An ecological and cultural review of the emu (*Dromaius novaehollandiae*): Dreamtime - present

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ABSTRACT

Since the first humans arrived on the continent of Australia, they have been in a symbiotic dance with the emu (*Dromaius novaehollandiae*). This member of the flightless ratite family is a testament to evolutionary adaptation and survival in harsh habitats. It has also played a key role in Aboriginal survival, as it is deeply rooted in Aboriginal mythology, culture, and medicine. The use of *emu oil* began with the Aborigines and its use is widespread today. The influence of the emu now reaches around the world. By virtue of its unique characteristics, the emu has been the subject of studies in contemporary evolutionary theory, phylogenetics, agriculture, and medicine.

INTRODUCTION

> In the Dreamtime, when humans only existed as the spirits of their ancestors, there was darkness. Dinewan, the emu, resided in the sky and looked down upon the Earth from the stars. Noticing the beauty inherent in its mountains and rivers, and the wonderful menagerie of plants and animals, Dinewan could not stand for it to be lost in the darkness. Sacrificing one of her giant emerald eggs, she tossed it into the sky where it cracked open. The bright yellow yolk burst into flames and became the sun that showers all the land and its inhabitants in light (Mares 2011).

This creation myth of the Aboriginal Australians has several different versions that have evolved over time. But in each telling, it is the emu that brings light to the earth, reserving its place in the Australian pantheon. Dinewan continued to play a significant role in the habitual, spiritual, and cultural lives of the Aborigines. In the endeavor to understand the 60,000-year-old relationship between the emu and the Aborigines, novel nutritional, cosmetic, and medicinal uses of emu have come to light. Emu products are a great source of lean protein, and the oil rendered from its fat has proven to be effective in treating a plethora of ailments from allergies and arthritis to broken bones and mucositis, a side effect of cancer chemotherapy (Lindsay et al. 2010).

EMU ECOLOGY

The emu (*Dromaius novaehollandiae*) is a member of the ratite family of flightless birds and is the second largest bird in the world behind its African ratite cousin, the ostrich. The females are the larger of the species, able to reach over 1.8 meters tall and weighing 50-55 kg, compared to about 1.5 meters and 35-40 kg for the males (Fowler 1991). With the exception of the legs and feet, the entirety of the emu body is covered with dark colored, two-shafted, furry feathers (Fowler 1991). The species is endemic to all of Australia, but exists in lowest numbers in the most extreme environments: very arid regions and the denser forested areas east of the Great Dividing Range (Fowler 1991).

Despite having lost the ability to fly, or perhaps because of it, the emu is an especially adept runner. In their study "Adaptations to high speed running", Patak and Baldwin (1998) studied the specific cursorial adaptations that enable emus to sustain running speeds of 50 kilometers per hour. They concluded that the pelvic and thigh muscles associated with running maintain a similar metabolism to the flight muscles in volant birds, and placed the running ability of the emu somewhere between the tireless aerobic flight capacity of the hummingbird and the powerful anaerobic burst flight of chickens. One adaptation unique to the emu even among its fellow ratites is the four-bellied gastrocnemius muscle used for plantar flexion of the foot, a motion integral to a fast and powerful stride. This extra muscle increases the area of the origin point of the muscle allowing for a stronger contraction (Patak and Baldwin 1998). Its existence may be the result of a migration of abductor and adductor muscles toward the sagittal plane of the lower leg, and serves to keep more of the animal's momentum in the cranial-caudal, rather than the medial-lateral, direction (Patak and Baldwin 1998).

In the arid land of nutrient-poor soil that is Australia, the emu needs its running ability to cover great distances in order to forage enough food for survival. It also helps that emu have what Davies (1978) refers to as a "catholic" and seasonal diet (Figure 1) that includes a wide array of plant shoots, seeds, and fruits as well as insects and even small lizards when they are available.

