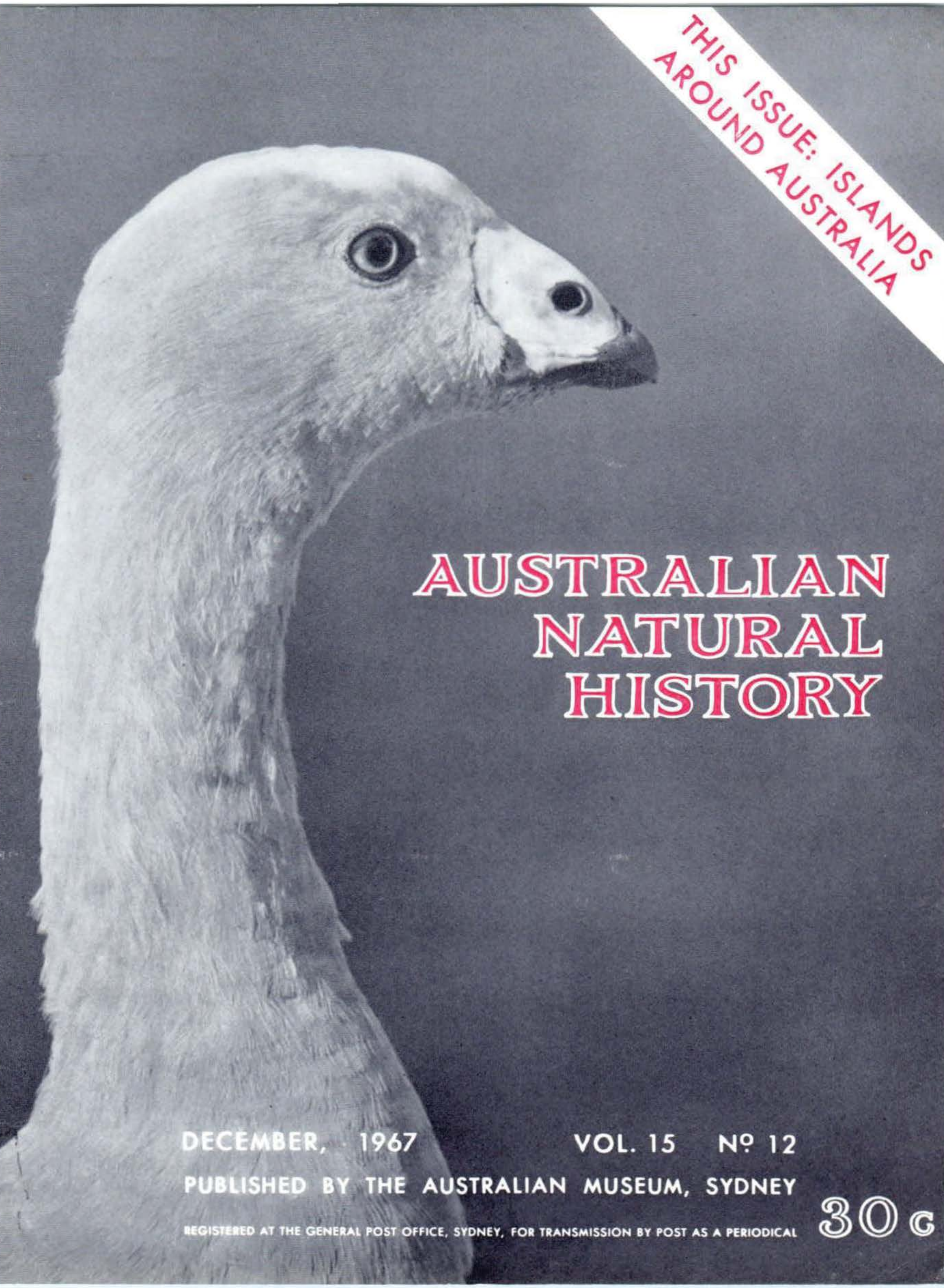

THIS ISSUE: ISLANDS AROUND AUSTRALIA

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This issue is devoted to the islands around Australia and their natural history. It contains twenty-eight extra pages.

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● FRONT COVER: The Cape Barren Goose (*Cereopsis novaehollandiae*) is found only in Australia. It nests on islands from southwestern Australia to Tasmania, and in summer is found on the coastal mainland. It is sometimes known as Pig Goose because of its pig-like grunt. Like most geese, it grazes on herbage. [Photo: C. V. Turner.] BACK COVER: Two young Australian Hair Seals (*Neophoca cinerea*) on Dangerous Reef, near Port Lincoln, Spencer Gulf, South Australia. [Photo: Howard Hughes.]

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The Challenge of Island Faunas

By ERNST MAYR

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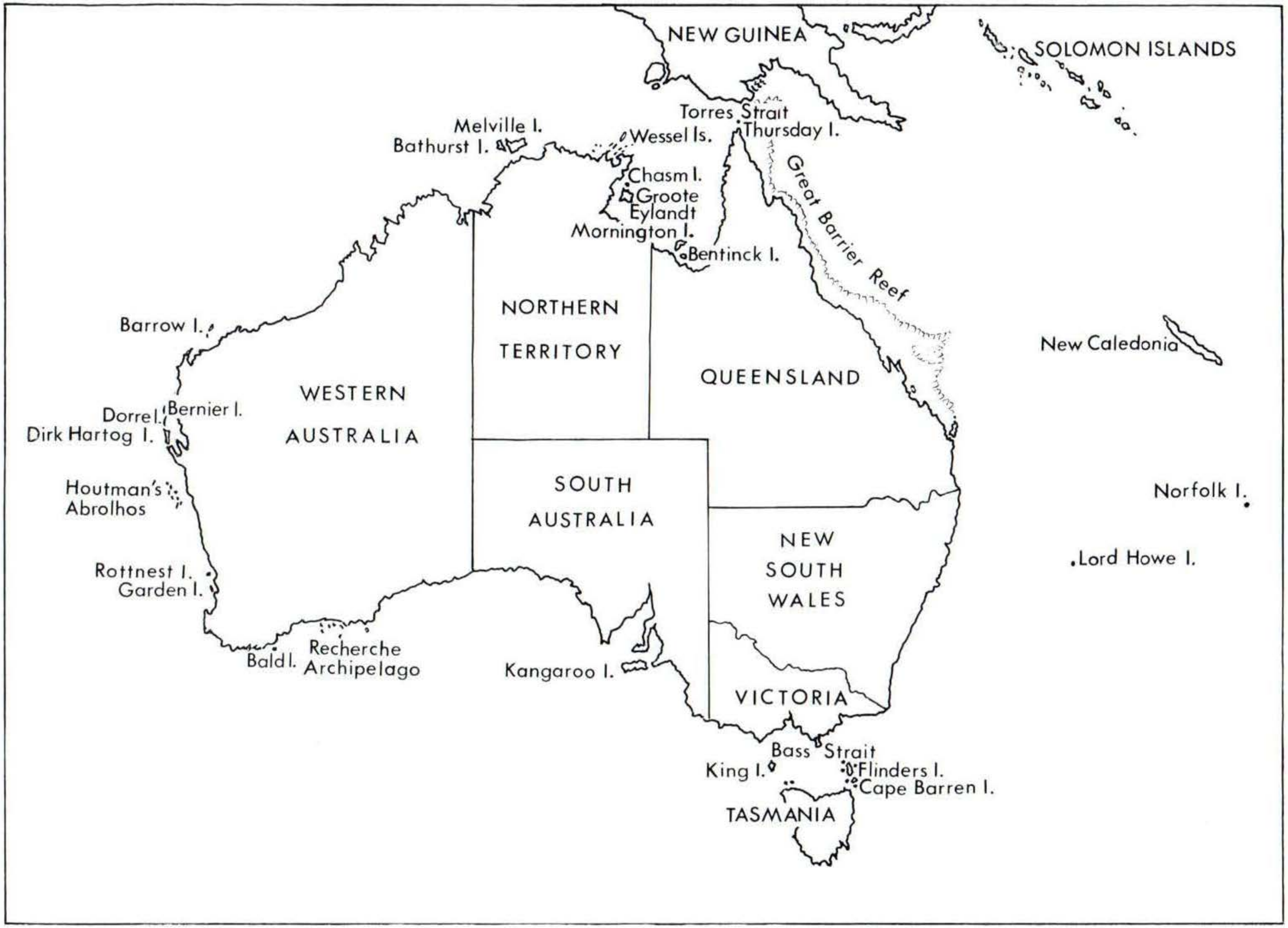
THE peculiarities of island faunas and floras have excited the imagination of naturalists from time immemorial. Everyone knows the familiar story of how Darwin, from a study of the fauna of the Galapagos, and Wallace of that of the Malay Archipelago, developed the theory of evolution through natural selection. The famous geologist L. von Buch had already, in 1825, proposed the theory of geographic speciation on the basis of studies of the Canary Islands.

What is this importance of islands for scientists? Why are island faunas such ideal material for research? The reason is that each island is a far more homogeneous universe than a rich continental mainland fauna. An island may demonstrate certain biological phenomena almost with the clarity of a test-tube experiment; indeed, every island biota is an experiment of its own. Each island is characterized by a different set of physical characteristics (size, altitude, etc.) and by a different composition of faunal and floral elements. It is as if nature had made a whole series of experiments and it was merely our task to analyse the results of such experiments.

Australia is sometimes referred to as the island-continent, and this label is indeed well deserved as far as the composition of the fauna is concerned. Nearly all of it (if not all of it) reached Australia by transoceanic colonization. The same is true for New Guinea, which, in the richness and uniqueness of its fauna, deserves to be labelled the Papuan continent. These two island-continents are the main source of the faunas of all the smaller islands in the Australian region.

I do not want to anticipate in this introduction to this issue of *Australian Natural History* what others will say in the ensuing articles. I will try not to become too specific in any of my discussions. However, I want to point out that the islands of the Australian region are of extraordinary diversity. First of all, there are small islands and archipelagos in Australia's coastal waters often still visible from the mainland. This includes the Recherche Archipelago and the Abrolhos in the southwest and an enormous number of small islands off the coasts of tropical Australia.



Australia and adjacent islands. [Map by Elvie Brown.]

A second class of islands is represented by such small, old, well-isolated islands as Lord Howe and Norfolk Islands. They have small distinctive faunas with considerable endemism mostly at the level of species and subspecies. There are a few large continental islands which were part of the mainland during various stages of the Pleistocene, like Tasmania, Kangaroo Island, Melville Island, and Groote Eylandt. Among these Tasmania has the most interesting fauna. And finally, there is a series of large islands at a considerable distance from Australia which, although in faunal connection with Australia, show also other faunal influences and have displayed much independence in their biogeographic history. I am referring to New Zealand, New Caledonia, and the islands of the Malayan and Papuan regions.

Peculiarities of island faunas

There is hardly a problem relating to island faunas which is not simultaneously of interest to the systematist, the evolutionist, the zoogeographer, and the ecologist. And this is why islands are of such vital concern to representatives of all four biological sciences. In view of this interlocking of subject matter it is possible only by a somewhat arbitrary division to arrange scientific problems relating to island faunas under specific headings. I shall do so for the sake of convenience, fully realizing that most of the treated subjects could be listed under all four headings.

Evolution

Perhaps the outstanding feature of all islands is that they are the exclusive home of certain species, the so-called endemic species of the particular island. These endemics are not always as different as the dodo of Mauritius or the kiwi of New Zealand; indeed in most cases they are only slightly different from the closest relative on the mainland or another nearby island. It is this observation which provided the evidence for the theory of geographic speciation. New species originate when a population becomes isolated on an island (or in an insular location on a mainland) and acquires during this period of spatial isolation those genetic differences that make it an independent biological species. Tasmania and the other islands around Australia abound in illustrations of this process.

Islands differ from each other in the percentage of endemic species. There is now great interest in determining the relative rôle of such factors as size of the island, richness of its fauna, distance from nearest mainland, etc. As a simple rule one can say that the larger an island and the more distant from a source of colonists the higher will be the percentage of endemics.

Islands are of great interest for the population geneticist. Colonization is usually effected by a small founder population which brought with it only a small portion of the total genetic variability of the parental species. Owing to the changed selection pressure in the new environment, this founder population may undergo a veritable genetic revolution and become appreciably different from the mainland population in a relatively short time. When this is correlated with an adaptive shift (see below), as is often the case, it may lead to greatly increased evolutionary changes.

To be a member of a founder population is, however, not an unmixed blessing. The depletion of genetic variability makes such populations quite vulnerable. They are usually unable to cope with sudden environmental changes and display a high rate of extinction. One of the most interesting findings of evolutionary biology is that the size of a population, or, as the geneticist puts it, the size of its gene pool, determines a great deal about its evolutionary potential. Vulnerability to extinction, rate of evolutionary change, and many other evolutionary phenomena are determined by the genetic variability of populations and this, in turn, by the size of the gene pool. Here is an exciting area of research that has just barely been initiated.

The vulnerability of island populations is abundantly documented in the Australian region. The extermination of most of the endemic island birds of Lord Howe Island by rats is a classical example. Extinction in Tasmania, New Zealand, and other areas are further illustrations. But there is now good evidence that this is merely an acceleration of a process that has been going on long before man appeared on the scene (see below under faunal turnover). Nevertheless, we have a responsibility to future generations not to contribute, as far as we can help it, to the extermination of interesting faunal elements on our islands. We must set aside natural reservations on these islands and we must do everything to prevent the introduction of alien faunal elements which either compete with the natives or carry disease organisms to which the native fauna is not immune.

Zoogeography

The students of the distribution of animals can be grouped into different schools. The regional zoogeographers are interested in subdividing the earth into different zoogeographic regions, the Palearctic region (for Eurasia), the Oriental region (from India to Malaysia), and so forth. Islands have always been a source of annoyance to the regional zoogeographer. The continental islands, like Tasmania, Japan, Ceylon, and Great Britain, are no problem. But where should one place New Zealand, Madagascar, or Hawaii? There are two reasons for the difficulties caused by these outlying islands. They are rich in peculiar elements (endemics and relicts) and they often contain a mixture of elements from two or more different continental faunas. New Caledonia as well as New Zealand, for instance, contain a mixture of tropical Papuan and of subtropical-temperate Australian elements. Even more distracting are the highly peculiar relict elements. The Tuatara (Sphenodon) of islands around New Zealand, the last remnant of a group of reptiles that was flourishing during the Mesozoic, can persist only because there are no effective predators where it occurs nor any serious competitors. The same is true for the kiwis and other New Zealand endemics, the kagu on New Caledonia, and the lemurs on Madagascar.

The fact that these islands fit the classical zoogeographic regions so poorly has been one of the reasons for the development of an entirely different school of zoogeography which attempts to discriminate faunal elements rather than to delimit faunal regions. This school tries to trace each faunal element back to the original founder and attempts to determine how this founder got there and when.

Islands are of paramount importance because they permit in many cases an extraordinarily precise reconstruction of the sequence of colonizations and of the circumstances under which these colonizations took place. The stress in recent decades has been on the continuity of the process of colonization. Charles Fleming, for instance, has shown for the 93 species of New Zealand land and freshwater birds that 19 are very recent immigrants, being still identical with populations in the country of origin (mostly Australia). Seventeen have differentiated subspecifically, 15 have reached the status of endemic species, and only in the case of 29 colonizations has the rate of divergence reached the level of genus or a still higher category. This means that the number of species (36) that have settled in New Zealand since the Pliocene is greater than the number of pre-Pleistocene colonizations (29) the descendants of which have not yet become extinct.

That colonization is a continuing process has been proven abundantly by the naturalists in residence in New Zealand and Lord Howe. These islands are visited every year by some enterprising individuals of Australian species of birds, and one or two of these have become established during every 10-year period. The invasion of New Zealand by the Tasmanian Silvereye (*Zosterops lateralis*) in the 1850's is a classical example.

There is at present a great interest among biogeographers in the biological properties of colonizers. Why are certain species such good colonizers but others are not? Here we must carefully distinguish between two aspects of colonization, the ability to cross water gaps (dispersal ability) and the ability to become established (colonizing ability). Marsupials and lizards, for instance, are far more tolerant of the exposure and deprivation caused by travel on a raft than are insectivores or snakes. Among birds certain groups are far more successful in crossing water gaps than others. Of the 62 families of birds that occur in New Guinea only 23 (37 per cent) have reached Fiji. Only 16 families are responsible for the major portion of the birds of Melanesia and Polynesia. Even though these families comprise only 59 per cent of the species of New Guinea birds they supply 84 per cent of the species of Fijian birds. The further away from New Guinea one gets, the higher the percentage of species that belong to characteristically colonizing genera.

It is not yet known whether it is superior dispersal facility or superior colonizing ability which is responsible for the success of these colonizers. Those kinds of birds that like to travel in flocks, like pigeons, parrots, starlings, silvereyes, honey-eaters, etc., are clearly among the most successful colonists. When such a flock is carried to a far-distant island both sexes will presumably be represented and a founder population can be established at once. Where colonization is effected by single individuals, it can lead to effective colonization only if a founder population can be established by a fertilized female or asexually, as in lower animals and many groups of plants. The study of the biology of successful colonists is at present one of the most active and exciting frontiers of biogeographical research.

The total number of faunal elements found on islands is invariably very much smaller than that found on continents. As stated above, the size of the island, the diversity of its habitat, the richness of the coexisting plant life, the distance from the nearest continent, and many other such factors determine the size of a given fauna. The more distant an island is from the nearest mainland the more one has an impression that the fauna is unsaturated—in other words, that the island could carry more species if only they could get there. In the Hawaiian Islands, for instance, only about 10 species of birds have become extinct since the beginning of the historical record while 44 other species have become successfully established. A close study by naturalists suggests for most of these islands that there are certain niches that are not fully occupied. Indeed, the presence of these unfilled niches is the reason for the spectacular adaptive radiation (see below) found in some of the islands.

Faunal turnover

The imbalance has two reasons. One is that many mainland groups are poor dispersers or colonizers and have simply been unable to get to the islands. But, as we stated above, there is a second reason, extinction. Every species faces a certain risk of extinction and the smaller the total species population and the smaller its gene pool, the greater is this risk; if there were no extinction one would expect that the faunas of all older islands would consist almost entirely of endemic species. However, this is true only for the largest (e.g., Madagascar) or most remote (e.g., Hawaii) islands. For all other islands the simple rule exists that the percentage of endemic species decreases with the size of the islands at a double logarithmic rate (Mayr, 1965). This means, as Fleming has pointed out for New Zealand, that there is an unexpectedly high rate of faunal turnover on islands. The smaller the island the more rapid this turnover. The turnover is due to the extinction of the native element and its continuous replacement by new immigrants. The study of such faunal turnover is, again, a new field of research and we are by no means ready to assign concrete numerical values to the various contributing factors.

Systematics

The study of island faunas has greatly contributed to the maturation of systematics. The polytypic species concept and indeed much of the so-called new systematics owe much to the study of geographic variation in island regions and to the necessity to find for island populations the appropriate position in the system. Taxonomists like K. Jordan, E. Hartert, Stresemann, and Rensch derived much of their insight from the study of island faunas. My own book, *Systematics and the Origin of Species* (1942), was based largely on a study of the island collections made by the Whitney-South Sea Expedition and on a study of the islands of the Papuan region. Students of lizards, butterflies, and snails have equally derived much taxonomic insight from the comparison of island faunas. But they have still a long way to go to apply these ideas consistently to the less well-known groups of animals. I would like to take this opportunity to stress the enormous importance of taxonomic research. Zoogeography, evolution, and ecology depend almost entirely on systematics. This dependence consists not only in the correct identification of individual species, but far more broadly in making available a broad documentation of all the manifold phenomena of the diversity of nature. It is not surprising, under the circumstances, that systematists play an increasingly important rôle in evolutionary and ecological researches.

There are two major areas of ecological research to which the study of islands has made particularly important contributions. One is the study of the causation of faunal diversity. Why does a temperate-zone forest provide niches for, let us say, 100 species of birds, while a tropical forest provides niches for 700 species? Why are there only 30 species of songbirds in the forests of an island while a seemingly similar mainland forest houses 200 species? This is the type of question that is now studied very actively by numerous naturalists. Are there more niches where richer faunas occur? Is it the availability of more food or the absence of seasonal fluctuations or the absence of natural catastrophies? Again islands are favourite material for such researches because the various factors can be described more accurately and because there is less disturbance by the influx of migrants and other confusing variables. This is an area where theory has perhaps outflanked factual information. I have little doubt that accurate censuses on islands, a detailed record of seasonal and annual changes, a more accurate measurement of species-specific niches, etc., made on appropriate islands will greatly contribute to ultimate solutions. What is the effect of competitors and what is that of predators? In view of the different composition of the faunas of each island it should be possible to test such factors far more satisfactorily on islands than anywhere on a mainland.

Adaptive radiation

The words "Darwin's finches and Hawaiian honey creepers" indicate to the evolutionist one of the most interesting evolutionary phenomena. When a founder population first reaches an archipelago it has the ecological requirements and adaptations of the mainland species from which it is derived. This was no doubt true for the first finch to reach the Galapagos Islands and for the ancestor of the Hawaiian drepanids. But as they colonized one island after the other in the respective archipelagos, they adjusted their ecological adaptation to the opportunities of each island and, more importantly, when undergoing geographic speciation they adjusted their ecological needs to each other. There are abundant empty niches on these oceanic archipelagos and the descendants of the original founders often succeed in occupying novel niches that are quite unexpected considering the seeming potential of the original founders. The Woodpecker Finch and the Warbler Finch on the Galapagos are typical examples of such adaptive radiation. This process has gone much further among the Hawaiian Honey Creepers, where one would question that such extremes as heavy grosbeak bills and long curved sickle bills could have been derived from a single ancestral bill type if most of the intermediate types were not still also in existence.

The emphasis in the case of adaptive radiation has been on archipelagos in the past. The Galapagos Islands and the Hawaiian Archipelago are indeed the classical demonstrations of this phenomenon. In recent years Allan Keast and others have called attention to the fact that adaptive radiation can also be demonstrated when we compare the niche occupation and adaptation found in colonists on a single island with that of their parental population. The birds of Tasmania illustrate such single-island adaptive radiation very well.

The importance of islands

Need I say anything more about the extraordinary importance of islands for the understanding of the world around us? Islands are an enormously important source of information and an unparalleled testing ground for various scientific theories. But this very importance of the islands imposes an obligation on us. Their biota is vulnerable and precarious. We must protect it. We have an obligation to future generations to hand over these unique faunas and floras with a minimum of loss from generation to generation. What is once lost is lost forever because so much of the island biota is unique. Island faunas offer us a great deal scientifically and aesthetically. Let us do our share to live up to our obligations for their permanent preservation.

A tuatara, or *Sphenodon*, a New Zealand reptile which has been extinct elsewhere in the world for 60,000,000 years. The specimen above is an adult male, with crest raised, foraging for ground insects at night. [Photo: M. D. King.]

COLONIZATION BY ANIMALS

By ALLAN KEAST
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IN August, 1883, the island of Krakatoa in the East Indies exploded after three months of repeated volcanic eruptions. Half disappeared entirely and the remainder, along with two adjoining smaller islands, was buried beneath a 90 to 180 feet blanket of glowing hot pumice. Ash from the volcano rose high into the air to girdle the earth for months, and beaches hundreds of miles away were scoured by tidal waves. All life on Krakatoa was wiped out, and what had formerly been a beautiful tropical island was reduced to a desert.

