

The Nikumaroro Bones Identification Controversy: First-hand Examination versus Evaluation by Proxy – Amelia Earhart Found or Still Missing?

Pamela J. Cross^{1*} and Richard Wright²

¹Archaeological Sciences, University of Bradford, Bradford UK, p.j.cross@student.bradford.ac.uk

²Emeritus Professor of Anthropology, University of Sydney, Australia

Abstract

American celebrity aviator Amelia Earhart was lost over the Pacific Ocean during her press-making 1937 round-the-world flight. The iconic woman pilot remains a media interest nearly 80 years after her disappearance, with perennial claims of finds pinpointing her location. Though no sign of the celebrity pilot or her plane have been definitively identified, possible skeletal remains have been attributed to Earhart. The partial skeleton recovered and investigated by British officials in 1940. Their investigation concluded the remains were those of a stocky, middle-aged male. A private historic group re-evaluated the British analysis in 1998 as part of research to establish Gardner (Nikumaroro) Island as the crash site. The 1998 report discredited the British conclusions and used cranial analysis software (FORDISC) results to suggest the skeleton was potentially a Northern European woman, and consistent with Amelia Earhart. A critical review of both investigations and contextual evidence shows the original British osteological analyses were made by experienced, reliable professionals, while the cranial analysis is unreliable given the available data. Without access to the missing original bones, it is impossible to be definitive, but on balance, the most robust scientific analysis and conclusions are those of the original British finding indicating the Nikumaroro bones belonged to a robust, middle-aged man, not Amelia Earhart.

Keywords: Palaeopathology; Forensic Analysis; Cranial Analysis; CRANID; Osteology; Human Identification; Female Airplane Pilots, D.W. Hoodless; Nikumaroro Skeleton

1. Introduction

Forensic and palaeopathological investigations of historical individuals often fascinate both the scientific community and the general public. The *Journal of Archaeological Science*, *British Medical Journal*, *Scientific American*, and *Journal of Forensic Sciences* have all published articles using physical anthropological methods to identify historic individuals such as Egil Skallagrimsson, Armstrong Custer, John Paul Jones, and Adolf Hitler (Byock 1995;

Hardarson and Snorraddottira 1996; Marchetti et al. 2005; Rogers et al. 2004; Weinstein 2005; Willey and Scott 1999). These articles, and other research, use expertise in osteology, taphonomic processes and palaeopathology to re-evaluate actual skeletal remains or published descriptions of remains to assign personal identity. This paper continues that tradition by evaluating two reports with contrasting findings regarding the identification of a set of skeletal remains as possibly those of the missing American celebrity pilot Amelia Earhart.

Earhart, one of the first female airplane pilots and a celebrity of the early 20th century, disappeared with her navigator, Fred Noonan, during their attempt to circumnavigate the world in 1937 (Adler 2015; Long and Long 2000: 11-15, 58). Amelia Earhart and her contemporary, Charles Lindbergh, were the glamorous faces of the 1930's Age of Aviation, and her status as an American icon was already well in the making when she and Noonan began their record-breaking journey around the world's equator. They never made that last record. Instead they became legends, when, after one last, brief radio message, they and their plane disappeared in the mid-Pacific. Today, the bright red Lockheed Vega Earhart flew solo across the Atlantic in 1932 flies in the Smithsonian galleries, a reminder and symbol of both her disappearance and her enduring fame.

On June 29th 1937, after flying some 20,000 miles, Earhart and Noonan began the last, most dangerous portion of their round-the-world flight. Between them and California was 7,000 miles of the vast, remote Pacific. Leaving Lae, New Guinea, their first refuelling stop was the tiny, two mile by one mile Howland Island 2,556 miles (4,113 km) away. Balancing flight conditions, speed, altitude and navigation were crucial and difficult. The plane left overloaded with the fuel necessary to make the long flight and soon after take-off the expected headwind speed increased dramatically from 15 to over 26 mph. Sporadic radio conditions plagued communication, but still indicated they were on course for Howland shortly before Earhart's last message saying they were nearly out of fuel. The US Coast Guard vessel waiting near Howland to help guide them in never sighted the plane. Extensive search efforts were made by the Coast Guard and Navy without success. Two years later, with no signs of the lost flight, Earhart and Noonan were declared dead. (Gillespie and TIGHAR 2006: 46-62, 101, 130, 188, 196; Long and Long 2000: 11-18, 214).

