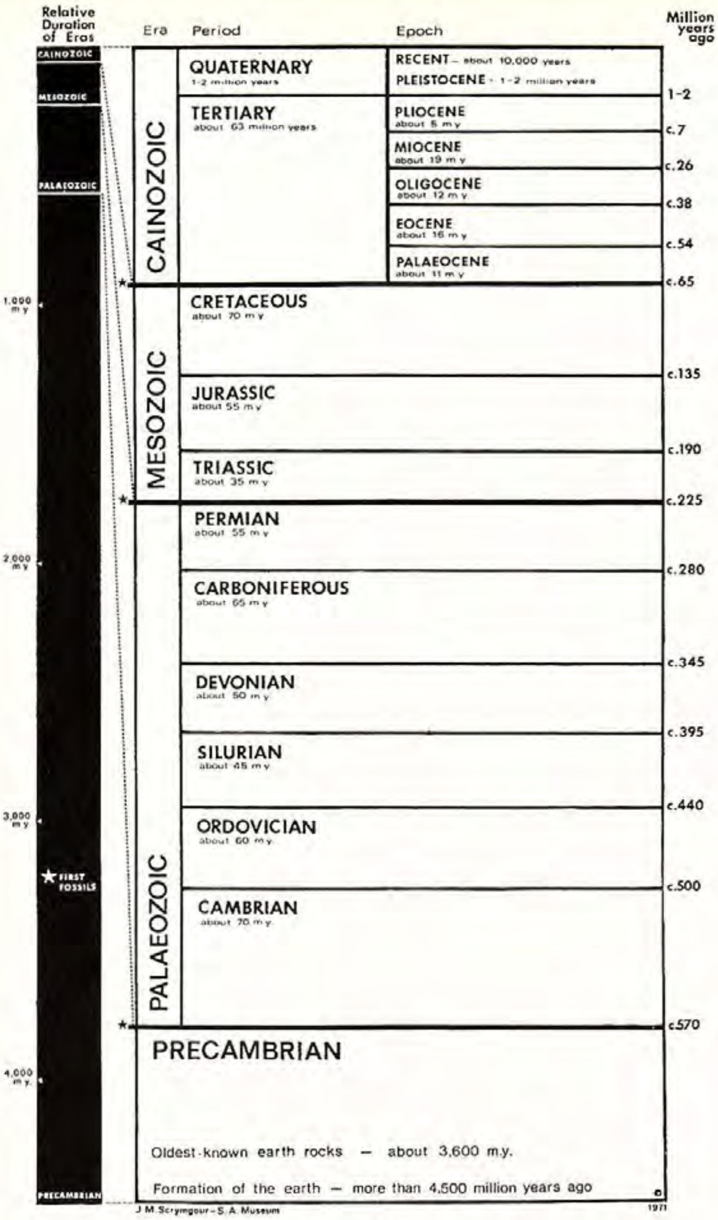
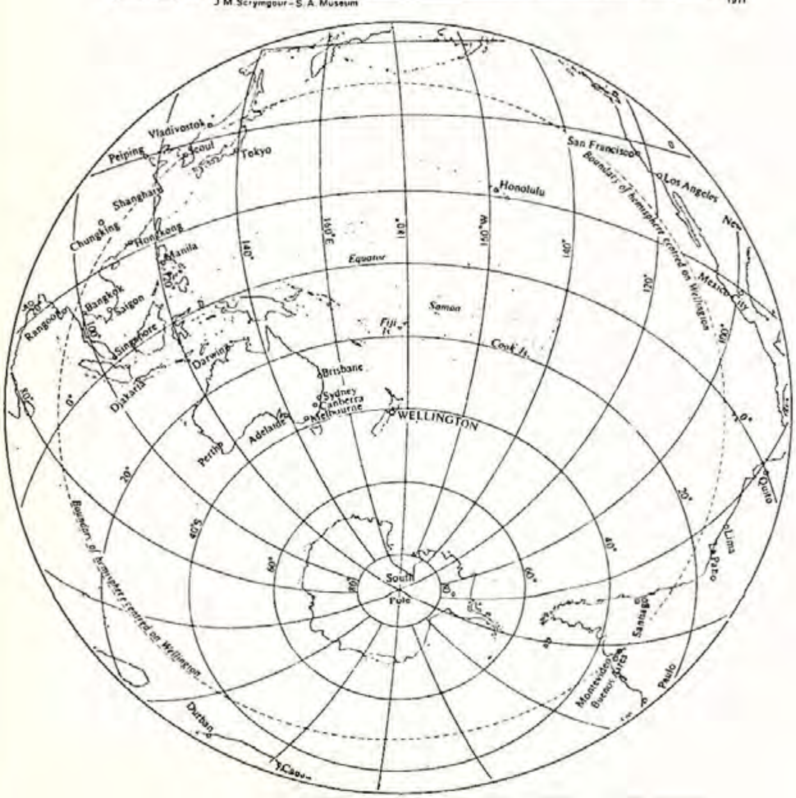
AUSTRALIAN NATURAL HISTORY

SPECIAL ISSUE
NEW ZEALAND

JUNE 1976 VOLUME 18 NUMBER 10 $1*





The isolation of New Zealand, illustrated by showing a hemisphere with the South Pole situated on Wellington (see article, page 358).

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Annette Burrows

COVER: Ferns, mosses and lichens, softening the outlines and adding to the variety. (Photo: Diane Brown)

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Howard Hughes/Australian Museum

Blow Holes and Pancake rocks at Punakaiki on the west coast of the South Island.

The lofty islands of New Zealand rise from a system of shallow submarine rises and plateaux between the Tasman Sea and the deep Pacific, forming part of the unstable seismic and volcanic belt which circumscribes the Pacific. Rapid geological changes in these areas have long intrigued the earth-scientist. Most geologists now believe that New Zealand was once a marginal fragment of the vast southern continent Gondwanaland, broken off by sea-floor spreading which developed a new ocean crust and in turn formed the South Atlantic and Indian Oceans, the Tasman Sea and finally the segment of Southern Ocean south of Australia.

A trough filled with Permian and Jurassic sediments, lying off the Pacific coast of Gondwanaland, was twisted and ruptured in the late Mesozoic, just before the Tasman Sea developed, widening to sunder New Zealand from East Australia and Antarctica. The sediments in the trough hardened to form the sandstone fragments of greywackes of New Zealand's main mountain ranges. Together with part of Gondwanaland, they formed a land much larger than the New Zealand of today.

New Zealand seems to have once shared with its neighbours common groups of plants and animals like the conifers *Araucaria* and *Agathis* and podocarps of several generic groups, the tuatara, the sole survivor of a most ancient order of reptiles, primitive frogs, Ratite birds (ancestors of the emus, moas and kiwis) and perhaps also lungfishes and monotremes. Most fragments of Gondwanaland seem to have remained fairly close until after early flowering plants such as the Southern Beech (*Nothofagus*) dispersed. Africa, a notable exception, had drifted apart too early to receive this group of trees, which botanists maintain cannot cross ocean barriers. It did, however, receive the Proteacea. Many of the plants and animals originally common to Australia, New Zealand and South America probably dispersed at this time, including many invertebrates, such as those of the forest-floor litter.

After New Zealand became isolated from other lands, its geographic outline and its coastline changed considerably as the sea transgressed its outlying parts. Sea flooded the rises and plateaux extending northwestward toward Lord Howe and Norfolk Islands and eastward to the Chatham Islands and also the Campbell Plateau, which extends southeastward to the subantarctic Auckland and Campbell Islands. Most of these islands, however, rose much later as volcanoes that built up above sea level. The coastline of the New Zealand archipelago constantly changed so that its geography was unstable. After the uplifting of mountains during the Mesozoic era the land was gradually worn down; chemical weathering was widespread and when the marine transgression reached its maximum in the Oligocene, the islands were reduced to quite small areas of low relief with deeply weathered soils, flanked by sediments composed of quartz pebbles and sand. This may have been a critical period for many plants and animals but most of the Eocene flora seems to have survived. If, on the other hand, New Zealand had been colonised by lungfishes and monotremes or even marsupials before achieving full isolation, they may have become extinct during this period.

If 'sweepstakes extinction' of part of New Zealand's Gondwana heritage is speculative in the absence of fossil evidence, there is no doubt that New Zealand, despite increasing isolation, continued to receive a 'sweepstakes colonisation' of plants and animals across the sea from outside her borders. The fossil record does give evidence of the first appearance, credibly by colonisation, of plants (from their pollen grains in dated sediments), shallow-water marine invertebrates (from their fossil shells and skeletons), and marine vertebrates (whales, penguins) but there is no significant fossil record of land animals. To judge by the fossils present, sea temperatures and land climates varied

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GONDWANA GENESIS

BY C.A. FLEMING

appreciably during the Cenozoic, becoming subtropical, or even marginally tropical, during the Upper Eocene and in the Lower Miocene. Afterwards a cooling but fluctuating trend led to the Quaternary—a sequence of about six cold glacial ages alternating with temperate interglacial ages from 1.8 million years ago until the present day.

Colonists can be grouped in terms of their apparent source area into Australian, Malayo-Pacific, Austral (or 'Antarctic') Holarctic (north temperate) elements. A steady trickle of Australian molluscs, crabs, and plants continued to establish themselves in New Zealand, some destined to remain, like the rock oyster (*Saccostrea*) and the teatree (*Leptospermum*); others such as the *Casuarina* became extinct. The Malayo-Pacific region became the major source of plants and animals colonizing New Zealand during the mid-Tertiary, when temperatures were warmest so that reef-corals, shelled protozoa ferns, mangroves, coconuts, cone shells and nautiloids joined other plants and seashore animals of tropical origin.

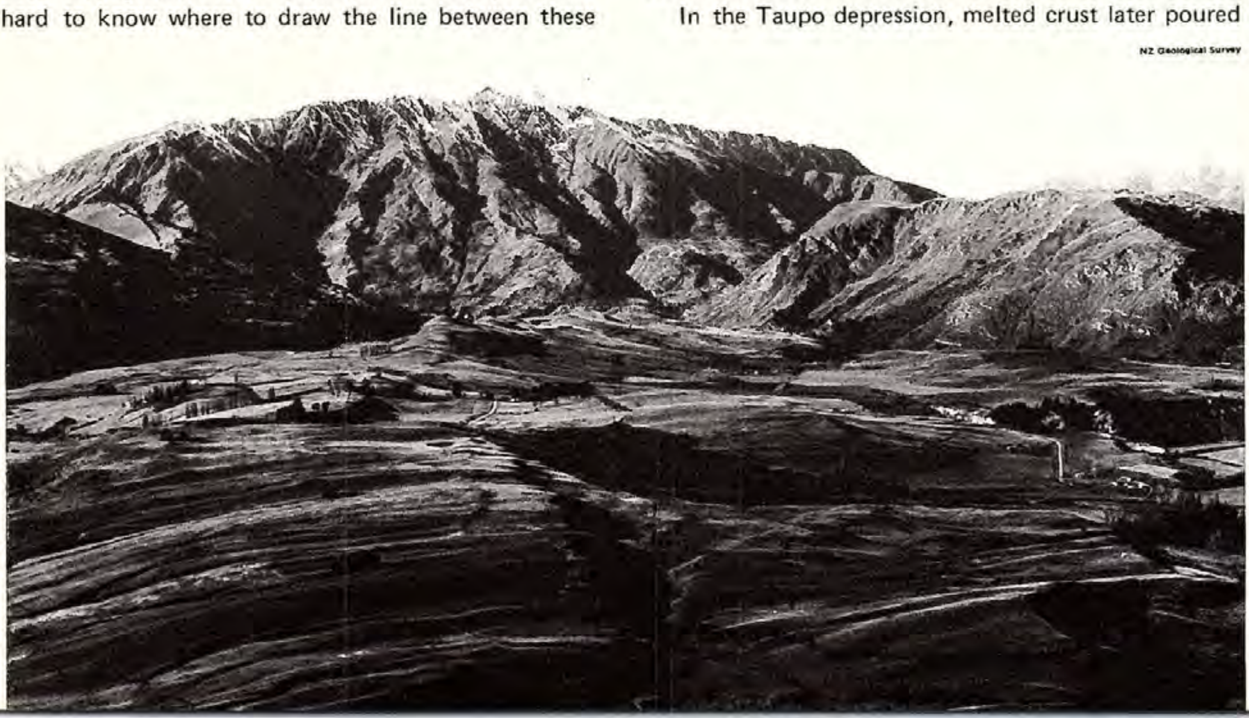
After the Cretaceous, the Austral elements that continued to arrive were probably all dispersed across the sea with the help of the West Wind Drift. They include seals, seabirds, fish and shellfish, and plants that are at least partly circumpolar, such as the Kowhai (*Sophora*) and *Ranunculus acaulis*. In contrast to the older Gondwana plants and animals (Paleoaustral), organisms that achieved a circumpolar or partly circumpolar distribution by dispersal across the southern ocean have been distinguished as a 'Neoaustral' element, but it is hard to know where to draw the line between these two groups, especially in the absence of a well documented fossil record. Some of the plants that achieved a partial circumpolar distribution by reaching both sides of the Pacific may have been of Malayo-Pacific origin, having extended south to points of entry into the West Wind Drift in Australia or New Zealand, leaving a diminishing trail of species as they spread downwind to the east. Fossil pollens suggest that *Coriaria* (tutu) and *Aristotelia* entered New Zealand in the early Miocene.

The rate of Malayo-Pacific immigration fell off in the late Miocene and Pliocene and many earlier colonists requiring subtropical climate failed to survive the Quaternary Ice Ages, among them the reef corals, many molluscs, coconuts, most of the Proteacea, some crabs, the *'brassi'* group of *Nothofaqus* (which survive on the mountains of New Guinea, New Britain and New Caledonia), and *Casuarina*. A recent discovery shows that *Acacia* briefly colonised New Zealand at the end of the Pliocene but did not survive long, although another young Australian colonist, the proteaceous *Persoonia*, survived in the Recent flora.

Toward the end of the Tertiary, mountain-building movements quickened New Zealand's mobile belt. Volcanoes had erupted at intervals both on the seafloor and on land throughout geological history, but they became especially active during the Miocene and Pliocene in arcs parallel to Northland, in the peninsulas of Otago and Canterbury, and in the outlying islands from the Kermadecs and Chathams to Campbell and the Aucklands.

In the Taupo depression, melted crust later poured

NZ Geological Survey



Glacial Ice of the Last Glaciation gouged out these parallel grooves by selecting out the softer bands in the schist near Lake Wakatipu.

out as rhyolite and ignimbrite sheets that produced a characteristic plateau landscape when subsequently dissected by streams. The mountain building, called the Kaikoura Orogeny after two young mountain ranges in Marlborough, was most acute in a belt running southwest from East Cape through Wellington to the alpine axis of the South Island and Fiordland and thus filling the gap between the Tonga-Kermadec and Macquarie submarine features. In the Quaternary, the Southern Alps were thrust up more than 5000m along a fracture that ranks as a major earth suture, probably the surface expression of the boundary between crustal plates that have moved 450km 'transcurrently' in a clockwise direction, at least partly in recent geological time. Whether this movement, which offsets the Paleozoic and early Mesozoic rock belts of Nelson from their continuation in Northwest Otago, took place mainly in the Rangitata (Mesozoic) or in the Kaikoura (Tertiary) Orogeny is controversial.

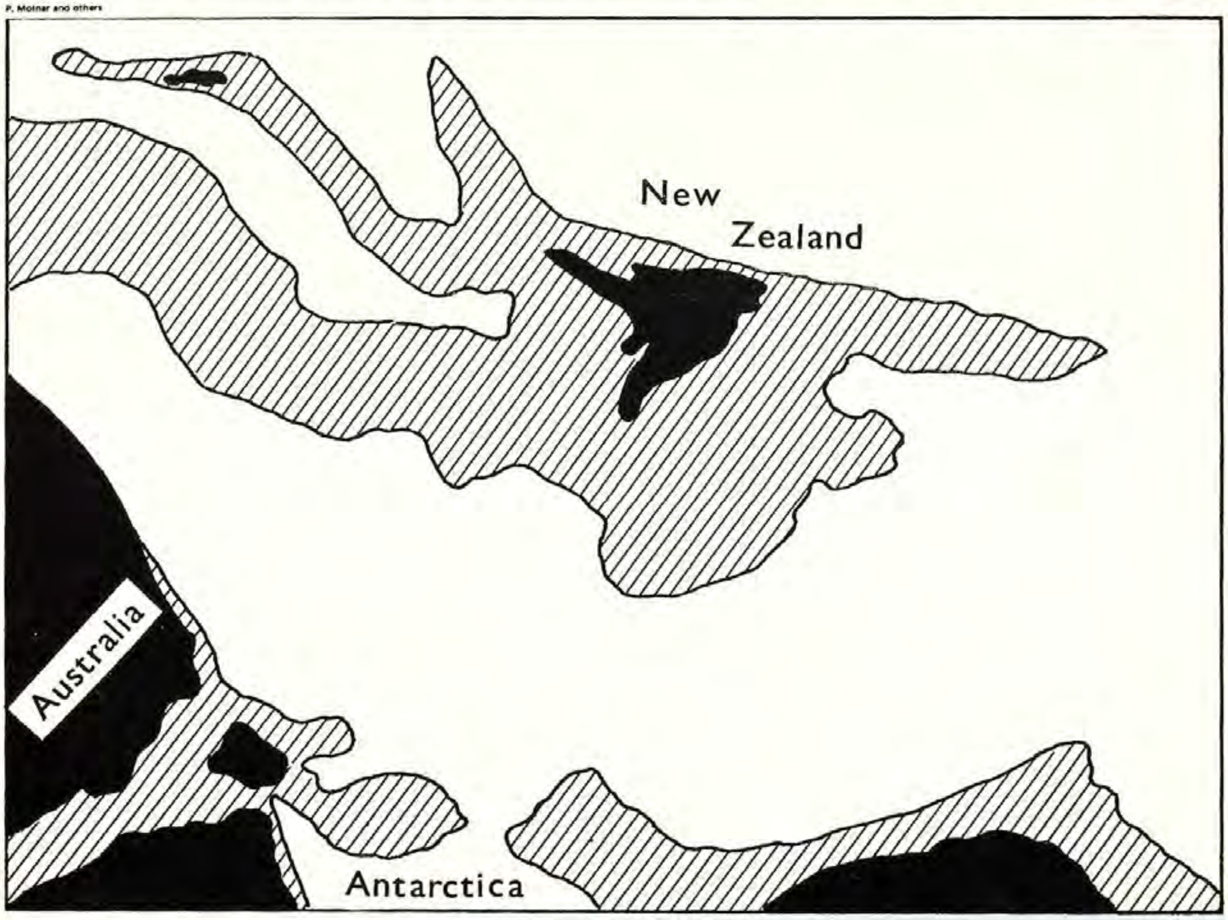
The Kaikoura Orogeny laid down the main lines of the landscape—the mountain ranges, synclinal depressions and fault escarpments on which the streams and rivers worked to carve the detailed shape of the land. Even during the last two million years, the effects of earth deformation and of the rise and fall of sea level as the ice waxed and waned on the world's mountains led to changes in the shape and number of the islands in the New Zealand archipelago. Early in the Quaternary Ice Age, a global cooling led to the growing mountains rising above the forest into subalpine scrub, meadow, fellfield and eventually to the zone of perpetual snow. Thereafter the fluctuating climate lead to repeated retreats of forest vegetation to the north at each of the glacial phases, separated by interglacial intervals when the climate was at least as warm as it is today.