Studies of Krakatoa over the ensuing half century by Dutch scientists have provided us with by far our best documented example of how life arrives, and builds up, on islands to form, eventually, a complete flora and fauna. The first colonizer of Krakatoa was a spider which was found optimistically tending a web amongst the black rock nine months after the eruption. Insects were non-existent! It was to be a quarter of a century before the island was to have clumps of grass and other vegetation and again support, besides insects, a few lizards, molluscs, snakes, land birds, and mammals. But, thereafter, the tempo of colonization quickened, increasing amounts of soil and a diversifying habitat permitting the establishment of ever more forms. The build-up can be illustrated by birds. From no species in 1883 the number rose to 13 in 1908, and 31 in 1919–21. On the next expedition, in 1932–34, although the number of species was the same, it was found that for the first time flycatchers had colonized the island, and that there were now no less than four species of them.

Krakatoa illustrates many of the major features of island colonization. Ninety per cent of the species, it was noted, were forms that could be distributed by air; the rest came over the water. The spores of fungi and ferns are carried far through the air, as are the thistledown of daisies and light seeds of various other plants. Investigations by Dr Linsley Gressitt, of the Bishop Museum, Honolulu, have shown that not only the winds but the jetstreams that circle the globe carry diverse life. Thus, Dr Gressitt has netted spiders as much as 400 miles from land over the Pacific, beetles and wasps 500 miles, winged termites, flies, and Homoptera 900 miles, and butterflies 2,000 miles. Birds and bats, of course, are forever turning up on islands, either because of being swept off-course or during their migrations. Even so, the number of bird species that regularly succeed in colonizing oceanic islands is small. Ernst Mayr has listed some of the characteristics of such successful colonizers: a tendency to be social and travel in small flocks, a "built-in" capacity for roaming widely (many ducks and herons, for example, utilize temporary ponds), and ecological flexibility.

Drifting on the surface of the ocean is the next most effective method of getting to islands. Various plants have seeds that float and can withstand immersion in salt-water for short or long periods. Cast up by a high tide, they germinate at the back of the beach. They include the so-called "strand plants", *Barringtonia*, and the coconut. Mangrove seeds, of course, are an excellent example of passage by sea. Lizards and small rodents commonly raft from island to island on drifting logs and branches. Other forms of life are accidentally, or deliberately, transported by man. The Polynesians, for example, planted breadfruit, sweet potato, and pandanas wherever they colonized. And their canoes carried stowaways such as the Polynesian Rat (*Rattus exulans*) and small lizards.

The second important aspect of island colonization is that the organism must be able to establish itself once it arrives. Vast numbers of spores and seeds, insects and spiders, must have reached Krakatoa in the years before it became habitable. As noted, it was 40 years before there were enough cover and diversity of insect life to support flycatchers. Many kinds of organisms have sophisticated or special needs in food, habitat, etc. Not even the richest islands can provide the diversity in living areas of continents. All islands, hence, are "biotically impoverished", i.e., limited in the numbers of species that they contain.

To sum up: (a) only certain species have the means of reaching islands; (b) which ones do arrive is partly a matter of chance; (c) only some succeed in establishing themselves.

Interesting evidence that most islands can support more species than they do is shown by the success of forms introduced by man. No fewer than 34 introduced birds are now established in New Zealand and 44 in Hawaii. It must be admitted, of course, that the success of many is due to man having altered the habitat in such a way as to suit these forms, e.g., clearing in New Zealand has tended to duplicate the ecological conditions under which many lived in Europe. But several have taken to the native forest both in Hawaii and New Zealand.

The basic features of island colonization can be seen by the astute observer on the many small islands off the Australian coast, and even on those in harbours and lakes. A mile off the coast near Port Kembla, New South Wales, are the tiny Five Islands. which range in size from about an acre to several acres. A day ashore on any one of them will show how many fewer species there are compared to an area of similar size on the mainland—unless, of course, it is spring or summer, when dense colonies of sea birds occupy them. The vegetation is limited to a few stunted shrubs like the Coast Rosemary and a couple of dozen species of other plants, presumably all that the sandy soil will support. The only land birds may be the Grassbird (*Megalurus gramineus*) and an occasional Pipit (*Arthus noudeseelandiae*) and Swamp Harrier (*Circus approximans*); the latter two can be seen, from time to time, flying to and from the islands. There are few small lizards, but no snakes. Assiduous collecting will bring to light various kinds of insects, but there will be none of the aggregations of grass-hoppers, for example, that characterize the adjacent mainland hills. At the same time, it is interesting to remain a few days and note the number of chance vagrants that, from time to time, drift or are blown over from the mainland—a Wanderer or Caper White Butterfly, a large black-and-orange wasp, a crane fly, a honey-bee. This demonstrates the dispersive powers of the wind and the capacity of insects, once

The Rufous Fantail (*Rhipidura rufifrons*), an Australian bird which is a common colonizer and has a wide range out into the Pacific. [Photo: T. Pescott.]

swept out to sea, to reach any resting place that presents itself. A few doubtless find a mate and breed, to establish themselves temporarily, or even permanently, as island residents.

Heron Island, the well-known tourist island of the Great Barrier Reef, provides another example of a typically impoverished island flora and fauna. Its common trees—horsetail casuarina, pandanus, and pisonia—are characteristic of islands over a wide area of the Pacific. But here are none of the gums and wattles that grow on what seems to be equally impoverished soil on the Queensland coast 30 miles away. The land birds on the island are a relative few that one quickly learns to regard as good island colonizers: Silvereyes (*Zosterops lateralis*), the Bar-shouldered Dove (*Geopelia humeralis*), and the Sacred Kingfisher (*Halcyon sanctus*). Only a small minority of Queensland birds ever turn up on the Barrier Reef islands, most, presumably, keeping close to their chosen mainland habitats. Others doubtless are swept out to sea, reach the islands but disappear, unable to establish themselves.

The colonization of the distant Pacific islands

In the table at the end of this article the numbers of species of land and freshwater vertebrates occurring on Pacific islands of varying degrees of isolation are summarized. In the case of birds only those species breeding on each island are included. General figures only can be given for New Guinea reptiles and frogs, as new species are still being discovered. The New Guinea

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mammal figures are a little high, as a few of the species are better thought of as only races. Again, some of the fifty-seven New Guinea and seventeen Solomon Island bats recorded may prove to be either migrants or chance records. Species introduced by man have been eliminated where possible, hence the Polynesian Rat, which occurs on almost all the islands, is not included. Nevertheless, two of the three Lord Howe Island species (geckos) are probably introduced, as are the four geckos and three skinks occurring on the Marquesas, Society Islands, and Samoa. Karl Schmidt notes that at least some of these species (*Gehyra oceanica*, *Peropus mutilatus*, *Hemidactylus garnotti*, *Lepidodactylus lugubris*, *Emoia cyanura*, *Leiolopisma noctua*, and *Cryptoblepharis poecilopleurus*) are commonly found hiding in native canoes pulled up on the beach, and that none of them vary at all geographically, indicating recent range-spread.

The table brings out clearly how rapidly numbers of species fall off once the shores of Australia and New Guinea are left behind. Beyond the Solomon Islands, which have one species of cuscus (*Phalanger*) and twelve rodents, only bats occur. But even the number of bats tapers off strikingly, from fifty-seven species in New Guinea to seventeen in the Solomons, and four in Fiji. Snakes and frogs extend no further east than the Solomons and Fiji. New Zealand has three frogs but no snakes. There is a progressive "faunistic attenuation" of lizards as far as Fiji. In birds, by far the most mobile group, this attenuation extends right across the Pacific to the Marquesas, some 4,650 miles east of Australia, where, from the 500–600 species of Australia and New Guinea, the number of species has fallen to about seven.

On the other side of the Pacific the Hawaiian and Galapagos Islands have richer faunas again. The Galapagos fauna is drawn entirely from the adjacent South American continent. Besides some interesting birds it includes rodents, iguanid lizards, snakes, and giant land tortoises. The Hawaiian bird fauna is largely of North American origin but there are a couple of honeyeaters from Australasia; in the case of other groups, like insects and plants, a strong Asian influence is apparent, these forms having apparently colonized along a former chain of volcanic islands of which Midway and Kure atolls are now the northwesternmost remnants.

The history and faunas of some of the islands

Dispersal distance is only one of three variables that determine the size of an island's fauna. The other two are the size of the land area and the age of the island. With regard to the first, it has been repeatedly demonstrated that there is a good correlation between the number of species occurring in an isolated area and its size: the greater the size the more diverse the fauna it will support. This is, however, not so on continents: certain physiographically diverse parts of Africa, the Nyassa highlands for example, have phenomenally rich faunas. The older an island the greater the opportunity it has had to evolve new forms. In island archipelagos like Hawaii, new species have evolved on the different islands in the group.

Of the islands listed in the table, Tasmania, New Guinea, New Zealand, New Caledonia, and Fiji are not true oceanic islands but, as suggested by the occurrence of sedimentary rocks, are "continental remnants". Tasmania and New Guinea lie on the Australian continental shelf and have been repeatedly connected to the mainland. New Guinea, with a surface area of 304,650 square miles, mountains reaching 16,000 feet, great climatic and topographic diversity, tropical, and with a remarkably rich flora, has nearly as many vertebrate species as Australia, ten times its size. Strictly speaking, however, it is really part of the continent. Tasmania, with 26,000 square miles and climatically cold-temperate, has a much smaller fauna. Cold-blooded reptiles and frogs are relatively few. There are no tortoises or geckos. It is hard to imagine that there has been a lot of secondary extinction in Tasmania due to cold: at the height of glaciation ice covered nearly half the land area.

New Zealand, with two major islands 200 miles in length and a total area of 100,000 square miles, is particularly interesting faunistically in that it has several most interesting relicts amongst its fauna. The tuatara or *Sphenodon*, a small reptile, superficially lizard-like, has been extinct elsewhere in the world for 60,000,000 years. The *Leiopelma* frogs are a primitive group whose nearest relatives are in North America. Many of the birds are unique and unlike forms elsewhere, especially the kiwi and now extinct moas. These distinctive faunal elements are additional evidence that New Zealand was part of a larger landmass cut off, presumably, before mammals arose in the world. The only mammals on the island are two species of bat.

New Caledonia, 6,223 square miles, and Fiji, with two major islands of 4,011 and 2,137 square miles respectively, are also interesting, the former because of its Antarctic Beeches and *Araucaria* pines, both of which occur only in a few other parts of Australasia and in South America, and the latter because of its iguanas. Iguanas are otherwise restricted to the Americas and Madagascar, so the Fijian ones are relicts from a time when these lizards had virtually a world-wide distribution. Fiji also has a couple of frogs which, as in the case of the New Zealand ones, indicate former direct land connections (this time, apparently, with the Philippines!). Frogs cannot travel over saltwater.

The original colonizers of these islands, it seems then, travelled either along land bridges or, at least, along island chains in which the successive islands were very close together. The islands' larger faunas are, hence, due to a combination of factors—their larger size and hence greater stratographic and biological diversity, greater age and, apparently, because they were once part of a continent.

Is it really possible that islands as remote as Fiji, New Caledonia and, for that matter, Lord Howe Island, have drifted from a formerly larger Australasian landmass? Scientists are naturally very guarded in admitting the possibility. No mechanism is known whereby this can happen but three partly relevant facts might be noted: (1) submarine ridges connect the Solomons, Fiji, New Caledonia, Lord Howe Island, and New Zealand; (2) the study of paleomagnetism shows that certain landmasses have altered their position with respect to the magnetic pole from time to time, i.e., have "drifted" or twisted somewhat; (3) the lavas of the above islands are andesitic, like those of continental volcanos, and in contrast to the basaltic ones of the true oceanic islands.

Tasmania and the evolutionary consequences of impoverishment

Tasmania has 104 species of breeding land and freshwater birds. This compares with about 176 species that occur in Victoria in habitats equivalent to those available on

Leiopelma hochstetteri, of New Zealand, one of a primitive group of frogs.

Leiolopisma lichenigera, a skink found only on Lord Howe Island and its small off-shore islands. [Photo: H. G. Cogger.]

the island. Thus, Tasmania has only about 58 per cent of the number of species of southern Victoria.

The deficiencies lie mostly in the small perching birds: robins, flycatchers, warblers, honeyeaters, and so on. There are no tree-creepers or sittellas so that true bark and trunk feeding birds are absent. There are only eight honeyeater species compared to twenty-two in southern Victoria. Common little warblers that live on insects in the foliage, such as the Striated and Little Thornbills (*Acanthiza lineata* and *A. ewingi*), the Weebill (*Smicrornis brevirostris*) and the Gerygones, are absent.

The more one thinks of such shortcomings in the fauna the more intriguing it becomes. Are all these proven ways of life simply lying idle and untenanted, just because the birds that normally occupy them have been unable to cross Bass Strait? Accordingly, during the last year I have been engaged on a study of the birds of Tasmania both from the viewpoint of ways of life and by an anatomical study, for a bird's ecology is clearly reflected in the structure of its bill, legs and claws, and in its general body form. What has emerged is that there has been an intriguing readjustment of the whole fauna to "fill the gaps", a redivision of the spoils, so to speak, amongst those species that do occur. Space will only permit reference to two such cases:

(1) **The trunk and bark-feeding niche.** On the mainland of Australia three main groups of small birds obtain their living from the trunks and bark of trees—the tree-creepers, the tree-runners, and the shrike-tit. The first two may be seen at any time in the bush, running up and down and over the bark, eagerly extracting small insects and spiders from the cracks and crevices. To fit them for this they have long bills and long, strong claws. None of these birds occur in Tasmania. There, however, we find that the Strong-billed Honeyeater (*Melithreptus validirostris*) has developed the trunk-feeding habit. It has developed a much longer, stronger bill and somewhat longer claws than its mainland relative, the Black-chinned Honeyeater (*M. gularis*), which feeds from trunks only incidentally, preferring insects from the branches and foliage, along with some

nectar. Other species, too, have moved into the feeding zone. The little Scrub-tit (*Sericornis magnus*), which belongs to a group that do all their feeding on the ground, now does some of its feeding on the trunks of trees. The Grey Thrush (*Colluricincla harmonica*), which feeds equally in the branches and on the ground in Australia, now spends a disproportionate amount of its time prodding the bark—and along with this has a 20 per cent longer bill.

(2) **Ground-feeding robins.** One of the commonest robins on the mainland is the Yellow Robin (*Eopsaltria australis*), which lives in the forest and feeds on the ground. It is well-known from its habit of visiting picnic spots for scraps. The bird is absent from Tasmania. Its place is taken there by the dainty Pink Robin (*Petroica rodinogaster*). But the Pink Robin is a very close relative of the mainland Rose Robin (*P. rosea*), which does all of its feeding in the upper branches and foliage of the rainforest trees and hence has rather weak feet. So similar are the two in colour that one has to look hard to tell them apart. One can only speculate as to how the Pink Robin came to utilize the vacant terrestrial feeding niche, unless it found it by sheer chance. Needless to say, anatomical studies show that the Pink Robin has acquired distinctly larger and stronger legs to go with its new way of life!

These instances give an insight into an intriguing aspect of island life. Many birds, once they find themselves on an island, obviously are able to change their way of life, given enough time, and so maximize the available opportunities. It is logical that their bodily structures should become slightly modified to help with this. But I confess I was pleasantly surprised to find how clear-cut this is in some Tasmanian birds and how readily the changes could be linked with the absence of the usual "owners" of these ways of life.

TABLE SUMMARIZING NUMBERS OF SPECIES RELATIVE TO DEGREE OF ISOLATION

Island	Distance from major landmass (miles)	Mammals	Land and freshwater birds	Lizards	Snakes	Frogs
Australia	——	229	520	240	140	115
New Guinea ..	90 from Australia	174 (57 bats) (53 rodents) (62 marsupials)	565	140 plus	100 plus	80 plus
Tasmania	130 from Australia	32 (6 bats) (4 rats) (20 marsupials)	104	17	3	10
New Zealand ..	1,100 from Australia	2 bats	69	about 20	nil	3
Lord Howe Is.	350 from Australia	2 bats	15	3	nil	nil
New Caledonia	800 from Australia	several bats	68	17	nil	nil
Solomon Is. ..	400 from New Guinea	30 (17 bats) (12 rodents) (1 marsupial)	136	10	4	10
Fiji	1,650 from Australia	5 (4 bats)	60	15	4	2
Samoa	2,250 from Australia	2 bats	33	7	nil	nil
Society Is. (Tahiti)	3,800 from Australia	nil	about 12	7	nil	nil
Marquesas Is. ..	4,650 from Australia	nil	about 7	7	nil	nil
Hawaiian Is. ..	2,400 from North America.	1 bat	44	nil	nil	nil
Galapagos Is. ..	600 from South America.	1 bat 5 rodents	26	about 8	3	nil

Data drawn from the published works of P. J. Darlington, E. Mayr, K. Schmidt, E. M. O. Laurie and J. E. Hill, S. W. Gorham, P. and N. Stephenson, K. A. Hindwood, E. H. Bryan, and others.

A view of Lord Howe Island from the top of Mt Gower. The older Mt Lidgbird volcanics are on the right, and the North Ridge volcanics are in the distance. The coral reef, which separates the shallow water of the lagoon from the ocean, can be traced by the waves breaking on it. [Photo: E. de Villa.]

ISLANDS AND SEAMOUNTS TO THE EAST OF AUSTRALIA

By J. C. STANDARD
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GEOLOGICALLY speaking, the islands around Australia may be divided into the following three groups:

- The islands which are actually part of the Australian continental landmass. These islands are located on the continental shelf and happen to be surrounded by water because of erosion, submergence, or eustatic change in sea-level. Being surrounded by water, however, does not make them geologically different from the nearby mainland. Examples of islands of this type are Thursday Island, Magnetic Island, and the Whitsunday group (in the Great Barrier Reef), islands of Bass Strait, Phillip Island (in Western Port, Victoria), Kangaroo Island, etc.

- True coral islands, such as Green Island, Heron Island, and numerous other islands and cays along the entire length of the Great Barrier Reef. These islands seldom have elevations in excess of 10 feet and many are exposed only at low tide.

- True oceanic islands, such as Lord Howe and Norfolk Islands.

Only the latter type will be discussed in detail in this article.

For many years the concept of a vast "Australasian" continent lying to the east of Australia was accepted by most geologists. Professor David referred to this continent as "Tasmantides". The islands of Lord Howe, Norfolk, New Zealand, New Caledonia, and Fiji were considered as being the only part of the sunken continent exposed above sea-level. All of the area between these islands was considered as being continental-type crustal material that had sunk beneath the sea to its present position on the bottom of the ocean.

Oceanographic and geophysical work in the last 10 or 12 years has shown that this is not the case and that continental-type crustal material does not extend more than a few tens of miles east of the present coastline.

Submarine mountains

Detailed soundings have revealed a series of four submarine mountains lying 160 to 310 miles east of the New South Wales coast. Each of these mountains has a total height of more than 14,000 feet. This is far greater than the 7,305 feet of Mt Kosciusko, Australia's highest mountain.

The Gascoyne Seamount, 310 miles east of Eden, is covered by only 330 feet of water.

These submarine peaks are volcanoes, probably similar to the olivine-rich alkali basaltic volcanoes of the Pacific Basin, which were truncated by wave action. The flat platform-like upper surfaces of the seamounts are probably associated with both eustatic change of sea-level and subsidence which has caused them to sink to their present position. *Acropora*-type branching coral has been dredged from the platform of the Derwent Hunter seamount at a depth of 1,176 feet. This indicates a submergence of several hundred feet since the coral grew on the platform.

The four seamounts are aligned along a north-south line which probably represents a fault or shear in the thin ocean crust.

Another submarine volcanic range is found about 100 miles off the coast of southern Queensland. Six peaks in this range have heights of more than 11,000 feet and four of them are covered with about 1,300 feet of water. The Recorder Seamount, 90 miles off Fraser Island, is over 13,000 feet high and is the northernmost peak of this range. It was only discovered in 1961. These submarine peaks are also aligned in a north-south direction, roughly parallel to the ones off the New South Wales coast, but to the west.

Ball's Pyramid, 12 miles south of Lord Howe Island. This erosional remnant is 1,811 feet high and is on top of a large wave-cut platform 11 miles long and 9 miles wide.

Phosphate rock has recently (August, 1967) been dredged from N.T. No. 5 Seamount, 320 miles east of Brisbane, Queensland, at a depth of about 950 feet.

A 6,000-feet seamount, that comes to within 84 feet of the surface, was discovered in August, 1967, 172 miles northeast of Cairns, Queensland. Additional seamounts will possibly be found as oceanographic work continues.

Islands

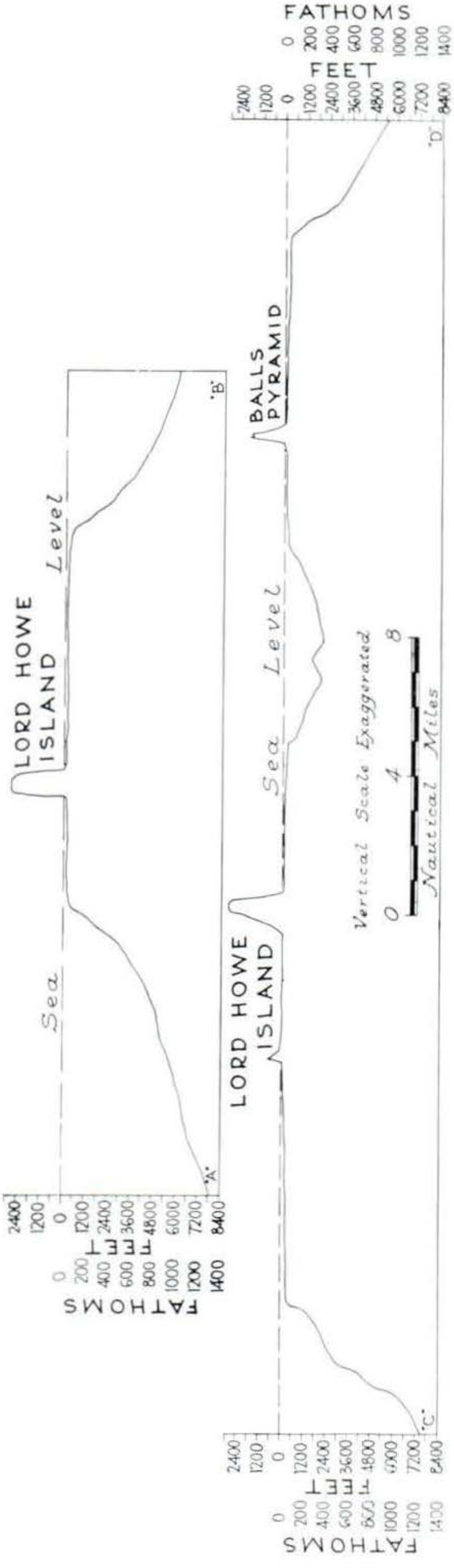
The islands comprising the Admiralty Group, Mutton Bird Island, Gower Island, and Lord Howe Island are all collectively referred to as Lord Howe Island. Ball's Pyramid Rock, which lies 12 miles to the south, is genetically related to Lord Howe Island but is separated by a depth of more than 2,100 feet of water.

