Pre-Columbian chickens of the Americas: a critical review of the hypotheses and evidence for their origins

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Abstract

The publications by Storey et al. (2007, 2008a, 2008b) describing the discovery and radiocarbon dating of pre-Columbian chicken remains from the archaeological site of El Arenal-1 in south central Chile reinvigorated longstanding debates about the presence of prehistoric domestic chickens in the Americas. Some have questioned the validity of the link between prehistoric Polynesian voyagers and the pre-Columbian chickens of El Arenal-1, requesting more details to verify the dates and the likely origin of the introduction. In this paper we provide an expanded account regarding the dating of the chicken remains from the site of El Arenal-1 in order to reaffirm their authenticity. Their prehistoric age established, we focus attention on a critical reanalysis of arguments surrounding the source of the first introductions of chickens to the Americas. These include historic accounts and hypotheses developed as a result of comparative morphology. Particular attention is focused on assessing the utility of evidence from the study of physical characteristics of both black-boned, black-meat chickens and the phenotypic traits of the Araucana (*Gallus inauris*) breed to support pre-Columbian introductions. As a result, we reinforce the previous hypothesis that a pre-Columbian introduction of chickens from Polynesia is the most parsimonious explanation for the available evidence.

Introduction

Prior to 2007, prevailing wisdom that Europeans introduced the first chickens to the Americas seemed to be supported by the available archaeological and historical evidence. Notable scholars including Charles Darwin (1875) gave consideration to the issue and found there was insufficient evidence for pre-Columbian chickens in the New World, despite the linguistic arguments presented by de Acosta (2002 [1590]). However, scholarly debate continued to present circumstantial evidence from both linguistics and morphological characteristics that seemed to suggest non-European sources for some American chicken flocks. This kept constant pressure on the dominant view and left many scholars feeling that the issues had never been fully resolved. On several occasions, George Carter (1975, 1981, 1998) had insinuated that secure pre-Columbian chicken bones existed in more than one American archaeological site. Unfortunately, none of the archaeological or chronometric data associated with these remains were provided for evaluation by the academic community. It was not until 2002 that the recovery of chicken bones from a pre-Columbian archaeological context on the south central coast of Chile provided a unique opportunity to directly assess the possibility that chickens were introduced to the Americas in prehistory.

The El Arenal-1 Chickens

The site of El Arenal-1 is located 5km inland from the coast of Chile on the south bank of the Quidico estuary, in the Arauco Province, Biobío Region, approximately 100km south of the city of Concepción (Figure 1). It is associated with large areas of active dunes known as El Arenal. The site itself is a sandy mound situated on the northern edge of the seasonal plain in a small watershed. Surface deposits exposed through erosion suggest the site may occupy an area of at least 350m^2. Between 2002 and 2008, five grids and a total of 15m^2 were excavated (see Figure 2 for a sketch map of the 2002 excavation units). The excavations revealed a clear stratigraphic sequence composed of five levels (I-V), of which III (Layers A and B) and IV (Layer C) correspond to periods of human occupation (Figure 3). Levels II and V were culturally sterile. Level I produced very little cultural material and no indication of European contact (Contreras et al. 2005). The chicken bearing strata were contextually associated with remains from the El Vergel Cultural Complex which began *circa* AD 1000 and persisted until the arrival of Europeans.

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Figure 1. Location of El Arenal-1 and other places in Chile mentioned in the text.

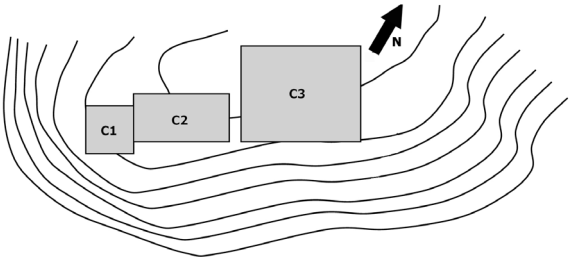

Figure 2. Sketch map of the 2002 excavations at the El Arenal-1 site in Chile showing the main excavation units.

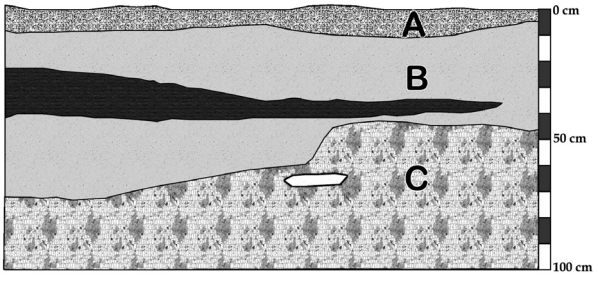

Figure 3. Stratigraphic profile of North Wall, Quadrant 2. This shows the regular and largely undisturbed layers described as A-C. Layer A was a matrix of yellowish brown sand with some organic content. Layer B was predominantly a brown sand matrix with carbon lenses, features, and clay conglomerations. The lowest stratum, C, was made up of a greyish brown sand with carbon lenses, clay conglomerations and features. The analysis of the ceramics recovered from the distinct layers demonstrated that they have not migrated between stratum. This indicates relative chronological security of the deposits. For more information the reader is directed to Contreras et al. 2005.

Analysis of the site's faunal assemblage revealed exploitation of a number of environments including wetlands, coastal, and marine. The assemblage included Chilean frogs (*Caudiverbera caudiverbera)*, ducks (*Anas flavirostis* and *A. georgica*) and coypu (*Myocaster coypus*), a semi-aquatic rodent, in addition to several domesticated or semi-domesticated animals including guanaco (*Lama guanicoe*), South American gray fox (*Pseudalopex griseus*) and chickens (*Gallus gallus*). These tamed species were probably introduced to El Arenal-1 and, in the case of guanacos and foxes, were likely also transported to nearby Mocha Island in prehistory (Becker 1997). Other evidence for subsistence included a botanical component of domesticated plants including quinoa (*Chenopodium quinoa*), pursulane (*Portulaca oleracea*) and five charred ears of corn (*Zea mays*).

Chicken bones were predominantly from the stratigraphically secure Layer B, in Level III. The chicken remains recovered during the 2002 investigations were initially discussed in Storey et al. (2007) and included 50 bones representing a minimum of five individual chickens. Subsequent excavations at the site resulted in the collection of another 33 elements identified as chicken from the same cultural and archaeological context (Quiroz et al. 2008).

The first occupation of the El Arenal-1 site is associated with a thermoluminescence (TL) date of AD 700 ± 130 from Layer C, which contained less cultural material than later occupations but greater percentages of shellfish and fish remains. Several dates were also obtained from Level III deposits (Layers A and B) from TL dating of contextually associated ceramics. All of these dates fall in the later pre-Columbian era for the Americas. In addition, the cultural chronology indicates that the site was abandoned prior to European contact (Contreras et al. 2005), as no artifacts associated with a European presence have ever been recovered. The available dates and pre-Columbian material culture point to a non-European source for the presence of chickens at El Arenal-1.