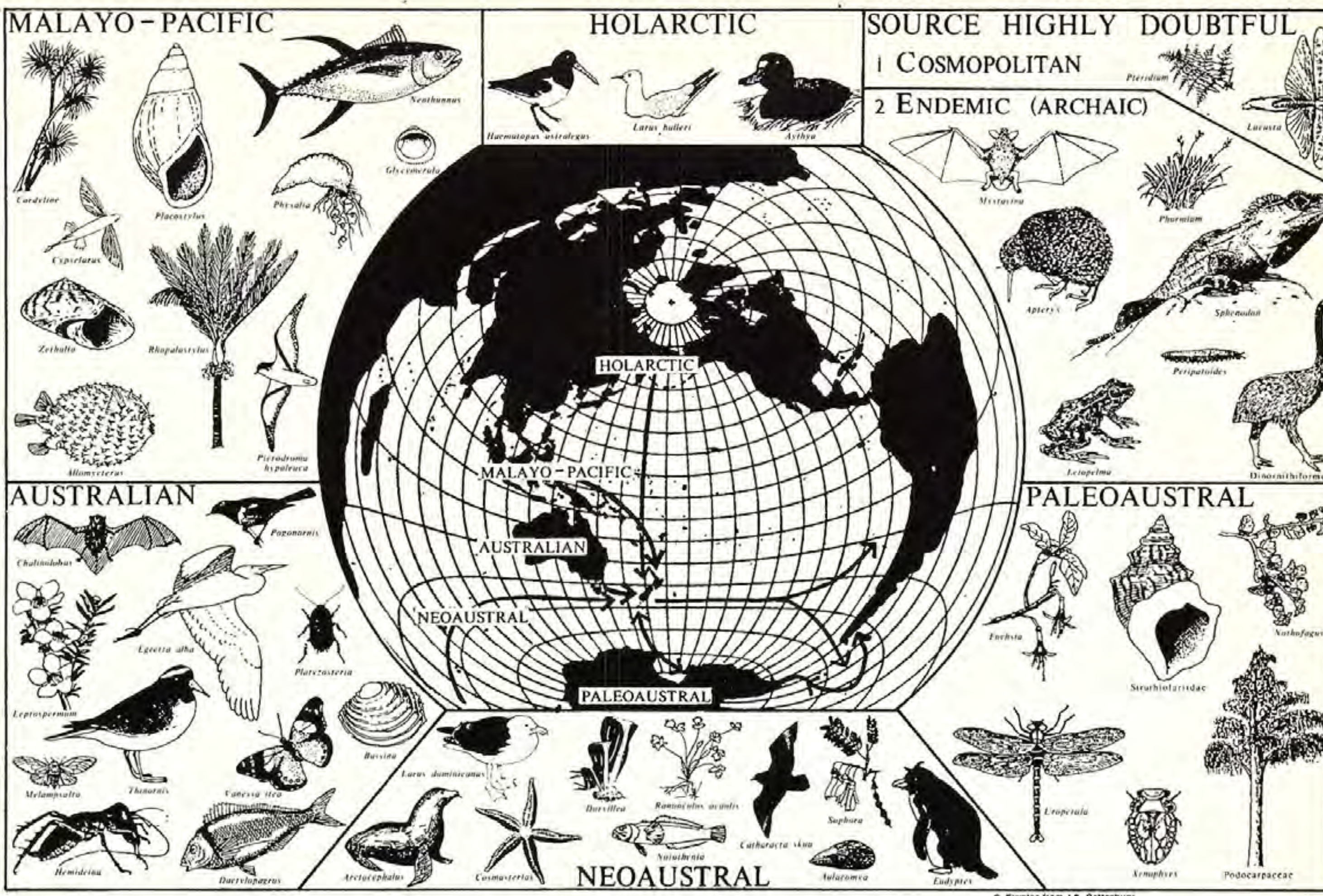
The Quaternary was a critical period in the history of the plants and animals. Many warmth-loving and otherwise sensitive organisms were exterminated, such as the Pliocene 'bird with false teeth' (*Pseudodontornis*), *Casuarina* and the *'brassi'* group of beeches. Cool temperate organisms such as the subantarctic fanshell *Chlamys delicatula* and King Crab (*Jacquinotia*) moved northward to colonise New Zealand. Indeed colonisation from the north was also encouraged by the extension of islands at times when low sea level bared their continental shelves. When the subalpine and alpine zone was first established it was colonised by plants and animals partly from forests, partly from lowland open country, partly, perhaps, by colonisation of old alpine plants from Antarctica before they were exterminated there, and by others from the Northern hemisphere, using the alpine tops of tropical mountains as stepping stones. At each glacial age, forest was banished from many South Island and some North Island districts but always persisted in more northern and coastal areas. Its precise distribution during the last glaciation is still being learned as pollen analysis provides new data.

Division of New Zealand into two or more islands by marine barriers at a time when glacial conditions set in could lead to ecological differentiation of isolated populations to produce alpine derivatives of forest plants, invertebrates and birds (such as the Kea or Alpine Parrot derived from the Kaka of the forests).

A reconstruction of the configuration of Gondwanaland fragments in the South Pacific about 63 million years ago when New Zealand attained its maximum area. Present land in black.

P. Molnar and others





C. Fleming from J.A. Rattenbury

New Zealand Biogeographic Elements with some examples.

Many alpine plant groups have developed species-swarms so young that hybridisation is rife, indicating continuing evolution before isolating mechanisms had time to develop.

Distribution patterns may reflect former barriers either of ice or barren outwash gravel in ice ages or of sea during the interglacial intervals of high sea level. Alpine plants from the north and south have expanded into the highly glaciated 'waist' of the South Island to constitute two elements in a rather impoverished flora. Scrub-dwelling cicadas suggest the presence in glacial ages of relict coastal areas of woody vegetation from which they have spread in post-glacial time.

Speciation on islands isolated by Pliocene and interglacial high sea levels may be reflected in the partly overlapping distribution areas of stag beetles and snails in the northern North Island.

As the climate warmed, during the past 14,000 years after the last glacial maximum advance, sea level rose rapidly to form the present Cook and Foveaux Straits about 10,000 to 9500 years ago and isolated many offshore islands. Subspecies differentiated in North and South Islands are thus less than 10,000 years old. In the south, grassland gave way to scrub and then to a forest succession, the sequence in detail depending on climate and geography and on the different spreading rates of different trees. Post-glacial alluvium, loess, bog peats and cave deposits are the chief source for bones of extinct ratite birds, the moas (Dinornithiformes).

The arrival of Polynesian man in New Zealand some 1000 years ago, bringing dogs, rats and fire,initiated a sequence of ecological changes that led to widespread extinction or drastic restriction of the less adaptable birds, reptiles, seals and even some invertebrates, a process accentuated after the arrival of European man. Immigrants, especially from Australia, among birds and insects, have continued to arrive unaided, and man has not only greatly modified the vegetation by clearing forest but also has introduced—by accident or design—a wide variety of plants and animals from other parts of the world.

Thus man, in laying the foundations of human culture, has also sounded the death-knell for an ecology of isolation.

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THE SHAKY ISLES

BY R.H. CLARK


National Publicity Studios NZ

The Bruce Road, looking towards Mount Ngauruhoe, Tongariro National Park, Wellington Province.

New Zealand is regarded by many as a somewhat unstable and insecure region—'the Shaky Isles'. It is true that the North Island has active volcanoes and, especially in the southern part, earthquakes. Earthquakes also affect the South Island. Some severe shocks have occurred in recent years.

Historic records go back only about 150 years, but in that time we have experienced many earthquakes. Destructive earthquakes affected Dusky Sound (1826), Wellington (1848, 1855, and, less severe, 1942), Murchison (1929), and Napier (1931). The town of Inangahua in Nelson was severely shaken in 1968. The most celebrated volcanic eruption in this period was that of Tarawera (1886), but other large eruptions were those of Ruapehu (1945) and Ngauruhoe (1954). Many smaller eruptions of Ruapehu, Ngauruhoe, Tongariro, and White Island have also occured.

In prehistory, a tremendous eruption of pumice from the Lake Taupo region occurred about 1800 years ago, and a large eruption from the Tarawera Centre in 1020 AD. Rangitoto, near Auckland, erupted about 1200, and Mt. Egmont in Taranaki, about 1755.

The fundamental reason for the volcanic eruptions in the northern part of New Zealand, and the earthquakes which affect most of the country, is to be found in New Zealand's position on the Earth's crust. In recent years it has been recognised that the crust and part of the outer mantle of the Earth consist mostly of a number of large, rigid plates. These plates are in motion relative to each other. Australia, the Tasman sea, and most of New Zealand form part of the Indian Plate. But the Pacific Ocean to the east of New Zealand is part of the huge Pacific Plate. The contact between these two plates lies just east of the North

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Island, and actually runs through much of the South Island.

We can regard the Pacific Plate as moving obliquely westward towards the Indian Plate. There is good evidence that the floor of the Pacific Ocean is continually being added to at the East Pacific Rise, about the longitude of Easter Island. Addition at the Rise of new ocean floor results in movement of the floor outwards; west of the Rise, this movement is towards New Zealand, at a rate of about 120mm per year.

At the Plate Boundary, the Pacific Plate moves down beneath the North Island of New Zealand, carrying with it wet sediments deposited on the seabed, especially in the trenches which usually exist where one plate moves beneath another.

The passage of the Pacific Plate beneath the North Island of New Zealand is marked by earthquake foci, deeper towards the west, as the angle of descent is about 50°. As wet sediments are carried down into the hot mantle, fusion occurs, magma is generated and, when this breaks out at the surface, volcanoes result.

All of the presently active volcanoes and volcanic areas of New Zealand are in the Central and Northern parts of the North Island. Dominant is the Taupo Volcanic Zone, which extends from Ohakune northeast to White Island. In the southwest part of this zone are the large andesite volcanoes of Ruapehu (2797m), Ngauruhoe (2291m) and Tongariro (1968m), a complex of volcanic centres. Ruapehu is famed for its excellent ski-slopes and also for its crater lake.

In 1945, Ruapehu produced its most notable eruption of historic times. The crater lake was replaced by a tholoid, or dome, of molten lava, with explosions which hurled blocks of lava high above the mountain. After months of this activity, the lava withdrew down the throat of the volcano and the crater lake slowly re-formed.

A tragic sequel to this eruption occurred more than eight years later, on Christmas Eve of 1953. During the eruption of 1945, a natural tunnel beneath the ice, through which the crater lake drained into the headwaters of the Wangaehu River, had become blocked, and when the lake reformed after the eruption, the lake level rose above it.

On December 24, 1953 the blockage suddenly cleared; the resulting surge of water from the crater lake down the Wangaehu created a rapidly moving mud-flow, or lahar, which destroyed the railway bridge at Tangiwai just before the northbound express was due to cross it. Part of the train crashed into the river, and 151 people were killed.

Since 1945, eruptions from Ruapehu's crater lake have produced fast-moving mudflows down the snow-covered slopes of the cone. As during winter months,

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The Pink and White Terraces which were situated on the shores of Lake Rotomahana, Rotorua, were destroyed by the eruption of Mount Tarawera in 1886. They were created by centuries of deposition of the impurities in geothermal water.

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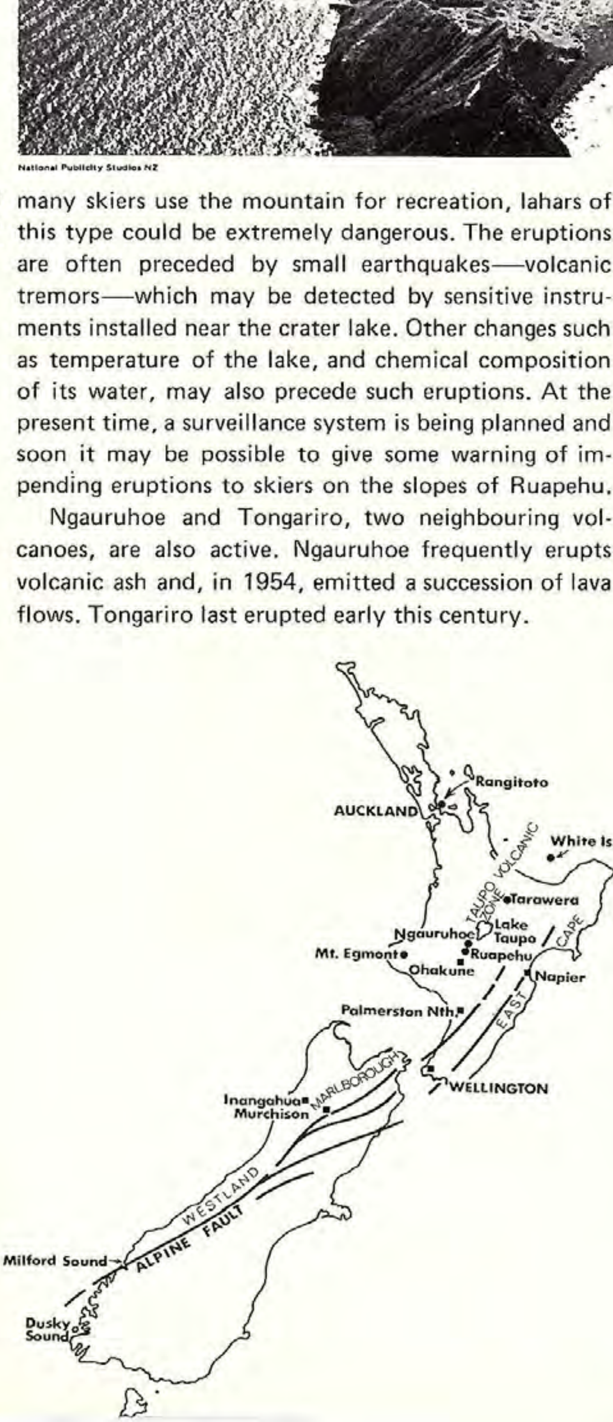
An aerial view of White Island, Auckland Province.

many skiers use the mountain for recreation, lahars of this type could be extremely dangerous. The eruptions are often preceded by small earthquakes—volcanic tremors—which may be detected by sensitive instruments installed near the crater lake. Other changes such as temperature of the lake, and chemical composition of its water, may also precede such eruptions. At the present time, a surveillance system is being planned and soon it may be possible to give some warning of impending eruptions to skiers on the slopes of Ruapehu.

Ngauruhoe and Tongariro, two neighbouring volcanoes, are also active. Ngauruhoe frequently erupts volcanic ash and, in 1954, emitted a succession of lava flows. Tongariro last erupted early this century.

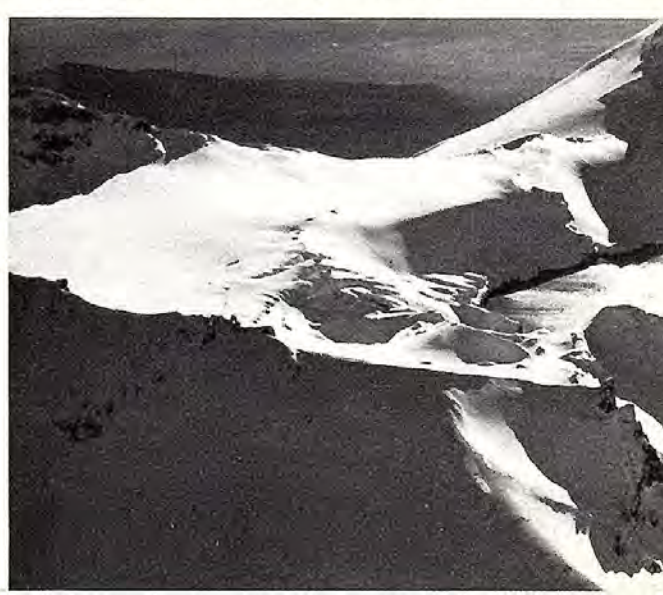


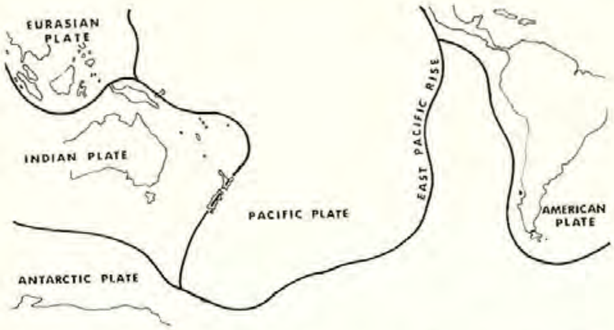
The most northeasterly volcano in New Zealand is White Island which lies off the Bay of Plenty coast, 50 kilometres from Whakatane. Sulphur was mined there early this century but, in 1914, collapse of part of the back wall of the crater resulted in blockage of the vents. The collapsed debris became saturated with hot water and steam and flowed over the crater floor, burying everything to a depth of several metres.

No trace was ever found of the eleven men employed on the island. Eight metres of mud and rubble lay over the site of their huts, but excavation was not possible because of the very hot water which permeated the mudflow.

Later attempts to mine sulphur were unsuccessful for economic reasons and now the island, which is owned by Mr. John Buttle, an Auckland stockbroker, is a private nature reserve. New Zealand scientists visit it at regular intervals to observe the changes which precede its fairly frequent eruptions.

Elsewhere in New Zealand, in Northland and around





Auckland City, small basalt volcanoes occur. None of these could be regarded individually as active, but it is significant that during the last 50,000 years there have been at least fifty eruptions in the Auckland area. There are good reasons for considering Auckland as still active.

Mt. Egmont, the spectacular cone which dominates Taranaki, last erupted about the year 1755. Mud-flows and ash from this volcano cover large areas of Taranaki, and the mineral content of volcanic products from Mt. Egmont has contributed to the fertility of this Province.

While earthquakes can and do occur throughout New Zealand, the great destructive earthquakes of the last century-and-a-half have occurred in a belt stretching northeast from Fiordland in the South Island towards East Cape in the North Island. Usually, these earthquakes have been accompanied by ground movements. In the 1855 Wellington earthquake, tilting of a large block of country occurred—three metres of uplift at the fault itself, two metres over much of Wellington. The beaches and shore platforms uplifted at this time facilitated road-building around Wellington coasts.

The Napier earthquake of 1931 was also accompanied by uplift, but many New Zealand earthquakes are accompanied by sideways displacements along fault lines, like that of San Francisco in 1906. The total lateral movement along the Alpine Fault, extending through Westland from Milford Sound to Marlborough, is approximately 500 kilometres over the last 100 million years. Most of this movement has taken place within the last 60 million years.

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An aerial view of the Crater Lake, Mount Ruapehu.

L. Homer, NZ Geological Survey

Road damaged by Inangahua earthquake, 1968.

Considerable progress has been made in various countries in the prediction of volcanic eruptions, and now progress is being made in the prediction of earthquakes. Many shallow earthquakes are thought to result from accumulation of strain in earth-blocks until friction along lines of weakness—fault lines—is overcome, and rupture occurs.

