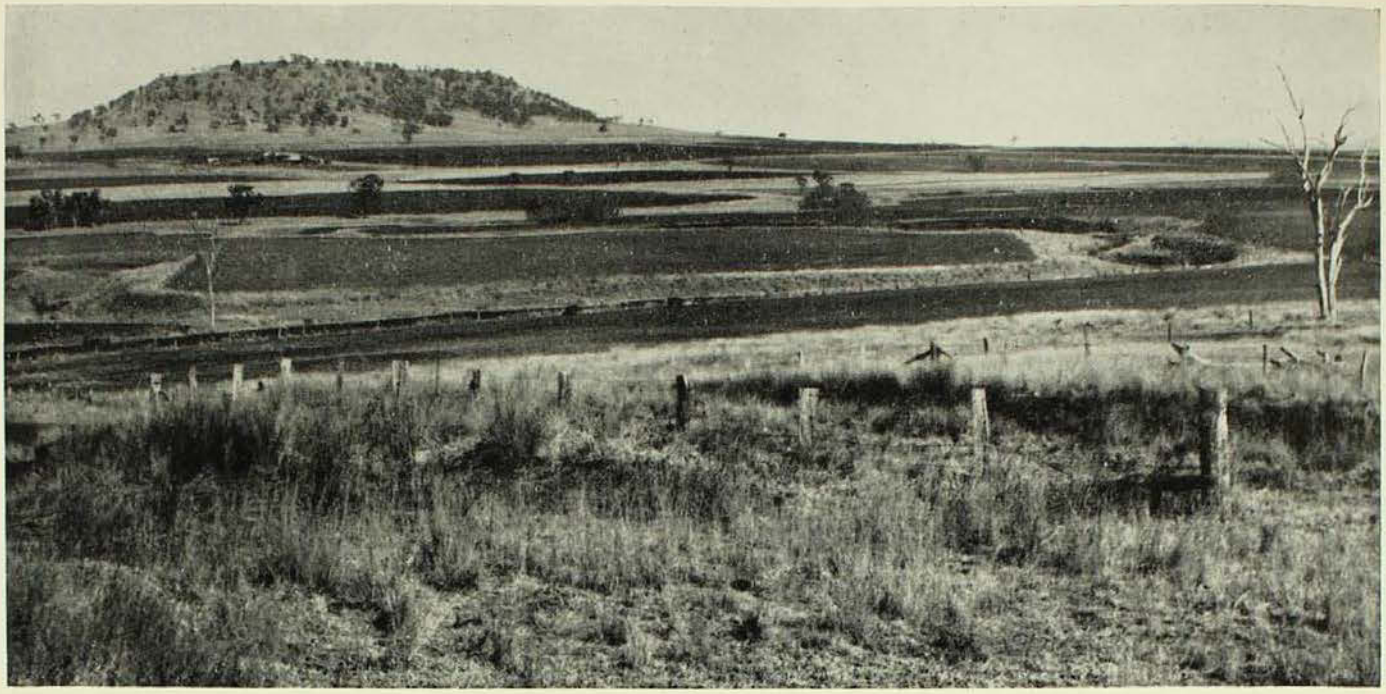
Associated with the termitarium there is normally a complex system of subterranean galleries which radiate to food sources in the vicinity. These galleries, which may be from a few inches to more than two feet down in the soil, sometimes extend up to 100 yards from the nest, and the entire gallery system of a colony may exploit all the food resources over an area of two acres.

The food of termites is normally cellulosic materials such as wood or grass, and foraging parties attack logs, stumps, standing trees, grass and shrubs to obtain it. Under natural conditions termites play an important role in returning plant material to the soil and in accelerating the breakdown of vegetable debris. The importance which these insects have assumed as a destructive agency of timber in service is largely the result of man's activities in concentrating large amounts of suitable food material (*e.g.*, constructional timber, poles, posts, etc.) within the feeding ranges of the countless colonies which are always waiting to exploit new food sources.