Given the dramatic life and disappearance of Amelia Earhart, it's not surprising the fate of that lost flight continues to intrigue. Books, papers, articles and television programs continue to speculate on the fate of the missing aviators and their plane. Theories abound from expert research to the most dubious of conspiracy theories and have produced films, articles and books (Adler 2015; Aron 2005; Burns et al. 1998; Fox 2011; Griffiths 2014; King 2009; King et al. 2004; Long and Long 2000; Lorenzi 2012; Mendelsohn 2012). The discovery of a partial skeleton on Nikumaroro, a small atoll of the Phoenix Islands about 300-400 miles from Howland Island seemed particularly significant (Burns et al. 1998; King et al. 2004:4). British officials treated the discovery seriously and had the remains analysed in 1940. The medical official, Dr. D. W. Hoodless, concluded the skeleton belonged to a stocky, middle-aged man and the investigation was dropped. Records of this investigation were found by researchers of The International Group for Historic Aircraft Recovery (TIGHAR) in the late 1990's, including the osteological report and examination notes by Dr D.W. Hoodless.

In 1998, a paper by TIGHAR and two forensic anthropologists re-examining the identification of the Nikumaroro skeleton was presented at the American Anthropological Association (AAA) annual convention (Burns et al. 1998). The paper was highly critical of the original British analysis and, with caveats, suggested the skeleton was more likely to have belonged to a European woman, consistent with Earhart. Aspects of the AAA paper are problematic, and following a brief summary of the historical context of the Nikumaroro Skeleton investigation, the authors evaluate the Burns et al. (1998) critique and conclusions.

The following summary of the British recovery and analysis of the bones from Nikumaroro is based on primary documentation from the Republic of Kiribati National Archives and Western Pacific High Commission archives (Burns et al. 1998; TIGHAR 2011b). In September 1940, British colonial administrator Gerald B. Gallagher discussed with various officials the discovery of a skull, bones, woman's shoe and sextant box which he felt might belong to the missing Amelia Earhart. These communications noted the c.1930 wreck of the ship, "*Norwich City*," (which lost eleven crew members, including Europeans) and recovery of some survivors from Nikumaroro. They also gave details of the remains and the deposition site. On the basis of the shoe, Gallagher suggested the skeleton might be female and therefore possibly Earhart. Gallagher listed the bones recovered, but declined to suggest the sex of the skeleton, saying an expert was required (Gallagher 1940d). Central Medical Authority, Dr.

Duncan C. M. Macpherson, concluded Gallagher's evidence was insufficient to identify or exclude the bones as belonging to Mrs. Putnam. He recommended the bones be sent to the University of Sydney Anatomical Department or Fiji (Central Medical School) for further examination (Macpherson 1940).

The remains were shipped to Suva (Fiji) via the R.C.S. "*Nimanoa*." On board they were examined by Dr. Lindsay Isaac, acting Senior Medical Officer "in charge of Medical and forensic investigation throughout the whole colony" (Isaac 1941a). Isaac examined the material and identified the remains as belonging to an "elderly male of Polynesian race," and adding, "the bones have been in sheltered position for upwards of 20 years and possibly much longer" (Isaac 1941b). Isaac also noted some of the bones crumbled during transport.

At the Central Medical School (CMS), the bones were examined by Dr. D. W. Hoodless (1941). Hoodless concluded the remains most likely belonged to a c. 5' 5 1/2" stocky male of European or mixed European ancestry, probably between 45-55 years old. Upon receipt of the Hoodless report, Macpherson concluded the remains were not those of Amelia Earhart and the case was closed without further action.

2. Examining the original analysis and counter claims

The re-examination of archaeological skeletal remains is undertaken on a regular basis. Different examiners bring different specialisms and perspectives, and new analytical techniques are developed offering new data for interpretation. Sometimes new examinations confirm old conclusions and sometimes they radically alter the old interpretation. In the case of the Nikumaroro bones, the skeletal evidence was lost during World War II. Subsequent attempts to trace the bones indicate they were moved to Australia, probably Sydney, but no further evidence has been found. Despite the lack of the original bones, TIGHAR, felt a re-examination of the reports and data using modern expertise might suggest different conclusions. Using the materials gathered by TIGHAR researchers, Burns et al. (1998) produced a paper re-analysing the case with two aims: evaluating Dr. Hoodless' competence, and applying new techniques to the data provided in Dr. Hoodless' papers. The Burns et al. (1998) paper accepts Hoodless' conclusion that the bones represented an individual too short

to be Noonan, but challenged the overall findings that the bones represented a c.65 inch, 45-55 year old stocky male of European or Mixed-European heritage.