Accumulating strain can be measured by repeated surveys across active faults, and by installation of strain gauges. Recently, methods developed by Soviet scientists, now being applied in New Zealand, depend on small changes in velocities of earthquake waves as they pass through strained rock. It is hoped that eventually, prediction sufficiently reliable to ensure evacuation before a destructive earthquake may be possible. Already this has happened in China.

In the meantime, while earthquakes cannot be prevented, nor yet predicted with accuracy, buildings can be constructed which are likely to survive severe earthquake. Building codes were generally raised after the 1931 Napier disaster. More recently, very strict codes have been introduced in cities such as Wellington, Palmerston North and other main centres within what some refer to as the 'earthquake belt'. Special attention is being paid to foundation material, and Civil Defence organisation has been active in preparation for serious quakes.

It is thus New Zealand's position at the plate boundary that is responsible for both volcanoes and earthquakes; the former related to a down-going slab of material under the North Island, the latter to release of stress along the major faults. Progress has been made in understanding the occurrence of earthquakes and process of volcanic eruptions, but a great deal more work is needed before we can forecast precisely when either earthquakes or volcanic eruptions will take place.

FROM HAWAIKI TO TE-IKA-MAU

BY JANET DAVIDSON

In the beginning was Te Kore, the Void. After the Void was Te Po, the Night. From out of the Night arose Rangi and Papa, the Sky Father above and the Earth Mother below. To them were born children who were gods, who separated their parents so that there was Light. And in that Light was created all manner of things, animate and inanimate. From one of the gods sprang Man. He was the ancestor of the Maori.

Within that mythical time when gods communed with Man, there arose the demi-god, Maui. Among his many feats he fished up New Zealand.

It was to this land, the fish of Maui, that the Maori came.

—Witi Ihimaera
Maori

Some Maori tribes believe that Kupe was the original discoverer of New Zealand; others give pride of place to other famous ancestors. All agree, however, that the legendary homeland from which these explorers came was *Hawaiki*. The name is found throughout Polynesia—present day Hawaii and the island of Savai'i in Samoa, for instance—but these are not to be identified with the *Hawaiki* of tradition. From *Hawaiki*, also, came the first settlers who spread across *Te-Ika-a-Maui*, the fish of Maui, and peopled the land.

The first Europeans to visit New Zealand, the expedition of Abel Tasman in 1642, had only a brief and unhappy encounter with the country's occupants. James Cook's first voyage in 1769-70 provided the first real description of both New Zealand and the New Zealanders. The similarity in language, customs and appearance between the New Zealand Maoris and the inhabitants of the islands to the north and northeast seemed obvious, and it was at this time that the question was first posed: "How shall we account for this nation spreading itself so far over this vast ocean?" Cook himself believed the Polynesians (as these people are now called) to have come from the west, and this is still the most widely held view. From time to time, however, people have suggested an American homeland, and there have even been those who proposed that the Polynesian islands are the remnants of a vast sunken

Howard Hughes/Australian Museum

H. Smith

A modern decorative panel in the traditional Maori style adorns the foyer of Wairoa Public Hospital.

continent. The question that intrigued Cook and his contemporaries has continued to cause interest and speculation for two centuries. One important strand in the development of archaeology and prehistory in New Zealand and the Pacific islands has been curiosity about Polynesian origins and migrations.

Studies of language, physical type and culture have tended to confirm Cook's opinion that the New Zealand Maoris are most closely related to the people living in the islands to the northeast of New Zealand in a vast triangle extending from New Zealand to Hawaii in the north and to Easter Island in the east. Within this group, the same lines of evidence point to a closer relationship between the New Zealand Maoris and the inhabitants of Tonga, the Polynesian archipelago nearest to New Zealand. The discovery in New Zealand in the mid-nineteenth century of bones of the extinct flightless birds now generally known as moas, and the further discovery which soon followed, that these bones were often found in human occupation sites, led to a period of intense archaeological activity in New Zealand in the latter part of the nineteenth century. Great controversy raged over who the moa-hunters were. Were they simply the earlier ancestors of the Maoris then living, or had they been an earlier and different race of people? Although the excitement died down amid fairly general agreement that the moa-hunters were early Maoris, the controversy left lingering feelings in the popular imagination that exciting though moa-hunting Maoris certainly were, it would be even more exciting if there had been an earlier and now extinct race of people in New Zealand. This feeling still reappears from time to time, and has done so quite recently, but reports of occupation much older than or different from the early Polynesian settlement have never yet been substantiated.

In the past twenty-five years, two developments have placed our understanding of Maori and Polynesian prehistory on a new and sounder basis. Archaeological excavations have been carried out not only in New Zealand (where excavations have been going on for more than a century) but in the other Polynesian island groups previously thought to have no sites worthy of excavation. The application of radiocarbon dating here, as elsewhere, has revolutionised previous ideas about the chronology of human settlement. In New Zealand, radiocarbon dates have indicated a period of Polynesian occupation comparable to that previously estimated or guessed on the basis of Maori traditions and common sense. It is in the other Pacific islands that radiocarbon dates are causing considerable reassessment of the length of occupation.

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National Museum of N.Z.

A nineteenth century lintel or storehouse front from Taranaki.

It may never be possible to say exactly when New Zealand was first settled, but increasingly precise estimates can be made. By about 1200 AD the coastline and at least some inland areas had been fairly thoroughly explored, and sites of approximately this age or slightly older are known from one end of the country to the other. Assemblages found in these sites, particularly stone adzes, fishhooks and ornaments, can now be compared with assemblages of various ages from other Polynesian islands. There are very striking resemblances between early New Zealand material and assemblages from the Society and Marquesas Islands which date between 800 and 1100 AD. So strikingly similar are the artefacts from the different areas that it may never be possible to say exactly which island or islands were the immediate source for the settlement of New Zealand. Nevertheless, the old theory that the Maoris came from the islands to the northeast has been strongly supported by recent archaeological work. It is possible to say with some confidence that New Zealand was settled between 800 and 1100 by people who laid the foundations for the development of Maori culture as it was seen by Europeans in 1769.

Wooden club of twisted root from the Sir William Dixson collection donated to The Australian Museum about 1951.

The islands of the Society and Marquesas groups had in turn been colonised from the west—from the area which includes Samoa, Tonga and Fiji. Radiocarbon dates suggest that these islands were settled between about 1000 and 1500 BC, although the movement further to the east took place considerably later. Beyond this point, Polynesian origins are obscure, and several authorities have recently suggested that Polynesian languages and culture first developed as distinct entities within Polynesia, specifically in Samoa and Tonga. The distinctive Lapita pottery made and used by the first settlers of Samoa and Tonga has been traced through Melanesia as far west as New Britain. It is increasingly clear, however, that older theories which saw the Polynesians, already a distinct group, moving rapidly across the Pacific within the last two thousand years from a homeland in Southeast Asia, India or North Africa cannot be sustained.

There has been much controversy over whether the Polynesian settlement of New Zealand was deliberate or accidental, and whether there were several waves of settlement or only one. Maori traditions have been interpreted to suggest several successive voyages culminating in a major planned migration in a number of famous canoes. It is now clear that this is a European synthesis resulting from extensive and unjustified editing and collating of traditions from different tribal areas. Careful study of the original sources has even led some authorities to suggest that the best-known migration traditions may refer not to the arrival of canoes from the tropical Pacific, but to internal migrations within New Zealand. This theory, however, has not yet gained general acceptance. Whereas the traditions imply a number of separate arrivals from the same general area, the archaeological record does not distinguish more than one basis for Maori culture, or any significant later arrivals once that basis has been established.

The Polynesian settlement of New Zealand was certainly deliberate in that the settlers were looking for a new land in which to live. The introduction of plants and animals cannot be explained by the arrival of fishermen or local inter-island travellers blown off course. Deliberate Polynesian colonisation, however, need not mean that the settlers knew where they were going, or how to get back to where they had come from. Indeed there is no archaeological evidence of any further contact with the homeland once the settlers had arrived in New Zealand. Rather, the later chapters of New Zealand prehistory are concerned with the continuing adaptation of one branch of Polynesian culture in isolation.

The Polynesians who settled in New Zealand found a country very different from anything in their previous experience. The islands of the Society, Cook and Marquesas groups are volcanic or coral islands and are very small, with a restricted range of fauna and flora. In comparison, New Zealand is a large land mass, and geologically it is continental with a much greater diversity of rocks. The islands are tropical, New Zealand is temperate. More striking even than the climatic differences to the first settlers, may have been the extraordinary bird fauna which flourished in the isolation of New Zealand before the arrival of man.

The life of the inhabitants of the tropical Polynesian islands was based on the cultivation of tropical root and tree crops such as taro, yam and breadfruit, with a considerable amount of fishing and some fowling. Domestic animals included pig, dog and chicken. The Maoris introduced sweet potato, taro, yam, gourd, paper mulberry and possibly one or two other plants to their new land. It is likely that they tried and failed to establish other plants such as breadfruit, coconut and bananas. Of the animals, only the dog and the rat seem to have survived the journey to New Zealand. (The small Polynesian rat had accompanied man, although whether as a stowaway or as a chosen companion is not clear.) Most of the Maori-introduced plants are of Southeast Asian origin. An important exception is the sweet potato, the only cultivated plant that grew sufficiently well in temperate New Zealand to make a significant contribution to Maori diet. It is almost certainly of South American origin, although the manner of its dispersal throughout Polynesia remains obscure. It was probably introduced to the Marquesas and spread from there; it seems to have reached New Zealand with the earliest settlers.

In view of the extent and diversity of New Zealand, it is hardly surprising that some regional variations developed in Maori culture, particularly in ways of subsistence. The adaptation to temperate conditions of the sweet potato, a tropical plant, was a considerable achievement. Nevertheless, the plant could be grown successfully only in the north and in central coastal regions, and even here was heavily supplemented by the edible rhizome of the bracken fern. The Maoris who settled in the south relied entirely on hunting and gathering. Hunting had been practised in the tropical Polynesian islands, and it is therefore not surprising that Polynesian settlers in all parts of New Zealand made the most of the opportunities they found there. Not only moas, but a wide range of other birds were hunted, seals were slaughtered in large numbers and fishing was also very important.

It has been customary to think of moa-hunting and agriculture as somehow incompatible, one replacing the other in those parts of the country where both were possible. It is now evident, however, that agriculture was well established in several parts of the North Island by about 1200, and that the vital innovation of lifting the sweet potato harvest and storing the tubers through the winter in sunken storehouses, which enabled the plant to be successfully cultivated in New Zealand, had already been made. Yet moa-hunting continued in parts of the North Island for at least another 300 years before the last of the moas disappeared. In the South Island, the gradual decline of moas led to an increasing reliance on other foods such as shellfish.

The impact of the Polynesians on New Zealand was considerable. In some areas, changes in vegetation came about following clearance and deliberate and accidental firing. The entire range of moas and a number of other bird species became extinct, while the distribution of others was restricted. The tuatara was eliminated from the mainland and survived only on small offshore islands. The face of New Zealand was quite different in some respects in 1769 from what it had been a thousand years earlier.

The arrival of Europeans brought about far-reaching changes in Maori culture. As explorers were followed by whalers, missionaries and settlers, Maoris eagerly adopted items such as metal tools, pigs, potatoes and guns. While some aspects of the old way of life were rapidly forgotten, other aspects of Maori culture have gone on changing and developing during the last two hundred years. The large, carved meeting house is a case in point. It is the epitome of Maori culture now and has a very real and important place in Maori life, just as it rightly takes pride of place in any museum lucky enough to have one; but there is no good evidence that such things existed in pre-European Maori society, the nearest thing probably being a chief's house with more/better carving than other houses had.

Increasingly, Maoris have adapted to a more European way of life, and this process has accelerated with the urban migration of recent years. Some elements of Maori culture, however, have always maintained their importance for Maoris, and today many young New Zealanders, both Maori and pakeha (white), want to understand *Maoritanga* (Maori-ness) and the traditions on which it is based. Ironically, *Maoritanga* is a post-European coining since the present meaning of *Maori* is itself of mid-nineteenth century origin. Much of what young Maoris think is *Maoritanga* is as different from 1769 as 1769 was from 1569. It is not a matter of preserving something that is dead, but of nurturing something that is still very much alive.

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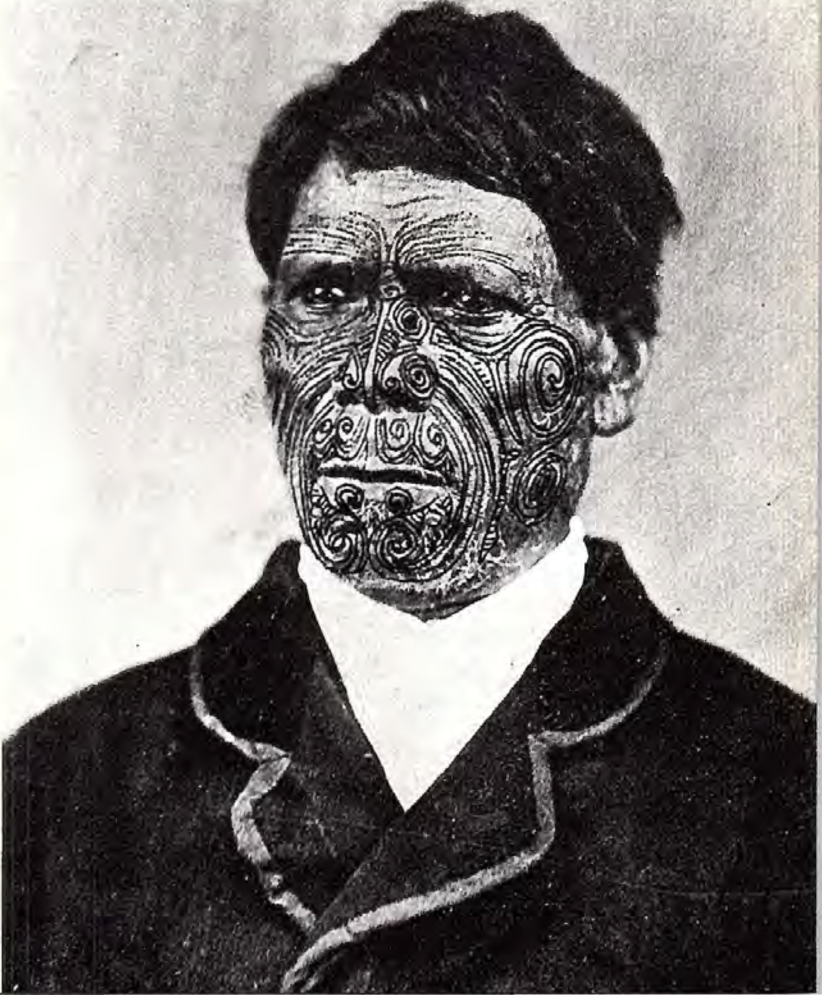

Porikapa (Polycarp) was one of the principal chiefs of the Ngaruahanga hapu, and was one of the few remaining fully tattooed Maori chiefs of earlier days. He died at Okato, December 1888, aged about ninety years. He was a Deacon of the Anglican Church.

David Milledge

FOREST IN ISOL

BY BRUCE HAMLIN

The flora of New Zealand is a product of the isolation of the land. This isolation is of very long standing, at least as far back as the Cretaceous and before the rise of the flowering plants. The colonization of New Zealand by higher plants has therefore had to be by long-distance dispersal methods. The significance of this can best be illustrated by regarding New Zealand as the centre of a hemisphere with Wellington on the pole, much as an astronaut, directly over Wellington, would see the world from several miles up.

In this view of the world, New Zealand appears as the centre of the Pacific, Antarctic, and Indian Oceans, with the great land masses on the other side of the globe. No other land area of size comparable with New Zealand is more isolated, the only major land areas included in the hemisphere, apart from Antarctica, being Australia, New Guinea, the edge of Southeast Asia and the tip of South America. It is not surprising, therefore, that these are precisely the areas which show the most influence on the flora of New Zealand

There are clear botanical indications that South America, New Zealand, Australia, New Caledonia and New Guinea have had some sort of link in the past. The most commonly cited examples are the podocarps and the southern beeches. With the latter, the genus *Nothofagus* is found in all the areas mentioned but this is not so simple a subject as the statement implies. For example, of the four New Zealand species, three hybridize readily amongst themselves, given the opportunity. The fourth species has its closest relatives in Australia (Tasmania and Victoria). There are moreover, fossil pollens of southern beeches no longer occurring in New Zealand but clearly related to species now found only in the mountains of New Caledonia and New Guinea.

The kauri, *Agathis australis*, perhaps New Zealand's best known and certainly its largest tree, belongs to a genus also occurring in Queensland, Fiji, New Caledonia, Indonesia and the Philippines. The genus is closely related to *Araucaria,* which includes the Norfolk Island pine and the Brazilian monkey puzzle, a genus which extends from South America to Australia, New Caledonia and New Guinea. Taken on its own, *Agathis* might appear to have reached New Zealand from the tropics, especially via the clear arc formed from New Guinea via New Caledonia. Such an interpretation is

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BRUCE HAMLIN, Curator of Botany at the National Museum of New Zealand, died suddenly before finishing this article. It has been completed and edited by staff of the Botany and Editorial Departments, National Museum of New Zealand.

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reinforced by the kauri's present confinement to the northern part of New Zealand. Fossil evidence, however, shows the kauri extended south to Otago in former times and the presence in South America of the related *Araucaria* indicates that *Agathis* may have moved north from a southern centre.

Another characteristic New Zealand plant, this time a sedge, the hookgrass *Uncinia*, has a distribution which is characteristically Oceanic, if by that term we may mean the area covered by New Zealand's hemisphere. It is found also in Tasmania, the mountains of the Victoria-New South Wales border, the highlands of New Caledonia, New Guinea and Borneo, but also in the Philippines and Hawaii. South America has several species and the genus is found on all the islands of the southern ocean large enough to support a vascular flora. The two species found in the Philippines and Hawaii are identical with two found in New Zealand. Both species are common in those parts of New Zealand where ground-burrowing petrels and shearwaters nest, and the Philippine and Hawaiian Islands lie close to the known migration route of these seabirds.

The genus *Coprosma* has nearly fifty species in New Zealand ranging from large-leaved small trees to prostrate, small-leaved mat-plants. The genus occurs on many of the high islands of the Pacific and also in Indonesia, New Guinea and Australia (Victoria and Tasmania). There is an inference here that the genus has a tropical origin.

Around the northern parts of New Zealand are groups of small islands carrying distinctive plants not found on the mainland. A large woody climber, *Tecomanthe speciosa*, whose nearest relative is at Moreton Bay, is found on the Three Kings Islands. On the Poor Knights Islands to the east of the Northland peninsula, lives *Xeronema*, a plant of the lily family with only one relative, a very closely related species in New Caledonia. A large-leaved tree, *Meryta sinclairii*, is also found on these islands and most of its related species are again in New Caledonia.

In addition to these curiosities, a substantial number of the trees and shrubs of New Zealand show clear relationships to the north. Apart from the mangrove of northern bays and estuaries which has obvious tropical or subtropical affinities, there are many plants of tropical origin which reach further south in the New Zealand region than anywhere else. Notable among these are the only New Zealand palm, the nikau (*Rhopalostylis sapida*), and five endemic species of *Cordyline*, of which the cabbage tree (*C. australis*), along with tall tree ferns (species of *Cyathea* and *Dicksonia*), are highly characteristic of the New Zealand scenery.

