Moas and the Maori

Unraveling the evolution and extinction of a large, flightless bird

by Joel Cracraft

On a wintry day in early February 1844, a large crowd assembled at the Royal Institution in London to hear a lecture about some old bird bones recently arrived from New Zealand. As was the custom, the gentlemen were at their attentive best on the main floor, the ladies were in their proper Victorian place high up in the gallery, and the physicist Michael Faraday was prepared to serve tea at the conclusion of the festivities.

That the famous of London’s scientific and literary society (Dickens and Carlyle were often in attendance at such functions) would spare the time to learn the latest about bird bones may seem curious, but the lecturer was none other than Prof. Richard Owen, England’s premier anatomist and paleontologist. And these were not ordinary bird bones he was to talk about—they were the relics of giant flightless birds that were thought to be, as Owen’s wife was to characterize them in her diary, the “only remaining types of a large creation as proper to an early state of the globe.”

The intellectual community’s keen interest in these birds had its origins five years earlier. In 1839 Owen had stunned his fellow scientists by describing a fragmentary scrap of limb bone, brought to him by a sailor just returned from New Zealand, as having come from a previously unknown form larger than an ostrich. When Owen submitted his paper to the Zoological Society of London, the publication committee protested strongly. After all, how could one reconstruct a giant flightless bird from such a small scrap? And how could such a large bird have escaped the eyes of several generations of New Zealanders? The bone was not fossilized, so if Owen was correct, the living bird surely would have been observed by someone. Finally, however, at Owen’s insistence—and at some risk to his reputation—the paper was published, and copies were distributed across New Zealand. Four years later more bones arrived from naturalists in New Zealand, and Owen had the proof he needed. Over the next forty years, he and others described dozens of species representing forms the size of a turkey to those standing taller than an ostrich.

How did these birds, called moas from the Polynesian word for fowl, come to occupy New Zealand? What factors facilitated their evolution, which resulted in remarkable taxonomic and morphological diversity? And why did they become extinct? These and other questions have puzzled scientists for more than a century, but only within the last decade have biologists and anthropologists begun to
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furnish some satisfactory answers. Moas belong to a group of birds known as ratites; included in this group are the rheas of South America, the ostriches of Africa, the extinct elephant birds of Madagascar, the emus and cassowaries of Australia and New Guinea, and the kiwis of New Zealand. Except for the kiwis, all these birds are large, flightless, and look much alike. Many experts, even as recently as fifteen years ago, considered them to be unrelated to one another. These workers hypothesized that each species had its own distinct ancestor, which flew to these far-flung southern landmasses and independently evolved large body size and flightlessness. Not unexpectedly, this hypothesis had special appeal to a scientific community that, at the time, accepted the notion of stable continents and ocean basins.

Then, in the 1960s and 1970s, ornithologists began to reinvestigate the comparative morphology, behavior, and biochemistry of these birds. All the available evidence provided by these studies supports a hypothesis of common ancestry for the ratites and a close relationship between them and the tinamous of South America, a family of grouse-like birds capable of flight. Moreover, on the basis of morphological data, biologists have postulated that rheas and the ostriches are each other’s closest relatives and that they, in turn, are related to the emus and cassowaries. These four families, furthermore, appear to share an ancestry with the elephant birds, and finally, all five can be related to the kiwis and moas.

This hypothesis of relationships has some important implications, two of which seem to answer the question about the origin of the moas. For example, the hypothesis implies that ratites evolved large body size and became flightless only once, near the beginning of their ancestry. The second implication is that ancestral ratites were rather widespread over a united Southern Hemisphere landmass. When the continents began to break up and drift apart in the middle to late Cretaceous (about 80 to 130 million years ago), progenitors of the modern families were isolated.

In the Cretaceous, a continental mass, which later became New Zealand, lay connected to the Ross Ice Shelf region of West Antarctica. Topologically and geologically distinct from East Antarctica, West Antarctica was apparently united intermittently not only to the New Zealand continental...
block but also to the southern Andean portion of South America. It can be postulated that at some time in the late Cretaceous an early ratite ancestor was distributed over a common New Zealand-West Antarctica-southern South America landmass. With the northward drift of New Zealand, beginning about eighty million years ago, that ancestor became isolated. A subsequent evolutionary event within the New Zealand continental fragment produced the lineages leading to moas on the one hand and kiwis on the other.

