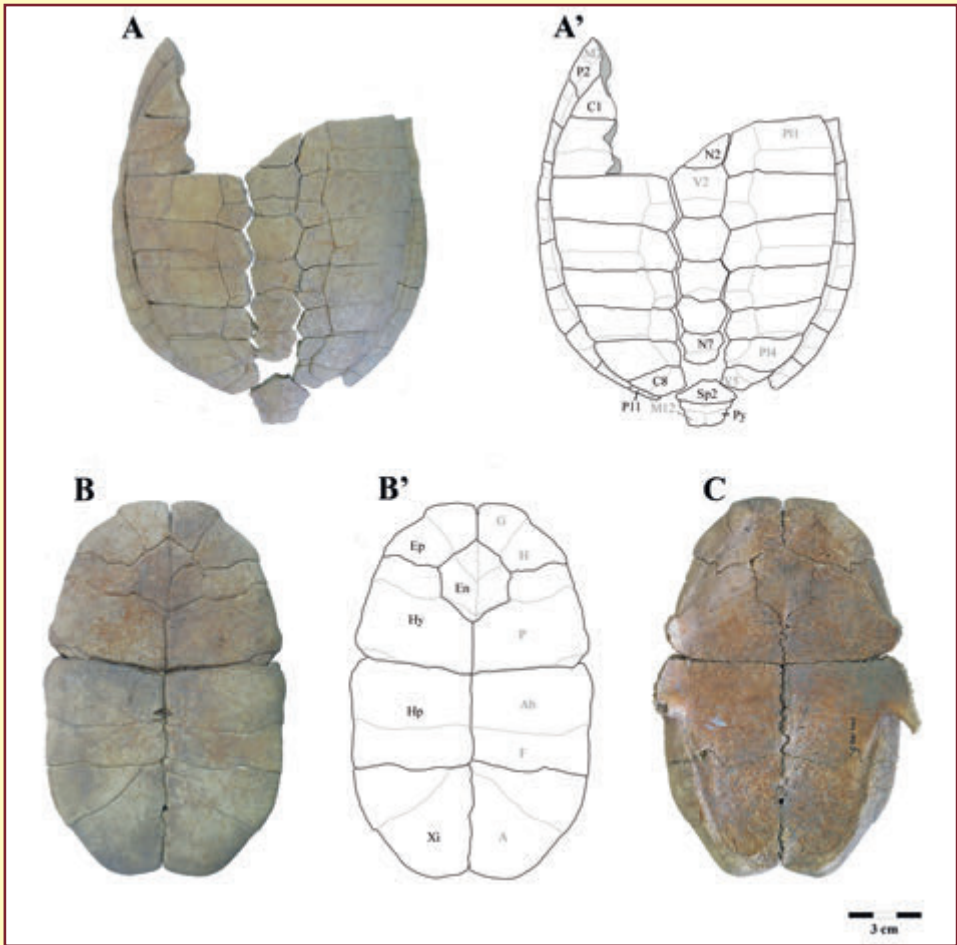


ARCHAEOFAUNA

INTERNATIONAL JOURNAL OF ARCHAEOZOOLOGY



ARCHAEOFAUNA

ARCHAEOFAUNA es una revista anual que publica trabajos originales relacionados con cualquier aspecto del estudio de restos animales recuperados en yacimientos arqueológicos. Los manuscritos deben enviarse a:

ARCHAEOFAUNA is an annual journal that publishes original papers dealing with aspects related to the study of animal remains from archaeological sites. Manuscripts should be sent to:

EUFRASIA ROSELLÓ IZQUIERDO

Laboratorio de Arqueozoología. Dpto. Biología. Universidad Autónoma de Madrid
28049 Madrid. España (Spain)

Para la elaboración de manuscritos, que serán evaluados por un mínimo de dos revisores externos, consultar las instrucciones de la contraportada. Todos los manuscritos no conformes con las normas de publicación serán automáticamente devueltos a los autores. Cada autor o grupo de autores recibirán un pdf de su trabajo.

For preparation of manuscripts, that will be evaluated by a minimum of two external referees, please follow the instructions to authors. All manuscripts not conforming to these instructions will be automatically returned to the authors. Each author (or group of authors) will receive a pdf of his/her (their) work.

Director: ARTURO MORALES MUÑIZ

Laboratorio de Arqueozoología. Dpto. Biología. Universidad Autónoma de Madrid
28049 Madrid. España (Spain)

Comité editorial / Editorial board:

U. ALBARELLA. Department of Archaeology, University of Sheffield, UK.

D. BENNET. equinestudies.org, USA.

I. CRUZ. Universidad Nacional de la Patagonia Austral, Argentina.

M. DOMÍNGUEZ RODRIGO. Departamento de Prehistoria, Universidad Complutense, Spain.

K. EMERY. Florida Museum of Natural History, USA.

E.M. GEIGL. Institute Jacques Monod, UMR CNRS Université Paris Diderot, France.

H. GREENFIELD. University of Manitoba and St. Paul's College, Winnipeg, Canada.

A. HADJIKOUMIS. Department of Archaeology, University of Sheffield, UK.

L. JONSSON. Gothenburg Museum of Natural History, Sweden.

C. LEFÈVRE. Muséum national d'Histoire naturelle UMR 7209, Paris.

A. LUDWIG. IZW, Humboldt-Universität zu Berlin, Germany.

R.H. MEADOW. Peabody Museum of Archaeology and Ethnology, Harvard University, USA.

M. MORENO GARCÍA. Instituto de Historia, CSIC, Spain.

N. MUNRO. Anthropology Department, University of Connecticut, USA.

J. NADAL LORENZO. Secció de Prehistoria i Arqueologia, Universitat de Barcelona, Spain.

N. SYKES. University of Exeter, UK.

M. ZEDER. Smithsonian Institution, Washington DC, USA.

Revista incluida en las bases de datos ICYT (CINDOC), Catálogo Latindex, Zoological Record, The Arts & Humanities Citation Index y Current Contents / Arts & Humanities (JCR)

ARCHAEOFAUNA

Laboratorio de Arqueozoología. Depto. Biología.
Universidad Autónoma de Madrid
Cantoblanco 28049. Madrid. España

Editor: Eufrasia Roselló Izquierdo

Editor Adjunto / Assitant Editor: Laura Llorente Rodríguez

Faculty of Archaeology, Universiteit Leiden, The Netherlands. l.lorente.rodriguez@arch.leidenuniv.nl



LAZ

Diseño y maquetación:

Ismael Sánchez Castro

Tel.: 670 763 012

ismasan76@gmail.com

Imprime:

ImpresiónA2

FRONTISPIECE: Carapaces of the European pond tortoise, *Emys orbicularis* L., 1748 from the Iron Age site of Soto de Medinilla (Valladolid, Spain).

ISSN - 1132-6891

ARCHAEOFAUNA

INTERNATIONAL JOURNAL OF ARCHAEOZOOLOGY



Depósito Legal: M. 30872-1992

Diseño y maquetación:
Ismael Sánchez Castro
Tel.: 670 763 012
ismasan76@gmail.com

Imprime:
ImpresiónA2

Índices/Contents

IN MEMORIAM: ANA FABIOLA GUZMÁN CAMACHO	7-9
Freshwater and Marine eels in the Pacific and New Zealand: Food Avoidance Behaviour and Prohibitions. <i>B.F. Leach, J.M. Davidson & F.J. Teal</i>	11-56
https://doi.org/ 10.15366/archaeofauna2021.31.001	
Subsistence strategies in the Inner Congo Basin since the 14 th century AD: the faunal remains from Nkile and Bolondo (DR Congo). <i>Laurent Nieblas Ramirez, Veerle Linseele, Wim Wouters, Hans-Peter Wotzka & Wim Van Neer</i>	57-75
https://doi.org/ 10.15366/archaeofauna2021.31.002	
Zoarqueología de todo un valle: cambios en el consumo de animales en los últimos 3.400 años en El Valle de Mauro, norte semiárido de Chile (31°s). All valley's zooarchaeology: changes in the consumption of animals in the last 3,400 years in El Mauro Valley, semiarid north of Chile (31°s). <i>Patricio López Mendoza, Daniela Villalón & Bárbara Rivera</i>	77-95
https://doi.org/10.15366/archaeofauna2021.30.003	
European Pond Turtle (<i>Emys orbicularis</i>) remains in Iron Age contexts of the Spanish Northern Iberian Peninsula. <i>Iratxe Boneta Jiménez, Corina Liesau Von Lettow-Vorbeck & Adán Pérez-García</i>	97-108
https://doi.org/ 10.15366/archaeofauna2021.31.004	
Gestión ganadera durante la Edad del Bronce Medio y Final en Mallorca (Islas Baleares). El caso del poblado de <i>Els Closos de Ca'n Gaià</i> . <i>Lua Valenzuela-Suau, Sílvia Valenzuela-Lamas, Bartomeu Salvà, Joan Fornés, David Javaloyas, Llorenç Oliver, Florent Rivals & Delphine Bosch</i>	109-132
https://doi.org/ 10.15366/archaeofauna2021.31.005	
Archaeozoological studies: new database and method based on alphanumeric codes. <i>Cristina Real, Juan Vicente Morales, Alfred Sanchis, Leopoldo Pérez, Manuel Pérez Ripoll†, Valentín Villaverde</i>	133-141
https://doi.org/ 10.15366/archaeofauna2021.31.006	
Mariscadores en las costas del Caribe colombiano en época prehispánica y moderna: una reflexión para evaluar el impacto humano en los ecosistemas marinos desde la arqueomacología y la etnoarqueología. <i>Diana Rocío Carvajal Contreras</i>	143-154
https://doi.org/ 10.15366/archaeofauna2021.31.007	
Étude ostéométrique des principaux os des membres et de la ceinture du membre thoracique chez le Faisan de Colchide (<i>Phasianus colchicus</i> L., 1758). Osteometric study of the main limb bones and of the thoracic limb girdle of the Common Pheasant (<i>Phasianus colchicus</i> L., 1758). <i>N. Mokrani, A. Borvon, A. Milla, C. Thorin & C. Guintard</i>	155-180
https://doi.org/ 10.15366/archaeofauna2021.31.008	
Announcements.....	181-185

Freshwater and Marine eels in the Pacific and New Zealand: Food Avoidance Behaviour and Prohibitions

B.F. LEACH¹, J.M. DAVIDSON¹ & F.J. TEAL²

¹Research Associate, Museum of New Zealand, Te Papa Tongarewa, PO Box 467, Wellington, New Zealand.

Corresponding author: Foss.Leach@gmail.com

²Lyttelton, New Zealand.

(Received 28 September 2020; Revised 3 June 2021; Accepted 21 August 2021)

ABSTRACT: Eels are ubiquitous throughout the Pacific and New Zealand, and offer a rich source of protein and fat. However, bones of eels are rare in archaeological sites. This contrast has been noted several times in archaeological literature, not just in the Pacific, but also in Europe. Explanations for the dearth of bones range from taphonomic processes, the bones are too small, or too fragile, or they preferentially self-destruct because they are rich with oil. We show that each of these reasons is false. We review the presence and absence of eel bones in 144 archaeological sites in the Pacific region, finding only 1,151 eel bones of a total NISP of 188,351 (0.61%). Allometric equations are established for estimating live length and weight from cranial bone measurements of freshwater eels. Prehistoric catches were mostly in the range of 430 to 500 mm, length with only 5 greater than 800 mm, with no sign of the huge eels about 1800 mm long recorded in historic episodes of mass harvesting by Māori. A review of myths and oral traditions in the Pacific about eels revealed some common themes. Eels represent the incarnation of a male deity, symbolising the penis, and that the personified eel tempts and defiles a woman sexually. A male, often an heroic ancestral figure, punishes the eel by cutting him up into pieces. We found that there is often a strong association of eels with danger, and that eels are either venerated or feared, but seldom considered food. In some Pacific societies, the arrival of Europeans resulted in the lifting of the prohibition of eels as food. We also found two historic instances in among Māori that eels were *tapu*, requiring an elaborate *tapu* removal ceremony before they could be eaten by people who were starving. We conclude that mass harvesting of eels in New Zealand, so evident in the historic era, was a post-European development with important implications for Māori settlement patterns, making it possible to establish permanent villages in the interior of major river systems in Central New Zealand.

KEYWORDS: EELS, PACIFIC ARCHAEOLOGY, ALLOMETRY, FOOD TABOOS, MYTHOLOGY

RESUMEN: Las anguilas se encuentran distribuidas por todo el Pacífico y Nueva Zelanda constituyendo una rica fuente de grasa y proteína. Sus huesos, curiosamente, son infrecuentes en depósitos arqueológicos. Tal contraste ha sido repetidamente referido en la literatura arqueológica no sólo en el Pacífico, sino también en Europa. Las razones que explicarían tal escasez de restos son variadas e incluirían procesos tafonómicos, el hecho de que los huesos son muy pequeños, o muy frágiles, o que se autodestruirían debido a su alto contenido de aceites. En este trabajo mostramos que todas estas explicaciones son equivocadas. Para ello, repasamos la presencia de anguilas en 144 yacimientos arqueológicos del Pacífico, donde registramos 1.151 elementos sobre un total de 188.351 (0,61%). Al tiempo, elaboramos, a partir de medidas tomadas en distintos huesos craneales de anguilas dulceacuícolas, ecuaciones alométricas que permiten estimar la longitud en vida y el peso de los ejemplares. Constatamos que las capturas prehistóricas oscilaron entre los 430-500 mm de longitud total, con sólo 5 ejemplares por encima de los 800 mm, sin evidencia alguna de las enormes anguilas de 1800 mm que citan los registros históricos en episo-



dios de pesca masiva realizada por los maoríes. Una revisión de los mitos y tradiciones orales referidos a las anguilas en el Pacífico evidenció una serie de temas recurrentes. Así, las anguilas representan la encarnación de una deidad masculina, simbolizando el pene, y el hecho que la anguila personificada tienta y profana sexualmente a la mujer. Un hombre, con frecuencia un personaje ancestral y heroico, castiga a esta anguila cortándola en partes. Constatamos igualmente una fuerte asociación de la anguila con el peligro, y que estos peces se veneran o se temen pero rara vez se consumen. Registramos dos casos históricos que mencionan la condición *tapu* de la anguila entre los maoríes lo cual requería una elaborada ceremonia para eliminar dicha condición antes de poder ser consumidas en momentos de hambruna. En algunas sociedades del Pacífico, la llegada de los europeos acabó con la prohibición de consumir anguila. Por todo esto, se concluye que las capturas masivas de anguilas en Nueva Zelanda, bien documentadas en épocas históricas, son un fenómeno ocurrido sólo tras la colonización europea que tuvo gran repercusión en los patrones de asentamiento de los maoríes, posibilitando el establecimiento de poblados permanentes en el interior de los grandes ríos de la Nueva Zelanda central.

PALABRAS CLAVE: ANGUILAS, ARQUEOLOGÍA DEL PACÍFICO, ALOMETRÍA, TABÚES ALIMENTARIOS, MITOLOGÍA

INTRODUCTION

Dr Samuel Johnson made the perceptive comments below in 1773 during his visit with James Boswell to the Hebrides islands of Scotland:

“Of their eels I can give no account, having never tasted them; for I believe they are not considered as wholesome food. It is not very easy to fix the principles upon which mankind have agreed to eat some animals, and reject others; and as the principle is not evident, it is not uniform. That which is selected as delicate in one country, is by its neighbours abhorred as loathsome. The Neapolitans lately refused to eat potatoes in a famine. An Englishman is not easily persuaded to dine on snails with an Italian, on frogs with a Frenchman, or on horse-flesh with a Tartar. The vulgar inhabitants of Skye, I know not whether of the other islands, have not only eels but pork and bacon in abhorrence; and accordingly I never saw a hog in the Hebrides, except one at Dunvegan” (Hill, 1773: 135-136).

This passage neatly captures the essence of an issue that has taxed archaeologists in several parts of the world: *since eels are common throughout the world, and easily caught, why are their bones so infrequently found in archaeological sites?* The more general issue of whether the apparent absence of some species of fauna in archaeological sites is due to the failure actually to find it because it was simply not present for capture, or because it was not found for some other reason, such as failure to identify it, is not a new one in literature on archaeofauna (Lyman, 1995). For example, the fish species

Anoplopoma fimbria is scarce or absent in many archaeological sites along the northwestern shores of the United States, yet this species is large, abundant and nutritious. In seeking to explain such patchy occurrences Nims and Butler examined such factors as post-depositional destruction, inadequate sieve mesh sizes, or sample size, or inaccurate identifications (Nims & Butler, 2019). In this paper we aim to reconcile the ethno-historic importance of the eel fishery in protohistoric New Zealand with the dearth of eel bones in archaeological sites. A similar disjunction is found in the wider Pacific, and evidence in this area is also reviewed. Our working hypothesis is that in cases where humans considered eels acceptable as food, their bones will be found in archaeological sites. Conversely, in cases where people abhorred the idea of eating eels, their bones will be rare in archaeological sites. In addition, we should not expect that likes and dislikes of eels as food would be constant in any one human culture over a period of time. Food avoidance behaviour is a complex and changing human phenomenon, as any parent of young children knows. In times of plenty there is ample opportunity for food fads to take root. In hard times, people will eat almost anything.

EELS AND MĀORI CULTURE IN 19TH CENTURY NEW ZEALAND

Elsdon Best, who spent a lot of his life studying the customs and habits of Māori, asserted “the eel

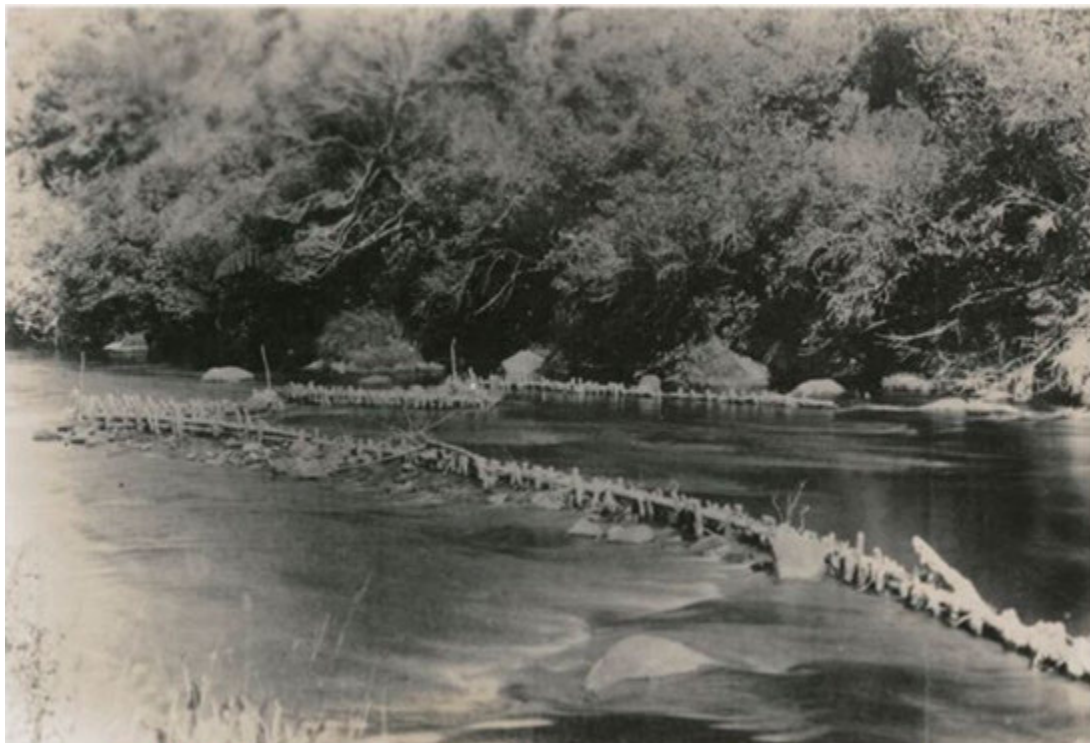


FIGURE 1

An eel weir on the Waingongoro River in Taranaki. Photo by J. Faris in 1888, printed by J. K. Hammonds, chemist, Inglewood. Courtesy Alexander Turnbull Library, Catalogue No: PAColl-4356.

furnished by far the most important food-supply” (Best, 1952: 275). Best published many books and articles in his lifetime, and the catching and processing of eels by Māori features prominently in many of these. Large scale weirs were constructed for their capture. Figure 1 shows a typical example. Eels are directed into a narrow area, where basket traps with a funnel entrance capture them (Figure 2). Construction and maintenance of these eel weirs represented a considerable investment of energy, which is further evidence of the importance of eels for 19th century Māori.