Vegetation is largely controlled by climate, which is related in part to topography and latitude. Lying with its high mountain backbone across the prevailing westerly winds and stretching over nearly 20° of latitude, New Zealand has a wide variety of climatic conditions. The drier areas are never very dry, especially when compared with Australia; and because no place in New Zealand is more than about 113km from the sea, the climate is consistently moist. So far, little mention has been made of New Zealand's nearest neighbour, Australia. Not surprisingly, a substantial influence can be seen in our flora with some two hundred species in common. Many of these plants have very small seeds capable of being wind-borne. There are a substantial number of genera in common, many of which have numerous New Zealand species. What is surprising is the lack of New Zealand representatives of such typically Australian plants as *Eucalyptus, Acacia, Casuarina, Banksia,* and *Grevillea.* Fossil pollen of some of these has been found in New Zealand. Therefore, the genera have been here in the past but, for unknown reasons, have died out.

A feature which is characteristic of the New Zealand flora is the number of genera which extend beyond New Zealand but which have the largest number of species here—*Uncinia, Coprosma, Epilobium, Myosotis, Dracophyllum, Aciphylla, Acaena, Hebe* and *Celmisia.* All these consist of closely related species which are difficult to distinguish. The similarities these species share may be a result of recent rapid evolution and diversification in response to a wide range of habitats available, and these plants are probably still adapting. A number of other genera, such as *Hebe* and *Olearia*, are well-represented in New Zealand and to these can be added endemic genera which have close relatives here or elsewhere. About eight percent of the flora, including more than forty genera, is endemic, giving the New Zealand scenery its typical character.

A dense, low mat or cushion is also characteristic of a number of New Zealand plants belonging to various families. This growth form occurs on shingle beaches, river gravels, bogs and mountain slopes. Many are shrubs in which the branches are greatly reduced and the terminal tufts of leaves are closely packed to form a surface of uniform height and density. This habit may be accompanied by hairiness or woolliness—an efficient protection against the drying effects of heat or cold.

Freycinetia, a pandanus-like epiphyte commonly covers the trunks and branches of forest trees.

Fiordland high-country herbfield, showing mountain daisies *(Celmisia)* in bloom, and hebe.

Another characteristic occurrence is the densely intertwined spreading habit in a considerable number of shrub species which, although belonging to widely differing genera, may be very difficult to tell apart in the field. A number of trees also pass through a juvenile phase in which growth and leaf shape are markedly different from that of the mature tree.

A group of plants, perhaps twenty-five species belonging to the families Ranunculaceae, Umbelliferae, Lobeliaceae, Compositae, Campanulaceae, Cruciferae and Caryophyllaceae, have become adapted to life on the steep, mobile scree slopes of the South Island mountains. On such inhospitable shingle screes these plants put down extensive rooting systems that draw moisture from the deeper stable levels and secure them from the effects of frost heave and the sliding scree surface. A low, summer-green rosette of succulent, glaucous, often finely-cut foliage is also characteristic of these plants.

In the high country above 1000m between the tree-line and the snow-line, one or more species of tall snow-tussock often up to 1m tall may be dominant. They belong to the genus *Chionochloa* and, at the lower levels of the alpine zone, may constitute a mixed snow tussock-scrub or snow tussock-herbfield association. In the mixed snow tussock-scrub association, which usually lies within the first 100m above the tree line, shrubs of *Dracophyllum, Coprosma, Hebe, Olearia* species, snow totara (*Podocarpus nivalis*) and mountain celery pine (*Phyllocladus alpinus*), as well as *Aciphylla* and mountain flax, may be present with smaller herbs and shrubs. Snow tussock-herbfield, an upward extension of the snow tussock-scrub, contains many of the large and conspicuous herbs—mountain daisies (*Celmisia* spp.), gentians, buttercups, ourisias and astelias.

The continued burning of high altitude snow tussock and heavy browsing by merino sheep and red deer has resulted in erosion, sometimes on a massive scale, particularly on the drier South Island mountains. In some areas also, unpalatable native species have increased to the extent that snow tussocks have been superceded by an induced vegetation of cotton daisy (*Celmisia spectabilis* or *C. coriacea*), golden spaniard (*Aciphylla aurea*), alpine fescue tussock (*Festuca novae-zelandiae*) and bristle tussock (*Notodanthonia setifolia*).

In the rain-shadow area to the east of the high South Island mountains where summer precipitation tends to be low, there is a relative lack of forest. Here are the grassland areas of New Zealand, the areas on which the pastoral economy of the country was built. The predominant growth form is the tussock tufts, mainly *Festuca* and *Poa* species interspersed with small herbs. To increase palatibility, the tussock was burnt so that stock could feed on the softer, green new growth, and with repeated burnings the tussock lost its vigour. By sowing more palatable species, the native grasses were gradually replaced until much of New Zealand's low tussock grassland has become an even lush green.

New Zealand forests are usually made up of many different species growing together. There is not the uniformity, or monotony which is to be found in most temperate areas and, in this respect, it resembles a tropical rainforest. A particular species or genus may predominate but not, as a rule, to the exclusion of other tree species. There are frequently layers of canopy within the forest, each layer made up of different groups of species having light or shade tolerances which enable them to fill a niche not only on a horizontal plain but also on a vertical elevation.

A very conspicuous feature of the rainforest is the abundance of epiphytes, plants which grow attached to, but not parasitic on, the larger plants. Trunks and branches are frequently covered with 'perching lilies' (*Astelia, Collospermum*), the pandanus-like *Freycinetia,* orchids, ferns, mosses and liverworts, softening the outlines and adding to the variety.

The southern beeches, of which there are four endemic New Zealand species, form forests of uniform aspect although all species may be found as an important component of mixed podocarp-beech forest. Mountain beech, *(Nothofagus solandri* var. *cliffortioides)* and silver beech (*N. menziesii*) are a conspicuous feature of the alpine landscape. They form a dense dark green forest of evergreen trees of uniform height with a sharply defined tree line at about 1450m in the North Island, descending to 900m in the Fiordland mountains. As silver beech has a higher moisture requirement than mountain beech there is often a dense growth of filmy ferns, bryophytes and lichens on the trunks and forest floor. Relatively few tree and shrub-species are present as an understorey in pure beech forests, their place being taken by beech saplings. Scarlet-flowered mistletoes are a feature of these forests. In lowland and montane areas, red beech (*N. fusca*), black beech (*N. solandri* var. *solandri*) and hard beech (*N. truncata*) are important forest trees. In the south of the South Island only silver beech is present at sea level at the limit of its range. Beech species are absent on Stewart Island.

The subject of forests cannot be left without reference to the enormous man-made forests that were planted after World War I. These forests of radiata pine are particularly conspicuous in the central North Island on volcanic land where deep layers of pumice buried the original forest in prehistoric times. Large forests of exotic conifers are also a conspicuous feature in Canterbury, Nelson and Otago. As well as *Pinus radiata,* Corsican pine (*P. nigra*) and Douglas fir (*Pseudotsuga menziesii*) are widely planted, while Lodgepole pine (*P. contorta*) has shown a remarkable capacity to invade the red tussock grasslands on the eastern flanks of Mt. Ruapehu to a height of 1800m—well above the natural tree-line. In this area some measure of control has been achieved, but Lodgepole pine is one of the exotic species being tried to halt severe erosion in South Island mountain localities where the original plant cover has been destroyed by burning and overgrazing.

With a history of European settlement of little more than 150 years, immense changes have been wrought on the original vegetation, resulting from the destruction of forest and grassland for farming and grazing, the draining of swamps and the reclamation of inlets and harbours. Now, an adventive flora of at least five hundred fully naturalized species, the result of the deliberate or accidental introduction of alien plants, has resulted in a lowland flora of great diversity. A century's management of pasture, planting of hedges, gardens, orchards, and shelter belts has completely altered the appearance of the land. Although many native plants make up part of this new flora, it is only in the more remote areas of forest, swamp, coast and mountain that the indigenous vegetation remains in a relatively undisturbed state.

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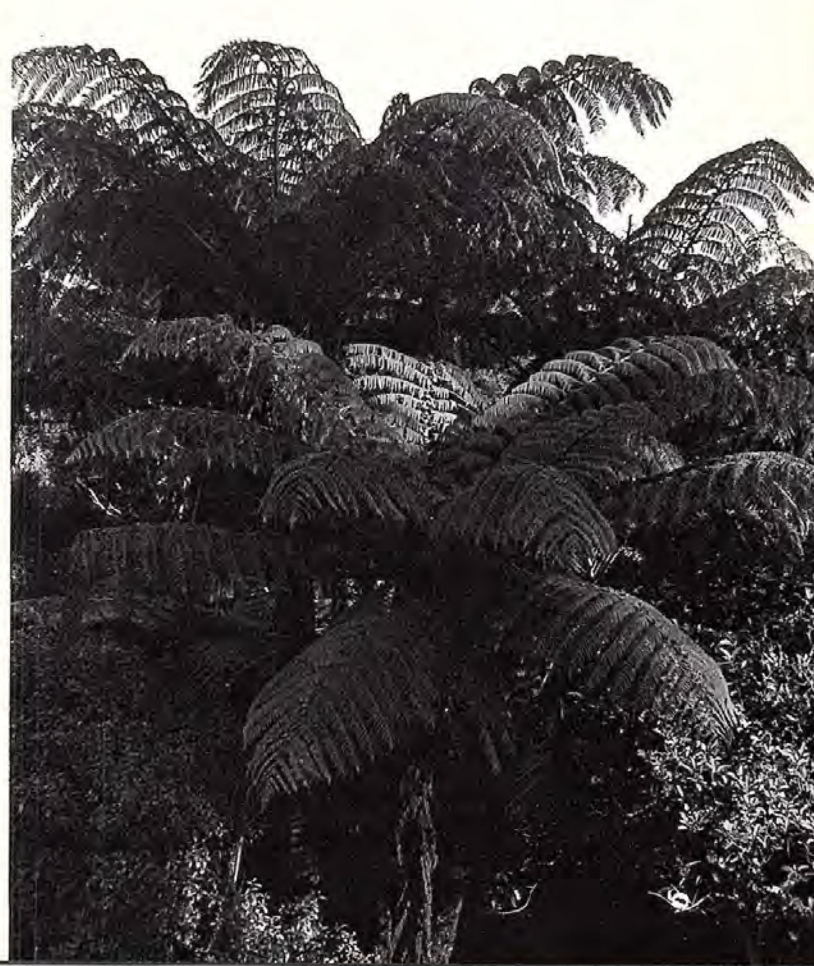


Fern trees or Pongas as the Maoris call them are a characteristic of the New Zealand bush.

ARCHAIC ELEMENTS AND A HOST OF IMMIGRANTS

BY IAN G. CROOK

New Zealand has few amphibians and terrestrial reptiles—three native and two introduced species of frogs, the tuatara (a lizard-like reptile) and some twenty-nine species of lizards (eighteen skinks and eleven geckos). However, the very existence of our native frogs (*Leiopelma* spp.) and the equally ancient tuatara make up for what we lack in diversity of species and ensure that New Zealand is prominently displayed on every herpetologist's map of the world.

The tuatara and the native frogs owe their fame to their ancient origins, and the fact of their survival to the geological history of New Zealand. To begin with, during the Cretaceous period (about a hundred million years ago), when Lepidosaurs like the tuatara were widespread and probably common, what is now New Zealand was connected to the great southern land mass of the time—Gondwanaland. The tuatara probably arrived by crossing the land bridge between the two, and this land connection would have been even more important to its contemporaries, the native frogs. Although it is conceivable, but unlikely, that the tuatara could have arrived in New Zealand by 'rafting' across open ocean, the frogs could certainly not have done so. Frogs generally cannot survive exposure to sea water, which explains their natural absence from truly oceanic islands; the natural occurrence of frogs in New Zealand was actually put forward as evidence of some past land connection by Charles Darwin in *On the Origin of Species.*

Leiopelma hochstetteri, one of the three native species of frog.

Gordon Grigg

Because of their origins and many primitive features, it is fitting that both the tuatara and the *Leiopelma* frogs should be regarded as part of the archaic element of our fauna, but a factor of importance second only to these is that they have managed to survive here while becoming extinct in all other parts of the world. The tuatara is the sole remaining member of an entire order of reptiles (the Rhynchocephalia) which otherwise disappeared by end of the Cretaceous—about 70 million years ago. The native frogs share the sub-Order Amphicoela, regarded as the most 'primitive' group of frogs in the world, with only one close relative, *Ascaphus truei*, from North America. (The relationship between *Ascaphus* and *Leiopelma* rests on certain anatomical features. In some other respects the two genera are as widely different as they are geographically separated, and the present classification could as easily represent an artefact of taxonomy as an indication of true relationship).

The survival of both tuatara and frogs in New Zealand can undoubtedly be attributed to the disappearance of the very land connection that facilitated their arrival. Since that time these islands have been quite isolated. New Zealand has become a fastness against the otherwise relentless march of evolution. Groups that have evolved since the end of the Cretaceous were unable to spread to New Zealand, which explains the absence of snakes and the natural absence of any terrestrial mammals apart from two species of bats. Since human settlement, of course, many other mammal species have been introduced, both intentionally and accidentally, and that the tuatara may owe its survival, at least in part, to this natural absence of mammals.

The isolation of New Zealand has also been the most important single factor in shaping our lizard fauna. Lizards, especially small ones and those found in coastal, estuarine and riverine habitats, may find themselves taking long sea voyages on rafts of driftwood and unintentionally landing upon foreign shores. All our lizards are thought to have arrived in this manner, which helps explain the paucity of species represented here.

IAN CROOK, a scientist for NZ Wildlife Service, is particularly involved with surveys of native fauna in forest areas and on offshore islands. He has also done intensive research on the natural history of the tuatara and native frogs.

The Tuatara, *Sphenodon punctatus,* the only surviving rhynchocephalian reptile.

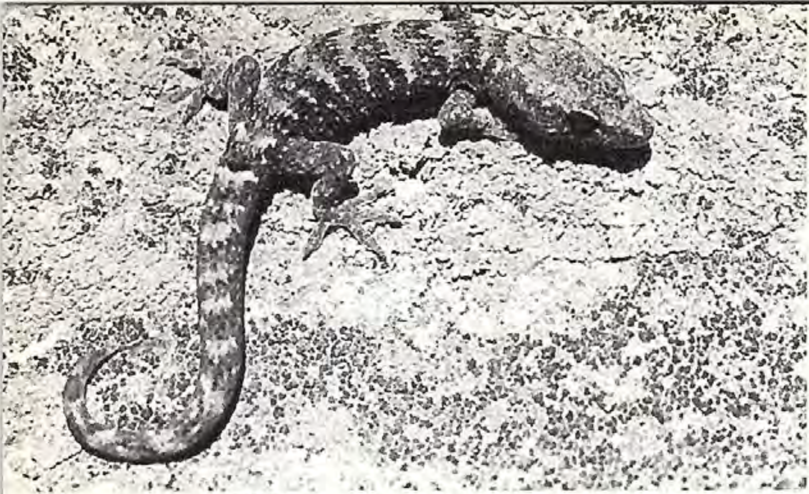
The probability of these chance journeys being successful must be low; the great majority of such migrants would die enroute, and of the remainder, a substantial proportion would fail in the colonisation of their new and alien habitats. Herpetologists consider that all of New Zealand's lizards are the product of only a handful of successful invasions.

One of these involved the geckos, all of which are members of the Carphodactylini, and the animals involved probably came from New Caledonia. However, there are clear affinities between the New Zealand and New Caledonian geckos, all the New Zealand species are endemic. They also have a number of primitive features and lack some specialised ones. For example, the arboreal representatives of the genera *Naultinus* and *Heterophilus* in New Zealand do not possess subcaudal lamellae (thin, scale-like structures under the tail)—a common feature in other arboreal geckos with prehensile tails. Similarly, New Zealand species such as *Hoplodactylus granulatus,* which spends its time clinging to the trunks and limbs of trees, lack the lateral fringes of skin found in many species with similar habits in other parts of the world. On the other hand, all the New Zealand geckos give birth to live young (and lack specialised egg teeth), a feature which separates them from all other geckos. (Strictly, the New Zealand geckos are ovoviviparous: the foetus develops inside the oviduct from a fully yolked egg, but placental attachment does occur.)

One explanation of this particular feature is that it is a recent adaptation which enabled our geckos to survive the Pleistocene ice ages, and in this connection, it is interesting to note that all but one of the New Zealand skinks are also live-bearing. The one that is not (*Leiolopisma suteri*) is found north of latitude 37°S and is probably a post-Pleistocene arrival.

The tuatara is also an exception to this rule, and it is found as far south as latitude 40°40'S, in Cook Strait. In November the tuatara lays clutches of eight to twelve eggs in shallow pits or short, blind tunnels dug in sandy ground; in this southern part of the animal's range the eggs take more than a year to hatch, the young appearing in January or February. The long incubation is partly the result of a variable period of embryonic hibernation which occurs during winter, and this is probably the reason for reported variations in the duration of incubation. The literature records incubation periods of 11 and 13 months; I looked after an egg which hatched only nine months after it was laid. This particular animal developed normally and survived to be released on Stephens Island, Cook Strait, some six months later.

This long period of incubation could be more than just a curiosity in the natural history of the tuatara. The egg of a reptile, laid and then abandoned by the parent to fend for itself, is very vulnerable to predation—certainly a weak spot in the life cycle of any species. This problem has been variously countered in different species by nest concealment and by abbreviation, or even abandonment, of a period of external development of the egg by various forms of viviparity. The tuatara, however, shows no such adaptation, and in this context it is interesting to note that the tuatara is apparently unable to survive in the presence of any species of rat which now occurs in the New Zealand region. The tuatara is restricted to some thirty islands off the northeast coast of the North Island and in Cook Strait, and no island in these regions to which rats have



Gordon Grigg

Hoplodactylus pacificus, one of New Zealand's endemic geckos.

been introduced (principally the Polynesian rat, *Rattus exulans*) also supports a self-maintaining population of tuataras. On some rat-inhabited islands tuataras have actually become extinct in recent times, on others tuataras are rare and on the verge of extinction and on the remainder they are no longer breeding.

This inability to survive in the presence of animals as opportunistic and invasive as rats may have enormous significance to the long-term survival of the tuatara (and what is long-term to a species that has already lived at least 120 million years?), but the most fascinating aspect of the tuatara's life history is its relationship with the large populations of seabirds—petrels and shearwaters—which share its island habitats. These birds nest in burrows which vary from simple tunnels about a metre in length with rounded chambers at their blind ends to enormous complexes of tunnels and chambers arranged in several levels. Each breeding pair of birds has a burrow, or at least a chamber, and the populations are so large on some islands that the ground becomes riddled with burrows. In some areas, it is quite impossible to move around without breaking through the crust of earth into the maze below.

The birds share their burrows with the tuatara population (though tuataras do sometimes dig their own) and, at first sight, the two co-exist fairly peacefully. However, the tuatara is a predator of petrels, finding no difficulty in killing the adults and chicks and eating the eggs, particularly of the smaller species. Some of the earliest observations of tuataras in their natural habitats refer both to tuataras attacking petrels and to the petrels stoutly defending themselves. Many tuataras, particularly older individuals, bear scars about the head and neck, probably as a result of petrels pecking them on the top of the head.

