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RECONSIDERING PRECOLUMBIAN HUMAN COLONIZATION IN THE GALÁPAGOS ISLANDS, REPUBLIC OF ECUADOR

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Fifty years ago, Heyerdahl and Skjølsvold (J 956, 1990) collected material from five archaeological sites in the Galápagos Islands. They retained earthenwares of possible precolumbian origin and discarded ceramic, metal, and glass artifacts post dating the arrival of the Spanish in A.D. 1535. Consequently, they argued that each site was formed as the results of a series of discard events from unrelated short-term occupations extending from the precolumbian to the historical era, and that earthenwares represented occasional visits by fishermen from precolumbian Peru and Ecuador. In 2005, we re-excavated the sites and collected all the excavated materials. Our results show that each class of material, irrespective of age or origin, was distributed spatially and stratigraphically in the same pattern, contradicting the former assumption of multiple, unrelated occupations. We reject the palimpsest model in favor of the null hypothesis of single-phase site occupation. Analysis of putatively precolumbian pottery using optically-stimulated luminescence dating indicates that it is mostly of historical age. Radiocarbon dating confirms that the archaeological sites are younger than the sixteenth century. Research on sedimentary cores shows probable anthropogenic impacts as restricted to the last 500 years. We conclude that there was no human occupation in the Galápagos Islands until the historical era.

Hace cincuenta años Heyerdahl y Skjølsvold (1956,1990) recuperaron material arqueológico en cinco sitios de las Islas pagos. Estos investigadores se enfocaron en los fragmentos de cerámica de supuesto origen precolombino y descartaron los artefactos posteriores a la llegada de los europeos, en 1535 d.C. Asimismo, sostuvieron que estos sitios eran "palimpsestos", resultado de la acumulación de materiales culturales durante distintas etapas de ocupación, desde el período prehistórico hasta tiempos modernos. Según ellos, los tiestos de barro sin esmalte vidrioso representaban visitas ocasionales de pescadores desde las costas del Perú y Ecuador. A partir del año 2005 hemos llevado a cabo nuevas investigaciones enfocadas en excavación de los mismos cinco sitios, pero nuestro análisis incluyó a todo el material en conjunto y concluimos que todos objetos, sin importar su edad y lugar de origen, se distribuyeron según los mismos patrones estratigráficos y espaciales. esta forma, rechazamos el modelo del palimpsesto y proponemos que hubo una sola fase de ocupación en estos sitios. Gracias a estudios como los análisis por OSL y radiocarbono, hemos determinado que la cerámica de supuesto origen precolombino fue fabricada en el período histórico y que los sitios arqueológicos no fueron ocupados antes del siglo dieciséis. La investigación paleo-ecológica se basó en el análisis de muestras sedimentarias de las Islas y ha demostrado que los probables impactos antropogénicos ocurrieron sólo en los últimos 500 años. Por todas estas razones, concluimos que no hubo ocupación humana en las Galápagos antes de la época histórica.

At the time of Spanish arrival in A.D. 1535, the Galápagos Islands (Republic of Ecuador) were uninhabited. Numerous subsequent visitors and colonists from A.D. 1546 onward reported no evidence of prehistoric occupation. In fact it seemed to some, as Byron wrote in 1825, that "the place is like a new creation" (Hickman 1985:71), or to Darwin in 1839 as "a little world within itself" (Larson 2001:81). Although arising from quite different perspectives, both conclusions assumed an absence of people in the prehistory of the Galápagos Islands.

That assumption has been questioned on grounds that reflect increasing appreciation of the possible extent of prehispanic maritime mobility in the region. The conventional hypothesis that Polynesian voyagers reached South America about 800 years ago and returned with the sweet potato and possibly the gourd (Green 2005; Jones et al. 2011), and the alternative hypothesis of Amerindian sailing to Polynesia (Anderson et al. 2007; Heyerdahl 1952; Heyerdahl and Skjølsvold 1990), have both raised the possibility of temporary occupation of the Galápagos Islands. The archipelago lies only 900 km west of mainland Ecuador. It presents a huge target of inter-visible islands 300 km wide, plus about 100 km of surrounding visibility from sea level. Computer simulation of possible precolumbian voyaging westward from the Gulf of Guayaquil shows that most sailing vessels pass through or near the Galápagos Islands (Fitzpatrick and Callaghan 2009). Consistent with that proposition is the existence of large sailing rafts in Ecuador from at least the early sixteenth century (Anderson et al. 2007; Estrada 1988), and evidence that the sweet potato, which arrived to the Pacific islands no later than the fourteenth century, originated in Peru-Ecuador (Roullier et al. 2013). Evidence of trading voyages between South and Central America, which involved substantial sailing offshore as early as 500 B.C. (Marcos 1995; Smith 2003), suggests another situation in which the Galápagos Islands might have been found in the pre-colonial period. Indirect evidence of balsa raft traffic along the Pacific coast as far as west Mexico has been discussed by Hosier (1994) and Anawalt (1998). Heyerdahl and Skjølsvold (1990) refer, without documentation, to rafting passages from Ecuador to the Galápagos in the nineteenth century and visits by artisanal Ecuadorian fishermen in the twentieth century. There is also a sailing route eastward across the Pacific Ocean that passes immediately north of the Galápagos Islands. Prehistoric Austronesian voyagers from Southeast Asia appear to have introduced the coconut to equatorial America by this route (Baudouin and Lebrun 2008; Gunn et al. 2011), and possibly also Indo-Chinese sailing rafts with guara or dagger boards (Edwards 1974; Langdon 2001).