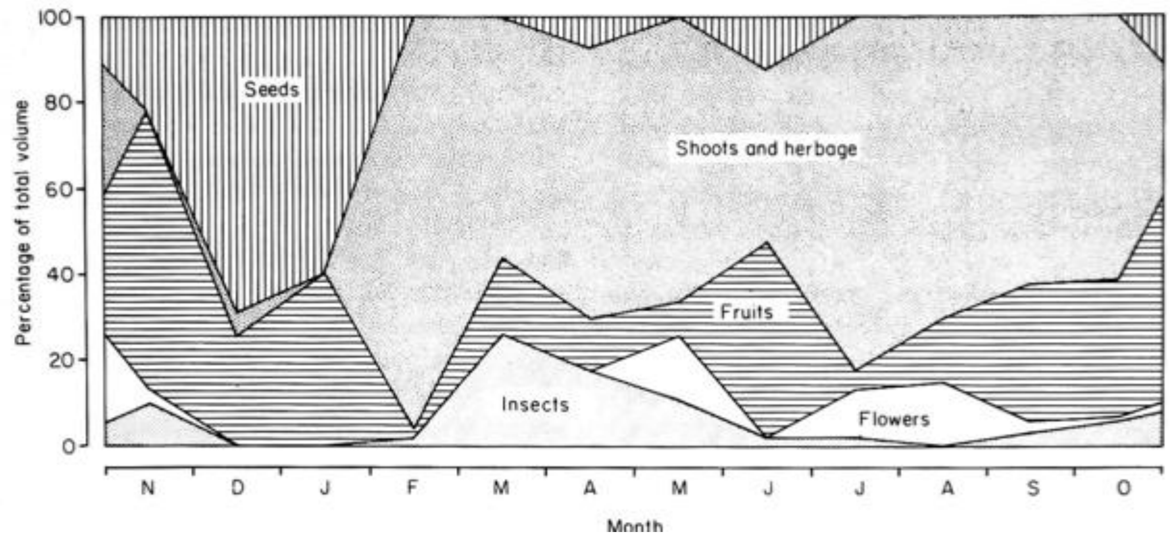

Figure 1. The emu is a highly opportunistic feeder whose diet exhibits great seasonal variation (Davies 1978).

Despite their propensity for consuming a wide array of foods, emu do show preferences when choices are available. Due to the aridity of their habitat, emus will always choose the more succulent plants and insects over other drier foods (Davies 1978).

Through study of emu eggshell carbon composition, Johnson et al. (2004) and Miller et al. (2005) were able to highlight two distinct occasions in the history of Australia when the diverse diet of the emu has saved it from starvation-driven population collapse and even extinction. The most recent event happened about two hundred years ago, upon arrival of the pastoral Europeans in Australia. Soil degradation due to overgrazing led to a collapse in the C4 plants (mostly grasses and succulents) preferred by emus and an abundance of C3 plants (woody plants, shrubs) (Johnson et al. 2004). The previous time this shift in plant biomass happened coincided with the arrival of the Aborigine and related mass extinctions between 60,000 and 45,000 years ago. That event appears to have driven the larger ratite relative of the emu, *Genyornis newtoni*, a more specialized feeder, to extinction (Miller et al. 2005).

In the dry season, when succulent foods are rare, the emu subsists on a high fiber diet of grasses. Many fiber-eating avian species have relatively large hindguts used for fermentation of plant material to better extract nutrients. Emu do not have this specific adaptation, but are equipped with an elongated cecum and can convert up to 45% of their fibrous intake into energy (Herd and Dawson 1984). The birds ingest small pebbles or other hard materials and store them in their gizzards for periods of three months or more, which helps in the breakdown and extraction of nutrients from fibrous foods (Davies 1978). This ability benefits not just the emu, but also the many plant species it ingests. A 2006 study sampled 112 emu droppings and discovered 68 different species of viable seed (Calvino-Cancela et al. 2006). The ability of the emu to travel great distances and store ingested material in the gizzard for several months hints at the major role they have played and continue to play in plant seed dispersal in Australia.

Emu do not tend to be social birds, but they exhibit a great curiosity and little fear. The necessary social activity of breeding occurs from December through April (Patodkar et al. 2009). A male and a female will pair off and mate several times throughout the season. The female will lay seven to twenty eggs, which are then left in the care of the male for incubation (~56 days) and rearing (~4 months) of the young (Fowler 1978). The only time emu will flock is in areas of abundant food. This does not seem to be true social behavior, but merely a utilitarian means to prevent predation, as each member of the group can spend more time foraging and still be alerted to the presence of any predators (Boland 2003). In a study conducted on large groups of wild emu in New South Wales where humans have hunted emu for 60,000 years, as flock size increased, individual vigilance decreased as did the time it took to detect predators, as can be seen in Figure 2 (Boland 2003).