In particular, the paper challenges Hoodless regarding his anatomical expertise and his methods for estimating stature. Towards the second aim, Burns et al. (1998) reinterpret Dr. Hoodless' cranial metric data using the statistical software FORDISC to produce the results the skull was most similar to Norse females. The paper concludes, with caveats, that the Nikumaroro bones appear consistent with the missing Earhart. Subsequent references tend to lose the caveats.

2.1 Hoodless' medical and osteological expertise

“Skeletal measurements taken over 55 years ago by a now-deceased individual of unknown expertise, with no description of the methods or assumptions employed, must be used with great caution” (Burns et al. 1998; King et al. 2004:237-42). The function of this statement appears simply to label Hoodless as not competent to assess or measure a human skeleton. However, even basic research reveals a great deal about Hoodless' expertise, all of which underscores his competence. King (2004:262) makes it clear that TIGHAR researched Hoodless' background.

Dr. David W. Hoodless (1887-1955) was not some 'individual of unknown expertise' asked to evaluate a partial skeleton on a whim. As is obvious from the communications referenced earlier, the British thought the remains might belong to Earhart or Noonan and considered their identification an important issue. Hoodless, chosen to make the assessment, was the Principal of the Central Medical School (CMS) in Fiji (Fig.1). At his death, the British Medical Journal described Hoodless (BSC, LMSSA) as a respected medical teacher and principal (1955). He completed his medical degree in 1935, having been teaching at the CMS since 1929. Hoodless taught theoretical/practical anatomy and physiology (CMS was known for dissection and skeletal analysis), and also did pathological lab work and clinical practice (Guthrie 1979:15, 20, 31, 34; King et al. 2004:262; Robertson 1991:55-6, 62). He could also be described as a practising cultural anthropologist. Hoodless was active in native communities as a doctor and collected information about Fijian beliefs and practices,

particularly regarding disease and health (1955; Guthrie 1979:23-5). While Hoodless was obviously not trained as a modern forensic anthropologist, his background indicates he was perfectly competent to assess sex, age, body type, and ancestry of a human skeleton.



Fig. 1: Students with Dr. Hoodless (R), Central Medical School, Fiji, 1937.
Courtesy of Dr. Rod Ewins (Ewins 2011)

2.2 Hoodless expertise: inappropriate terminology?

Burns et al. (1998) criticizes Hoodless use of the terms *zygoma* and *malar* to indicate two bones and his reference to thirteen bones as “less than half of the total skeleton” (Hoodless 1941). The suggestion is that since *zygoma* and *malar* are two terms for the same bone Hoodless’ skeletal knowledge is poor. Modern bioarchaeologists, forensic anthropologists and clinicians are well aware anatomical terms vary over time and by country. *Zygoma* can refer to the zygomatic arch, the *malar* bone itself, the zygomatic process of the temporal bone, or the process of the *malar*. Numerous anatomy references available to a 1930-1950’s British physician refer to the zygoma and malar as two distinct entities (Frazer 1933:182-3;

Lockhart 1928-9; Quain et al. 1856: 45-7) (Fig. 2).

The second point made is that thirteen bones of a total 206 in an adult human is quite a bit less than 50%, again bringing into question Hoodless' knowledge (Burns et al. 1998). The criticism is pedantic. Aside from Hoodless being correct, if unspecific, there is no accepted standard for what constitutes 'half a skeleton', and the elements examined represented the major bones of the body (Fig. 3). Illustrative of his professionalism, even for this preliminary report, Hoodless specifically lists each element with notes on side of body and condition/completeness. The Nikumaroro bones present and examined are those primarily used in typical identification analyses to evaluate sex, age, stature, race and body type.