Archaeological evidence that might indicate human occupation in the Galápagos Islands prior to the sixteenth century is relatively insubstantial. It consists almost entirely of ceramic sherds collected by the Norwegian Archaeological Expedition in 1953 at four archaeological sites: James Bay, Buccaneer Bay, Whale Bay, and Black Beach (Figure 1), to which a collection from Cabo Colorado, made in 1954 by the Walt Disney Expedition, was added (Heyerdahl and Skjølsvold 1956, 1990; the later volume incorporates, unaltered, the main text from 1956). The combined collection consisted of 1,961 unglazed earthen ware sherds. These were regarded as being of "aboriginal" South American origin. Here they are named collectively as "redware" because they are very frequently red-slipped (Stohtert 2007). Ceramic specialists, notably Clifford Evans of the Smithsonian Institution, assigned about 40 percent of them to prehispanic pottery types from Peru and Ecuador. This suggested to Heyerdahl and Skjølsvold (1990:65) "that the Galápagos were visited repeatedly in pre-European time," probably on fishing expeditions from Peru and Ecuador that repeatedly used the same campsites (Heyerdahl and Skjølsvold 1990:67).

Several criticisms were leveled at this proposition (Rydén 1958; Suggs 1967), and partly answered by Heyerdahl (2000). The most cogent of these is that the sample of material on which the proposition was based was far from representative of the full range of archaeological material found at the sites. Specifically, European ceramic materials, metalwork, and glass found in the same stratigraphic contexts as the aboriginal wares had been discarded prior to analysis. The rationale for this was an assumption that the historical material remains had been deposited, coincidentally, upon the older prehispanic sites. As European mariners had chosen places such as James Bay, Buccaneer Bay, and Whale Bay as landing places, often repeatedly, the "palimpsest" model of site formation implicit in this reasoning is at least theoretically plausible. On that basis, the Heyerdahl and Skjølsvold hypothesis of prehispanic occupation came to be regarded widely as valid (e.g., Bahn and Flenley 1992:47¹⁸; Black 1980; Callaghan 2003; Ferdon 1963; Green 2005; Holm 1964; Johansen 2000; Langdon 1996; Lanning 1969; Lothrop 1957; Skjølsvold 1990; Terrell 1986: 94—106).

The question addressed here is whether that conclusion, first reached 50 years ago, can still be sustained archaeologically and in light of relevant data from other sources. In 2005, a combined

archaeological-palaeoecological project reinvestigated the original archaeological sites, and cored new sedimentary sites, in order to evaluate the hypothesis of the prehispanic colonization in the Galápagos Islands (Anderson et al. 2014; Stothert 2007). This article presents our archaeological results and a summary of relevant palaeoecological evidence (Flett and Haberle 2008; Froyd et al. 2010), from which we conclude that there is no current evidence of human colonization of the Galápagos Islands before the arrival of Europeans.

Archaeological Fieldwork in 2005

Our archaeological research focused on the key weakness of the Heyerdahl and Skjølsvold (1990) interpretation, which was its inability to reject convincingly the null hypothesis that all of the archaeological remains were deposited in the historical era. The palimpsest model was criticized by Suggs (1967:241-243) as statistically improbable; he calculated the odds of its validity at 13 sites (counting each of the James Bay deposits as a separate site) as 1:1.5 million. Even if the number of sites is only five (above) the odds would still be very long. Heyerdahl and Skjølsvold's model also needed to be tested directly by archaeological evidence. New evidence was required because the original excavators had discarded a large part of the material they collected (Heyerdahl and Skjølsvold 1956,1990). As a result there was no archaeological chronology available that was independent of mainland South American ceramic typologies. The latter had, themselves, changed considerably since the 1950s. Our archaeological fieldwork proposed to test the palimpsest model by searching for sites that contained only redware, by sampling all the cultural material on existing sites and its patterns of deposition, and by dating ceramic manufacture and site occupation. We also analyzed archaeological collections in the Charles Darwin Research Centre (CDRC), Puerto Ayora, which added a site at Los Jaboncillos spring, Santiago Island, and a collection made by Raul Maruri Diaz at James Bay in 1963. These collections are described in Stothert (2007). Identifying new sites involved survey of back beach deposits up to about 100 m inland, a process facilitated by the general paucity of vegetation cover. Test pits were dug in promising areas of clay soils, and a sand auger (8-cm diameter bit) was used to test dune sands. This survey strategy was carried out wherever there was limited boat access, especially around Santa Cruz Island (Figure 1) and, to a much lesser extent, in Santiago, Santa Maria, and Southern Isabela. Various deposits of ceramics, glass, metal, and bone (fish, turtle, bird, goat, and cattle) were recorded but none disclosed any stratigraphic depth or any earthenware of pre-European provenance (Anderson et al. 2014). No inland sites containing pottery or other material of prehispanic provenance have been reported. Nevertheless, several areas on higher ground were also investigated, because they have the most reliable water sources and the best prospects for agriculture. Turning to the known archaeological sites (described by Heyerdahl and Skjølsvold 1990:23-31), we found the Black Beach and James Bay sites to have been heavily disturbed by earth moving since 1953. The former was effectively destroyed and the latter found about half intact. The remaining three sites remained largely intact. James Bay, Whale Bay, and Cabo Colorado were mapped, surface-collected, and test-excavated (recording cultural material by 10-cm arbitrary levels to determine stratigraphy and the depth of cultural material). At Buccaneer Bay, the site surface was preserved at .4 - .6 m deep within a sand dune and part of it was exposed and excavated. At each site all cultural material, such as ceramics, glass, metal, flint, and faunal remains, was recorded, collected, identified, and catalogued. Fieldwork for each island is summarized here.