Even though Lord Howe Island lies only 436 miles northeast of Sydney, geologically speaking it has little relationship to the Australian continent. It is separated from the mainland by a depth of over 16,000 feet of water which covers the vast, featureless Tasman Abyssal Plain.

Lord Howe Rise is a major physiographic feature of the southwest Pacific that joins the Coral Sea Platform in the north and the South Island of New Zealand in the south. The rise is covered by about 4,000 feet of water. Lord Howe Island is located near the western edge of Lord Howe Rise but is separated from the main part of the rise.

Lord Howe Island, which is about 1 mile wide and 6 miles long, is located on top of a much larger wave-cut platform that measures 14 miles by 20 miles. This large flat platform has a depth of about 300 feet and was formed by wave action associated with eustatic change of sea-level during periods of glaciation.

Ball's Pyramid, which is only 0.2 miles wide and rises abruptly to a height of 1,811 feet, is also located on top of a wave-cut platform 9 miles wide and 11 miles long. Both Lord Howe Island and Ball's Pyramid are part of a much larger base which rises from the ocean depth. Geologically speaking, both Lord Howe Island and Ball's Pyramid may eventually be eroded away to form flat-top seamounts similar to those in the Tasman Sea.



East–west profile of Lord Howe Island and north–south profile of Lord Howe Island and Ball's Pyramid. [Diagram by the author.]

A view from North Ridge of the older volcanic rocks of Mt Lidgbird and Mt Gower in the distance behind the lagoon. Rounded younger North Ridge volcanics of Intermediate Hill are at upper left. Breakers behind Rabbit Island, centre-right, indicate the position of the coral reef. The rocks exposed in the lagoon between land and Rabbit Island are calcarenite. [Photo: K. Gillett.]

The most important rocks of Lord Howe Island are the Lidgbird Volcanics, which form the southern half of the island and include the peaks of Mt Gower (2,836 feet) and Mt Lidgbird (2,545 feet). These rocks are of an olivine basaltic composition and are similar to rocks from other ocean basins. The Lidgbird Volcanics have been referred to as the "older volcanics"; they form the core of the island upon which the North Ridge Volcanics, the "younger volcanics", and in turn the windblown calcareous sandstones, are deposited.

The North Ridge Volcanics contain a much lower percentage of olivine than the older volcanic rocks, and masses of jasper up to a few inches in diameter are occasionally found. Pyroclastic scoria and ash beds are found and remnant flow structures give a recent appearance to some of the younger volcanics. These lavas are considered to be Pliocene to Pleistocene in age, though no exact age has yet been determined.

The sediments of the island include calcarenites, sand dunes, recent and ancient soil horizons, and the coral reef. All are considered Pleistocene or Recent in age. The calcarenite, which forms the bulk of the sedimentary rocks on the island, is composed almost entirely of calcium carbonate. The most widespread occurrence of calcarenite is found behind Ned's Beach where a ridge, which is up to 150 feet in height, is composed almost entirely of calcarenite.

During the Pleistocene period, when the sea-level dropped 300 feet, the size of the island was greatly increased and a broad, flat, wave-cut terrace up to 20 miles in diameter was exposed above sea-level. This wave-cut terrace supplied the calcareous material which was deposited by the wind around the base of the existing hills.

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The calcarenite is composed largely of fragmental detritus from lithothamnion (coralline algae or nullipore) and halimeda, with pulverized coral, foraminifera, fragmented mollusc shells, etc. comprising only a small portion of the total composition of the rock.

The calcarenite is a "sandstone" comprising calcareous grains which, when viewed from a distance, looks very much like a typical cross-bedded quartz sandstone found around Sydney. The highest location at which it has been found is on the northeast slope of Transit Hill, where outcrops are found at an elevation of 250 feet; this indicates that sand dunes accumulated on the windward side of Transit Hill to a height of at least 250 feet above present sea-level.

The calcarenite is extremely susceptible to subaerial weathering, and most of the outcrops are "honeycombed" and contain up to 70 per cent pore space. Vertical "solution pipes", which are formed by downward percolation of ground water and which have walls of redeposited calcite up to several inches thick, are common. The effect of subaerial weathering stops abruptly at high watermark, and a single rock which is honeycombed and extremely porous above high watermark may, a few inches lower, beneath high watermark, be very solid and without noticeable porosity. Features identical to those above have been observed in the calcarenite on Norfolk Island.

At the north end of the island, northeast of North Bay Beach, several caves are found in the calcarenite. The largest of these is accessible only by a collapsed vertical "solution pipe" about 3 feet in diameter and 15 feet to 20 feet deep. The area of the caves is in the drainage of North Ridge and the ground water easily flows through the extremely permeable calcarenite until it reaches the underlying basalt; it then flows downward along the top of the basalt to the lagoon. It is in the calcarenite above the basalt contact where the largest cave, which is several hundred feet in length, has been formed. It is quite unusual to see caves formed in highly cross-bedded "sandstone", though occasionally the more typical cave appearance is found in areas where stalactites and stalagmites are formed.

Several periods of deposition are noted in the calcarenite deposits which are separated from one another by soil accumulation of several feet. These soil horizons, which commonly contain fossils of bird bones and of the land snail *Placostylus bivaricosus*, have been found in elevations ranging from 8 feet to 65 feet.

The only sand dune on the island is behind Blinkenthorpe Beach. This dune, approximately 300 feet long and 80 feet wide, is about 30 feet high and contains calcareous sand grains that have been blown by the prevailing westward winds from Blinkenthorpe Beach. The steeper lee side of the dune faces east towards the lagoon. The dune is composed of much the same material as the calcarenite and the beach sand, but the grain size is somewhat smaller than that of the beach sand.

The coral reef on the west side of the island is the furthest south that a true coral reef has been recorded. This reef has grown on top of a wave-cut platform, and is thought to be Pleistocene to Recent in age. Coral growth is common on all sides of the island, but only on the west side has a reef formed.

Probably because of colder water, the coral reef and the shallow water around Lord Howe Island contain a much higher percentage of lithothamnion than do the waters around the Great Barrier Reef, and the cementation by the lithothamnion is perhaps more important to the formation of the reef than that of the coral itself. Lithothamnion growth is especially noticeable at extreme low tide in the southern part of the lagoon at Lover's Bay and Johnson's Beach, where large areas are covered with a pinkish-mauve carpet of lithothamnion which in places forms pools that resemble terraced pools such as those found in thermal springs areas. These pools, which are about 2 feet to 3 feet wide and up to a foot in depth, are surrounded by rims of lithothamnion and lithothamnion-precipitated $CaCO_3$.

The coral reef almost completely blocks the lagoon, with only three passages existing that are suitable for boats' passage—the North Passage (about 40 feet deep), Rabbit Island Passage (about 30 feet deep), and Erscott's Passage (about 75 feet deep). These passages are very narrow, and much of the large volume of water that covers the reef and fills the lagoon at high tide must pass out through these openings as the tide recedes. This produces very strong rip currents in these passages as the tide lowers, and this has an effect upon the distribution and shape of the coral growth within the lagoon. The coral polyps have arranged themselves in an arch-like pattern parallel to the flow of the strongest current.

The coral reef acts as a breaker for storm waves which might have otherwise cut the island in half at its narrowest point, between the lagoon and Blinkenthorpe Beach, and eroded away much of the alluvial material and calcarenite.

Probably because of the colder water, the underwater scenery of Lord Howe Island is quite different from that of the Great Barrier Reef. Most of the Lord Howe Island reef is made up of massive-type corals such as the *Acropora brueggermanni* and *Gonianstrea benhami*. The fine branching types of coral such as the staghorn coral *Acropora pulchra*, so commonly found on the Great Barrier Reef, are almost completely missing. Much of the associated reef life, especially the molluscs, are much smaller, and the amount of algae and seaweed growth is much greater.

The lagoon is extremely shallow, being an average of only about 3 feet deep at maximum low tide. The floor of almost the entire lagoon is covered with calcareous sand, which, except for the coarser grain size, is basically of the same composition as the calcarenite, being composed primarily of coralline algae and halimeda material, with pulverized coral, mollusc shells and foraminifera, etc., forming only a minor portion of the total material. The sand is much coarser near the beach in the area of wave action, and becomes finer both landward and seaward.

Possible origin of the fauna and flora of Lord Howe Island

Paramonov (1959) entitled his paper on Lord Howe Island "a Riddle of the Pacific". A large part of this riddle is connected with the fact that, while Lord Howe Island is closer to Australia than to New Zealand, a large number of plants and animals, many of which are not supposed to be able to travel over large distances of water, are more similar to New Zealand types than to Australian types.

If we consider the size and distribution of the islands that existed during the lowering of sea-level 300 feet, associated with Pleistocene glaciation, this does not present such a great problem. An investigation of oceanographic charts reveals that Wanganella Bank, which is 274 miles northwest of the North Island of New Zealand, 426 miles southeast of Lord Howe, and 210 miles south of Norfolk Island, was exposed during the Pleistocene lowering of sea-level.

This island may have acted as a stepping stone for New Zealand type fauna to migrate to both Lord Howe Island and Norfolk Island. With more detailed oceanographic soundings it is probable that other shallow seamounts, which were islands during the lowering of the sea-level associated with glaciation, will be found along Lord Howe Rise, and these islands may have also acted as stepping stones. Several specimens of an extinct turtle, *Meiolania*, have been found embedded in the calcarenite of Lord Howe Island. Since the same species of turtle has been found in Australia, and since this turtle was thought to be a land turtle, previous workers, both biologists and geologists, erroneously concluded that Lord Howe Island and Australia were connected.

Evolution during the prolonged isolation before and since the Pleistocene has probably been responsible for the development of the large number of endemic species found on the island. Many species, especially among the bird population, have become entirely extinct since the island was discovered in 1788. There is no record, or indication, that the Polynesians or any other race of man ever discovered the island prior to 1788.

Many other isolated islands throughout the Pacific probably had a similar number of endemic species prior to the coming of man. The rapid extinction of the weaker species probably occurred on these islands, just as it did on Lord Howe Island, after the arrival of man, but it was not recorded by the Polynesians or other native people who first settled there.

The quokka (*Setonix brachyurus*), which is common on Rottnest Island, Western Australia. [Photo: Author.]

Islands as Natural Laboratories

By A. R. MAIN
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ISLANDS attract people because of their romantic appeal as places where it is possible to "get away from it all". This association gives them a high priority as holiday resorts, and it is unfortunate that this is the only interest that the general public has in islands.

To biologists islands are fascinating because they represent field laboratories where native fauna have been isolated for varying lengths of time and under ecological conditions quite different from their mainland occurrence. For example, around the Western Australian coastline numerous islands and their native fauna have been cut off as the seas rose with the melting of the ice at the close of the last glaciation. Not all islands were cut off at the same time and there are islands which range in age from 15,000 years to 7,000 years. On the west and south coasts numerous islands support marsupial populations and only one (Garden Island) is not a reserve for the preservation of fauna and flora.

The quokka

Fauna are protected on Rottnest Island but it is a reserve for recreation and is widely known as a holiday resort. However, it is also the one locality where the quokka (*Setonix*) is abundant. The reasons which make the island attractive as a holiday resort, e.g., closeness to Perth, good transport (air or boat) and good roads, also make it attractive as a site for biologists to study this small wallaby, which has apparently been isolated from the mainland for 7,000 years.

Granted that the quokka has persisted on this 4,500 acres of sand and limestone for longer than man has been civilized, is this the only reason for studying it? The answer is no, and for a very complex set of reasons.

We all know that the marsupials, the pouched mammals, are different from other mammals. But how different? To answer this question one must have plenty of animals, easy to catch, easily domesticated, economic to keep and capable of being studied in the field as well as the laboratory. Preferably the field occurrence of the animals should be close to a research centre. What could be better than the quokka on Rottnest Island, 20 air miles west of Perth?

The quokka research has now been in progress for almost 20 years and it stands as the pioneer modern work on marsupials, where nearly all the techniques for study in other macropod marsupials were developed.

The development of the research has been relatively simple. Field observations have established what happens in nature, and the causes and reasons for the field happenings are studied by means of laboratory experiments. This has added up to a rather complete biology of the quokka. The salient features of the biology relate to reproduction, nutrition, and causes of death.

The quokka breeds in February and mates again immediately after the single young is born. The egg fertilized at this mating develops for a short while and then remains quiescent as a blastocyst. No development takes place in the blastocyst while the first-born remains as a joey in the pouch. However, should the joey die then the blastocyst continues development as a typical embryo. In the field joeys mature in two years and individually marked animals have been recaptured for 8 or 9 years.

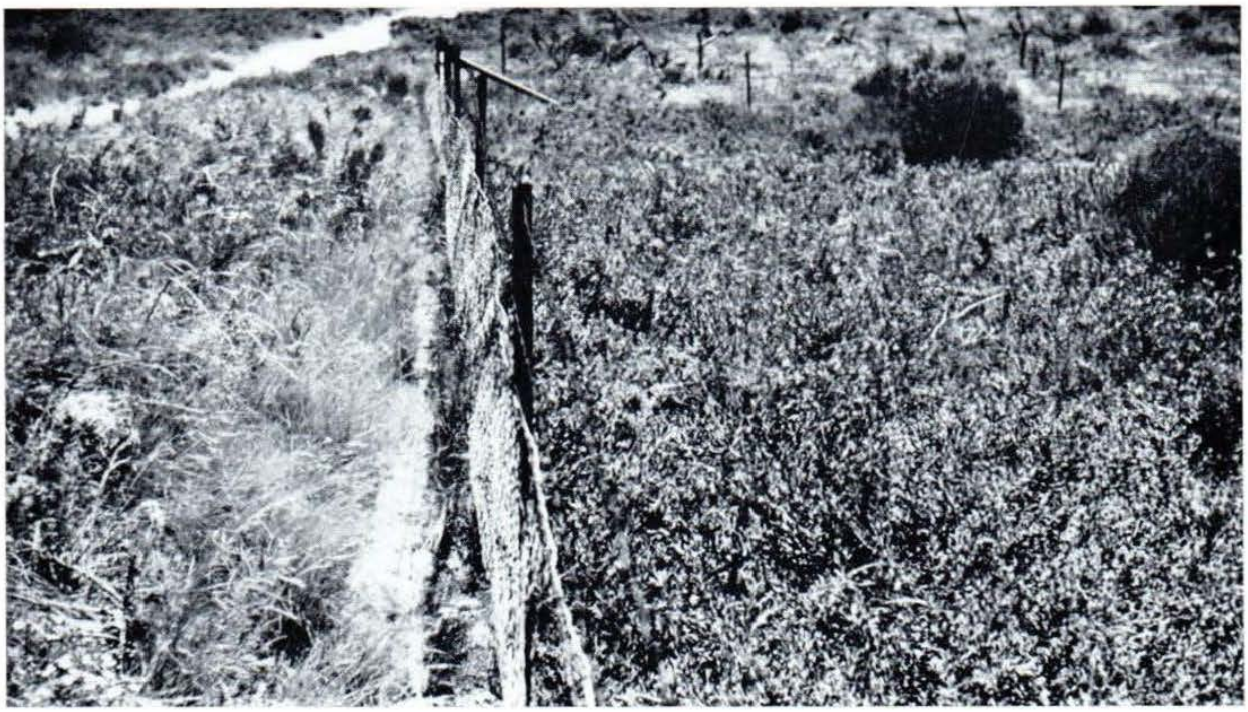
Weight-loss and anaemia

When the quokka populations are studied by means of individually marked animals so that individuals can be identified when they are recaptured, it becomes apparent that as each summer proceeds animals suffer increased weight-loss. Many quokkas die towards the end of long dry summers, apparently following excessive loss of weight. Deaths could be caused by starvation. Analysis of the blood indicates that parallel to the weight-loss an anaemia is developed. Upon investigation the anaemia turns out not to be due to copper, iron, or cobalt deficiency (sheep die on the island due to cobalt deficiency) but is apparently caused by deficiency of protein in the diet.

Analysis of plants through all seasons of the year indicated that protein levels were high in spring, followed by a marked decline during the summer. These changes in protein level in the plants showed close correspondence with the seasonal changes in weight-loss of quokkas. Laboratory feeding trials show that, depending on the season, quokkas only remain in weight balance when they obtain from about 1.7 to 3.0 gm of protein per day. However, the quokka may not require to ingest this amount of plant protein each day because it is ruminant-like in its digestion, i.e., the large saccular stomach retains food while it is fermented by bacteria. The quokka then absorbs the fermentation products and digests the bacteria for their protein. On occasions when the diet has less protein than needed for balance, it is possible for the quokka to retain the nitrogen waste which would be excreted in the urine as urea. The retained urea diffuses across the stomach wall and is utilized by the bacteria to synthesize protein and grow. By this means the quokka is able to supplement meagre protein supplies. However, the bacteria also need ready sources of energy, e.g., sugars and starches, and if these are in short supply recycling urea does not lead to proliferation of the bacteria and hence protein shortage is not alleviated. The interpretation of the weight-loss and anaemia during late summer appears then to be due to a shortage of both protein and energy in the diet.

Quality of diet

These findings indicate that the quality of the diet is important, so exclosures were erected leaving areas of vegetation free



A typical example of over-grazing by quokkas on Rottnest Island. The dominant plant within the exclosure (to the right of the fence) is *Eremophila brownii*. It is absent outside the exclosure, where the common plant is the unpalatable *Acanthacorpus preissii*. [Photo: Author.]

from grazing by quokkas. Highly nutritious plants grew profusely within the exclosures and were scarcely apparent outside, suggesting that the vegetation was overgrazed. This suggestion was confirmed by analysing the faeces of quokkas. It so happens that the epidermis of the plants eaten passes through the alimentary canal, so the individual species of plants eaten can still be determined in the faeces. From this discovery it was possible to confirm that everywhere the quokka was selectively eating the most nutritious plants available. The upshot of this work was the establishment of a number of large exclosures within which the native vegetation was allowed to re-establish. At present managed regeneration is proceeding by this method.

An additional cause of death in late summer has been related to the decline of vitamin E in the forage. The absence of adequate amounts of this vitamin leads to severe muscle wastage and death. However, the disease can be cured by administering the appropriate vitamin or, as happens on Rottnest, by the fresh plant growth following late autumn rains. Surprisingly, in view of the years of study and the obvious malnutrition in some summers, no deaths attributable to disease caused by pathogens such as bacteria have been found.

Successful conservation

Most of these discoveries, e.g., method of nutrition, protein requirements, etc., were not anticipated when the inquiry began but they have an extraordinarily wide application. For the first time we are beginning to see the causes of survival and death in the field. The deficiencies of a particular environment are being constantly demonstrated. Finally, if we return to the length of time that the quokka has persisted on Rottnest we can view the 7,000 years as an example of successful conservation. It is what we hope will occur on the reserves we are now creating for fauna and flora which are islands of native biota in a sea of developed land.

Naturally, the other islands around the coast differ from Rottnest. Many are much smaller, and on only one (Bald Island) does the quokka occur. There has not been the time or physical resources to study them all as intensively as Rottnest, but most have been visited. A study programme has proceeded on the Tammar Wallaby on the

Abrolhos Islands, since 1959. No mass deaths have been observed and in physiological terms the Tammar appears to be extraordinarily efficient.

It is interesting to note that faunal diversity (as reflected by the number of species present) is restricted on small islands. For example Rottnest Island (4,500 acres) and all smaller islands have only one macropod species, while Bernier (about 11,000 acres) and Dorre (about 15,000 acres) have three, and Barrow Island (about 55,000 acres) has four.

The story of the survival of the fauna of each island is important in its own right. Each is an extraordinary illustration of ecological principles and a demonstration of how animals function in nature. Moreover, each study is a contribution to our understanding of what must be done in order to preserve our native fauna which is being restricted to fauna reserves or sanctuaries.

To the question of how different are marsupials and eutherians we have no clear answer. Kangaroos and wallabies are ruminant-like in their digestion, i.e., they resemble sheep and cattle. Nevertheless, they are quite unlike sheep in their ability to tolerate cobalt deficiencies. Marsupial reproduction is unique, but their heat regulation and kidney function are similar to and as good as those of conventional mammals. No doubt the continued study of the fauna of the accessible islands will provide work for generations of biologists and many more opportunities for making comparisons of marsupials and eutherians.

SHELL COLLECTORS' CONVENTION

The First Australian Shell Collectors' Convention was held in Yeppoon, Queensland, in September. It was organized by the Keppel Bay Shell Club, of Yeppoon, and the Malacological Society of Australia.

About 250 shell collectors from Australia, New Zealand, the United States, and Pacific islands attended the convention, at which scientific and popular talks on shells and shell collecting were given. Collecting expeditions to nearby islands and beaches were organized.

BOOK REVIEWS

THE FRINGE OF THE SEA, by Isobel Bennett, with photographs by F. G. Myers and Keith Gillett; 1967; Rigby, Adelaide; 261 pages; 179 plates. $10.

LIFE ON THE AUSTRALIAN SEASHORE, by Gladys Y. McKeon; 1966; Jacaranda Press, Brisbane; 150 pages; 24 plates. $4.95.

Those Australian naturalists who have been interested in seashore life have had a lean time of it for many years. With the exception of Dakin's *Australian Seashores*, there has been little in the way of literature to help them with the identification of the wonderfully interesting array of animals and plants which are to be found living between tidemarks. Now, within a few months, two books have appeared which describe the living creatures of this zone.

The first and more impressive is Isobel Bennett's book, magnificently illustrated by photographs by two of Sydney's leading marine photographers. Seldom has such a fine collection of illustrations of marine organisms been assembled, and they will permit ready identification of many species, principally from eastern Australia. Unfortunately, there are a number of errors in the spelling of scientific names which could have been avoided had the text been checked by specialists in the various groups, but these do not detract from the wealth of information about the animals which are described, both individually and as members of the classes and orders to which they belong.

Beautifully produced, the book is not cheap at $10, but for enthusiasts this will be a good investment which will yield much valuable information and at the same time delight the eye with the wealth of its illustrations. Isobel Bennett, F. G. Myers, and Keith Gillett are Associates of the Australian Museum.

Mrs McKeon's book is intended for a different audience, but it fulfils its purpose just as well. It is more detailed, covering plants and vertebrates (fishes and birds) as well as the invertebrate groups. The various animals are not identified with scientific names, but common names are used throughout. The one exception is the Mollusca, for which the scientific names equivalent to the common names are given in an 8-page appendix. The illustrations are line drawings by Mrs McKeon and for the most part are perfectly adequate for the identification of the species concerned. Although the title suggests an Australia-wide coverage, the species are principally from eastern Australia, and primarily from coastal Queensland and New South Wales, with relatively few Barrier Reef shells. This is no failing, for the latter can usually be identified from a variety of other works covering tropical marine faunas, whereas the coastal species are less well covered.

Priced at $4.95, the book is a good buy and will provide a splendid introduction to seashore organisms for the young or beginner naturalist who does not want to be overwhelmed with scientific names but who does want to learn something about the animals and plants which he sees there.—*D. F. McMichael.*

Norfolk Island's two satellite islets, Nepean (left) and Philip (right), differ rather markedly in their geology. Philip Island's rocks are volcanic in origin and have suffered marked erosion, but Nepean Island's are of aeolian limestone and have fared somewhat better. The ruins in the foreground are a reminder that early settlement of Norfolk Island was by convicts. [Photo by courtesy of the Department of Territories.]