Dating the El Arenal-1 Chickens

Given the pre-Columbian context of these chicken bones and the associated TL dates, obtaining direct dates for the remains was of paramount importance. Post-contact remains could have been introduced from Europe, the Pacific or from Asia, depending on the age. Alternatively, very old chicken bones predating the Polynesian expansion may have pointed to direct introductions from Asia. However, pre-Columbian

remains that fell within the range of AD 1000 to 1400, as suggested by the cultural associations and TL dates, would fit within the period of eastward expansion of Polynesian voyagers. In addition, it would also lend support to other independent lines of evidence for pre-contact Polynesian landings along the west coast of the Americas (Jones et al. 2011). Three individual bones from the El Arenal-1 site were sent to the Rafter Radiocarbon Laboratory in New Zealand for radiocarbon dating using accelerator mass spectrometry (AMS).

The first sample sent for dating was designated CHLARA001 and produced an uncalibrated radiocarbon age of 622 ± 35 BP (NZA 26115) (Table 1). Stable isotope analysis for $\delta^{13}C$ was also provided for this sample (*cf.* Beavan-Athfield et al. 2008) but due to the small amount of material available for analysis after the requirements for mitochondrial DNA (mtDNA) testing and replication, there was insufficient sample material for a $\delta^{15}N$ measurement. However, the $\delta^{13}C$ value of -20.9‰ sits well within the range expected for terrestrial herbivores (Storey et al. in prep). This value indicates no significant marine contribution to the diet of the chicken, and therefore does not require a calculation of a ΔR offset to the radiocarbon age due to marine reservoir effects (Stuiver et al. 1986).

Subsequently, two additional chicken bones were sent for radiocarbon dating. Samples CHLARA003 and CHLARA004 provided ages of 510 ± 30 BP (NZA 28271) and 503 ± 30 BP (NZA 28272), respectively. These estimates were slightly younger than the first radiocarbon date and the two TL dates from Layer B ceramics [650 ± 65 BP and 610 ± 55 BP (Storey et al. 2008b)]. The results, however, confirm the previous observation that the calibrated calendar date ranges for the El Arenal-1 chicken bones, even at two standard deviations, fall within the pre-Columbian era (Table 1).

To further examine the possibility that marine foods were part of the El Arenal-1 chickens' diets, we obtained measurements of ^{15}N and ^{34}S for CHLARA003 and CHLARA004, as sample sizes allowed (Table 1). The $\delta^{13}C$ values are in the terrestrial range, and the $\delta^{15}N$ values are associated with an herbivore diet trophic level (DeNiro & Epstein 1978, 1981); moreover, even the single $\delta^{34}S$ value for CHLARA003 substantiates a terrestrial-range diet (Krouse & Herbert 1988). These additional data confirm our original observation for CHLARA001 (Storey et al. 2007) that the pre-Columbian chickens of El Arenal-1 did not derive protein from marine sources and thus did not require a marine offset correction to their radiocarbon ages. Furthermore, the atomic carbon to nitrogen ratios (C:N; Table 1) also indicate that the protein derived from the samples in question was well-preserved, and within the C:N range for modern bone protein [2.9 and 3.6 range (DeNiro 1985)] establishing that the radiocarbon ages derived from those samples are reliable.

The radiocarbon and TL dating of the El Arenal-1 assemblage demonstrates that chickens were introduced to the west coast of the Americas well before de Molia introduced them to Peru in AD 1528. They also predate the AD 1492 voyage of Columbus to the West Indies. As a result, even at the latest possible portion of the 2σ range of the youngest [503 ± 30 BP (1427-1459 cal AD)] directly dated chicken bone, those of El Arenal-1 are *at least* 40 years older than those introduced to Brazil by Álvares Cabral in AD 1500. With the definitive evidence from direct dating, it is confirmed that chickens recovered from El Arenal-1 were indeed pre-Columbian in age. As a result, we examined the evidence from mtDNA sequences to investigate the genetic affinities and thus determine the likely origin of these individuals.

The Mitochondrial DNA of the El Arenal-1 Chickens

To date, with the exception of studies by Storey et al. (2007, 2010), phylogeographic reconstructions of chicken domestication centers and subsequent dispersals have been based on modern mtDNA data (e.g., Akishinonomiya et al. 1994; Komiyama et al. 2004; Liu et al. 2006). However, few of these studies have acknowledged factors such as long-standing trade and exchange networks, industrialization of poultry production, and the intensive crossbreeding of chickens to develop show breeds. These more recent events are likely to obscure and mask early phylogeographic

Sample Number	Lab Number	Conventional Radiocarbon Age (CRA)	Calibrated Age (2σ)	$\delta^{13}C$‰	$\delta^{15}N$‰	$\delta^{34}S$‰	C:N
CHLARA001	NZA 26115	622 ± 35	650 -500 cal BP AD 1304-1424	-20.9	n.d.	n.d.	n.d.
CHLARA003	NZA 28271	510 ± 30	550-450 cal BP AD 1427-1459	-19.85	2.6	2.16	3.2
CHLARA004	NZA 28272	503 ±30	550-450 cal BP AD 1426-1457	-19.45	3.5	n.d.	3.2

Table 1. Radiocarbon determinations and associated isotope data for three chicken bone samples from El Arenal-1. Conventional Radiocarbon Ages (CRA) were calibrated and calendar age ranges determined using CALIB 3.0 (Stuiver and Reimer 1993) and a Southern Hemisphere atmospheric curve (SHCal04; McCormac, et al. 2004) and are reported at 2σ. All isotope values are represented as parts per mil (‰). Atomic C:N ratios are within expected parameters for well preserved protein.

signals indicating the initial founding population origins. In fact, Crawford (1984: 305) observed that "[s]ince the mid 19th Century, domestic fowl have undergone a rate of evolution exceeding that which occurred in all the centuries following domestication." Thus, in order to avoid complicating historical factors, we focused our studies on analyses of ancient DNA from chicken remains recovered from archaeological contexts in order to identify the path of prehistoric chicken dispersal out of Asia and across the Pacific (Storey et al. 2007, 2010).

The introduction of chickens to the Pacific Islands is associated with the spread of the Lapita Cultural Complex, which first appeared in Near Oceania around 3350 BP and rapidly expanded into Remote Oceania. Chickens reached the Reef Santa Cruz Islands and Vanuatu by 3100 BP and Samoa and Tonga, at the edge of the Polynesian Triangle by 2900 BP (Beavan-Athfield et al. 2008; Storey et al. 2008a, 2010). The Lapita peoples introduced a range of plants and animals to the islands they colonized in an economic strategy often referred to as a transported landscape (Kirch 2000). Chicken bones have been recovered from the earliest Lapita occupation layers in Remote Oceania, where they were found in direct association with the distinctive dentate stamped pottery that is one of the defining components of Lapita sites (Storey et al. 2010).