Santa Cruz Island

At Las Palmides, we located two small sites containing marine shell and turtle bone remains commingled with modern European glass and pottery. An additional site, containing nine sherds collections in the Charles Darwin Research Centre (CDRC), Puerto Ayora, which added a site at Los Jaboncillos spring, Santiago Island, and a collection made by Raul Maruri Diaz at James Bay in 1963. These collections are described in Stothert (2007). Identifying new sites involved survey of back beach deposits up to about 100 m inland, a process facilitated by the general paucity of vegetation cover. Test pits were dug in promising areas of clay soils, and a sand auger (8-cm diameter bit) was used to test dune sands. This survey strategy was carried out wherever there was limited boat access, especially around Santa Cruz Island (Figure 1) and, to a much lesser extent, in Santiago, Santa Maria, and Southern Isabela. Various deposits of ceramics, glass, metal, and bone (fish, turtle, bird, goat, and cattle) were recorded but none disclosed any stratigraphic depth or any earthenware of pre-European provenance (Anderson et al. 2014). No inland sites containing pottery or other material of prehispanic provenance have been reported. Nevertheless, several areas on higher ground were also investigated, because they have the most reliable water sources and the best prospects for agriculture. Turning to the known archaeological

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Much of the forested zone on the southwest slopes of Santa Cruz has been turned into farm land. Interviews with 24 farmers in this district, most of them first-generation settlers from main land Ecuador, were informative because the farmers were familiar with similar pottery sherds they had seen as youths on their family farms on the mainland. They reported occasional sherds only at the Santa Rosa spring and near the Salasaca ponds. Our test excavations and augering yielded no charcoal or cultural material in the vicinity of these locations. The El Chato freshwater lagoon, at an elevation of about 200 m asl, covers an area of 2 ha in the wet season. It is inhabited by numerous tortoises and ducks, but no sherds were observed on the exposed surfaces along its shore. Santiago Island At James Bay, areas A, B, C, J, and L labeled by Heyerdahl and Skjølsvold (1990:23-29) were too disturbed to warrant investigation and area K has been completely removed. In site areas D-I, the site appears to be largely intact and stratigraphically undisturbed since 1953. Twenty-one test pits of .5 m x .5 m were excavated across these site areas through silt and sand to the bedrock at .2 to .6 m depth. Only four test pits disclosed any material beneath the loose surface sediments (0-10 cm deep). The greatest variety and density of material was visible in area E, where we conducted systematic surface collections. The earthenware, notably from terracotta storage jars known locally as 'Spanish jars,' included some redware glazed pottery, glass, iron, and clay pipe fragments was also a silver half-real, from the reign of Carlos II (1655-1700) of Spain, which had been minted in Lima in A.D. 1684, and a button from a U.S. Federal Navy officer uniform. The design on the latter shows the eagle and anchor surrounded by 13 six-pointed stars, a style used by the manufacturer, Lewis and Tomes, from 1802 to 1825 (Tice 1997). In area Ha 4.5m x 1.5 m excavation was placed over two patches of charcoal and ash. The sediments proved shallow (3-15 cm), and the fire places were associated with ovicaprid bone and iron nails. At Buccaneer Bay, a cultural horizon was seen at .6-m depth in the face of an eroding dune. It was exposed horizontally by an excavation unit of 2 m x 2 m. The cultural deposit proved to be a fireplace that produced a charcoal sample. Around it were scattered earthenware fragments, including a piece of a 'Spanish jar,' a copper bolt, a mirror, half of a metal scissors, some glass, and pieces of

ovicaprid bone. A test pit of 1 m x.5 m was excavated through the same stratigraphy 10 m away. It produced redware sherds, strap iron, and a piece of a clay pipe within the same layer. The pipe bowl is decorated with a delicate rib and-leaf design of British origin, dating to the first half of the nineteenth century (Anderson et al. 2014). Santa Maria Island The site at Black Beach yielded redware pottery when it was investigated by the Norwegian expedition, and some small fragments of that material can still be found on the surface. Four test pits were excavated through silt and gravel to basalt at .3-.4 m depth below surface. No cultural remains were recovered below the surface.