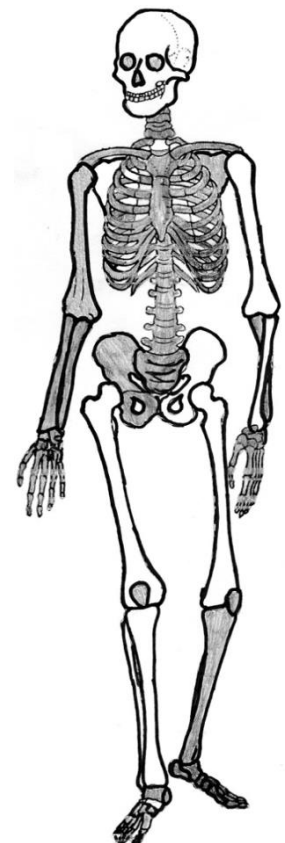
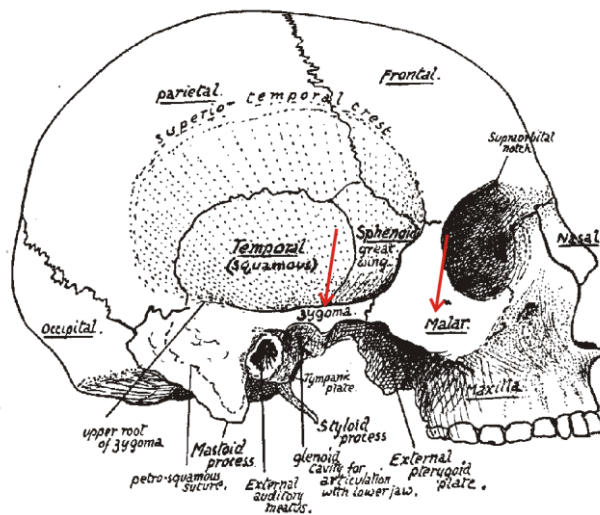


Fig. 2: Diagram of skull showing zygoma and malar as separate bones (Frazer 1933: 182, Fig. 160). Usage maintained from 1933 to 1965. (Red arrows, author).

Fig. 3 Skeletal representation of elements (unshaded) given in Hoodless report (1941): 1) skull - right zygoma and malar broken; mandible- four teeth; 3) partial right scapula; 4) first thoracic vertebra; 5) rib portion (? 2nd right); 6) left humerus; 7) right radius; 8) right innominate; 9) right femur; 10) left femur; 11) right tibia; 12) right fibula; 13) right scaphoid, foot. (Drawing by author).

2.3 Hoodless stature estimate

Four criticisms were made regarding stature: Hoodless includes no standard error, the result

of “5 feet, 5 ½ inches approximately” is too exact, and the height estimates from each bone measurement vary too widely (Burns et al. 1998; Hoodless 1941). Hoodless uses the Pearson equations to estimate height, an accepted method still used today, and the original publication did not include error terms (Pearson 1898-9). Height estimates are inherently approximate, and Hoodless states the figure is approximate. The variation in estimates is moderately more significant, though given the degree of approximation inherent in all stature methods, c.2.5 inches is not that great. Average values +/- 2 to 4 inches (c.5 cm) are not unreasonable (Ousley 1995).

More importantly, the reason for the variance, if it was considered inappropriate, should have been investigated by forensic anthropologists experienced in osteometry. A review of the calculations uncovered two slight transcription errors for Pearson’s equation constants used by Hoodless: 163.406 cm instead of 164.406 cm (humerus) and 89.925 cm instead of 85.925 cm (radius). These are easy errors to make and the resulting variance was not large enough to alert either Hoodless when he made the original calculations or Burns et al. (1998) when they evaluated the report. Once the transcription errors are corrected, the height variance is reduced to a very acceptable c.1 inch (2.65cm). Burns et al. (1998) recalculated the Nikumaroro skeleton’s height using Ousley (1995) and state the height estimate is 5’6” to 5’7” (167.7-170.2 cm) and suggest Earhart exaggerated her height of 5’8” (172.7 cm), although that is the height listed on her pilot’s license (Boyette 1930).