At certain times of year there are mass migrations of eels in New Zealand as they move out of streams, rivers and lakes and take to the sea for breeding. It is not known for certain where New Zealand eels spawn, but a study by Jellyman hints at the south Fiji basin (Jellyman, 2014: 143). In one area of New Zealand, at Lake Onoke in the Wairarapa, there is a 7 km long sand bar between the sea and the lake. Occasionally, the entrance in the sand bar closes after a storm, and rising freshwater level triggers the migration of eels to the sea between

February and March each year. Wairarapa Māori in the 19th and early 20th century dug channels into the sand bar and placed basket traps (Figure 2) along the side of these to capture eels as they tried to get to the sea. An important Māori Village called Okorewa was established at the entrance to the sea (Downes, 1918: 305). The annual eel harvest at Okorewa has been described by Saunders (1965), and details are still remembered by residents today. Wairarapa Māori recognised four types of eel (*tuna*), the *hao*, also referred to as the King eels by local Māori, the *riko*, the *paranui*, and the *kokopu tuna* (Saunders, 1965: 37). Saunders described the process as follows: The first to appear in these migrations are the *hao*. They have a silver belly and are about 30 cm long. They are hung out for a while to dry and then grilled over a fire, and then dried in the sun. When the *riko* arrive they have a green back and are 90 to 120 cm long. They are split open and the backbone is removed. Saunders commented that this backbone is very good eating. They are dipped in salted water and then dried in the sun. The *paranui* arrive next. They are dark and thick

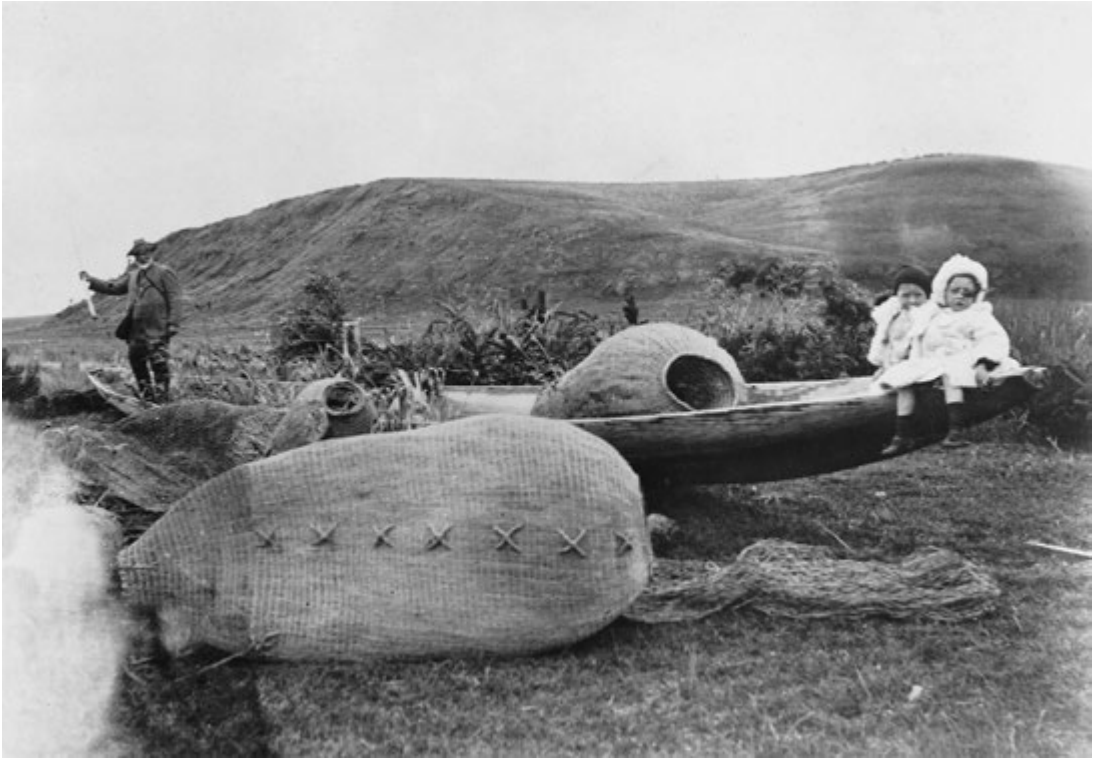


FIGURE 2

Several Māori basket traps, *hinaki*, for capturing eels at Lake Onoke, during a visit to the area by the Scenery Preservation Committee in 1904. Major Tunuiarangi Brown stands in the stern of the canoe (*waka*). Photo courtesy National Museum of New Zealand Te Papa Tongarewa.

skinned, and slightly smaller than *riko*. They are treated in the same way as *riko*, and are the longest lasting of the eels when sun dried. The last to arrive at Okorewa are the *kokopu tuna*, they are about 180 cm long and can weigh as much as 27 kg (Figure 4). When split open, they can be 60 cm wide, and are salted and smoked. The *kokopu tuna* are bound to be the long-finned eels, *Anguilla dieffenbachii*, which tend to migrate further inland by rivers and streams, and would arrive at Okorewa later. The short-finned eels, *Anguilla australis*, are commonest in coastal ponds, lakes and swamps (Paul, 2000: 43). A 91 years old Māori elder gave a vivid description at the eel harvesting at Okorewa in 1946:

“I was standing in the shallow fresh water beside the sand bar when a wave from the sea crashed over the sand bar. In an instant the water all around me boiled with thousands of eels trying to find their way to the sea. I couldn’t walk through the mass of eels thrashing about all around me” (Nelson Rangi Te Kai Waho to the author BFL, pers. comm., 2020).

Once the eels are split open they are dried in the sun on special wooden racks (*whata*). These dried eels were traded far afield for other products.

“These fish are obtainable all the year round in the lake, and in the lagoons and streams along the margin; but the main fishery is in April and May, along the sandspit at the mouth of the lower lake, and where the lake is closed. At this season eels, in a good year, are captured by hundreds of tons and dried in great quantities and distributed throughout the entire North Island, the silver and other descriptions of eels being famed throughout the length and breadth of the Island” (Mackay, 1891: 12).

There are many photos of these eel drying racks in New Zealand photographic archives. An example is given here, Figure 3. Close examination of such photos reveals that there are no heads on the drying eels, which means that when the eels are eventually consumed well away from the place of their capture and processing areas they will end up in archaeological sites without any cranial bones. We have



FIGURE 3

Eels drying on racks (*pataka-tuna*), at Raukawa marae, Ōtaki, New Zealand, during the opening ceremony of Raukawa meeting house. Note there are no heads present. Photograph taken on 14 March 1936 by George Leslie Adkin. Courtesy of Alexander Turnbull Library, Catalogue No: PA1-f-005-386.



FIGURE 4

Left: These two eels were caught at Bell Block and Okato, Taranaki, weighing 25 and 25.5 lb. Evening Post Newspaper 21 April 1928, page 17. Right: The author, BFL aged 17, and his sister Josephine, with an eel caught in a flounder net in Lake Wairarapa 1960, length c.1,370 mm.

not come across any detailed description of what Māori did with the heads at these mass harvesting and processing sites; however, there are three very interesting photos taken in 1988 at Waiwera (Lake Forsyth) in the South Island of New Zealand (Te Papa #MA1076381-2). These show more details of the processing work. The dead eels are strung up along a fence line with their heads still attached. They are shown at an angle to the main part of the body hanging down. Our interpretation is that the eels were opened up and the entrails removed, and cut behind the operculum so that the head could be placed over the wire and allow the body to hang down. This would explain why the heads appear at an angle to the body on the fence in the photo. The bodies of the eels still appear as round shapes, and therefore have not been split open at this stage as they hang on the fence. About 20 metres from the end of this fence is the drying rack where the split eels are placed over wooden rails. Heads are no longer present, and the bodies are opened up with two flat sides.

The purpose of this two stage process is not clear, but has important taphonomic implications. One possibility of their being placed nearly intact along the fence line would be to allow the skin to partly dry. Freshly caught eels are very slimy and difficult to handle. Splitting them open with a metal knife, let alone with a small sharp flake of chert or obsidian, is not easy when they are wet and slimy. Having the bodies hanging vertically to stiffen and dry would be an advantage.

What happened to the heads during this processing has not been recorded, but is an important point. Māori would not waste the food content in the heads, because there is a lot of food energy there. In some fish species, such as blue cod, the head actually contains more protein food than the fillet (Leach, 2006: 245). Best records that during mass harvesting of barracouta in the South Island the heads were cut off and discarded (Best, 1923: 54–55). In this species, the head contains much less food (ibid.). Whatever is the case, at any of these processing sites where eels were split and dried, we should expect large numbers of head bones and, perhaps, very few vertebrae.

So far, consideration has been focused on mass harvesting of eels. This was generally a seasonal event in New Zealand to take advantage of mass migrations. During the rest of the year processing and its taphonomic implications would be different. In New Zealand eels are very numerous and easily

caught by spear or net at any time of year and many would be eaten fresh. They would be taken back to the village and eaten there. We should therefore expect the whole range of bones to be present at village sites.

The foregoing brief review of ethnographic descriptions of eel capture among 19th century Māori society is heavily biased towards the spectacular mass harvesting of eels. As so often happens with historical descriptions, the more mundane everyday events do not get the same coverage. Archaeological sites, on the other hand, are all about the mundane. Middens tell us what people actually ate on a day to day basis. If one day the site at Okorewa is excavated, the midden there may be informative on every day life as well as the spectacular annual event when eels migrated out to sea in that vicinity. Eels represent two economic advantages over other sources of food – first, mass harvesting provides a surplus that can be traded for other commodities and, secondly, eels provide an all important rich source of oil, that helps to offset seasonal shortages of carbohydrate food.

THE EEL PROBLEM IN NEW ZEALAND

The question which now arises is whether these 19th century descriptions of eel harvesting applied in earlier times? New Zealand has a very short prehistoric period of 1,000 years at most (Higham & Hogg, 1997: 149; Hogg *et al.*, 2002: 116; Wilmshurst *et al.* 2008: 7676), and archaeological research has revealed very few eel bones in middens until recently, and then only in very small numbers. This has puzzled archaeologists and culture-historians (Marshall, 1987). In her book on New Zealand prehistory, Davidson comments “there is as yet very little indication that eels were a major food resource, except in the protohistoric period” (Davidson, 1984: 146-147). Sutton, commenting on this problem, describes “eel head parts as small and fragile” (Sutton, 1986: 310), and offers taphonomic reasons why they are not being found by archaeologists, and suggests a change of focus on to the more distinctive and robust vertebrae. This is a good point and since eel vertebrae are quite distinctive should be quantified in future studies.

The rise of economic prehistory and environmental archaeology at Cambridge University had a profound effect on archaeology in New Zealand,

and as a result we now know a great deal more about the numerical abundance of all types of fishes that were caught and eaten by Māori in the pre-European era. A review of 126 such sites from all regions and periods (Leach, 2006: 345-346) shows that the most important fish species was barracouta with a total MNI (minimum number of individuals) for all sites combined of 10,075. The total for all species was 40,433. So barracouta contributed an average of just on 25% of the New Zealand wide catch. By contrast, conger eels are represented by less than 0.5%, and freshwater eels by a mere 0.3%) This shows that as far as food is concerned, during the pre-European era, Māori consumed very few eels at all. Contrary to the large Māori nomenclature relating to eels, Strickland's list of Māori fish names has only three words for barracouta: *maka*, *makā*, and *mangā*, which are arguably all the same word. The numerical abundance of eels in archaeological sites will be thoroughly reviewed below.

This curious contrast between the cultural importance of eels (as described in 19th century ethnographic literature) and their apparent economic unimportance is not limited to New Zealand, but is found in the wider Pacific as well. This apparent gulf is the main focus of this paper.

Some scholars have gone to extraordinary lengths to suggest that the dearth of eel bones in archaeological sites means there is something wrong with the archaeological evidence. Various suggestions have been advanced, such as that the bones are too small, or too fragile, or they preferentially self-destruct because they are rich with oil. There seems to be a reluctance to accept anything except that which is staring us all in the face – that recorded behaviour from the early historic period does not document behaviour which prevailed during the pre-historic period. This problem of failing to accept that the past was not the same as the present was once widespread among Pacific and New Zealand scholars, and was clearly described by Daniellson when reviewing the career of Kenneth Emory.

“The answer to this well-justified question is that no archaeological excavations were ever undertaken in Polynesia prior to 1950, simply because everybody knew for certain that it was absolutely meaningless and useless to do so... All I can do here, however, is to specify the premises on which this strange dogma was founded. These were the four more or less explicitly stated contentions that it was not worth while understating any archaeological excavations in Poly-

nesia: (1): because the arrival of man was so recent that no stratified layers could have had time to form; (2) Because the frequent hurricanes and tidal waves constantly overturned and scraped the soil bare, and would have destroyed anything left by earlier inhabitants; (3) Because no artefacts could have been preserved in the damp corrosive climate except those of stone – of which there already existed rich collections in the museums, and (4) Because pottery, the key artefact that the archaeologists relied on elsewhere in the world for constructing their chronological sequences, was totally absent from all the islands” (Daniellson, 1967: 33).

Daniellson points out that such a blinkered viewpoint was finally challenged by Emory's excavation of the Kuliouou cave shelter on Oahu in 1950, where he found well defined strata containing artefacts not known in ethnographic collections. In short, as a great deal of subsequent archaeological research has shown, the Pacific does indeed have a past that is different from what historical ethnographic observations portray. Nevertheless, Pacific ethnography has a residual tyranny over archaeology, in the form of the *Direct Historical Approach*. Contrary to this, archaeology surely is all about finding out new things about the past, not simply affirming what we think we already know from observations made during the historic period.

THEORIES WHY EEL BONES ARE RARE

The most recently stated explanation for why eel bones appear to be less frequent in New Zealand archaeological sites than expected was made from DNA identification from 38 bulk bone powder samples, 21 of which were from middens. This 15 author paper, published in the prestigious journal of the National Academy of Sciences, has this to say:

“Because of taphonomy and difficulties in identifying eel remains, it has long been hypothesized that these animals were of greater importance than their bone remains in midden assemblages reflect [The authors cite Marshall 1987 here]. Our data demonstrate that we can detect previously identified species (*Anguilla* and *Conger*) and new species (*Gnathopis*), using DNA. Still, we do not detect eel frequently. This suggests that in the sites sampled, eel were likely an important seasonal supplement to Māori diet, but not a primary food source” (Seersholm *et al.*, 2018: 4).

The two reasons they mention are the most common advanced world wide to explain the discrepancy between expectation and observation of eel remains in archaeological sites. The first – taphonomy – what exactly does this mean? It refers to the entire history of an item from first encounter with a human to its final resting place in the ground. This can be quite complex. In the case of an eel caught, say, with a fish hook, the person catching it might cut the head off and throw it overboard. As anyone experienced in catching eels knows, their teeth have a nasty habit of latching on and can then be difficult to remove, not to say painful. Clearly, if a head was discarded at sea or river, the cranial bones are not going to end up in a midden site. Cranial bones are the usual anatomical element that archaeologists identify in New Zealand. An alternative version of this is that the heads were cut off and given to dogs to eat and any eel bone fragments would be difficult to identify from coprolites, let alone quantify. Contrary to this, otoliths would survive intact and are simple to quantify. Another taphonomic scenario might be that the eels were split down the middle, dried in the sun, and then transported miles way to be eaten much later. No eels bones would then appear in a site close to where the eels were caught and processed. On the contrary, the ethnographic description outlined above suggests that such sites would be replete with cranial bones and practically no vertebrae. In a limiting case, where no bones, otoliths or any other hard parts remain at some site where eels were processed, there could still be residual evidence. Fankhauser has reported that the lipid profile, distinctive of eels, can be detected from archaeological sediments where eels were processed, regardless of whether there are any bones present (Fankhauser, 2002; Buih, 2014).

The second reason, cited above, is that eel bones are difficult to identify compared with other bones. This is asinine, and scarcely deserves comment. Anyone can be trained in five minutes to distinguish the main cranial bones of eel from other fishes. They are highly distinctive.

One more point arises from the bulk bone DNA study. Eel DNA was infrequent among the 436 taxa identified at family level. This result is similar to those found from regular osteological research on middens, reviewed below.

This issue of a surprising lack of eel bones in middens is not confined to New Zealand, and has been noticed in Europe. Eel bones were expect-

ed but hardly represented in early medieval sites in the southern Baltic area. Lepiksaar & Heinrich (1977: 113-114) and Benecke (1983: 284-285) argue that eel bones were under-represented and suggest it is the result of autolysis of eel bones by the fatty acids released from the fat in the bones. Prummel, reviewing this matter (1986), notes that such a problem should occur with all fat-rich fishes such as herring, eel, mackerel, and salmons, and goes on to describe his own analysis of a series of sites near Oldenburg in Schleswig-Holstein dating from AD 650 to 1260, where bones from freshwater eels are abundant. Moreover, herrings were by far the most common fish in the medieval sites in the southern Baltic and these should also have been affected by the same autolysis suggested for eels. The Oldenburg site had 1,040 eel bones. Other common fish species were herring (1,159 bones), pike (476 bones, and flat-fish (392 bones). In all, bones from 26 fish taxa were recovered (Prummel, 1994: 317). In short, Prummel argues that autolysis of eel bones is a modern-day myth. He also considers the environmental setting of each site, such as water salinity, the functional status of each site (trade centres and religious sites), and the ethnicity of the regions where they are based (Slavonic or Viking). None of these three factors explains the relative abundance of eel bones in different sites to his satisfaction.

On the same issue of preferential survival, Kettle comments “fish with a high fat content – like eel, salmon, or tuna – have the potential to acidify the soil matrix in which the remains are found leading to preferential autolysis or dissolution of the bone remains ... Although this potential bias is often quoted for salmon, it is not regarded as a potential source of under-representation for eel remains from archaeological sites [citing Eng-hoff, 1986: 67]” (Kettle *et al.*, 2008: 1313). In a thorough review of bone degradation processes in archaeological sites, Nicholson comments on the matter of fish with high oil content thus: “Until the widespread adoption of soil sampling and sieving, an absence of herring bones in archaeology was attributed to the autolysis of bones from fatty fish in aerobic conditions [citing Lepiksaar & Heinrich, 1977], a hypothesis which can no longer be sustained” (Nicholson, 1996: 526).

With better recovery methods now being employed, eel bones are more commonly being identified in European archaeological sites. A typical example is at the type site of Ertebølle in northern

Jutland where 18 fish taxa were identified (total NISP¹ = 16,159). Cyprinids were the most abundant, and freshwater eel second (17.3%). The most common cranial bones of eel were dentale, keratohyale, and premaxillare² (Enghoff, 1986: 66). Eel had the same relative abundance among post-cranial bones identified. Of these, vertebrae were the most common bone identified (eel NISP = 1,494). Similarly, the Havnø site in Denmark, which spans the Late Mesolithic Ertebølle and the Early Neolithic Funnel Beaker cultures from about 5000–3500 B.C., of the 12 taxa of fish identified with a NISP of 306, freshwater eel dominate, comprising 71% of the collection (Robson *et al.*, 2013: 172).

In conclusion, surely now we can finally lay to rest the suggestions that eel bones are not found in archaeological sites because they are too small and fragile to survive, and/or that they are too difficult to identify, and/or that they contain so much oil that they preferentially decay in soil and therefore do not survive. All these things are simply incorrect.

SOME BIOLOGICAL CONSIDERATIONS

A few basic details of eel biology need outlining before considering the presence of eels in archaeological sites. There are many species of eel in the Pacific region (Table 1). Those which have potential economic importance to prehistoric people belong to three families: Anguillidae, Muraenidae and Congridae. The latter two are more numerous, have wider distributions, and feature more prominently in archaeological sites. Both Muraenidae and Anguillidae are mainly nocturnal in habits. That is, they are far more active at night. However, from personal experience, both can easily be caught during daylight hours, and are instantly attracted to any bait in their vicinity. Conger eels also are easily taken on hook and line during daylight hours. The annual migration of freshwater eels from New Zealand to the Pacific made mass harvesting possible. This has been described earlier.

¹ Number of Identified Specimens

² Enghoff is mistaken here. *Anguilla* spp. do not possess a premaxilla (discussed below); the bone he identified was most probably the maxilla.

<i>Anguilla australis</i>	New Zealand, Auckland islands
<i>Anguilla bicolor</i>	Papua New Guinea
<i>Anguilla celebensis</i>	Western Papua New Guinea
<i>Anguilla dieffenbachii</i>	New Zealand, Auckland Islands
<i>Anguilla marmorata</i>	Most oceanic islands north to the Marianas, and south to Papua New Guinea, New Caledonia, and Society Islands.
<i>Anguilla mauritana</i>	Central Pacific
<i>Anguilla megastomata</i>	New Caledonia, Solomon Islands, eastern Pacific, Fiji, Tonga, Samoa, Marquesas, Tuamotu, Tahiti
<i>Anguilla obscura</i>	Papua New Guinea, East Polynesia, Tonga, Samoa, Marquesas, Tuamotu, Tahiti
<i>Anguilla pacifica</i>	East Pacific
<i>Anguilla reinhardi</i>	New Caledonia

TABLE 1

Distribution of species of the genus *Anguilla* in the Pacific islands. From Lane (1978), following Eales (1968). See also Nandlal (2005).

The security of the taxonomy of different species is constantly under review. One study comparing morphology with M-DNA suggested a concordance of about 80% (Aoyama *et al.*, 1999: 196).

Concerning the distribution of eels in the Pacific, the Hawaiian islands are a somewhat unusual case.

According to Titcombe there are numerous types of eels in Hawaii and she documents six congers, one snipe eel, eight snake eels, and 35 morays (Titcomb, 1951: 136), and many details of catching, preparation and consumption. She states “Salt water eels were eaten, but freshwater eels were used only ceremonially. Of details of this use there is no available record” (ibid.: 124). Although there is some suggestion that Chinese immigrants may have introduced a species of freshwater eel in historic times that are now found in streams, James and Suzumoto’s careful review of all evidence concludes:

“Until now *Anguilla* have not been reported from any Hawaiian stream. Although larvae of freshwater *Anguilla* species are distributed by oceanic currents, it is unlikely that [an] individual found on Maui arrived without human intervention. ... the non-occurrence of *Anguillidae* in the Hawaiian Islands is somewhat surprising given its widespread nature elsewhere in the western Pacific. The isolation of the Hawaiian Islands, both geographically and in terms of oceanic current flow, plus factors of deep-ocean salinity, have

been, and continue to be, sufficient barriers preventing this family from reaching the Hawaiian Islands” (James & Suzumoto, 2006: 57).

In many Pacific islands, wetland taro (*Colocasia* sp. and *Alocasia* sp.) are often cultivated in prepared swamps. These locations should be excellent habitats for freshwater eels, but there are few records of this. However, Anderson records that in 2002, large freshwater eels were abundant in taro ponds on Rapa (Anderson, 2012: 42). More generally, only in islands that are large enough to have suitable habitats can we expect to find significant populations of freshwater eels.

FRESHWATER EELS AND NUTRITION

One especially important nutritional feature of eels is the abundant oil³ they carry. It would not be surprising to find that a community under stress for adequate food might easily forego their horror of eating eels, precisely because of the rich oil reserves they have. Best appreciated this issue when he commented “The Maori is much given to the use of fat foods, and hence a dish of eels is greatly appreciated by him” (Best, 1922: 109). This same sentiment is expanded upon by Johnstone.

“In Maori economy, the eel played a most important part. More than every other kind of food it represented fat, the nutriment which man, whether savage or civilized, universally craves. The beauty of Bel-gravia, and the Brahmin of Benares, would alike waste and pine were they deprived of milk and butter, pastry and sweetmeats. They must both eat fat in some shape or other. In Maori there were no animals deserving the name of quadrupeds. Man was therefore forced to gratify his craving for fat at the expense of a lower order of creation. Fish was his staple article of diet, and of all fish the eel was to him of the greatest importance” (Johnstone, 1874: 98).

Augustus Hamilton also fully understood how important a source of oil was to the economy of Māori, and in his influential book on *Fishing and*

Sea-foods of the Ancient Maori, copied the first part of this passage verbatim from Johnstone’s book, without acknowledgement (Hamilton, 1908: 67). Only in the northern half of the North Island of New Zealand was there a reliable source of carbohydrate food, in the form of kumara (*Ipomoea batatas*). Carbohydrate offsets the nutritional craving for fat in human nutrition. In the southern parts of the North Island, the cultivation of kumara was marginal, and there was a ‘hungry gap’ between the last reserves of stored kumara (August to October) from the previous harvest, and supplies from the next harvest in April. This period of 6–8 months, when there was no carbohydrate from kumara, the main sources of food available were protein-rich sea foods and forest birds, neither of which possess much fat⁴. The problem of a protein-rich diet, depleted of either carbohydrate or fat, is known as ‘rabbit starvation’ (Speth, 1983, 2020; Speth & Spielman, 1983; Noli & Avery, 1988; Cordain *et al.*, 2000), and is graphically described by Stefansson in his *Arctic Manual*:

“If you are transferred suddenly from a diet normal in fat to one consisting wholly of rabbit you eat bigger and bigger meals for the first few days until at the end of about a week you are eating in pounds three or four times as much as you were at the beginning of the week. By that time you are showing both signs of starvation and of protein poisoning. You eat numerous meals; you feel hungry at the end of each; you are in discomfort through distention of the stomach with so much food and you begin to feel a vague restlessness. Diarrhoea will start in from a week to 10 days and will not be relieved unless you secure fat. Death will result after several weeks” (Stefansson, 1957: 234).