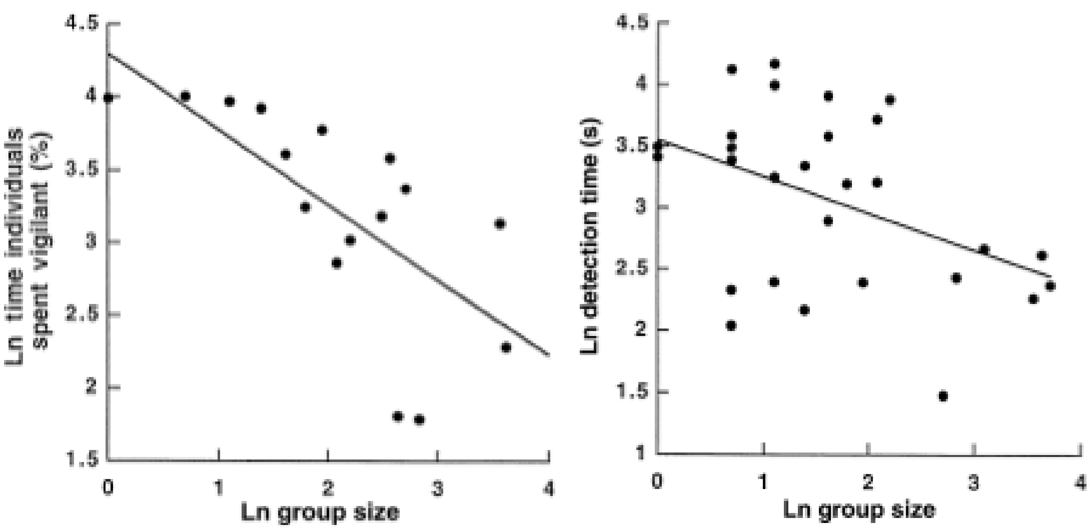

Figure 2. Effect of group size on individual vigilance and predator detection (Boland 2003).

ORIGIN OF THE EMU

The Aboriginal Dreamtime story of the creation of the emu, as told by K.L. Parker in a collection by J. Lambert (1993), goes like this:

> During a fierce battle between two tribes, a young man named Dinewan who was not involved was struck through the chest with a spear and died. Distraught, his mother

journeyed with her son's body to his spirit tree, where she knew his spirit would go upon leaving the body. Three days she waited there, circling the tree ceaselessly. When the spirit arrived, she grabbed it and breathed it back into the man's body. He rose and together they walked back to their tribe. As they neared the village, all were stunned to see this man they thought to be dead walking across the heath toward them. They cried out in joy "Glad to see you, uncle!" But as they did, they saw him turn as if to run away, and they saw his body change into the largest bird they had ever seen, the bird known to the Aborigine as Dinewan, the emu. And still today, the emu has a dent in the top of its chest where the spear entered the chest of Dinewan the man.[1]

There has been much research into the evolutionary origins of the emu, and of its ratite family in particular, that is no less fascinating than Aboriginal myth but does pay greater heed to chronology. Exactly how and when the ratite family lost flight ability and spread out geographically has been a quandary for over a century. Ratites belong to an evolutionarily ancient group of birds called the palaeognaths, a designation based on the bone structure of the palate, which includes only ratites and the volant tinamous family (Harshman et al. 2008). In the 19th century the debate raged as to whether ratites lost the ability to fly or branched off the phylogenetic tree before the tinamous family, considered one of the more ancient bird groups, gained flight. Both sides of this debate were based on anatomic and morphologic arguments. Thanks in part to the work of deBeer (1956), a consensus was reached that ratites in fact did have a volant ancestor based on structures of the wing and skull. But in the same paper where he presented his findings (deBeer 1956), he posed the next ornithological puzzler: Were the ratites a single group or did their loss of flight happen in parallel fashion on the continents they inhabit?

Theories abounded, but it wasn't until the advent of DNA and protein analysis that promising answers began trickling in and consequently the ratites became a proving ground for new techniques in evolutionary biology. In the early 1980's it was generally assumed that the breakup of the southern supercontinent Gondwana accounted for the geographic distribution of the flightless birds, and all that was left to answer was the order of the relations between ratites and their common ancestor (Edelson 1980). But the more biologists sought to close the door on this mystery, the more questions arose, not the least of which involved the growing knowledge of plate tectonics.

Ratites can be found throughout the Southern Hemisphere. Africa's ostrich, South America's rhea, Australia's emu and cassowary, New Zealand's kiwi, and extinct species in New Zealand and Madagascar suggest a Gondwanan origin for the ratite lineage. But an estimated divergence of these species beginning 90 million years ago, and the breakup of Gondwana, beginning with Africa 150 million years ago, presented a problem: the ostrich would have had a long swim between Gondwana and Africa (vanTuinen et al. 1998). A mtDNA analysis by vanTuinen and company (1998) seemed to finally set the record straight[2]. The team compared ratite mtDNA for mutations that occur at a constant rate over time and came up with this phylogenetic tree:

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[1] Note to the reader: Please disregard any penchant to assume a linear chronology between this and the previous creation myth; they took place, after all, in the Dreamtime, "the vast epoch that occurred, according to the Aborigines, before time began. " (Lambert 1993)

[2] vanTuinen et al. used the entirety of the 12SrRNA, t-RNA^{Val}, and 16S rRNA mtDNA regions for comparison.