To date, two mtDNA lineages have been identified in archaeological chicken remains in the Pacific. Early Lapita associated chicken bones from Vanuatu, along with remains from slightly later post-Lapita sites in Samoa and Tonga all belong to Haplogroup E (Storey et al. 2010). A later dispersal of chickens into the Pacific has been detected, which is represented by Haplogroup D (Storey et al. 2007). It appears that these two lineages converged in Central Eastern Polynesia before being dispersed to Hawai'i and Rapa Nui. To date, only Haplogroup E has been detected in pre-Columbian chicken bones from Chile, which has led some authors to question the validity of the ancient DNA results and our hypothesis for a Polynesian introduction (Gongora et al. 2008a, 2008b). In light of our new archaeological and radiocarbon evidence, we critically review the alternative hypotheses to account for the introduction of chickens to the Americas. This review confirms our hypothesis that a Polynesian introduction is the most parsimonious explanation for the origin for the pre-Columbian chickens at El Arenal-1.

Understanding the Complex Origins of American Chickens

Prior to the excavation and direct dating of the El Arenal-1 chicken remains (Storey et al. 2007), arguments for pre-Columbian chicken introductions were reliant on evidence from early ethnographic and historical literature, comparative linguistics and the morphology of contemporary chicken populations in widely separated geographic locations. As a result, the evidence supported the conventional story that chickens were first introduced to continental South America by early Portuguese and/or Spanish explorers (Nordenskiöld 1922; Seligmann 1987), the first of whom was Pedro Álvares Cabral (Greenlee 1939). However, an analysis of European historical accounts reveals that the early distribution of chickens in the Americas may be too wide to be satisfactorily explained solely by introductions after European contact with the New World. This conundrum led numerous scholars to speculate about the existence and origins of earlier, pre-Columbian chicken introductions to the Americas (Austin 1961; Carter 1971, 1975, 1998; Hargrave 1972; Johannessen 1982; Langdon 1989; Ramírez 1990). As an alternative to the predominant view that the first chickens came via Spanish and Portuguese sailing ships, Polynesian and Asian contacts have been proposed as possible sources for west coast introductions (Gilmore 1950; Green 2001; Johannessen 1982; Langdon 1989; Meggers 1975; Sauer 1952). In addition, the Norse have been identified as a possible source of pre-Columbian introductions along the east coast of North America (Hargrave 1972).

The ubiquity of chickens in the Old World, the existence of multiple ports of introduction and numerous possible sources, as well as reliance on historical data dominated by European ethnographies and ships' records, are unlikely to provide the means by which the *first* chickens to reach the Americas may be identified. However, in order to reliably interpret the mtDNA data, both modern and ancient, it is imperative that a comprehensive assessment of the relevant historic literature is undertaken. In this way the mtDNA evidence can be placed in its appropriate context.

European Origins

While there is ample historical evidence to reconstruct the introduction of domestic chickens to the Americas by Europeans after AD 1492, these accounts do not, in and of themselves, form an evidential basis for precluding earlier introductions. Those accounts do, in some cases, provide absolute numbers relating to introductions, which are useful in evaluating the potential for specific introductions to have led to the establishment of New World flocks. In addition, the likelihood that these stocks, once established, were subsequently distributed through indigenous trade networks can be assessed. This endeavor, though, is complicated by the fact that the records are in a variety of languages which may have been mistranslated and are not always easily accessible for reassessment. Nomenclature is also a considerable source of bias in the historic accounts. For example, Termer (1951) argued that the only domestic birds reported by the early European explorers were turkeys, but this is not supported by the available evidence; Latcham (1922) found descriptions of both chickens and ducks, as well as turkeys, in early records. In Spanish documents, chickens were occasionally referred to as being 'like those of Castille'. Turkeys, however, were often identified as 'pea fowl' (Caudill 1975). While Europeans generally made an effort to distinguish the species they encountered in the New World, the use of sex-specific

identifications such as rooster, cock or hen leads to confusion and debate about whether specific records were referring to chickens, turkeys or other birds. In addition, the ubiquity of chickens in the Old World meant that the presence of chickens in the New World may not have been recorded by Europeans who would not necessarily have seen the familiar fowl as an exotic or non-native species worthy of note.

Considering the chronology of European arrivals in the New World, the earliest possible agent of introduction for chickens to the east coast of the Americas was the Norse (Hargrave 1972). This very reasonable hypothesis is one which has been generally overlooked by other proponents of pre-Columbian introductions. The first evidence for a European presence in the New World is the Norse settlement of L'Anse Aux Meadows in contemporary Newfoundland, Canada. The settlement was most likely established and inhabited between AD 800 and 1000 (Ingstad 2000; Park 2008; Wallace 1991). While the assemblage from this site is small and may not represent the only landfall of the Norse in pre-Columbian North America, chicken bones were not recovered from the small L'Anse Aux Meadows faunal component. Pig was the only domestic animal identified at the site (Ingstad 2000; Rick 1977). In order to rule out the possibility of a Norse introduction to another location in the Americas the evidential search net was cast further afield.

To definitively dismiss the possibility of chicken introductions by the Vikings, a review of the literature was expanded to determine if chickens were likely to have been on Norse ships in the pre-Columbian era. Archaeologists working in both Greenland and Iceland have rarely reported chickens amongst their archaeological assemblages (Pálsdóttir et al. 2007). Recent excavations in northern Iceland have resulted in the recovery of only two chicken bones from site contexts associated with an age range of AD 1262-1300 (Hicks & Harrison 2009) postdating the abandonment of the L'Anse Aux Meadows settlement.

Thus, if there is no evidence for pre-Columbian Norse introductions of chickens to the Americas, the potential European sources must be sought in the years after AD 1492. The first recorded introduction of chickens to the Americas was to farms in Espanola in AD 1495 (Termer 1951). Two hundred chickens, which came from stocks propagated in Gomera, in the Canary Islands, were provided to the inhabitants of Espanola during Columbus' second voyage. However, a famine struck the settlement soon after they were introduced and all food supplies were consumed (Cohen et al. 1988: 175). As a result, the chickens were not available to be passed along to the indigenous inhabitants of the island or beyond into continental America.

The first recorded European introduction of a chicken to continental South America was in AD 1500 when the Portuguese explorer, Pedro Álvares Cabral, gifted a single hen to an indigenous individual in Brazil (Greenlee 1939: 12). Subsequent accounts identify chickens within 20 years and in places quite distant from this lone introduction and raise the question of whether other and earlier introductions may have occurred. Nordenskiöld (1922: 2) claimed that when Álvares Cabral sent prisoners ashore in South America he sent chickens with them, but Sauer (1952) argued that very detailed records of Álvares Cabral's voyages are available and there is no mention of sending chickens ashore. If then, the single hen was indeed the first chicken introduced along the coast, the fowl must have established itself and spread very quickly. In 1515, Montes reported seeing chickens in Argentina, and between 1519 and 1529, Magellan, Pigafetta and Cabot reported chickens in Brazil (Nordenskiöld 1922) hundreds of miles away from the site of Álvares Cabral's contact (Sauer 1952).