Moa bones are known from natural deposits 600 to 33,000 years old and from sites associated with human activity, all of which are less than 1,000 years old. These remains are now classified into six genera and about thirteen to fifteen species. The genera are characterized by differences in body proportions and in the shape of the head and bill, suggesting that the species of each genus had a distinct method of obtaining food. Within each genus, however, the species are differentiated from one another primarily on the basis of size. This twofold aspect of evolutionary divergence—by shape among genera and by size within each genus—has produced a remarkable radiation in morphological diversity. As an example, the genus Dinornis contains four medium (five to six feet tall) to very tall (nine to ten feet) species, all of which have broad, flattened skulls and bills and extremely thin legs for birds their size. The genera Euryapteryx and Pachyornis, on the other hand, have two species each—one small (three to four feet) and one medium to large (five to seven feet)—and are robust, heavy-boned birds with deep, strong skulls and beaks. The remaining genera, Megalapteryx, Anomalopteryx, and Emeus, consist generally of smaller species (four to five feet tall) with relatively weak bills of varying shape. (Another interesting morphological characteristic of moas is that they are the only group of birds known to have lost all the bones of their wings.)

How can this pattern of species and morphological diversity be explained? The answer to this question probably has two components, one relating to paleogeographic and paleoclimatic changes that took place during the Tertiary and Pleistocene and the other to the ecological interactions that occur among species faced with exploiting similar and restricted resources. As is frequently the case in paleontological

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reconstructions, both components can be inferred to have been important in moa evolution, but constructing rigorous tests of these hypotheses may prove impossible.

Biologists have established that new species can arise when populations of previously existing species are fragmented in some manner by climatic or geographic barriers. Once in isolation, these fragmented populations diverge, either rapidly or slowly, to become distinct species. One key to a rapid proliferation of species within a restricted geographic area—called an evolutionary radiation—is the occurrence of cycles of population fragmentation, divergence in isolation and reunion of these newly evolved species, followed by another cycle of fragmentation and isolation. In this way an original species gives rise to two or more new species in isolation; then when barriers are eliminated, some of these species may come to occupy the same area. If new barriers arise, the population of each new species is fragmented and additional species evolve. Diversity can thereby increase rapidly.

We can hypothesize that this model of species evolution provides an explanation for the taxonomic diversity of moas. Throughout the Cretaceous, and especially during the Cenozoic, the New Zealand landmass was constantly changing in surface area and topographic features. As the New Zealand continental plateau drifted slowly northward, islands of various sizes and shapes emerged, became united to form large land areas, and were divided once again by rising sea levels. There are at present only two major islands, North Island and South Island, but a series of islands existed for varying periods of time in the early and middle Cenozoic. And in the Pleistocene, the cyclical changes in sea levels, which were correlated with the waxing and waning of the polar icecaps, repeatedly separated and then joined North Island and South Island. This then is the paleogeographic setting that undoubtedly influenced moa evolution. Given the frequency of geographic isolating events that took place during the last forty or fifty million years, it is not surprising to see high species diversity in a group of birds. What makes the radiation of moas interesting, however, is that it involved taxa of large body size and took place on a relatively small landmass. Within birds, the only comparable situation is that of the now extinct elephant birds of Madagascar.
where seven species apparently evolved in isolation. In contrast, the classic examples of island evolutionary radiations, such as the Galápagos finches and the Hawaiian honeycreepers, involved species of small body size.

It will be recalled that when moas first arrived on New Zealand they were already flightless and probably of fairly large body size. Subsequent geographic events facilitating evolutionary diversification contributed to modify this basic model. This raises the question: How did numerous species of generally similar body plan coexist in an environment in which the diversity of food resources for large flightless birds appears rather limited? Living ratites, except the kiwis, are omnivorous, and so too probably were the moas. New Zealand did not have an especially high plant species diversity and the small vertebrate fauna available as food for ratites was inapposite.

Some current ecological research suggests that if two closely related species come to share overlapping distributions, and if food resources are limited, then either one of the species will go extinct or the two species will diverge in those aspects of their morphology, behavior, and ecology that are related to resource utilization. If divergence occurs, the species will be able to coexist. In those situations in which many similar species coexist, the problem of dividing up the available resources becomes more acute, and we would predict marked divergence to evolve, presumably to reduce interspecific competitive pressures.

This ecological theory may explain the divergence in body size and bill shape exhibited by the moas. Differences among genera reflect variation in bill shape and body proportions, whereas differences among species of the same genus primarily reflect variation in size. The species in any one location, therefore, apparently manifested a broad range of morphological and, presumably, ecological diversity. Because the stomach contents of some individual moas have been preserved, we know that they fed on leaves, twigs, and fruits.

The striking diversity in bill shape suggests there was a corresponding variety of feeding methods. Compare, for example, the large species *Pachyornis elephantopus*—even its name characterizes this ponderous six-foot bird—with the slightly smaller *Euryapteryx geranoides*. Both were roughly similar in size and occurred together over

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much of South Island. *P. elephantopus* possessed a high, rounded cranium with a long, narrow, pointed bill. Its jaw apparatus was heavily constructed, and the large jaw muscle scars indicate a species capable of crushing or tearing highly resistant foods. On the other hand, *E. geranoides* had a broad, flattened cranium with a short, broad bill rounded at the tip. Although the skull presents an impression of strength, the relatively small jaw muscle scars indicate a more limited ability to crush and tear food. Another species in the same deposits, *Emeus crassus*, was the same size as *Euryapteryx geranoides* but had a jaw mechanism as weak as that found in some much smaller species. This example could be applied to the species assemblage known to occur at any given location.