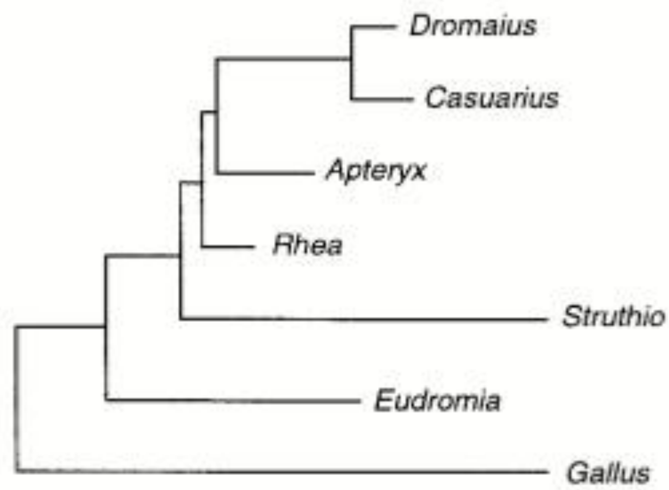

Figure 3. mtDNA-based phylogeny of ratites (from top to bottom: emu, cassowary, kiwi, rhea, ostrich, tinamous, chicken) (vanTuinen et. al. 1998).

Based on this interpretation the ostrich was the first ratite to differentiate, yet after divergence of the tinamous family. With regards to the Gondwanan problem, the team offered two possible scenarios. The first was that ratites diverged in Africa. The ostrich stayed put while its pioneering cousins dispersed into Laurasia (the Northern hemisphere equivalent of Gondwana), through modern-day Europe and North America, across a pre-Caribbean land bridge, into South America where more divergence occurred. They then crossed another land bridge into Antarctica and onto the Australian land mass before it finally broke away (vanTuinen et al. 1998). The second scenario involved a South American origin wherein the ostrich diverged and traveled the reverse route into North America, Europe, and Africa. The Australasian ratites diverged later and crossed Antarctica and into Australia (vanTuinen et al. 1998).

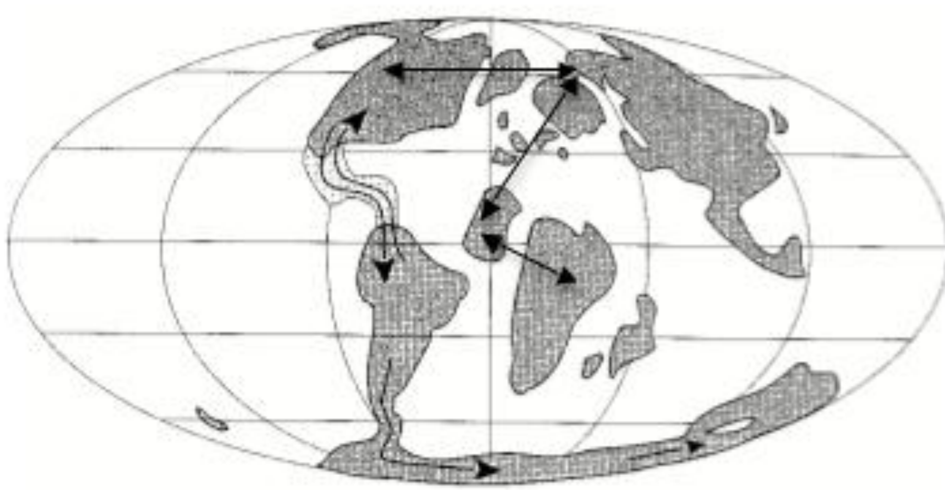

Figure 4. Possible migration routes of ratites based on mtDNA phylogeny (vanTuinen et al. 1998).

Regardless of migration routes, this proposed phylogeny was the general consensus for a decade, until further advances in DNA technology led to a team of researchers turning this theory on its head in 2008. Using a similar technique to that of vanTuinen et al. on twenty common avian loci on nuclear DNA[3], researchers found evidence that the common ratite ancestor was able to fly to the respective continents and there were likely three separate losses of flight among the ratites (Harshman et al. 2008; Figure 5).