The problem of how to obtain adequate supplies of either carbohydrate or fat to offset starvation from a protein-rich diet among pre-European Māori is described in detail by Leach (2006: 232–273). There are many historical records of half starved Māori relishing rotting shark for the oil, rancid seal blubber, train oil, lamp oil, and even the oil-soaked cotton and wick from lamps, and females giving sexual favours for these morsels (*ibid.*: 250). With such a background, is it easy to

³ Some authors refer to the lipids in eels as fat and others as oil. Fats have high levels of saturated fatty acids, while oils are mainly composed of unsaturated fatty acids. Fats are normally solid at room temperature, and oils liquid. Eel lipids are about 25% saturated fatty acids, and 75% unsaturated (Lovern, 1938: 1217), so strictly speaking the term oil should be used.

⁴ Fern root (*Pteridium aquilinum* var. *esculentum*) provides a modest amount of starch, and was highly prized by Māori, but its quantitative role in the economy could only be minor – basically a famine food. In addition, fern root has highly toxic compounds in addition to starch; these cause cancer of the stomach and other organs.

see how important oil-rich eels could be to people living in areas where kumara cultivation was marginal or impossible. As will be seen below, an episode of starvation during the Brunner expedition in the South Island provided the circumstance for a *tapu* removal ceremony so that eels could be eaten by the Māori guides. Did episodic semi-starvation in some districts provide the impetus for abandoning an ancestral *tapu* on eels altogether, at some stage in the pre-European period? Archaeological evidence should be able to show this, by a sudden appearance of quantities of eel bones in middens, hitherto only rare.

The USDA Nutrition database provides average nutritional values across mixed species of raw eel as follows: protein 18.4, lipid 11.66, carbohydrate 0.0, ash 1.41, all g/100g, and gross energy as 184 kcal/100g. Around these figures there is considerable variation as shown by the research carried out by Shortland & Russell (1948) for the two New Zealand freshwater species. They show that for immature⁵ eels, the total oil content varied from 7-23% for *Anguilla australis*, and 8-18% for *A. dieffenbachii*, and that in general oil content in-

creases with the length of the eel (ibid.: 164). This is illustrated in Figure 5. It is important to note that there is considerable variation from one species to another, from one season of the year to another, and also the animal's condition during maturation. Oil content was highest in the skin, lower in the tail portion, and still lower in the head and trunk (ibid.: 169). It will be noted in Figure 5 that the two New Zealand species generally have less oil than the European eel, *Anguilla vulgaris* [*anguilla*], and also the Japanese eel, *Anguilla japonica* (Sumner & Hopkirk, 1976: 933). Fatty acid profiles (Shortland & Russell, 1948: 167, and Sumner & Hopkirk, 1976). These show marine profiles for eels living in estuarine environments.

When we consider the value of eels for human nutrition, at the most basic level such raw figures need to be converted to caloric energy using the normally recognised figures of 4, 9 and 4 kcal/g for protein, fat and carbohydrate respectively (Davidson *et al.*, 1972: 10). For example, the USDA figures cited above convert to 74, 105, and 179 kcal/100g for protein, oil, and total respectively (zero carbohydrate). When converted to proportions, these are 41.3% energy from protein, and 58.7% from oil. Note that this calculated value of total caloric energy of 179 is slightly less than the value of 184 reported by USDS.

However, it is equally important to note that there is an upper limit to how much protein the hu-

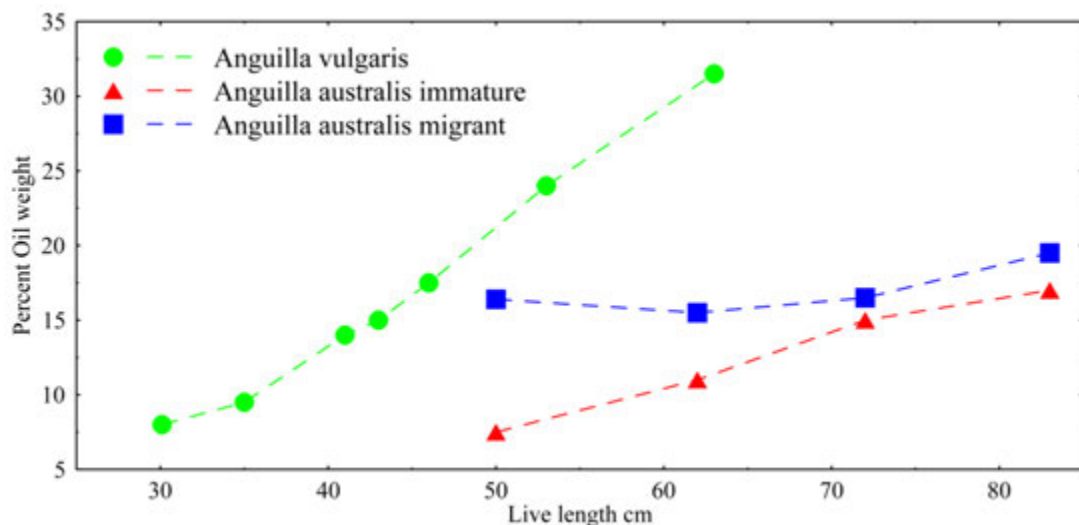


FIGURE 5

Three examples showing how oil content rises as body length increases. *Anguilla vulgaris* (syn. *Anguilla anguilla*) data from Lovren (1938: 1217), and *Anguilla australis* from Shortland & Russell (1948: 178).

man body can cope with. The eel value of 41.3% is very high, and would be dangerous unless accompanied by additional sources of fat or carbohydrate. According to Speth, an extreme upper limit that can be consumed safely on a sustained basis is approximately 300 g per day. This figure represents a protein intake of roughly 50% of total daily caloric intake under normal, non-stressful conditions (Speth, 1990: 155). A more realistic maximum daily protein intake may represent 20-30% of daily caloric intake, and would be in the region of 120-180 g of protein per day. Draper (1977: 311) has reported a protein intake of 200 g per day for pre-modern Arctic Inuit, an intake which represented 32% of

their daily caloric intake. So a general guideline for the upper limit of energy from protein sources is suggested as 30%.

The study by Shortland & Russell (1948) shows that for two New Zealand species, the proportion of energy from oil ranges from 53-72%, and from protein 27-47%, depending on length (Figure 6). All but two of the specimens studied by Shortland and Russell are above the 30% threshold of energy from protein. The main point to remember from these simple calculations is that eels represent a bountiful supply of oil, outstripping anything else available to Māori in their environment except marine mammals. For example, no shellfish

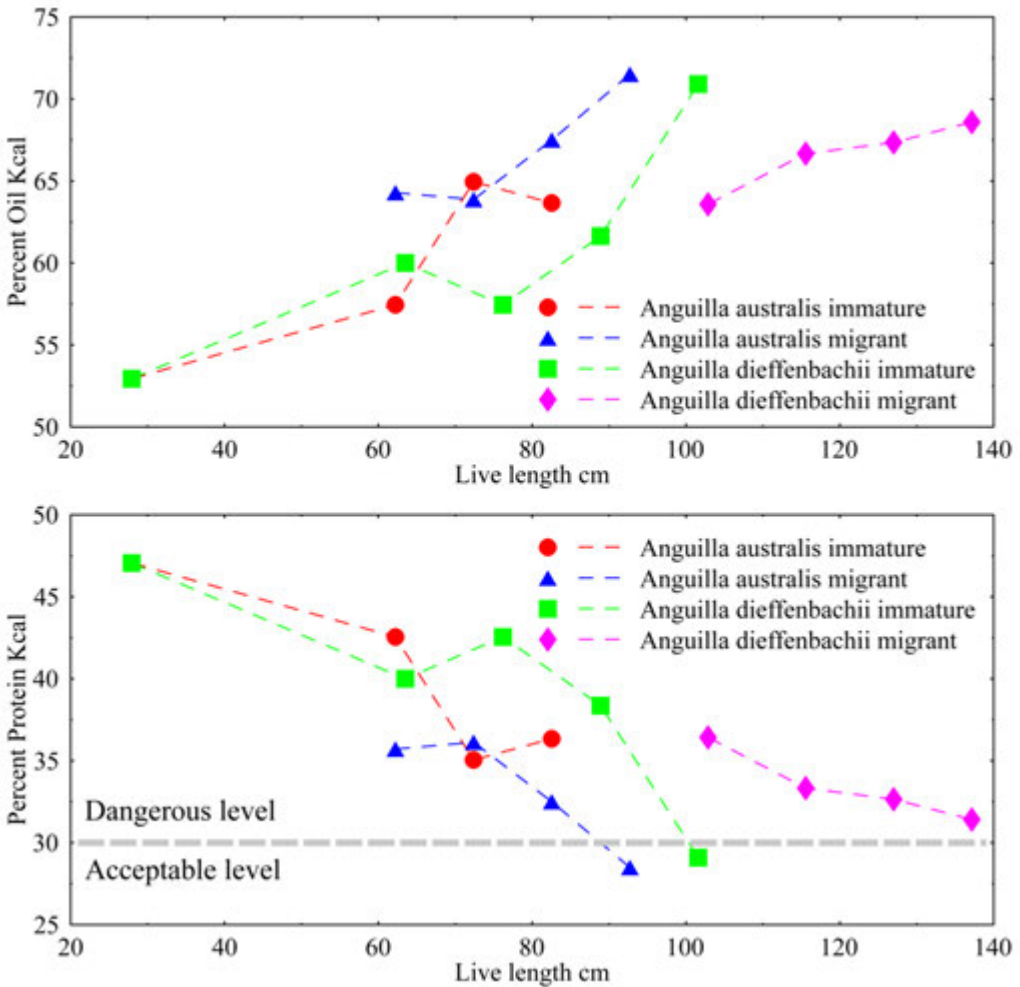


FIGURE 6

Nutritional value of oil and protein in New Zealand eels from proximate analysis. Calculated from graphical data in Shortland & Russell (1948: 182). As a sole food source, protein caloric energy should be less than 30% of daily consumption.

available in New Zealand has as much oil+carbohydrate as eel (Leach, 2006: 239, table 8.4). Only marine mammals would be a superior source of fat for Māori. As Smith has shown, marine mammals had a wide distribution when Polynesians first arrived in New Zealand, but by AD 1500 there were only rare seasonal occurrences in the North Island (Smith, 1989: 92). They continued to have an important economic role in the pre-European Māori economy in the South Island.

From the foregoing it can be seen that eels represented a significant source of oil for pre-European Māori in New Zealand. For people living in warm coastal environments where kumara could be cultivated a balanced diet was possible with carbohydrate from kumara and an inexhaustible supply of protein from fish in the sea. In more southern coastal areas south of about latitude 44°S, a 'hungry gap' was an annual event, and 'Harris lines' are observed in long bones in some communities (Sutton, 1979: 197). Starvation could have been avoided by eating the oil rich skin and tail of eels, but as will be seen below archaeological evidence suggests that the Polynesian immigrants to New Zealand did not consider eels as suitable food, except in the historic period.

Unless prehistoric people chose to take advantage of the abundant oil in eels to augment a protein rich diet it would be impossible to live for any length of time in the interior parts of southern New Zealand, as there are only limited sources of carbohydrate and/or fat available. Any attempt at permanent settlement in large inland river systems in the North Island, such as Wanganui, Manawatu, and Ruamahanga, would be inviting 'rabbit starvation', unless eels were consumed. We have seen above that mass harvesting of eels was undertaken in precisely these areas in the 19th century. The question which must be answered, however, is whether eels were harvested in this way in the prehistoric period. Only archaeological research can answer this.

EELS AND LANGUAGE

In a useful review of the lexemes relating to New Zealand fishes, Strickland lists 198 separate words in the Māori language which, when translated to English, would appear simply as 'eel' (both conger and freshwater species). These words are used to describe numerous different types or quali-

ties of eel that are separately recognised by Māori. For example, the word *putaioire* is used for a type of eel that is blue-black with blue eyes, and has large pectoral fins (Strickland, 1990: 34-37).

Having such a large number of words referring to some single feature of the environment is usually taken to indicate the special importance of it to the group of people whose language it is. An oft-quoted example of this, much disputed, is that among the Eskimo-Aleut languages there are a large number of words that are used to refer to snow (Krupnik & Müller-Wille, 2010). Similarly, the Sami people have 175-180 words related to snow and ice (Magga, 2006: 34). Incredibly, they have around 1,000 words for reindeer (ibid.: 31).

The observation therefore, that there are 198 words in the Māori language referring to eel, seems a fair indication that eels are or were important in Māori society. However, whether this is true for Māori in all regions, indeed, for all periods during their occupation of New Zealand, are questions to be answered. Moreover, it would be wrong simply to assume that this linguistic importance relates equally to their role in Māori diet, as it does in mythology, for example.

Although there are many separate words in the Polynesian languages that refer to various types of eel found in the environment, two words stand out which are almost universal: *Pusi*, referring to seawater eels, and *tuna*, referring to freshwater eels. The various cognates of these two words are listed in Tables 2 and 3, and are derived from Biggs's comparative Polynesian Lexicon Project (POLLEX, Walsh & Biggs, 1966). The words were extracted from the 1996 version (Biggs & Clark, 1966).

It is interesting that in spite of the rarity of moray eels in New Zealand, the name *Puhi-rokoroko* is applied to a type of yellow saltwater eel, and also to the lamprey. Williams records *Puhi* as a very large variety of eel, and *Puhikorokoro* as *Gymnothorax prasinus*, a yellow moray eel which is found between North Cape and Mahia Peninsula (Williams, 1971: 304-305).

The most common form of seawater eel in New Zealand is the conger eel, *Conger verreauxi*. Strickland records several words for this type of eel: *koiero*, *kōiro*, *kōiro*, *ngoiro*, *ngoingoi*; *ngoio*; *ngōiro* (Strickland, 1990). Members of the Congridae family are rare in the Pacific, but are present in Hawaii, for example.

“*tuna (freshwater eel) is a very ancient term. It is reconstructible to PpN (Proto-Polynesian) and also to Proto Oceanic, and, as *tuNa, to Proto Austronesian. *pusi (sea eel, Gymnothorax spp.) is widely reflected in Nuclear Polynesian languages. It is absent in the Tongic languages (Tongan and Niuean) but is recorded (as pusi) in a Lau dialect of Fijian so can be attributed to PpN. A bunch of somewhat similar terms, with irregular sound correspondences, occur in other Oceanic subgroups” (Pawley, pers. comm. to BFL, 2019)

What this shows, is that no matter where Polynesians voyaged across the Pacific ocean, they took with them their knowledge of their ancestral environment and applied existing language to familiar things when they settled in new lands. We should also expect that common customs relating to eels would also be transferred to newly settled lands.

Hawaii	Kuna	Eel freshwater <i>spp.</i>
Maori	Tuna	Freshwater eel
Niue	Tuna	Eel, freshwater <i>spp.</i>
Nukuoro	Duna	Larvae of mosquito
Penrhyn	Tuna	Eel
Pukapuka	Tuna	Striped lagoon eel
Rarotonga	Tuna	Eel, freshwater <i>spp.</i>
Rennell	Tuna	Kind of lake eel
Rotuma	Funa	Freshwater eel
Samoa	Tuna	Eel, freshwater <i>spp.</i>
Takuu	Tuna	Moray eel
Tikopia	Tuna	Eels, especially lake eels
Tonga	Tuna	tahi, vai. Eel <i>spp.</i>
Tuamotu	Tuna	Eel
West Futuna	Tuna	Freshwater eel
Waya	Tuna	Freshwater eels, Anguillidae

TABLE 3

Polynesian cognates of *Tuna*, from Biggs & Clark (1996).

Tuvalu	Pusi	Saltwater eel
East Futuna	Pusi	Moray eels
East Uvea	Pusi	Saltwater eel
Hawaii	Puuhi	Eel
Emae	Pusi	Parasitic worm
Maori	Puhi	Large eel variety
Maori	Puhi-rokoroko	Yellow Saltwater Eel, Lamprey
Mele-Fila	Pusi	Sea eel
Marquesas	Puhi	Anguille
Penrhyn	Pusi	Fish sp.
Pukapuka	Pui	Small sp. of eel
Rarotonga	Pu`i	Large black, sea-eel, not Moray
Rennell	Pusi	Starry or clouded moray eel
Rotuma	Tepuhi	A sea-snake with transverse stripes
Samoa	Pusi	Moray Eel
Sikiana	Pusi	Eel spp.
Tahiti	Puhi	General name for moray eels
Tokelau	Pusi	Moray eel
Tuamotu	Puhi	Eel
West Uvea	Pusi	Sorte d'anguille de mer
Sikiana	Pusilokiloki	Eel <i>sp.</i>

TABLE 2

Polynesian cognates of *Pusi*, from Biggs & Clark (1996).

Anuta	Tuna	Freshwater eel, said to be extinct.
Tuvalu	Tuna	Eel, freshwater crayfish.
East Futuna	Tuna	Freshwater eel.
East Uvea	Tuna	Eel of brackish or fresh water
Fiji	Duna	Freshwater eel

MYTHS AND TRADITIONS ABOUT EELS

In the introduction to this paper, Samuel Johnson’s observation about the Scottish abhorrence of eels and pork as food was cited, and that the opposite was the case in England. In considering the presence or absence of eels in the archaeological record, we clearly need to bear in mind the cultural attitudes that people in different societies have towards eels, and whether these may have changed over time.

The important role that eels played as food throughout English history has been reviewed by Righton & Roberts (2014), and archaeological evidence suggests that this attitude towards eels, contrasting with the Scots, has some antiquity. A site in Southampton, for example showed that bones of freshwater eels were consistently very common for five separate periods from AD 900 to 1750 (Nicholson, 2011: table 1). However, there is some evidence that in other sites in England the herring fishery increased in importance and that eel declined in late Saxon times (Holmes, 2017: 39). The town known as Ely is named after the eel, and there is an annual festival devoted to eels with parades and food stalls (Svanberg & Locker, 2020: 19). The Scottish prohibition on eating eels may not have much time depth as Neolithic, Bronze age, Mediaeval, and Viking archaeological sites certainly contain eel bones (Barrett *et al.*, 1999: 366, 380, 382, 384).

Donald Mackenzie, a Scottish historian argued that the prohibition of eating eels and pork meat among the Scots could be traced back to a centuries old religious cult derived from Mosaic law. The origin of this is in the third book of Moses, called Leviticus, in which is found:

“And all that have not fins and scales in the seas, and in the rivers, of all that move in the waters, and of any living thing which is in the waters, they shall be an abomination unto you: They shall be even an abomination unto you; ye shall not eat of their flesh, but ye shall have their carcasses in abomination” (Leviticus 11:10-11).

The main culprit here is the humble eel. Although moray eels do not have scales, freshwater eels certainly do, although they are small and embedded in the skin. An especially interesting version of this myth is discussed by Ingvar Svanberg, as follows:

“The Estonian and Swedish speaking settlers of the island of Wormsö did not eat it [eel]. There is a folk legend recorded from that area that tries to explain why eels should not be eaten. The legend tells how kinship between the eel and the snake began. It is said that the snake had seduced the first parents in paradise and thereby raised the wrath of God. Jesus then took a stick and cut the snake into two pieces. The part with the head fell on the dry land, while the tail part fell into the water. A new snake grew from the former part, while the eel emerged from the latter” (Svanberg, 1999: 132 [citing Russwurm, 1855: 189]).

One interpretation of the snake in the garden of Eden is that it symbolises the penis, and that eating from the forbidden fruit is a metaphor for sex. These two ingredients, the penis and sex, are common in myths about eels throughout Melanesia and Polynesia. The second part of the Wormsö myth, concerning cutting up the snake into pieces is not, to our knowledge, derived from biblical sources but, as will be seen below, has clear parallels with Pacific mythology⁶.

Throughout the Pacific, from the tropics to temperate New Zealand, myths and traditions about eels abound. Although these vary a great deal,

there are also common threads. A small selection of excerpts from Pacific ethnographic literature relating to eels is provided in Appendix 1. A few are presented here to illustrate these common themes.

Tikopia is a Polynesian outlier in the Solomon Islands, inhabited for about 3,000 years. The people on the island today consider that eels are disgusting and would never consider eating them. Some types of eels are totemic, representing ancestral figures for clans. Of particular interest is the central position of eels in origin mythology on this island. Both freshwater and marine eels are strongly repulsive to Tikopians [see Appendix 1 for excerpts from Firth (1981) and Park (1973)]. The eel god Tangata-katoa (meaning all men) is the original generative deity of Tikopia and symbolically identified with the penis. Various types of eel are formed by chopping up the elongated penis of the deity. Firth notes that by 1973 some Tikopians were then eating eels, putting them in soup, even though others disapproved and were still afraid of eels (Firth, 1981: 219).

This origin myth, present here in a Polynesian society, is also found in non-Polynesian societies further west in Melanesia. For example, Malinowski described the legend of a mythical demi-god called Inuvayla'u who had a very long penis and was inclined to wriggle along the ground like a snake and impregnate women when they were alone or vulnerable. His brothers were furious with the foul pranks of Inuvayla'u, so they cut the penis up into small pieces with an axe. Each piece turned into stone. One piece was placed in front of the headman's house in the village of Kwabulo, another piece where the men moor their canoes. Finally, the testicles were cut off and turned into two large white coral boulders in a creek. The elements of this myth are present in Māori society (see below, Best, 1923: 56).

Ethnographic literature documents numerous examples of the very special place which eels have in the magico-religious systems of people from Papua New Guinea to Easter Island. The involvement of eels in the totemic behaviour on Tikopia, cited above, is a typical example. The Reverend Gill made the following observation about eels in the Pacific islands⁷:

⁶ Best comments on this as follows: “As in other lands, the eel enters into the myths of our Maori folk, and in the myth concerning the first woman it takes the place of the snake in the Biblical story” (Best, 1929: 73).

⁷ It is not explicitly stated in this passage which island he is referring to. Mangaia in the Cook Islands is suspected, since he spent 20 years living there, from 1852-1872.

“Fear is the ruling motive of heathen worship; and it is interesting to observe that this feeling has led to the worship of the serpent wherever that reptile is known. May not this species of idolatry have been connected with the memory of the arch serpent that deceived Eve? ... In all these eastern islands, where the serpent is unknown, the salt and fresh water eel (*Muraenidae*) takes its place in the superstitious veneration of the natives, both being regarded as incarnations of deity. Until Christianity came, it was unlawful for women to taste eels, on the alleged ground that in the olden time a divinity assumed the form of a great eel in order to approach an unsuspecting woman while bathing. To this day nothing can exceed the disgust most of the native women feel at eels, which they refuse even to touch. A woman once secretly ate the sea-eel. On discovering the sacrilege, the husband fled from her in horror, and never lived with her again, regarding her as possessed of an evil spirit which would be sure to kill and devour him on some future occasion” (Gill, 1876: 278-279).

Gill goes on to relate examples of severe reactions for eating eels. In 1863 about 80 people in the Tokelau islands were expelled for eating a sea eel that was considered sacred. On another occasion an islander inadvertently ate part of a sea eel, and when he was made aware of it, immediately vomited and exclaimed in horror “Aue tâu⁸ Atua e ! (Alas for my God !)” (Gill, 1876: 279).