Archaeological Analyses

The groups and numbers of artifacts collected during our fieldwork, or recorded in collections stored in the CDRC, are summarized in Table 1. There are three broad classes of ceramic material (Stothert 2007). Class 1 is redware, the unglazed earthenware. When unslipped, the paste can turn black, brown, tan, or orange in firing, sometimes in the same vessel; otherwise, the earthenware is red-slipped. Vessel and rim forms in the Galápagos are very similar to those found in nineteenth-century sites of coastal Ecuador (Stothert et al. 1997). In the Norwegian collections, redware was assigned to several different Ecuadorian and Peruvian types corresponding to prehispanic cultural periods (Heyerdahl and Skjølsvold 1990:63-64, Tables 1 and 2). Redware pottery was made throughout the Americas from the prehispanic period to modern times. It could have been carried prehistorically to the Galápagos Islands, or even have been made there. It was also distributed widely as traded or discarded items of utilitarian use on European ships throughout the colonial era (Plischke 1961). Amongst the Galápagos red wares, we distinguished a number of informal types: Type 1, brightly burnished red-slipped sherds which, on observation of larger samples, now seem to belong to class 2 (below); Type 2, thick, coarse-tempered pottery, rarely slipped; Types 3 and 4, the most common redwares, the former paler and with coarser temper than the latter but both red-slipped, often inside and out; Type 5, thin hard-paste sherds fired black in section; Type 7, thin, buff-colored coarse-tempered sherds. An early Type 6 was later discarded as its few representatives fitted better amongst other types. Class 2 included soft-paste, unglazed or glazed earthenware, but fragments of this class were barely noticed by Heyerdahl and Skjølsvold (1990). Such material, also called folkware, includes lead- and tin-glazed, low-fired earthen wares that were produced widely from Mexico to Peru in the early colonial period and later. Within this class are brown, glazed plates made in northwest Mexico from about 1820-1840, which occur widely in the Galápagos sites (e.g., Heyerdahl and Skjølsvold 1990:54,62). Class 3, European ceramics, is assigned to after A.D. 1535. It includes many examples of hard-paste, refined earthenwares, particularly chinaware, dating to the eighteenth century and later (Stothert 2007:2), as well as terracotta storage jars, roof tiles, tobacco pipes, etc. Our analytical focus was upon the redware pottery. In order to test whether there were important compositional or chronological variations amongst the Class 1 ceramic materials, several methods were used.

Chemical Characterization

Three samples of nineteenth-century redware from Tambo River, mainland Ecuador (Stothert et al. 1997), and nine samples from the Galápagos were analyzed for chemical composition using an electron microprobe (JEOL JXA 8600) with an energy dispersive spectrometer, at the Department of Geology, University of Otago, New Zealand (Findlater 2006). To define pottery groups, elemental data (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, and Ni as oxides) from clay matrices and mineral non-plastic inclusions were analyzed using principal components and correspondence analyses. Except for one sample of red-slipped pottery from area F at James Bay, Galápagos, none were significantly different chemically, suggesting that they had substantially common elemental sources. X-ray diffraction (XRD) analysis, which identifies the minerals and their proportions in each sample, was undertaken at the Australian National University, on 14 sherds that also had optically stimulated luminescence (OSL) age estimates (below). The results, quantified by software program Siroquant, separated redwares from the other classes. Of the 20 samples dated by OSL, seven were analyzed with neutron activation analyses (NAA) and the remainder with inductively coupled plasma mass spectrometry (ICP-MS). These techniques determined the incidence of radioactive elements K, U, and Th, so that we could calculate within sample annual radiation doses to the quartz crystals over the lifetime of the pottery samples. The data made possible the comparison of differences between the visually determined pottery types. The results of both NAA and ICP-MS analyses showed that pottery types 1, 2, 5, and 7 differed significantly from each other in their amounts of K, U, and Th. In contrast, pottery types 3 and 4 contained low and similar amounts of these elements (Anderson et al. 2014, and references therein). The principal implication of these results is that types 3 and 4, the main types of red wares in Galápagos sites, are

