MOA'S ARK

the natural world of the Moa

by Barney Brewster

Long before Polynesian seafarers discovered and settled New Zealand, this ancient archipelago was inhabited by a race of giant birds — the moa.

When our primaeval islands first drifted off from the Gondwana supercontinent, around 80 million years ago, the ancestral moa had already embarked for the long ocean journey. Moas were the original New Zealanders — a feathered family remarkable for their size, their lack of wings and their uniqueness to New Zealand.

Because the moa is extinct, scientific study of the bird has been made particularly difficult. The dodo of Mauritius, that epitome of extinction, left something for science in the way of travellers' descriptions, paintings and preserved parts; but of the moa? Bones, and more bones, and few other traces.

Over the last century moa bones have turned up in their thousands in caves, swamps, river beds and sand dunes, as well as early Polynesian middens. But complete moa skeletons, with bones still articulated, are quite rare, although vital for species identification. This is important because definite knowledge of an animal's biological status forms the basis of all further scientific enquiry.

Since the mid-19th century, many zoological systematists have laboured over the moa's family tree, suggesting over 60 names. W.H. Oliver, the author of the most recent scientific monograph on the moa (1949), considered there were 28 species. Since then, the number of species has been whittled down to 12. Such an array is surprising when contrasted with the limited number of types of New Zealand's other ancient bird lineages — the wrens, wattle birds, thrushes and kiwis. The number of moa species, and especially the absence of sub-species, has also been criticised from an ecological perspective.

The ultimate answer

Because our moa heritage remains mostly in the form of bones, the reconstruction of species can only really be assessed from variations in bones, principally the skull, pelvis or the leg bones (the most commonly found). But, then, today's scientists have serious difficulties in differentiating between the bones of different kiwi species, and between keas and kakas — birds readily distinguished in real life. 'Scientists are no closer to being certain about how many species of moa existed in New Zealand than they were 150 years ago', according to Dr Phil Millener, an avian paleontologist now with the Smithsonian Institute. He believes that biochemistry is the ultimate answer. You can't argue with biochemical labels, he told the 1983 Pacific Science Congress.

Fortunately, there is at least general agreement on moa generics, although the lack of common names for the six broader categories of moas makes for a forbidding list: *Anomalopteryx, Megalapteryx, Pachyornis, Emeus, Euryapteryx* and *Dinornis*. This catalogue of scientific tongue-stoppers must be very off-putting to the average museum visitor!

Moas came in a great range of sizes. The *Dinornis* species were the largest. Recent scientific estimates of their maximum height vary from 2.7m to around 4m, but they are regarded as the tallest of modern birds. Other moas graduated in size down to about 1m high, but there were some notable variations in build. Some were slender and probably graceful, others were very squat and heavy birds, and would have waddled about in a most ungainly fashion. All were entirely wingless. It is this which makes the moa truly unique among birds. Even the kiwi has vestigial wings, 5cm long, with a reptilian claw at the end, but the shoulder girdle of the moas lacked even a socket for a wingbone to fit into.

This extraordinary devolution of the forelimbs must be linked to the very favourable circumstances that the original moa bird inherited millions of years ago, when this capacious ark set sail from the rest of Gondwanaland. The ancestral moa occupied a tract of country larger than the New Zealand of today, with little or no competition, or danger from serious predators. We can presume this from the success of the moa's radiation into many species.

Massive penguin

From the immense numbers of subfossil bones, still being found in caves, swamps and mudsprings to this day, we can be confident that moas were flourishing only a few thousand years ago.

Flightlessness and giantism are hallmarks of isolated populations of birds, and there have been other examples in New Zealand. The kakapo survives (just) as the world's largest parrot, whereas the flightless NZ goose (*Cnemiornis*) and the giant flightless rail *Aptornis* do not appear to have lingered long after the arrival of people. Our islands were once home to another giant bird, the penguin *Pachydyptes*. This massive bird, around 1.6m in height and weighing about 100kg, is known from 40 million-year-old marine sediments at Oamaru. On the basis of the huge size of the kiwi egg, relative to bodyweight, it has also been suggested that the kiwi was once a much larger bird. Its present size might be a specific adaptation to nocturnal life in the deep forest.