Thus, the relationship between petrels and tuataras is not altogether one of peaceful burrow-sharing, but it does not end with predation and defense either. The petrels feed at sea exclusively and bring ashore and leave behind copious amounts of guano, rich in mineral nutrients and organic matter. They effectively fertilise the soil and, at the same time, cultivate it with their burrowing activity to produce a fine and friable soil. This appears to be an ideal habitat for large populations of invertebrates and small lizards, both of which occur in super-abundance on the petrel/tuatara islands. And both invertebrates and small lizards serve as tuatara food between courses of birds and bird eggs.

So the life of the tuatara is inextricably entwined with that of breeding populations of petrels, and though the importance of this relationship in the survival of the tuatara has not been clarified, it is interesting to observe that self-maintaining populations of tuataras are today, as clearly restricted to islands with large populations of the smaller petrel species as they are absent from those infested with rats. To go further than this would be premature, not least because large populations of the smaller petrel species are also restricted to rat-free islands; even the Polynesian rat has been shown to be a predator of these birds.

Gordon Grigg

Probably the most famous of the tuatara/petrel islands is Stephens Island in Cook Strait, which is also one of only two places where the rarest of our three native frogs (*Leiopelma hamiltoni*) is found. As a frog habitat though, it appears to leave a great deal to be desired. The frogs are found only in a small rock tumble some twenty metres square near the summit of the island, 300m above sea level, and there is no pool or stream, nor any permanent standing water, anywhere on the island. In addition to this, the island, particularly the summit, is regularly battered by gales (for which Cook Strait is world famous), and salt-burnt and wind-cut vegetation is a common sight. Finally, the exposure of the frog habitat was made almost complete sometime between 1915 and 1927 when the original forest cover was totally destroyed. Not unnaturally, the frogs were considered extinct for many years after this, but they were rediscovered, hopping around the surface of their rock bank on a warm, misty night in the early 1950s.

Their survival during this period can be attributed to a series of fortunate chances. To begin, the rock bank is not totally exposed but is set in a little hollow below the summit ridge of the island. Although no accurate measurement of wind run have been made, the hollow is obviously a relatively calm place. Secondly, the climate of the summit is not as harsh as it would appear to be. Data on temperature, relative humidity and rainfall have been collected over a twelve month period, and comparative data from the frogs' second habitat in tall forest just above sea level on another island a few kilometres south of Stephens, shows that the microclimate of the surface of the rock bank closely resembles that of the forest floor. The moistness of the summit on Stephens is largely the result of cloud which envelopes the island during northwesterly winds which prevail in this area. The final factor seems to be the depth of the broken rocks themselves. This layer goes down more than a metre in some places and would help to trap a layer of moist, still air that would aid the survival of frogs during exceptionally dry conditions.

Be that as it may, *Leiopelma hamiltoni* would not be able to survive on Stephens Island (or in its other habitat—Maud Island—which also lacks free-standing water) were it not for intracapsular development; none of the three *Leiopelma* species has a free-swimming tadpole stage. Reduced webbing between their hind toes attests to their adaptation to relatively dry habitats. However, while such an adaptation would suggest the frogs could survive in a wide range of habitats, all three species are, in fact, more-or-less restricted in their distribution, and the reasons for the restrictions remain obscure.

Both the tuatara and native frogs have other remarkable and unique features, but in an article of this length it is possible to give only tantalising glimpses. However, a great deal of research effort in New Zealand and in other countries has been and is being focussed on them. Most work on the physiology, anatomy and morphology is done outside New Zealand; research here is concentrated on the ecology and natural history. Much of this is being done by the New Zealand Wildlife Service, and a comprehensive survey of all the known tuatara populations and all the known and likely tuatara islands has recently been completed by the research and field staff of that organisation. This is the work that has established the links between the distribution of tuatara, petrels and rats. The Wildlife Service is also pursuing a more intensive study of tuatara petrel relationships on Stephens Island. The visits this entails also provides opportunities to study the frogs and, in addition to microclimate studies, the population and its patterns of activity is being investigated. Colour photographs have shown that individual frogs have unique and apparently permanent markings of brown on their background colour of gold, and over 100 individuals have now been identified.

Naultinus elegans, a bright green native gecko, well camouflaged in vegetation on Stephens Island.

Work on the breeding behaviour and physiology of *Leiopelma hamiltoni* is also being carried on at the Victoria University of Wellington, and scientists based at the Ecology Division of the Department of Scientific and Industrial Research are working on lizard distribution, biogeography and ecology. Hopefully, this research effort together with a vigorous management policy based on legislation protecting both the animals and their habitats, attempts to rehabilitate these habitats where necessary and protect the islands from further invasion by rats, will prove sufficient to ensure the continued survival of tuatara, frogs and lizards alike.

Gordon Grieg

The rock bank habitat of *Leiopelma hamiltoni,* on the summit of Stephens Island.

IN THE FLIGHTLESS TRADITION

BY G.R. WILLIAMS

New Zealand has been an oceanic island or group of islands since it first became effectively isolated from the great southern continent of Gondwanaland during the upper Cretaceous period about 80 million years ago. This early isolation, plus the fact that the New Zealand archipelago lies to the east (2000km) of the Australian continent and in the path of the West Wind Drift, explains much of our earlier natural history. Add the effects of volcanism and glaciation, the first arrival of man about 1500 years ago and settlement by Europeans about 150 years ago, and we have most of the fundamental information which would allow us to understand the biological happenings of not only the last two million years, but especially the last 10,000 when the rising seas of the last interglacial shaped and divided New Zealand into the three main islands (North, South and Stewart) we know today.

Three convenient divisions may be made of New Zealand's avifaunal history—fossil, subfossil and recent—roughly corresponding with the pre-human, Polynesian and European periods. Relics of the fossil avifauna are scarce and are mainly of seabirds. The fauna of the subfossil period is richer and is notable for the remains of an order of birds found nowhere else, the Dinornithiformes or moas. Apart from these—whose ancestors, along with those of the apparently equally ancient and endemic Apterygiformes or kiwis, are generally regarded as having reached New Zealand on foot during the Cretaceous—the Australian element in the avifauna was already predominant, thanks to the West Wind Drift.

According to the most up-to-date checklist, New Zealand has 285 species of birds ranging from those almost as ancient as the moas and kiwis such as the New Zealand wrens, thrushes and wattlebirds whose origins are obscure, to a whole variety of others, obviously of Australian origin. Some of these birds have been here long enough to become clearly different (kakapo, takahe, the local honeyeaters, the blue-duck, etc.). Others, subspecies, are very similar to their Australian counterparts (shoveler, fantail, white-throated shag, kingfisher, etc.). Several colonists have established themselves during the last hundred years (silvereye, white-faced heron, black-fronted dotterel, welcome swallow, etc.). New Zealand is also home to ninety-three non-breeding migrants and stragglers. In addition, thirty-four species have been introduced and established by man (although one of these, the red vented bulbul, is almost certainly extinct). Eighteen of these species have come from Europe, mainly Britain, four species from North America, five species from Asia and seven from Australia. The following table gives the distribution of the New Zealand species according to major habitat types.

O.V. Merton, NZ Wildlife Service

The Kakapo *(Sprigops habroptilus)*, New Zealand's largest parrot, was once widespread but now occurs only in very small numbers in a few valleys in Fiordland.

Antarctic	9	
Pelagic	48	
Exposed coasts	35	
Freshwaters and their margins (includes estuaries)	47	(43 native, 4 introduced)
Lowland grasslands, pastures, etc.	28	(8 native, 20 introduced)
Lowland forest and scrub	46	(36 native, 10 introduced)
Subalpine scrub, grasslands, etc.	3	

One unusual characteristic of the New Zealand bird fauna is the high proportion of species that are either flightless or have weak powers of flight. Of the fifty terrestrial natives, fourteen are in this category as are two races of one of the eight species of waterfowl. The absence of mammalian predators until the arrival of man and his introductions is generally regarded as the main reason for this situation. There is also a higher-than-usual incidence of melanism or dark colouration which may have had a high survival value under the ecological conditions of primitive New Zealand. A common characteristic of island organisms, giantism, is also evident—especially in the more ancient bird forms. Examples of this are the moas; the extinct goose, *Cnemiornis*; the near-flightless parrot, kakapo; and the rail, takahe.

Because of New Zealand's oceanic isolation and small size there are only two external migrants among the true land birds—the long-tailed and shining cuckoos which winter in a wide arc of islands just south of the equator. The rest are sea or shore birds, most of which are trans-equatorial migrants, some breeding in New Zealand, the rest in the arctic or sub-arctic. More interestingly, there is an east-west migration of a few birds breeding in New Zealand (the Australasian gannet, banded (i.e. double-banded) dotterel and the white-fronted tern). There is at present no clear evidence of a reverse situation.

Although New Zealand has been an archipelago for most of the last 80 million years, relatively little adaptive radiation has occurred beyond the subspecies level. The wattlebirds have differentiated into three genera each containing one species, the wrens into two genera, one genera having three species, the other having one. One genus of parakeet has four New Zealand species and the three species of kiwi occur within one genus. The three species of robin also occur within one genus. Island subspecies are common, those on North, South and Stewart Islands being less than 10,000 years old (the age of formation of Cook and Foveaux Straits).

The moas were, apparently, a notable exception.

R. Morris, NZ Wildlife Service

The Takahe *(Notornis mantelli)* had been considered extinct for fifty years before its rediscovery in the southwest of the South Island in 1948.

Their two families comprise seven genera and twenty-four species but like the elephant birds of Madagascar the moas are gone, victims of the hazards posed by predatory stone age man and by being insular species. The last of the great moas succumbed about 1700 AD; the smallest (one of the so-called bush moas) may have lingered on in the southwest of the South Island until the European era—perhaps until as recently as about a century ago. Moa bones have been known to Europeans for almost 150 years and have been found abundantly (and as near-complete skeletons) in swamps, sandhills, caves, early Polynesian burial sites and kitchen middens. Eggs, feathers, dried tissues, nest sites, gizzard stones and even undigested food have aslo been found. With these remains and Maori legends, it has been possible to reconstruct not only the skeletons, but also much of the birds' appearance and life history. All species probably looked rather like stocky-legged, wingless and tail-less cassowaries—the largest, *Dinornis maximus*, standing about 3.5m and the smallest, *Megalapteryx,* about 1m. They were browsers and grazers (the local ecological equivalents in this regard of mammals elsewhere), the largest living in grasslands, the smallest in forests, some in both.

Kiwis, the ratite contemporaries of the moas, are still very much alive and not as rare as threatened with extinction as is generally believed. There are three

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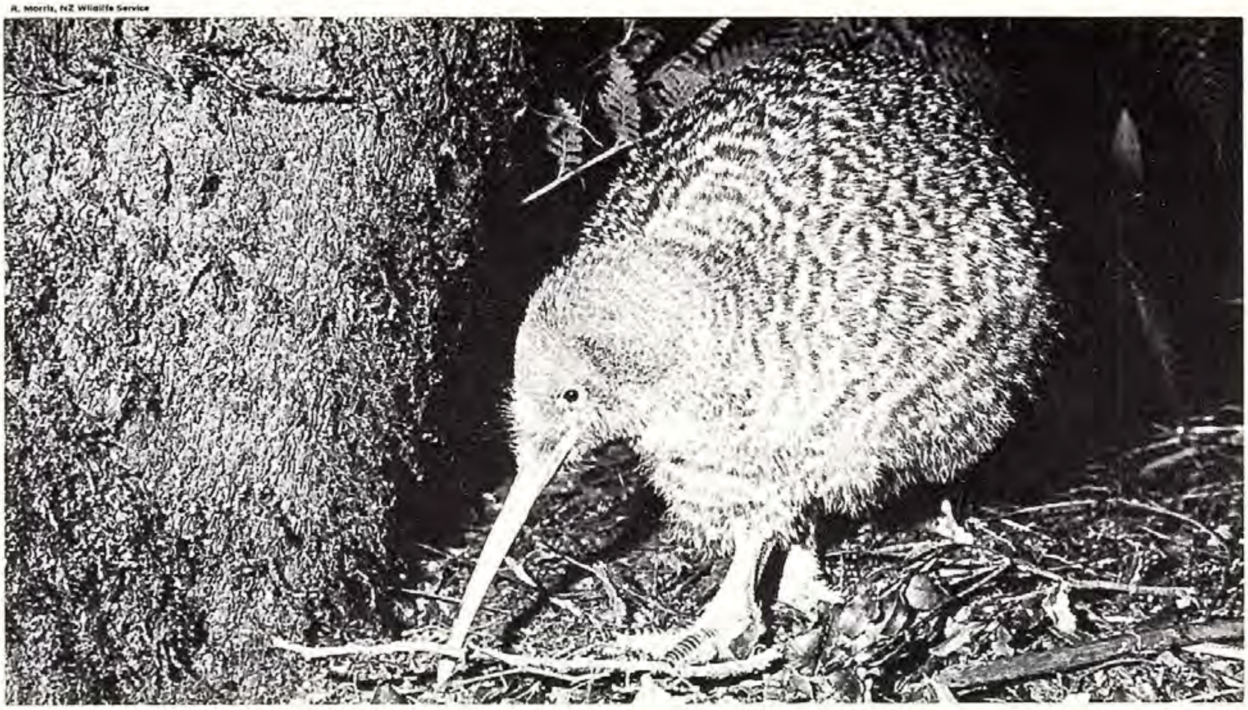
species: the brown or common kiwi (*Apteryx australis*) which occurs on all three main islands, each of which has its own subspecies; the little spotted kiwi (*A. oweni*) presumed extinct in the North Island but common on the West Coast of the South Island, and the great spotted kiwi (*A. haasti*) not known from the North Island but found on the west coast of the South Island, especially in its northern half. Subfossil remains of all three species and reports of the distribution of live birds before 1900 indicate that there has been a long-term trend for kiwis to disappear from the southern half of the North Island and the eastern half of the South Island. Distinctive features include a long and slightly curved bill with nostrils near the tip, a cone-shaped body (mainly because of the virtual absence of wings—they are reduced to appendages about the size of matchsticks) that tapers to a strong neck and small head, stout muscular legs, small eyes, large ear apertures and long bristle-like feathers about the face and base of the bill and no tail. Plumage is loose and hair-like. The largest kiwis, Stewart Island brown, are about as big as an Australorp hen; the smallest, the little spotted, about as big as a bantam. Females are about twenty percent heavier than males and have longer bills. Kiwis are primarily nocturnal birds of the indigenous rain forests though they may now be found in exotic forests and pastoral country. Their food, which is found mainly by smell, is made up of earthworms, leaves and berries, insects and snails. One or two eggs make up the clutch which is laid in a burrow and incubation, which is wholly taken over by the male after a few days, lasts for 11-12 weeks. The calls of the sexes are different: males utter a shrill prolonged whistle slightly ascending and descending (from which the bird's name is derived), females have a lower, hoarser cry.

The Great Spotted Kiwi, *(Apteryx haasti)* found on the west coast of the South Island.

R. Morris, NZ Wildlife Service



The wattlebird family comprises three species, each belonging to a different genus—the kokako (*Callaeas cinerea*), also commonly but wrongly called the 'native crow', the saddleback (*Philesturnus carunculatus*) and, most notable of all, the huia (*Heteralocha acutirostris*), officially regarded as having been extinct since 1908. There are North and South Island subspecies of kokako and saddleback, but the huia was apparently restricted to the North Island. Wattlebirds are forest-dwellers, ranging in size from that of a starling (the saddleback) to that of a little crow (the huia). Both species have fleshy orange lobes (except in the North Island kokako in which they are blue) at the corners of their mouths—hence the common name. Plumage is mainly black or dark grey. All three species have limited powers of flight but bound over the ground or through the trees with a monkey-like locomotion. The huia and saddleback are predominantly insectivorous, the kokako mainly vegetarian. Their songs are loud and characteristic, that of the kokako often mellow and bell-like. Two to three eggs make up the usual clutch.

The huia is, or was, remarkable for the great difference between the sexes in the size and shape of the bill—a difference far more extreme than that found in any other species of bird. The male's bill was stout, about 6cm long with a slight downward curve, the female's slender, about 8.5cm long and very strongly curved downward. As might be expected, each sex had different feeding habits. The male used his bill as a chisel to break up rotten wood and widen insect holes; the female used hers as a probe. Hence each could obtain food often inaccessible to the other.

Though the North Island kokako is erratically distributed, it is locally common and not in any immediate danger of extinction. On the other hand, the South Island subspecies is very rare and must be considered to be in a critical state. The two races of saddleback are now confined to a few small offshore islands (to some of which they have been successfully introduced by the New Zealand Wildlife Service) and are, at least temporarily, out of danger.

The takahe, the large flightless rail, (*Notornis mantelli*—a more colourful version of the eastern swamp hen or pukeko) had been considered extinct for fifty years before its rediscovery in the southwest of the South Island in 1948. Since then it has been intensively studied by scientists of the Wildlife Service and found to be almost entirely restricted to the subalpine meadows (on which it grazes) of one mountain range and to number perhaps 300. Although the average clutch size is about two eggs, seldom is more than one chick raised per pair and there have been clear indications recently of a decline in the population which may, however, be only temporary. Though a few birds have been kept successfully in captivity at the Wildlife Service's Native Bird Reserve at Mt. Bruce, it is only during the last three years that fertile eggs have been produced and only in the 1975/76 breeding season has a chick survived.

The kakapo, a nocturnal and almost flightless parrot, is perhaps New Zealand's most fascinating bird. Though, like most of the species we have been discussing, it was once widespread, it is now known to occur in very small numbers in only a few valleys in Fiordland not far from the last haunts of the takahe.

The moss-green and lemon-yellow kakapo is the largest of New Zealand's parrots (weighing about 2.5kg) and has an owl-like face, complete with long feathers like cats' whiskers at the base of the bill (no doubt with similar functions) and a very un-parrot-like medley of calls, the most characteristic of which is a deep and resonant booming which the birds utter from specially-constructed bowls which seem to be so made as to act as efficient sound reflectors. Booming is heard during the breeding season and is supposed to attract females, though recent observations have not detected any females. This is a strange and perhaps ominous sign; furthermore, of the nine kakapo captured over about as many years all have proved to be males. A solution to this mystery is hoped for soon as more birds are captured for transfer to a specially-chosen predator-free island. Kakapos are burrow-nesters and predominantly vegetarian.

The causes of the disappearance of various New Zealand birds appears to be complex. Man has obviously played at least some direct part over the last 1500 years; so, too, have the introduced carnivores (especially the ship rat). But some species still flourish in the midst of a variety of introduced mammalian predators. Perhaps, at least as far as some species are concerned insularity combined with such changes as may occur in climate, have also played an important part.


National Publicity Studios

This picture was reproduced in the 'Otaga Witness' in 1903. The reconstructed Moa was placed in a natural setting in the Dunedin Public Gardens.