THE "DOUBLE-HEADED" CATERPILLAR



This striking photo shows the larva of the Geebung Hawk Moth (*Coequosa triangularis*), which occurs in eastern Australia generally, and possibly in other parts as well. This caterpillar measures up to 5 in. long, and is buff or green in colour. It is sometimes called the double-headed caterpillar because the enlarged posterior end, with its pair of eye-like spots, resembles a head. The actual head (at the left of the picture) is much less conspicuous. The larva feeds on the leaves and fruits of the Geebung (*Persoonia lanceolata*), on which it is here shown, and on wattles (*Acacia*). The mature moth is a handsome insect with grey, brown and orange wings, and a wing expanse of about 6 in. It has the strong, swift flight characteristic of other hawk moths.



Looking across the valley of King Creek, with a flat-topped basalt hill in the background. This scene is typical of the eastern Darling Downs, Queensland.

Photo.—The Queensland Museum.

A Million Years on the Darling Downs

By J. T. WOODS

Of the Geological Survey of Queensland

SOME 80 or 90 miles by road west of Brisbane one leaves the coastal lowlands and ascends the steep scarp of the Main Dividing Range. Westward the gradient is gentle, and the descent is made through valleys widening between flat-topped hills to gently rolling country—the Darling Downs, which merge with the western plains of the State. Much of the area lies within the watershed of the Condamine River, and is part of the vast Murray-Darling basin of eastern Australia.

About one million acres of the Downs are cultivated, and they comprise some of the richest agricultural land in Australia. Grain crops, chiefly wheat, are dry-farmed, as most of the annual rainfall of nearly 30 inches is received in late summer and not in the growing season between May and December. Nevertheless, wheat yields of over 20 bushels per acre tell their own story of soil fertility. Dairy cattle receive supplementary grazing on fodder crops, and in the western part of the region, with poorer soils and lower rainfall, beef cattle and sheep are important.

For the source of these fertile black and red-brown agricultural soils one must look to the rocks of the hills of the eastern Downs. They form the dissected remnants of a plateau of the volcanic rock basalt erupted during the Tertiary period, probably over ten million years ago. With the progressive erosion of this plateau large thicknesses of alluvia have been deposited in the valleys.

The Darling Downs have interested fossil-hunters for over a century, and many bones of extinct marsupials and other animals have been found in the old alluvia exposed in the banks of creeks and gullies. Some of the earliest pastoral settlers of the 1840's had attended universities in England and Scotland, and realized the significance of the strange bones found on their extensive holdings. Within a few years fossils from the Downs came into the hands of Sir Richard

Owen, the famous anatomist and vertebrate palaeontologist in London. Owen had a few years previously described the first fossil marsupials found in Australia, from the Wellington Caves, west of Sydney.

Pleistocene Fossils

The fossils from the eastern Downs are all considered to be of Pleistocene age—that is, the animals are believed to have lived within the last million years. Many of them are the remains of plant-eating marsupials, and their abundance shows that large populations flourished in this fertile land. The rapid deposition of alluvium in times of flood ensured the burial and preservation of the bones, but the vigorous stream action scattered the skeletons so that usually only isolated bones or fragments of bones are found. They are well preserved as a rule, but occasionally an elaborate procedure, involving hardening with shellac and bandaging with burlap strips soaked in plaster of Paris, is necessary to ensure their successful excavation. Some specimens when found have a hard coating of lime carbonate which also forms the abundant light-coloured soil nodules of the area. This matrix is difficult to remove mechanically, but in recent years dilute acetic acid has been successfully used to dissolve or soften it, so that fine details of bones and teeth may be studied.

The most common fossils are extinct kangaroos of many species. Some were related to the living grey and red kangaroos, but exceeded them in size; ohers, equally large, of the genus *Protemnodon*, were more closely related to living wallabies. More interesting, perhaps, are the short-faced kangaroos, grouped as *Procoptdon*, which had high, heavy skulls and strongly ridged molar teeth. They have no living relatives, and it is believed that they may have fed on herbage rather than on grass.