Hoodless estimated the Nikumaroro individual’s height as 5’ 5.5” (166.4 cm). Using the original Pearson (1898-99) values produces a height of c.5’ 4” (162.6 cm) if the skeleton was female. Using Trotter (1970), recommended over Pearson for modern Europeans, or Ousley (1995), as used by Burns et al. (1998), the height estimate is c. 5’ 6” - 5’ 7” (167.7-170.2 cm). It’s interesting that Hoodless’ estimate is virtually the same as the more modern calculations and may suggest he was using a modified formula rather than erred in his constant values.

Given the high error margins associated with height estimation (Ousley 1995), Earhart cannot be excluded due to stature, though she falls at the tallest extremes of the accepted range. Hoodless does not specifically state he excludes her based on height but his height estimate would support such a conclusion. This is certainly an example where more modern methods better understand the inaccuracy of stature calculations and tend to give ranges rather than a

single approximation. Because of the high levels of error, height should never be considered a definitive identification trait. Sex however is certainly an eliminatory identification trait.

2.4 Hoodless determination of sex

A sex determination of female is obviously the key point of any argument suggesting the Nikumaroro remains could belong to Amelia Earhart. In this crucial area, Hoodless is both more detailed in his reasoning and definite in his conclusions. The language used in the report does not indicate Hoodless was an obvious “non-osteologist,” or that his analysis “lacked methodological rigor” (Burns et al. 1998). Hoodless used the sub-pubic angle (pubic arch) of the right innominate bone (os coxae), the set of the two femora (angulation to the pelvis) and the ratio of the circumferences of the long bones to their individual lengths to make a determination of “MALE” (Hoodless 1941). These are all criteria still in use today.

The primary criticisms of this evaluation are threefold: that there is no comparison against a particular population, not enough metric data is recorded and no cranial-based sexually dimorphic traits are given. Burns et al. (1998) suggest, therefore, the analysis is probably incorrect. Many osteologists make an overall evaluation of skeletal remains which is informed by their entire expertise, and then prepare a report appropriate to the recipient, which will include varying amounts of detail. The paper work available for this reanalysis is an informal summary document for a non-expert audience which assumed Hoodless’ competency.

The information given is not unreasonable, but it is not detailed enough for a more detailed reanalysis. The fact that Hoodless does not list cranial evaluation does not mean it did not form part of his overall assessment. Additionally, while it is disputably considered the second best indicator, the skull, like most of the skeleton indicates sexual dimorphism primarily as a function of robusticity. Males are generally larger and more muscular than females. If Hoodless had relied on cranial morphology, then a comparison with a similar population would be a more significant criticism. Women from a physically active population may be more robust than males from non-active populations, and there can be nutritional effects on robusticity as well. The most accurate indicator of sex is the pelvis, where the morphology is

based on biological function (Mays and Cox 2000; Spradley and Jantz 2011; White and Folkens 2005: 385-398). Hoodless' use of a well-established pelvic method and related femoral traits is supportive of his expertise.

2.5 Hoodless age estimation

Age estimation of adults is even more approximate than stature estimation, and is a particular issue given the weathering of the bones. Hoodless (1941) makes a point of emphasizing this in his estimate: "Owing to the weather-beaten condition of all the bones it is impossible to be dogmatic in regard to the age of the person at the time of death." Since his report does not include details for his age estimation, it is unknown whether he considered any of the methods mentioned by Burns et al. (1998), such as osteoarthritis, cranial sutures (notoriously unreliable) or tooth wear (more usual for estimating age in pre-modern populations). The criticism of not using pubic symphysis (Brooks and Suchey 1990) and rib contour (İşcan and Lothe 1986), techniques which may not have been applied to heavily weathered bones, and which were developed after Hoodless' time, is hardly reasonable. Hoodless' estimated the individual's age as c.45-55, probably towards the end of that range. While this is greater than Earhart's age, who would have turned 40 a few weeks after her disappearance (Boyette 1930), like the stature, the difference is insufficient to eliminate Earhart. However, it is more unsupportive than supportive, given that Earhart was from a social class unlikely to show heightened skeletal aging due to manual labour. Certainly, the photographs available suggest, if anything, Earhart appeared younger than chronological age.