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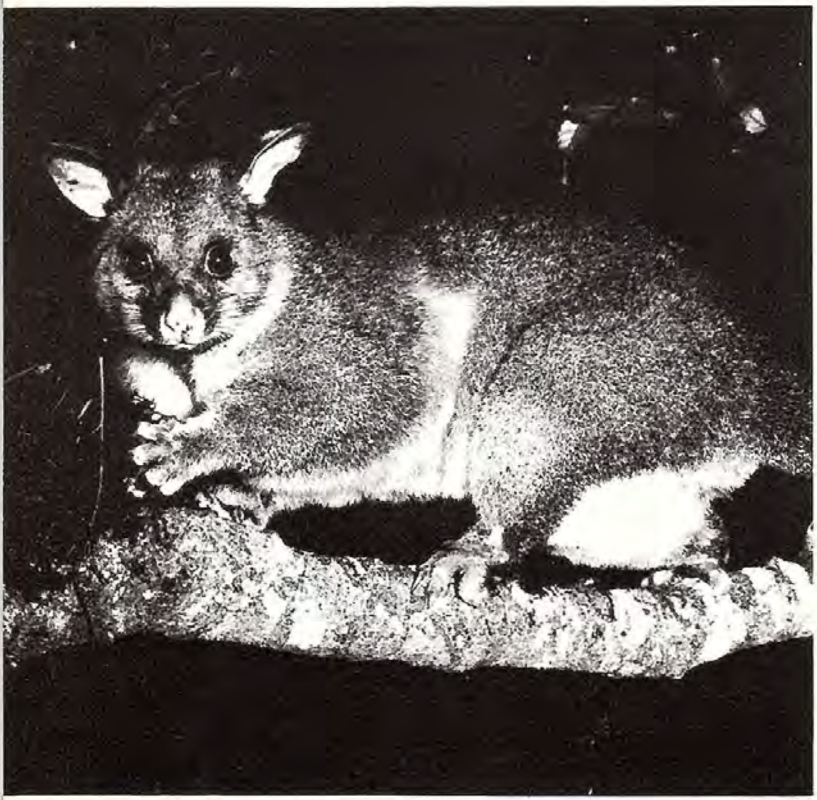
AN IMPORTED FAUNA

BY M.J. DANIEL



J.H. Johns

Opossum at the Orongorongo River Research Station; the animals are kept for research in breeding and gestation.

No other country more clearly demonstrates the ecological mistakes made by the introduction of exotic fauna than does New Zealand. Because of its long geographical isolation from other lands the endemic terrestrial mammal fauna of New Zealand consists solely of two species of bats. However, as if to make up for this paucity, New Zealand contains many archaic faunal elements whose origin can be traced back to the Cretaceous, some 70-80 million years ago, before New Zealand became separated from Gondwanaland. These include the tuatara (*Sphenodon punctatus*), the only surviving rhynchocephalian reptile, two endemic orders of ratite birds (the kiwis and extinct moas) and an endemic genus of primitive frogs (*Leiopelma*).

One of the two endemic bats is the short-tailed bat (*Mystacina tuberculata*) which, because it has no close relationship to other bats, is classified as the sole member of its own family, the Mystacinidae. The ancestors of this archaic bat may have reached New Zealand during the early or middle Tertiary 60 to 20 million years ago. This unique bat has structural adaptations which enable it to crawl with surprising agility on the ground and on branches and tree trunks without damaging its wings. Recent research has shown that as well as being insectivorous, the short-tailed bat also feeds on fruit and possibly on pollen and nectar, as do many Australian species of the Family Pteropodidae and several South and Central American species of the family Phyllostomatidae. The other New Zealand bat, the long-tailed bat (*Chalinolobus tuberculatus*), is solely an aerial insectivore and is closely related to other members of its genus in Australia. The ancestors of this bat probably reached New Zealand from Australia comparatively recently, during or following the Pleistocene. Undoubtedly other Australian and Pacific Island bats have been blown to New Zealand at different times in the past, but apparently none have become established or left a fossil record.

The first strictly terrestrial mammals to arrive in New Zealand were the Polynesians about 1000 years ago. These early voyagers brought with them dogs and Polynesian rats (*Rattus exulans*), also called *kiore* or Maori rats. The dogs were probably used for hunting moas and other flightless birds and for meat and the skins for clothing. Polynesian rats were a favoured food of the Maori and in time the rats spread over the forests of both North and South Islands and were taken, perhaps intentionally, to many off-shore islands

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An adult male wallaby, *Macropus rufogrisea*, in the Hunters Hills, Waimate.

where they are still found today. In years of heavy seedfall of beech (*Nothofagus*) these rats reached plague numbers and thousands of them would have been caught in ingenious pitfall traps and snares made of flax and vines, and eaten.

The first recorded Europeans to visit New Zealand were the Dutchman Abel Tasman and his crew of the ships 'Heemskerck' and 'Zeehaen' in 1642. However, because of hostilities with the Maoris, Tasman didn't land or, as far as we know, add any mammals such as ship rats (*Rattus rattus*) to the New Zealand fauna. The real discovery and initial exploration was made by Captain James Cook in the 'Endeavour' in 1769. His second and third visits in 1774 and 1779 marked the beginning of the next period of exotic mammal introduction. Having noticed on his first visit the lack of mammals for food, he brought goats and pigs for the local Maoris and accidentally introduced ship rats and probably mice as well. The sealers and whalers who followed in the next few years also introduced pigs and goats to many settlements round the coast and on off-shore and sub-antarctic islands as food for castaways. In addition they brought in Norway rats (*R. norvegious*), ship rats, mice, cats and dogs.

Following intensive European settlement in the early 1800's there was a natural desire among the early settlers for the familiar mammals, birds, fish and plants of their homelands. Numerous acclimatisation societies were formed, as they were in Australia, and with great enthusiasm but apparently little forethought of the consequences, an incredible variety of mammals, birds and plants was brought into the country. With hindsight it is easy to ridicule some of the seemingly indiscriminate introductions, but while the early settlers were creating an agricultural environment literally from the ashes of dense rain forest, this must have seemed a praiseworthy aim in a land of mammals and familiar birds.

The first of many introductions of Australian brush-tailed possums (*Trichosurus vulpecula*) (in New Zealand called opossums) for their valuable fur, was in 1837 in Southland. Today the possum ranks in the top three most serious mammal pests—with rabbits and red deer. Only recently, possums have been implicated in the spread of bovine tuberculosis which is causing considerable concern to farmers in some areas. Domestic rabbits were introduced for meat from about 1838 onwards but apparently could not survive in the wild, however the many introductions of the wild rabbit

J.L. Kendrick

J.L. Kendrick

The short-tailed bat *(Mystacina tuberculata)* is able to crawl with surprising agility on the ground and on branches and tree trunks without damaging its wings.

The long-tailed bat *(Chalinolobus tuberculatus)* is closely related to other members of its genus in Australia.

(*Oryctolagus cuniculus*) from 1864-68 were alarmingly successful, as in Australia, and within a few years farmers in both North and South Island were being driven off their farms by swarms of rabbits.

Red deer (*Cervus elaphus*) and hares (*Lepus europaeus*) were first brought in in 1851. Many hundreds of subsequent red deer liberations were made and today they are the most widespread of all the deer species. The first hares jumped from a ship's porthole and swam ashore in Lyttleton harbour. They are now found in all suitable habitats in both North and South Islands. Fallow deer (*Dama dama*) were introduced in 1864 and sambar deer (*Cervus unicolor*), a large species from India and Ceylon, in 1875. Hedgehogs (*Erinaceus europaeus*) were first released in 1870 to control garden pests and are now much more common in New Zealand than in Britain.

The dramatic spread of rabbits, in spite of constant trapping, shooting, poisoning and hundreds of miles of rabbit-proof fences, led to the widespread introduction in the 1880s of three natural mustelid predators from Britain. These were the ferret (*Mustela putorius*), stoat (*M. erminea*) and weasel (*M. nivalis*). The department of Agriculture bred thousands of ferrets and stoats

J.H. Johns

Red Deer at mouth of Murphy's Creek Havelock branch of Rangitata River.

Chamois on the lower slopes of Malte Brun Range, Southern Alps.

which were then released on rabbit-infested farms all over the country. The value of these predators in controlling rabbits is still debated. Although rabbits may have declined in some areas due to heavy predation, it is a fact that in most areas they did not stop the rabbits reaching plague proportions. It is only in the last twenty years or so that rabbits have been dramatically reduced to low levels in most areas by intensive poisoning operations costing millions of dollars and by wise farm management. The major ecological damage done by these predators in about a hundred years is the serious decline in the bird fauna of New Zealand although in this, the losses caused by the mustelids are difficult to separate from those caused by the rats. Several species of endemic birds are now extinct or very rare on North and South Islands and others are only found on a few off-shore islands that are free of mustelids and ship and Norway rats.

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In 1870, a viverrid predator was introduced to help control both rabbits and rats. This was the Indian grey mongoose (*Herpestes edwardsi*). Fifteen of these were liberated on a farm in Southland following reports of another species of mongoose being successfully liberated in the West Indies and in Hawaii to control rats on sugar cane plantations. Luckily the grey mongoose did not become established, although one was caught alive in a rabbit trap the following year and exhibited in a hotel. The destrictiveness of the mongoose in Hawaii and the West Indies to the endemic bird fauna is similar to that in New Zealand with ferrets, stoats and weasels.

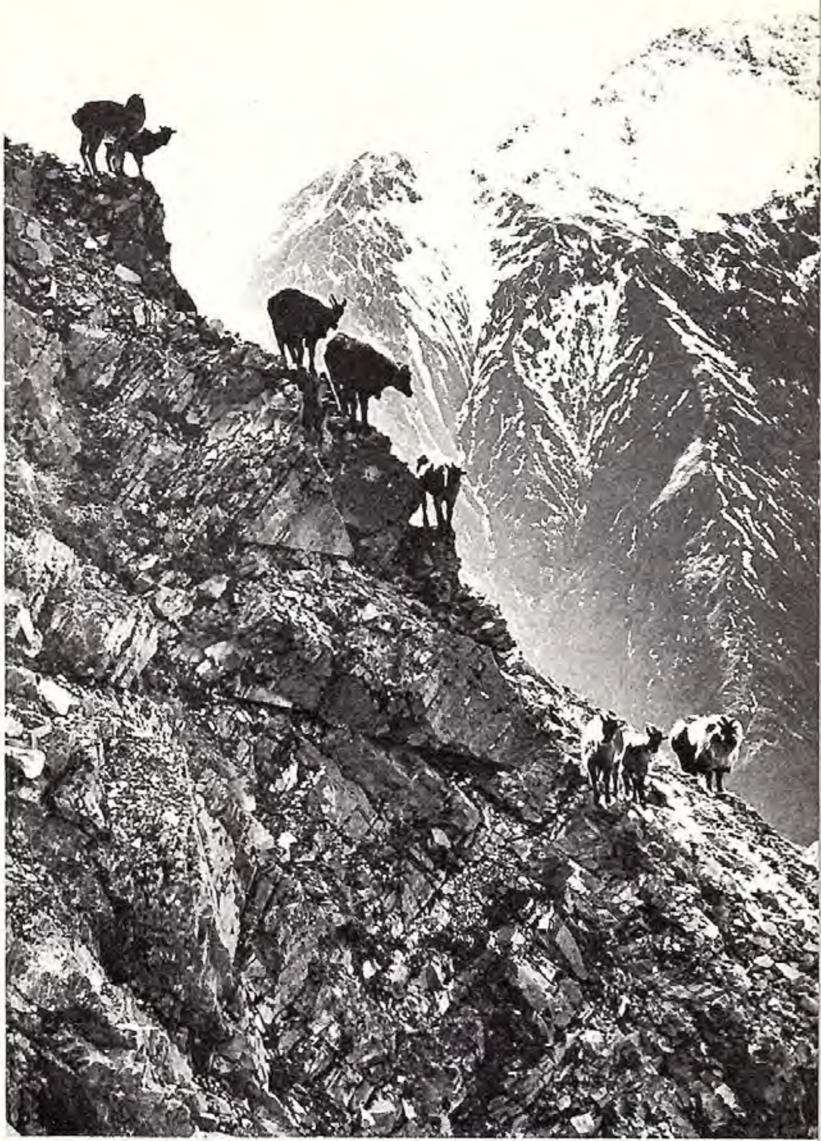
The introduction of foxes (*Vulpes vulpes*) was wisely prohibited by law in 1867 about the time they were liberated in Australia for sporting purposes. One authority in New Zealand even suggested introducing arctic foxes because their furs were so valuable, but this suggestion was also rejected.

Although many of the early introductions were from Britain, the fascinating and diverse mammal fauna of Australia proved irresistible to some of the early settlers. In 1876 Governor Sir George Grey, perhaps impressed with the success of the brush-tailed possum on North and South Islands, introduced five species of wallabies from Australia to Kawau Island in the Hauraki Gulf near Auckland. He brought in other remarkable mammals to Kawau Island including tree-kangaroos, zebra and gnu but these soon died out .eaving the wallabies, of which there are at least four species present today. These are vigorously controlled by shooting because of bark-biting damage to young pine trees. Recently one of these wallabies was identified as the parma or white-throated wallaby (*Macropus parma*) which was then believed extinct in its native Australia. This rather unusual situation of a species believed extinct in its native land being shot on sight on a small New Zealand island led to the live-trapping of parma wallabies on Kawau from where they were sent to zoos all round the world to ensure their survival. Since then however, a few parma wallabies have been found in their original Australian habitat. A sixth species of wallaby, the red-necked wallaby (*Macropus rufogriseus*) is now widespread over the Hunter Hills in the South Island and the Tammar wallaby (*M. eugenii*), one of the species on Kawau Island, is also found in forest and scrub around Rotorua in the North Island.

In the first decade of this century, many more species of game mammals were introduced to add to the red deer, fallow and samber deer already present. The aim of these introductions was apparently to fill the forests and alpine lands with the best selection of game animals that could be found anywhere in the world. These new species included wapiti (*C. elephus canadensis*), moose (*Alces alces*), Virginia deer (*Odocoileus virginianus*) and mule deer (*O. hemionus*) from North America; Himalayan tahr (*Hemitragus jemlahicus*) and spotted deer (*Axis axis*) from India; chamois (*Rupicapra rupicapra*) from Austria; Japanese deer (*Cervus nippon*) from Japan and Javan rusa deer (*C. timorensis*) from New Caledonia. Of this exotic collection of big game animals, only the mule deer and spotted deer failed to establish. The others multiplied and increased their range dramatically, with the exception of moose and rusa deer which remained near their liberation points. Apart from the moose, all the introduced ungulates are actively controlled by hunting where high numbers threaten regeneration of exotic pine forests, watershed protection forests and erosion-prone alpine tussock grasslands.

By about 1915-20 the flood of introductions ceased as more people became aware of the extent of the damage being caused—particularly be rabbits, the mustelids, the many species of deer and other ungulates and the brush-tailed possum—to agricultural land, native bird fauna and the forest and alpine flora.

J.H. Johns



Gordon Roberts

Thar in upper Carney's Creek, Rangitata River.

In spite of the millions of dollars being spent each year to control many of the mammal species regarded as noxious pests, it is unlikely that any of the thirty-three species established in the wild will be completely eliminated. Some such as the few remaining moose in Fiordland National Park may die out, but the others must now be regarded as established members, however unwelcome, of the New Zealand fauna.

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This slightly apprehensive Sika Stag has flared his rump patch to expose the maximum amount of white hair in order to signal to the other deer before moving off.

The Girrafe Weevil, *(Lasiorrhynchus barbicornis)* may attain a length of 75mm.

A HA

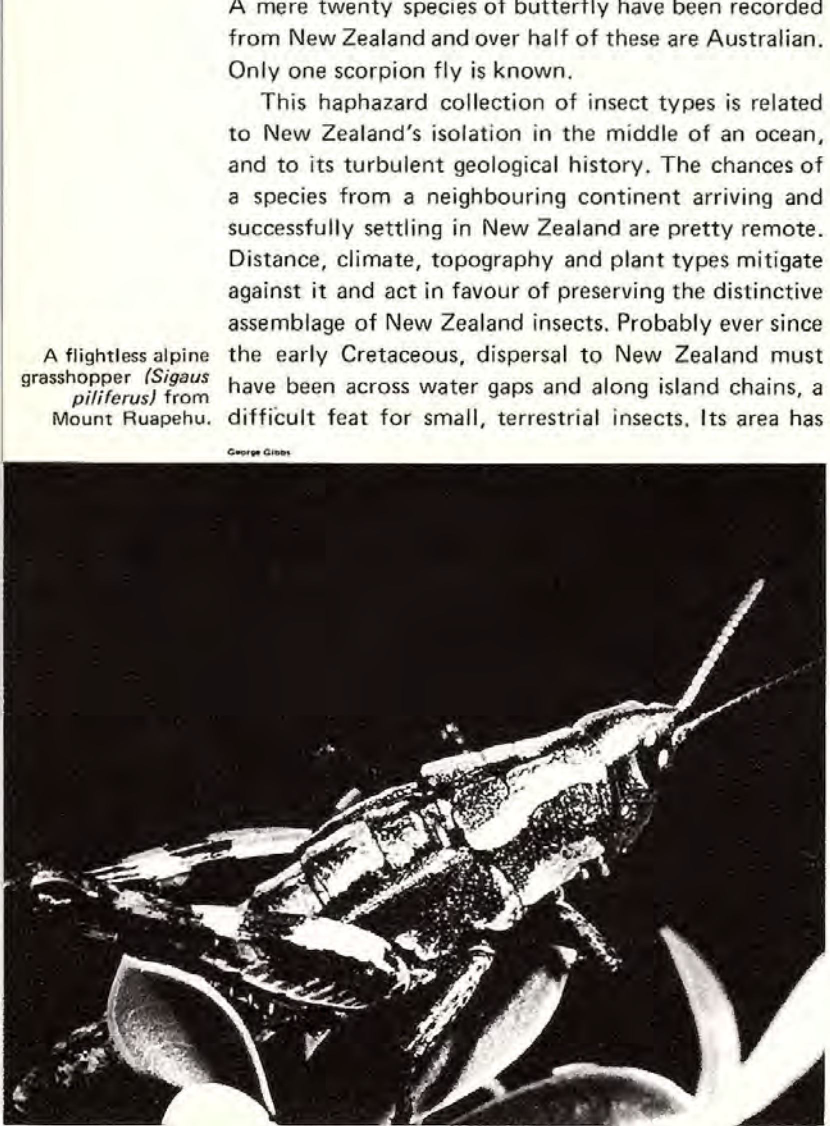
To the uninitiated, New Zealand's insects are represented by hordes of tiny black 'sandflies' congregating around scenic gems, or maybe the grotesque weta, rasping away in the dead of night, or, if one's interests are nearer the 'grassroots' of the economy, the grass-grub problem. But to those in the know, there is more to the insect fauna than that. Much of the interest in New Zealand's insects is concerned with their relationships to those of other lands. As the prominent biogeographer Dr. J. L. Grissitt has said, the fauna "is one of the most intriguing in the world".

At first glance, the insects seem to be a rather haphazard assemblage of the types found in other parts of the world, as if drawn out of a hat in a prehistoric lottery. One would naturally expect some close relationship with Australia, but many whole groups of insects at subfamily and high levels of classification are absent or very poorly represented in New Zealand. A mere twenty species of butterfly have been recorded from New Zealand and over half of these are Australian. Only one scorpion fly is known.