Giant Marsupial

The giant quadrupedal marsupial, *Diprotodon*, which is better known than most of its contemporaries because of skeletons from Lake Callabonna in eastern South Australia, appears to have existed in numbers on the Downs. Smaller relatives, *Nototherium* and *Euowenia*, each about the size of a large Queensland bullock, were not as common as the rhinoceros-sized *Diprotodon*. All these animals are frequently, but incorrectly, referred to as "giant wombats"; they belong to a distinct marsupial family. *Palorchestes*, which was regarded as a gigantic kangaroo, also belongs to this family. It was much smaller and more lightly built than the other forms, and its skull structure shows that, unlike its more robust relatives, it grazed rather than browsed on herbage.

Wombats were on the Downs in variety. Gigantism, almost universally apparent in Pleistocene mammals, had no exception there. *Phascolonus* reached a length of about 5 ft.; other species, more closely related to living forms, exceeded them in size. One locality on King Creek is rich in these fossils. The remains of three individuals, including one nearly complete skeleton, have

A broken and crushed skull of *Euryzygoma*, a bullock-sized member of the *Diprotodon* family, in the course of excavation at Chinchilla. The large lateral bony projection of the upper jaw, which gave the skull such great width, is seen just above the foot-rule.

Photo.—The Queensland Museum.

been recovered there in recent years. One may conjecture that quickly-rising flood-waters trapped the animals in their burrows.

Of the carnivorous marsupials of those times, the most fearsome must have been *Thylacoleo*, a jaguar-sized animal with strong jaws equipped with massive shearing teeth. No doubt it found ready prey in the slow-moving giant marsupials and their young. Also represented were extinct species of the marsupial wolf *Thylacinus* and the marsupial devil *Sarcophilus;* both are closely related to those species which have survived in Tasmania to recent times.

The smaller marsupials, both herbivores and carnivores, are rare as fossils in the deposits of the Darling Downs. Their general forest habitat and small size reduced their chances of preservation in the stream deposits of the valleys and plains.

15 ft. Lizard

The predators and scavengers among the marsupials had strong and large competitors in the reptiles. Imagine a "goanna" 15 ft. in length! This giant varanid lizard, *Megalania*, is known only from fragments, but the estimate of its length will probably prove to be conservative. *Pallimnarchus*, a heavily-built freshwater crocodile, may have been larger than the lizard. More grotesque, but perhaps with a more gentle way of life, was *Meiolania*, a horned tortoise with a heavily-armoured skull over 18 in. in width and a tail sheath to match. Only one specimen has been found in Queensland, but a related species is known from New South Wales and Lord Howe Island.

In southern Australia it has been established that the early Aborigines co-existed with some of the extinct marsupials. Indeed, they may have contributed to the extinction of some of the giant forms. However, similar evidence has not been found so far on the Darling Downs. A crushed and mineralized Aboriginal skull was found at Talgai many years ago. It is believed to have been recovered from the brown clays, which commonly underlie the black soils. Most of the fossil marsupials are found in the brown clays in other parts of the Downs, but none has been collected from Talgai.

Skull's Great Breadth

The fossils collected in the early days and studied by Sir Richard Owen came, with few exceptions, from the eastern Downs, but when Mr. C. W. De Vis, Curator of the Queensland Museum at the time, became interested in these fossils in the 1880's, an able collector in the person of Mr. Kendal Broadbent obtained many specimens from near Chinchilla, to the north-west. It has lately been realized that the fossils from this area show important differences from the Pleistocene forms of the eastern Downs. They appear to be older, and may extend back to Pliocene times, over one million years ago.

The most remarkable of the marsupials from Chinchilla is one studied by Mr. H. A. Longman, late Director of the Queensland Museum, and named by him *Euryzygoma*. This was another bullock-sized member of the *Diprotodon* family. It must have been of remarkable appearance, for lateral bony processes of the upper jaw were so developed that the width of the skull exceeded its length. Fragments of crocodiles and tortoises are more common at Chinchilla than in the deposits to the south-east.

Much more collecting and research need to be done before the full story of these past inhabitants of the Darling Downs can be told, and even then it will only be a fragment of the history of the marsupials which thrived and diversified in their long period of isolation, probably over 60 million years, in our continent. One thing stands out, however, from even a casual study of these fossils—they have left a more complete record than many of their descendants which roamed this land before the coming of white settlers a little over 100 years ago.