One of the greatest of all heroic figures in Polynesian mythology is a man called Maui, sometimes called *Maui of a thousand tricks*. Many fabulous tales are recorded of this man. One involves his introduction of coconuts to the world:

“Throughout Polynesia, a coconut tree is said to have sprung from the severed head of Tuna, a giant eel who courted Hina. Certain variants state that Tuna is killed by Maui, who is jealous of his wife’s attentions to Tuna, or that he kills Tuna when Hina, a stranger to him, asks Maui to save her from the eel. The coconut did not grow in New Zealand, but the Maori who had brought the myth of Tuna with them from central Polynesia, state that after Maui kills Tuna, various species of fresh and salt water eels grow from parts of Tuna’s body” (Luomala, 1949: 120).

“At Mangaia, Tuna makes love to Hina with curious results, as Hina is the moon” (Best, 1923: 58).

⁸ Tâu here is Gill’s way of rendering a glottal stop for a missing consonant, which in this case is k, so the original word is taku meaning my.

There are numerous variations of the myth concerning the origin of coconuts and how the eel is involved in this. In Samoa, for example, there are variations of the same story, relating to the violation with his tail of a girl by the god Pili, regarded as being an eel; and, according to one version, this was followed by the death of the eel and the growth of a coconut, evidently supposed to have been the first coconut, out of the dead eel’s head. Both these ideas of an eel copulating with a woman by its tail and of the growth of the coconut out of an eel’s head are found in other islands (Williamson, 1924, III(2): 233).

In Samoa, the story of Sina and her pet eel is a complex love story in which the eel pursues Sina no matter how far away from her village she tries to escape. In some variants her lover switches back and forth from human to eel form. In other variants it is Sina who pursues the eel. However, in all variations the eel must eventually die. He makes one final wish to Sina – that when he is dead she should cut off his head and bury it near her house, and from this a very special tree will grow. This of course is the coconut tree, all parts of which are of great value to Oceanic peoples.

It is little wonder that in many parts of the Pacific, people would never dream of eating eels. This would be sacrilege. As with so many aspects of spiritual values, the spread of Christianity had the effect of changing this deeply entrenched attitude towards eels in the Pacific.

On Mangareva, Peter Buck recorded that people in the past would not think of eating marine eels, but that this repugnance has disappeared: “Formerly the sea eel was not eaten, as it was said to be a man named Te Marautoro, who entered the woman Meto and became smeared with the vaginal secretion (*pakaokao*). With the change in ideas, the repugnance to eating sea eel vanished” (Hiroa, 1938: 197). As we will see below, there is archaeological evidence of changes in human behaviour towards eel on Mangaia. Of freshwater eels on Mangareva, Buck recorded this:

“When Te-aio was killed, his blood flowed into a stream and was drunk by an eel. The spirit of Te-aio entered the eel, which after Te-aio was deified, became his incarnation. The eel went out to sea, came in contact with a shark, and the spirit of Te-aio passed over to the shark. The shark also became an incarnation. This is the mechanism found in New Zealand, where any fish, reptile, bird, or animal which touches or drinks the blood of an ancestor may become the incarnation of that deified ancestor” (ibid.: 171).

Of the Cook Islands in General, Hiroa comments “Fresh-water eels seem to be considered unimportant, except in Mitiaro where they are obtained in large quantities from an inland lagoon” (Hiroa, 1944: 245); and, on the small island of Mitiaro, northeast of Rarotonga “in the middle is a small area of good volcanic soil surrounded by swampy land. A fair sized lake and the swamps supply the *itiki* eel peculiar to Mitiaro” (Hiroa, 1944: 6). There is further information on this below.

In New Zealand itself, the earliest historical records date to the 18th century but, unfortunately, there are few relevant details. For example, there is no mention of eels in the first and second voyages in the journals of Cook, Banks, or Forster; however, there is a short note by the Scotsman Anderson that some large conger eels were supplied by Māori in Queen Charlotte Sound (Cook, 1967, III(2): 807). There is far more useful information in the 19th century.

“Consider the story of the creation of eels, told to Wohlers in the 1840s. It also concerns the famous Maui and his wife Raukura. Raukura complained that she had been attacked by a person named Long Tuna [Tuna is the common Māori word for freshwater eel] who had dragged her into the water of the river and raped her. Maui went down to the river, lured Long Tuna ashore and chopped him up. He threw the head into the sea where it became the conger eel and body he threw into the river where it became a freshwater eel, a *tuna*” (Biggs, 1993).

Best described a wide range of versions of the story about how the personified eel defiled a woman and was cut into pieces in 19th century Māori mythology. Here are three recorded by Elsdon Best, the latter two citing White (1887: 69, 76).

“#1: Maui of immortal fame, discovered that Hine-nui-te-Po, the goddess of Hades, was carrying on something more than a flirtation with Tuna, the eel-god. Maui, being attentive to the morals of other persons, proposed to put a stop to the above state of things. He did so by destroying Tuna. This was one of Maui’s acts which eventually caused his death, for Hine was not taking interference quietly, and so, by dread arts of magic, caused the death of Maui...#2: Maui married Hine, a daughter of Tuna and Repo, and that he slew Tuna for interfering with Hine. When slain the head of Tuna fled to the fresh water, and that is the origin of fresh water eels; while the tail of Tuna fled to the ocean and became the conger eel...#3: a Ngati Hau legend states that Hine was a sister of Irawaru, and Tuna a son of Manga-wai-roa. Also that Tuna

concealed himself in a pool named Muriwai-o-Hata...where he was slain by Maui” (Best, 1902: 65).

Yet another version of this myth was recorded by Best from the Taranaki region of New Zealand.

“Then one day when the woman was bathing, an eel came round her body, and, with his tail, so excited the woman that there was awakened in her the sexual desire. She then went to seek Tiki, and succeeded in exciting him to an equal extent, thence there came to them the Knowledge [upper case by Best]. This act was viewed a most serious *hara* (misdemeanour, sin), hence Tiki, knowing that the eel had caused the woman to lead him astray, resolved to take vengeance. He therefore slew the eel, and cut him into six pieces. From these six pieces sprang the six varieties of eels known to man” (Best, 1923: 56).

Polach who travelled widely in the North Island in the 1830s noted that in the vicinity of Tauranga, “eel was viewed as an *atua* [a God] by the local natives. Eels are said to have been *tapu*⁹ to those folk, hence they could not eat them, and a saying concerning them was, *He uri no Puhi kaore e kai I te tuna* (The offspring of Puhi do not eat eels). Puhi and Tuna are both terms used to denote the tutelary being of eels, or the personified form of such” (Best, 1929: 73).

The *tapu* status of eels, referred to in this passage, is further touched upon by another historical record which deserves special attention. This relates to a sojourn on the West Coast of the South Island by Thomas Brunner in 1846-8. At a time when the party were starving for food he found that his Māori guides caught some eels to eat, but before doing so took part in an elaborate form of spiritual cleansing. This suggests that they considered them potentially dangerous to handle. Perhaps we have here an example of a custom making an historical transition from the sacred to the profane, in the Māori language from *tapu* to *noa* [harmless]. The passage in Brunner’s journal is instructive.

“There is a particular *tapu* existing among the natives relating to the eel. You must wash your hands before going to catch them, and also on returning, and the bait must be prepared some distance from the house. There must be a distinct fire for cooking the eel, for which you must have a special tinder-box; your

⁹ The Māori word *tapu* has a very similar meaning as the English word taboo.

hands and mouth must be washed both before and after partaking of them, and should it be necessary to drink from the same stream from which the eels are caught, you must have two vessels of water, the one to drink from, the other to dip from the stream. Whether this relates to particular places or not, I am not able to say, but I found it strictly adhered to at Okitika and Okarita and at the former place I had to walk half a mile for water, with a stream running within a few yards of our station” (Taylor, 1959: 274–275).

Taylor, who edited Brunner’s journal for publication, observed in a footnote at this point: “Hokitika and Okarito, which he had not visited at this stage. In the *Nelson Examiner and New Zealand Chronicle*¹⁰ this *eel-tapu* passage is placed much later, on 12 February 1848, when returning up the Grey River” (Taylor, 1959: 275). Brunner must have thought this matter of some importance when he found the custom to be more widespread, after he had travelled further south, and inserted the passage in the entry for the 19th April 1847, where he had first come across the behaviour among Māori.

Elsdon Best was obviously puzzled about this *tapu* cleansing behaviour amongst Māori, for he remarked:

“A peculiar note comes from a South Island source [not identified by Best] to the effect that when about to set an eel-pot a Maori would wash his hands. ‘If this act be neglected’, says our informant, ‘then no eels will enter the pot’. This may be so, but I cannot say that such a precaution ever came under my own observation. These punctilious eel-trappers must have died out before my time, or possibly the usage did not extend to the North Island... When exploring Westland in 1847, Brunner noted this superstitious practice among eel-fishers [citing Hamilton (1908: 69) as his source of information] (Best, 1977: 188–189).

Hamilton did not specify which manuscript he consulted for Brunner’s observation, when he recounted these same details in his own publication (cited above). Unfortunately, we are now so far removed from the primary historical observations that we may never fully understand what was happening to Māori customs relating to eels after the first encounter with Captain Cook in 1769. However, there are indications in these stories which present an intriguing possibility – that in earlier times

in New Zealand eels were *tapu*, and not considered as food (like to many places in tropical Polynesia), but for some reason this *tapu* was set aside, and eels became one of the most important sources of food for Māori, as was certainly the case in Tuhoe-land, Wanganui, Taranaki, and Wairarapa in the 19th century.

Summary Observations on Eel Myths and Traditions

This review of myths and traditions concerning eels among the Austronesian peoples in the wider Pacific, from Melanesia, Micronesia, and Polynesia, reveal a number of common themes.

#1: The eel, either marine or freshwater, is the incarnation of a male deity and symbolises the penis.

#2: The personified eel tempts and defiles a woman sexually.

#3: A male, often an heroic ancestral figure, punishes the eel by cutting him up into pieces.

#4: There is a strong association of eels with danger.

#5: The eel is either venerated or feared and is certainly not considered food.

#6: In some societies, the arrival of Europeans resulted in the lifting of the taboo of eels as food.

It is hardly surprising that the Polynesians from the tropical Pacific who discovered and settled New Zealand in the last 1,000 years brought with them a raft of existing myths, customs, and cultural attitudes towards catching and eating freshwater and seawater eels. It is reasonable to conclude that the earliest immigrants to New Zealand brought with them an over-arching theme that eels were associated with divine beings, danger and fear, and not considered food. In the course of time in different areas, the oral traditions and myths diverged to varying degrees, so that many versions were recorded in the 19th and 20th centuries. In two recorded cases in the early historic period, one near Tauranga, and the other in Westland, eels were certainly considered *tapu* and not food. During the Brunner expedition, both the explorers and their Māori guides were starving and resorted to eating eels only after an elaborate *tapu* removing ceremony. However, for many parts of New Zealand eels

¹⁰ *Nelson Examiner and New Zealand Chronicle*, 14 October 1848, Page 3.

came to be a very important source of food. We suggest that at some stage in the cultural transformation of the New Zealand settlers from Polynesian to Māori eels changed from divine to ordinary, from *tapu* to *noa*, from non-food to food. Our view on how and when this transformation happened is discussed below.

THE CRANIAL OSTEOLOGY OF EELS

Identifiable Anatomy

For reasons described elsewhere (Leach, 1997), the bones most commonly chosen for systematic identification of fish from archaeological sites in New Zealand and the Pacific are five paired cranial bones and certain 'special' bones which are particularly characteristic of some species. The five cranial bones are: dentary, premaxilla, articular, maxilla, and quadrate, in order of their ease of identification to species¹¹. The main osteological focus of this paper is the bones of the common species of eels that are found in New Zealand, rather than the wider Pacific, and tropical marine eels are not considered in this section except in passing. These are the two

species of freshwater eel, and the marine conger eel (*Conger verreauxi*) in New Zealand. These bones are illustrated in Figure 7.

The bones of conger eel are very different from those of freshwater eels and present little difficulty of identification. However, the two species of freshwater eel are much more difficult to distinguish. The long finned eel, *Anguilla dieffenbachii*, grows to a much larger size than the short finned eel, *Anguilla australis*. So, assuming one can estimate the live fish size from bones using a suitable allometric equation, a specimen more than about 100 cm fork length is probably a long finned eel. However, there is an additional problem here, because the linear equations linking bone size and fork length appear to be different for the two species (discussed below).

Fortunately, there is another cranial bone with features by which each species may reliably be identified. This is the vomer. The distribution of teeth on this bone is quite different for the two species. Referring to Figure 7, it may be observed that in the case of the long finned eel the teeth continue posteriorly along the mid-line, tailing off to a narrow point. By contrast, in the short finned eel, these teeth are truncated anteriorly, and are rounded off, rather than narrowing towards the mid-line (See Figure 9).

It may be noticed in Figure 7 that the premaxilla is not illustrated. The reason for this is that eels do not have a separate premaxilla, and, unlike in many

¹¹ As Ford showed in 1937, eel vertebrae are very distinctive from other fish species, having an unusual housing for the spinal cord and lateral spines (Ford, 1937: 10, 51-52).

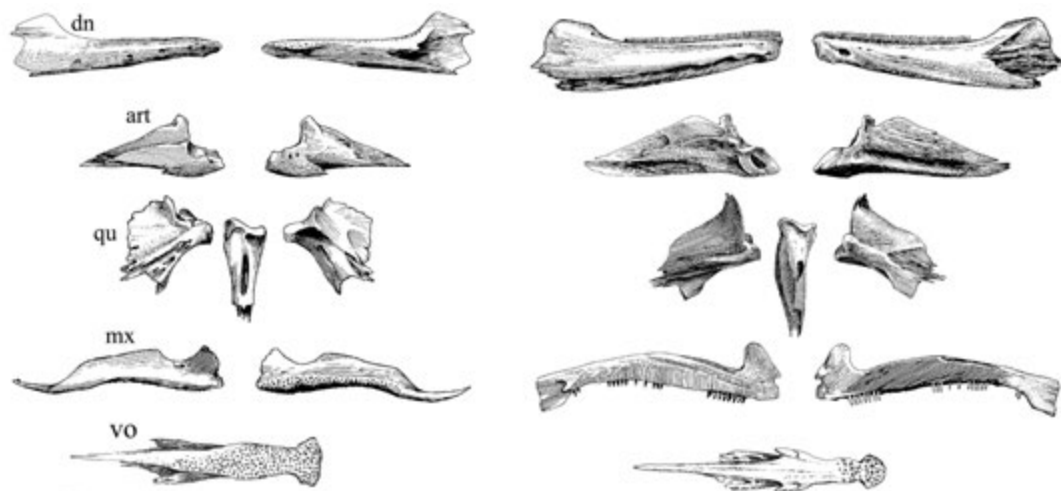


FIGURE 7

Commonly identified cranial bones of eels. Left: the long finned eel, *Anguilla dieffenbachii*. Right, conger eel, *Conger verreauxi* (abbreviations are listed at the end of this paper). Right elements are shown.

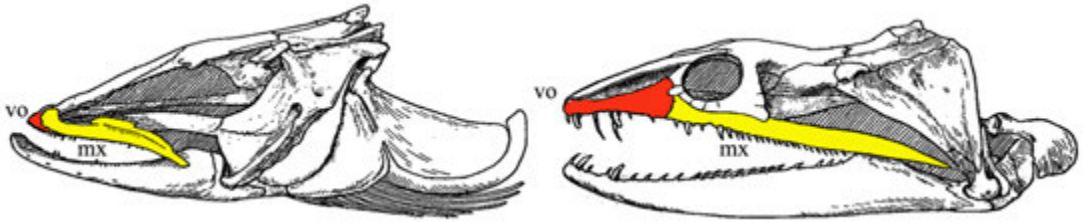


FIGURE 8

Cranial bones of a freshwater eel, *Anguilla rostrata* (left), and a marine moray eel, *Lycodontis funebris*, syn. *Gymnothorax funebris*, highlighting the vomer and maxilla bones, adapted from Gregory (1959: 202).

other fish species, the upper teeth are situated on the maxillary. This is clearly illustrated in Figure 8. In a detailed study of the development of the chondocranium of the freshwater eel *Anguilla vulgaris*, Norman (1926) described how the premaxillaries, the mesethmoid, and the vomer became fused to form a single bone in embryos:

“No premaxillary bones are present in a specimen of 31 mm, but in larvae of 40 to 78 mm the rudiments of these bones are apparent. They lie above the rostrum, and have the form of incomplete bony tubes, each of which surrounds a sensory canal; these tubes unite posteriorly just in front of the mesethmoid bones” (Norman, 1926: 398).

The comparative cranial anatomy of the Order Apodes was studied in detail by Regan in his seminal paper in 1912. He defines the main cranial features of the entire order at the outset, before discussing each family in turn. He states:

“Praemaxillaries not developed as distinct elements... praemaxillaries, mesethmoid, and lateral ethmoids represented by a single dentigerous bone”, and “It can hardly be doubted that the dentigerous bone in front of the vomer and between the maxillaries represents the premaxillaries ankylosed to the mesethmoid” (Regan, 1912: 378).

Regan added a footnote referring to Boulenger’s contribution to *The Cambridge History* volume for additional information on the issue. Boulenger, in discussing the premaxilla in the Order Apodes states:

“There has been much difference of opinion in the determination of the bones of the upper jaw in these fishes. Cuvier regarded the lateral bones of the upper jaw as praemaxillaries, Owen and Richardson as palatines (at least in the Muraenas), whilst ...most recent authors have identified them throughout as maxillaries” (Boulenger, 1904: 599-600).

Boulenger, also footnotes this comment, referring to Jacoby’s discussion on Moray eels. Jacoby describes the premaxillary to be “entirely wanting” in Muraenidae (Jacoby, 1867: 261). The only non 19th century comment we found on this issue is that “the premaxillary-ethmoid fusion is conventional for anguilliformes” (Robbins & Robbins, 1971:135).

Allometric Analysis

A sample of 99 modern eels was collected, 49 of the long finned eel and 50 of the short finned eel. Each was boiled down, the five cranial bones already described were extracted, and cleaned, and 20 measurements were made with calipers (Teal, 1974). The methods of measurement and metrical analysis follow a series of earlier publications on snapper, *Pagrus auratus* (Leach & Boocock, 1995), kahawai, *Arripis trutta* (Leach *et al.*, 1996), barracouta, *Thyrstites atun* (Leach *et al.*, 1999), blue cod, *Parapercis colias* (Leach *et al.*, 2000). Labridae (Leach & Davidson, 2001), and red cod, *Pseudophycis bachus* (Leach *et al.*, 2001), and need not be described further here. In the case of eels, the live total length and weight were measured, and then two measurements were taken on each of the four main cranial bones; one of the maximum length, which can be taken on whole specimens, and another appropriate to a fragment of the bone. Finally, two measurements were taken of the vomer. Thus there are two live measurements, two measurements on each of five bones, both left and right, totalling 22 data for each specimen. The anatomical landmarks used for the measurements are illustrated in Figure 9.

There was considerable difficulty in obtaining large specimens of the short-finned species, and

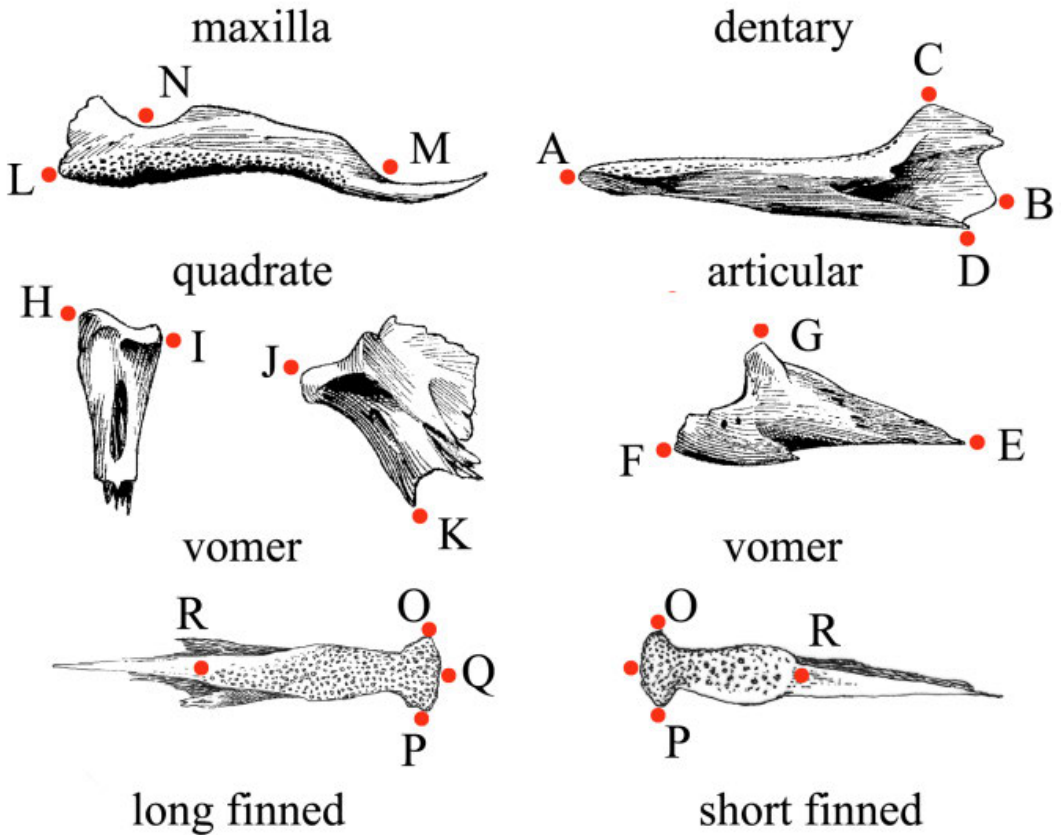


FIGURE 9

Landmarks for measurements on eel cranial bones. For the vomer, both species are illustrated. The remainder are the right elements of the long finned eel which is all but indistinguishable from the short finned eel. RD1=A-B, RD2=C-D, RA1=E-F, RA2=F-G, RQ1=H-I, RQ2=J-K, RM1=L-M, RM2=L-N, VO1=P-O, VO2=R-Q.

only one specimen greater than 600 mm was captured (847 mm).

The bone metrical data were subjected to statistical analysis, to determine the best allometric relationship between bone size and live fish length and weight. Least squares regression analysis was carried out on the measurements, using several models for best fit (linear, exponential, logarithmic, power curve fit, and cubic fit). We initially considered the two species separately, but found very little difference between them. In any event, with the exception of the vomer, the two species are virtually impossible to differentiate from bone anatomy. There was no choice but to combine the two sets of data during statistical analysis.

Deciding which model best fits the modern data could take into account one or more of three things: #1: the standard errors of the estimate for each mod-

el, #2: analysis of residuals for each, and #3: visual analysis of how well the various curves fit the modern data when plotted together. The third suggestion is particularly important, and should never be overlooked in this type of study. In this respect, it is useful to generate the line of best fit, and the two lines which show the boundaries of the standard errors of the line. When the modern data are plotted on a graph with these three lines, the success or otherwise of the model is usually much clearer than by simply examining the standard error or residuals.