Norfolk and Lord Howe Islands

By LOISETTE MARSH and ELIZABETH POPE, Curator of Worms and Echinoderms, Australian Museum

ALTHOUGH the Norfolk and Lord Howe Island groups appear as mere dots in Pacific Ocean maps, lying some hundreds of miles to the east of Australia, their interest and importance in the all over picture of the geographical distributions of plants and animals far outweigh their insignificant size, for they lie like widely separated stepping-stones along what we surmise might have been the migration routes for land-dwelling organisms between Australia and New Caledonia and New Zealand and Fiji. Lord Howe Island is almost half-way between Australia and New Zealand, while Norfolk Island lies between New Caledonia and New Zealand.

Both islands have therefore received a good deal of attention from naturalists in the past, and many of the scientific accounts of their plants and animals have attempted to draw conclusions about the relationships, close or distant, of their floras and faunas with those of neighbouring land masses; recent studies of their geology and that of the Tasman Sea floor are arousing renewed interest in this problem. Several recent accounts have appeared of Lord Howe's natural history but no one has attempted to give a similar all over picture of Norfolk Island, although many articles have been written about its colourful history from convict times, through the resettlement

Remnants of Norfolk Island's original dense cover of graceful pines, *Araucaria heterophylla*, remain in some of the steep-sided valleys, dissected by streams, in the undulating plateau which forms the main part of the island. [Photo by courtesy of the Department of Territories.]

on its shores of the Pitcairn Islanders, to the present day. It is therefore proposed, in this present article, to place more emphasis on Norfolk Island.

Both island groups owe their origins to volcanic activity and are surrounded by hundreds of miles of deep oceanic water. Both had highly characteristic floras and faunas of their own which showed, as one would expect, intriguing differences and resemblances one with the other. When discovered by Europeans in the late 18th century neither island was populated by a native Pacific people, although Norfolk Island shows evidence of at least occasional visits from Polynesian peoples, since a few stone implements have been unearthed there. No such evidence has been found on Lord Howe Island, so one can infer that when first viewed by Europeans these island floras and faunas had evolved without, or at least with minimal, interference from man. It is interesting to follow the fate of the vegetation and their animal populations since.

The Norfolk Island group (latitude 29° 2′ S. and longitude 167° 57′ E.) comprises a main island approximately 5 miles long by 3 miles wide with two tiny satellite islets, Nepean and Phillip Islands, lying half a mile and 3½ miles, respectively, to the south of it. There are in addition about half a dozen rocky stacks, big enough to be capped by vegetation, lying off the north coast of the main island. In the October, 1960, issue of the *National Geographic Magazine* there is an excellent aerial photo-map of the island, which is of great interest to naturalists as it shows present land usage and how little of the original vegetation now remains. When Captain James Cook discovered Norfolk Island in 1774, during his second voyage round the world, he observed:

> Many trees and plants common at New Zealand, and in particular, the flax plant, which is rather more luxuriant here than in any part of that country; but the chief produce is a sort of spruce pine which grows in great abundance and to a large size, many of the trees being as thick, breast high, as two men could fathom, and exceedingly straight and tall. For about 200 yards from the shore the ground is covered so thick with shrubs and plants as hardly to be penetrated inland. The woods were perfectly clear and free from underwood, and the soil seemed rich and deep.

Cook also noted the all-important presence of fresh water and "cabbage palms, wood sorrel, sow-thistle and samphire

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abounding in places on the shore. The cabbage is, properly speaking, the bud of the tree; each tree producing but one cabbage, which is at the crown, where the leaves spring out and is enclosed in the stem. The cutting off of the cabbage effectually destroys the tree", but one can excuse the destruction of these "trees" by Cook's men when one reads, "The vegetable is not only wholesome, but exceedingly palatable, and proved the most agreeable repast we had for some time". This is undoubtedly the first record of man's depredations of Norfolk Island's plants.

Another interesting early account by Philip Gidley King in 1788 described the island as "one entire wood, without a single acre of clear land".

Except for one limited area on the south coast, near the old town of Kingston, where there is some low-lying flat land from which juts a headland of sand rock with a limestone reef enclosing a small lagoon, the rest of the Norfolk Island coastline comprises cliffs about 250 feet high. Inland the island consists of an undulating plateau, dissected here and there by small streams which have carved out steep-sided valleys in some of which permanent streams flow, reaching the sea as waterfalls over the cliffs. The main plateau is about 350 feet above sea-level, sloping up towards the northwest part of the island to form two low mountains, Mt Pitt and Mt Bates, both of which are a little over 1,000 feet high. Originally the whole island was covered either by dense growths of subtropical rainforest or by stands of the stately Norfolk Island Pines (*Araucaria heterophylla*).

The Lord Howe group (latitude 31° 31′ S. and longitude 159° 04′ E.) was not discovered until 1788, the year of the first settlement on Norfolk. It owes its discovery to the fact that it is situated almost on the direct route between Sydney and Norfolk Island and Lieut Lidgbird Ball sighted the islands while on his way to the latter place, where he was to take formal possession of Norfolk Island for the British authorities in order to prevent any other European power gaining access to the "useful plant products noted there by Captain Cook". On the return journey to Sydney Lieut Ball took a closer look at Lord Howe Island, finding a main island approximately 6 miles long and varying from about half a mile to a mile in width and having the greater part of its area occupied by two impressive, sheer-sided, basalt mountains, Mt Gower (2,836 feet) and Mt Lidgbird (2,545 feet).

These two mountains form the southern end of the island, the northern end comprising a series of hills forming the North Ridge, of which Malabar Hill (658 feet) is the highest and Mt Eliza (490 feet) the most picturesque. In between rise two more basaltic hills which add greatly to the beauty of Lord Howe's scenery. These higher parts of the island are, as it were, joined together by lower-lying rocks of a different type—a coarse-grained sedimentary calcarenite or sandstone rock composed of fragmented materials such as coralline and nullipore algae and animal matter such as bits of corals, foram shells, and broken-up molluscs.

Clustered around this main island are some dozen tiny islets, the chief of which are the Admiralties, and about 12 miles to the south is the Pinnacle, or Ball's Pyramid. This latter is an amazing sliver of rock, the erosional remnant of a once much bigger island, rising from a small base to a height of 1,811 feet.

Lord Howe Island's original discoverers described it as a paradise with a dense vegetation, where "coconuts and cabbages" were plentiful and where the numerous kinds of birds were so unused to man and so fearless that they came up to the sailors and could be knocked over with a stick or be caught by hand. No indigenous mammals were noted, other than bats, but turtles and fish were easy to take in the lagoon. The reference in Bowe's diary of 1788 to "coconuts" probably refers to the presence of stands of graceful *Howea* palms, since there are no coconuts there and it is impossible to get them to flourish there so far south of the equator. "Cabbages", of course, refers to the growing tip of a young palm as it did in the early accounts of Norfolk Island.

Howea palms, tall *Pandanus* trees, banyans (*Ficus columnaris*) and lianas and a sort of low scrub resistant to the salt-laden winds clothe the lower levels of the island. On the tops of the two mountains and in the hanging valley between them (Erskine Valley), which are frequently enshrouded in cloud or mists, there is a most interesting moss forest in which small trees and shrubs, mosses, lichens, palms, tree ferns and ferns (many unique to Lord Howe) abound and the trees are draped with epiphytic plants that hang down like spanish moss. It is in this infrequently visited, mountainous area of the island that some of the rarer fauna still survives, such as the small flightless wood hen *Tricholimnas sylvestris* or the Brown-headed Petrel (*Pterodroma melanopus*), which nests on the slopes of Mt Gower. Alan McCulloch's description in Volume 1, No. 2, of *The Australian Museum Magazine* still remains the best general account of Lord Howe in the early days and up to 1921, while Keith Hindwood's "The Birds of Lord Howe Island" in Vol. XL, Part 1, of *The Emu*, not only tells of the bird fauna and the depredations caused by man and his introduced animals but also gives a naturalist's history of the island. These works are well worth consulting.

Settlement and its effect on Norfolk Island

Today Norfolk Island still impresses as an immensely fertile, vividly green island with high sea-girt cliffs fringed with tall Norfolk Island Pines, but the immense stands described by early historians are terribly reduced. The first settlers, most of whom were convicts, cleared 1,500 of the island's 8,500 acres to grow the native flax (*Phormium tenax*), wheat, and vegetables, but although the soil was fertile they enjoyed only limited success because of pests and the fact that the flax proved to be of low quality.

The early settlers also introduced such plants as lemons, apple-fruited guava, and cherry guava, and even as early as 1835 James Backhouse states that these plants had overrun the island. Guavas still grow over much of the uncultivated land and the cherry guavas are greatly enjoyed by all there today.

Norfolk Island began as a penal settlement in 1788 on the southern side of the island, and this settlement became Kingston. By 1804 the population had grown to 1,100 and comprised free settlers, as well as convicts.

Some times of terrible privation were experienced, as, for instance, in 1790 after the supply ship *Sirius* was wrecked at Kingston—a disaster which coincided with crop failures and a relatively large increase in the population. During this first severe food shortage, the islanders literally kept themselves alive by eating thousands of Brown-headed Petrels (*Pterodroma melanopus*), which nested in burrows on Mt Pitt. Norfolk Islanders called it the Bird of Providence, for its annual migration to the island that year just happened to bring the

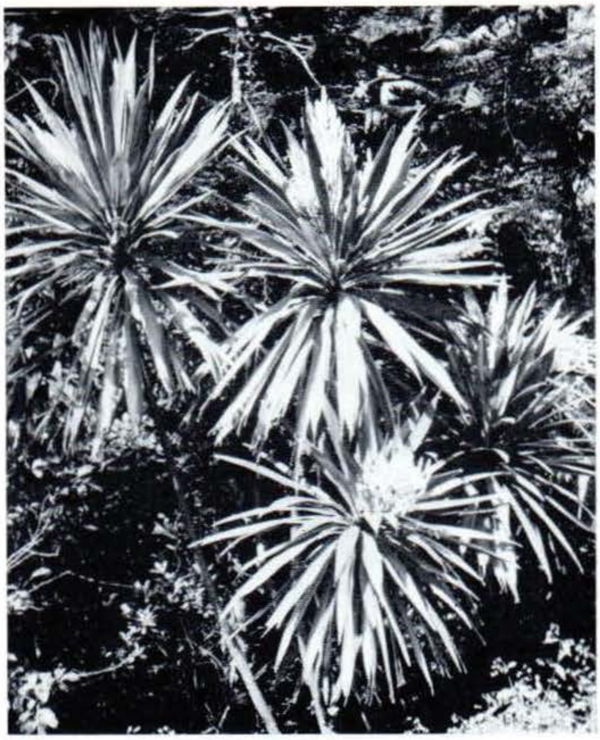
A view of Cascade Bay, Norfolk Island, showing the steep coastal cliffs typical of much of the island. (The whale was later towed across the basalt boulder beach to the whaling station.) [Photo: Loisette Marsh.]

birds to the island in the nick of time, when the islanders were facing starvation. It has been calculated that, between April and July, 1790, more than 170,000 birds were eaten. While acknowledging the Providence Petrels as their saviours, the Norfolk Islanders continued to slaughter them wholesale during subsequent breeding seasons, until the bird was exterminated.

It is thought that rats swam ashore from the ill-fated *Sirius*, for they arrived about that time and have continued to take serious toll of the bird populations ever since, and have generally upset the natural ecological balance of the island habitat.

Norfolk Island's history and the fate of its plants and animals are so closely bound together that one must make a brief survey of past events in order to understand present-day conditions. The expense of maintaining Norfolk Island's penal colony proved to be too great and so, by 1813, it was abandoned and the people were transferred elsewhere. However, in 1825 it was reoccupied as a punishment centre for convicts sent from New South Wales. Once more the land was worked and more native vegetation cleared, and it was during this period that the substantial and impressive stone buildings and bridges were constructed. It became a brutal settlement—"a place of the extremest punishment short of death". But again official policy changed and Norfolk Island was abandoned as a convict settlement.

In 1856 the population of Pitcairn Island, descendants of the *Bounty* mutineers and their Tahitian wives, replaced the convicts, thus setting up a free settlement on Norfolk Island. They brought with them a Polynesian knowledge of the uses of native plants and, no doubt, they introduced a few plants from Pitcairn. For instance, they used one species, the Norfolk Island Breadfruit (*Cordyline* species), as food, and another (*Cordyline terminalis*) for brewing an "ardent spirit", while the leaves of the palm *Cyperus haematodes* were plaited into baskets and the tree fern *Alsophila* provided food for pigs, sheep, and goats. A species of taro (*Colocasia antiquorum*), thought to be introduced, was grown in some swampy areas and at all times they took heavy toll of the graceful native Norfolk Pines. These activities have naturally greatly changed the vegetation of the island and upset the ecological balance. Areas to the south of Duncombe Bay and to the west of Steel's Point are today mainly cultivated for food crops. French Bean seed was grown for export for more than 60 years, but that trade has almost disappeared now due to competition from newly irrigated areas of Queensland.



The Norfolk Island breadfruit (*Cordyline obtecta*) growing on the slopes of Mt Pitt. [Photo: Loisette Marsh.]

Norfolk Island's flora and fauna today

Today most of the island is kept cleared but many of the small valleys, too steep to cultivate, are used as pasture and have delightful stands of the native pines left for shade. Near the cliff tops the unfenced common land has a park-like appearance, with closely cropped grass, stands of Norfolk Island Pines, and huge White Oaks (*Lagunaria patersonii*) with their attractive hibiscus-like flowers. Flax plants (*Phromium tenax*) grow at the cliff edge or on the cliff face where it is not too precipitous. In the Mt Pitt and Mt Bates area, between Puppy's Point and the north coast, is a forest reserve in parts of which regeneration of Norfolk Pines is occurring, but some eroded areas or clear parts of this reserve are being

Part of the Norfolk Island forestry reserve, viewed from the Mt Bates road, containing a remnant of the island's virgin forest. A few pines thrust upwards through the general forest, while tree-ferns, palms, and breadfruit can be recognized in the foreground. In the background are park-like grazing land and farmlets of the kind that cover so much of the island. [Photo: Loisette Marsh.]

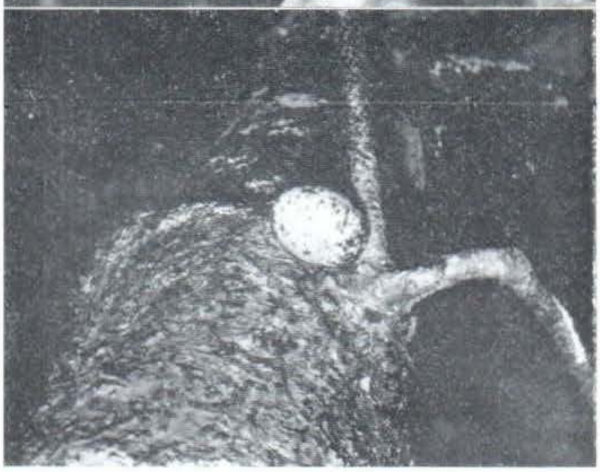
re-afforested with introduced eucalypts. There is another small forest reserve at Rocky Point (near the southeast corner of the island). These two areas are all that remain of the island's virgin forest. The mountain tops are accessible by road and several walking tracks lead off to join other roads or to skirt the cliff edge along the north coast. Further roads and quarrying projects are therefore threatening this last stronghold of Norfolk Island's unique vegetation.

Lantana thickets make penetration of the bush from the road difficult, but, where it is possible, one steps into a world of deep shade, mossy stones, Tree Ferns (*Alsophila excelsa*), King Ferns (*Marattia fraxinea*) with their 14-foot fronds, Birds' Nest Ferns and about fifty species of smaller ferns, palms (*Rhophalostylis baueri*) and huge pines (*Araucaria heterophylla*) which may reach 140 feet in height and 37 feet in girth. There are two species of pepper (*Piper excelsum* and *P. psittacorum*) and peperomias on the rocks. In some places there is a tangle of the Norfolk Island Screw Pine (*Freycinetia baueriana*), the only member of the Pandanaceae on the island. Creepers abound, like Samson's Sinew or the native wistaria (*Milletia australis*), which has an attractive purple and green pea flower, and the two species of native passion-flower.

This forest area has, in the past, proved a remarkably rich collecting ground for land snails, over seventy species of which were recorded by Iredale from Norfolk and its outlying islets. Many are rather small in size but are none the less interesting on this account. The same collector and author recorded sixty-eight species of land snails from Lord Howe in *The Australian Zoologist* for 1944. These included the large, interesting *Placostylus bivaricosus*, whose empty shells are seen lying around on the forest floor in many parts of the island and remind one of the giant *Placostylus* snails seen in New Caledonia. *Placostylus* is not found on Norfolk Island. Summing up the facts about the land molluscan faunas of these two tiny island groups, one can only stand amazed at their extraordinary richness and the high percentage both of endemic species and genera found in each of them. While the snails of Lord Howe show obvious relationships with those of New Zealand and New Caledonia, they differ rather markedly from those of neighbouring Norfolk Island. Here is a fascinating problem for some enterprising zoogeographer—just one of the many posed by these two islands.

According to Keith Hindwood, who has taken a special interest in the fate of Norfolk Island's birds, some sixty species have been recorded—that is discounting records since found to be erroneous, such as that of the White Swamp Hen (*Porphyrio albus*), which careful investigation has shown occurred only on Lord Howe. Of these sixty species, approximately half must be reckoned as come-by-chance stragglers. The remainder are either permanent residents or regular migrants to the island, with a scattering of species introduced by man, or "squatters" that introduced themselves and became firmly established.

Nine species of sea birds (three noddies, two terns, a gannet, a tropic-bird and two species of petrels) breed on the island or its outliers. As mentioned above, the Brown-headed or Providence Petrel was literally eaten out in the early days. Wedge-tailed Petrels still nest on Norfolk in certain areas and the Red-tailed Tropic-bird nests on cliff edges; Sooty Terns (the so-called Whale Bird), *Sterna fuscata*, breeds on Phillip and Nepean Islands or on rock stacks like Red Stone, off the north coast of the main island. White Terns (*Gygis alba royana*) fly or hover in pairs near the cliff tops. They make no proper nest, merely laying their eggs on the branches of Norfolk Island Pines in places where a twig or knob on the bark is the only safeguard between the egg and the disaster of its rolling off to plunge some 30 to 100 feet below. Nevertheless, these White Terns seem to survive and occupy trees all around the coast, with greatest concentrations near Creswell Bay, at Rocky Point (near Ball Bay), and on the northern slopes of Mt Bates. Their young are fed on small fish, as a rule, but mollusc shells such as those of *Spirula* and even small *Argonauta* occur under trees in which birds have been breeding. Of course, storms take a heavy toll of their eggs and young but luckily rarely occur during the nesting period.

The White Tern (*Gygis alba royana*) makes no nest but lays a single egg on a branch—usually of a Norfolk Island Pine—high above the ground. A twig or slight projection on the bark is all that prevents the egg from rolling off. Above: The bird sitting on the egg. Below: The "nest". [Photos: B. Marsh.]

About twenty species of land birds breed on Norfolk and of these some six or so are merely geographical variants of species found in Australia or in western Pacific islands. They include an owl, a parrakeet, a scarlet robin, a kingfisher, a native starling, and a fantail. A few genera and species of birds are peculiar to Norfolk Island, and it is among them that we look for pointers as to the affinities and origins of the island's bird fauna. Two very interesting ones are, or rather were, the large pigeon *Hemiphaga argetraea* and the Norfolk Parrot (*Nestor hypopolius*), for both are now extinct. These had distinct affinities with birds in New Zealand. Other interesting birds found only on Norfolk are the small grey and olive-brown Flyeater (*Royigerygone modesta*); the beautiful little Caterpillar-catcher (*Diaphoropterus leucopygus*); the Thickhead (*Pachycephala xanthoprocta*); the two Norfolk Silvereyes (*Nesozosterops albogularis* and *N. tenuirostris*), which are slightly larger than the ones we are familiar with, and the Grey-headed Blackbird (*Turdus poliocephalus*). Most of these have related forms on Lord Howe Island, but even a superficial perusal of the beautiful coloured illustrations in Mathews' classic account, *The Birds of Norfolk and Lord Howe Islands*, is sufficient to convince one that real differences have evolved between related species on these two neighbouring islands.

Regular migrators to Norfolk include two kinds of cuckoos which commute annually between New Zealand, where they normally breed, and some of the tropical Pacific islands, where they spend the winter. These may stopover in Norfolk Island (and in Lord Howe) en route or, in the case of the Bronze Cuckoo, may sometimes breed in

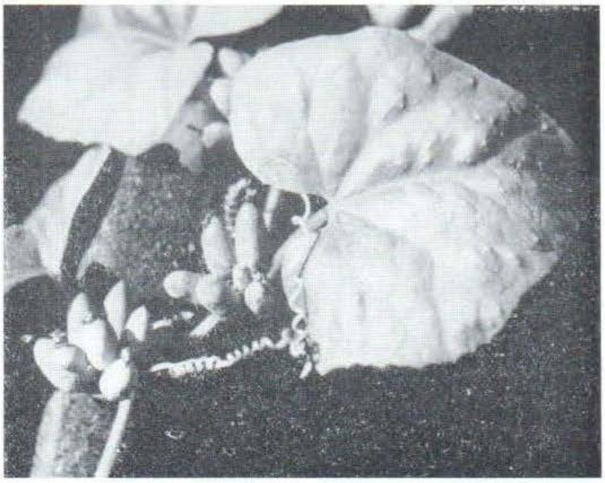
Norfolk. Waders like turnstones, godwits, and whimbrels regularly stage at Norfolk on their way from Siberia to points further south, making one think of modern jet-age travellers who enjoy brief stopovers on Pacific islands during round-the-world flights.

Analyses of Norfolk and Lord Howe bird populations made by various authors seem to reach the same general conclusions, namely, that in both faunas the most important element in the indigenous land species seems to have its origins in the New Caledonian area, with a secondary influence coming from New Zealand. The influence of the Australian region is seen chiefly among birds classed as stragglers, casual visitors, or immigrants of one kind or another.

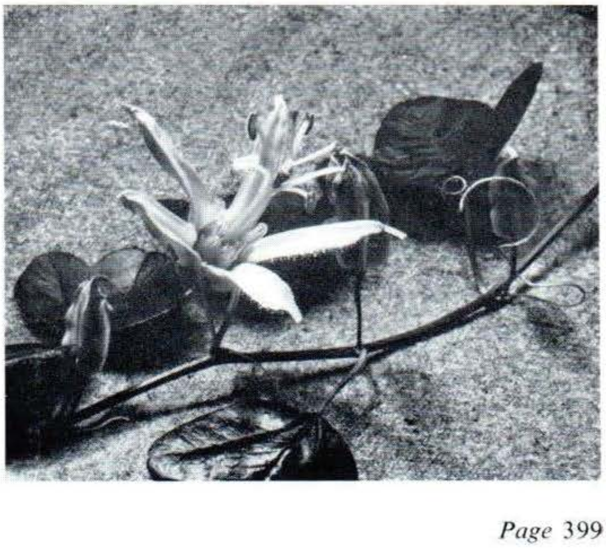
As is to be expected in such isolated small islands, reptiles and amphibians are not conspicuous. A small, rather attractive gecko (*Phyllodactylus guentheri*) occurs in both groups. Thought for some years to be extinct, it first turned up once more on outlying islets—on Rabbit Island in Lord Howe's lagoon and on Nepean Island at Norfolk. Subsequent investigation in the Lord Howe group by a specialist has shown that these geckos are also on the main island and breeding freely in places where it is difficult to detect and capture them. The indigenous skink, *Leiolopisma lichenigera*, long thought to be extinct by Lord Howe Islanders, was also taken by the expert and has been seen and photographed on distant Ball's Pyramid. No frogs are known from the islands.