The Possum in New Zealand

By C. H. TYNDALE-BISCOE
Zoology Department, University of Western Australia

THE possum in New Zealand is the same species as the brush-tailed possum of Australia (*Trichosurus vulpecula*). It was, in fact, introduced to New Zealand from Australia intentionally as a desirable fur-bearing animal. Today in its new home it is considered to be one of New Zealand's most serious pests, and wholesale destruction of it is being attempted; in Australia, however, it is a protected species and, though widespread, is relatively harmless. Even in Tasmania and Victoria, where it is most abundant, it is not destructive because forests and mammals have evolved together, but the New Zealand forests, having evolved without mammals, are more vulnerable.

This contrast between the possum in its original home and its new one well illustrates the interaction of a potentially adaptable species and a naturally protected, empty environment. Recent research both of the forests and of the biology of the possum has helped us to understand this interaction in New Zealand.

The Forest Environment

New Zealand has been an island since the evolution of mammals. Consequently, its only native mammals are two bats and the seals around the coasts. Marsupials, which entered Australia, never crossed the Tasman Sea, and the forests which clothed New Zealand when the Polynesians landed harboured no browsing animals except the Moas, and those large flightless birds were already dying out. Therefore many species of plants in the forests had evolved without any particular means of protection against the effects of animal-browsing.

Furthermore, browsing animals in other countries have often accelerated changes from one forest type to another more suitable to changed climatic conditions. In

The brush-tailed possum.

Photo.—H. Burrell.

New Zealand two types of forest predominate—the podocarp rain forest and the beech forest. The former prefers a warm, moist climate, the latter a cooler drier one. Holloway suggests that the change to a cooler climate throughout the world during the last 500 years has in New Zealand favoured the beech forest at the expense of the podocarp forest. Slowly the beech forests have been invading, and becoming established in, country formerly occupied by rain forest, and where rain forest remains today it often consists of mature trees with little or no regeneration. Because of the absence of mammals the changes have been slower then elsewhere, and forests have persisted which are out of phase with the present climate, making them particularly vunerable to any disturbance.

Into this vulnerable and slowly changing environment during the past century have come a host of mammals, evolved in the severe environments of Europe, Asia and Australia. Since Captain Cook liberated pig and goat in 1777, 50 species of mammals have been introduced to New Zealand and 29 have become established as wild populations. The settlers who introduced them, together with birds and plants, were unaware of the effect this would have on New

Zealand. As G. M. Thomson wrote, "No doubt some utilitarian ideas were mingled with those of romance and early association but the latter were in the ascendant. They recked not of new conditions, they knew nothing of the possibilities possessed by species of plants and animals which in the severe struggle for existence of their northern home had reached a more or less stable position." Common in the forest today are deer, goat and pig on the ground and possums in the canopy, but the process of invasion is not yet complete and there are still quite large tracts of forest lacking one or more of these species. However, in some areas which have had wild ungulates (hoofed animals) for a century wholesale mortality of the forest can be seen and the forest floor is denuded. The animals are blamed for this, but the thesis here presented is that they have been catalysts, accelerating a change inherent in the forests before their introduction.