In the case of reconstructing fork length from a bone dimension, there is good reason to think that a linear equation would be the best fit. However, when the modern data are unevenly spread through the size range, and dominated by smaller specimens, it has frequently been found in practice that some form of non linear curve captures the

data better. In most of the previous studies of fish osteology cited earlier, a power curve was found to best capture the modern data. However, in the case of the eels, so few very large eels were able to be caught and measured that the accumulated data were very patchy across the size range. Neither linear nor power curve fit captured the distribution adequately, but an exponential fit did.

In the case of reconstructing live weight from a bone dimension there are good reasons for choosing a cubic function but, as with the above case, several models should be attempted, to make sure unequally distributed sized fish are all reasonably well captured. Once again, in previous studies, the power curve fit has been the most common model accepted after careful examination. However, in the case of eel bones, after examining both the statistics (standard errors and residuals), and a careful study of the graphs for each model, it was decided that the best fits were all cubic equations.

An example of the curves of best fit are plotted out in Figure 10 for the LD1 bone measurement, and the various constants for each bone measurement are provided in Table 4, together with the standard errors of the estimates. For example, the live length of an eel can be estimated from the left dentary maximum length measurement as follows:

$$\text{Live length} = 307.207 * \exp(0.0223 * \text{LD1}) \pm 68.2$$

Similarly, the live weight can be estimated from the same bone measurement as:

$$\text{Live weight} = 0.029 * \text{LD1}^3 \pm 277.8$$

Measurement	Live Length			Live Weight	
	Const A	Const B	SEE	Const C	SEE
LD1	307.207	0.0223	68.2	0.029	277.8
LD2	324.969	0.0736	76.2	1.131	439.2
LA1	293.054	0.0358	65.8	0.108	278.8
LA2	314.366	0.0668	70.6	0.817	372.4
LQ1	354.666	0.1464	92.2	10.961	886.8
LQ2	293.670	0.0810	91.0	1.259	569.4
LM1	326.100	0.0313	74.8	0.084	626.3
LM2	305.459	0.1248	65.6	4.640	310.0
RD1	307.420	0.0223	69.0	0.029	297.6
RD2	330.552	0.0707	73.5	1.047	385.2
RA1	296.997	0.0349	66.0	0.104	268.6
RA2	313.568	0.0668	72.8	0.840	360.2
RQ1	353.225	0.1472	93.8	11.433	794.9
RQ2	295.235	0.0790	88.0	1.174	634.3
RM1	324.016	0.0313	75.2	0.082	638.7
RM2	303.621	0.1259	69.4	4.764	344.7
VO1	346.490	0.1022	110.2	4.333	999.7
VO2	351.533	0.0351	75.7	0.165	510.1

TABLE 4

Equations for estimating live length and weight from bone measurements of both species of eel.

As an example of the utility of these estimates, the LD1 measurement for a mid range specimen

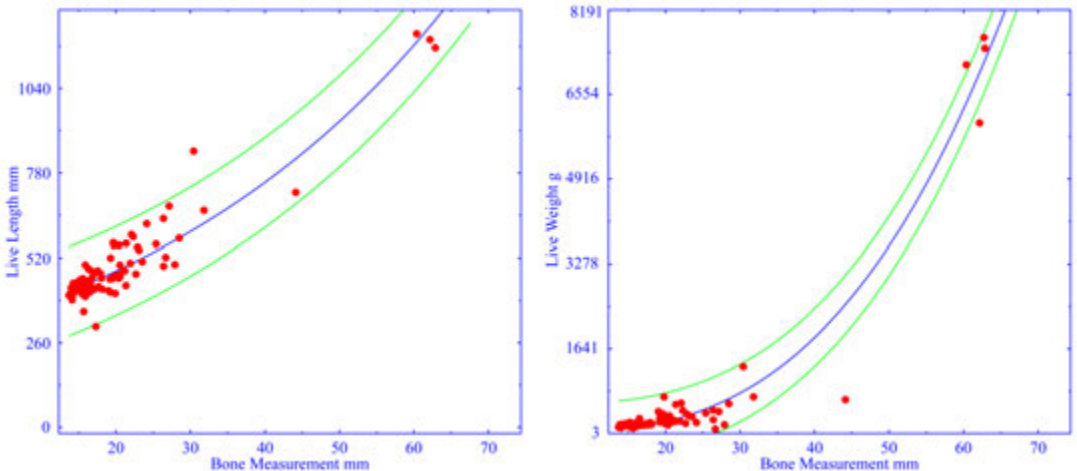


FIGURE 10

Scatterplot showing the typical relationship between the LD1 bone size and live fish size for the two species of eels combined. Left live length, right live weight. The line of best fit is the blue line, and the green lines show the standard error of the estimate across the size range.

(catalogue number FA539) measures 28.50 mm. It had a live length of 580 mm and the live weight was 578 g. Using the constants listed in Table 4, the estimated length and weight for this specimen can be calculated as 580.03 mm and 671.32 mm respectively. The difference between real and calculated length is minimal, and for weight 93g.

Although these are very satisfactory results for an individual specimen, the scatterplot shown in Figure 10 suggests that not all eel specimens will conform as well as this. In particular, live weight will depend a great deal on the condition of specimens, since eels can accumulate considerable oil

reserves when food is abundant. In addition, there are likely to be differences between male and female specimens that cannot be determined from bone anatomy. These differences are reflected in large standard errors of the estimates for weight in Table 4, which averages about 500 g, and is as much as 1000 g in the case of vomer measurements.

It has to be accepted that estimating live body weight of eels directly from bone measurement is not easily accomplished. This is most unfortunate, because calculating the caloric contribution to palaeo-diet from faunal remains is an important objective in economic archaeology.

Excavation	Anguilliformes	Muraenidae	Anguillidae	Subtotal	Total
Kapingamarangi	2	194	-	196	4260
Palau	-	94	-	94	7605
Nan Madol, Ponape	-	50	-	50	3182
Kaloko, Hawaii	-	-	32	32	262
Fais, Caroline Is	-	-	21	21	5183
Ngaaitutaki, Mangaia	-	-	20	20	236
Tiouande Site 5, New Cal	-	10	7	17	631
Fa'ahia Sinoto excavation	-	7	5	12	1708
Vaito'otia	-	7	4	11	1639
Fa'ahia Navorro excavation	-	1	8	9	2277
Rota	-	8	-	8	519
Tiouande Site 14, New Cal	3	4	-	7	110
Motupore	-	5	-	5	2305
Hane, Ua Huka, Marquesas	-	2	2	4	1246
Taumako	1	2	-	3	327
Tiwi Cave, New Caledonia	-	1	2	3	852
Motupore, PNG (Groube)	-	-	3	3	2880
Tepaopao, Mangaia	-	-	2	2	7
Dongan, PNG	-	-	2	2	207
Cikobia, Site 037, Fiji	-	-	2	2	36
Anaio, Ma'uke, Cook Is	-	-	2	2	266
Yalu, Malekula, Vanuatu	-	-	1	1	2
Ponamla, Erromanga, Vanuatu	-	-	1	1	141
Mangaas, Efate, Vanuatu	-	-	1	1	259
Lapita, New Cal, Sand	-	1	-	1	651
Erua, Mangaia, Cook Is	-	-	1	1	25
Nukuoro	-	-	1	1	1599
Totals	6	386	117	509	38,415

TABLE 5

Twenty-seven archaeological sites in the tropical Pacific region containing eel bones at various taxonomic levels of identification. NISP values.

From the foregoing, the method outlined above for estimating live weight from bone dimensions is a one step process, where the equations are established from the available osteological comparative collection (N=99 specimens). An alternative would be to use a two step process, estimating live length from bone dimension and then using well established formulae for estimating eel weight from live length, which are based on much larger samples.

For example, Jellyman *et al.* (2013: 453, 455) presents the equation:

$$W = A * L^B$$

Where W = weight in g, and L = length in mm, and the constants A and B are 4.905×10^{-7} and 3.224 for the short finned eel, and 3.624×10^{-7} and 3.307 for the long finned eel respectively. These

Excavation	<i>Anguilla</i> spp.	<i>Conger</i> spp.	Sub-total	Total
Mana Island North	0	118	118	3949
Washpool Site	55	6	61	1562
Foxton	66	-	66	5504
Parewanui Midden	55	0	55	211
Black Rocks BR4	0	20	20	1678
Te Ika a Maru, Flat	0	16	16	531
Chalky Is	0	13	13	158
Breaksea Sound 1	0	11	11	5795
Paremata	0	9	9	569
Southport 1	0	8	8	1050
Southport 4, Cave	0	7	7	205
Long Island, Dusky	0	7	7	440
Cascade Cove, Dusky	0	7	7	230
Southport 6	0	6	6	470
Makara Beach Midden	0	5	5	82
Titirangi Sandhills,	0	4	4	87
Te Ika a Maru, East Flat	0	4	4	201
Southport 7	0	4	4	218
Black Rocks BR3	0	4	4	353
Black Rocks BR2	0	4	4	275
Wakapatu	1	2	3	289
Mana Island South	0	3	3	2431
Hot Water Beach	3	0	3	915
Southport 5, Cave	0	2	2	250
Shag River Mouth	2	0	2	8004
Tiwai Point	0	1	1	226
Titirangi Cattleyard	0	1	1	33
Sandhill Point 1	0	1	1	954
Makotukutuku M3	0	1	1	39
Coopers Island	0	1	1	481
Totals	116	265	381	37,190

TABLE 6

Twenty-nine archaeological sites from New Zealand containing bones of either freshwater eels or marine conger eels. NISP values. NB: The total NISP for Foxton was published as 4,109 in Davidson *et al.* (2000: 79). Since then, additional analyses were made, increasing the total to 5,504.

constants were established from huge samples of the two species (N=34,891 and 41,070). Unfortunately, no similar equation is available for the two species combined.

The two-step option is certainly the best option, however, with the exception of the vomer bone, the two New Zealand species cannot be differentiated from their cranial anatomy. Therefore, with the exception of the vomer, each bone measurement yields two estimates of the live weight, appropriate to each species.

On the whole, this metrical study of the bones of a comparative collection of modern eels has not been as definitive as past studies of other species of New Zealand fish. It proved very difficult to obtain large specimens of both species, and almost impossible for short finned eels. As can be seen from Figure 10, there are large gaps in the size range, which is anything but evenly distributed. However, this study represents a starting point that hopefully can be built upon in future.

The procedure outlined above was used to study archaeological collections from New Zealand and the Chatham Islands that have yielded eel bones, and results are discussed below.

EEL BONES IN PACIFIC AND NEW ZEALAND ARCHAEOLOGICAL SITES

Over a period of years from 1987 to 2001 a small staff of researchers at the Archaeozoology Laboratory at the Museum of New Zealand Te Papa Tongarewa identified (and in some cases re-identified) the fish remains from a large number of archaeological sites from the tropical Pacific, the Chatham Islands, and New Zealand. The precise locations of sites mentioned here are provided in an appendix in Leach (2006: 331 ff). Extensive comparative material was available on specially prepared boards organised anatomically for ease of identification. The methods of analysis and identification were carefully controlled and are described in detail elsewhere Leach (1986). As pointed out earlier, there are two species of freshwater eel in New Zealand. With the exception of the vomer, the cranial anatomy of these two species are difficult to distinguish. During analysis of archaeological collections careful attention was paid to vomers for this reason. In most cases, fragmentation made species determination impossible, but at Foxton five

Archaeofauna 31 (2022): 11-56

could be identified – four were *Anguilla dieffenbachii*, and one was *A. australis*. At the Waihora site in the Chatham Islands, 16 vomers were *A. australis*, and one was probably *A. dieffenbachii*.

The NISP values for these three groups of excavations are provided in Tables 5, 6, and 7. The total number of identifications in these tables and the sites without eel bones is 188, 351.

Excavation	<i>Anguilla</i> spp.	<i>Conger</i> spp.	Sub-total	Total
Waihora	54	88	142	22249
Kahiti South	84	18	102	503
Kahiti North	8	1	9	268
CHB	2	4	6	31704
Ohinemamao	2	-	2	27
CHA	-	-	0	3819
CHC	-	-	0	5
Te Ngaio	-	-	0	5
Pokiakio	-	-	0	8
Totals	150	111	261	58,588

TABLE 7

Archaeological sites from the Chatham Islands containing bones of either freshwater eels or marine conger eels. NISP values.

EELS IN ARCHAEOLOGICAL SITES IN THE TROPICAL PACIFIC

In the Pacific region there are many species belonging to the Order Anguilliformes, and comparative material is limited. Some specimens were unable to be identified with certainty as Muraenidae and are listed as Anguilliformes. However, both moray eels (Muraenidae) and freshwater eels (Anguillidae) are reasonably easy to distinguish, and are differentiated in Table 5. It is important to note that moray eels are implicated in numerous modern examples of ciguatera poisoning, and the threat is considered serious enough for the general warning “the public should be repeatedly warned to avoid eating moray eels” (Chan, 2017: 1). Although the head, skin and viscera (especially the liver) are considered the most dangerous parts of the animal, eating the flesh can also be fatal (Chan, 2016: 708). Disturbance of coral reefs during stormy weather is known to increase the toxicity of species susceptible to accumulating ciguatera in their tissues (ibid.).

In spite of the dangers of eating moray eels, they are highly nutritious. One nutrient analysis shows 57.8% by weight crude protein, and 14.1% fat (Goodman-Lowe *et al.*, 1999: 139).

The following 37 Pacific excavations produced no eel bones at any level of taxon. The total NISP of identified fish bones in each collection is given in parentheses. The **NISP Grand Total = 6,630**.

Tinian (1,038), Mouli B, Loyalty Is (962), Hnajoisisi, Hna Cave, Loyalty Is (954), Cikobia, Site 006, Fiji (711), Kosrae (404), Rurutu (354), Mouli A, Loyalty Is (270), Rota-SIU (261), Hnajoisisi, Loyalty Is (257), Guam (254), Ponape (247), Vatcha Site Ch1 New Caledonia (183), Cikobia, Site 001, Fiji (154), Nikunau Island, Kiribati (135), Arapus, Efate, Vanuatu (86), Hnenigec, Loyalty Is (57), Cikobia, Site 005, Fiji (47), Navatu, Fiji (46), Pwekina, New Caledonia (45), Peete, Loyalty Is (40), Ifo, Erromango, Vanuatu (31), Vatcha Site Ch2 New Caledonia (20), Kurin, Loyalty Is (19), Woplamlam, Malekula, Vanuatu (13), Navaprah, Malekula, Vanuatu (11), Vatcha Sondage A New Caledonia (7), Malua Bay, Malekula, Vanuatu (6), Cikobia, Site 04, Fiji (4), Vatcha Sondage C New Caledonia (3), Vatcha Sondage B New Caledonia (2), Nonime, Loyalty Islands (2), Keny, Loyalty Islands (2), Wambrat, Malekula, Vanuatu (1), Ndavru, Malekula, Vanuatu (1), Cikobia, Site 090, Fiji (1), Cikobia, Site 087, Fiji (1), Cikobia, Site 047, Fiji (1).

EELS IN ARCHAEOLOGICAL SITES IN NEW ZEALAND

The most common species of freshwater eel in New Zealand and the nearby Chatham Islands is the short finned eel, *Anguilla australis*. The long-finned eel, *Anguilla dieffenbachii*, attains a much greater length and tends to be further inland. There are more than 20 species of seawater eels in New Zealand coastal waters, most are deep in northern warmer waters, and have yet to be identified from archaeological sites. The most common seawater eel is *Conger verreauxi*, and this is found in many sites.

Also significant, the following 42 New Zealand excavations produced no eel bones at any level of taxon. The total NISP of identified fish bones in each collection is given in parentheses. The NISP grand total = 47,528.

Long Beach (34,035), Kokohuia (2,578), Sandhill Point 3 (2,341), Cross Creek (1,980), Fox River (695), Sunde Site (610), The Glen (580), Station Bay Pa (532), Omihia (508), Midden 8, Matakana (485), Port Craig Cave (445), Takahanga Post (417), Ross's Rocks (403), Sandhill Point (286), Harataonga Bay (214), Te Kiri Kiri (209), Taiaroa Head (170), Peketa Pa (136), Tumbledown Bay (119), Panau (113), Port Jackson (108), Hudson's Site (94), Black Rocks Fan (81), Davidson Un defended (79), Papatowai (70), Port Craig (54), Makara Terrace (44), Lee Island (31), Leahy Un defended (29), Milford (19), Parangiaio (17), Southport 8 (13), Harataonga Bay Pa (9), Makotukutuku M1 (5), Sandhill Point 2 (4), Goose Bay Midden (4), Titarangi Pa (3), Southport 9 (2), Port Craig1 (2), Port Craig2 (2), Garden Island (1), Breaksea Sound (1).

EELS IN ARCHAEOLOGICAL SITES IN THE CHATHAM ISLANDS

Information on fish catches from nine excavations are in the database at present. The archaeological sites are Waihora (Sutton, 1989); CHA, CHB and CHC (Smith, 1985); Kahiti North, Kahiti South, Te Ngaio, Ohinemamao, and Pokiakio (McIlwraith, 1976). The NISP values are given in Table 7. Four sites which did not contain any eel bones are included in the table.

It is abundantly clear from these tabulated results that eels were only rarely caught by pre-European people in the Pacific and New Zealand. The total number of freshwater eel bones identified was 383, which is a mere 0.2% of the total NISP (188, 351). Marine eels are about twice as abundant with a total NISP of 768, or 0.4% of the total. Even so, this is a very small number.

Only two archaeological sites stand out as having more than average eel bones. These are Kapingamarangi, with 4.6% marine eels, and the Parewanui site which has 26.1% freshwater eels. The alternative measure of abundance of Minimum Number of Individuals (MNI) gives a value of 5.4% for Kapingamarangi, and 53.7% for Parewanui (Leach, 2006: 189). Regardless of which measure is used, these two sites stand well out from others in having far greater relative abundance than any other sites. The Parewanui site is close to historically recorded eel channels and was radiocarbon dated to <250 years (NZ7354, Cassels *et al.*, 1988: 120).

LENGTH AND WEIGHT ESTIMATES OF EELS FROM BONES

Measurements were made on as many as possible of the bones of freshwater eel in the sites listed above, and using the allometric equations discussed earlier (constants in Table 4), estimates were made of the corresponding length and weight of each fish represented in these sites. The total number of measurements able to be made was 169 (Washpool 49, Parewanui 42, Foxton 37, Kahiti South 32, Kahiti North 7, and Wakapatu 2). It may be noticed that these numbers are a little lower than the NISP values given in Tables 6 and 7. This is because some bone fragments, although identifiable to genus, did not possess the anatomical landmarks necessary for measurements to be made.

The length and weight ranges of these eels is given in Figure 11. The most abundant eels are in the size range of 430 to 500 mm, which is quite small. The largest eel is estimated to have been 1323 mm, and to have weighed c. 8251 g. The weight of this large eel may also be estimated using Jellyman's formulae for each of the two species, cited earlier. Thus, the specimen with length of 1323 mm would have been either circa 5684 or 7624 g using their two formulae. Our value of 8251 is either 2.5 kg or 0.6 kg too heavy depending on whether the bone belonged to short or long finned species. Clearly for large eels, there can be significant errors in estimating live body weight from ar-

chaeological bones, largely because of our inability to determine which species is present.

SPECIFIC SITES FROM THE TROPICAL PACIFIC

The results above from 144 sites scattered through the Pacific and New Zealand were all studied in the Archaeozoology Laboratory at the Museum of New Zealand using strictly comparable methods.

A few of these stand out for additional comments below (Tikopia, Nukuoro and Kapingamangi), but before doing so there are a few additional studies in the Pacific that deserve mention, even though in some cases the methods of analysis are not quite the same as those summarised above. The sites in question produced significant numbers of eel bones.

Rapanui and Rapaiti

These two islands are well below the tropics¹², Rapanui (Easter Island) lying at 27° 10'S and Rapaiti at 27° 35'S. As such, their marine fauna are con-

¹² The southern border of the tropics is considered to be 23° 26'S.

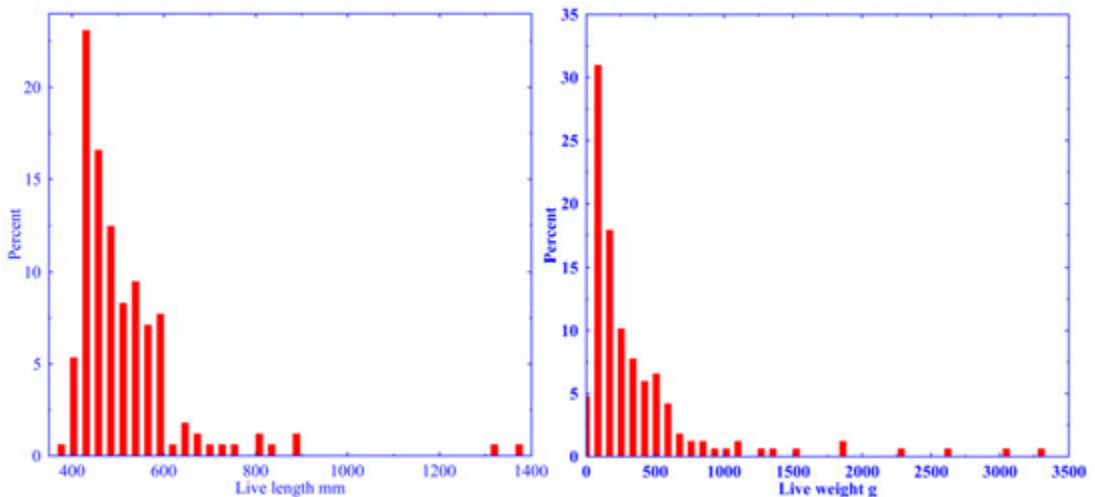


FIGURE 11

Size-frequency distribution of catches of eels present in New Zealand and Chatham Island archaeological sites (N-169). The right hand graph is truncated at 3.5 kg (see text).

siderably different to those of the islands considered above. Neither island has a fringing reef, so there are more limited opportunities for inshore fishing than around islands in the tropics.

Ayres documents eels in considerable numbers in his excavations on Rapanui. He combines the abundance figures for three families of eels together (Muraenidae, Congridae, and Brotulidae¹³) in his tabulation as 28.6%, 26.2%, and 23.2% of the total fish catches by MNI, for sites Runga Va'e (12-1), Papa te Kena (34-2) and Anakena (35-7) respectively (Ayres, 1985: 123). The total MNI for these three sites was 76, 626, and 194). He also did some measurements on dentaries (type of eel not specified), and obtained mean values of 24.7, 25.2, and 24.5 mm for the same three sites (N=15, 90, and 30, *ibid.*: 112). Without knowing what type of eel these measurements refer to, the live fish length cannot be estimated. By way of comparison, the average dentary length for the New Zealand ling is about 70 mm. In spite of the preliminary nature of Ayres' study, these records from Easter Island are very significant, and certainly show that the people living there in the past targeted marine eels in their fishing activities.

Recent research at two moai in Rano Raraku on Rapanui also produced bones of marine eels. Muraenidae were 6.9% of a total NISP of 434 Teleostei bones in the pre-contact era, and 10.3% of a total NISP of 408 bones in the post-contact period. One bone of Congridae was also present in both time periods (Wake, 2021, and Wake, 2021 pers. comm.). Although these more recent results are derived from much smaller samples than Ayres' study, and come from quite different cultural contexts, they certainly show that marine eels were a significant food source for prehistoric people on Rapanui. Freshwater is strictly limited on the island, so a population of freshwater eels would not be sustainable.