quite similar in composition. The commonality of elemental pottery sources in mainland Ecuador and the Galápagos Islands is probably the result of transport of pottery from the former to the latter. Other unglazed pottery types are more disparate and variable. OSL Dating of Pottery OSL dating measures the amount of luminescence emitted by a sample after it has been stimulated by light. The amount is approximately proportional to the length of time elapsed since the sample was last exposed to light (or to heat above 400°C). Calculations for working out the age (i.e., the time since last exposure) take into account the natural radioactivity of the sample and its surroundings, since the luminescence signal accumulates as a result of exposure to ionizing radiation (Aitken 1998:38—41). Fragments of pottery and associated soil samples were analyzed in the OSL laboratory at the Australian National University. We tested seven pieces of pottery from Heyerdahl's collection with the OSL technique in 2005 prior to fieldwork to determine whether results could be obtained. After fieldwork in 2006, 29 additional samples from the Heyerdahl, Maruri, and Anderson 2005 collections, plus four archaeological samples (from Stothert collections) from coastal Ecuadorian earthenware of approximately known but well-constrained age (Stothert et al. 1997) were used for comparison. Overall, 32 of the 40 samples were identified as Types 3 and 4 redwares. Standard OSL pre-treatment was used, but with minor modifications. Under restricted laboratory lighting, pieces were broken from the selected sherds of pottery, and a small electric drill was used to grind a sample out of the center of each, avoiding the surfaces of the pottery as these had almost certainly been exposed to sunlight after firing. The powdered samples were treated with hydrochloric acid to remove any carbonate coatings on the grains. Samples were treated with concentrated hydrofluoric acid for approximately 5 minutes to help remove feldspar grains, remove grain coatings, and to etch the outermost parts of quartz grains. Etched samples were loaded on to 9-mm steel discs using silicon oil, and OSL measurements were carried out on a Risø reader. Age results were obtained by using the following calculation: Age (years) = Palaeodose (Gy) / Annual Dose (Gy/year), where the Palaeodose (P) is the dose of radiation received by the grain from the environment. It is calculated by determining the equivalent dose (De), which is the laboratory dose required to induce the observed luminescence. The Single-Aliquot Regenerative (SAR) dose protocol was used. Of the 40 samples on which OSL was attempted, only 20 contained quartz grains suitable for dating. Insufficient luminescence was a problem in many samples. This is a common issue in OSL dating generally because relatively few grains, typically around 20 percent but sometimes as low as 1 percent of grains in a sample, have inherent OSL detectable above-background levels (Jacobs and Roberts 2007). In the present case, there was considerable variability and many samples fell below the acceptable value of about 1,000 counts in the OSL integral. Zero of six samples from Buccaneer Bay exhibited sufficient initial sensitivity to produce OSL dates. The relationship between initial brightness and ability to obtain a date is not linear, and some dates were obtained on four samples with very low natural sensitivity: samples K0333, K0334, K0791, and K0795. These results, which include all Galápagos Type 4 redware samples, are considered less reliable than others here. Of the 16 OSL samples of acceptable brightness (Table 2, Figure 2), the control samples from mainland Ecuador have later dates, as expected. The Tambo River material dates to about A.D. 1840, and three of the four OSL results on samples of it (K0777, K0778, K0779) all post-date A.D. 1535. Sample K0803 might be an unreliable result technically, or represent an accurate result for a fragment of older redware incorporated in the site. All but one of the remaining OSL dates on Galápagos samples overlapped with or post-dated A.D. 1535 at 1 sigma. Eight samples of Type 3 redware originated from James Bay (K0303, K0781, K0783) and from Whale Bay (K0307, K0793, K0786, K0789, K0792). With the exception of K0307, all of these results are clearly later than A.D. 1535. K0785, which groups with them, was a sample of Spanish storage jar from James Bay.

K0302, K0305, and K0332 are samples of earthenware types 2, 1, and 5, respectively from the Norwegian collection (Heyerdahl and Skjølsvold 1990: Appendix, catalog numbers 16,7,6). Only K0305 seems clearly earlier than A.D. 1535. That aside, we conclude provisionally that the OSL dates on samples of acceptable initial brightness support the argument that non-European pottery in the Galápagos was largely, if not wholly, manufactured after A.D. 1535.

Radiocarbon Dating

Charcoal fragments were excavated from five sites: James Bay and Buccaneer Bay on Santiago Island, and Whale Bay, Las Palmitas, and Cabo Colorado on Santa Cruz Island. Sampling was done at 10-cm intervals where possible, but most sites exhibited little or no stratigraphy. We collected charcoal from hearths and the surrounding areas. Representative samples were collected from all material found in primary context. The charcoal was identified to taxa and the most suitable pieces selected for radiocarbon dating. Nine charcoal samples obtained from four of the sites were radiocarbon-dated to