2.5 Hoodless evaluation of race and body type

In the critique, race and body type are considered together. Burns et al. (1998) again suggest the terminology in the report indicate Hoodless is presumptuous without proof and unable to make the judgements he reports. Given Hoodless' experience in the Fiji area, which included an intimate knowledge of local body types, his opinion that he could identify and discount accurately in this instance that the individual was not completely native South Seas seems a reasonable one. His suggestion of European or mixed native/European is offered as a

possibility only. This opinion, does not exclude Earhart (European/American), so perhaps it is not surprising that the main criticisms relate to the description of the individual as short, muscular and stocky, all at odds with Earhart.

Burns et al. (1998) state that “stocky” requires knowledge of weight and cannot be assessed from bones. “Stocky” can be interpreted quite reasonably to refer to robusticity, as can the term “muscular,” which Burns et al. (1998) state requires analysis of muscle attachments. Robusticity is not simply a function of enthesophytic development or weight. It can be observed from the overall morphology and relative diameter of the long bones (Patrick 2007; Porter 1995; Porter 1999; Ruff et al. 1991; Stock and Shaw 2007). It is clear from the report that Hoodless made an overall assessment of the individual represented by the Nikumaroro bones and he specifically states that he compared the length and circumference of the long bones.

Earhart was a tall, slender, gracile individual, a description easily verified from numerous photographs and documents, including data on her height (68 inches) and weight (118 pounds) from her pilot’s license (Boyette 1930). From these values, her Body Mass Index (BMI) can be calculated (Patrick, 2007). Earhart’s BMI, 17.9, is at the extreme end of the scale in the slender-lean category. Hoodless worked amongst the Fijians, a population which includes gracile and robust individuals, for many years and was familiar with male and female morphology. It seems highly unlikely he would describe skeletal remains belonging to an individual of Earhart’s body morphology as short, stocky and muscular (Fig. 4).



Fig. 4: Images of Amelia Earhart illustrating her gracile morphology.

A (left): Earhart portrait from 1963 United States stamp. Photo by Richard Wright.
B (right): Earhart and President Hoover in 1932. Hoodless' analysis of the Nikumaroro skeleton, suggest a man c. 5" shorter, but similar in build to Hoover rather than the gracile Earhart.
(Photo 1931-76B: <http://www.hoover.archives.gov/exhibits/Hooverstory/gallery03/index.html>)

3 Applications of modern analysis to the Nikumaroro skeleton

3.1 Computerised cranial analysis: FORDISC and CRANID

The primary supporting evidence for an interpretation of the Nikumaroro bones as consistent with Earhart are the results of a craniometric analysis. Burns et al. (1998) used Hoodless' cranial data (skull length and breadth, and orbit height and breadth) with the forensic crania identification software FORDISC to classify the skull's probable ancestry and sex. Their stated results indicate the skull cannot be excluded from any population and any identification has a low level of certainty. Despite this, the result reported is the skull is "more likely European" and if European "most likely female" (Burns et al. 1998). There are problems with the craniometric analysis and with the way the results have been reported.

One of the authors, Wright, developed an alternative forensic craniometric software application CRANID (Wright 2008; Wright 2012) with a larger sample base and a broader worldwide spread than the crania sample used in FORDISC. To parallel the FORDISC analysis, a CRANID analysis was run using the same four measurements and method of linear discriminant analysis. A similar result was obtained with six ethnic groups as the "top" probable matches, including Norse female. CRANID found the nearest group, the best probable match, to the Nikumaroro skull is a Japanese male sample. However, to simply present this result without the associated probability is highly misleading. The probability the skull actually belongs with the Japanese male sample is a very low 4.6%.

Furthermore, the five other "matching" groups have similarly low probability (3.5% to 4.6%). These groups are: Bedouin (unsexed), Norse female, Chinese male (Anyang and Atayal), and Peruvian male. This discordance of sex and geography shows the results are worthless for determining ancestry on a worldwide basis when only these four measurements are used. To report the findings of *Japanese male* or *Norse female*, as of highest probability when the

likely accuracy is so low, invites misunderstanding. Readers unfamiliar with the field of statistics and probability will ignore any qualifications and simply report the apparent conclusion. Exactly this situation has occurred with subsequent reporting of the FORDISC results (TIGHAR 2004; TIGHAR 2010).