This haphazard collection of insect types is related to New Zealand's isolation in the middle of an ocean, and to its turbulent geological history. The chances of a species from a neighbouring continent arriving and successfully settling in New Zealand are pretty remote. Distance, climate, topography and plant types mitigate against it and act in favour of preserving the distinctive assemblage of New Zealand insects. Probably ever since the early Cretaceous, dispersal to New Zealand must have been across water gaps and along island chains, a difficult feat for small, terrestrial insects. Its area has fluctuated with changes in sea level, while its climate has undergone changes from tropical in the Eocene to glaciated in the Pleistocene. Sheltered refuges during ice advances must have been of small extent so that many species that may have made it to New Zealand in early geological times could have been eliminated by the more recent glaciations.

A flightless alpine grasshopper *(Sigaus piliferus)* from Mount Ruapehu.

George Gibbs



The older, more characteristic New Zealand insects are those of ancient derivation which have survived the glaciation. Some are large and flightless, such as the wetas. These formidable relatives of grasshoppers and crickets are nocturnal and capable of producing a rasping type of stridulatory sound by raising and lowering their large hind legs. The common tree weta (*Hemideina thoracica*) lives in crevices and holes in living or dead wood, while the larger more cumbersome *Deinacrida* species are found among subalpine rock slides or on offshore islands. The wetas, although related to the king crickets of Australia, may be Malayo-Pacific elements that reached both sides of the Tasman independently. Most of the native grasshoppers are flightless and particularly characteristic of the alpine region where these large hoppers may be exceedingly common in the snow-tussock. Their nearest relatives are in Tasmania and Chile. Also large and flightless, the ground-beetles (Carabidae) are another old group, greatly diversified in New Zealand, but most likely with South American affinities.

In spite of the glacial periods, some predominantly tropical insect groups have persisted in New Zealand. For instance, the stick insects, or Phasmids, are well represented by a number of large, wingless species that are masters of camouflage. One of the more spectacular insects with tropical affinities is the giraffe weevil (*Lasiorrhynchus barbicornis*) an extraordinary example of sexual dimorphism and bizarre development of the rostrum in a weevil. This flying insect is found in forest where its larvae are woodborers.

Some New Zealand insect groups show evidence of multiple invasions at widely spaced time intervals. It was a fascination with the trilling songs of cicadas that led Dr. Charles Fleming to embark on a tape-recording programme around the seacoasts, forests, scrub and mountains of New Zealand to record cicada songs. This work showed up the speciation patterns of these song-

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AZARD INSECT ASSEMBLAGE

BY GEORGE W. GIBBS

sters which seem to represent a series of invasions of four different stocks from Australia over a long period of geological time.

Although in the past, insects have entered New Zealand from the north by way of the Melanesian Arc or from the southern land masses, including Antartica, present-day dispersal is limited almost entirely to the route across the Tasman Sea from Australia, or to introduction by man. Studies on butterflies, moths and aphids have clearly shown that there is a remarkable amount of natural insect traffic across the Tasman Sea. Two well-known butterflies, the painted lady (*Cynthia kershawi*) and the blue moon (*Hypolimnas bolina nerina*)—known as the common eggfly in Australia—are spasmodic visitors to New Zealand. Large numbers of blue moons arrived in 1956 and again in 1971, coinciding each time with unusual extension of range in eastern Australia. Meteorological conditions during these and other trans-Tasman migrations which have been studied indicate that the insects are carried by westerly winds and may take only two to three days for the journey. Butterflies attract attention, but it is the less conspicuous immigrants that can have the greatest impact. For instance, in October 1967, a severe outbreak of a grain aphid, *Macrosiphum miscanthi*, in Victoria, Australia, was followed by an outbreak in Canterbury, the first time this species had been observed on wheat crops in Canterbury. Another instance of a tiny insect with a mighty effect was the arrival of a scale insect in about 1937, whose host plant, 'manuka', (*Leptospermum scoparium*) has since suffered a major die-back due to a black fungal infection that follows in the footsteps of scale insect attack. Since manuka colonises potential farm pasture, this latter epidemic is regarded as beneficial weed control. Both these invasions are thought to be from windborne insects.

Man has profoundly upset the endemic New Zealand animal and plant life, allowing many cosmopolitan insects to become established and certain native ones to dramatically increase their numbers. Some have been introduced unintentionally, such as the European wasp (*Vespula germanica*), the small white butterfly (*Pieris rapae*), or the Sirex wasp (*Sirex noctilio*) and many others that have become pests on introduced plants. On the other hand, certain insects have been intentionally introduced for beneficial purposes. These are primarily Hymenoptera, such as the tiny parasitic wasps released to act as biological control agents against pest species, or bees to pollinate crops that are ignored by the small solitary native bees. Agricultural modification of the natural environment has stimulated two endemic grassland insects, the grassgrub beetle (*Costelytra zealandica*) and porina moth (*Wiseana* spp.) to expand into this new habitat with astounding success, necessitating expensive control measures.

New Zealand's only Scorpion Fly (*Choristella philpotti*).

Visitors to New Zealand may take severe exception to some small black flies that are remarkably adept at finding exposed areas of skin for their blood meals. These 'sandflies' (Austrosimulium spp.) are especially notorious on the west coast of the South Island but neither these nor the few mosquitos in New Zealand are known to carry diseases. Biting flies may seem important to the tourist, but are insignificant in terms of research effort. Entomological research in the country is devoted largely towards pests of agriculture and forestry and to a lesser extent to the identification and classification of the native fauna. This latter aspect still has a long way to go before we reach the stage when most of our interests have been adequately described and related to those of other lands.

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ISLANDS OCEANS AND MARI

BY ALAN BAKER AND JOHN YALDWYN

The zebra snake, *Ophiuropsis constrictum*, on a black coral tree. This sea snake is restricted to the north of East Cape and was photographed at a depth of 20 metres off the Poor Knights Islands.

The marine environment of the New Zealand archipelago is influenced by several factors that are reflected in the islands' marine flora and fauna. The islands extend over 2000 kilometres of latitude, they are surrounded by a diverse submarine topography, and they are washed by ocean currents derived from the tropical Pacific, Australia and the subantarctic.

New Zealand's continental shelf is narrow, the continental slope is steep, and several areas of great ocean deeps lie close to the land. The archibenthal region (200-1000 metres) around New Zealand is dominated by the Challenger and Campbell Plateaux in the west and south, and the Chatham Rise in the east. The abyssal depths (1000 metres and more) are found in the New Caledonian Basin and Kermadec Trench in the north, and the Tasman Basin, Hikurangi Trench and Bounty Trough in the south. The deep regions to the east and west of the southern South Island, adjacent to Cook Strait and to the Bay of Plenty, come to within a few miles of the land, and it is possible, therefore, to find a great diversity of benthic organisms and habitats over a short horizontal distance. This closeness of deep water to the land, and the ease with which small vessels can reach and work such areas, has meant that New Zealand's deep-water fauna is now probably one of the best-known in the Southern Hemisphere.

The New Zealand Oceanographic Institute, the Zoology Department of Victoria University of Wellington, and the National Museum of New Zealand have been the prominent researching agencies in the

ALAN N. BAKER is Curator of Echinoderms at the National Museum of New Zealand, and his main research interest is the systematics and distribution of Indo-Pacific brittlestars and sea urchins. JOHN YALDWYN, a former Curator of Crustacea at the Australian Museum, is now Assistant Director, National Museum of New Zealand, and his research interests include the systematics of shrimps, prawns and squat-lobsters.

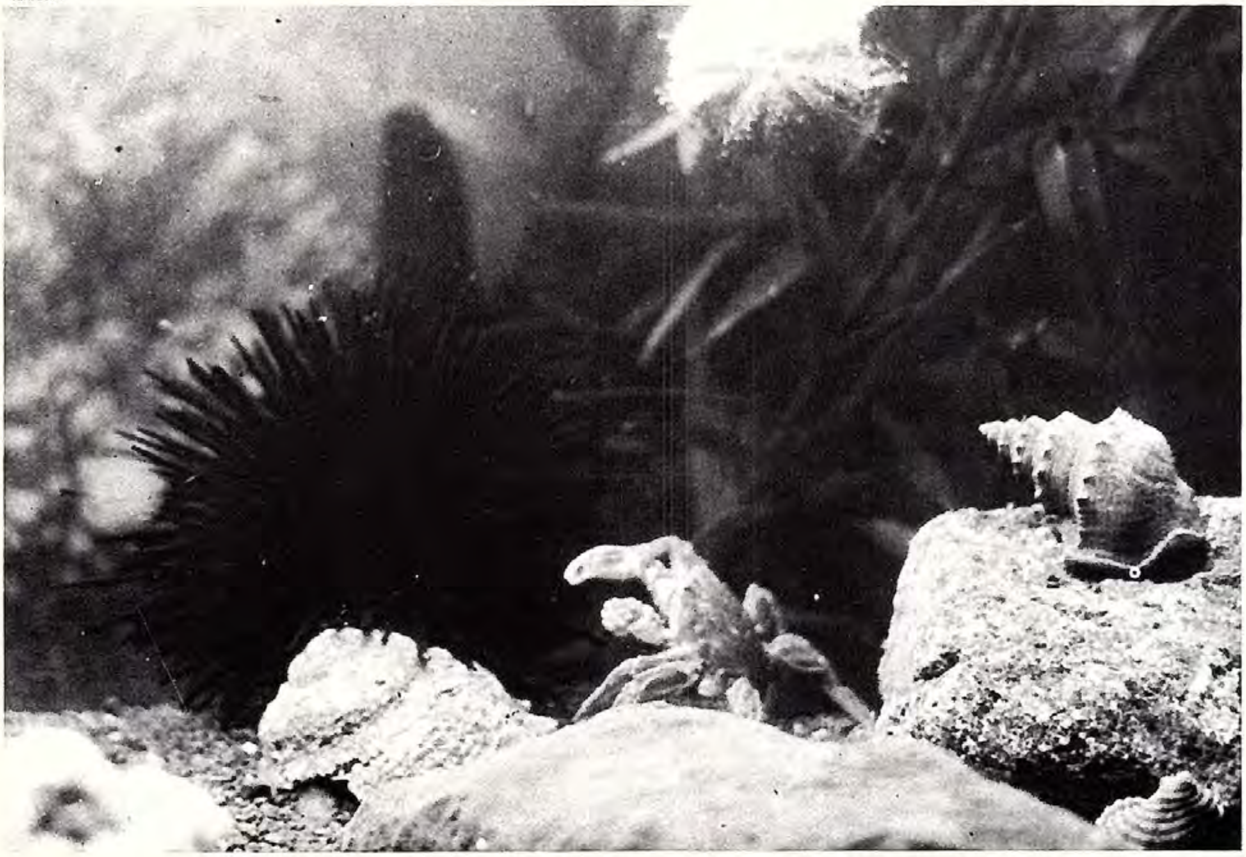
LIFE PATTERNS

study of the deepwater sea bed, and they have also given much attention to the fauna and flora of the continental shelf. Since 1960, the Oceanographic Institute has systematically worked about 400 stations in deep water around the New Zealand coast, and the National Museum has occupied over 500 biological stations between the Kermadec Islands and Campbell Island. The New Zealand universities have also been active in shallow-water studies, with their marine laboratories at Portobello, Kaikoura, Island Bay and Leigh playing significant roles. As a consequence of these efforts, knowledge of the composition, distribution and ecology of New Zealand's marine flora and fauna is now well advanced.

The major physical influence on the New Zealand marine biota is the ocean current system, which is dominated in the north and east by the warm subtropical Trade Wind Drift, and in the south and west by the Tasman Current and the cold West Wind Drift. Adjacent to both coasts of the South Island are broad convergence zones where the subtropical and subantarctic waters meet. These zones are characterized by steep temperature and salinity gradients, and their exact positions vary from month to month.

The distribution of marine plants and animals around New Zealand then is strongly influenced by currents, temperature and salinity, through the effects they have on the physiology and ecology of the organisms (particularly those with free-floating stages in their life history). The distributional patterns that emerge show that many species and some genera have restricted latitudinal ranges. These patterns are based on warm northern and cold southern centres of distribution, with intermediate warm and cool temperate areas. There are no clearly defined boundaries between the centres that form these patterns and there are differences in distribution patterns between faunas of the intertidal region and those of the continental shelf. From these centres, containing certain characteristic species with restricted distributions, other species range varying distances north and south forming a transitional zone along the central east coast of the country which

A.N. Baker



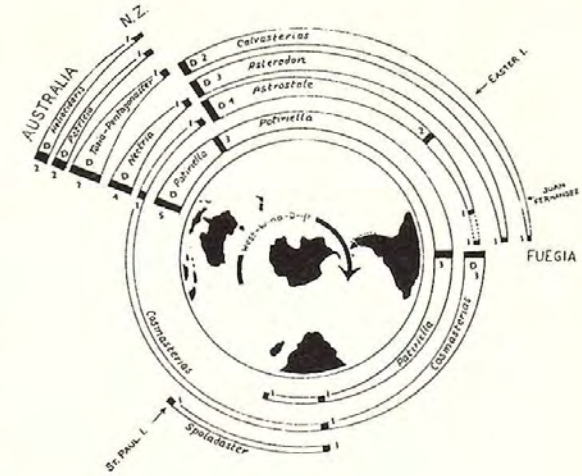
Sea urchins, molluscs and a crab, from the Bay of Plenty, North Island.

is influenced by fluctuating oceanic conditions.

In most animal groups there are also some species, mostly endemic, which range the entire archipelago. The strong endemic element (about 53% in crabs and sea urchins) in the New Zealand marine flora and fauna indicates that species have either been isolated here for a long time, or have developed here. It also suggests that the migration route to New Zealand is not an easy one, despite some evidence that immigration from the north and west is still continuing particularly in fishes, crabs and echinoderms.

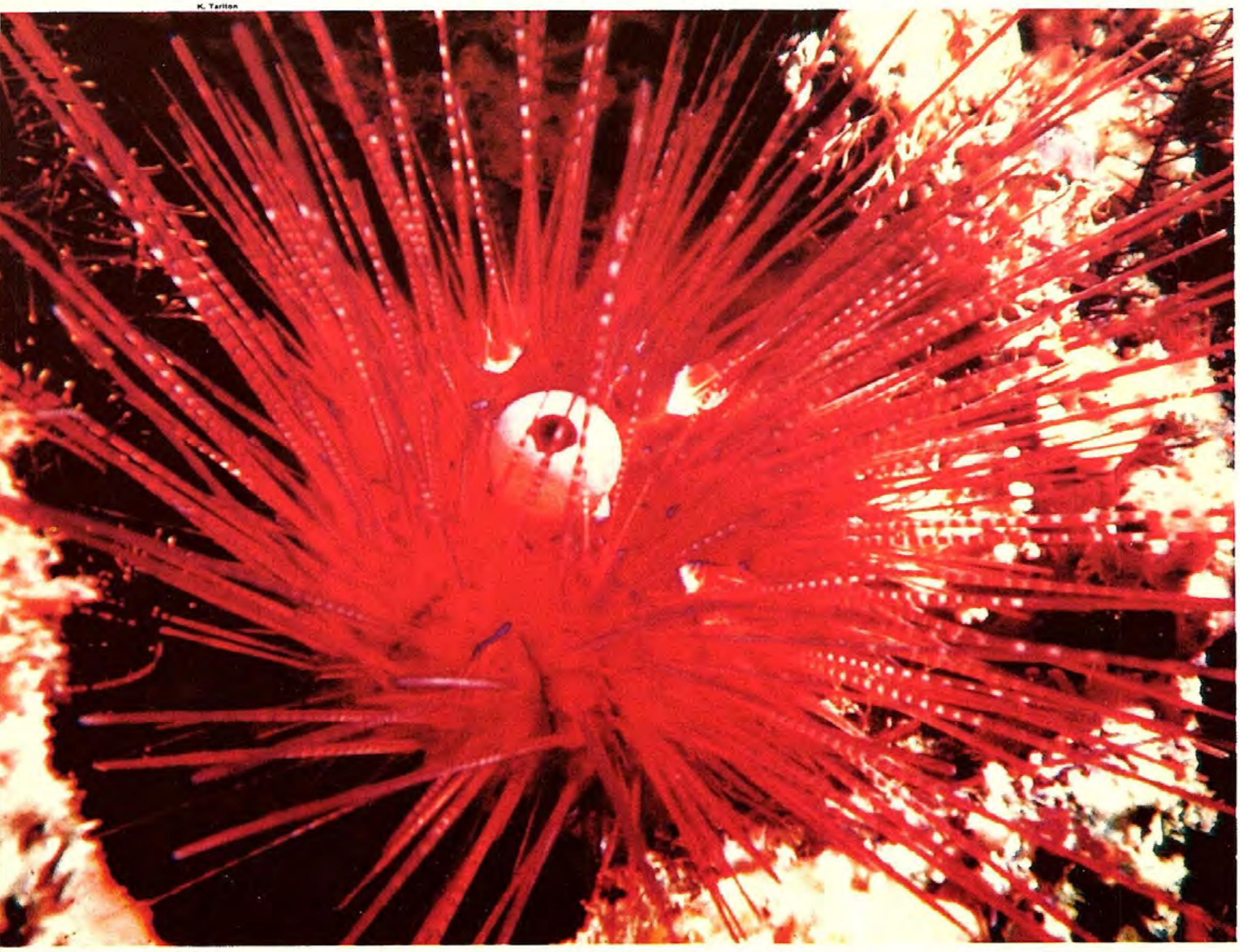
A feature of the endemic species is that although many are distinct, they have close relations in Australia and the near tropical Pacific. Indeed, the marine fauna as a whole shows affinities with that of the Malayo-Pacific area, and although there is a strong Australian element present, Australia may be regarded as a staging post for the southeasterly migration of warm water organisms from further north.

There is a small subantarctic element in the New Zealand fauna, the relationship being noticeable mainly

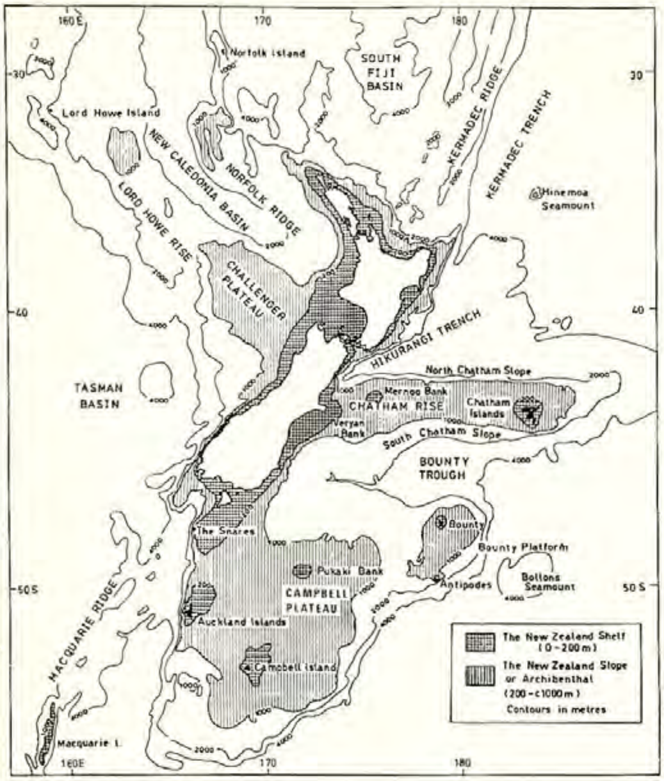


West Wind Drift dispersal of echinoderm genera in the Southern Hemisphere showing diminishing trail of species eastward down-wind from assumed origins in Australia, New Zealand, South America and South Africa. Figures indicate number of species in each genus.