determine the age of the woody material and the inferred date of camp site occupation (Table 3). Calendar ages were calibrated based on the SHCal04 dataset (Mc Cormac et al. 2004) and calculated at the 2s level using the probability distribution method, CALIB 5.0.1 (Stuiver and Reimer 1993). The radiocarbon results (reported in Froyd et al. 2010) came from charcoal in association with redware. Because the sites consist largely of remains on the surface, or within the uppermost sediments, the association of pottery and charcoal was generally less reliable than that from samples within sealed stratigraphy. However, radiocarbon dates from samples collected in stratigraphically sealed contexts at James Bay and Buccaneer Bay were equally young. All of the dated charcoal fragments originated during the historic period, with median calibrated ages ranging between A.D. 1575 and A.D. 1825 (Table 3), with one exception. A sample from a fireplace in Area H, James Bay, was dated as post-A.D. 1950 (Table 3). The full range of calibrated ages for the site samples, calculated at the 2 σ level, ranged from A.D. 1500 to A.D. 1950 (Froyd et al. 2010), indicating occupation within the European era. Palaeoecological Research Palaeoecological researchers in the Galápagos Islands have investigated several potential indicators of anthropogenic change. Analysis of radio carbon-dated land snail deposits from cave sites on Santa Cruz and Santa Maria shows late Holocene declines that are attributed to post-European habitat destruction by goats, donkeys, and pigs, and to predation by introduced rodents (Chambers and Steadman 1986; Steadman et al. 1991). Similarly, the endemic rodents, the Galápagos Giant rat (*Megaoryzomys*) and species of the genus *Nesoryzomys*, existed up until the introduction of the black rat (*Rattus rattus*) in the colonial era (Steadman and Ray 1982). A detailed study of all Holocene vertebrates on Santa Maria concluded that, "all extinction on Santa Maria occurred in historic times" (Steadman 1986:87; Steadman and DeLeon 1999). As in the case of fauna, there is no clear evidence for the extinction of native species or the introduction of exotic plants prior to A.D. 1535. A number of 'doubtful natives' have been confirmed in the palaeoecological records as long-term inhabitants of the Galápagos Islands (Coffey et al. 2011). Common animals commonly associated with pre hispanic occupation of oceanic islands, such as the common house gecko (*Hemidactylus frenatus*), were absent until after European settlement (Phillips et al. 2012). Interpreting changes in the sedimentological record is more complex, primarily because of climatic volatility associated with shifts in the Intertropical Convergence Zone in the eastern Pacific (Sachs et al. 2009) and increasing strength and frequency of El Niño events over the last 1,000 years (Conroy et al. 2009). High-resolution pollen records from the highlands of Santa Cruz and San Cristobal (Coffey et al. 2012; van der Knaap et al. 2012) (Bush et al 2014; Restrepo et al. 2012) show that there were few fire events under a relatively humid climate state prior to A.D. 1535 and throughout much of the late Holocene. The climate seems to have become somewhat drier locally, with increased burning beginning as early as A.D. 1200. A decline in Santa Cruz upland tortoise populations also began 700-500 years ago (Froyd et al. 2014). Increased burning and declining tortoise populations probably reflect longer-term climate change and wet land loss, with anthropogenic influence added in the colonial period.

To explore additional environmental proxies potentially indicative of anthropogenic influence at highland and lowland sites, we subjected sediment samples from our coring project to a range of analyses including: (i) X-ray fluorescence to quantify variations in 30 elements at 2-mm intervals (Croudace et al. 2006); (ii) Magnetic susceptibility to determine the concentration and composition of magnetic minerals, these data reflecting climatic variability or anthropogenic disturbance; (iii) Charcoal analysis (Whitlock and Larsen 2001) to determine fire event frequency; and (iv) Humification to measure the degree of decay under dry conditions in peat profiles, this indicating relative wet-dry conditions through time (Chambers et al. 2010). A summary of the results for three sites located within different ecological zones (Figure 3 a-c) shows the degree of environmental change associated with anthropogenic influences at each site.

The core chronology at Espumilla Lagoon, Santiago Island, extends to ~3300 cal B.P. A major shift in sediment type dating to 500-400 cal B.P. (Figure 3f) is marked by a rapid rise in magnetic susceptibility and Ti (clastic sediment) input into the basin. This is most likely a response to cultural burning as well as erosion resulting from the introduction of goats and pigs. The core from Salt Mine Crater, Santiago Island, has a sequence of black sandy silts that exhibit high magnetic susceptibility values. The silt deposits derived from erosion events probably were caused by heavy rainfall. They alternate with layers of gypsum-rich clays and microbial mats precipitated during dry phases. The charcoal counts through the site show phases of high charcoal concentration around 1,500-200 years ago, increasing in frequency toward the present (Figure 3e). Quinine Bog, Santa Cruz Island, is located at 800 m asl. It was cored to a depth of 420 cm. The upper 350 cm of the core consisted of organic-rich peats and silty clays dating to around 2200 cal B.P. High-resolution humification analysis revealed peak wet periods at 1800-1600, 1000-800, and 300-200 cal B.P. These periods coincide with phases of low charcoal

abundance (Figure 3d). Our data indicate massive changes in sediment mobilization within the last 1,000 years. Overall, they reflect significant decadal to centennial-scale climatic shifts across the Galápagos Islands, driven primarily by southward movement of the ITCZ. These shifts were associated in particular with the Little Ice Age 500-200 years ago, which brought higher rainfall events, warmer ocean waters, and reduced easterly winds. The last of these ITCZ movements may have limited voyaging opportunities from mainland South America. There is increasing catchment erosion in coastal areas beginning 500-300 years ago, and in the high lands of Santa Cruz the bogs record major ecological shifts driven by changes in fire regimes and humidity. These areas are remote from the documented human settlement on the island but are still vulnerable to impacts from cattle, goats, invasive plants, and fire. It remains unclear whether a general climatic shift from humid to more arid conditions occurred in the highlands of Santa Cruz 1,000-500 years ago. Despite the sensitivity of the Galápagos Island environment to anthropogenic activity, all the lines of palaeoecological evidence point towards initial human occupation taking place after A.D. 1535.