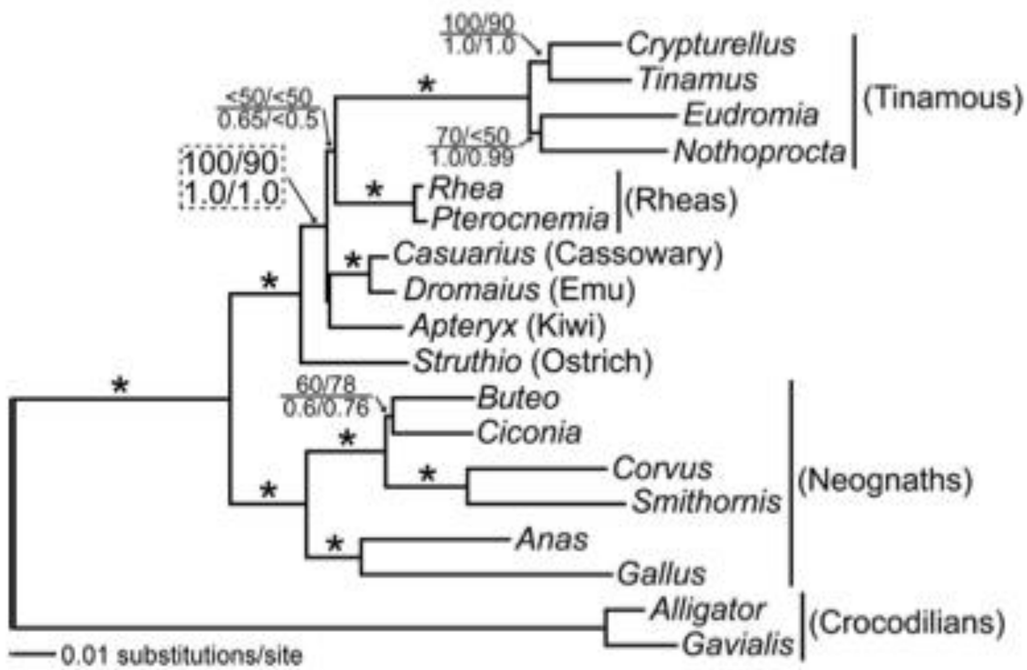

Figure 5. nDNA-based phylogeny of ratites. Branches for which all support measures were 100% are indicated with an asterisk (Harshman et. al. 2008).

The results unequivocally pointed toward a late divergence of the volant tinamous. This meant that either the tinamous evolved out of and then back into flight or that there were three convergent losses of flight among ratites: one in South America, one in Africa, and one in Australasia (Harshman et al. 2008). The latter theory seemed to solve the Gondwana problem in a much more elegant fashion than previous studies and had unequivocal support from the body of evolutionary knowledge. There are no known instances of a species evolving out of a trait and then back into it, but evolutionary losses of organs, limbs, and faculties are well documented across the animal kingdom. Flight ability is a common loss for birds, occurring independently across eight different orders and driven by ecological factors such as a lack of predators (e.g., the renowned dodo), a specific advantage to larger body size or altered wing morphology (e.g., penguin wings adapted for swimming), or energy conservation in the face of scarcity (McNab 1994). All of these circumstances are applicable in the case of the emu. Harshman and company

[3] The loci used in the Harshman et al. study are as follows (gene symbol - chromosome): ALDOB – Z, BDNF – 5, CLTC – 19, CLTCL1 – 15, CRYAA – 1, EEF2 – 28, EGR1 – 13, FGB – 4, GH1 – 27, HMGN2 – 23, IRF2 – 4, MB – 1, MUSK – Z, MYC – 2, NGF – 26, NTF3 – 1, PCBD1 – 6, RHO – 12, TGFB2 – 3, and TPM1 – 10.

recognized their discrediting of the long held beliefs about a single loss of flight and the fantastical migration of ratites, and even eulogized it in their report with a quote by famed ornithologist T.H. Huxley concerning "the great tragedy of science – the slaying of a beautiful theory by an ugly fact" (Harshman et al. 2008).

Because of the contradictory nature of phylogenies built using mitochondrial DNA (mtDNA) versus those derived from nuclear DNA (nDNA), evolutionary biologists have argued over which is more apt to uncover the natural relationships among organisms. The debate is ongoing, with staunch advocates on both sides. mtDNA has given us decades of information, most of which has been taxonomically useful (Rubinoff and Holland 2005). However, considering that it represents a small and idiosyncratic percent of the genome, it is now considered to be less accurate than the multi-locus analysis of nDNA, especially in examining broad phylogenies such as that of the entire ratite family (Rubinoff and Holland 2005).