Hoodless gave a highly qualified morphological opinion on the ancestry of the Nikumaroro bones, stating only that the individual was probably not a “pure South Seas islander” (Hoodless 1941). He concluded this after seeing all the properties of the bones he had in front of him and with decades of experience in anatomy and local morphology. His assessment is worth more than any craniometrics analysis utilizing only four measurements (Kallenberger and Pilbrow 2012). Certainly, based on the available data, the ancestry of the bones cannot be determined by FORDISC or CRANID multivariate methods.

3.2 Evaluating the taphonomic evidence: weathering and exposure

According to the British documents, the physical condition of the bones was assessed by Gallagher (Gallagher 1940d) initially, then by Isaac (Isaac 1941b) and later by Hoodless (Hoodless 1941). All three men who examined the bones considered the weathering significant. Burns et al. (1998) and King and TIGHAR (2004: 242) suggest, without any evidence, that Gallagher’s experience of decomposition and taphonomy might be based on a hypothetical dead cow he once saw. The documentation shows that while the investigation may not have met some modern standards, both Gallagher and his superiors were aware of forensic requirements regarding identification of bodies (Gallagher 1940a; Gallagher 1940c; Gallagher 1940d; Macpherson 1940; Vaskess 1940):

“Please telegraph to me particulars of finding of skeleton in Gardner Island, including where found and state reason for believing it to be that of a woman and whether this belief based on anatomical characteristics. State dental condition and whether any evidence of dental work on jaw, length of skeleton from vertex of skull to arch of foot, approximate age and condition of bones and whether any hair found in the vicinity of skeleton. ... Secretary, Western Pacific High Commission.” (Vaskess 1940)

“no positive evidence of identification was found, and I am afraid the data available does nothing to establish the skeleton as that of Mrs. Putnam. It is unfortunate that the complete pelvis is not available as this would have done much to establish remains as

being those of a woman. ...no evidence of dental work was found as this frequently affords a most valuable means of identification. Bones...value as regards identification, although of course sex and age can often be established... bones be sent either to the Anatomical Department at the University of Sydney or to Fiji for farther [sic] examination, and that the search be continued with a view to discovering farther [sic] bones, personal trinkets, etc. ... D. C. M. Macpherson, Acting Central Medical Authority.” (Macpherson 1940)

To further assess the taphonomic evidence available, first the known time sequence needs to be reviewed:

- 1937: Earhart and Noonan disappeared in July 1937.
- 1940: Nikumaroro bones were first discovered circa April 1940, at which point the skull was buried but the post-cranial elements left exposed (Gallagher 1940a).
- 1940: Site was reviewed and material recovered in October 1940 (Gallagher 1940d).
- 1941: Bones medically assessed in February (Isaac 1941b) and April (Hoodless 1941).

The discovery of the skeletalised material was less than 3 years (c.32 months) after the disappearance of Earhart and Noonan. The systematic recovery took place c.39 months after the plane disappeared. Gallagher states “All small bones ... removed by giant coconut crabs... difficult to estimate age bones owing to activities of crabs but am quite certain they are not less than four years old and probably much older...no hair found” (Gallagher 1940d). At post c.43 months, Isaac declared the bones in a state consistent with being in a “sheltered position for upwards of 20 years and possibly much longer” (Isaac 1941b). The term ‘sheltered’ matches well with the Gallagher report description of the site (Gallagher 1940d). Hoodless, at post c.45 months is more conservative, describing the bones as “very weather-beaten...exposed to the open air for a considerable time. Except in one or two small areas all traces of muscular attachments and the various ridges and prominences have been obliterated” (Hoodless 1941). The documentation indicates these three evaluations were all made by professionals familiar with the environment, forensic procedures, and anatomy (even the non-physician, Gallagher correctly specifically identified most of the bones, including a *thoracic* vertebra). The documentation also suggests their very similar conclusions were made independently of each other.

Spennemann and Franke (1995) published the results of a taphonomic study of

decomposition on Pacific coral atolls covering a period of just under seven years (80 months). The study environment, Mejjatto Island, is very similar geographically and geologically to Nikumaroro (figure 5). Associated research and sample results given by the paper indicated hair preserved up to 80 months, skin decomposed at 40 months with low tissue depth elements skeletalised completely, while ligamentous connections were retained up to 60 months in open conditions. Earhart was missing only 39 months when the Nikumaroro bones were recovered with no hair or soft tissue surviving. Ubelaker's (1997) and Behrensmeyer's (1978) work also suggest insufficient time had elapsed to account for the degree of weathering indicated by Gallagher, Isaac and Hoodless. The descriptions suggest the Nikumaroro bones were at least in weathering stage 3 (4-15+ years since death) and possibly in stage 4 (6-15+ years) (Behrensmeyer 1978: 157).