The insect fauna of Lord Howe has been reviewed as recently as 1963 by Paramanov, but one interesting new fact has emerged since then. This is the rediscovery of the black phasmid *Dryococelus australis* on Ball's Pyramid by a party of climbers in 1964. A member of the party photographed a recently dead specimen of "this peculiar insect" which was recognized for what it was by curators of the Australian Museum. The fact that no live specimen was seen is not surprising since it is known to be nocturnal. Formerly known as the "land lobster" or "tree lobster" by the Lord Howe Islanders, it was believed to have been exterminated after the accidental introduction of rats to Lord Howe in 1918. The phasmid is illustrated elsewhere in this issue. Its reappearance on an outlying islet offers renewed hopes of finding it somewhere on the main island. The little that is known of Norfolk's insect fauna shows that it is, in the main, similar in composition to that of Lord Howe and, like the avifauna, shows the same sort of distinctions in closely related species. Differences have evolved but they are not of great magnitude. However, the phasmid has never been recorded from Norfolk.

No records of native mammals are known for Norfolk Island, though visitors early introduced pigs and goats and, in the case of Philip Island, also rabbits. These



Above: One of Norfolk Island's native species of cucumber, *Zehneria bauerana*. Below: The island's passion flowers, *Passifloria* species, are now fairly rare and grow only in one or two places on Mt Bates. Pale fleshy-cream in colour when it first opens, the flower darkens to a copper colour as it ages. [Photos: Loisette Marsh.]



introduced animals caused the usual sad trail of destruction of the natural environment which has in turn led to the extinction of some native plants and animals. Lord Howe Island originally had a species of bat living there, but there were no other native species of mammal. Again deliberate and accidental introductions of domestic animals (many of which are still feral in remoter parts of the island) and rats have led to the decimation of the native birds, and the natural balance of plant and animal communities has been upset on the more accessible parts of the island.

The reefs and marine animals

On the southern coast of Norfolk Island, between the pier at Kingston and Point Hunter, the beach is protected by a limestone reef forming a solid barrier for most of its length but with a somewhat broken area opposite the entrance to Emily Bay. Beach rock fringes the shore at Slaughter Bay, and between the reefs is a small, sand-floored lagoon, about 8 feet deep, in which skindiving is pleasant and safe. Here corals such as species of *Acropora* and *Pocillopora* or more massive kinds like astreids or meandrines are abundant, together with other typical tropical animals like the sea urchins *Echinometra mathaei* and *Tripneustes gratilla*. Several species of chaetodont fishes and the Banded Shrimp (*Stenopus hispidus*) can be seen. Also common is the interesting alga *Caulerpa sedoides*, which looks somewhat like bunches of bright-green grape hyacinths. Associated with this *Caulerpa* are the very interesting tiny bivalved gastropods, a species of *Tamanovalva*, and *Lobiger viridus*, which was illustrated in an earlier issue of this magazine (Vol. 14, No. 12).

An excellent general account of the lagoon at Lord Howe Island is given in Dr J. C. Standard's article in this issue, and further information can be obtained from the account in Gillett and McNeill's book *The Great Barrier Reef and Adjacent Isles*. The most interesting fact that emerges when the two reef faunas are compared is the greater richness of tropical species at Lord Howe—this despite the fact that it lies further to the south than does Norfolk Island. Probably the distances of the two islands from what might be considered the source areas of the marine faunas in the tropics and the sweep of the currents account for this.

Marine vertebrates

Lord Howe used to be visited by breeding turtles in the days just after its discovery but they were ruthlessly eaten by visiting sailors, hungry for fresh meat; an occasional sighting by skindivers is all that is seen of them today.

Whaling by open-boat methods was practised by the Norfolk Islanders for many years, taking toll of the whales as they passed the island during their annual migrations from Antarctic to tropic seas to breed. In 1956 a modern whaling station was opened at Cascade and allotted a quota of 150 Humpback Whales per season. This figure was increased to 170 in 1961, but in 1962 southern whale stocks declined to such an extent that the Norfolk Island station could no longer operate economically and it was closed down. Sperm Whale also pass by Norfolk occasionally during their migrations.

The fate of the plants and animals in both the Norfolk and Lord Howe groups of islands serves as a classic example of how interference by so-called civilized man upsets the delicate balance of nature that had evolved in their island environments over a long period of time. Interference, even if well-meant, changes the habitat. This, in turn, often leads to reduction of the populations of some native species and even ultimately to their extinction. As tourists like to visit different places and see in one place, say, palms and banyans and in another tree ferns and mosses and pines it behoves the residents in places with unique and refreshingly different vegetation and animals to guard them and ensure that variety of scene is retained. It may in the long run turn out to be worth hard cash for there are all too few wild places where weary city-dwellers may go to seek rest and refreshment of mind and spirit. There are also still so many fascinating scientific riddles about the plants and animals of these two islands which have to be solved that there are a thousand reasons why the people on these two delightful islands should try and guard their natural beauties and keep as much of the islands as they possibly can in their virgin state.

One of the few known illustrations of the now-extinct dwarf Black Emu of King Island (*Dromaius ater*), drawn by the French naturalist Lesueur in 1802.

THE BASS STRAIT ISLANDS

By D. L. SERVENTY
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PERHAPS no island groups around the Australian mainland equal in the sum of their biological and human interest those in Bass Strait, particularly the two groups at the western and eastern ends centred around King and Flinders Islands. Barrow Island in northwestern Australia is perhaps Australia's most mammal-rich island, and the cays in the Great Barrier Reef and in the Abrolhos Islands possess a great wealth of spectacular sea-bird colonies; the Abrolhos Islands are probably unparalleled for isolated dramatic historical episodes. But in the totality of these appeals to students of biology and human history the Bass Strait islands would, I think, lead all others.

The Bass Strait islands are the permanent remnants of intermittent land connections between southeastern Australia (the home of Australia's richest fauna, the Bassian) and Tasmania. The periodic "make and break" connections across Bass Strait have left enticing speciation problems which are still to be unravelled fully, whilst the rich sealing, mutton-birding and guano resources of the islands attracted white adventurers from the earliest days of European settlement and they have contributed colourful chapters to our social history.

Bass Strait, as a seaway, appears to have had an ancient history and may have had an existence since the early Tertiary (Jennings, 1959) but from the viewpoint of the biologist its vicissitudes are of most interest during the Pleistocene and later, when the eustatic rise and fall of sea-level, due to the accumulation and melting of the Polar ice-caps during the ice ages, in turn maintained and obliterated the strait. The land bridge enabled the mainland fauna to cross over to Tasmania and when it ceased to function permitted the Tasmanian fauna to evolve separately in isolation.

Fluctuating sea-levels

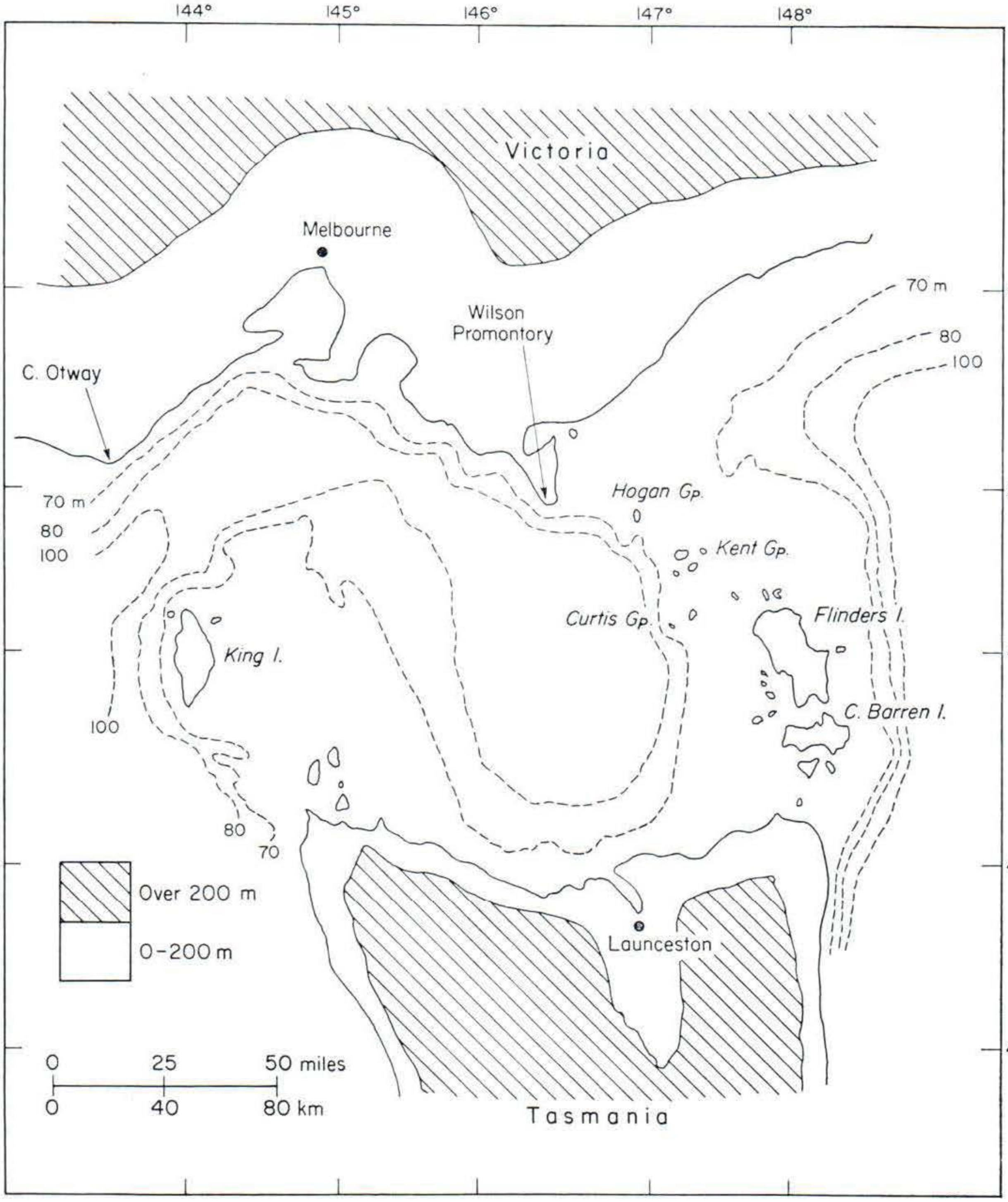
The present sea-level was reached only about 6,000 years ago. Prior to that there were fluctuations of level over a range of some 300 metres. It is believed that the first two glacial peaks did not cause the sea-level to drop below the present. However, the third glacial peak (the "Riss" of Alpine geologists or "Illinoian" of American terminology) caused the sea-level to fall to 75 metres below the present. This closed both Torres Strait and Bass Strait for a period which endured some 10,000 years (from 120,000 to 110,000 years B.P., i.e., before the present, in current terminology). In the succeeding warm interglacial interval melting of the polar ice again inundated the shallow coastal plains and the straits between were reopened. The fourth, and last, glacial period (the "Würm" or "Wisconsin" glaciation) had an even greater effect. Sea-level again dropped below the present in 70,000 B.P., and reached its minimum of 100–110 metres at 20,000 B.P. This joined Tasmania and Victoria for about 60,000 years.

There is evidence that the sea has not yet returned to its preglacial high level (R. W. Fairbridge, personal communication). Since the last major retreat of the ice there have been lesser fluctuations of climate. The most significant was a period of maximum warmth between 6,000 and 4,000 years ago (the "Climatic Optimum" of Scandinavian geologists, the "Arid Period" of Australian workers), when mountain glaciers disappeared from Europe. Subsequently colder conditions returned (the "Little Ice Age") and minor fluctuations of climate have been recorded since in historical times. At the moment there is a pronounced amelioration of climate in sub-polar regions, with another retreat of the glaciers. All these fairly recent changes will mean fluctuations in sea-level which affect the size and very existence of numerous islets in Bass Strait.

Strait's bathymetry

As the bathymetry of the strait suggests, the western end of Bass Strait would remain open for longer periods than the eastern, where a land connection from Wilson's Promontory, through the Flinders Island chain, to northeastern Tasmania would endure for a considerable period, whilst a sea gap would exist between King Island and Cape Otway in Victoria. Furthermore, King Island would remain in spatial isolation from neighbouring lands longer than would Flinders Island. During the periods of low sea-level the two great river systems on the northern and southern shores of Bass Strait, the Yarra and the Tamar, might have joined before they debouched as one mighty river into the Southern Ocean between King Island and Cape Otway. The first Commonwealth fisheries investigator, H. C. Dannevig, who did important pioneering soundings in Bass Strait, coined a name for the combined river—the Tamar Major. However, though the general submarine contours suggest its existence no trace of the actual channel can be recognized in the practically featureless flat floor of the main part of Bass Strait. Jennings (1959) has pointed out that one can scarcely expect to find a relict river channel on the weak sediments which exist in this area as they would have been rapidly concealed by later marine sedimentation and erosion.

As there were two main periods in the Pleistocene when the King Island and Flinders Island chains offered transportation routes to the flora and fauna between Victoria and Tasmania, and subsequently closed to allow opportunity for secondary differentiation of plants and animals in Tasmania and the Bass Strait islands, one may expect two groups of related assemblages of recent plants and animals. This has been found to be the case. Professor H. N. Barber, in his phyto-geographical studies



Bass Strait, showing submarine contours (in metres) and adjacent land and its relief. [From Ridpath and Moreau, 1966, after Jennings, 1959.]

of Tasmania, was able to recognize, in the genus *Eucalyptus*, two groups of species—one group of full endemics very easily distinguishable from their nearest mainland relatives and a second group of species common to both sides of Bass Strait or with difficulty distinguishable from mainland species. These latter he called "half-endemics".

"Double invasions"

There are similar groupings among animals. I am most familiar with the birds. Here we have cases of "double invasions"—that is, of two similar species, obviously closely related, occurring in Tasmania, whilst only one exists in southeastern Australia. The phenomenon is best illustrated by an example. The Brown Thornbill (*Acanthiza pusilla*) is a well-known mainland species. It is represented in Tasmania by a subspecies (*A. p. diemenensis*), barely separable from the Victorian form—a counterpart of Professor Barber's semi-endemics among the eucalypts. However, Tasmania possesses in addition, but Victoria does not, a bird very much like the Brown Thornbill in appearance but with physical characteristics compelling its acceptance as a separate full species, which does not interbreed with ordinary *A. pusilla*. It is Ewing's Thornbill (*Acanthiza ewingii*). We interpret Ewing's Thornbill as originally part of the common stock of Brown Thornbills which occurred in Victoria and Tasmania when the two landmasses were earlier joined ("Riss" Glaciation). When Tasmania became separated during the succeeding interglacial period the isolated Brown Thornbills there had opportunity to evolve into distinct birds. When Tasmania and Victoria were again joined at the last Glacial Period Victorian Brown Thornbills spread over and met their differentiated relatives in competition. Though interbreeding was no longer possible they were still sufficiently close in habits that they could not co-exist in the same habitat. Ewing's Thornbill now inhabits the temperate rainforest and other high wet forests, while the more recent colonizer, the Brown Thornbill, is essentially a bird of the dry sclerophyll country, the two overlapping in the wet sclerophyll (Ridpath and Moreau, 1966).

Another example of this type of double invasion is found in the diamond-birds or pardalotes. The rare Forty-spotted Pardalote (*Pardalotus quadragintus*) would correspond with Ewing's Thornbill, an earlier derivative of the Spotted Pardalote (*P. punctatus*), so well-known on the mainland. The Spotted also occurs in Tasmania, a later arrival there corresponding with the Brown Thornbill, and it appears to be in process of ousting the Forty-spotted. Evidently in this case the two related species have not been able to share out Tasmania into separate ecological niches and the comparative newcomer is likely to succeed as sole possessor.

Tasmanian currawongs

The two Tasmanian currawongs illustrate a double colonization of a slightly different sort. Their mainland ancestors were not one, but two, separate species, members of separate faunas, the Eyrean (*Strepera versicolor*) and the Bassian (*S. graculina*), one living, in general, inland of the Great Dividing Range and the other seaward of it. In Tasmania their derivatives are not geographically separated but have a sort of mosaic distribution dependent on habitat. The Clinking Currawong (*S. arguta*) is a very well-marked form of *S. versicolor*, and it is now considered only a subspecies of that bird. The second Tasmanian species, locally called the Black Jay (*S. fuliginosa*), belongs to the *S. graculina* group but is so well differentiated that it is considered a separate full species. It may have reached Tasmania in the same period as Ewing's Thornbill and the Forty-spotted Pardalote. *S. fuliginosa* breeds in high wet areas, *S. arguta* favouring dry sclerophyll areas. On the whole they live apart, and both are plentiful.

It may be asked why there has been colonizing activity only from Victoria to Tasmania, whilst land-bridges existed, and not in the reverse direction. This is a fascinating aspect of animal introductions, and there is a lesson we should bear in mind when we attempt the process ourselves through acclimatization. The explanation was given long ago by Charles Darwin and has been re-stated in a lively manner recently by Western Australian zoologist Dr G. M. Storr (1958), with a further review by myself (1960). Briefly, it is that species evolved on larger landmasses are at a premium when they are brought into competition with similar species evolved on smaller areas. As Darwin said: "Widely-ranging species, abounding in individuals, which have already triumphed over many competitors in their own widely-extended homes, will have the best chance of seizing on new places, when they spread into new countries".

Another question. What is the situation in the Bass Strait islands in respect to the older and newer members of the species pairs? It would appear that it is the older species which occurs on the islands, and the newer is absent. Thus, in the currawongs, *S. fuliginosa* occurs on both Flinders and King Islands, but not *S. arguta*. In the thornbills, *Acanthiza ewingii* is found on both islands, but apparently not *A. pusilla*. Mr R. H. Green, of the Queen Victoria Museum, Launceston, has collected only *A. ewingii* on Flinders Island, and made the very interesting observation that there it occupied a far wider range of habitats than it did in Tasmania, where it was exclusively a rainforest and wet-gully bird. In other words, in the absence of the competing species it was able to spread out into a wider range of environments. With these examples one would expect the Forty-spotted Pardalote also to be the one on the islands. It was earlier recorded on King Island, but it is failing to hold its ground. It seems to be a declining species and is leaving a void which, now, in the case of Flinders Island at any rate, is in process of being filled by the Spotted Pardalote.

Sharing of habitats

It seems that none of the Bass Strait islands are sufficiently large to enable two closely similar and competing species, as those we have mentioned, to co-exist, though on a larger landmass, like Tasmania itself, most are able to do so by sharing habitats. This reduction of species on islands is well known and in other parts of Australia (Serventy, 1951) produces the interesting phenomenon of one species of a closely related group being found on one island and a different species of the same group on another. Faunal surveys of the numerous islets in Bass Strait are incomplete as yet and one cannot cite many examples here, partly also because of the fewness of the species as a whole. Perhaps the best example is found in the two snakes, the Tiger Snake (*Notechis scutatus*) and the Copperhead (*Denisonia superba*). Both live on the main large island of Flinders, but on the smaller islets in its vicinity occurs either one or the other, but not both together. In this case it would seem that the bevelling out of effective differences between ecological niches on small islands means that only one of a species group with rather similar habits will, in general, survive. The consequent freedom from competition often results in the single surviving species being able to occupy habitats in which it would not normally be found on the mainland. Thus, the Tiger Snake on Chappell Island occurs now in most un-Tiger Snake country (on mainland standards) and it does so in incredibly large numbers.

An interesting feature of the speciation problem on the Bass Strait islands has recently been revealed by investigators. As early as 1934 the ornithologist George Mack drew attention to the similarity in plumage characteristics of the Blue Wren (*Malurus cyaneus*) on King and Flinders Islands and their differences from the same species in Tasmania. He failed to follow up the implications of this interesting discovery, the discussion of which was left to Ridpath and Moreau (1966). They pointed out that the similarities between the King Island and Flinders Island birds could scarcely be due to gene-flow between them, without Tasmania also being involved. Either the identical features shared by the two island populations arose independently after their separation from Tasmania, or the King and Flinders Islands birds represented the original condition common to them and Tasmania but now lost in the large island. About the same time, and independently, similar characteristics have been discovered in several species of honey-eaters on King and Flinders Islands by the Danish ornithologist Finn Salomonsen (1967, and personal communication), who is now working up the Australian honey-eaters for Peter's *Checklist of Birds of the World* (Vol. 12, in press). Obviously something interesting is happening in these isolated small populations and it would be of value if museums were to make collections of Passerines—and other terrestrial fauna—on these islands to document the phenomenon. Obviously, with the small populations involved it would be injudicious, from the conservation point of view, to collect too many individuals at the one time, but specimens should be "harvested", as it were, by small gatherings at periodic intervals. In this way sufficiently large samples, statistically significant, could be accumulated for study.

Parallels in Western Australian islands

The Bass Strait islands are not the only Australian islands showing this particular problem. In Western Australia, on Dirk Hartog Island and on Barrow Island, over 350 miles apart, are the highly distinctive Black and White Wrens (*Malurus leucopterus*), while on the adjoining mainland is found the Blue and White Wren (*M. leuconotus*), differing only in that the black in the plumage is replaced by blue. How did the two groups of melanic island birds arise? I am inclined to the belief that the explanation, as in the Bass Strait wrens and honeyeaters, is that the same factor, or series of factors, is operating independently in the islands environment to produce, by selection, a similar result in each. In other words, we have a type of ecotypic variation.

The dwarf emu of King Island

The most extreme example of the evolution of a distinct bird species on the Bass Strait islands is in the emus, and, unfortunately, both the one in Tasmania and that on the islands are now extinct. The Tasmanian Emu was, from specimens preserved in the British Museum (Natural History), so similar to the mainland Australian one (*Dromaius novae-hollandiae*) in size and plumage, that it can be matched by selected specimens from Australia—so much so that the Tasmanian Fauna Board now plans to produce a replica of the original Tasmanian type through selective breeding. The emu on King Island, however, was distinctly different. Until about 8 years ago it was known only from skeletal remains, though the early sealers on King Island had described it to members of the Baudin Expedition in 1803. In 1959 Dr Christian Jouanin, of the Natural History Museum, Paris,

The earliest known illustration of the Tasmanian Mutton-bird (*Puffinus tenuirostris*)—a painting by artist William Ellis during Captain Cook's Third Expedition, 1778. [Reproduced by courtesy of the Trustees of the British Museum ([Natural History).]

demonstrated that the mounted specimen of a dwarf black emu in their collections, which had hitherto been believed to be from Kangaroo Island, South Australia, originated in reality from King Island. It was quite distinct from the Tasmanian and Australian emu, deserving to be ranked as a full species, not a subspecies, and would bear the scientific name of *Dromaius ater*. It is not known how or when it became extinct, but no doubt the combination of hunting by white sealers and the burning of the park-like *Eucalyptus* forests was responsible. These forests once covered much of the island (Campbell, 1888) and were almost all destroyed by the end of the century, profoundly altering the environment, and undoubtedly, in consequence, the status of the animals occurring in them.