Extensive anatomical analyses have recently been conducted in an effort to further elucidate the divergence of ratites from volant birds. Comparative studies of the emu tongue (Crole and Soley 2010), feathers (Chernova and Fadeeva 2009), nervous tissue (Weir and Lunam 2006), and skin (Weir and Lunam 2004) have yielded interesting results in terms of structure. The latter study illustrated unique variation in emu skin, notably a more significant dermal fat store than most any other bird, but ultimately concluded that emu skin is not histologically or morphologically distinct from other birds (Weir and Lunam 2004). While not particularly helpful in phylogeny, such studies are invaluable for their insight into evolutionary processes that occur in conjunction with loss of flight.

SURVIVAL AND SUCCESS IN AUSTRALIA

Whatever the ratite habitat is on other continents, a large portion of the range of the emu in Australia lies in the vast, arid, sun-drenched interior where this diurnal bird must forage for scarce resources in the hot sun. The average summer temperature in central Australia is 36°C with fewer than 28 cm of rain (Australian Government 2011). In this habitat, the prosperity of the ecosystem is dependent on economy of resources. It would seem at first that the dark colored feathers of the emu would be a distinct disadvantage in these climes where solar radiation reaches levels upward of 1000 W/m^2 (Maloney and Dawson 1995). Their specialized double-shafted feathers absorb 90% of this radiation near the surface of the plumage, thereby preventing it from ever reaching the skin, and are even more efficient if there is even the slightest wind (Maloney and Dawson 1995). This deflection saves the bird from having to take in an inordinate amount of water for thermoregulation, which is in short supply in the Australian outback.

Another adaptation that contributes to the long success of the emu in a harsh land is a low resting metabolic rate. Studies done across a spectrum of avian species set a standard curve for metabolism of non-passerine (simply put, birds that do not perch) species based on body mass, and the emu comes in 20-25% lower than the expected values for its mass (Calder and Dawson

1978). In addition to its widely varied diet, the emu has an insurance policy in its low energy needs. Calder and Dawson (1978), in studying the kiwi and emu, speculate that low metabolic rates may have coevolved with the loss of flight. Such an energy advantage may have been a driving force of ratite evolution in Australasia.

The Aborigines have been in a symbiotic dance with the emu for their entire tenure on the Australian continent. Ever since the Dreamtime when Dinewan was transformed into an emu, the abundant and flightless bird has been such a ubiquitous symbol of rebirth and a connection to the world of spirits that the ceremonial dance performed at Aboriginal funerals is an imitation of emu behavior (Lambert 1993). The corporeal connection to the emu is equally as strong, as it has been food and medicine to the Aborigines for millennia. In his impressive treatise entitled "Aboriginal subsistence in the Western desert", Cane (1987) implicates emu meat and eggs as integral to the Aboriginal diet year-round, despite not seeing a bird harvested throughout the course of his study (Figure 6).