In 1527, Pizarro acquired chickens from Panama, which Alonso de Molia then introduced to Tumbez, Peru in 1528 (Hemming 1970). Unfortunately, the source of the Panamanian chickens and the number of birds transferred to Peru is yet to be determined. However, if the birds were truly a new introduction in 1528 they were quickly incorporated, appearing in the 1615 chronicle of Don Felipe Guaman Poma de Ayala (1615), as part of a normal Peruvian village scene (Figure 4).

Figure 4. From Don Felipe Guaman Poma de Ayala's 1615 Chronicle. Drawing 324 depicts native horticulturists tending their garden: this may provide evidence for the early incorporation of chickens into local economic systems. Reproduced with permission from the Department of Manuscripts & Rare Books, The Royal Library, Copenhagen.

In 1531, while travelling through Venezuela, Nikolaus Federmann claimed to have heard the crow of a rooster from the jungle and inquired about the source of the birds. The local indigenous people told Federmann they had received the birds from traders who came from the Southern Ocean in a big house (Federmann 1557: 156). Some later academic interpretations of this event took the view that the indigenous informants were mistaken and it was not the southern sea, but the mouth of the Amazon River they referred to, and the house was in fact a European sailing ship (Nordenskiöld 1922). We take the opportunity at this juncture to note that the long distance sailing canoes used by Polynesian peoples were often stocked with domestic items such as chickens and that these vessels also were likely to have had at least one shelter erected upon them (Hornell 1943). Therefore, it is not impossible that Polynesian voyaging canoes are the boats of significant size which appeared as the "big houses" the Venezuelans referred to. The stories of the big ships must have accompanied the exotic bird into the interior of the country and it cannot be said with certainty from these third hand accounts which vessels the tales were referring to.

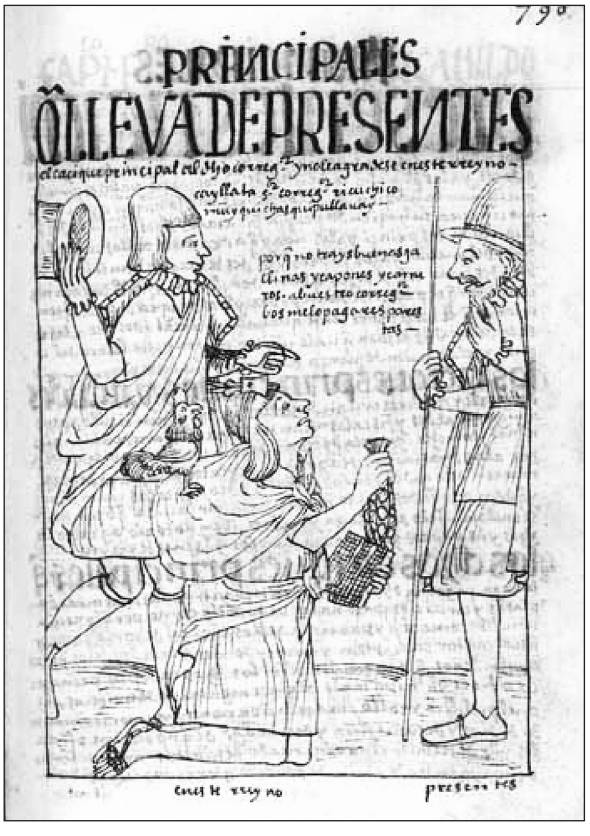

Figure 5. From Don Felipe Guaman Poma de Ayala's 1615 Chronicle. Drawing 297 records an exchange between an indigenous elite and a Spanish Royal Administrator. The tribute offered by the Peruvian is found lacking by the Spaniard who asks "Why don't you bring me instead hens, capons, and llamas?" Reproduced with permission from the Department of Manuscripts & Rare Books, the Royal Library, Copenhagen.

After AD 1540, the possible sources for introduced chickens expand from Europe (or African ports frequented by Europeans) to potentially include European-mediated introductions of birds obtained in the islands of the Pacific, Island Southeast Asia and the Asian mainland. As a result, even more careful critical review will be required of ships logs and manifests of both cargo and slave ships arriving in the Americas after this point to understand the complex imports and exports of domesticated and exotic plants and animals and their probable impacts on modern phylogeographies of American chicken flocks.

Another potential complicating factor is that the Spanish encouraged the acceptance and intensification of chicken production by the indigenous peoples in the Americas by requiring them to pay tribute in hens and eggs (Caudill 1975: 19). This was depicted by Don Felipe Guaman Poma de Ayala in an illustration of an Inca tribute exchange in which the Royal Administrator specifically asks the local indigenous elite for hens and capons (Figure 5). This resulted in the perception of eggs and hens as currency and thus an important or high ranking trade item (Capa 1915; de Gómara and Lacroix 1979: 129), reducing their value as food to indigenous populations. Ruschenberger (1835: 364) noted that even in the early 1830s, due to the influence of early Spanish edicts, South Americans were reluctant to eat eggs as it was "like eating up their own gold!" The trade value of poultry encouraged intensification of production and certainly of trade and exchange amongst communities and thus would have expedited the spread of all and any chickens introduced to the Americas at this time. It may also provide a more feasible explanation to the noted aversion of indigenous groups in both North and South America to eating eggs; a fact which has been used by some to suggest a direct Asian introduction to the Americas (Carter 1971).

The historical literature does leave several unresolved issues in identifying the possible origins of South American chickens, not the least of which is the timing of their arrival on the east and west coasts and the identity of the people who may have transported them there. As a result, some scholars have concluded that earlier introductions must have come to the Americas directly from Asia in the pre-Columbian era. Indeed, even Gongora et al. (2008a: 10311) allude to this in their paper as a reasonable alternative to Polynesian introductions.

Asian Introductions

There are several authors who have speculated that if chickens were introduced to the Americas before Columbus, they must have been introduced directly from Island Southeast Asia or the Asian mainland (Carter 1971, 1975, 1998; Johannessen 1981, 1982; Langdon 1989; Menzies 2002; Pearce & Pearce 2010; Sauer 1952; Sorenson & Johannessen 2006, 2009). The supporters of Asian introductions have used morphological, linguistic and cultural data to support their arguments. We will now critically assess their claims and offer alternative explanations which can be linked to historic processes post-dating European contact.