No bone or egg remains of this dwarf emu exist in museum collections from Tasmania or other Bass Strait islands, though Mr Frank Jackson, of Emita, Flinders

Island, told me that he had found fragments of eggshell on that island. Such remains, and bones, should be sought, to determine whether this dwarf bird was once generally distributed in the Tasmanian region. It would seem likely that it was a member of the older fauna which was able to survive until recent times only on King Island, as that island would be isolated from Tasmania longer than Flinders Island. The large emu probably reached Tasmania only during the last interglacial period, perhaps by the Wilson's Promontory-Flinders Island route, maybe never reaching King Island.

Human colonization

This eastern land route across Bass Strait, open longer and more continuously than the western parts of the strait, was probably also used by the ancestral Aborigines to reach Tasmania. Through radio-carbon dating techniques it has been established that the antiquity of man in Australia goes back far longer than we had previously supposed and the original Tasmanians could have walked across land bridges rather than navigated by sea. However, at the time of arrival of the European settlers no native peoples lived either on Flinders or King Islands. Native artefacts, however, have been found on Flinders Island in circumstances precluding an origin associated with the temporary sojourn of exiles brought there by the white Tasmanians last century.

However, we know nothing about this early island occupation and the real interest at the present day stems from the resettlement of the islands by the white sealers at the end of the 18th and beginning of the 19th centuries and their bringing with them native consorts. These adventurous pioneers were drawn to the area by the discovery of the Fur Seal resources and the reports of navigators like Matthew Flinders and George Bass. It is sometimes forgotten how much natural history knowledge of the Bass Strait islands was discovered by these early explorers, French and British. Bass and Flinders discovered the nesting colony of the Shy Albatross (*Diomedea cauta*) on Albatross Island in 1798 and gave a good account of it. It was not until almost a century later, in 1894, that a professed naturalist landed on this difficult rock and adequately reported on the colony.

Similarly with the Gannet (*Sula serrator*) colony on Cat Island, near Flinders Island, and the various nesting islands of shearwaters, Cape Barren Geese and other sea birds. Aside from a few desultory visits by later naturalists, like John Gould's in 1839, the real natural history investigations of the area did not start until the series of expeditions from 1887 onwards organized by the Field Naturalists' Club of Victoria. Their reports are an invaluable record of the fauna and conditions at the time

Early natural history records

It is very unfortunate that the white sealing captains who penetrated every islet and rock in the area left so few records. They exploited the guano deposits of Albatross Island and of Cat Island, climbed the almost inaccessible Black Pyramid, and in the course of their activities exterminated the Dwarf Emu and Elephant Seal of King Island and almost did the same to the Fur Seal. Unhappily there was no Boswell or Dampier among them to chronicle their doings, and so a great murk obscures what they saw and what they did in the natural history line. However, scraps of information surviving here and there indicate they were acute and competent observers. Documents in the Mitchell Library, Sydney, of reports by the boatman James Campbell in 1828 provide a useful survey of the animals that lived on the small islets around Flinders Island and of the environmental conditions obtaining at the time. The information provided by George Augustus Robinson in the 1830's (Plomley, 1966) is most valuable, and that vouchsafed by the islanders in 1872 to Canon Brownrigg on the nesting habits of mutton birds is surprisingly accurate, as is the knowledge of the bird possessed by their descendants at the present day.

The sealers and their descendants

The image which these sealers left behind, as far as the average modern Australian is concerned, is a distinctly unfavourable one—that they were a gang of lawless, brutal ruffians who shockingly maltreated their kidnapped native women and squandered the natural wealth of the islands. The recently published journals of the native conciliator Robinson, just cited, confirm this appraisal. However, in later years of sealer occupancy of the islands one knows that an altogether different situation reigned in the Flinders Island region. The people who endured through the tough pioneering decade or two, and left descendants, must have had many admirable "survival characteristics". As these white sealers aged and mellowed and their half-caste sons and daughters began to prevail in the population, records by responsible visitors give a very different picture to the grim one painted by Robinson. When reading the accounts of the English traveller Robert Elwes in 1849, of Bishop Nixon in 1854, of Archdeacon Thomas Reibey in 1863 and of Canon Brownrigg in 1872, one gathers the impression of quite a likeable people, living contentedly and in harmony with each other on the several small islands in the Furneaux Group (which consists of Flinders and Cape Barren Islands and the islands around them), skilled boatbuilders and boatmen, with their small herds of cattle, sheep, and goats, but depending to a great extent on mutton-birding for a livelihood. Those of us who know the islands, with their magnificent scenery, might even go so far as to say the islanders during this phase of their history led an almost idyllic existence which could be compared with the accounts of similar isolated island communities like the one Martin Martin gave of a visit to St Kilda, in the Outer Hebrides, in 1697, and of later travellers to Tristan da Cunha.

Decline of an idyllic life

The careful studies of the Adelaide anthropologist, Tindale (1953), show that these interesting Flinders Island people were descended from a small group of about twelve white sealers (mostly English seamen), nine Tasmanian Aboriginal women, four Australian Aboriginal women, and one Maori woman from New Zealand. The last of the white ancestors died in 1876. Their known descendants at the time of Tindale's survey numbered nearly 350. Unhappily, the heyday of these island people passed when Flinders Island received a large influx of new settlers from Tasmania and elsewhere. Against their more sophisticated ways and more modern resources the islanders could not compete. The old home islands were gradually lost to them and they came to be segregated at the western end of Cape Barren Island. Living standards declined and some of the temptations of modern civilized life, such as alcoholic liquor, could not be withstood. Still, as everyone keeps on telling us, we cannot stop progress, and Flinders Island is now indeed progressing. Its picturesque old island people, the Cape Barren Islanders, are gradually being absorbed, fortunately in the circumstances, and are merging into the general population. They will disappear as a separate ethnic group as the old ways of their forbears have already gone. However, those of us whose job it is to study the natural history of the islands and, though in an attenuated way, live something like the old islanders, feel that our lines are cast in pleasant places. We have a notion that the vanished era had its appeal. Sometimes, on one of those fine glorious days not infrequent in Franklin Sound, as we contemplate the sad ruins of the old sealers' dwellings on Guncarriage (Vansittart) Island, we feel a touch of envy and regret that the life of the mid-19th century islander had to pass away.

KANGAROO ISLAND AND ITS VERTEBRATE LAND FAUNA

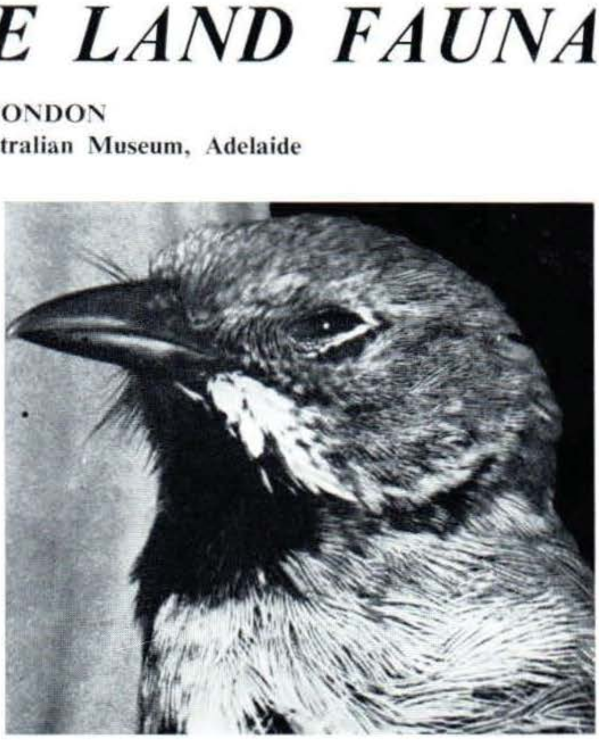
By H. T. CONDON
Curator of Birds, South Australian Museum, Adelaide

KANGAROO ISLAND, after Tasmania, is the second largest island off southern Australia. Formal European settlement began in July, 1836, following earlier occupation by bands of sealers who first arrived about 1805. The population is listed as 3,295 (1961 census) and there is one large modern town, Kingscote, with 1,250 people. Lesser communities have been formed at Penneshaw, American River, Parndana and Vivonne Bay. The main pursuits are agricultural and fishing, but the mild climate and scenic attractions draw a large tourist trade and Kingscote is world-famous as a headquarters for big-game fishermen.

The island, which appears from the north as a huge, flat-topped landmass with vertical seaboard cliffs many hundreds of feet high, is structurally part of the Mt Lofty Horst. It consists of a deep-seated granitic core overlain by a thick formation of ancient marine limestones and windblown sands. It is over 90 miles long from east to west, with an average width of about 25 miles, and its land surface measures 1,680 square miles. Adelaide, the capital of South Australia, is 90 miles distant to the northeast.

The greater part of the island, where the annual average rainfall is from 22 to 25 inches, was originally covered with dense, often impenetrable mallee, a plant association which consists of small eucalypts and undershrubs from 10 to 20 feet high.

In the wetter parts, such as at the western end, where the annual rainfall may be 30 inches or more, dry sclerophyll forest occurs; tall gum-trees and other eucalypts are numerous, as they are also along the watercourses all over the island, and undershrubs are well-developed. Ferns cover the banks of the Breakneck River. The sclerophyll forest is, without doubt, a relict formation which, like the forests of the Mt Lofty Ranges on the adjacent mainland, was once connected to the similar open forests of southeastern Australia.

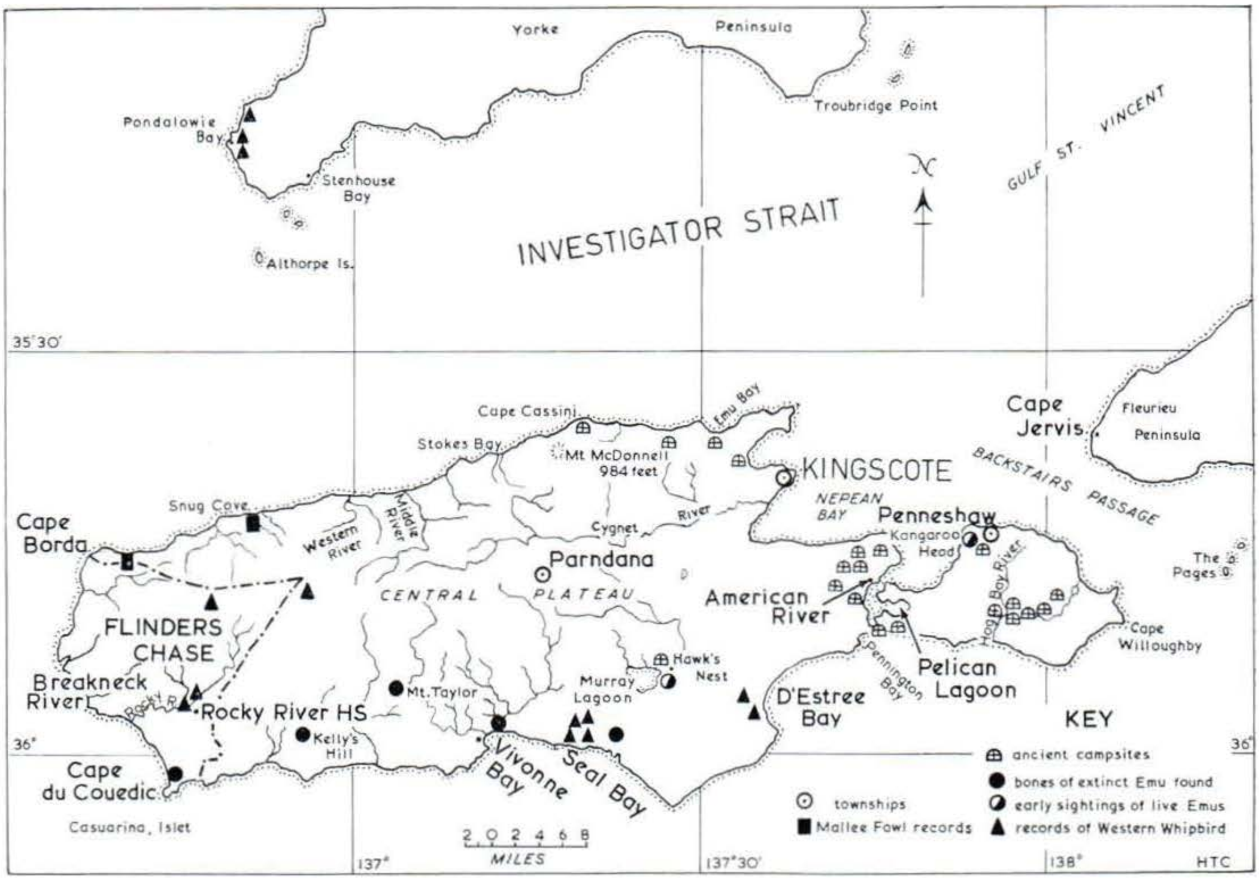


The Western Whipbird (*Psophodes nigrogularis*) was recently discovered on Kangaroo Island, South Australia, where it lives in dense undergrowth. Rarely seen, it betrays its presence by loud calls. Its general coloration is dull olive-green, with black throat edged with white. [Photo: David Condon.]

The separation of the island is believed to have occurred in early Recent times, perhaps less than 10,000 years ago, as a result of the formation of Investigator Strait and a narrow, deep passage called the Backstairs, which is less than 9 miles across near Cape Jervis.

In still earlier times, during the Pleistocene, Kangaroo Island was incorporated in a continental landmass that extended much farther to the west, south, and east, and it was during this period of geological history that the bulk of the animal and plant species of today was acquired.

When the first whites visited the island they found no Aboriginal inhabitants. However, about 30 years ago, an ancient campsite was discovered inland from the cliffs of the south coast, 4 miles from



Kangaroo Island. [Map by the author.]

Pennington Bay. Later discoveries, and the widespread incidence of numerous stone implements, especially at the eastern end of the island, indicate the presence of a considerable previous population. It is difficult to offer any sound explanation regarding the disappearance of these ancient people, whose true identity remains a mystery.

The ill-effects of European occupation have come more slowly to Kangaroo Island than elsewhere. For over a century after the island's discovery the population remained small and there were only a few low-grade farms. The land was unsuitable for wheat-growing and sheep pastured on limestone areas suffered from a mysterious malady known as "coast disease". During the 1930's, however, it was established by CSIRO research workers that "coast disease" in sheep and the failure of the pastures were caused by a lack of copper and cobalt in the soils. Since World War II agricultural development has begun in earnest, with the unavoidable destruction of the natural vegetation over a large portion of the island, especially in the elevated central plateau area.

Fortunately, these losses are mitigated to some extent by the presence of a large fauna and flora reserve on the western end, known as Flinders Chase. This reserve, which was named in honour of Captain Matthew Flinders, occupies some 212 square miles south of the Cape Borda road and, except for about 9,000 acres near Rocky River in the south, is completely unspoiled by grazing or agriculture. There is a resident ranger at the old homestead at Rocky River and the area is properly fenced, with good firebreaks but few roads.

Bushfires, which have been a frequent and sad occurrence from one end of the island to the other in the past, do not appear to have affected the local fauna adversely. One exception, perhaps, is the small emu, which is known to have died out, between 1802 and 1836, as the result of some sudden catastrophe.

A SHORT GUIDE TO THE ISLAND'S HIGHER ANIMALS

Because of the diversity of habitats and its large size, Kangaroo Island has remained a refuge for a selection of mainland species that were cut off or marooned following the last rise in sea-level, perhaps 8,000 to 10,000 years ago. Without doubt, a few birds and other winged creatures have reached the island since that time, but there is no direct evidence of this prior to human settlement. About twenty species of migratory birds are annual visitors.

As might be expected, there is a minor development of endemic forms, with a tendency towards melanism and/or large size in some mammals, birds, reptiles, and amphibians.

There is also an unusual admixture of faunal types from east and west. One authority has stated that west of the South Australian gulf system the insects exhibit western affinities which are shared by Kangaroo Island, and conchologists have detected a similar situation in the land shells. On the other hand, the majority of bird species are southeastern open-forest and woodland forms. Among the mammals there are both western and eastern types.

Fossil remains have been found, at Rocky River, of the Giant Wombat (*Diprotodon australis*), which was larger than a rhinoceros and roamed over much of Australia during Pleistocene and early Recent times.

Mammals

About a dozen species have been recorded, excluding cetaceans and those introduced from the mainland. In addition, domestic pigs and goats are early introductions which have become firmly established, and feral cats are numerous. Also, the house mouse and brown and long-tailed ship rats are present, but there are no foxes or rabbits.

Kangaroo Island Kangaroo (*Macropus giganteus fuliginosus*): Matthew Flinders, the discoverer, landed on Kangaroo Island on 22nd May, 1802, and gave it the name it bears in consequence of finding large numbers of "kanguroos" of this species to the west of what is now Penneshaw, on the northeast coast; thirty-one were shot by his crew on the first day. Still numerous, but mainly on Flinders Chase, this large, sooty-brown animal is an insular form of the Forester or Grey Kangaroo of the adjacent mainland and eastern Australia.

Kangaroo Island Wallaby (*Protemnodon eugenii decres*): An insular subspecies of the no longer common mainland Tammar or Scrub Wallaby. It is numerous and widespread and is a frequent victim of automobiles on the recently-completed network of well-made roads. The species, which is extinct on other South Australian islands, occurs on Eyre Peninsula and in southwest Australia.

Broad-faced Rat-kangaroo (*Potorous platyops morgani*): An extinct, endemic form, known only from bones in limestone caves. This small and little-known member of the kangaroo family was originally thought to be confined to southwest Australia, where it is extremely rare.

Other mainland species which have been recorded include the Native Porcupine (*Tachyglossus aculeata*), Brush-tailed Possum (*Trichosurus vulpecula*), Grey's Rat (*Rattus greyi*), Native Cat (*Dasyurus quoll*) (possibly extinct), Short-nosed Bandicoot (*Isoodon obesulus*) (an eastern type), Dormouse Possum (*Cercartetus concinnus*) (western type), and Long-eared Bat (*Nyctophilus geoffroyi pacificus*) (common, a southeastern mainland form).

Seals occur along the south coast and at the western end. At the beginning of the 19th century, these animals attracted renegade seamen and other adventurers, who slaughtered countless numbers for their skins. Until recently, the seals faced extinction, but legislation and the proclamation of sanctuaries have halted the decline in numbers. Two species are present—the Hair Seal or Sea Lion (*Neophoca cinerea*), which occurs in small numbers towards the western end of the island, and the Fur Seal (*Gypsophoca dorifera*), which is now a great tourist attraction and can be seen on the seashore at Bales Beach, Seal Bay, and near Cape du Couedic.

The following have been introduced on Flinders Chase from the mainland:

Koala (*Phascolarctos cinereus*): An introduction from Victoria; it is well-established in the Manna Gums (*Eucalyptus viminalis*), near Rocky River homestead. Six individuals were liberated in December, 1923; six pairs, with cubs, were set free in April, 1925.

Ring-tailed Possum (*Pseudocheirus peregrinus*): Now fairly widespread. Fifteen individuals were set free in October, 1925.

Platypus (*Ornithorhynchus anatinus*): Three were liberated in January, 1928; six in 1931; and six in 1946.

Birds

Of the 428 species which can be listed for South Australia, 167 have now been recorded for Kangaroo Island; these included 50 sea birds and water birds, 20 migrants, and 5 exotic species which have made their way from the mainland.

Kangaroo Island Emu (*Dromaius diemenianus*): Extinct. Live birds were seen at the northeastern end by Flinders in 1802 and in the south, near Hawk's Nest Station, by Captain George Sutherland in 1819. For long it was believed that Baudin captured some live specimens in 1803 and took them back to France, but lately it has been suggested that these birds were obtained on King Island, in Bass Strait. The Kangaroo Island Emu, which was probably a dwarf population of the mainland emu rather than a distinct species, is known only from bones found in caves and sand dunes. It died out before formal white settlement in 1836.

Some mainland emus (*D. novaehollandiae*) were introduced on Flinders Chase in 1926, 1928, 1929, and later.

Pelican (*Pelecanus conspicillatus*): Encountered by Flinders near American River, where it bred on an island in Pelican Lagoon. It is common, but there are no breeding records since about 1890.

Cape Barren Goose (*Cereopsis novaehollandiae*): Introduced on the Chase in 1932, 1936, and later. Several hundred live in a semi-domesticated state at Rocky River.

Mallee Fowl (*Leipoa ocellata*): Not endemic. Seventeen birds from Eyre Peninsula were liberated near Cape Borda in 1911 and others were set free in 1923, 1924, and 1936. There have been no reports of nesting mounds for many years.

Burmese Spotted Dove (*Streptopelia chinensis tigrina*): This introduction on the mainland reached the island about the year 1953.

Glossy Black Cockatoo (*Calyptorhynchus lathami*): A southeastern form, which does not occur on the South Australian mainland. It is restricted to the western end; its numbers have been estimated at not more than fifty pairs.

Crimson Rosella (*Platycercus elegans melanoptera*): An endemic, melanistic form of an eastern mainland species.

Galah (*Cacatua roseicapilla*): Common; it probably reached the island about 60 years ago.

Western Whipbird (*Psophodes nigrogularis*): A southwestern Australian species, until recently only known in South Australia from the mallee north of Pinnaroo. It was discovered on Flinders Chase in January, 1967. During a visit by the writer in March, 1967, the Whipbird was recorded at many places, from the western end at Rocky River and Cape Borda Road to Seal and D'Estree Bays on the south coast. The habitat varies from dry sclerophyll forest to mallee woodland, and a primary requirement is dense undergrowth. In late 1965 and 1966 the Whipbird was found for the first time on southern Yorke and Eyre Peninsulas.

Successful introductions on the Chase include the Peaceful Dove, the Common Bronzewing and Crested Pigeons, and the Kookaburra.

Reptiles and Amphibians

About eighteen species of lizards (skinks, dragons, geckoes) and less than half that number of frogs have been listed; there is only one snake. Several melanistic forms have been described.

Common Goanna (*Varanus varius*): This is the most frequently seen reptile, which may attain a length of over 6 feet. It feeds on other small lizards, small mammals and birds, including young penguins.

About fifty Sleepy Lizards (*Tiliqua rugosa*) were set free on Flinders Chase in October, 1925; they are said to have died out.

Black Tiger Snake (*Notechis scutatus niger*): This snake grows to a length of over 6 feet. It is also present on other South Australian islands and Eyre Peninsula.

HOUTMAN'S ABROLHOS

By P. M. O'LOUGHLIN
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FROM the period of their discovery by Frederik de Houtman in July, 1619, the Abrolhos Islands, Western Australia, have been a rich field for the natural historian, and a scene of shipwreck and human tragedy. A fascinating fauna does not efface memories of men claimed by the sea or dying of thirst, of women and children brutally killed, and of men punished on the gallows or marooned. Between 1844 and 1945 the islands were exploited for their guano, and today they are the temporary winter home of fishermen engaged in the crayfish industry.