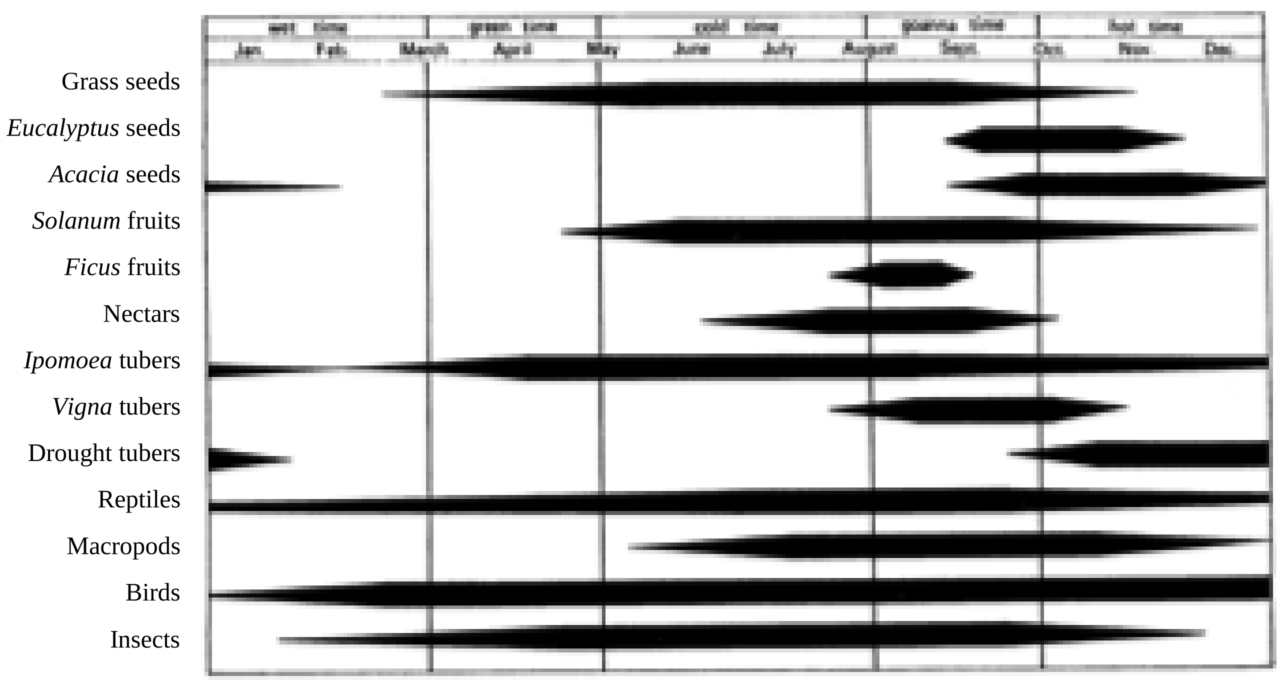

Figure 6. Composition of the Aboriginal diet in Western Australia. Birds (including emu and their eggs) are a steady source of nutrition year-round and are critical as the hot time gives way to the wet time, before the nourishing rains take effect (Cane 1987).

Contrary to Cane not witnessing an emu kill, evidence exists of extensive hunting in a bygone era. Aboriginal traditional hunting methods often exploited the natural curiosity (and small brain) of the emu by using whistles, shiny objects, even flailing of the arms and legs to lure unsuspecting birds into nets or pits (Isaacs 1987). Another method of emu hunting described by Isaacs (1987) included the use of toxic plants in watering holes and immediate butchering of disoriented animals (the toxins would dissipate after the next rain).[4] These methods may seem somewhat uncouth, but the great respect of the Aborigines for their ancestor Dinewan is evident in the reverence paid to the deceased animal. Young hunters taking their first emu are instructed to lie atop the bird, empathizing with the bird and recognizing its death provides life through nourishment (Lambert 1993). Some tribes were also in the practice of skinning the bird, stuffing the feathered hide with grasses and using sticks to peg the openings together again, allowing it to retain its form during the three days it may take the spirit to move on (Lambert 1993 and Isaacs 1987).

These sorts of practices were widespread in Aboriginal society in which the health and well-being of the tribe and all its individuals depended on strict adherence to the Dreamtime law. Illness and injury were seen as swift punishment doled out by spirits for deviance from social mores, so bush medicines were often used to alleviate symptoms while the root cause was sought out (Cawte 1975). Sorcerers were sometimes tasked with handing out punishments to taboo-breakers, illustrating both the psychosomatic aspect of sickness and the rule of law inherent in Aboriginal medicine (Maher 1999). Because of the assumed connection with the spirit world, sorcerers often used emu leg bones as a wand when casting their spells (Byard 1988).

More often than not, the emu was a force for good in Aboriginal culture, and we are still discovering just how good it was. The meat from the emu was determined by a University of Wisconsin study to contain higher levels of protein, creatine, and heme iron than deer, cattle, bison, elk, ostrich, or turkey (Pegg et al. 2006). The lipid profile of emu meat is highly favorable. It contains higher levels of essential fatty acids than do chicken or beef, and the ratio of health-promoting polyunsaturated fatty acids to saturated fatty acids is 26% higher than in chicken and a remarkable 240% higher than in beef (Pegg et al. 2006). These discoveries led to the advent of a new livestock industry, and emus are now commonly raised for meat, leather, and the oil rendered from their fat.

Emu oil may be the blockbuster drug to arise out of Aboriginal medicine. Emu fat is used by the Aborigines in several ways, but primarily as a liniment for soothing cuts, burns and scrapes, as well as for alleviating arthritic symptoms (Fein et al. 1995). It is also used as a vehicle for topical botanical medicines, and recent composition analyses have shown a number of permeation enhancers inherent in the oil (Lindsay et al. 2010). Its use was so important and universal among the Aborigines that traditionally children were taught the techniques of its preparation and use at a young age (Pearn 2005).