Much more information about ancient fishing is available from Rapaiti (commonly known as Rapa).

Anderson, in his paper on the ethnohistory of Rapa, has several useful observations on eels. In a passage referring to Stokes' unpublished manuscript (Stokes, n.d.) he states:

¹³ Brotulidae is classed as a sub-family of Ophidiidae (cusk eels) by Nelson (1994: 225). The New Zealand ling (*Genypterus blacodes*) is an example of a cusk eel and features as a minor component in prehistoric fish catches there (Leach, 2006: 62).

"Freshwater eel occurred commonly but was not eaten. In 2002, large freshwater eels were abundant in the streams and taro ponds and still were not eaten. Local people have a legend about a guardian spirit in the form of a blonde-haired woman who changes into an eel, which accounts for it not being killed or eaten... Marine eels were snared in the coral-reef shallows by women. They used two sticks, one of which held a bait, and the other a slip noose" (Anderson, 2012: 42).

Moray eels can be quite dangerous, and this proposed method of capture would not be without risk. Again citing Stokes' unpublished manuscript: "Following snaring, the eel was dashed against the rocks to kill it" (Szabo *et al.*, 2012: 153).

We can't help wondering if this woman who changes into an eel is a somewhat distorted 'folk memory' of the story of Hina and the eel, so widespread throughout Polynesia. A version of this myth even occurs on Rapanui where, unlike Rapaiti, freshwater eels are not present. Métraux notes that *tuna* is considered to be a man on Rapanui.

"Of extreme importance is the mention of Riri-tuna-rai as the female being who, with Atua-metua, conceives the coconut (niu). Here is a faint suggestion of the wide-spread Polynesian myth of the origin of the coconut which grew from the head of an eel (tuna), the lover of Hina. A version of this myth is present in Mangareva, but as fresh-water eels do not exist in these islands, Tuna is considered there as Man. On Easter Island there are no fresh-water eels or coconuts, and the name niu is given to the fruit of the *Thespesia populnea*, but the chant has retained the traditional association of the eel with the coconut" (Métraux, 1940: 323).

While the archaeological sites on Rapaiti produced no bones of freshwater eels so far, those of marine eels are present in considerable number. As Vogel observed:

"The large number of marine eels present in the Rapan assemblages, particularly those from Tangarutu, is also somewhat anomalous. This is unlikely to be due to methodology, as MNIs for these were based on the five paired mouth parts for both Congridae and Muraenidae. Rather, it seems likely that the environmental conditions on Rapa resulted in eels being more easily accessible, or perhaps more plentiful, than those families usually more favoured by Polynesians" (Vogel, 2005: 93).

She also notes a significant change in the relative abundance of Muraenidae eels over time at the Tangarutu site. This is clearly seen when either the MNI or NISP values are tabulated (Vogel, 2005: 80-85, and Vogel, 2012: 118-123). From her MNI and NISP values, possible changes through time can be plotted out with appropriate standard errors (discussed earlier) in Figure 13. The Tangarutu site has a time depth of c. 500 years (Vogel, 2012: 126). Vogel offers a number of hypotheses for these observed changes through time.

Rapaiti is an interesting case, where there is a clear differentiation between freshwater and marine eels – one being avoided (*tapu*) and the other being acceptable as food (*noa*).

Aitutaki, Cook Islands

Some very interesting results have been obtained from four excavations on this island. The Ureia site produced 52 bones of Muraenidae from a total NISP of 2930 (1.8%), the Hosea site, 48 from 931 (5.2%), the Aretai site, 9 from 319 (2.8%), and 1275 from 11,183 (11.4%) from the Moturakau site (Allen, 1992: 546-550). The first three sites are situated on open air living spaces, while the latter is a rock shelter on an outlying islet. The high proportion of

moray eels from the rockshelter, contrasting with the open sites, raises an issue of site functionality. The main source of food energy in the Cook islands is carbohydrate from taro. This is not available on the islet of Moturakau, so an alternative calorie-rich source of food had to be found for anyone living on this islet for any length of time. The fat-rich reserves in moray eels would help to provide this.

Mangaia, Cook Islands

The Tangatatau rock-shelter on Mangaia was studied by Butler (2017). Although Butler's methods are not exactly the same as those at the Museum of New Zealand, they are close enough for direct comparison with the above site data. One small point relating to methodology is her comment that the eel "premaxilla is extremely reduced in size and lacks distinctive features; none were identified from the site" (Butler, 2017: 104). As described earlier, eels do not develop a separate premaxilla during the embryonic stage of development. This is the reason none were found at Tangatatau. The Tangatatau site consisted of 19 stratigraphic zones. Sixty ^{14}C dates establish a chronology from the earliest zone 1 to the latest zone 17, from circa 1,000 AD to the historic period (Weisler *et al.*, 2016: 8151). Mangaia

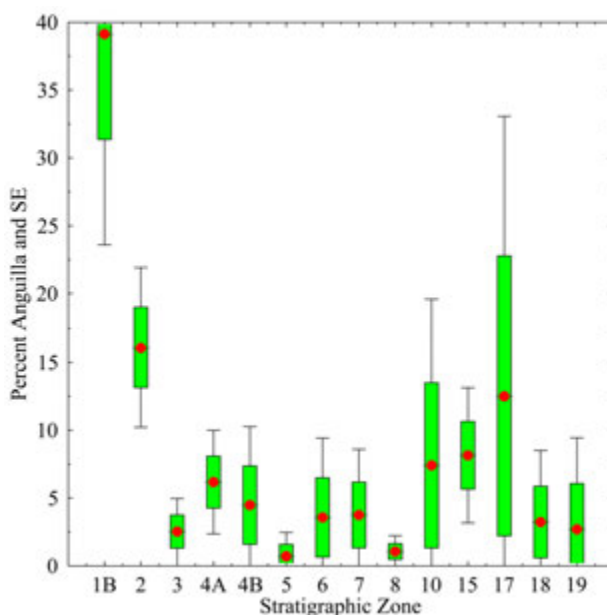


FIGURE 12

Relative abundance of freshwater eels at the Tangatatau site on Mangaia (NISP) over time. Zone 1 is c. AD 1000, through to Zone 19 in the historic period. The standard error is also shown.

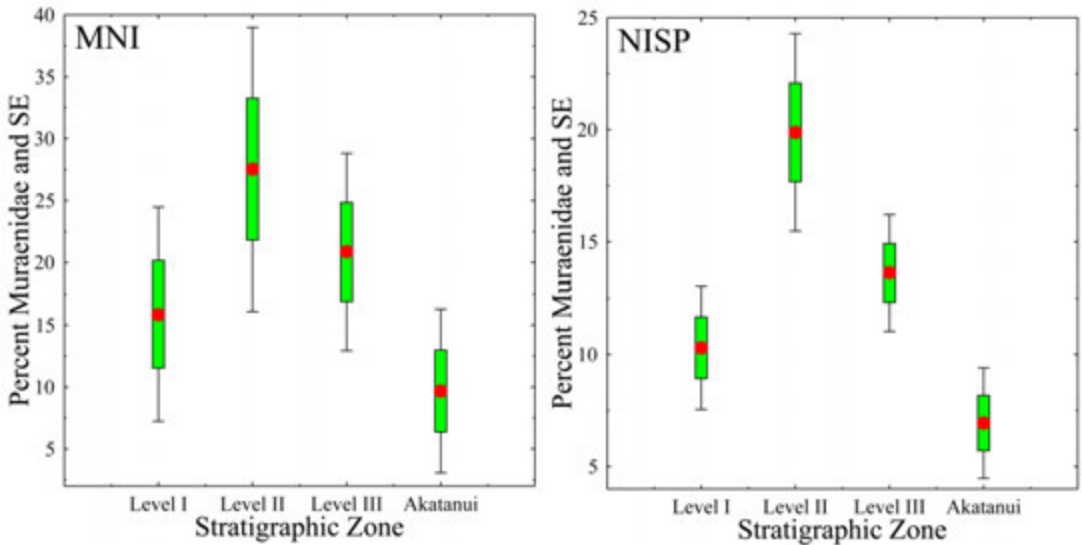


FIGURE 13

The relative abundance (with standard error bars) of Muraenidae through the stratigraphic sequence at the Tangarutu site, followed by the Akatanui site.

is a volcanic island with an elevated limestone reef around it (makatea¹⁴). Between the makatea and the rocky island there are many swamps; these are very suitable habitats for freshwater eels.

Butler identified 92 bones of freshwater eel. The total NISP of all fish species was 1649, so eels represent 5.6% overall. The most common bones were dentaries (47). The frequency through the history of the site is illustrated in Figure 12, using data from Butler (2017: 118-199). The error bars are 68 and 95% confidence limits of a proportion (also known as the standard error of a proportion), and follows Snedecor & Cochran (1967: 210-211; also see Leach & de Souza, 1979: 32).

Butler observed no appreciable change in size throughout the 1,000 year long sequence (Butler, 2017: 132, figure 7.12 upper), and she did not pay much attention to the possibility of change through time of eel capture, but our graph (Figure 12) does suggest the possibility that eels were more favoured than other fish earlier in the sequence and declined towards the historic period [see also Butler (2017: 127, figure 7.9 upper)]. Bones from sea-eels (Muraenidae) number 59 NISP (c. 3.6%), and were clearly less important.

Of interest is Butler's observation that the eels caught by the prehistoric people on Mangaia were very small specimens. She notes that a modern specimen almost 500 mm long had a dentary height measurement of 3.1 mm. The mean dentary height of the archaeological specimens was less than half of this modern specimen at 1.37 mm, and the largest dentary height was 2.01 mm. Butler notes that on the nearby makatea island of Mitiaro the modern eels are of comparable size to those on Mangaia. According to Jellyman the species on Mitiaro is *Anguilla obscura*. He caught 264 eels from the inland lake there. The smallest was 337 mm and the largest 780 mm, average 538 mm (Jellyman, 1991: 366). In our own comparative collection of 99 specimens, described above, the smallest dentary height measurement was 3.87 mm, corresponding to a live eel measuring 430 mm long. So, the Tangatatau archaeological eels are certainly very small indeed.

Butler suggests two possibilities for their small size – that the eel population had been depleted by earlier occupants on Mangaia, resulting in smaller size. Alternatively, that hillside erosion resulting from intensive horticulture had reduced the aquatic habitat, preventing eels from reaching their full potential size (Butler, 2017: 131, see also Kirch *et al.*, 1995: 56). To these can be added another possibility, that small eels were considered food, but large ones were treated as *atua* by the prehistoric Mangaian people.

¹⁴ The makatea is attributed to a fall in sea level in the late Holocene, circa 3400 yres BP (Yonekura, *et al.*, 1988).

Tikopia in the Solomon Islands

Another important archaeological find of eels in the Pacific was on the island of Tikopia. In this case of sea-eels, not freshwater eels. It will be recalled from the discussion of myths and oral traditions on Tikopia that the idea of eating both kinds of eel was considered disgusting, because of a strong association of eel with a deity representing the penis. Archaeological excavations, however, revealed bones of marine eels in the early part of the archaeological sequence, but not later. Kirch and Yen document 133 Muraenidae identifications from of a total NISP for marine fish bones of 5,788, or 2.3% overall (Kirch & Yen, 1982: 286). The provenance of these bones is confined to the Sinapu and Tuakamali phases, between 900 BC and before about AD 1700 (ibid.: 286, 292), and they are certainly not present in the more recent provenances. The same pattern occurs with the porcupine fish, *Diodon hystrix*, which, like marine eels, modern Tokipians refuse to eat. Kirch and Yen provide a compelling argument that the strong *tapu* against eels which Firth describes in detail during the historic period was not in place in earlier times on Tikopia. Kirch and Yen speculate that the *tapu* may have been imposed because of an outbreak of ciguatera poisoning on the island, something that can effect a number of fish types including morays and porcupine fishes. It is important to note that Kirch and Yen consider that the cultural facies they attribute as ‘Polynesian’ begins during the Tuakamali phase, at a time when eels and porcupine fishes were still considered food. The prohibition appears late in the Tuakamali phase.

We should note in passing that these archaeological findings are confined to marine creatures (moray eels and porcupine fish), and not freshwater eels. There are plenty of freshwater eels on Tikopia, but they were not found archaeologically. Raymond Firth’s comments about the Tikopian’s horror of eels was directed at both freshwater and marine eels. The absence of freshwater eels in the archaeological sites on Tikopia suggests that the people differentiated between marine and freshwater eels in the past – one was food and the other was not.

What is singularly important in this example from Tikopia, covering a period of 3,000 years, is that food prohibitions and taboos are cultural norms that can abruptly change, and, with careful analysis, can be documented archaeologically.

Nukuoro and Kapingamarangi in the Caroline Islands

The eel remains on these two Polynesian outliers deserve additional attention. Kapingamarangi is one of the most isolated islands in the Pacific, just north of the equator, and Nukuoro is its nearest neighbor, 215 km distant.

Although the languages on both islands are Polynesian they are rather dissimilar (Leach & Ward, 1981: 86). Both have similar time depth of human occupation, around 700-1,000 years. Both being atolls, there is very limited habitat for freshwater eels, although both have significant areas devoted to swamp taro, so it is possible *Anguilla* spp. could take up residence in these. The marine lagoon on Nukuoro is considerably deeper than on Kapingamarangi, but other than that the marine environments and fishing opportunities are very similar. Archaeological excavations on Nukuoro reached a maximum depth of 2.9m, and 4.1m on Kapingamarangi. Only one *Anguilliforme*¹⁵ bone was found in the excavations on Nukuoro in a total fishbone NISP of 1,599 (0.06%). On Kapingamarangi, however, 196 *Anguilliforme* bones from a total fishbone NISP of 4,260 (4.6%) were recovered (Table 5). The sites on both islands are very similar, coral gravel house floors built up over centuries, as people refurbished their floors with clean gravel brought in baskets from surrounding islets at low tide.

During historic times, the people on Kapingamarangi specifically targeted marine eels, and made elaborate traps for catching them. During his research on the island, Peter Buck commented of fishing in general “The best for eating is said to be the sea eel, and to judge by the number of sea-eel traps seen in the canoe sheds, this must be true” (Hiroa, 1950: 48). He describes the manufacture of these eel traps in considerable detail (ibid.: 255-256, 265). No such behavior has been observed on Nukuoro in the historic period.

Such an enormous difference between two such similar islands, so close together, both occupied by

¹⁵ The reason why this high level taxon is used here is that identifications of fish remains on these two islands involved different taxonomic levels. The one bone on Nukuoro was *Anguilla* sp.; whereas on Kapingamarangi, most bones were from Muraenidae, while two bones belonged to two different unidentified *Anguilliforme* families.

Polynesians for a similar length of time, can only have one explanation – that the cultural attitude towards eels was totally different between the two islands. It must surely put to rest once and for all that the absence of eel bones in archaeological sites in areas where they are locally available reflects one and only one reason – that the people did not consider eels as food.

The fish remains from Kapingamarangi were recovered from four sites, and the stratigraphy in each was divided into four periods: Level I 1000–700 BP, Level II 700–300 BP, Level III 300–100 BP, and Level IV 100–present (Leach & Ward, 1981: 52, figure 35). The proportion of eels in each period are graphed in Figure 14. In Level I the total MNI is only 39, so the standard error is huge and not graphed. The average percent of MNI for the other three periods is 10.0%. No obvious change through time is indicated. Note that in Table 5 NISP figures are given, and the overall percent of eels by this method is 4.6%.

SPECIFIC NEW ZEALAND SITES

Turning now to a final few New Zealand archaeological examples relating to eels – Fox and Cassels reported an MNI of one freshwater eel from their excavation at the Aotea site, Waikato, along-

side 10 snapper (Fox & Cassels 1983: 102). The site dates to about 400 B.P.

Prickett comments about his excavation at Raupa in the Firth of Thames: “In the midst of a very large area of swamp and waterways eel was almost certainly of importance, as would have been snapper and other fish of the Hauraki Gulf (Prickett, 1990: 145). Unfortunately, the excavation produced rather few remains of fish, but there was one possible identification of eel in Area V (ibid.). This site is late pre-European in age, and it is a great pity that more fish remains were not recovered to shed light on the relative abundance of eel remains.

One archaeological site where eel bones could be expected to have been abundant is the swamp pa called Kohika, in the Bay of Plenty, occupied between AD 1610 and 1810 [95% confidence limits, see Irwin & Jones (2004: 80)]. As Irwin points out:

“Though finds of eel bones in New Zealand sites are rare, it might have been expected that Kohika, surrounded by streams and lakes, would produce some. This has proved not to be the case, however, and close examination of the material reveals no trace of their very distinctive bones. Clearly, eels were available locally and survival conditions for their bones were excellent had they been eaten and their bones disposed of in the same way as other fish” (Irwin, 2004: 206).

Like Kohika, another site where eel bones would be expected to be present in large number

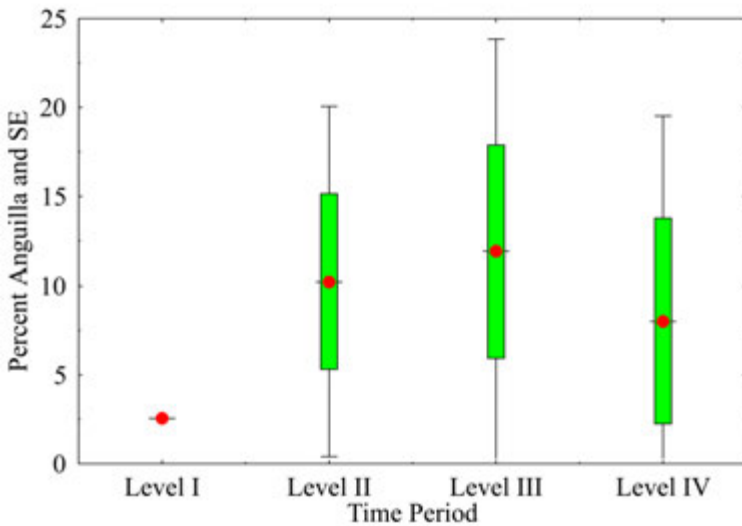


FIGURE 14

Relative abundance of marine eels on Kapingamarangi (MNI) arranged in chronological periods. Level I is c. 1000 BP, and Level IV is historic period. The standard errors are also shown.

considering its location on a sandy knoll amongst a series of swamps and lagoons is the site of Foxton. The site contained considerable evidence of moa-hunting, and was occupied for a long period. Of the 5,504 fish bones identified only 66 were of freshwater eel, occurring in both early and late contexts (Davidson *et al.*, 2000: 79, 81). Clearly, eels contributed only a tiny fraction of fish caught and eaten by the people at Foxton (1.2%), and therefore cannot be considered a major target species as was observed among a number of 19th century Māori communities nearby (Curtis, 1964).

One archaeological site which seemed likely to contain abundant eel remains was a midden in the close vicinity of a fortified Pā site at Parewanui where there are artificial eel channels in the surrounding swampy lands. The Pā is known to have been occupied in the early 19th century. The eel channels are similar to those seen on the Horowhenua flood plane and Manawatu river, described in the early 1900s (Cassels *et al.*, 1988: 110). Historical records in the 1940s of Māori communities living at Parewanui attest to dried eels being prominent (*ibid.*: 111). The midden was therefore expected to have eel bones in it, and indeed it did. It was radiocarbon dated to <250 years (*ibid.*: 120). Although only a small sample with a total MNI of 54 across 5 taxa, eel contributed 29 individuals, representing 53.7% of the catch (NB: eel NISP = 55, of total NISP of 211 = 26.1%). The authors of the publication reported that the eel bones were:

“all from small specimens. This contrasts with what might be expected from nineteenth century Maori eeling practice as it is generally understood. This involves the mass seaward migration of adult eels for spawning and suggests that there is no functional relationship between the midden and the eel-trapping channels” (Cassels *et al.*, 1988: 123).

They further comment as follows:

“the remains are probably those of young elvers migrating into the lakes and swamps rather than mature eels taken during their migration to the sea. The latter were the focus of eel fishing according to historical records. The possibility that large scale eel fishing was a development of the contact period is not ruled out by the results of this excavation” (*ibid.* 125).

There is a minor confusion here. The juvenile transparent forms, known as glass eels, return from breeding grounds in the sea. When they migrate into freshwater they turn black, and are then known

as elvers (5-7 cm long), and travel upstream. It is adults that are found in swamps. Moreover, no details are provided by the authors as to what they mean by ‘small specimens’. As will be seen below the eels in this site, while not enormous, were not very small at all.

TIME-TREND ANALYSIS OF EELS IN NEW ZEALAND

In an earlier study of fish remains in New Zealand and the Chatham Islands, an attempt was made to pool data on fish remains into three periods, to see if time-trends could be observed in fish catches (Leach, 2006: 189-191). This earlier study strongly confirmed the conclusions which have been arrived at in this present paper – that pre-European Māori caught very few eels until after Europeans arrived (see Table 8). In a short chronology of only c.1,000 years, this time-trend study is not without problems, and details can be disputed. In addition, such a study ignores the fact that far more sites have no eel bones, in spite of the fact that eels are close at hand in almost all environments. The absence of eel bones is also evidence that they were being ignored by people.

EEL LIVE LENGTH ESTIMATES FROM SPECIFIC SITES

Measurements were taken from as many bones as possible from archaeological collections from New Zealand sites known as Foxton, Parewanui, Waihora, Wakapatu, and Washpool; and from Chatham Islands sites known as Kahiti north, Kahiti south, and Waihora. Rather than illustrate these catches as simple histograms it was decided to present the length data cumulative graphs, or sigmoid curves. This makes it possible to see at a glance the cumulative contribution of different sized fish to the overall catch (Figure 15). For example, At Parewanui, 75% of the eel catch were less than 540 mm long. Such curves provide a simple snapshot of the catch composition.