These scattered coral islands and reefs are 40 miles from the Western Australian coast, towards the edge of the continental shelf. The four natural groups lie roughly parallel to the coast between latitudes 28° 15′ S. and 29° S., and stretch for 60 miles from the Pelsart Group, which is west-southwest of Geraldton, north through the Easter and Wallabi Groups, to North Island.

West Wallabi Island is the largest, with an area of just over 2 square miles. The highest point is on East Wallabi, where the dunes attain a height of almost 50 feet. The numerous other islands are small, low, flat, and confusingly similar in appearance. Their size is in contrast with the many square miles of surrounding coral-reef limestone on which they rise. The reefs are in places emergent at low tide, are made discontinuous by deep lagoons, and vary in texture from hard limestone to brittle living coral, facts which combine to make many of the islands very difficult of access. Beaches of calcareous sand fringe some of the islands.

Apart from North Island and East and West Wallabi, with their cappings of consolidated and unconsolidated dune sand, two other quite different types of islands can be distinguished. The eastern islands consist of loose heaps of bleached coral fragments massed on the fringes of the reef platforms. In contrast, the coral of the western islands is consolidated into a hard limestone which has undergone marine planing to a surface about 8 feet above the present reef, and is generally deeply undercut by solution. Contrasting forces of aggradation and degradation are evident in these two island types. Freshwater cannot accumulate on the former, but does collect and persist in "sink-holes" in the limestone of the latter type.

The Carpet Snake (*Python spilotus*), largest and most placid of the Abrolhos reptiles. These snakes have been known to swallow young wallabies, but rarely show signs of aggression when disturbed.

Reptiles dominant

Reptiles are the dominant terrestrial vertebrates of the Abrolhos, and the presence or absence of a variety of species on a particular island is a useful indication of its origin. That nineteen species occur on East and West Wallabi is strong evidence that both islands were once part of the Australian continent. Such a reptile fauna could only be a surviving mainland one.

With some interesting exceptions, the eastern islands are devoid of vertebrate residents. These islands have been built up more recently by the sea, and colonization must be transmarine.

It has been assumed that North Island and the western islands of the Wallabi Group are the only remnants of the older coastline. However, an expedition to the Pelsart Group in August, 1966, established the presence of six reptile species on Middle Island, including the Large Spiny-tailed Skink (*Egernia stokesi*), and four different species on Gun Island. It seems, then, that these western islands of the Pelsart Group are also surviving remnants from the mainland. The Easter Group has yet to be thoroughly explored.

A probable case of transmarine colonization by a reptile is that of *Ablepharus greyi*. A population of these small elusive skinks was found on Eastern Island of the Wallabi Group in 1965. This reptile has not been recorded elsewhere in the Abrolhos; the small island of loose coral is of recent origin from the sea, and has never been occupied by fishermen or guano workers who might have introduced the skink. In some way it has reached Eastern Island from the mainland across 35 miles of ocean.

Pelsaert's journals

Francisco Pelsaert was senior merchant of the Dutch East India Company on the *Batavia* when it foundered on Morning Reef in the Wallabi Group on 4th June, 1629. His journals chronicle in detail the events of the subsequent 5½ months—mutiny, murders, rescue, trials, and executions. The Dutch left behind on West Wallabi, Long and Beacon Islands stone constructions which remain today after the passage of more than three centuries. Dating back to 1629 with these historical structures is the first written account of our Australian fauna. Pelsaert was fascinated by the Tammar Wallaby (*Macropus eugenii*), and his journal entry of 15th November reveals that his examination of this marsupial was sufficiently detailed for him to be able to describe the young in the pouch: "nipple in mouth, only as large as a bean, but limbs entirely in proportion".

The Tammar formerly occurred on North Island but is now confined, within the Abrolhos, to East and West Wallabi, where it is abundant. Not as numerous, and collected for the first time early in this century, is a second mammal, the indigenous native rodent *Rattus glauerti*. This mammal is known from East and West Wallabi only. It has none of the speed or agility of its domestic counterpart, and is quite easily caught by hand if forced onto open ground. Fear is held for its survival if either the ship's rat or domestic cat becomes established on these islands.

The types of seven reptile species came from the Abrolhos Islands, collections beginning with the visit of H.M.S. *Beagle* in 1840. The ten species recently discovered in the Pelsart Group were all previously on record for East and West Wallabi, where a further nine species are represented. The placid Carpet Snake (*Python spilotus*) is encountered frequently on the two main

West Wallabi Island, showing its flatness, stunted scrub vegetation, and the historic walls built by *Batavia* survivors in 1629.

Tammar Wallaby (*Macropus eugenii*) and low scrub vegetation on West Wallabi Island. This marsupial was described in 1629 by Francisco Pelsaert, the first European to record the Abrolhos fauna.

Wallabi Islands, as also is the very active Western Jew Lizard (*Amphibolurus barbatus minimus*). In view of Pelsaert's careful study of the Tammar, it is surprising to find a comment in his journal that, apart from "grey turtledoves", there were "no other creatures" on the islands. The *Batavia* survivors did not weigh anchor to leave until 15th November, so that any winter inactivity of the reptiles could not explain Pelsaert's failure to note their conspicuous abundance. The other species, in addition to those already mentioned, are the geckos *Diplodactylus spinigerus* and *Heteronota bynoei*, the pygopids *Lialis burtoni* and *Delma fraseri*, the skinks *Rhodona nigriceps* and *Ablepharus elegans*, and the Bandy Bandy (*Rhynchoelaps bertholdi*).

Unfortunately, the major names associated with the southern islands of Houtman's Abrolhos are historically misplaced. "Pelsart Group", "Pelsart Island", "Batavia Road", and "Wreck Point" were assigned by Commanders Wickham and Stokes, of the *Beagle*. Their mistaken assumption in 1840 that it was in this group that the *Batavia* wreck lay was a source of confusion until the actual wreck was confirmed on 4th June, 1963, in the Wallabi Group. In retrospect it is of interest that, in a paper on the Abrolhos read in 1917, Professor W. J. Dakin included evidence which should have corrected the mistaken thought on the *Batavia* wreck site. Professor Dakin actually quoted Pelsaert's description of the Tammar, which does not occur on the southern islands, but failed to associate its presence in the Wallabi Group with *Batavia* history.

Dutch wreck in Pelsart Group

An historic Dutch wreck does lie in the Pelsart Group. The *Zeewyk* sailed onto the western reef on 9th June, 1727, almost a century after the *Batavia*. By a fateful coincidence the watch on both ships saw the white surf on the reefs in ample time but thought that it was moonlight reflection. The *Zeewyk* survivors were to spend 10 months on Gun Island, and the second mate, Adriaen van der Graeff, kept a detailed log. The early part of his journal reflects a natural preoccupation with survival, but this is gradually replaced by interest in the building of a ship which finally carried the eighty-two survivors to Batavia. There is much of interest to the naturalist in the log.

The Hair Seal (*Neophoca cinerea*) was evidently abundant on the beaches and was a principal source of food. The early fear was that it would become timid! In the first 3 months at least 147 were killed. The scene today in the Abrolhos is a desolate one by contrast. In four recent visits to the islands the author has seen this seal on only two occasions—a bull, cow, and two calves on Jubilee Island in the Pelsart Group in August, 1966, and a single seal near Pigeon Island in the Wallabi Group in 1964.

Birds of the islands

Van der Graeff's log also contains an account of the Mutton Bird or Wedge-tailed Shearwater (*Puffinus pacificus*). His description in 1727 of the black colour, long black beak with curved tip, webbed feet, "bat-like" nocturnal flight, and habit of nesting in hollows or burrows from which

Characteristic deeply-undercut shoreline of one of the western islands of the Abrolhos. The hard limestone was planed by an earlier cycle of erosion, but such islands have probably been emergent since separation from the mainland.

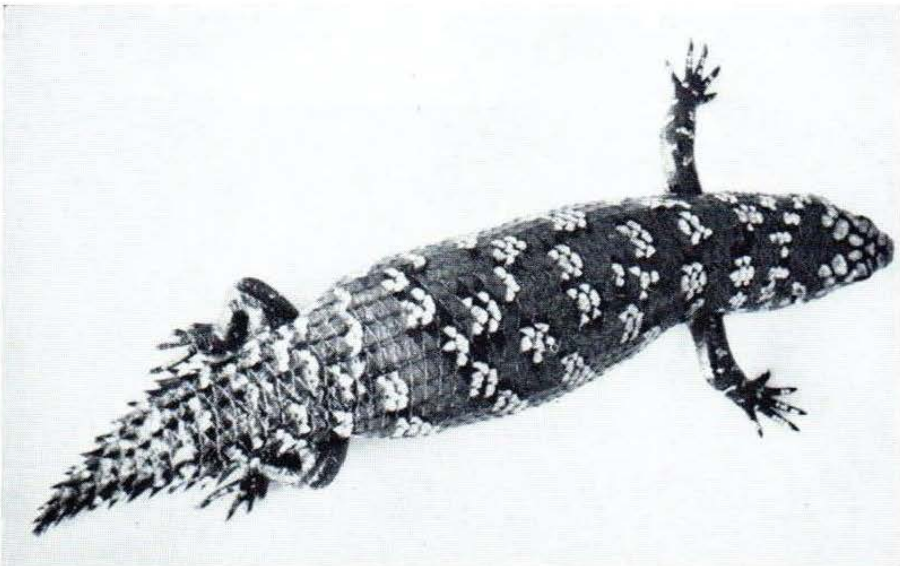
they were readily pulled, leaves no doubt as to the identity. He observed its arrival on Gun Island in the evening of 20th August, The old unoccupied burrows had been noticed but were attributed to the lizards seen using them. More than 700 of these birds were killed for food in the first week after their arrival. There is no indication today of decreasing numbers. The soft dune and coral grit accumulations throughout the Abrolhos are completely undermined by the burrows of Wedge-tailed Shearwaters and Little Shearwaters (*Puffinus assimilis*). Many thousands of the former occupy extensive rookeries during the summer months.

A common sight above the islands is a soaring Osprey (*Pandion haliaetus*) or Sea Eagle (*Haliaeetus leucogaster*). The massive nests of the former are often a distinctive relief feature on the flat islands. In an incomplete exploration of the Pelsart Group during late August, 1966, six Osprey nests were found, four with the characteristic clutch of three cream and russet eggs, one with fledglings, and one where laying was occurring. Two occupied nests of Sea Eagles were seen with one and two white eggs. Other resident sea birds found nesting as early as August were a colony of Crested Tern (*Sterna bergii*), individual nests of Pacific Gulls (*Larus pacificus*) and Silver Gulls (*L. novae-hollandiae*), and nest-scrapes of Pied Oyster-catchers (*Haematopus ostralegus*) and Sooty Oyster-catchers (*H. fuliginosus*).

The most intriguing sights on these islands are the nesting colonies of many thousands of Common Noddies (*Anous stolidus*) and Lesser Noddies (*A. tenuirostris*). The former is a northern tern whose most southerly nesting ground is the Abrolhos. More than a million once nested on Rat Island in the Easter Group. The only colony now surviving nests during the summer months on the saltbush (*Atriplex cinerea*) and nitre-bush (*Nitraria schoberi*) at the southern end of Pelsart Island. The Lesser Noddy nests on the mangroves (*Avicennia marina*) which thrive in the coral mud in shallows well-sheltered by reefs and islands. A big colony of these terns breeds on the mangroves of Pelsart Island. This same island is the only known regular nesting station of the Red-tailed Tropic-bird (*Phaethon rubricauda*). Many other sea birds breed in colonies on the Abrolhos during late spring and summer—Pied Cormorants (*Phalacrocorax varius*), Bridled Terns (*Sterna anaetheta*), Fairy Terns (*S. nereis*), Roseate Terns (*S. dougallii*), Sooty Terns (*S. fuscata*), and Caspian Terns (*Hydroprogne caspia*).

The "grey turtledoves" of Pelsaert's journal are the Brush Bronzewing (*Phaps elegans*). This pigeon and the Painted Quail (*Turnix varia*) are frequently disturbed on East and West Wallabi. Other resident

The Large Spiny-tailed Skink (*Egernia stokesi*), which is abundant on most of the western islands of the Abrolhos. The original types for this species were collected during the visit of H.M.S. *Beagle* in 1840. The skink's name commemorates Commander Stokes, of the *Beagle*.



land birds here are the Spotted Scrub-Wren (*Sericornis maculatus*), Grey-breasted Silvereye (*Zosterops lateralis*), and the Welcome Swallow (*Hirundo neoxena*).

Unlike the avifauna, the vegetation of the Abrolhos is quite unspectacular. There are no trees and in only a few areas do the stunted shrubs grow to a height of more than 3 feet. Extensive areas of hard limestone and recent coral shingle lack any form of plant cover. However, the vegetation does provide supporting evidence when the geological history of an island is being considered. As would be expected, a characteristic insular flora is established on the recent eastern islands. The very low, woody perennials are dominated by the saltbush (*Atriplex cinerea*). Other shrubs are *Nitraria schoberi*, *Myoporum insulare*, *Enchylaena tomentosa*, and *Threlkeldia diffusa*, none reaching a height on these islands of more than 3 feet. Other perennials are Pig-face (*Carpobrotus aequilaterus*), *Spinifex longifolius*, and Saltwort (*Salsola kali*). The common annual herbs are the Crucifers *Cakile maritima* and *Lepidium pseudo ruderale*, Composite (*Senecio lautus*), *Lavatera plebeia* and *Parietaria debilis*.

In contrast with these few recurring species, 114 vascular plants are listed for the western islands of the Wallabi Group. A recent collection on the smaller Gun and Middle Islands of the Pelsart Group revealed a similar pattern for the western islands of this group also. The dominant shrubs on Middle Island were *Grevillea argyrophylla*, *Frankenia pauciflora*, *Pittosporum phillyraeoides*, *Eremophila glabra*, and *Sarcostemma australe*. All are represented on the Wallabi Islands also, where the shrubs are up to 8 feet tall. Such plants undoubtedly represent a surviving mainland flora.

The only method of travel to the Abrolhos is on the "carrier" or "scooter" boats of the fishermen who make the crossing regularly throughout the winter season. The danger of the reefs and the desolate appearance of these lonely islands do not attract the visitor, and it is not surprising that the historic features, the good fishing, the quaint unfrightened fauna, and the beauty of the unruffled coral lagoons have not been exploited as tourist potential.

[*Photos in this article are by Aquinas College expeditions.*]

How the Aboriginal past is traced.—An Australian Museum party excavating a large rock shelter in eastern New South Wales. Such shelters were favourite camping places of the Aborigines and often contain deep deposits, accumulated over thousands of years. [Photo: Author.]

Island Clues to Aboriginal Prehistory

By DAVID R. MOORE
Curator of Anthropology, Australian Museum

WHO are the Australian Aborigines? Where did they come from? When did they first reach Australia? These questions have tantalized thinking people in all parts of the world ever since the first discovery and subsequent European settlement of the continent. Now at last there is a possibility of finding definite answers to these problems.

We are at present in a most exciting period in Australian archaeology, because an intensive programme of excavation of Aboriginal occupation sites in many parts of the Australian continent is producing significant Carbon 14 dates, together with an increasing knowledge of changes in Aboriginal technology and environment over a time-span of more than 20,000 years. Through the correlation of these changes, both temporally and spatially, a definite pattern is beginning to emerge for the prehistory of the Aboriginal peoples of the Australasian region.

The earliest carbon date obtained in definite association with Aboriginal occupation in southern Australia is of the order of 18,000 B.C. from a site in the vast underground caves at Koonalda on the Nullabor Plain. However, this sample was obtained from a level 6 feet from the top of a 24-foot deposit, and it is likely that carbon from the bottom layer, when processed, will yield a date earlier than 20,000 B.C. In northern Australia a carbon date of about 20,000 B.C. has been obtained from a rock-shelter occupation site near Oenpelli

Mission, in western Arnhem Land. It is unlikely that either of these dates refers to anything like the period of initial entry into the continent, since at the time in question the sites from which they were derived would have been far inland. The ancestors of the Australian Aborigines must surely have arrived somewhere on the northern coast and gradually spread into the southern half of the continent. The pattern of dates so far gained would seem to indicate that the east coast was occupied later than the centre and north, since the earliest date from the eastern side of the Great Dividing Range is about 5,500 B.C. from a rock shelter in Royal National Park, just south of Sydney. But it may be that older sites have not been located in the eastern part of the continent. In the west and northwest no sites of any antiquity have yet been discovered, but of course these regions have not been searched so intensively as the north and east of Australia.

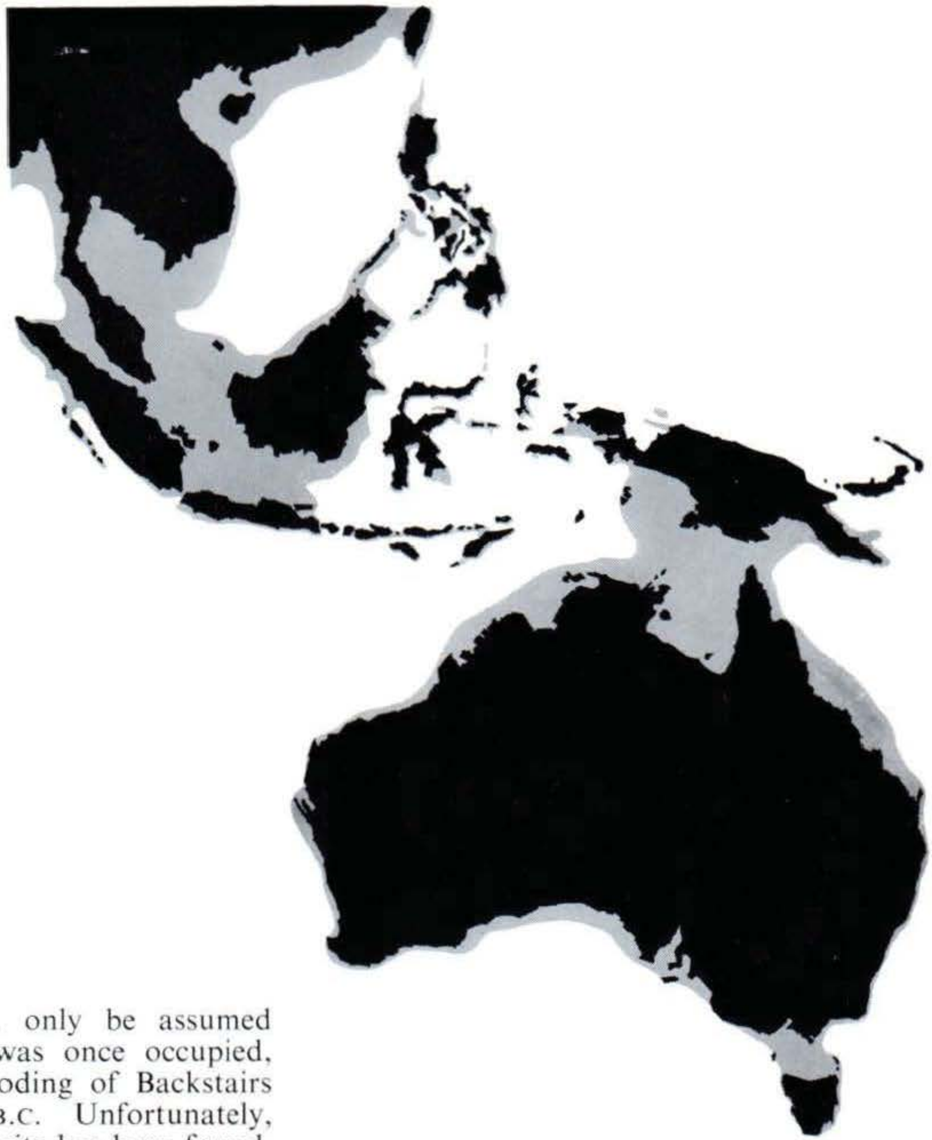
From the historical point of view, the importance of these early carbon dates is that they place the time of arrival of the first human groups in Australia well back into the last ice age, into a period when the whole human race was living in caves and subsisting by hunting and collecting foods as they occurred naturally. Archaeologically, they are significant because we know that Australia in the late Pleistocene was a totally different sort of place from what it is now. The climate, flora, and fauna were quite unlike those of today and, even more important, the shape of the continent itself was very different. Fairbridge and Cotton have estimated that, due to the locking up of great masses of the earth's water in the northern ice-cap during the final glaciation, there would have been a eustatic lowering of sea-level of up to 250 feet in about 14,000 B.C., and probably even lower sea-levels, of the order of 400 feet below the present mark, before 16,000 B.C. They also think it possible that there were land-bridges between New Guinea and Australia and between Tasmania and the mainland up to as late as 8,000 B.C. With a lowering of the sea by 400 feet the water barrier to the northwest of Australia, between the Kimberleys and Timor, would have been greatly reduced, while the Indonesian island chain would have been an almost continuous landmass joined to Malaya. The map on page 420 shows the sort of shape these changes in land form might have taken with a lowering of sea-level of 400 feet below the present level; that is, it shows how the southeast Asian region might have been at the time when the Aborigines first moved into the continent of Australia.

This brings us to the significance of the off-shore islands to Australian archaeology. Obviously, at the time when human beings first reached Australia, such present-day islands as Melville and Bathurst, Kangaroo Island, Tasmania, and most of the islands of Torres Strait would have been ranges of hills and mountains rising from coastal plains and peninsulas. They are, therefore, unlikely to have been areas of permanent occupation, but must surely have been traversed by the pristine inhabitants in their incessant search for food. Assuming that these people brought a stone technology of some sort with them, one would expect to find traces at least of the earliest occupation hidden beneath the soil of the islands and likely to be revealed by erosion or the bulldozer at any time. The problem is that untrained people rarely can recognize such important remains, though several skeletons of significance have been discovered in this way. Some archaeological work has already been carried out on off-shore islands and it would be best to summarize the knowledge thus obtained before considering what might be done in the future on islands as yet untouched archaeologically.

The southern coasts

Strangely enough, we have a great deal more archaeological knowledge about Kangaroo Island, Tasmania, and the islands of Bass Strait than we have about the islands of the north. Norman B. Tindale and associates of the South Australian Museum have made examinations of all these southern islands over a considerable period. Kangaroo Island was unoccupied when first investigated and the mainland Aborigines asserted that they had never crossed dangerous Backstairs Passage to visit it. Nevertheless, an important stone industry has been found there and named the Kartan (from a mainland Aboriginal name for

Australasia and southeast Asia in the late Pleistocene.—
In this map the black areas represent the present landmasses and the grey areas show the additional dry land that would emerge if the sea-level was 400 feet lower than now, as was the case before 16,000 B.C. It is likely that something close to this situation existed at the time when the first group or groups of Australian Aboriginal people reached the Australian continent. Although land-bridges would then have occupied most of what is now sea, there would have been a number of gaps at the eastern end of the Indonesian archipelago, as well as a considerable stretch of sea between Timor and northwestern Australia and between the Celebes and western New Guinea. [Map by David Rae.]



the island) and it can only be assumed that Kangaroo Island was once occupied, probably before the flooding of Backstairs Passage in about 8,000 B.C. Unfortunately, no stratified excavation site has been found, so that Carbon 14 dates cannot be obtained. Tindale considered the Kartan implements to be similar to what he called the "old Tasmanian series". However, this statement was made prior to any scientific excavation in Tasmania. This has now been started by Rhys Jones, of the University of Sydney, and has revealed a developing technology of some sophistication in a midden at Rocky Cape, in northwest Tasmania. The earliest carbon date from this site is about 6,170 B.C., but the sample in question was obtained from a level 1 foot from the bottom of the deposit and may be slightly later than the start of the occupation. A dating of about 6,700 B.C. was obtained for charcoal from the bottom of a shell midden on the Carlton River in southeast Tasmania. Currently, Rhys Jones is investigating an undisturbed cave deposit in the Rocky Cape area, and this may well provide important new information. At present it does not seem that there is any correlation between the earlier Tasmanian assemblages and Tindale's Kartan. However, there does appear to be some similarity between the early Tasmanian material and that obtained from the lowest levels of inland sites in New South Wales and southwest Queensland.