Currently, emu oil is produced commercially by rendering the roughly 10 kg of fat on a mature bird with heat and filtration (Whitehouse 1998). Therapeutic properties can vary greatly depending on the diet and lifestyle of individual birds, with oil from feral birds exhibiting the best fatty acid profile, most efficacy in reduction of arthritic swelling, and an analgesic quality comparable to that of naproxen (Whitehouse 1998). These results were supported by a later study on artificially swollen ears of lab mice, which showed a great reduction in edema only six hours after emu oil application (Lopez et al. 1999). Results of the study done by Whitehouse et al. (1998) show a spectrum of efficacy in the reduction of musculoskeletal swelling between back and gut fat in feral versus farmed emu (Table 1).

[4] Coincidentally, one of the common toxic plants used in the interior desert for this method, *Prostanthera striatiflora* (Lamiaceae), has recently drawn the attention of cancer researchers as a potentially therapeutic drug at low doses (Mijajlovich et al. 2006).

	Percent reduction (on day 14) of paw swelling (%)	
Bird/Fat source	**Rear**	**Front**
Feral, gut fat	70	33
Feral, back fat	50	11
Intensive farmed, gut fat	55	24
Intensive farmed, back fat	28	5
Naturally farmed, gut fat	59	54
Naturally farmed, back fat	23	51

Table 1. Reduction of swelling in arthritic rats by application of emu oil (adapted from Whitehouse et al. 1998).

The Whitehouse et al. (1998) study also produced evidence that among farmed birds, oil from those farmed in Australia had far better therapeutic properties than those farmed in North America or Europe. There is 1-2% of emu oil composition that has not been positively identified, but it is thought to contain a varying mixture of natural antioxidants and other enhancers (Lindsay 2010). The Australian birds were farmed by Aborigines, suggesting that a more natural, stress-free state (due to a unique knowledge of the emu that is not present in the west) creates a more therapeutic composition in the oil (Lindsay 2010). This discrepancy exists despite a plethora of research-based data available on emu husbandry techniques, embryonic development, sperm quality, and all the trappings of contemporary agriculture.

Efforts to apply the therapeutic properties of emu oil to cancer research have been promising, at least in the alleviation of symptoms caused by chemotherapy. Mucositis is a common and serious side effect of chemotherapy treatments characterized by a deterioration of the mucosal lining of the gastrointestinal tract. Citing the now well-documented anti-inflammatory and analgesic properties of emu oil, Lindsay et al. (2010) set out to test it against this disorder. After oral administration of emu oil to rats suffering from mucositis, histological samples of intestines were taken and results measured by villus height, crypt depth, and specific biochemical markers, all of which are known to be reliable indicators of the severity of mucositis (Lindsay et al. 2010). The researchers concluded that emu oil had no preventative effect against mucositis, but that it did decrease inflammation in the small intestine and made for better and faster recovery from the disorder (Lindsay et al. 2010).

A study by Wilson et al. (2004) suggests that the ability of emu oil to reduce atherosclerosis in mice was equal to that of olive oil and is significantly better than olive oil at reducing total cholesterol and increasing the ratio of HDL to LDL. Crude emu oil consistently produced better results than refined emu oil in these studies. A U.S. patent was awarded in 1995 for therapeutic use of emu oil, with the inventors citing its ability to lower cholesterol and providing anecdotal evidence of its ability to increase growth rate and health of nails, prevent allergy symptoms, smooth out aging wrinkles, treat migraine headaches, prevent and erase scarring, treat sore throats, and reduce symptoms of PMS in women (Fein 1995).

In light of what Aboriginal culture has brought to the realm of natural medicine in the form of emu oil, it is harrowing to think of what has been lost. Whereas for the past 60,000 years Aboriginal children were brought up in the oral tradition of bush medicine, by the turn of the millennium, a survey indicated only 1 in 5 Aboriginal people had used traditional medicines in the past 6 months (Maher 1999). No matter the fate of the Australian Aboriginal way, the light it shone on the emu has been a boon to contemporary evolutionary and medicinal sciences. And for its part, the extraordinary emu will abide and adapt as it has for millions of years: as a testament to the resiliency and resourcefulness of body and spirit on Earth and in the Dreamtime.

ACKNOWLEDGEMENTS

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Figure 7. The emu in the sky, seen as dark clouds in the Milky Way, stands above her engraving in Ku-ring-gai Chase National Park. She is only seen in this position when real-life emus are laying their eggs. (Norris 2007)

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