Moas and kiwis are grouped with other large flightless birds — the Australian emu, the cassowary of New Guinea and Queensland, the African ostrich and the rhea of South America — under the name 'ratites'. The Latin-derived term refers to the ridgeless breastbone of these birds; flighted birds retain the ridge for the attachment of flight muscles.

Many scientists believed that all these birds had a common ancestor, and until the theories of continental drift gained wide currency in the 1960s, the natural tendency of northern hemisphere scientists was to locate the origins of these birds close to home. Contemporary wisdom now focuses on the forests of South America as the ratite family seat, and on Antarctica as the bridge for their wide dispersal.

Flying ancestor

Some scientists have regarded the anatomical and structural similarities among the ratites as only a good example of the converging forces of evolution, but studies of chromosome material from the living ratites now suggest a common origin from a flying ancestor, at an early stage in the age of birds.

The kiwi and the moa have been paired in the popular mind from the earliest days of their scientific discovery. The curiosity of the British and European public was considerably aroused by reports of the strange tailless, 'wingless' kiwi, while the moa became famous by an astute diagnosis from a single bone, brought to London in 1839. Biochemical studies of kiwi genetic material suggest a split with other birds of the Australasian region only 40-45 million years ago. However this conflicts with the geological evidence, as a split from emu/cassowary stock at this time would postdate the oceanic separation of that continent and New Zealand.

It is generally thought that moas came to this country on foot, around 150-140 million years ago, before the development of mammals and the break-up of Gondwanaland. Unfortunately the fossil record has nothing to add to this, nor does it give any clues to the subsequent evolution of moas in New Zealand. Terrestrial vertebrate fossils are in fact completely lacking fot this extended period, with not even that most ancient of animals, the tuatara, making an appearance. However, we can be sure that moas were witness to the long series of changes as this primordial land rose and weathered over the aeons. Climatic change accompanied the purely topogragraphic. Twenty million years ago, coconut palms grew in Northland, kauris prospered in Southland, and moas saw it all.

The ratite connection gives us good reason to look at the moa's living cousins, es-

pecially the kiwi, the emu and the cassowary, for the probable habits of the extinct bird. We should also contrast the outline of the moa with a fearful contemporary from South America, the giant terror bird (*Andalgalornis*) which died out about 3 million years ago.

The terror bird compares well in height with a middle-sized moa such as *Emeus*, but the terror bird's large and powerful head, and athletic build, are adaptations for a carnivorous way of life. Different features bring out the opposite in the moa; the small skull and heavy legs and feet of *Emeus* imply an unhurried, herbivorous life.

Only the *Dinornis* moa exceeded the terror bird in size; in silhouette *Dinornis* was also much lighter on its feet than two other of the middle-sized moas (*Pachyornis* and *Eurypteryx*) and could be considered the giraffe moa, although early reconstructions exaggerated its height by articulating the skeleton to maximum effect!

Pachyornis was the remarkble heavyweight of the middle-sized moas, but all three types were around 1.3m tall. The smaller moas, sometimes called 'bush moas', were *Anomalopteryx* and *Megalapteryx*. These two genera have a more graceful appearance, and were no doubt more agile than the larger moas. Like *Emeus, Megalapteryx* seems to have been restricted to the South Island.

Appearance of the moa

Well, what did moas look like, and how did they live? From mummified fragments of *Megalapteryx*, discovered in Central Otago last century, we know that this moa had a downy cover of feathers — with purplish black centres and golden buff edges — from the base of its bill down to its toes. On the examples of the emu, cassowary and kiwi, scientists have supposed that other moas may not have had a complete covering of feathers. Some moas may have had the bare neck of the emu, or the colourful fleshy neck wattles of the cassowary, or the bare lower legs and feet that characterises all three Australasian relatives.