Discussion and Conclusions

If there is no case advanced by the palaeoecological evidence for human intervention in the Galápagos Islands prior to the sixteenth century, then does the archaeological hypothesis for earlier occupation remain valid? As noted at the outset, the critical issue is whether the palimpsest model of site formation adopted by Heyerdahl and Skjølsvold (1990:67-71) is demonstrable. It is not demonstrated by site stratigraphy. The archaeological material is almost always well mixed on each site surface (0-10 cm), and also, rarely, at greater depth. In our research at James Bay, fragments of Spanish jar were recovered at 40 cm in area A; in test pit F1, there was one red ware sherd at 10-20 cm; in test pit F2, there were unidentifiable sherds, a metal hinge, nail, and pieces of iron at 20-40 cm, and in area H iron bolts were recovered to a depth of 30 cm. At Buccaneer Bay, where the archaeological site is stratigraphically sealed by a sand dune, our test pit 4 had redware sherds and clay tobacco pipe pieces to a depth of 20 cm with glass and iron fragments to 40 cm below surface. These data support the contention of Heyerdahl and Skjølsvold that "there is no stratigraphy and modern and ancient materials were found together" (Heyerdahl and Skjølsvold 1990:30), a conclusion advanced for all their sites except for Whale Bay. There, aboriginal sherds were "more frequently found underneath the surface, to a depth of 30 cm in some cases" (Heyerdahl and Skjølsvold 1990:30). We could not substantiate this assertion. Our inspection of the 1953 excavation balks, and our additional excavations at Whale Bay, disclosed no material below a depth of 10 cm. Nothing suggested that the site has been stratigraphically disturbed to any extent since 1953. In summary, there is no clear evidence that there was, or is now, stratigraphic separation of redware pottery from colonial and European period remains in the Galápagos sites. Spatially, redwares were mixed superficially with colonial and European ceramic materials at all sites. They always occurred in association with European materials at every scale of analysis. The point is most readily demonstrable in the largest dataset, from Whale Bay. The distribution of cultural remains by 5m x 5m collection squares shows that there is no full or partial spatial separation of redwares from other materials anywhere at the site irrespective of the density of remains per square. In addition, remains of pottery and other materials show the same relative abundance over each of the 34 squares (each of 25 m²). In other words, there are no different patterns of spatial distribution for redware versus other historical period pottery types, nor for metal and glass. Relative abundance across space was the same for all types of materials (Figure 4). This is also supported by the high correlation coefficients for numbers of different artifact classes (Table 4). These results, observable also in the small datasets from other sites (Stoother 2007), are not possible under a palimpsest assumption unless the density distribution of discarded prehispanic redware across the site was repeatedly matched in the discard patterns of different material culture assemblages during later site occupations. A coincidence upon one site, let alone upon five, is vanishingly improbable. We therefore reject the palimpsest model as a plausible scenario for these data. The alternative null hypothesis is that all types of material were deposited during one phase of activity within the historical era. A few examples of Chimu or Sican clay appliqué figures and the clay whistle found by the Norwegian Expedition (Heyerdahl and Skjølsvold 1990:51-52, 56) do constitute potentially valid evidence of prehispanic discovery of the Galápagos Islands, but it is equally possible that such articles were carried as intact trophies or souvenirs by Amerindian or European passengers or crew on European ships; they were discarded along with the other material found on the sites. Metallic and lithic material culture of comparable age was not present, although European gunflints are quite common on the sites. It is interesting to note that while giant, perforated stone anchors used on balsa rafts occur abundantly along the mainland coast of Ecuador, they are not reported from the Galápagos Islands. Radiocarbon dating of the archaeological sites showed that all of them were occupied in the European settlement era. Although the OSL dates are still

problematic, they also suggest that the redware pottery was manufactured during the historical era. In fact, the representation of numerous articles of nineteenth-century manufacture, including pottery types, suggests relatively late historical habitation. While the palaeoenvironmental data are still under analysis, our preliminary results, set alongside results from other projects, indicate that human interference in Galápagos ecosystems did not occur until the European era. We conclude that the hypothesis of prehispanic habitation in the Galápagos Islands is unsustainable in the light of current evidence. It is not inherently implausible, but our evidence indicates that, despite the existence of long-distance sailing in the eastern Pacific, the Galápagos Islands were probably not found until their historically recorded discovery in A.D. 1535.

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Data availability

The excavated material discussed in this article has been deposited with the Charles Darwin Research Station, Puerto Ayora, Galápagos Islands, and INPC Ecuador. The analytical data are reported in Stothert (2007) and Anderson et al. (2014).

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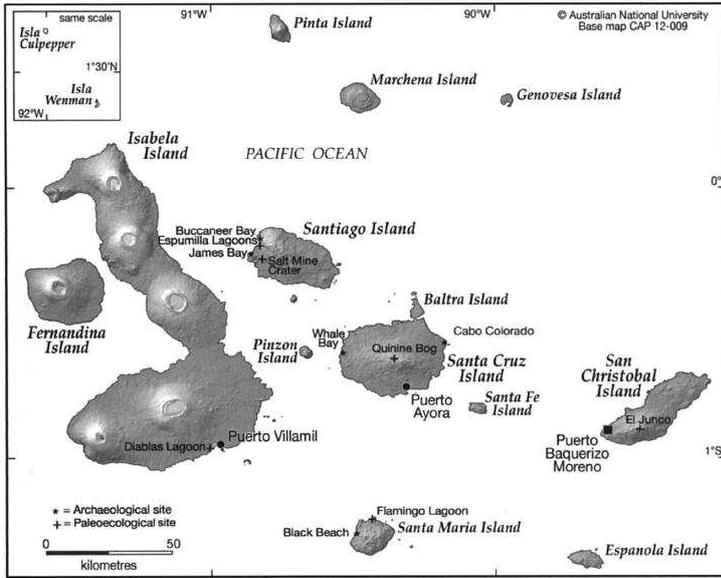