These observations suggest that the species of moas may have avoided competition for the available food resources because they browsed at different heights in the vegetation and possessed contrasting abilities to harvest foods. The millions of years of geographic isolation and differentiation, accompanied by the evolution of differences in size and shape, resulted in the presence of approximately fifteen species in geologically recent times. Why then did the moas go extinct, apparently all within the last thousand years?

The answer to the question of moa extinction is complex and has been debated for more than a century by archeologists, biologists, and geologists. The difficulty is that the historical record—whether of natural or archeological deposits—is woefully inadequate. Nevertheless, as more sites are discovered and aged by radiocarbon-dating techniques, our picture of moa history is steadily improving.

The Maori people arrived on New Zealand from eastern Polynesia about a thousand years ago. Archeological evidence reveals that both North and South islands were widely settled by 700 years B.P. Bruce McFadgen, a New Zealand anthropologist, estimates the total population of the colonizers at between 500 and 1,000 individuals, but by the fifteenth century those numbers had grown to somewhere between 10,000 and 100,000.

The first human inhabitants found themselves in a wild and pristine land. A lush forest of mixed podocarp-broadleaf trees covered the subtropical areas of North Island and the west coast of South Island, and an equally dense southern beech forest was distributed widely in mountainous and temperate lowland locales, especially on South Island. These forests made penetration and agricultural exploitation of the island interior extremely difficult and nearly all coastal settlements practiced clearance by fire. McFadgen estimates that after 300 to 500 years of occupation perhaps as much as one-third of the forests had been burned.

The lands and waters of New Zealand offered the Maori colonizer a diversity and abundance of food sources. The ocean and coastal waters had fish, shellfish, and large numbers of the New Zealand fur seal. The forests yielded many kinds of edible plants. There were no native land mammals other than bats, but there were giant birds. One can almost imagine what the first sight of moas must have meant to these colonizers at the end of a journey that had taken them over 1,500 miles of open ocean. And they rapidly took advantage of this readily available food source. Moas were harvested in great numbers. Their bones were broken, probably for the marrow, certainly for their use in making tools, such as fish hooks, and for decorative ornaments. Moa nests were also exploited as a food source, as eggshells are abundant at some sites.

From the frequency of moa bones associated with dated Maori sites, the evidence is fairly clear that large numbers of moas were killed in a short period of time. Hunting of moas was apparently a regional phenomenon, depending upon the local abundance of the birds and other foods. Along the coast, for example, food was gathered primarily from the ocean, and moas were rarely used as a food source. Hunting pressure was more severe on South Island, and this probably reflected the vast differences in climate encountered over the whole of New Zealand. On North Island, as moas and other animals became scarce from overhunting, the Maori shifted from a predominantly hunter-gatherer economy to one based on agriculture of the East Polynesian sweet potato and other cultigens. The climate over much of South Island, on the other hand, was too cool to effectively grow many of these plants. Thus, southern Maori populations were forced to rely more on hunting.

Did hunting pressure alone result in the extinction of the moas? This is difficult to say. Certainly, hunting was crucial in many ways. Bones of young birds are frequently found at Maori sites, and the removal of eggs and young would have affected future population numbers much more severely than if the killing had been restricted to adult birds (which may have bred before they were killed). Evidence for a strong effect of hunting is also presented by the large array of other ex-

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Sir Richard Owen with moa bones, 1846

 distint species of birds that are commonly found at Maori sites. These included a giant goose, a flightless duck, an eagle, rails, and a crow; one could also add to this list many of the species that are now very rare on the islands. There can be little question that hunting had an impact on virtually the entire avifauna.

But hunting cannot be the only cause of moa extinction. Surely the felling of the forests, with its consequent destruction of thousands of square miles of habitat, had a devastating effect because most of the species of moas were distributed primarily in the lowlands. Apparently, only a few of the smaller species commonly occupied the mountainous regions. A reasonable assumption is that the restriction of moa populations to small tracts of relict forest greatly increased their chances of random extinction.

The species of Dinornis, Emeus, and Pachyornis were the first to be exterminated, probably within several hundred years after human colonization. Euryapteryx was still commonly found between 600 and 800 years B.P., but was extinct by 300 to 400 years B.P. There is no verified record of survival of any moas after this latter date, but some authorities believe that a small species of Anomalopteryx or Megalapteryx may have survived in the remote wilderness of the Southern Alps until the eighteenth or nineteenth centuries.

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