The Red Junglefowl, the ancestor of domestic chickens, is found broadly distributed across the Asian mainland (Beebe 1938; Crawford 1990; Johnsgard 1999). All modern domestic chickens are ultimately derived from animals that lived thousands of years ago in Asia. Thus, the existence of Asian characteristics in particular flocks of chickens cannot be taken as evidence for direct ancestry, as it may instead reflect an ancestral phenotype inherited from the Asian Red Junglefowl. Nevertheless, Menzies (2002: 158) claimed that, using the descriptions provided by de Acosta (2002 [1590]), three distinct chicken introductions to South America could be recognized; Frizzle types from China, Black Melanotic strains from Southeast Asia and China, and Asian Red Junglefowl from Southeast Asia. De Acosta (2002 [1590]), in fact, commented on the non-Spanish names used by the indigenous South Americas when referring to chickens as evidence for their pre-Columbian origin. On the issue of their physical appearance, he said only "in the Indies there are many species of animals and birds resembling those of Europe, which the Spaniards found there….." (de Acosta 2002 [1590]: 235). Thus, Menzies (2002) could not have derived his conclusions from de Acosta's account.

In their recent review of the evidence, Pearce and Pearce (2010) suggested that three temporally distinct pre-Columbian introductions of chickens took place in the Americas: the first of small Indian melanotic strains, the second of Japanese rumpless silkies and a third of white chickens which they speculate may have come via Lombok and the Philippines. Other arguments include Johannessen's (1982) southern Chinese origin for South American stocks and Carter's (1998) attempt to document multiple pre-Columbian introductions from Asia, including Chinese, Indian and Japanese flocks.

Yet another proponent for pre-Columbian trans-oceanic chicken transfers was Robert Langdon (1989), who argued that evidence from linguistics and morphology indicated that chickens may have been directly introduced to the Americas from Japan. He also argued that this was in line with the Valdivia pottery diffusion hypothesis of Meggers (1975, 1998). Meggers' hypothesis suggested that at approximately 3000 BC, Jomon era Japanese sailors arrived on the shores of Ecuador just north of the Gulf of Guayaquil. Green (2001) has already addressed many of the issues raised in Langdon's paper, particularly those focused on linguistics. However, the chicken evidence is also equally untenable, particularly as the first chickens in Japan were Jidori types introduced from Korea in the Yayoi Era (300 BC to AD 300) (Oka et al. 2007). Therefore, historical and archaeological evidence suggests that chickens were not present in Japan at the time suggested by Meggers (1975, 1998) for Jomon cultural diffusion to the Americas and thereby invalidates Langdon's hypothesis.

With regards to potential post-contact introductions of Asiatic birds, Spanish agents of the Manila galleon can certainly be cited as likely intermediates in the dispersal of birds with Asian traits to the Americas in prehistory through trade with China and India through ports in the Philippines. The first potential transfer was in AD 1596, when a 200 ton ship laden with Chinese goods was sent to Peru (Levesque 1992: 21). Just fourteen years later in AD 1610, the *San Buenaventura* left Japan for Acapulco carrying Japanese cargo and merchants (Levesque 1992: 324). Over the next six years several ships journeyed back and forth between Acapulco and Japan.

In some cases, an exploration of the history of chicken introductions and breeds can be used to invalidate specific arguments. However, where written records do not exist it becomes more difficult both to make and dispute circumstantial evidence for pre-Columbian introductions. As a result, the morphological traits of black-boned, black-meat chickens (BB/BM) and Araucana breeds of chickens have often been used to make compelling arguments for the existence of chickens in the Americas before European contact. These warrant more careful consideration with a view to untangling potential evidence for pre-Columbian introductions from post-contact translocations of chickens.

Physical Characteristics as Evidence for Origins

Black-Boned, Black Meat Chickens (BB/BM)

One of the morphological features which has been cited as a clear indicator of pre-Columbian chicken introductions is the BB/BM chickens currently found in the Americas and their use in symbolic and religious contexts (Johannessen 1981, 1982; Pearce & Pearce 2010). Silky fowl, the breed most commonly exhibiting these characteristics, were bred in China by at least the 3rd century as a pharmaceutical strain (Shen et al. 1999). Consumption of their eggs was purported to cure a variety of ailments including; hypertension, diabetes, neuralgia, and rheumatism. It is these properties and their medicinal use by some Mexican populations which led Johannessen (1981, 1982) to suggest these may have been introduced to the Americas before European contact.

In addition to their distribution in the Americas, Johannessen (1981: 428) reported that there were BB/BM individuals in several Polynesian archipelagos in the mid-1970s and that in Hawai'i they were prized as fighting stock. More recently, Pearce and Pearce (2010) misinterpreted our conclusions regarding the ancient DNA data for Pacific chickens as including evidence for the melanotic type. They said,

> "Storey et al. (2007) ascribe the two Easter Island lineages that they document to different Asian origins. They connect the melanotic chicken to the modern chickens from Southeast Asia, specifically from the Yunnan region of China and Vietnam" (Pearce & Pearce 2010: 114).

At no point did we address the existence of BB/BM chickens in Polynesia or the Americas and there is currently no evidence to support the presence of these animals in the

Pacific before contact. There is no evidence of black bones being recovered from Pacific archaeological sites (Steadman 2006; Storey et al. 2008a) and as of yet, no evidence has been published for their recovery in American archaeological contexts (Darwin 1875). Langdon (1989: 181) researched the early explorers' accounts of chickens on Rapa Nui and the limited evidence would suggest the birds were like those available in Europe; no mention is made of black flesh or blue eggs. Indeed, of the over 500 chickens observed by Roggeveen on Rapa Nui in 1722, none were singled out for being different than those found in Europe (Badger 1988). Perhaps more importantly, mtDNA is not an appropriate marker to distinguish animals phenotypically, particularly the section we targeted (the control region) which does not code for functional proteins. A quick survey of mtDNA sequences for silky and other BB/BM chickens in GenBank reveals individuals in Liu et al.'s (2006) Haplogroups A, B, C, D, E and G. This further demonstrates the inappropriateness of using non-coding mtDNA data to identify melanotic strains of chickens.

Fibromelanosis (black skin) was reported in both Asian and African flocks by AD 1635 (Sauer 1952). Darwin (1875: 211) specifically mentioned Indian breeds of curly feathered fowl with imperfect tail feathers and a black *periosteum* around their bones. Jardine (1836) also commented on the Negro or Blackmoor breed with black bones and dull purple skin. He recorded that these black-boned fowl were imported to Europe as rarities from China and Japan. The first record of the trait in the Americas is from Paraguay at around AD 1800, where they were used for assistance with fertility and healing.