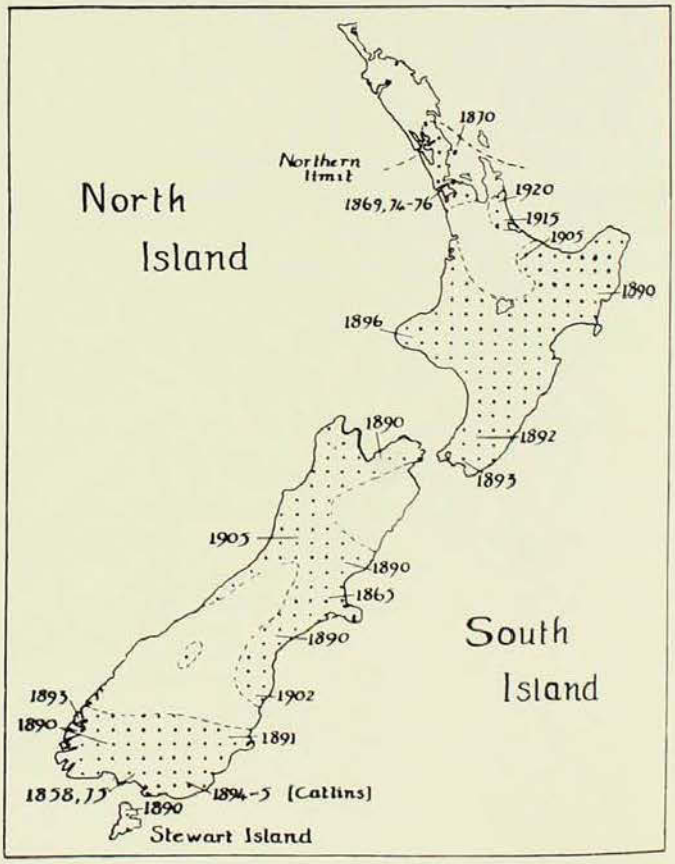
The Spread Of The Possum

Considering the possum itself: what in its biology has enabled it to exploit the New Zealand environment so quickly and effectively? If we assess a species' success by its numerical abundance and wide distribution the possum has been very successful in New Zealand. The population began from 600 animals, severally captured in Victoria, Tasmania and, to a lesser extent, New South Wales, from 1858 to 1920, and liberated in four areas of both the North Island and the South Island, and on Stewart Island. During and after this period, the spread of possums continued by introductions of New Zealand-bred stock to new areas, so that by 1946 they were recorded from nearly every part of the land and the Wildlife Branch of the Internal Affairs Department estimated the total population at 23 million. However, some parts were then still free of possums, and it is precisely these parts that never had an introduction from Australia. In fact, a comparison of the original liberation points and the 1946 distribution (see map) is instructive in showing the close connection between the two, and suggests that the species' natural powers of spread have been considerably assisted by man. Three main factors have determined the success of the possum—its reproductive potential, its average life-span and its powers of dispersal and invasion.

Reproductive Potential

The male possum attains sexual maturity during the second year of life, and most evidence suggests that thereafter it produces spermatozoa and is capable of fertilising the female throughout its life. The male contribution to the reproductive potential is fulfilled, therefore, if there are sufficient males to fertilise every available female on heat. Results in Australia and New Zealand indicate that males outnumber females among the immature animals, females outnumber males among the oldest animals and there is parity of the sexes among the young adults.

Like the male, the female can attain sexual maturity in the second year of life, the criterion of this being the production of ripe



The distribution of possums in New Zealand in 1946 (indicated by the dotted areas) and the sites and dates of the original liberations of possums brought from Australia.

Compiled from K. A. Wodzicki, "Introduced Mammals of New Zealand", 1950.

eggs from the ovaries. In the absence of the male, an adult female possum will produce one egg (very rarely two) on the average every 24 days, except during the non-breeding period, which in New Zealand extends from December to February. In the wild condition she will accept the male at the time the egg is shed into the oviduct, when she is said to be in oestrus. Fertilisation probably occurs within 24 hours of copulation and development proceeds in the uterus.

The young is born, on the average, 17 days after copulation, and immediately crawls by its own efforts into the pouch and becomes attached to a teat; the mother, meanwhile sits on her tail, hind limbs apart. Like other marsupials, the new-born possum is remarkably undeveloped except for the forelimbs armed with claws, which it uses to crawl through the mother's fur; its sense organs are undeveloped, as are its hind limbs. It remains continuously in the pouch for four months, then ventures out of the pouch for progressively longer periods until, after a further two months, it is too large to enter the pouch and, now fully-furred, rides on its mother's back.

Should the new-born joey fail to reach the pouch or be lost during pouch life, the mother will come into oestrus four to ten days later and can conceive again. Furthermore, in some instances in New Zealand and Australia, oestrus may occur after the first joey leaves the pouch and a second conception for the year result; females have been caught in November with a small joey in the pouch and a fully-furred young one riding on the back.