The rate of degradation of bodies is highly dependent on the specific environment. While the Behrensmeyer (1978) study involved areas open to scavenging, the Spennemann and Franke (1995) study involved buried bodies not affected by scavenging. The Nikumaroro remains, though relatively sheltered, with the skull buried for c.7 months between discovery and recovery, were subject to scavenging by coconut crabs and probably rats (Gallagher 1940c). While these crabs normally subsist primarily on vegetable matter, they will scavenge flesh. They are not a social species and generally restrict themselves to foraging within a limited distance from their burrows (Burggren and McMahon 1988:16-18; Brown et al. 1991:5, 112). Scavenging might conceivably account for the complete skeletalisation of the assemblage within 32 months. However, scavenging may not explain the lack of hair specifically looked for by Gallagher or the degree of weathering observed. The taphonomic studies suggest deposition of the Nikumaroro remains prior to the disappearance of Earhart. The island was known for human use (of various ethnicities) and habitation both prior to and after 1937, including the shipwreck of the *Norwich City*, with eleven sailors (English and Arab) killed, approximately ten years prior to the recovery of the Nikumaroro bones (Gallagher 1940b; King et al. 2004:71).



Fig. 5: Map of the Pacific area showing Earhart and Noonan target flight path, location of Nikumaroro remains, and Mejatto, the site of Spenneman and Franke (1995) degradation study. Map © Google Earth, markings in red by authors.

3.3 Other Evidence

The other evidence given to support an identification of the bones as Earhart’s are the site location, associated finds and some new biological evidence, but none are especially robust. Nikumaroro atoll is within a 400 mile radius of Earhart’s destination (Figure 5), but as mentioned above was by no means isolated from human use and occupation by various Europeans, Americans and Pacific populations. The finds associated with the recovery site included a woman’s shoe and a sextant case. A shoe-heel, recovered later by TIGHAR, was identified as an American make of suitable period but not the same size as Earhart’s shoes (TIGHAR 2001). The sextant case was identified in 1941 as English or French make, “of some age” and used as a receptacle (TIGHAR 2011b). As with the bones, these items may be associated with the earlier shipwreck, or other occupations of the atoll. The new biological finds consist of the possible human/turtle/? phalanx? and faecal matter. In particular reference to the newly recovered bone fragment, remember Gallagher stated: “In spite of an intensive search, none of the smaller bones have been discovered” (Gallagher 1940c). Modern analysis on the fragment was inconclusive regarding species or DNA (TIGHAR 2011a). The fecal

analysis was also inconclusive, though the presence of human DNA was identified (TIGHAR 2011a).

4. Discussion and Conclusions

Reassessing whether the Nikumaroro remains may have been Amelia Earhart's has addressed a number of points regarding forensic and bioarchaeological methods. On the basis of the historical documentation, the British recovery and examination of the Nikumaroro (aka Gardner Island) human remains in 1940-1941 was performed by professionals familiar with human anatomy and forensic practices. The language and questions expressed by the officials involved is comparable to modern investigations and show an understanding of the requirements for identification. Regarding age, stature and taphonomy, the evidence suggests the Nikumaroro individual was not Earhart, but cannot be considered conclusive. In contrast, the evidence regarding sex and body-type does exclude Earhart. Two medical doctors, one an anatomist and the other the forensics officer for the area, separately concluded very strongly that the remains were male. In addition, Hoodless described the individual as short, stocky and muscular, which is opposite to Earhart's morphology.

The only modern technique applied by Burns et al. (1998) was craniometric analysis using four measurements which supposedly suggested a female European. The result was considered unlikely even by the original presenters. Further craniometric analysis using CRANID has shown that attempting to determine ancestry given only four measurements is a worthless and potentially misleading exercise. This critical review of the original British investigation and the 1998 reassessment finds there is no supportable evidence to impugn the original British analyses. The most robust analysis of the Nikumaroro bones indicates the individual was most likely a stocky male, not Amelia Earhart.

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