Our investigations into the probable origin of the distinctive black meat chickens in the Americas led to evidence that the Angolian Bantus introduced a melanotic chicken to South America in the 1500s (Caudill 1975). In fact, Caudill (1975: 57) has argued that "the majority of poultry with oriental characteristics are African introductions and not, as is often supposed, brought by Dutch pirates or Spanish colonizers." Johannessen (1981) disputed this explanation and has suggested that this is an unlikely mechanism to have resulted in the transport of BB/BM chickens to the Americas. He argues that the broad distribution of the black meat chicken (from Mexico to Chile) contrasted starkly with a very restricted distribution of the use of the bird for Asiatic medical practices. However, his arguments that the Spanish would not have carried BB/BM chickens on their ships for religious reasons and that non-Catholics were not allowed in New Spain is not sufficient proof that these birds were introduced before AD 1492 (Johannessen 1981). Acapulco was the New World port for the Manila galleon trade and ship builders, refitters and laborers were often of Chinese and Malay origin (Banzuela 2009). It is very possible that, even if they did not themselves import the BB/BM flocks, those arriving from Africa via Dutch traders would be used in the traditional ways. In addition, since BB/BM chickens were indeed known in Europe and were purchased as ornamentals, it is not as preposterous that they may have been aboard European ships as proposed by Sorenson and Johannessen (2009). In addition, Japanese and Chinese goods were imported regularly to New World ports such as Acapulco and Peru in the late 1500s and early 1600s, both by Spanish middle-men and Chinese and Japanese merchants (Levesque 1992).

The introduction of Indian strains of BB/BM chickens to the Americas by way of Africa nearly 400 years before Johannessen's study is likely sufficient for the physical characteristics and traditional use of melanotic chickens to appear well established in indigenous cultures in the 1970s. However, there is no way to date the development of cultural attitudes to animals in societies without written records. Since these traits cannot be extended back in time critically, it is safer to assume that Asian attitudes towards chickens, particularly those with BB/BM characteristics, are likely to have been introduced after AD 1500.

The Araucana Chicken

Perhaps one of the most oft cited examples of morphological features pointing to a pre-Columbian introduction of chickens is the Araucana breed. Given that its origins lay in Chile, it has the potential to provide valuable insights regarding the source of the El Arenal-1 chickens. As a result we focus attention on the history of the breed and its idiosyncratic phenotypic traits.

Castello (1921) first reported the Araucana breed at the First World Poultry Congress, where it was distinguished by the laying of blue eggs, the lack of a tail, and the presence of ear tufts. It was classified as a new species, *Gallus inauris* from the Latin 'inauris' or earring (Castello 1924). Castello later discovered that the birds were not an ancient breed but instead a relatively new one developed by Dr. Ruben Bustos, who later related to Castello that he had crossed two distinct Chilean breeds, a rooster with ear tufts and a rumpless blue egg laying hen, to produce the birds. These two breeds, which were recovered from distinct geographic locales in the Arauco region of Chile, presented a challenging task to successfully cross and rarely produced true breeding progeny. At the Second World Poultry Congress, Castello (1924) retracted the earlier description and instead identified three types of Chilean chickens, some of which laid blue eggs and some of which did not.

Castello's (1924: 113-114) three types of chicken are as follows:

1. Common Chilean fowl which were morphologically similar to the Spanish type but laid blue eggs;
2. A tailless hen which in the Arauco region predominantly laid blue eggs; and
3. Ear-tufted varieties which laid blue eggs infrequently.

Two years earlier, Latcham (1922) had also identified three distinct types of Chilean chickens, all of which laid blue eggs:

1. *trintre* – curly feathered;
2. *collonca* – tailless; and
3. *francolinas* or *gallinas de arêtes* – chickens with ear puffs.

Although Gongora et al. (2008a: 10308) have asserted that the "Araucana breed is thought to be descended from Indigenous Amerindian chickens" this is clearly not the whole story. The crossing of distinct breeds, each with unique morphological traits, to develop the Araucana chicken presents a new puzzle to determine the origins of the specific traits associated with the Araucana type.

Trintre type chickens may be descended from Portuguese 'Frizzle' types which were imported to the Americas by way of African Guyana. Darwin (1875: 211) observed that Frizzle or Caffre Fowls were common in India and not only had feathers which curled backwards but also had black bones. These Frizzle feathered birds were also discussed by Aldrovandi (Lind 1963 [1600]) in the 1600s and thus were well known to Europeans. It is probable that these birds were taken to Chile from the Old World before the late 1800s (Caudill 1975).

The Dutch are a likely source for the second type, *collonca* or tailless fowl. Tailless fowls were known in Europe in the 1800s (Jardine 1836; Johannessen 1982) and the Boers possessed a rumpless variety of fowl in the 1600s. These may have been transported to the Americas early in the post-contact period. However, it is also possible that a flock of Chilean tailless chickens were taken to Holland from the Americas by Dutch pirates who, like many pirates of the time, frequented the Arauco region off the coast of South Central Chile from as early as AD 1600 (Caudill 1975: 54, 87). These pirates and privateers rarely left records relating to the movement of domesticated animals.

The first date which can be firmly related to hens which lay blue eggs is a secondary report of blue egg layers being transported from Chile to Brazil in 1880 to be crossed with Caipira ('native'/free ranging) chickens (da Veiga Lima-Rosa et al. 2005). Transfers such as this led to a wide geographic range in which the laying of blue eggs was observed. By the early 1900s when Castello first saw the blue egg laying chickens in the market at Punta Arenas in 1914, the distribution of this trait was reported to extend from Chile, Bolivia and Peru through to Columbia, Ecuador, Brazil and Mexico (Castello 1921, 1924, 1939; Latcham 1922). Blue egg laying chickens were reported to live in a semi-wild state roosting in trees and were not penned or selectively bred (Castello 1924).

Curiously, Darwin (1875) does not mention blue eggs in his lengthy discussion of domestic chickens, despite mentioning rumplessness, curly feathered fowl, crested fowl and black-boned, black-meat birds, among others. During his time on the *Beagle*, Darwin spent a significant period of time along the west coast of the Americas, and even ventured into the interior of South America, particularly in Chile. In 1834-5 he had visited Valparaíso, Chiloe Island, Valdivia, Concepción, Santiago and Lima. Therefore, it seems unlikely that if blue eggs had been available in markets as they were in the early 1900s, that Darwin would have missed them. Raschenberger (1835) who wrote about cock-fighting in Lima and described many domestic scenes as well as buying eggs in South American markets also does not mention any of the characteristic Araucana traits in his accounts of Chile and Peru. This may provide evidence for the development of the blue egg laying trait, or at least its wide distribution in Chile, after AD 1835. This suggestion was also made to Castello, by a Mr. Pardo of Chile, who told him that blue egg laying was a sudden and spontaneous change that took place in the southern parts of the continent in the latter part of the 19th century and was then carried northwards (Castello 1924: 116).