Moa feathers have been found up to 18cm long, and some are double-shafted, that is, have a smaller accessory plume. Like other ratite feathers, moa feathers have lost any semblance of aerodynamic efficiency, and have more of a soft, hair-like quality. 'Stuffed' moas in our museums have been recreated using emu and kiwi feathers over wooden frames. ('Monstrously bad reconstructions', for the most part, according to one paleontologist). Isolated moa feathers have been found with a variety of colourings — a brownish red, white on black, speckled grey and bluish purple — but apart from *Megalapteryx*, there has been no possible identification. Maori legend reports weka and kiwi colourings for some moas, and a tradition published early this century links *Dinornis* to the name *kuranui*, which may be translated as either 'big red' or 'big prize'. Memories of the moa are very vague in Maori oral tradition, however, and at least one story of *kuranui* contains elements suggestive of a lingering image of the extinct NZ eagle.

Feather pits have been noted in some skulls of *Dinornis* and *Pachyornis*, indicating a feather crest, probably sexual, on the top of the head for some moas, although preserved remains of *Megalapteryx* show a reduced, downy covering on the head. Interestingly, in only two cases have moa feathers been found among Maori relics, although bird feathers were especially prized by the Maori. At the British Museum, Sir James Hector discovered moa feathers attached to a taiaha, a souvenir of Cook's voyages. The only moa skin recorded in an archaeological context was a narrow strip of *Megalapteryx* skin, sewn in a cloak of weka skins, found in an Otago burial cave about 1890.

Moas feature with any certainty in only two of the Maori cave drawings which have survived. A particularly impressive group of three bird outlines in the Craigmore cave, near Pareora, South Canterbury, can only be interpreted as moas. The three figures, regarded as authentically pre-European, show a bulky body resting on solid, earth-bound legs and huge feet; a long neck gracefully tapers to a small head held high. One moa holds a leg cocked, as if ready to strike. Though we think of moas as slow, witless creatures, this cave drawing shows a bird capable of defending itself, either from human hunters or in the rigours of mate selection.

These cave depictions are at odds with the prevailing scientific feeling that moas carried their heads forward, with their necks in the more relaxed position of the emu and cassowary, rather than the more erect neck posture of the rhea and the ostrich. However, as National Museum scientist Robin Watt comments, "What's important about the neck of the moa was that it was capable of a vast number of movements," not a surprising development for a wingless, browsing bird.

Small brains

For their size, moas had quite small skulls, and some were also flattened in appearance. A plaster cast of the brain case of a *Dinornis*, on display in the Canterbury Museum, reveals an impressively small brain, about the size and shape of a small, green pepper. Comparative studies last century on moa skulls suggested a bird with relatively weak vision, but a strong sense of smell. The moa genera differ in the shape of their bills, and in their face muscles. These differences indicate the variety of feeding habits that one would expect, but little work appears to have been done from this approach.

The proportions of moa leg bones and the shape of the moa foot inspired their scientific champion, Sir Richard Owen, to believe that the birds fed largely on fern root, scratching about in the manner of domestic fowls. This was confirmed by Maori tradition, but perhaps in response to leading questions. One of Owen's contemporaries did find in tissue traces a strong case for a powerful middle toe on the moa foot, to support this contention. (Moas actually had four toes, but the first was a hind one, well off the ground.)

Research this century gives a more definite idea of moa diet. From the well-preserved gizzard contents found with individual moa skeletons in the Pyramid Valley swamp, North Canterbury, as well as other places, has come a clear picture of the moa as a bird with broad tastes, but a special preference for twigs. Gizzard samples from *Dinornis, Emeus* and *Euryapteryx* showed a predominance of twigs from a variety of woody plants, with some seeds, fruits and leaves. In one typical *Dinornis* gizzard, Colin Burrows, botanist at the University of Canterbury, found that short pieces of twig made up over 90% of the content: 'The twigs were not counted but it is estimated that there were several thousand pieces of *Olearia* stem and many hundred *Coprosma* twigs.'

This interest in twigs is unusual among birds, but probably extended to the other moas as well. Under a limestone overhang in Takahe Valley, in Fiordland, in 1949, Dr Robert Falla and Ken Miers found moa dung preserved with the remains of *Megalapteryx*. "Falla thought this dung to be human at first," recalled Ken Miers in 1985. "But when he broke a piece of it in half, there was a big, characteristic coprosma twig in it, at least 1cm long and about the thickness of a glasses stem".