The sigmoid curves for these sites are quite similar in the case of Parewanui, Kahiti South, and Waihora, but the catches at the Washpool and Foxton stand out from these three (Figure 15). Most of the catch at the Washpool were very small eels,

	Eel MNI	Total MNI	%	±	SE%	Archaeological Site
<i>Protohistoric Period (eels present in 1 of 8 sites)</i>						
	29	54	53.7	±	14.5	Parewanui Midden, Bulls, Manawatu
Simple Mean			53.7	±	14.5	
<i>Late Prehistoric (eels present in 10 of 63 sites)</i>						
	1	5	20.0	±	53.8	Northland Harbour Board, Whangarei
	24	159	15.1	±	5.9	Kahiti South, Hansons Bay, Chatham Is
	6	95	6.3	±	5.5	Kahiti North, Hansons Bay, Chatham Is
	1	17	5.9	±	14.9	Ohinemamao, Petre Bay, Chatham Is
	1	25	4.0	±	10.1	Raupa N53/37, T13/13, Hauraki Plains
	1	35	2.9	±	7.1	Aotea N64/25, North Island west coast
	14	4197	0.33	±	0.19	Waihora, Chatham Islands
	2	1206	0.17	±	0.27	Mana Island North Settlement R26/141
	1	884	0.11	±	0.28	CHA, Chatham Islands
	4	4978	0.08	±	0.09	CHB, Chatham Islands
Simple Mean			5.5			
Weighted Mean			0.47	±	0.13	
<i>Early Prehistoric (eels present in 9 or 55 sites)</i>						
	1	14	7.1	±	18.2	Riverton, Southland
	37	771	4.8	±	1.6	Washpool Site, Palliser Bay
	3	278	1.1	±	1.4	Hot Water Beach, Coromandel
	1	94	1.1	±	2.6	Wakapatu, Western Southland
	1	401	0.25	±	0.61	Sunde Site soft shore midden, Motutapu
	1	585	0.17	±	0.42	Rotokura, Tasman Bay
	1	584	0.17	±	0.42	Sunde Site Oyster lens, Motutapu
	1	2134	0.05	±	0.12	Shag River Mouth, Otago
	1	2425	0.04	±	0.10	Houhora, Northland
Simple Mean			1.6			
Weighted Mean			0.65	±	0.19	

TABLE 8

Time Trends in the presence of eel bones in New Zealand and Chatham Islands archaeological sites, after Leach (2006: 189). The weighted mean takes into account different sample sizes (Snedecor & Cochran, 1967: 521), and the standard error of proportion is described by Snedecor & Cochran (ibid.: 210).

while at Foxton they were much larger eels. The Foxton curve has a long tail to the right; with the largest eel estimated as 1320 mm in length. Only Foxton has eels greater than 677 mm live length (eight specimens). As will be seen from Figure 15, 75% of the eel catch was less than 450 mm long at the Washpool site, 540 mm long at both Parewanui and Waihora, 570 mm at Kahiti south, and 590 mm at Foxton. These are considerably different catch compositions and presumably reflect local availability and whether catches were during

eel migration behaviour. There are no swamps in the vicinity of the Washpool, so larger eels may not be so abundant. The opposite is the case at Foxton, where there are large areas of swampy ground. Parewanui has a similar environment to Foxton so it is surprising that so few large eels were caught. The two sites at Kahiti are both on sand dunes which are backed by swampy land, so larger eels would be present there. Waihora is somewhat unusual, displaying similar catch characteristics to Kahiti South, but the Waihora site is close to a rocky

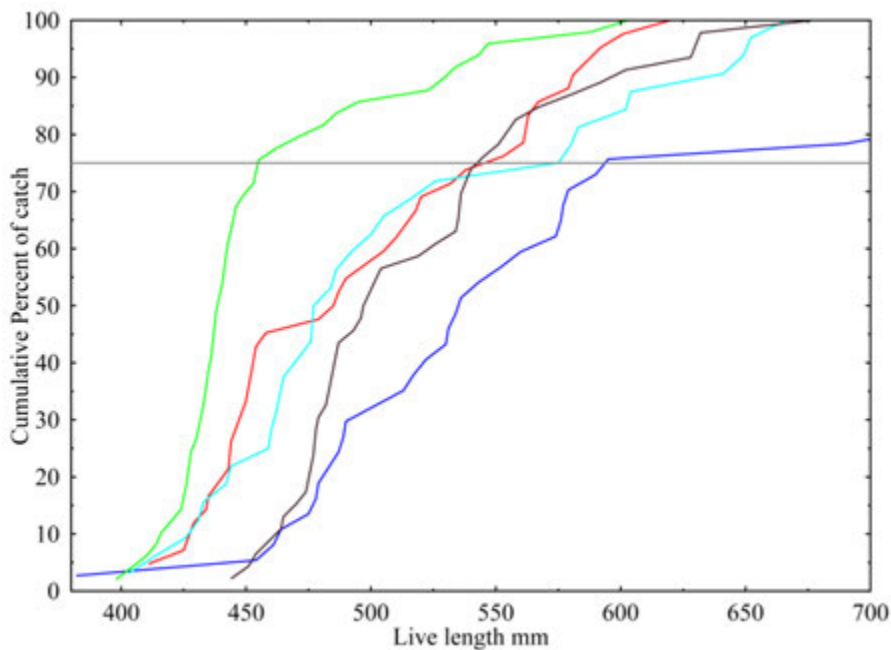


FIGURE 15

Sigmoid curve of eel catches for four New Zealand sites, to illustrate the size of eels that form 75% of the fish caught. Washpool green, Parewanui red, Katiti South cyan, Waihora brown, and Foxton blue.

shore environment with no swamplands in the near vicinity, although there are streams running into the interior of the island. A few measurements are available on eel bones from two more sites: Wakapatu (N=2) and Kahiti North (N=7). These yield live length ranges of 527-684 mm, and 447-542 mm respectively. There is no sign of large eels in these sites.

These eel catches for which we have been able to make estimates of live length are pitifully small samples. With the possible exception of Parewanui, none could be considered as representative of the massive eel harvests so vividly described in 19th century ethnographic literature of Māori communities. We have no doubt that excavations in the future of 19th century villages in areas where these mass harvests were made will reveal substantial deposits of eel bones, including of large females. However, the foregoing has shown that eels were only rarely caught by pre-European Māori. Of the 80 archaeological sites reviewed from New Zealand and nearby Chatham Islands, only 226 eel bones were identified of a total NISP of 143,306 (0.19%).

A single site at Parewanui stand out above all others as having enough eel bones to suggest that Archaeofauna 31 (2022): 11-56

eels were an important food for the people who lived there. The site was close to landscape features interpreted as eel channels, precisely for harvesting eels, described in the historic period. It is very difficult to come to any other conclusion than that mass eel harvests in New Zealand only began either very late in the prehistoric period or after European contact.

SUMMARY OBSERVATIONS ON EELS IN ARCHAEOLOGICAL SITES FROM THE PACIFIC AND NEW ZEALAND

The foregoing analyses have shown that with very few (but notable) exceptions, eel bones are infrequently found in archaeological sites in the Pacific and New Zealand. The numerical abundance data are summarised in Table 9. The total number of fish bones identified in this review is 188,351 from 144 sites. Only 1,151 eel bones were identified in these sites, 0.61% overall.

In the tropical Pacific, eels, mainly marine species, account for about 1.1% of fish catches, compared with only 0.5% in New Zealand. However,

	No Sites Without	Sub-Total NISP	No Sites With	Sub-Total NISP	Eel NISP	Total NISP	Eel Percent
Pacific	37	6,630	27	38,415	509	45,045	1.13%
New Zealand	42	47,528	29	37,190	381	84,718	0.45%
Chatham Is	4	3,837	5	54,751	261	58,588	0.45%
Totals	83	57,995	61	130,356	1,151	188,351	0.61%

TABLE 9

Summary presence and absence of eel bones in Pacific and New Zealand archaeological sites.

such overall averages can be very misleading. In the Pacific 89% of all eel bones come from only nine of the 64 sites. This variation does not reflect variable natural local abundance, but deep rooted cultural beliefs about what is and what is not acceptable as food.

Two atolls in the Caroline islands with basically the same climate and soil conditions and length of human occupation present contrasting fish catches in the archaeological sites. The sites on Kapingamarangi have abundant marine eel remains throughout the time sequence; whereas those on Nukuoro have none. Surprisingly, sites on both islands have one or two freshwater eels in them (Table 5). Ethnographic records in the historic period confirm the importance of eels to the people on Kapingamarangi. The idea that eel bones are rare in archaeological sites because they decay easily from the high fat content is therefore rejected by the analysis presented here.

Another Polynesian outlier, Tikopia, in the Solomon Islands, presents an intriguing possibility that eels were once considered food, but that in the course of time a prohibition emerged. Moray eel bones are common from 900 BC to AD 1700, but are absent in later layers in the historic period. Historic ethnographic records show that both freshwater and marine eels are considered disgusting to eat. Although freshwater eels occur on the island, none were found in the archaeological sites.

At the Tangatatau site on Mangaia in the Cook Islands the opposite picture emerges – marine eels are rare, and freshwater eels are common. There is a hint from the abundance figures through time that eels were much more common in the earliest part of the sequence and declined to low levels thereafter, following a similar pattern to Tikopia. Ethnographic records on this island, once again, show that eating eels was considered disgusting. Observations of the bone size of the archaeological eels suggest that only tiny eels were caught and eaten in the past, even though much larger eels are present

on more than one island in the Cook Islands. The absence of large eels in the site raises the possibility that they were considered different in the folk taxonomy relating to eels.

Analysis of a sample of 169 eel bones from archaeological sites in New Zealand and the Chatham Islands revealed that almost all fish were less than 600 mm live fish size. This suggests that the bulk of fish caught were probably *Anguilla australis*. The larger species, *A. dieffenbachii*, is the last to migrate from the upper waterways in New Zealand to the sea, when they then travel to the south Fiji basin for breeding. The mass harvesting of eels that was observed among many Māori communities living close to the sea would certainly have these large fish in their catch. The dearth of them in the archaeological record suggests that none of the 80 sites investigated were involved in such mass harvesting. The low numbers of eel bones in all these sites supports the same conclusion. Smaller numbers of *A. dieffenbachii* are certainly found in lakes and swampy areas close to the sea, and could have been caught at times other than during mass migrations. The rarity of large eels in New Zealand sites is in concert with the finds at Tangatatau on Mangaia.

Three archaeological sites that are situated in environments which have abundant eels available year-round, all had careful attention paid to fish remains, and produced contrasting results. At the Foxton site, eels contributed only $1.2\% \pm 0.3$ of the fish catch. Most of them are from the early part of the site, circa 700 years BP. For the people living at this site, eels were a trivial component of diet. Parewanui is an early historic period site, and eels contributed $26.1\% \pm 6.2$ of the fish catch. The site is close to artificial water channels thought to be for harvesting eels. This site is consistent with ethnographic reports of mass harvesting of eels. Finally, the Kohika site, occupied between AD 1610 and 1810, has no eel bones at all, and could well be an example of food avoidance behaviour, eels being prohibited. These three sites display characteris-

tics which are in concert with historic observations about the variable role of eels in Māori culture, cited earlier. On one hand we have Polach's observation that eels were *tapu* and could not be eaten by people living in the vicinity of Tauranga in the 1830s, and Brunner's observation of a cleansing ceremony to lift the *tapu* on eels so they could be eaten by Māori along the West Coast of the South Island during an episode of starvation. On the other hand, we have many records of mass harvesting of eels for food among Māori resident in three major river systems in the North Island: Wanganui, Manawatu and Ruamahanga.

CONCLUSIONS

Marine eels are ubiquitous throughout the Pacific region, and freshwater eels are found in islands large enough to have abundant sources of freshwater. Contrary to expectation, both marine and freshwater eels are surprisingly rare in archaeological sites in the Pacific and New Zealand, considering their natural abundance and ease of capture, although there are some notable exceptions. This is something that has also been observed in European archaeology, and has commonly been attributed to taphonomic effects, or that the bones are small and difficult to identify, or that they break down in soil by autolysis because they are rich in oil. In this paper we show that each of these reasons is false. The mere fact that in some modern societies, where eels are considered desirable as food and abundant eel bones are found in their ancestral archaeological sites, repudiates most of these suggestions.

Eels are very easy to catch and provide a rich source of protein and fat. The amount of fat increases with age of animal and typically an eel can provide 74, 105, and 179 kcal/100g for protein, oil, and total respectively. This represents nearly 59% caloric energy from fat. Humans require more than 70% of their caloric energy from non protein sources, either from carbohydrate or fat. For societies where carbohydrate foods are in limited supply, eels can provide the difference between survival and starvation. Finding this nutritional balance is not a problem in tropical and sub-tropical Pacific communities, because carbohydrate rich foods are easily cultivated.

New Zealand ranges from subtropical in the north to subantarctic in the south. Tropical tubers

introduced from the Pacific in prehistoric times formed the basis of a secure carbohydrate economy in the north, but was progressively less favourable for successful gardening southwards. In the far south, the economy was firmly hunter-gatherer in character, with sources of fat assuming far greater importance in the diet than in the north. Maintaining a horticultural economy in the intermediate area, between 40°-43°S was very difficult, and major river valleys in the central area, where tubers could not be grown and stored, prohibited permanent settlements being established. During the 19th century, following colonisation by Europeans, there are many records of Māori in this central region taking part in mass harvesting of freshwater eels with their abundant fat reserves. Prehistoric archaeological sites in the same region have very few eel bones.

We review aspects of the cranial osteology of eels, and the most commonly found bones in archaeological sites. Allometric analysis was carried out to establish equations for estimating live length and weight from bone measurements. A total of 1,151 eel bones have been found among 188,351 fish bones from 144 archaeological sites in the Pacific (64), New Zealand (71), and the Chatham Islands (9), representing an overall abundance of just 0.61%. Of these, only 383 bones were from freshwater eels (0.2%). We were able to take measurements on 169 of these 383 bones and use the allometric equations to estimate live length and weight. The analysis showed that the most abundant eels were in the range of 430 to 500 mm length, with only 5 greater than 800 mm. There are vivid ethnographic descriptions of mass harvesting by 19th century Māori, describing the migration of eels to the sea. The second variety to arrive, called *riko*, were from 900-1200 mm long, followed by the *kokopu tuna*, about 1800 mm long. Only two archaeological eel bones belong to eels over 900 mm.

Three of the 144 tropical Pacific sites are of special interest: The people on Kapingamarangi atoll in the historic period made special traps to catch marine eels, and during the prehistoric period marine eels were about 10% of all fish caught. A site known as Tangatatau, on the island of Manguaia, had significant freshwater eels in the deposits, averaging 5-10% of the catch. Finally, on Tikopia marine eel bones are about 2.3% of fish caught, but are only found from about 900 BC to AD 1700. In the historic period, both marine and freshwater

eels were considered disgusting to eat. This one example shows that social attitudes towards eels can change over time in any one society.

In the tropical Pacific, eels represented the incarnation of a male deity, symbolising the penis, and the personified eel tempts and defiles a woman sexually. A male, often an heroic ancestral figure, punishes the eel by cutting him up into pieces. We found that there is often a strong association of eels with danger, and that the eel is either venerated or feared, and is certainly not considered food. In some Pacific societies, the arrival of Europeans resulted in the lifting of the *tapu* of eels as food.

We argue that the Polynesians who settled New Zealand from the tropical Pacific brought with them a fear and loathing of eels embedded in their mythology and oral history, and this is the reason for the dearth of eel bones in archaeological sites – that is, the people who settled New Zealand came from a part of the Pacific where eels were considered *tapu*, and not eaten. We document two examples in 19th century ethnographic records where Māori considered eels to be *tapu*, and in one case of starvation, could only be eaten after an elaborate *tapu* removal ceremony. In short, the transition of eels from sacred to profane, from *tapu* to *noa*, took place during the tumult of the clash of cultures in the post-European era. Such a dramatic change had several unanticipated advantages – the fat reserves that eels possess made it possible for major river valleys in the central area to be populated with permanent settlements for the first time. These proto-historic communities also benefited from the introduction of potato and feral pigs.

ACKNOWLEDGEMENTS

The authors would like to sincerely thank Matua Nelson Rangi Te Kai Waho, aged 91, for his acute memory of the famous eel harvest at Okorewa, near Lake Onoke, in South Wairarapa. His help in making clear to us the details of the processing of eels during these mass harvests was invaluable. Special thanks are also due to Martin Lewis and Nicola Calwell, reference librarians at the Museum of New Zealand Te Papa Tongarewa, for their tireless effort helping us during literature research on eels in ethnographic literature and getting documents by interloan. We would also like to thank Donaghy's Industries for providing most of the eels in our comparative collection, and two anonymous

referees who made useful comments on a draft of this paper. Finally, the authors would like to thank the Foundation for Research, Science and Technology for financial support for research projects in the Archaeozoology Laboratory at the Museum of New Zealand Te Papa Tongarewa.

APPENDIX 1: ADDITIONAL ETHNOGRAPHIC RECORDS RELATING TO EELS

The following extracts are listed in alphabetical order by island name.

Hawaii: Titcomb (1982) has many useful observations about the role of eels (*puhi*) in Hawaiian society. "Salt water eels were eaten, but freshwater eels were used ceremonially only. Of details of this use there is no available record" (Titcomb, 1982: 124).

Kapingamarangi and Nukuoro: The Samoan story about Sina and the eel is not present on Kapingamarangi or Nukuoro. However, Sina or Hina is a common female name in many parts of Polynesia, celebrated in myths and stories, including Kapingamarangi (Elbert, 1949: 243). As Fischer has shown, Hina is also cognate with the Nukuoro story of Sinonukataha (Fischer, 1958: 12). Since freshwater eels are not present on atolls, it is not surprising that the Samoan eel myth is absent on these two atolls. The myth could not be applied to seawater eels, because, unlike freshwater eels, they are dangerous to humans, and not personified as a penis. It is interesting that the common Polynesian names of *pusi* for saltwater eels and *tuna* for freshwater eels, are not found on either of these atolls. Carroll provides the word *labodo*, meaning snake, also eel, water snake, etc. for Nukuoro (Carroll, 1965: 470). This cognates with *labodu* for marine eels on Kapingamarangi, and perhaps *laboto* among the Raluana people (Tolai or Kuanua language) of New Britain (Brown, 1981: 98). On this issue Ross Clark reports as follows: "the labodo/u word came up in my 1994 paper on language contact at the Polynesian Outliers [Clark, 1994: 122]. I found Woleaian labut(o) 'snake, worm, eel' and Ponapean lapwed 'salt water eel (generic)'. Bender *et al.* give a Proto Central Micronesian *lapw(ou) so 'moray eel', with several more cognates [Bend-

er *et al.*, 2003]. Going back further, Ross, Pawley & Osmond have Proto-Oceanic *[la]bwa(s,j)i ‘moray eel’ [Ross *et al.*, 2011: 44]. This means that the NKO word, though clearly borrowed from a Micronesian source, may be a distant cognate of Polynesian *pusi. In that paper I found that NKO and KAP were among those Outliers least linguistically influenced by their non-Polynesian neighbours” (Clark to BFL pers. comm. 2020).

Kosrae: Rochers (citing Sarfert, 1919) comments: “Although eel [*semis* is the Kosrae name referring to salt water eel] is presently a fairly common food in Kosrae, it was once considered tabu and not eaten. Formerly, it was believed that if one killed an eel it would come and sleep with the person and cause illness and eventually death” (Rochers, 1992: 16).

Mangaia: “When Te-aio was killed, his blood flowed into a stream and was drunk by an eel. The spirit of Te-aio entered the eel, which after Te-aio was deified, became his incarnation. The eel went out to sea, came in contact with a shark, and the spirit of Ta-aio passed over the shark. The shark also became an incarnation. This is the mechanism followed in New Zealand, where any fish, bird, or animal which touches or drinks the blood of an ancestor may become the incarnation of that deified ancestor” (Hiroa, 1934: 171).

New Zealand: Discussed in the main text.

Ponape: “There is one species of fish universally held sacred by the islanders, a species of eel, inhabiting the fresh water... to our enquiries why this fish enjoyed such a peculiar and universal exemption, the only answer had been *Majorhowi!*” (O’Connell, 1972: 137). In a footnote there is reference to the logbook of a Sydney vessel, *The Gypsy*, at Ponape in 1841, which states “the river eels are worshipped by the natives, and in such veneration are they held, that should they be caught and cooked on board ship and the natives got knowledge of it, every soul would directly abandon her with the greatest abhorrence. The taboo against consuming the fresh water eel persists today.” (ibid.: 138).

Taumako: This is a Polynesian outlier in the outer eastern Solomon Islands, close to Tikopia. Archaeofauna 31 (2022): 11-56

Freshwater eels are found in the inland swampy areas of river valleys. They are referred to as *te atu*, which is an abbreviation of *te atua* (Leach & Davidson, 1978: 47). *Atua* is a Polynesian word referring to a deity or supernatural being. In spite of this, the Taumako people today consider both moray eels and freshwater eels to be good food (ibid.: 65, 67).

Tikopia: “Most marked among taxa in this field [totemism] were eels. All kinds of eels have been looked upon by Tikopia both traditionally and in modern times as very unpleasant creatures, and normally no Tikopian would eat an eel. Traditionally such an attitude could be related to the mythical origin of eels from the phallus of a primal deity, but whether this is now current or not, even the sight of an eel may bring a strong demonstration of repugnance. Two types, the eel of the lake (*Anguilla* sp.), and the grey-brown reef eel (*Gymnothorax* sp.) continue to be regarded as especially repulsive creatures in themselves, and as *atua*, to be symbolic of spirit powers embodying a great deal of evil, representing male lust and responsible for bodily affliction of the digestive organs” (Firth, 1981: 222).

Firth provides further details on this notion “including an origin myth in which the various types of eels were created by successive truncations of the elongated phallus of a generative deity. Linked with this was the notion that eels in their spirit form were essentially concupiscent; conceived as always male, they were therefore very dangerous to women. More generally, the eel gods were conceived as suspicious, jealous, personifications of punishment for offenders” (Firth, 1967: 556).

“In 1973 I was told (rather unwillingly) that a few Tikopia in the new colonies had even eaten eels, putting them in soup, in a new food style and in breach of custom. This was strongly disapproved by many Tikopia, who were still afraid of eels. I have now learned from Judith Macdonald, recently returned (1980) from a very fruitful research expedition to Tikopia, that she found in the island community the same expressions of disgust and fear about eels, and saw the same behaviour, as I recorded” (Firth, 1967: 219, footnote).

Trobriand Islands: Malinowski describes the legend of Inuvayla’u thus: “In the village of Kwabulo there lived Inuvayla’u the head of his

clan, the Lukuba clan; the head of his village. He copulated with the wives of his younger brothers, of his maternal nephews.

When the men went out fishing, he would stand outside a house, and make a hole in the thatch; he then thrust his penis through the thatch and fornicated. His penis was very long; his penis was like a long snake. He would go into the garden when the women made kouwala (clearing the ground from debris preparatory to planting); or when they pwa-kova (weeded the ground). He would stand right away behind the fence, he stood in the uncut bush and his penis wriggled on the ground like a snake. The penis crept along all the way. The penis would approach a woman from behind as she was bending down to her task. It would strike her hard till she fell, and on all fours she would be fornicated with as the penis entered the vulva.

Or when women went to bathe in the lagoon, the penis would go under the water like an eel and enter the vulva. Or when they went to collect shells, as women do on the western shore (pl. 80), wading and feeling for them with the toes in the mud of the lagoon, Inuvayla'u would fornicate with them. When the women went to the water-hole, he would smash their coco-nut shell bottles and fornicate with them. The men were then very angry for they had no water to drink. They would abuse the women. The women would be too ashamed to speak, for their bottles had been broken. One day the men ordered, telling their wives: 'Cook fish, cook *taytu*, make pudding of taro, so that our revered old man eats his fill.' 'No', answered the women, 'we shall not do it; this man does wrong by us; when you go to fish, and we remain in the village, when we work in the garden, by the water-hole, in the lagoon, he does violence to us'.

Then the men watched him. They said they were going to fish. They hid in the *weyka* (the thick scrub surrounding the village), they saw: Inuvayla'u stood outside a hut, he made a hole in the thatch; his penis sneaked on the ground, it crept through the hole, it came in: he wronged the wife of his younger brother. The men went to the garden... (here the various conditions under which the hero plays his foul pranks on the women are again enumerated, in almost exactly the same words as before).