All three types of Chilean chickens, with their unique characteristics, quickly became an object of interest for European fancy breeders and were exported to Germany in 1907 and to England in 1928. Once there, some were bred as purebreds and others were crossed with European breeds to experiment with the properties of blue egg laying (Wilhelm 1978). By the early 1920s, and possibly earlier, North American chicken breeds, such as Plymouth Rocks and Rhode Island Reds, as well as European breeds including Leghorns, were widely available in all major South American and Mexican cities. This served to intermix traits and genes on both sides of the Atlantic at an early date (Castello 1939). In the 1930s, an American breeder found it impossible to procure 'pure' Araucana hens from Chile due to extensive crossbreeding with American types including Rhode Island Reds and Plymouth Rocks (Vosburgh 1948). The eagerness to cross chicken breeds, particularly the exciting new Chilean varieties, led Wilhelm (1978: 195) to lament that the blue egg laying chickens were "on their way to extinction because of crossbreeding and substitution." However, it may have been such crossbreeding which produced them in the first place. Castello (1924) suggested that the unique characters of the Chilean fowl could have resulted from the crossbreeding of a pre-Columbian chicken, which may have laid blue eggs, with the Spanish/European types during the early post-contact period. Thus the examination of both the unique morphological traits of Araucana chickens and their nuclear DNA may be required to resolve their multi-breed origins (Storey et al. in prep).

Considering the Origins of Araucana Traits

As it is now clear that the origin of the Araucana chicken lies in the controlled breeding experiments which occurred in Chile in the late 1800s, we turn to an examination of the potential genetic and geographic origins of the three defining traits of the breed. Understanding the available literature is essential in interpreting the results of modern and ancient DNA phylogenies as they relate to Araucana chickens, or in fact, any domestic animal breed. Here, we disentangle the Araucana traits of taillessness, ear tufts, and blue egg laying.

Taillessness is a heritable trait which can appear spontaneously in flocks of birds and is controlled by a simple dominant allele (Zwilling 1942). There is some debate in the literature about the impact of taillessness on fecundity, with

some arguing that it leads to high infertility (Dunn 1925), while others report that purebred rumpless hens are very productive (Zwilling 1942). It was noted by Darwin (1875: 214) that several English breeders kept rumpless fowls as exotics but that examples he had seen were too varied to be considered a breed of their own. Rumpless chickens were reported from several geographic regions in the Old World, but Persia was the most commonly cited locale (Darwin 1875; Jardine 1836; Lind 1963 [1600]). Despite this, Carter (1971: 26) suggested that the trait was Chinese in origin and Langdon (1989) pointed to the existence of tailless fowl in Japan as proof that this was the source population for the Chilean birds. Terminology related specifically to tailless fowl in the Pacific has been recorded for Rapa Nui and the Marquesas (Tregear 1891; Wilhelm 1978). However, these terms were recorded well into the historic period and are more likely to relate to post-contact introductions.

Spontaneous rumplessness can be induced through variations in incubation temperature, shaking eggs before incubation and the presence/absence of certain chemical compounds (Valasek et al. 2007). Although Araucana chickens are thought to have shorter tails as a result of a genetic predisposition, this can be further affected by any of the conditions listed above (Valasek et al. 2007: 4433). Thus, the lack of a tail is a trait that can appear spontaneously in a population both as a growth defect and a heritable condition and so does not necessarily indicate a direct relationship between Chilean and other chickens.

In the chicken, tufted ears are an incomplete dominant allele (Et) which is lethal in the homozygous form and in approximately 20% of heterozygotes (Bartels 2003; Somes 1981). The presence of earrings or tufts is not unique to the Araucana fowl (Somes 1990); it was also observed in Indian fowl in the 1600s (Aldrovandi (1963 [1600]). Darwin (1875: 252) observed that chickens, ducks and geese with this trait also had imperfections in the ossification of the skull. Contemporary studies of the ear tufts has shown that the formation of the structure often also results in malformation of the cranium, particularly in the size and shape of the ear opening, but also other abnormalities in the fusion of bones (Pabilonia & Somes 1981; Tsudzuki & Wakasugi 1988).

Although tufts had been observed in European fowl previously, the tufts in the ear region are often cited as unique to the Araucana breed (Bartels 2003; Crawford 1990). And yet, the trait appeared spontaneously in a group of Japanese quail that were then selectively bred to retain the tufts in order to better understand its expression and heritability (Tsudzuki & Wakasugi 1988). Based on these facts, the mutation for ear tufts may have appeared spontaneously in Chile sometime after the first introduction of chickens to the area, but before AD 1900. Unfortunately, without archaeological remains of the fragile cranial bones which may have the characteristic malformations around the ear opening, it is impossible to say, at this stage, if ear-tufted fowl existed in prehistory either in the Pacific or South America.

Punnett (1933) investigated the genetics of blue egg laying hens and reported that it had arisen as a dominant mutation among domestic fowl in South America. He also noted that this trait had been observed in Dutch flocks imported from Asia. Since blue egg laying is a trait that has been observed in Chinese flocks (Blench & MacDonald 2000) it was potentially present in the ancestral gene pool and may have appeared spontaneously or was introduced in the historic period through Spanish trade with China via the Philippines (de Morga 1868; Hough 1900). Wilhelm (1978) reported seeing blue egg layers on Rapa Nui long after a period of significant contact between Chile and the Pacific in the historic period. As yet there is no evidence for blue egg layers in the Pacific during the early contact period. It is a striking enough trait that had it existed in the Pacific Islands, one might expect the explorers and traders to have noted it. The blue egg mutation may have occurred in either Polynesian, Asian or European breeds of chicken after their introduction to the Americas and does not in and of itself suggest an origin or an age for this trait.

Thus, it can be seen that using a combination of archaeological, historical, morphological and genetic evidence, the circumstantial suggestions offered up from studies of chicken morphology, speculative linguistics and insufficient historical information can be dismissed. These arguments are reliant on the morphological traits of animals observed in the last 40 years. These are unlikely to be an accurate representation of chicken flocks distributed across the Americas in the early contact period. The use of modern evidence presupposes that the contemporary phenotypic dichotomy has always existed between Mediterranean/ European fowl and those of Asia. As a result, these arguments do not take into account the intensive inter-continental interactions facilitated by Spanish galleons linking China and the Americas via the Philippines in the 1500 and 1600s. For example, it has been suggested that most of the South American fighting breeds were European introductions from Southeast Asian ports (Finsterbusch 1929).

Supporters of pre-Columbian Asian introductions also neglect to search for early post-contact sources such as trade between Japan and Acapulco or China and Peru (Levesque 1992). It is particularly interesting to note that the Dutch had active trade relationships with Japan in the late 1500s and early 1600s and that captured Dutch ships were brought to Acapulco by the Spanish (Levesque 1992). Thus, it is possible that these early interactions could account for similarities noted between Japanese, Dutch and South American flocks of chickens, particularly traits such as taillessness and blue egg laying noted in all three regions (Langdon 1989: 1321).

International trade relationships had the potential not only to spread chickens from Asia to the Americas, but also through the Pacific Islands where ships may have stopped en route (Badger 1988; Hough 1900). In addition, while 'Mediterranean' breeds such as Leghorns are likely

descended from ancient Italian breeds, their "characters have been fixed in America and Britain by selection, and modifications have taken place in the last-named country" (Brown 1906: 72). Therefore, it is imperative that anyone referring to Mediterranean phenotypes be explicit about what traits they are referring to, their antiquity and their origins to ensure they are not referring to traits bred into the lines in the Americas after the 1800s.