Figure 1

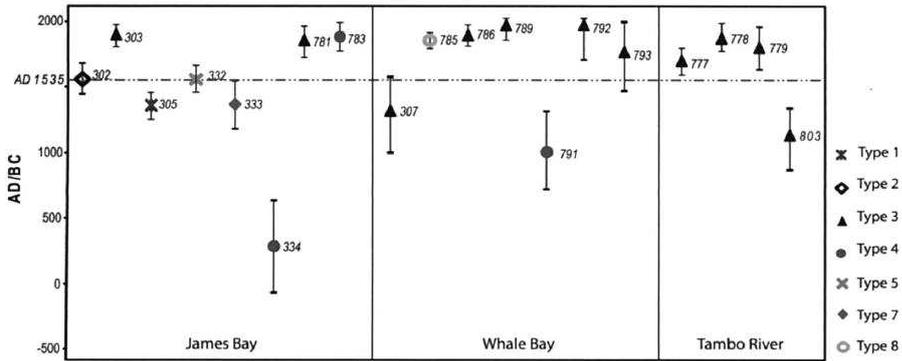


Figure 2

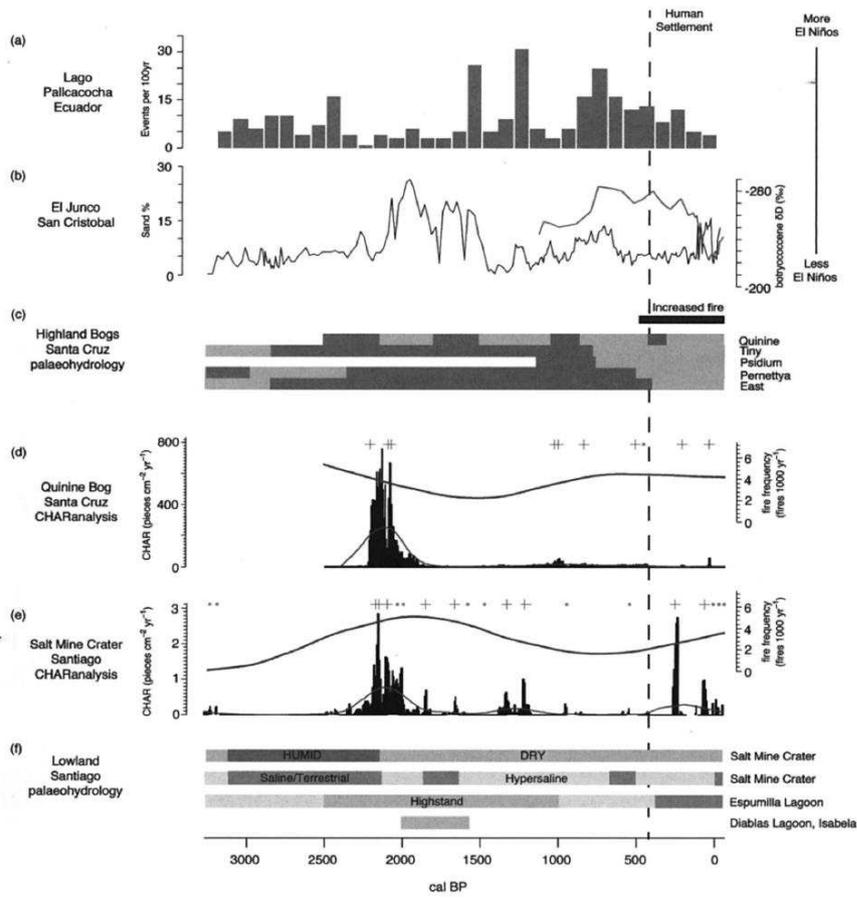


Figure 3.

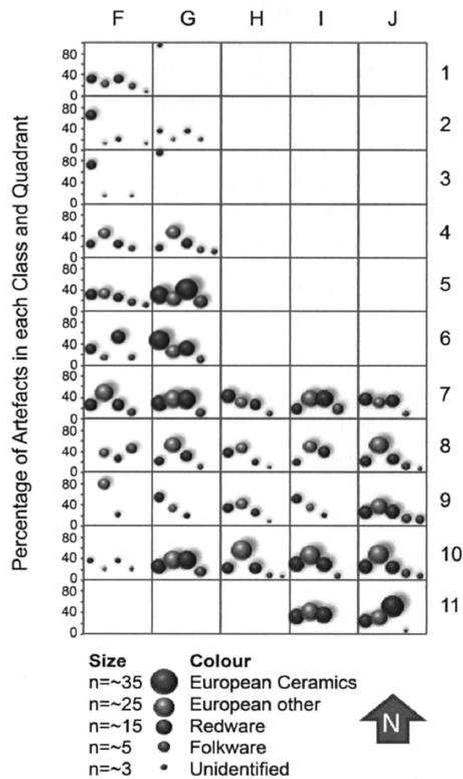


Figure 4.