Despite the Pyramid Valley gizzard material, which came to light over 1939-1940, and although a twiggy matrix in gizzard residues had been noted as early as the 1880s, leading moa scientists of the 1940s and 50s (notably Duff, Oliver, Falla and Archey) placed a greater stress on the role of grasses in moa diet, and so located the birds on the grassy plains of New Zealand. These plains have been deforested for only a few centuries, but a whole generation of New Zealanders has grown up with the impression that the moas were restricted to a grassland habitat. The evidence suggests quite the contrary.

Not grassland birds

Moas were primarily birds of the forest and scrub. Only a thousand years ago virtually all of lowland New Zealand was forest-covered, or scrubland, and correspondingly moa remains have been found everywhere: from the dunes near Cape Reinga to Mason's Bay in Stewart Island. Though not common, moa relics have also been found on the volcanic plateau in the North Island. Bones have been discovered on Great Barrier Island, but on no other island. Off Wellington's western coast — an extensive lowland up until ten thousand years ago — moa bones have been dredged up twice in recent years.

European settlers last century often commented that in areas of inland Otago and Canterbury, moa bones were amazingly abundant on or near the surface of the ground, and that some bones were surprisingly fresh. In both islands, moa gizzard stones can still be found. These stones, often quartzose and sometimes semi-precious, remain after all other trace of the bird has decayed. Collectively, these gizzard stones can weigh up to 3kg, and because they usually relate to the local geology, scientists have supposed that the moa, unlike the emu, was not a migratory

Did the moa look like this depiction of a giant moa, *Dinornis*, the tallest bird ever to have lived? The illustration, by artist Chris Gaskin, is from the book *Moa, the story of a fabulous bird*, written by Philip Temple and reproduced with the kind permission of the authors and the publishers, Collins.

bird. However, gizzard stones and bones show that moas travelled to alpine areas in summer. J.C. Andersen, author and Turnbull librarian, saw moa stones at around 1660m in the Mt Cook area, in 1909, while in the 1860s Captain Fraser discovered enormous slaughter-heaps of moa bones at about 1500m on the Carrick tops in Central Otago.

A scientific report in 1971 gave an intriguing account of the excavation of at least five species of moa from a cave near Mt Owen, in the Murchison area, at an altitude of about 1305m, not far above the subalpine shrub belt. The moas, it seems, made summer forays to the tops to feed on the subalpine vegetation, and the authors wondered if 'the abundance of mountain plants bearing coloured and fleshy fruits in summer could be explained in part as a response to the presence of moas.' The implication is that moas aided seed dispersal of some alpine plants. No other scientist since appear to have taken up this challenge, while others have cautiously explained the remains of moas at higher altitudes in terms of refugees from forest fires, or declining bushlines. The Mt Owen report maintained that 'plant remains found with the bones indicate the vegetation of the area has been consistently subalpine to alpine throughout the period of deposition.' (Bell and Bell).

Browsing effects

Such speculation opens up a much broader, ecological perspective on the intimate association of moas with New Zealand's plant life over tens of millions of years. Such an approach came with the 1977 suggestion by two New Zealand scientists that moa browsing had influenced the growth patterns of our native flora, by encouraging the divaricating habit in many plants.

An unusual number of native plants (around 10%) have a close, thicket-like juvenile stage. Examples are weeping matipo, pokaka and coprosma species. The moa browsing theory has had some support from gizzard findings and nutrient analyses. Lancewood (*Pseudopanax*), for instance, has been shown to undergo a marked increase in protein content and soluble carbohydrates when the sapling reaches around 4m in height — just beyond reach of *Dinornis*, perhaps. However the moa browsing theory has since been rebutted by other arguments which favour a climatic explanation for the divaricating habit.

Dr Falla, with his view of moas as mainly grassland creatures, believed their affect on the New Zealand landscape would have been similar to that of sheep now, especially if — and this is doubtful — moas were gregarious. Certainly, moas with their heavy feet and prodigious digestive processes were long term soil conditioners. A more obvious role would be that of seed dispersal of such native trees as the miro, tawa, taraire and karaka. This important commission now rests with the wood pigeon, the only native bird which can swallow intact the large fruits of these trees. Passage through the pigeon gut has been shown to improve germination rates also, so it is likely that fruit-bearing native trees benefited in more than one way from the presence of moas.