Until recently most authorities considered the historic Tasmanians to have been a quite distinct race, differing markedly from the mainland Australians. However, Professor N. W. G. Macintosh, of the University of Sydney, a world authority on Australian skeletal material, has recently expressed the view that the surviving Tasmanian skeletal remains are in all important respects very similar to the Australian Aboriginal norm; he suggests that the Tasmanians were a small group of Aborigines isolated by the flooding of Bass Strait, also probably about 8,000 B.C., and that apparent differences may perhaps be due to the isolation of such a small breeding group over a period of some 10,000 years. It would seem probable that the people who left the Kartan-type stone implements on Kangaroo Island may have been a similar group, but so far there is no skeletal material from the island to support such a view.

It should be added that the Tasmanians, according to the early observers, were lacking a number of important Australian artefacts, such as the spearthrower, the boomerang, and the bark canoe. Their technology, in fact, was considerably more elementary than that of the mainlanders and may have been closer to that which the Aborigines brought with them to Australia in the first place. Obviously the people of the Australian mainland were exposed to a number of outside influences in the north, and these influences may well have stimulated changes on the mainland which could not reach those isolated in the southern islands.

Islands of the north coast

Turning now to the north coast of Australia, where one would expect to find significant clues to help in answering the questions with which this article commenced, we are faced with a blank archaeological sheet. It would seem almost certain that the ancestors of the present Australian Aborigines must have reached the Australian continent either in the northwest, via Timor and into the Kimberleys or Arnhem Land, or else via southwestern New Guinea and across what is now Torres Strait into north Queensland.

The significant islands in the northwest would seem to be Melville and Bathurst. There we find also a population which, on first contact, seemed to have had no communication with the mainland over a great period of time. Yet they were markedly Aboriginal in appearance and had many social and religious traits in common with the mainlanders. However, the Melville and Bathurst Islanders, like the Tasmanians, did not possess a number of basic Australian implements, for example the spearthrower and the returning boomerang, though their general technology and their social and ritual institutions were considerably more advanced than those of the Tasmanians. For example, they had a well-developed form of wood-carving and painting and an economic and social system perhaps more sophisticated even than that of northeast Arnhem Land. However, it is likely that there had been exterior influences, for example Indonesian, over a considerable time, though this is denied by the islanders themselves. To date no archaeological site worth excavating has been found on Melville or Bathurst, and it may be that here and elsewhere archaeologists will have to go beneath the sea to find the requisite prehistoric material.

No sites of any significant antiquity have yet been found on any of the islands off the coasts of Arnhem Land, though important painted caves and ceremonial sites on the Wessel Islands, Groote Eylandt, and Chasm Island have been investigated and recorded by F. D. McCarthy, former Curator of Anthropology at the Australian Museum and now Principal of the Australian Institute of Aboriginal Studies. The islands of the Gulf of Carpentaria, such as Mornington and Bentinck, also carried isolated Aboriginal populations when first visited, but again no sites of significance for Aboriginal antiquity have been discovered.

However, the islands and coastline of Arnhem Land do contain a number of living and working areas of the Macassans, the Indonesian seafarers who visited northern Australia for several centuries to collect trepang, or bêche-de-mer, a sea-slug considered a great delicacy by the Chinese. The Macassans had considerable contact with the north-coast Aborigines, who helped in the collecting and drying of the trepang in return for trade goods, such as dugout canoes, tobacco, and liquor.

These Macassan sites are currently under archaeological investigation by J. D. Mulvaney, of the Australian National University. We should before long have definite information as to the duration of the Macassan contact, as a result of which many innovations are known to have spread throughout Aboriginal Australia long before European settlement.

Cape York Peninsula and Torres Strait

In the area of Cape York, with its easy access from New Guinea, we have a prime archaeological query awaiting an answer. For it is obvious that Cape York and Torres Strait must either have been an initial point of entry into Australia, or, alternatively, may well have been the last area of the whole continent to be occupied by the Aborigines. The earliest carbon date so far obtained from the peninsula is about 5,000 B.C. from an occupation site near Laura, some 400 miles south of the cape itself. This was excavated by Richard Wright, of the University of Sydney, and the sample came from only 6 feet below the surface of a deposit which went down to 14 feet. Unfortunately, no datable material was found in the lower levels, but on the basis of the rate of accumulation of the top 6 feet, it appears that the bottom might date back to something of the order of 12,000 B.C.

Study of the tribes of Cape York Peninsula has revealed an extensive Papuan influence in ritual and art, while many Aborigines of the area showed, on first contact, marked Papuan physical characteristics. We know that there was intermarriage between the tribes of northern Cape York and the Torres Strait islanders, while there were regular Papuan trading expeditions by canoe down the east coast of the peninsula as far as Princess Charlotte Bay and down the west coast to the Batavia River. Also certain Torres Strait influences and actual artefacts (especially polished axes and adzes) were spread far into the interior of the Australian continent before the arrival of any Europeans. However, the indications are that these contacts with Papua may not have been of very great antiquity. We are left, therefore, with specific problems in the Cape York region which will probably be solved only by intensive work on the mainland and islands, as well as on the adjacent coasts of New Guinea. Such study would entail the interviewing of old people, a detailed analysis of the rock art of the area, and a series of excavations of key sites. Here, again, the ultimate answer may well lie beneath the waters of Torres Strait, and Australian archaeologists may in future have to use the aqualung as part of their basic equipment.

The east coast

The islands of eastern Queensland and New South Wales, though almost all occupied by Aboriginal groups when first visited by Europeans, have not yet been found to yield anything of archaeological significance. However, as we know that during the period of first Aboriginal settlement in Australia the coastline would have been many miles farther out than at present, the sites that have been investigated on the islands and along the coast to the east of the Great Dividing Range may represent an inland occupation which took place considerably later than that of a coastline now far out beneath the Pacific Ocean. It seems reasonable to suppose that the coast might first have been fully occupied and that only when natural increase in population forced groups to seek new living areas would the Aborigines have moved into the more difficult inland environment. Nevertheless, as already mentioned, the overall pattern of carbon dates so far obtained would seem to indicate that the eastern coastal regions of New South Wales and Queensland were probably the last parts of the continent to be occupied by the Aboriginal people, so that the general opinion of prehistorians at present is that the initial point of entry into Australia was probably somewhere in the north or northwest of the continent. As to where the first groups of Aborigines originated, the answer to this question must await the carrying out of extensive excavation in Indonesia and possibly mainland south-east Asia.

Barrow Island, Western Australia, site of a developing oilfield, was proclaimed an A class fauna and flora reserve in 1908. The effect of man's occupation of the island is already evident, and it is to be hoped that the exceptionally interesting native animals will survive this profound change in their ecology. [Photo by courtesy of the Western Australian Government Tourist Bureau.]

The Conservation of Animals and Plants

By DONALD F. McMICHAEL
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THE Australian off-shore islands are of special significance to the conservationist. Their significance is somewhat paradoxical, since on the one hand they have been the places where many interesting animals and plants have been exterminated during the comparatively brief period of European occupancy, yet on the other hand they play an important part in the conservation programmes of the various State authorities, because they have frequently acted as refuges in which species have survived long after disappearing from adjacent mainland areas.

When one looks at the list of species which have become extinct in historic time, a surprisingly large percentage are found to be island species. Professor Ernst Mayr, of Harvard University's Museum of Comparative Zoology, has estimated that, although less than 20 per cent of all birds are island birds, more than 90 per cent of the species which have become extinct in historic time are island species. "As dead as the Dodo" has become a part of our language. This curious, ungainly, flightless relative of the pigeons was but one of several species of birds formerly confined to the tiny

Indian Ocean island of Mauritius which have long since vanished from the face of the earth.

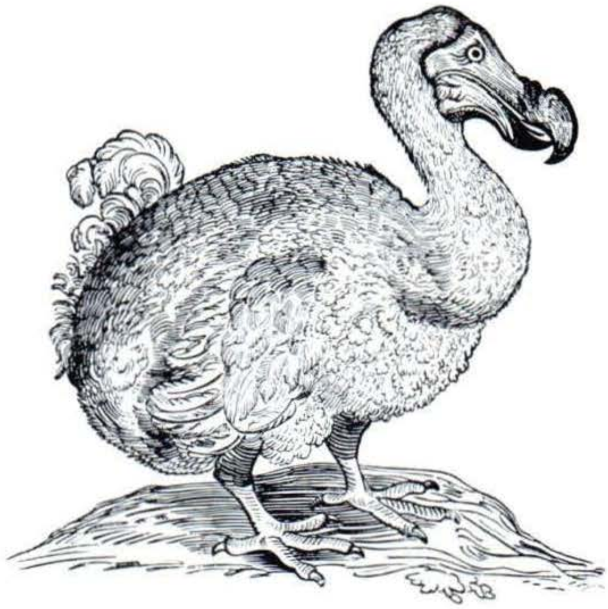
Kangaroo Island Emu

Unfortunately, there are a number of similar examples from Australia's off-shore islands. Among them may be mentioned the Kangaroo Island Emu, first recorded by Baudin and his naturalists Peron and Lesueur, of the French exploration ship *Geographe* in 1802, and by Matthew Flinders about the same time. Even at that early date, sealers were taking the Kangaroo Island Emus for food, and by 1836 the population was exterminated.

An even more depressing story is that of the birds of Lord Howe Island. At least eight species have become extinct since the island was first settled in 1834. Of these only a single skin of the White Gallinule or Swamp Hen is known to exist, and not any part of the Lord Howe Island Pigeon, despite the fact that it was once extremely common and very tame. One species which has survived, luckily, is the Brown-headed Petrel or Bird of Providence. This bird once bred in thousands on Norfolk Island and saved the penal colony from starvation when food ran short during the early days of settlement. The Norfolk birds were soon exterminated, but fortunately a breeding colony exists on the tops of the mountains on Lord Howe Island practically inaccessible to man and, therefore, safe.

Araucaria forests

Plant communities are just as vulnerable on islands as are the animal populations. There is much concern at the present time that the very distinctive *Araucaria* forests of Norfolk Island (original home of the stately Norfolk Island Pine) may be reduced to a level from which they cannot recover. The effect which man has had on these forests is best illustrated by the story of Philip Island, which lies some 4 miles south of Kingston, Norfolk Island. It is a small, precipitous island, about $1\frac{1}{4}$ miles long and rising to a height of 920 feet. When Lieut Philip Gidley King first visited the island in 1788, he found it "wooded but not thick. I do not suppose that there are above 150 pine trees on the whole island. Most of the hills are covered by a thick entangled kind of reed." King released pigs on the island, which eventually became wild, and later goats and rabbits were introduced, all three being plentiful by the late 1830's. Between them these animals denuded the hills, leaving the steep slopes open to severe erosion. Today the surface of the island is dry within a day of heavy rain, while the sea around about is stained red. The island is virtually a desert with a little remaining vegetation in some of the valleys and on the less steep seaward slope. Four pine trees were still living in 1961, but their roots were undermined by erosion and their foliage sparse. The pigs and goats have died out long ago, but a few rabbits survive on the leaves of the shrubby White Oaks and other plants.



The extinct dodo (*Raphus cucullatus*) as illustrated in Piso's 1658 edition of Bontius' *Historiae Naturalis et Medicae Indiae Orientalis libri sex*. This drawing is thought to have been copied from a painting by Roelandt Savery, which was probably based on living dodos in a Dutch menagerie of the day.

Grim reminder

With the loss of the vegetation went most of the indigenous fauna, including the Philip Island Parrot (*Nestor productus*), which fed on grubs in the pine trees. Land snails which were once collected there in abundance appear now to be extinct. Philip Island today, with its eroded slopes shading from purple to red to apricot and yellow where hard but flaky weathered rock

Above: The rich forests of Norfolk Island, containing *Araucaria* and tree-fern, in the foreground contrast with the barrenness of Philip Island some distance off-shore. The small island closer to shore is Nepean Island. Below: The eroded surface of Philip Island is the result of the introduction of pigs, goats, and rabbits, which denuded the hills of vegetation. Erosion is so intense that the surrounding sea is stained red with the richly-coloured soil carried down by heavy rain. [Photos: Loisette Marsh.]

and tuff are exposed, serves as a colourful but grim reminder of man's effects on island communities. A similar story could be told for mammals, reptiles, insects, and other terrestrial groups. Species which are initially abundant rapidly decline in numbers until they reach extinction or survive only as rare individuals in isolated areas. What is the reason for this? Obviously, the primary cause of these extinctions is the effect of man and the animals which travel with him. In some cases, the numbers have been reduced as a direct consequence of hunting or forestry activities, while in others the reduction has been due to changes in the habitat. Land has been cleared, forests and grasslands have been burnt, and exotic plants introduced. The effects of man's domestic animals, especially dogs and cats, goats, pigs, and rabbits on island communities have often been devastating. Up to 1918, only three of the Lord Howe Island species had been exterminated, but when rats were introduced to the island, apparently following the wreck of the *Makambo*, another five species disappeared, probably as a result of the depredations of rats on the eggs.

However, this does not explain the disproportionate number of island species which have become extinct, since similar threats to survival operate on mainland species. The size of most islands is an important factor, as they are too small to provide areas which alien species, fires, or man himself cannot reach. On the continents, such areas act as refuges in which fragments of the original population can survive. Another reason lies in the genetic structure of island populations. These usually arise by the accidental introduction of a "founder" colony from the adjacent mainland. In the case of most plants, birds, and insects, these founders are probably blown to the island during storms, while mammals and other sedentary creatures are probably rafted across on floating vegetation after floods. The small initial colony, if it succeeds in establishing itself as a breeding population, will carry a more limited range of genes than will the larger and more widespread mainland stock from which it originated. Furthermore, on the island conditions will be different from the mainland—new ecological opportunities will present themselves, habitats will vary, predators and parasites may be absent, so that the selective effect of the new environment will in all probability be different. This change in selection pressure, acting on a much smaller gene-pool, is likely to lead to rapid evolutionary change. It is for this reason that so many island populations differ markedly from their mainland relatives, often having evolved into distinct species. Mayr has shown that a probable consequence of this evolutionary change is a reduction in genetic variability, and thus the island populations are less adaptable. He writes: "Such populations are not very plastic. If they live on an island . . . they will probably be successful as long as conditions remain stationary. However, such populations rarely have the capacity to adapt themselves to environmental shocks. The arrival of a new competitor or of a new enemy or a drastic change of vegetation or of the physical environment is apt to lead to extinction."

Islands save many species

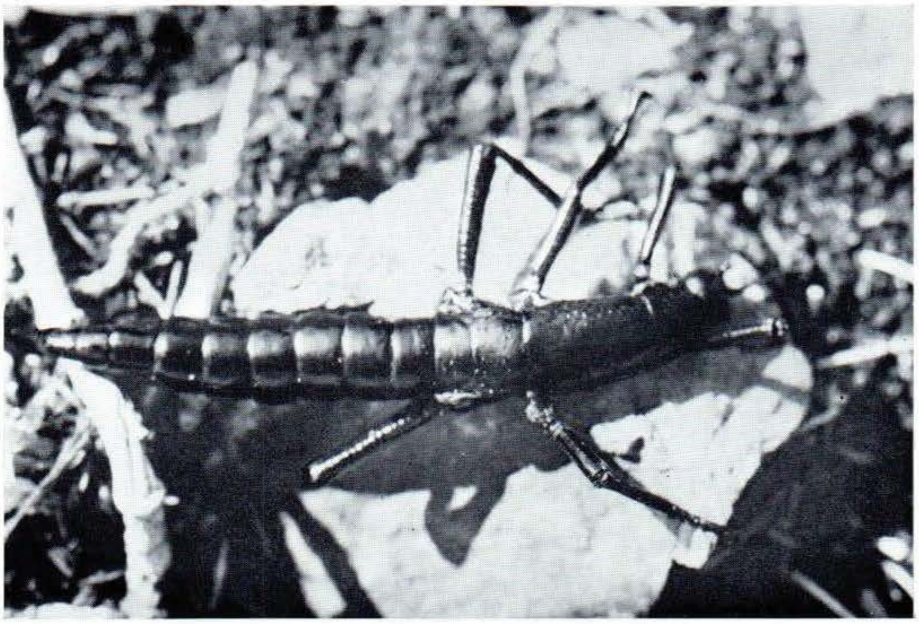
So much for the debit side of the story. But there is also a credit side for islands in the conservationist's account book. Were it not for the off-shore islands, especially those which man has not occupied, many species of great interest would not have survived. The isolation of some of them from such factors as fire, introduced predators (especially the fox), and the alterations of habitat caused by rabbits and sheep, have made them safe refuges for numbers of species which have become extremely rare, if not extinct, on the mainland. This is especially true in Western Australia, where many of the off-shore islands remain virtually untouched by man.

Conservation authorities in every State have recognized that islands are easier to protect from fire and predators (including man) than mainland areas, so that many islands have been declared as sanctuaries (either as flora and fauna reserves, or as national parks). Space precludes a description of all of them, but a few are of special interest. In New South Wales, the first fauna reserve proclaimed under the Fauna Protection Act was on Cabbage Tree Island, off Port Stephens, which is the only known breeding ground of the White-winged or Gould's Petrel. This species is one of the less common petrels and protection of its breeding colony is essential to its survival. The very important islands of Bass Strait are dealt with elsewhere in this issue by D. L. Serventy. A number of these are breeding sites for the Cape Barren Goose, of which about 5,000 or 6,000 individuals are thought to exist, and it is hoped that some islands can be set aside as permanent sanctuaries for them.

As an example of the way in which islands act as refuges for species exterminated elsewhere, the case of the Lord Howe Island phasmid is classic. This species, *Dryococelus australis*, is the sole representative of its genus, which, like some other stick insects, has lost the ability to fly. It was known on Lord Howe as the "land lobster" or "tree lobster" and, until rats reached the island, was quite common. However, following that tragic introduction, the species became increasingly uncommon and by the 1930's was considered to be extinct. It has not been seen on Lord Howe Island in recent years. Happily, in November, 1964, a party of climbers visited Ball's Pyramid, a precipitous rocky island some 14 miles south of Lord Howe, and a recently dead specimen of *Dryococelus* was photographed by Mr David Rootes. The photograph, from a colour transparency, is reproduced here, and provides encouraging evidence that the species still lives on Ball's Pyramid, where it has been safe from introduced predators.

Permanency of reserves important

One of the great difficulties which faces conservation everywhere is that of ensuring the permanency of reserves and other protective measures. It is for this reason that national parks and nature reserves should, once established, be revokable or alterable only by Parliament itself, and even then there should be very special reasons for making any alterations. Conservation battles, once fought and lost, are lost forever, but those which are won are not necessarily won forever, since the species or area conserved is always likely to be the target for future attempts at exploitation or development. Perhaps the most unfortunate example of this in recent years has been that of Barrow Island, Western Australia. This is one of the oldest and most important island reserves, having been set aside in 1908 as a class A reserve for the protection of fauna and flora. Such reserve classification means that it "shall for ever remain dedicated to the purpose declared in such proclamation, until by an Act of Parliament in which such lands are specified it is otherwise enacted". However, these reserves, set up under the Lands Act, are not exempted from the Mining Act, and, consequently, when oil was discovered on



The Lord Howe Island phasmid or "tree lobster" (*Dryococelus australis*), photographed recently on Ball's Pyramid. This specimen, though dead, indicates that the species is not extinct as had been thought previously. [Photo: D. Rootes.]

Barrow Island the development of a major oilfield followed. Barrow Island has been described as the most mammal-rich island off the Australian coast. No less than six species of native mammals have been collected there, most of which are well differentiated from mainland relatives. In addition, eighteen species of birds have been recorded, of which several are of special interest. A group of experts reporting on this reserve some years ago stated that, in their opinion, Barrow Island should remain a class A reserve and that it should be scheduled as a national nature reserve, maintained as natural bush without special facilities for the residence of tourists, and that no wharf or jetty should be built from the island, to reduce the chance of rodents being introduced.

The oil company developing the field has been very co-operative in impressing on its employees the need for careful conservation of the native fauna and flora, but it will be surprising if exotic plants and animals are not introduced to the island, and if their presence, together with the other changes which man's use of the island must produce, does not have a profound effect on the native species. When the island was first reserved, no one could have imagined the importance which oil has today in the national economy. In a century or two, it is likely that oil will no longer be of importance and the field may well be dry or abandoned. Meanwhile, the world may well have lost forever these animals and plants of exceptional interest and we shall all be the poorer.

BOOK REVIEW

THE GREAT BARRIER REEF AND ADJACENT ISLES, by Keith Gillett and Frank McNeill, former Curator of Crustaceans and Coelenterates at the Australian Museum. Coral Press Pty Ltd, Sydney. Revised 3rd edition, 1967. Pp. i–xiii, 1–209, 2 frontispieces, 168 plates, 5 charts, 3 text figs. Price, $7.50.

The third edition of this magnificent book—the standard, modern guide to the flora and fauna of the Great Barrier Reef and Lord Howe Island—is a welcome addition to the slowly growing range of authoritative and adequately illustrated works on the natural history of Australia. Since the first edition was reviewed at length in *The Australian Museum Magazine*, March, 1960, page 157, new colour plates and numerous new black and white photographs have been added, and a new section (chapter 13), giving the first available popular account of the little-known Swain Reefs at the extreme southeast of the Barrier Reef, increases the size of the book by fifteen pages.

The additional photographs are, to a large extent, in the section on the corals and their allies. There we are now able to see and directly compare, in a series of outstanding close-up photographs, the fundamentally different types of polyps (or individual, sea-anemone-like coral animals) characteristic of alcyonarian soft corals, organ-pipe coral, antipatharian black corals and true scleractinian stony corals. Other new photographs include reef fish in colour, a group hardly dealt with otherwise in this work, a sea snake, a living sea wasp *Chironex*, a land hermit crab and several underwater scenes from the clear shallow waters of the Swain Reefs. It is a pity that the dramatic, large-format aerial view of One Tree Island cay and encircling reef, attached as a foldout inside the front cover of the second edition, had to be dispensed with, but we have most attractive, coral-patterned endpapers and an extra frontispiece beach scene to partly make up for it. Perhaps the next edition will have an aerial view at the back as well.

The numerous changed and additional scientific names appearing in this revised edition show the advance in our knowledge of tropical reef biology even since 1959. Indeed, they demonstrate how the earlier editions of this book have in themselves stimulated and challenged marine biologists to study and identify many of the previously unknown animals from Great Barrier Reef waters first illustrated in the superb pages of this book.—*J. C. Yaldwyn.*

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