Adult females in New Zealand first come into oestrus during March and April and in most cases conception takes place then, for most births occur in April and May. In one area of the South Island 88 per cent. of the females were pregnant or already had a small joey in the pouch by early May, and three months later at the same place 89 per cent. had joeys in the pouch, indicating a very high survival of joeys during pouch life. Some females produce second joeys in September or October, as mentioned above; these stay with their mothers through the anoestrous period to January or February. This second peak of breeding may depend on locality and the general conditions of the environment, but there is evidence for it in several places in New Zealand as well as New South Wales and Canberra.

So although the female only produces one young at a time, post-natal care is so effective that this one has a very good chance of surviving. Should it die in the pouch the mechanism of renewed oestrous cycles ensures that a second conceptus will replace it. Furthermore, a second offspring may be produced after the first has been reared, so that an adult female is potentially capable of producing two young per year.

Life Expectancy

No adequate criteria for determining the age of wild possums has yet been discovered, so we can only make a guess at the life expectancy. Captive possums have been known to live for 12 years in New Zealand, but this does not tell us how long the majority live in the wild. However, a sample of animals can be divided into those over and under about two years old on the basis of the fusion of the epiphyses to the ends of the long bones—a criterion used by anthropologists for finding the ages of primitive people and ancient human skeletons. In one sample of possums taken from a stable well-established population 80 per cent. had fused bones, indicating that animals over two years old were four times as numerous as those under two. This gives a rough figure of five to six years as the average life expectancy.

This applies to an undisturbed population, but where possums are regularly destroyed the proportion of young animals may be much higher. Here again is another mechanism of the species which allows rapid utilisation of a favourable environment. Where possums are being taken out of the population artificially or the area is not fully occupied, more young animals will survive than in an area fully occupied by old animals already established. In the latter circumstances the young animals must either die or escape to a new area less densely occupied. This, incidentally, poses a dilemma for conservationists, because human intervention by removing established animals enables young ones to replace them

so that the resulting population consists of younger and more vigorous animals than the initial population.

Movement and Dispersal

To understand the movements of wild animals it is essential to study a population the members of which have been individually marked and can be regularly recaptured or identified. This is a time-consuming job, and has only been attempted twice for the possum. From these somewhat inadequate studies it appears that adult possums establish an individual range and keep within it fairly permanently. Females have a much more restricted range than males, but will tolerate other possums in their area. The male, however, probably does not tolerate another adult male in his range, and the noisy nocturnal fights of possums may be the result of this. After the association with the mother has weakened, juveniles and young adults of both sexes probably move quite widely before establishing their own range and, as in other wild mammals, this is the age group that colonizes new country.

Interaction

The foregoing considerations show that the manner of reproduction, coupled with a fairly long life, enables the possum to increase in numbers rapidly, provided there is sufficient country to exploit. One recorded case illustrates this quite dramatically. Thirty-six possums were liberated in the Catlins district of the South Island—24 in 1894 and 12 in 1895. Eighteen years later, in 1912, 60,000 skins were taken from this district. Increase of this order is well within the potential of the species. However, where conditions are not so suitable or maximum numbers have been attained, checks to further increase become manifest; the second breeding peak in September fails and mortality among the newly-weaned is higher. Dispersal to new unoccupied country is probably effected by young animals at the periphery of the occupied area, but at the centre of the occupied area, where they cannot escape, the density may rise above the capacity of the forest, with harmful results. That spread has been from discrete centres of original liberation has been already mentioned, and is illustrated in the map.

Rain forests in New Zealand which have been occupied by deer, goats and possums for over 50 years show spectacular mortality in many places, undershrubs being absent and the large trees, dead or dying, standing in loose scree slopes. In these areas we see the final results of introducing two kinds of browsing mammals into inherently unstable forests. In their initial colonization both deer and possums probably increased so much that their numbers could not be adequately supported and, because natural dispersal is slow, their feeding behaviour tipped the scale against the forest and accelerated its demise.

It seems most unlikely that New Zealand forests can ever now be cleared of browsing mammals and, even if it were possible to do so, it is unlikely that the forests would recover their primeval condition. This implies that an attempt to reclothe the denuded country with forest types more in harmony with present climates and able to support mammals might be wiser than trying to exterminate animals which have demonstrated only too well their ability to live in New Zealand.