Dr Phil Millener's doctoral thesis summarises extensive fieldwork in the dunelands of the Far North, and with cave deposits in the King Country. In the extreme north of the North Island, for example, he established that with the exception of the kaka, moas outnumbered all other birds, in total numbers. The most common moa of the four genera present was *Euryapteryx*, with 367 of the 530 individual remains identified to this genus. Ponderous *Pachyornis* was present in good numbers (118 individuals), and *Dinornis* reasonably so. Only five *Anomalopteryx* remains were found.

A similar sample (607 individuals) of the caves of the King Country revealed a different balance of species. Three times the number of *Dinornis* moas were discovered (126 vs 40 in the Far North), whereas *Euryapteryx* and *Pachyornis* were present in much reduced numbers (94 and 44 respectively). Dominating the field, as *Euryapteryx* had done in the Far North, was *Anomalopteryx*, with the remains of 343 individuals.

The weka was the next most common bird in the north, the kakapo in the King Country.

Rugged landscape

Two other points emerged from the King Country study: that this area had been deeply forested for the duration, and that

even in the difficult topography of this region, a variety of moas lived and flourished. The scientists who excavated the Mt Owen cave also commented on the rugged landscape of the surrounding country. Similarly, a very large collection of subfossil moa bones have been discovered in the last few years in caves in the jumbled limestone of the Oparara Valley, near Karamea. The remains were part of a special National Museum study, led by Dr Millener.

Moa enthusiast Bill Hartree discovered over 40 moa nesting sites in the steep hill country of the Wairarapa and Hawkes Bay, and was able to identify *Anomalopteryx* nests from bones adjacent. He found evidence for only a single egg, in scoop nests usually protected from the weather by an overhang or rock shelter. Dr Millener states in his Oparara report that some moa species probably nested in caves, and there is good evidence for this. Other records from last century indicate moas also nested out in the open. Geologist Alexander Mackay, as one example, briefly records his finding 'a moa's nest', in the 'western districts of Nelson', probably in 1879. The nest held the remains of a chick, and was open to the weather. In the open country of Marlborough, too, large quantities of eggshells have been noted.

Millener's doctorate suggests that *Pachyornis* used the dunes of the Far North as nesting sites. Moa eggshell fragments are common in many coastal dunes around New Zealand, but at Tokerau Beach they can be found in "phenomenal quantities", according to Brian Reeve, "with carpets of eggshell where the sand has blown out." Eggshells are usually cream coloured, although some bleaching is common when exposed to the weather. Some olive green pieces have been found in other localities. Half of a dark green egg, the first discovered, was recently excavated from a nesting site in the Upper Rakaia Valley, in Canterbury. Identification of eggshell to species is very rare, because a direct association with identifiable bone is required, but in single locations this has been accomplished with *Euryapteryx* and *Emeus*.

Over a dozen moa eggs have been uncovered whole, and sometimes in perfect condition. They have been found mainly in river silt or sand deposits, as well as in early Maori burials. Of course moa eggs are large — about 18 hens' eggs in average volume — but not proportionately larger than a kiwi egg. *Dinornis* eggs measure up to 27cm in length, but they in turn would be overshadowed by the egg of the elephant bird. A specimen in the British Museum is a colossal 75cm in girth, with an estimated liquid capacity of over nine litres.

Although Hartree uncovered mainly single-egg nests, other evidence points to moas also laying more. When one unbroken moa egg was discovered in a small cave at a Southland quarry in 1920, 'the others were broken in the nest' he wrote in a 1947 *Weekly News*. The bones of four chicks were found underneath a perfectly preserved *Dinornis* skeleton in alluvial deposits in Central Otago in 1864, but this intriguing fact was mentioned only in passing by the discoverers. Along with the bones of the parent, these relics were quickly dispatched to England.

Male on the nest

This adult moa was undoubtedly a male, as the task of incubation and care of the young is delegated to the male in all three surviving Australasian ratites, and is also the main domain of the male ostrich and rhea. Kiwi, cassowary and emu males are smaller than the females, and are dominated by them, so it seems likely that moas were similar. Kiwis usually lay two eggs, and cassowaries average three to four, but emus lay as many as nine eggs. These birds having evolved in a more competitive and predatory environment, we can assume that moas survived with smaller broods, perhaps not even reproducing every year.