Imports of chickens from Asia and perhaps even from the Pacific were likely to have been relatively steady from first European contact to the modern era. Thus, in the 400 years since the arrival of Columbus, many traits had the potential to be introduced to American chicken flocks from all over the globe. However, specific episodes of introduction may have had more impact than others. The hen or chicken craze of the 1800s was focused on the importation of Chinese birds for hobby breeders to keep as pure lines in foreign ports and more commonly to crossbreed with other types to develop new strains (Crawford 1984: 305). Records indicate that during this period, Chinese breeds of chickens including Cochins, Brahmas, Langshams, Silkies and Aseels were exported to Europe and the Americas to be used in intensive breeding programs (Crawford 1990; Stevens 1991). Thus, it is imperative that any review of the morphological evidence be evaluated with due consideration for the disconnection between the contemporary evidence cited and its ability to be projected back reliably in time. This includes periods before the intensive import of Chinese breeds in the 1800s and long term trade networks between Asia and the New World facilitated by Dutch, Spanish and other European economic interests in the 1500s and 1600s. But perhaps most damning for the morphological argument is the observation by Crawford (1990: 17) that "nearly all of the mutants claimed to be Asiatic were also known in the Mediterranean and Africa at the same time – pea comb, silky, frizzles, rumplessness, fibromelanosis, crest – although they were not necessarily common there."

Not only is the evidence from morphology often untenable, evidence from recent ethnographic studies is also difficult to project back in time to the 1500s and before. It is likely that the Coolies from both India and China brought chickens, as well as their attitudes about them, with them to the New World. Sorenson and Johannassen (2009: 76) have argued that "no Chinese (or any other non-Catholics) were legally allowed to settle in early colonial Mexico or Central America, so these esoteric practices appear to have originated earlier." However, Chinese, Malay and Filipino shipbuilders and labor were routinely used in Manila during the galleon trade which linked the Philippines directly with Mexico. In fact, the Malays were often employed to man the galleons between Manila and Acapulco and by AD 1724 generally outnumbered the Spaniards on board (Banzuela 2009). Many of these sailors deserted in the New World and later vexed the Spanish wine producers, as the Southeast Asian immigrants began to produce palm wine which became the drink of choice in New Spain. This clearly demonstrates that a large number of people from Island and likely mainland Southeast Asia were in residence in the New World at an early date.

The contacts and relationships between the marginalized melting pot of disadvantaged peoples and cultures in the Americas from the 16th century onwards were probably much more influential in the diffusion of cultural traits than has been recognized. Unfortunately, most of these people were not literate and did not keep records of their imports or interactions. This aspect of post-contact American culture change is a fertile area for continuing research. Due to a lack of intensive study relating to the interactions between marginalized peoples, including slaves and indentured servants, more strength is given to circumstantial evidence for pre-Columbian contacts with Asia as well as those with the Pacific. More focused study is sure to reveal that many of the traits attributed to pre-contact Asian influences are in fact due to early historic era interactions.

Support for a Polynesian Origin

The preceding review of the archaeological, radiocarbon, mtDNA, historical and morphological evidence supports our hypothesis that Polynesian voyagers are the most likely agents of introduction for the pre-Columbian chickens recovered from the 14-15th century deposits at the site of El Arenal-1, Chile. However, the chicken evidence is only part of a much larger suite of evidence for pre-historic contacts between Polynesia and the Americas. This has recently been detailed in a volume by Jones et al. (2011) entitled *Polynesians in America* but a review of some of the supporting lines of evidence is presented here in brief. Perhaps the most compelling evidence for Polynesian contact with the Americas is derived from the prehistoric distribution of the South American sweet potato in the Pacific at a time well before European contact with the Americas (Green 2005; Hather & Kirch 1991; Horrocks & Wozniak 2008; Ladefoged et al. 2005; Wallin et al. 2005). In addition, similarities between Quechua and Pacific names for sweet potato suggest the crop was acquired through direct interaction (Scaglion 2005) as opposed to transported naturally by drifting on the prevailing currents (Montenegro et al. 2008). Simulated voyages by Fitzpatrick and Callaghan (2008) also strongly support the possibility of Polynesian landfalls in South America before Columbus.

Another tantalizing lead comes from the reanalysis of morphometric traits from a series of skeletons recovered from Mocha Island, located off the coast of the Arauco Peninsula. These remains have revealed a suite of Polynesian traits which may indicate admixture between Chilean and Pacific populations (Matisoo-Smith & Ramírez 2010). This finding lends strong support the long-standing hypotheses of Ramírez that artifactual and linguistic similarities observed between Chilean and Pacific artifacts, such as *clava* and *toki*, represent long term prehistoric relationships (Ramírez 1990). It stands to reason that the relative proximity of Polynesia to South

America and the current dates for the eastward expansion of the Polynesians point to the peoples of the Pacific as the agents for the transportation of the pre-Columbian chicken of El Arenal-1 (Weisler and Green 2008, 2011). Even with this weighty evidence, Gongora et al. (2008a: 10311) suggest "a pre-Columbian Asian introduction" was a more likely source for the E Haplogroup mtDNA signature of the El Arenal-1 chicken remains. This is incongruous with the current evidence and is a particularly strange stance to take in light of their focus on attempting to discredit evidence for pre-Columbian chicken remains in the Americas. In order to resolve these issues it is imperative that researchers working all along the west coast of the Americas reassess the contents of their faunal collections for bones of animals known to have been transported by Polynesians. Remains such as bones of chickens or pigs which may have been classified as intrusive previously may provide evidence of other points of contact between Polynesia and the Americas.

Conclusions

We have shown that the chickens of El Arenal-1 are definitively pre-Columbian in age and their date is well within an acceptable range of dates for an eastward expansion of Polynesian voyagers. The dates also indicate contact before the documented decline in long distance voyaging at around AD 1450 (Allen & Kahn 2010). We have investigated alternative agents of pre-Columbian chicken introductions, including the Norse and direct introductions from Asia, and found these possibilities far less convincing than an introduction from the Pacific. Most of the arguments for direct introductions from Asia are based on evidence which is circumstantial at best and rely on a firm belief that the distribution of chickens with particular physical traits has remained relatively stable since their first introduction to the modern day. We do not find such arguments compelling. Our evidence from direct radiocarbon dating and mtDNA analyses finds a great deal of support from independent lines of evidence for prehistoric transfers of sweet potatoes and linguistic borrowings as well as data from simulated voyaging. We are now anxious to move on to exploring new lines of evidence from chicken remains and other biological, artifactual and linguistic lines of evidence to more rigorously test our hypothesis of the pre-Columbian introduction of chickens to the coast of South America by Polynesian voyagers.

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