K. Tarlton



The long spined sea urchin, *Diadema palmeri*, at Poor Knights Islands.



The New Zealand region showing bathymetry.

at the generic and family levels. Such cold water forms are largely circumpolar, and have been distributed by the West Wind Drift. In the far south of the New Zealand archipelago, around the Antipodes, Auckland, and Campbell Islands, this cold water fauna is notable for its low number of species.

The distribution of New Zealand coastal marine animals and plants has been analysed by a number of workers in recent years. The main patterns that emerge are as follows:

(i) a large group of species restricted to the area north of East Cape. Taking sea urchins as a particular example, we find that of the total known fauna of 62 species, 28 are found only in that northern area. Some are widespread tropical species and others are endemic species with close relatives in the tropical Pacific and Australia, e.g. the needle-spined urchin, *Diadema palmeri*.

(ii) Northern species ranging varying distances south, e.g. the sand dollar *Fellaster zelandiae* (to Banks Peninsula).

(iii) southern species restricted to the southern third of the South Island e.g. the umbrella urchin *Goniocidaris parasol*.

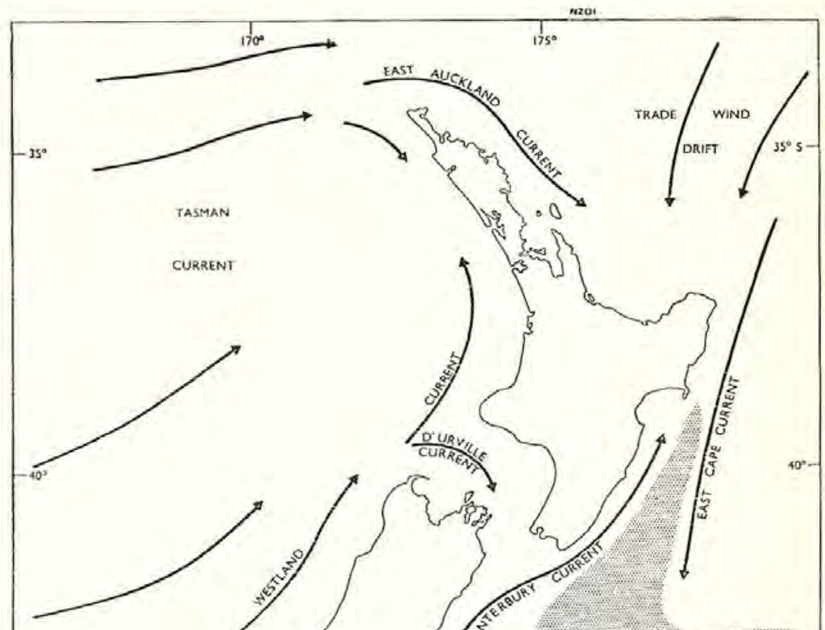
(iv) southern species extending varying distances north e.g. the urchins *Pseudechinus albocinctus* (to about Cape Egmont) and *P. novaezelandiae* (to Cook Strait).

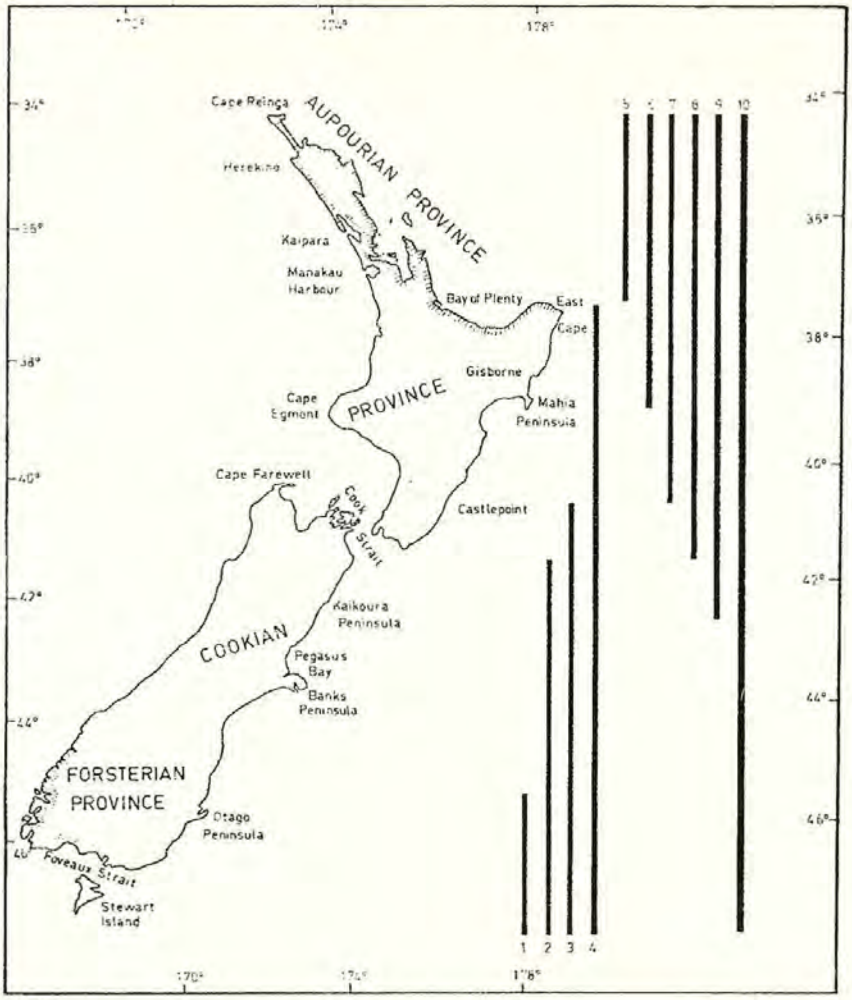
(v) A group of species found mainly in the central New Zealand area, e.g. the purple heart urchin *Spatangus multispinus*.

(vi) A widespread group of species including some endemics (the biscuit urchin *Peronella hinemoae* and the common sea-egg or kina *Evechinus chloroticus*), and some cosmopolitan forms such as the abundant shallow-water heart urchin or sea mouse, *Echinocardium cordatum*.

Historically, biogeographers have recognized and named a number of marine 'provinces' for the intertidal and shallow shelf faunas from around the New Zealand coastline. A tropical-subtropical Kermadecian province was proposed for the Kermadec Islands (about 870 kilometres north of East Cape), a warm temperate Aupourian province for North Auckland and the Bay of Plenty, a cool-temperate mixed-water Cookian province for central New Zealand including Cook Strait, another cool-temperate mixed-water province—the Moriorian—for the isolated Chatham Islands (725 kilometres east of Banks Peninsula), a cold-temperate transitional Forsterian province for the southern South Island and Stewart Island, as well as a subantarctic cold temperate Antipodean province for the New Zealand subantarctic islands (Antipodes, Bounty, Aucklands, and Campbell between 300 and 650 kilometres east and south of Stewart Island) and Australia's isolated Macquarie Island (900 kilometres south of Stewart Island).

Surface currents and convergence zone in the New Zealand region.





G.A. Knox

Distribution patterns of some common plants and animals along the New Zealand mainland east coast. Column 1, red alga *Apophlaea lyallii*, and gastropods *Margarella* spp. and *Kerguelenella* spp.; 2, southern spp. of brown algae *Cystophora*, limpit *Cellana strigilis redimiculum;* 3, bladder kelp *Macrocystis pyrifera*, endemic bull-kelp *Durvillea willana*, jewel star *Pentagonaster pulchellus;* 4, urchin *Pseudechinus albocinctus*, spotted spiny dogfish *Squalus acanthias;* 5, brown alga *Carpophyllum angustifolium*, fire-brick star *Asterodiscides truncatus;* 6, red alga *Vidalia colensoi;* 7, brown alga *Carpophyllum plumosum*, crested weedfish *Cristiceps aurantiacus;* 8, red alga *Apophlaea sinclairii*, three spp. of green algae *Caulerpa*, black periwinkle *Nerita melanotragus*, spiky dogfish *Squallus blainvillii;* 9, red alga *Pterocladia lucida*, limpet *Cellana denticulata*, eagleray, *Myliobatus tenuicordatus;* 10, Venus's necklace or bubble weed *Hormosira banksii*, brown alga *Lessonia variegata*, bull-kelp *Durvillea antarctica* (exposed headlands), barnacle, *Elminius plicatus*, yellow-eyed mullet *Aldrichetta forsteri*.

The status of these provinces has been discussed by many workers over the years and it is generally agreed now that no clear boundaries can be defined for any of the mainland seashore provinces, and that distributional patterns for shelf animals do not coincide with those for plants and animals that live between the tidemarks. A modern dynamic view envisages New Zealand's marine flora and fauna as being composed of three elements: a northern warm-temperate component, a southern cold-temperate component, and a universal component. The subantarctic cold-temperate is best regarded as a subdivision of the southern cold-temperate. Despite this simplified dynamic approach, the marine provincial concept is still a useful one in any discussion of the biogeography and ecology of the New Zealand region.

A New Zealand Fur Seal, *Arctocephalus forsteri*, at Long Reef (Awarna) Big Bay, South Island.

D. Brown

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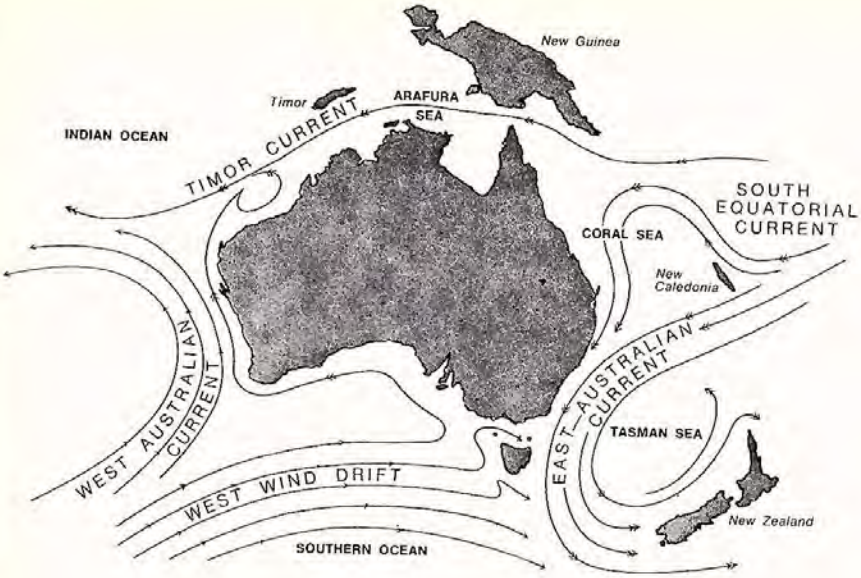
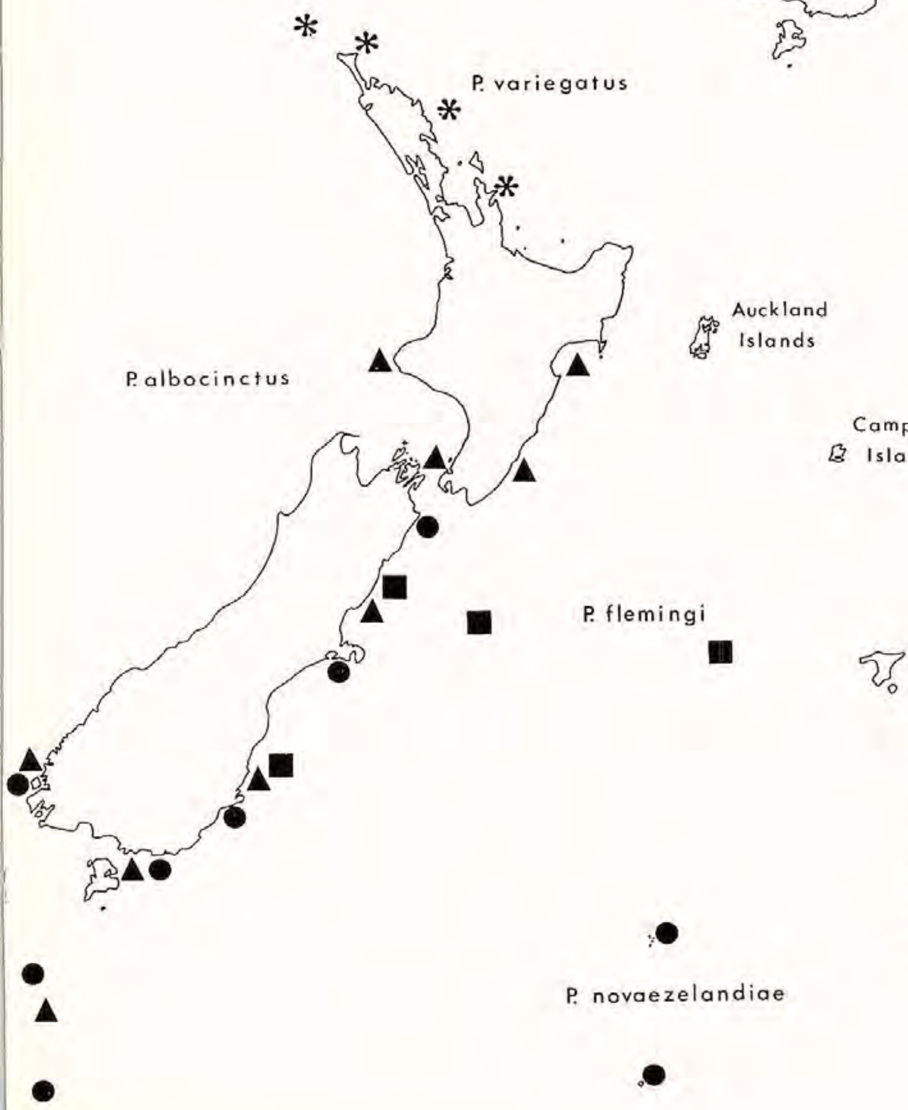
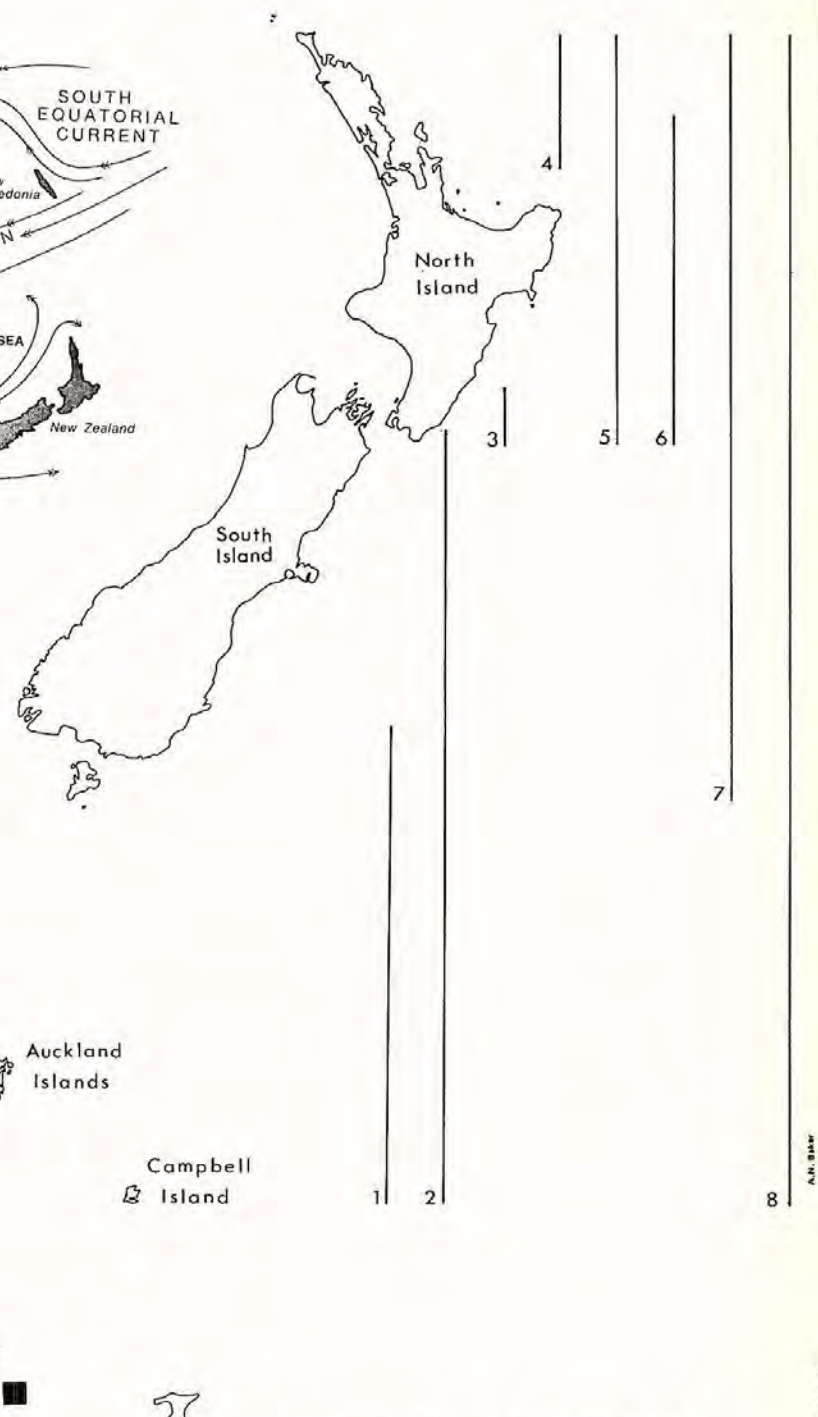


Above: New Zealand and Australia showing general water circulation in the area, double arrows — warm currents, single arrows — cold currents.

Below: New Zealand showing distribution of some species of the echinoid echinoid genus *Pseudechinus.*





Above: New Zealand showing generalized latitudinal distribution of selected crabs. Column 1, giant subantarctic spider crab *Jacquinitia;* 2, spider crabs *Leptomithrax australis* and *L. longpipes;* 3, spider crab *Eurynome;* 4, mud crab *Scylla serrata,* blue swimmer *Portunus pelagicus,* estuary crab *Pilumnopeus* (all three Australian immigrants); 5, sponge crab *Petalomera wilsoni,* black-fingered crab *Oxius,* rock crabs, *Leptograpsus* and *Plagusia;* 6, harp crab *Lyreidus tridentatus;* 7, spider crabs *Notomithrax* spp., swimming crab *Ovalipes catharus,* shore crabs *Hemigrapsus* spp. and *Helice crassa,* pea crab Pinnotheres; 8, *Cancer novaezelandiae* (introduced to Tasmania), spider crab *Chlorinoides filholi,* swimming crab *Nectocarcinus antarcticus.*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