Incubation times for the moa's living kin give a good idea of gestation in the extinct bird. As for emu and cassowary, eight weeks' gestation would be a likely length for the moa, with the male leaving the nest only occasionally, to feed or eliminate. The chicks would be mobile not long after hatching, as they would have to forage for themselves.

After their initial mobility, the development of young ratites can proceed at a more leisurely pace, relative to flighted birds, as there are not the same pressures to become airborne.

40-year life span

The life span of a moa may have been forty years or more, such longevity being common with large birds with low reproductive rates and few enemies. Not that life for the moa in primaeval New Zealand was without danger or hazards. The extinct NZ eagle *Harpagornis* and the extinct large NZ harrier *Circus* were quite possibly a threat to the unguarded young. It is also possible that the weka preyed upon moa eggs, as it is claimed to do on little spotted kiwi eggs on Kapiti Island. Moa eggs were relatively thin (2mm maximum) for their size, and unguarded no doubt presented an attractive meal to the opportunist weka.

Other hazards to moas were floods (although their ratite cousins are surprisingly competent swimmers), slips and fire, not to mention volcanic eruption. Hector counted thirty-seven moa skeletons on the surface of the ground, in a small area between a steep mountain side and Lake Wakatipu, in 1862. He attributed the find to the onslaught of fire, but a snowstorm could also be an explanation. Maori legend supports Hector's interpretation: the fires of Tamatea were an ancestral event held chiefly to blame for the decimation of the moas.

Despite their ability to negotiate very difficult terrain, moas were frequent victims to pot-holes, and had an amazing propensity for bogging themselves in swamps and mudsprings. "It would be hard to imagine a creature more beautifully adapted to becoming mired, than a moa," said Dr R. C. Murphy, an American scientist involved with the 1949 excavations at the Pyramid Valley swamp. Nineteenth century naturalists were staggered by the sheer numbers of bones that could be retrieved from a very small area of bog, and contrived all sorts of theories to explain them. In one deposit in the Maniatoto, 400 birds were estimated in 1874 to have been trapped in a crescent-shaped area measuring only 12m from point to point, and about 5m at the widest.

In many of these swamp deposits, the geography is strikingly similar, with the remains concentrated in particular spots, at the foot of ridges and spurs from higher ground. Over the years, moas had become bogged, either in crossing to the other side of the swamp, or while trying to drink. The chemistry of most of New Zealand's swamps is unfavourable for the preservation of moa bones, but in localities such as Pyramid Valley, the remains of a great variety and number of animals, not only moas, have been perfectly preserved.

Whose tracks?

The siting of these swamp discoveries corroborates other evidence from a few other locations that moas had their own tracks through the forest and fernlands. In the Taupo area (1975) and Hawkes Bay (1963) researchers reported the excavations of compacted paths of heavy footed creatures from long ago. Two of these former trackways were traced down slopes to watercourses, while a third wound its way through a former swamp. The cassowary is known to make habit paths, and it seems likely that moas were obliged to form and retain easy access through the forest and forest margins. The difficulties of making a way through such vegetation were quickly noted by New Zealand's early European explorers. Who knows if the old Maori tracks mentioned by European bushmen and surveyors were in fact first formed by human feet at all? Kakapo keep paths too, and the effect in an area where their populations were undisturbed was remarked on by the men of the survey ship *Acheron*, while exploring the southern sounds in 1852. From the many criss-cross trails they came upon, the *Acheron* men at first thought they were near a Maori village.

What is clear from this review of moa's ark is that in their heyday moas were a very tangible part of the New Zealand landscape. While the birds were perhaps well dispersed through the endless forest — population densities are very hard to reconstruct — we should imagine, from their remains, a country where the big birds were always somehow or somewhere in evidence. If not the birds themselves, then their calls, or their heavy footfalls in the litter of the forest floor, or their footprints on river banks and estuaries, or their abundant droppings. Their easy dominancy in the life of the forest continued for age after age, but what seemed for always was not forever.

This article summarises my moa research to date. I would be grateful for any unpublished material regarding the moa, such as manuscripts or old newspaper clippings, and these can be addressed to me at PO Box 602, Nelson.

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