When his younger brothers, his maternal nephews, saw this, they grew very angry. Next morning they ducked him; they ducked him in the head pool of the tidal creek, which comes up to the village of Kwabulo (pl. 81).

He came out of the water. He returned to his house, his mind was full of shame and of sorrow. He spoke to his mother Lidoya: 'Bake some *taytu* and fish. Bake it in the ground. Pack all our belongings and the food in your big basket; lift it and put it on your head; we shall go, we shall leave this place'.

When all was ready, he came out of his house, which stood on the *baku* (central place of the village). He wailed aloud, facing the *baku*. He took his *kema* (axe), he cut at his penis. First he wailed and wailed over it, holding it in his hands. Then he cut off the point of his penis; it came off on the *baku* in front of his house; it was turned into stone. The stone is still there, on the *baku* of Kwabulo in front of the headman's house. He cried and wailed and went on. He stood outside the outer ring of houses, he looked back, he took his penis and wept over it. He struck again with his axe. The second bit fell off and was turned into stone. It can be seen still outside the village in Kwabulo. He cried and wailed and went on. Half-way between the village and the tidal pool of the creek he stopped. He looked back towards the houses. He took his penis into the palms of his hands, he wept over it and cut off another bit. It turned into stone, and can be seen there not far from Kwabulo. He came to the canoes; he looked back towards the village, he wept over his genitals. He took the axe and cut off the remaining stump of his penis. It was turned into stone, and it lies now near where the Kwabulo men moor their canoes. He entered his canoe and punted along. Half-way down the creek he wept once more. He gripped his axe and cut off his testicles. Large white coral boulders (*vatu*) lie in the creek. They are the token: they show where Inuvayla'u cut off his testicles" (Malinowski, 1932: 348-350).

Tubuai: "Eels (*puhi*) although abundant in fresh water, are not eaten, and the salt-water eel, which attains considerable size, is regarded as poisonous" (Aitken, 1971: 37).

Tuamotu Islands: "The moray eel harvest was quite important on 'Anaa because in addition to the food it supplied, congers' jaws (*nihokamia*) were used as the part of warriors' attire designed to shred the skin of their adversaries during combat... or as a kind of saw called *kamia* or *oreore*" (Torrente, 2015: 19). Emory provided illustrations of these unusual toothed knives (Emory, 1975: 133).

REFERENCES

- AITKEN, R.T. 1971: Ethnology of Tubuai. *Bernice P. Bishop Museum Bulletin* 70.
- ALLEN, M.S. 1992: Dynamic landscapes and human subsistence: Archaeological investigations on Aitutaki island, southern Cook Islands. Unpublished PhD thesis, Washington University.
- ANDERSON, A.J. 2012: Dwelling carelessly, quiet and secure: A brief ethnohistory of Rapa Island, French Polynesia, AD 1791-1840. In: Anderson, A.J. & Kennett, J. (eds.): *Taking the High Ground: The archaeology of Rapa, a fortified island in remote East Polynesia*: 25-45. *Terra Australis* 37.
- AOYAMA, J.; MOCHIOKA, N.; OTAKE, T.; ISHIKAWA, S.; KAWAKAMI, Y.; CASTLE, P.; NISHIDA, M. & TSUKAMOTO, K. 1999: Distribution and dispersal of anguillid leptocephali in the western Pacific ocean revealed by molecular analysis. *Marine Ecology Progress Series* 188: 193-200.
- AYRES, W.S. 1985: Easter Island subsistence. *Journal de la Société des Océanistes* 80: 103-124.
- BARRETT, J.H.; NICHOLSON, R.A. & CERÓN-CARRASCO, R. 1999: Archaeo-ichthyological evidence for long-term socioeconomic trends in Northern Scotland: 3500 BC to AD 1500. *Journal of Archaeological Science* 26: 353-388.
- BENDER, B.W.; GOODENOUGH, W.H.; JACKSON, F.H.; MARCK, J.C.; REHG, K.L.; SOHN, H.; TRUSSEL, S. & WANG, J.W. 2003: Proto-Micronesian Reconstructions 1. *Oceanic Linguistics* 42(1): 1-110. Proto-Micronesian Reconstructions 2. *Oceanic Linguistics* 42(2): 271-358.
- BENECKE, N. 1983: Die Terreste aus einer frühmittelalterlichen Siedlung in Ralswiek/Kreis Rügen - ein Beitrag zur Frühgeschichte der Haustierfauna im Südlichen Ostseegebiet 1/1-3 and 2/1-3. Thesis, Berlin.
- BEST, E. 1902: Food products of Tuhoeland. *Transactions and Proceedings of the Royal Society of New Zealand* 35: 45-111.
- 1922: An eel fiesta. *New Zealand Journal of Science and Technology* 5: 108-109.
- 1923: Maori personifications. Anthropogeny, solar myths and phallic symbolism: as exemplified in the demiurgic concepts of Tane and Tiki. *Journal of the Polynesian Society* 32(126): 53-69.
- 1929: Fishing methods and devices of the Maori. *Dominion Museum Bulletin* 12. Government Printer, Wellington.
- 1952: *The Maori as he was*. Government Printer, Wellington.
- 1977: *Fishing Methods and Devices of the Maori*. *Dominion Museum Bulletin* 12. Government Printer, Wellington. Repaginated reprint of 1929 edition.
- BIGGS, B. 1993: Lecture 3 Māori Studies class, University of Auckland, February 25, 1993, 8:18 am.
- BIGGS, B. & CLARK, R. 1996: The comparative Polynesian Lexicon Project (POLLEX). Version: December 14 1996. University of Auckland.
- BOULENGER, G.A. 1904: Fishes (systematic account of Teleostei). In: Harmer, S.F. & Shipley, A.E. (eds.): *The Cambridge Natural History*. 597 pp. ff. MacMillan and Co, New York.
- BROWN, C.H. 1981: Growth and development of folk zoological life-forms in Polynesian languages. *Journal of the Polynesian Society* 90(1): 83-110.
- BUILTH, H. 2014: Ancient Aboriginal aquaculture rediscovered: The archaeology of an Australian cultural landscape. Lambert Academic Publishing.
- BUTLER, V.L. 2017: Fish remains from Tangatatau rockshelter. In: Kirch, P.V. (ed.): *Tangatatau rockshelter: The evolution of an Eastern Polynesian Socio-Ecosystem*: 103-137. UCLA Cotsen Institute of Archaeology Press. *Monumenta Archaeologica* 40.
- Carroll, V. 1965: An outline of the structure of the language of Nukuoro. *Journal of the Polynesian Society* 74(4): 451 – 472.
- CASSELS, R.J.S.; JONES, K.L.; WALTON, A. & WORTHY, T.H. 1988: Late prehistoric subsistence practices at Parewanui, Lower Rangitikei River, New Zealand. *New Zealand Journal of Archaeology* 10: 109-128.
- CHAN, T.Y.K. 2016: Characteristic features and contributory factors in fatal ciguatera fish poisoning – Implications for prevention and public education. *The American Society of Tropical Medicine and Hygiene* 94(4): 704-709.
- 2017: Regional variations in the risk and severity of ciguatera caused by eating moray eels. *Toxins* 9(201): 1-11.
- CLARK, R. 1994: The Polynesian Outliers as a locus of language contact. In: Dutton, T. & Tryon, D.T. (eds.): *Language Contact and Change in the Austronesian World*: 109-139. Mouton de Gruyter, Berlin.
- COOK, J. 1967: *The Journals of Captain James Cook on his Voyages of Discovery. The Voyage of the Resolution and Discovery, 1776–1780*. In: Beaglehole, J.C. (ed.). Cambridge University Press for the Hakluyt Society. 2 vols.
- CORDAIN, L.; MILLER, J.B.; EATON, S.B.; MANN, N.; HOLT, S.H.A. & SPETH, J.D. 2000: Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets. *American Journal of Clinical Nutrition* 71: 682-692.
- Archaeofauna 31 (2022): 11-56

- CURTIS, C.S. 1964: Notes on eel weirs and Maori fishing methods. *Journal of the Polynesian Society* 73(2): 167-170.
- DANIELSSON, B. 1967: Kia ora Keneti. In: Highland, G.A.; Force, W.W.; Howard, A.; Kelly, M. & Sinoto, Y.H.: *Polynesian Culture History Essays in Honor of Kenneth P. Emory*: 1-41. Bernice P. Bishop Special Publication 56.
- DAVIDSON, J.M. 1984: *The Prehistory of New Zealand*. Longman Paul, Auckland.
- DAVIDSON, J.M.; LEACH, B.F.; GREIG, K. & LEACH, P.C. 2000: Pre-European Maori fishing at Foxton, Manawatu, New Zealand. *New Zealand Journal of Archaeology* 22: 75-90.
- DAVIDSON, S. Sr; PASSMORE, R. & Brock, S. 1972: *Human Nutrition and Dietetics*. Churchill Livingstone, Edinburgh.
- DOWNES, T.W. 1918: Notes on Eels and Eel-weirs (Tuna and Pa-tuna). *Transactions and Proceedings of the Royal Society of New Zealand* 50: 296-316.
- DRAPER, H.H. 1977: The aboriginal eskimo diet in modern perspective. *American Anthropologist* 79: 309-316.
- ELBERT, S.H. 1949: Uta-Matua and Other Tales of Kapingamarangi. *The Journal of American Folklore* 62(245): 240-246.
- EALLES, J.G. 1968: The eel fisheries of eastern Canada. *Bulletin of the fisheries research board of Canada* 166. 79 pp.
- ENGHOFF, I.B. 1986: Freshwater fishing from a sea-coast settlement – the Ertebølle locus classicus revisited. *Journal of Danish Archaeology* 5: 62-76.
- EMORY, K.P. 1975: Material culture of the Tuamotu Archipelago. *Pacific Anthropological Records* 22: 1-253.
- FANKHAUSER, B. 2002: Fatty Acid Analysis of Eel from New Zealand and Total Lipids Analysis of Archaeological Sediments from Western Victoria, Australia. Unpublished report to Foss Leach, June 2002.
- FIRTH, R. 1967: Sea creatures and spirits in Tikopia belief. In: Highland, G.A.; Force, W.W.; Howard, A.; Kelly, M. & Sinoto, Y.H. (eds.): *Polynesian Culture History Essays in Honor of Kenneth P. Emory*: 539-546. Bernice P. Bishop Special Publication 56.
- 1981: Figuration and symbolism in Tikopia fishing and fish use. *Journal de la Société des Océanistes* 37: 219-226.
- FISCHER, J.L. 1958: Folktales, social structure, and environment in two Polynesian outliers. *Journal of the Polynesian Society* 67(1): 11-36.
- FORD, E. 1937: Vertebral variation in teleostean fishes. *Journal of the Marine Biological Association* 22: 1-60, 16 plates.
- FOX, A. & CASSELS, R. 1983: Excavations at Aotea, Waikato, 1972-75. *Records of the Auckland Institute and Museum* 20: 65-106.
- GILL, W.W. 1876: *Life in the Southern Isles; or, Scenes and Incidents in the South Pacific and New Guinea*. The Religious Tract Society, London.
- GOODMAN-LOWE, G.D.; CARPENTER, S.; ATKINSON, S. & AKO, H. 1999: Nutrient, fatty acid, amino acid and mineral analysis of natural prey of the Hawaiian monk seal, *Monachus schauinslandi*. *Comparative Biochemistry and Physiology Part A*, 123: 137-146.
- GREGORY, W.K. 1959: *Fish Skulls: A Study of the Evolution of Natural Mechanisms*. Eric Lundberg, Laurel, Florida.
- HAMILTON, A. 1908: Fishing and sea food of the ancient Maori. *Dominion Museum Bulletin* 2. Government Printer, Wellington.
- HIGHAM, T.F.G. & HOGG, A.G. 1997: Evidence for late Polynesian colonisation of New Zealand: University of Waikato radiocarbon measurements. *Radiocarbon* 39(2): 149-192.
- HILL, G.B. (ed.) 1773: *Boswell's Life of Johnson, including Boswell's journal of a tour to the Hebrides and Johnson's diary of a journal into North Wales*. Pembroke College, Oxford. Volume 5: *The life of Johnson*.
- HIROA, TE RANGI. (P.H. Buck) 1934: *Mangaian Society*. Bernice P. Bishop Museum Bulletin 122.
- 1938: *Ethnology of Mangareva*. Bernice P. Bishop Museum Bulletin 157.
- 1944: *Arts and Crafts of the Cook Islands*. Bernice P. Bishop Museum Bulletin 179.
- 1950: *Material Culture of Kapingamarangi*. Bernice P. Bishop Museum Bulletin 200.
- HOGG, A.G.; HIGHAM, T.F.G.; LOWE, D.J.; PALMER, J.G.; REIMER, P.J. & NEWNHAM, R.M. 2002: A wiggle-match date for Polynesian settlement of New Zealand. *Antiquity* 77: 116-125.
- HOLMES, M. 2017: *Southern England: A Review of Animal Remains from Saxon, Medieval and Post-Medieval Archaeological Sites*. Research Report Series No. 08/2017.
- IRWIN, G.J. (ed.) 2004: *Kohika: The Archaeology of a Late Maori Lake Village in the Ngati Awa Rohe, Bay of Plenty, New Zealand*. Auckland University Press, Auckland.
- IRWIN, G.J. & JONES, M.D. 2004: Site Chronology. In: Irwin, G.J. (ed.): *Kohika: The Archaeology of a Late Maori Lake Village in the Ngati Awa Rohe, Bay of Plenty, New Zealand*: 76-82. Auckland University Press, Auckland.

- JACOBY, L. 1867: Ueber den knochenbau der oberkinnlade bei den allen (Muraenoidei Mull.) Mit 8 Tefeln. *Zeitschrift für die gesammten Naturwissenschaft*. 30(9): 267-274.
- JAMES, S.A. & SUZUMOTO, A.Y. 2006: Non native occurrence of *Anguilla marmorata* in Hawai'i: Identification Using Morphological and Molecular Characters. Records of the Hawaii Biological Survey for 2004-2005. In: Evenhuis, N.L. & Eldredge, L.G. (eds.). *Bishop Museum Occasional Papers* 87: 55-61.
- JELLYMAN, D.J. 1991: Biology of the Shortfinned Eel *Anguilla obscura* in Lake Te Rotonui, Mitiaro, Cook Islands. *Pacific Science* 45(4): 362-373.
- 2014: Freshwater eels and people in New Zealand: a love/hate relationship. In: Tsukamoto, K. & Kuroki, M. (eds.): *Eels and humans*: 143-153. Springer, Japan.
- JELLYMAN, P.G.; BOOKER, D.J.; CROW, S.K.; BONNETT, M.L. & JELLYMAN, D.J. 2013: Does one size fit all? An evaluation of length-weight relationships for New Zealand's freshwater fish species. *New Zealand Journal of Marine and Freshwater Research* 47(4): 450-468.
- JOHNSTONE, CAPTAIN J.C. 1874: *Maoria: A Sketch of the Manners and Customs of the Aboriginal Inhabitants of New Zealand*. Chapman & Hall Limited, London.
- KETTLE, A.J.; HEINRICH, D.; BARRETT, J.H.; BENECKE, N. & LOCKER, A. 2008: Past distributions of the European freshwater eel from archaeological and palaeontological evidence. *Quaternary Science Reviews* 27: 1309-1334.
- KIRCH, P.V. & YEN, D.E. 1982: *Tikopia: The Prehistory and Ecology of a Polynesian Outlier*. Bernice P. Bishop Museum Bulletin 238. Bishop Museum Press, Honolulu.
- KIRCH, P.V.; STEADMAN, D.W.; BUTLER, V.L.; HATHER, J. & WEISLER, M.I. 1995: Prehistory and human ecology in Eastern Polynesia: Excavations at Tangatatau rockshelter, Mangaia, Cook Islands. *Archaeology in Oceania* 30: 47-65.
- KRUPNIK, I. & MÜLLER-WILLE, L. 2010: Franz Boas and Inuktitut terminology for ice and snow: from the emergence of the field to the "Great Eskimo Vocabulary Hoax". In: Krupnik, I.; Aporta, C.; Gearheard, S.; Laidler, G.J.; Kielsen Holm, L. (eds.): *SIKU: Knowing Our Ice. Documenting Inuit Sea Ice Knowledge and Use*: 385-410. Springer, New York.
- LANE, J.P. 1978: Eels and their distribution. *Marine fisheries review*. MFR Paper 1303: 1-20.
- LEACH, B.F. 1986: A method for analysis of Pacific island fishbone assemblages and an associated data base management system. *Journal of Archaeological Science* 13(2): 147-159.
- 1997: A Guide to the Identification of Fish Remains from New Zealand Archaeological Sites. *New Zealand Journal of Archaeology Special Publication*. 129 pp.
- 2006: *Fishing in Pre-European New Zealand*. *New Zealand Journal of Archaeology Special Publication*. 359 pp.
- LEACH, B.F. & BOOCOOCK, A. 1995: The estimation of live fish catches from archaeological bone fragments of the New Zealand snapper *Pagrus auratus*. *Tuhinga: Records of the Museum of New Zealand Te Papa Tongarewa* 3: 1-28.
- LEACH, B.F. & DAVIDSON, J.M. 1978: *Taumako: A Polynesian outlier in the outer eastern Solomon Islands*. Unpublished Archaeological fieldwork diary. 143 pp.
- 2001: Estimating fish size from archaeological bones within one family: a detailed look at three species of Labridae. *Archaeofauna* 10: 137-147.
- LEACH, B.F.; DAVIDSON, J.M.; HORWOOD, L.M. & MALLON, S. 1996: The estimation of live fish size from archaeological cranial bones of the New Zealand kahawai *Arripis trutta*. *Tuhinga: Records of the Museum of New Zealand Te Papa Tongarewa* 7: 1-20.
- LEACH, B.F.; DAVIDSON, J.M.; FRASER, K. & ANDERSON, A.J. 1999: Pre-European catches of barracouta, *Thyrsites atun*, at Long Beach and Shag River, Otago, New Zealand. *Archaeofauna* 8: 11-30.
- LEACH, B.F.; DAVIDSON, J.M. & FRASER, K. 2000: Pre-European Catches of Blue Cod (*Parapercis colias*) in the Chatham Islands and Cook Strait, New Zealand. *New Zealand Journal of Archaeology* 21(1999): 119-138.
- LEACH, B.F.; DAVIDSON, J.M.; ROBERTSHAW, M. & LEACH, P.C. 2001: The estimation of live fish size from archaeological cranial bones of New Zealand red cod *Pseudophycis bachus*. *Tuhinga: Records of the Museum of New Zealand Te Papa Tongarewa* 12: 17-38.
- LEACH, B.F. & WARD, G.K. 1981: *Archaeology on Kapingamarangi Atoll: a Polynesian outlier in the Eastern Caroline Islands*. *Studies in Prehistoric Anthropology* 16. 150 pp.
- LEACH, B.F. & DE SOUZA, P. 1979: The changing proportions of Mayor Island obsidian in New Zealand prehistory. *New Zealand Journal of Archaeology* 1: 29-51.
- LEPIKSAAR, J. & HEINRICH, D. 1977: Untersuchungen an Fischresten aus der frühmittelalterlichen Siedlung Haithabu. *Berichte Über die Ausgrabungen in Haithabu* 10S: 9-122.
- LOVERN, J.A. 1938: Fat metabolism in fishes. XIII Factors influencing the composition of the depot fat of fishes. *Biochemical Journal* 32: 1214-1224.

- LUOMALA, K. 1949: Maui-of-a-thousand-tricks: his oceanic and European biographers. *Bernice P. Bishop Museum bulletin* 198.
- LYMAN, R.L. 1995: Determining when rare (zoo-) archaeological phenomena are truly absent. *Journal of Archaeological Method and Theory* 2(4): 369–424.
- MACKAY, A. 1891: Claims of natives to Wairarapa lakes and adjacent lands. Appendix to the Journals of the House of Representatives, 1891 Session II, G-04.
- MCILWRAITH, M.A. 1976: Archaeology, Middens and People. Unpublished MA Thesis, Anthropology, University of Otago.
- MAGGA, O.H. 2006: Diversity in Saami terminology for reindeer, snow, and ice. *International Social Science Journal* 58(187): 25–34.
- MALINOWSKI, B. 1932: *The sexual life of savages in North-West Melanesia*. Routledge and Sons, London.
- MARSHALL, Y. 1987: Maori mass capture of freshwater eels: An ethnoarchaeological reconstruction of prehistoric subsistence and social behaviour. *New Zealand Journal of Archaeology* 9: 55–79.
- MÉTRAUX, A. 1940: *Ethnology of Easter Island*. Bernice P. Bishop Museum Bulletin 160.
- NANDLAL, S. 2005: Catching eels in Pacific Island countries and territories. *South Pacific Commission Fisheries Newsletter* 115: 44–48.
- NELSON, J.S. 1994: *Fishes of the world*. John Wiley and Sons, New York.
- NICHOLSON, R.A. 1996: Bone Degradation, Burial Medium and Species Representation: Debunking the Myths, an Experiment-based Approach. *Journal of Archaeological Science* 23: 513–533.
- NICHOLSON, R. 2011: Southampton French Quarter 1382 Specialist Report Download E2: Fish Bone. Unpublished manuscript, Southampton University.
- NIMS, R. & BUTLER, V.L. 2019: Increasing the robustness of meta-analysis through life history and middle-range models: an example from the Northeast Pacific. *Journal of Archaeological Method and Theory* 26(2): 581–618.
- NOLI, D. & AVERY, G. 1988: Protein poisoning and coastal subsistence. *Journal of Archaeological Science* 15: 395–401.
- NORMAN, J.R. 1926: The development of the chondrocranium of the eel (*Anguilla vulgaris*), with observations on the comparative morphology and development of the chondrocranium in bony fishes. *Journal of the Royal Society B, Biological Sciences* 214: 369–464.
- O'CONNELL, J.F. 1972: *A Residence of Eleven Years in New Holland and the Caroline Islands*. Riesenberg, S.H. (ed.). Australian National University Press.
- PARK, J. 1973: A consideration of the Tikopia 'sacred tale'. *Journal of the Polynesian Society* 82(2): 154–175.
- PAUL, L. 2000: *New Zealand Fishes*. Reed Books, Auckland.
- PRICKETT, N. 1990: Archaeological excavations at Raupa: The 1987 season. *Records of the Auckland Institute and Museum* 27: 73–154.
- PRUMMEL, W. 1986: The presence of bones of eel, *Anguilla*, in relation to taphonomic processes, cultural factors and the abundance of eels. In: Brinkhuizen, D.C. & Clason, A.T. (eds.): *Fish and Archaeology: Studies in Osteometry, Taphonomy, Seasonality, and Fishing Methods*: 114–122. B.A.R. (International Series) 294. Oxford.
- 1994: Birds and mammals as indicators for fishing methods. *Offa* 51: 316–318.
- REGAN, C.T. 1912: The osteology and classification of the teleostean fishes of the Order Apodes. *Annals and Magazine of Natural History, Series 8*, 10(58): 377–387.
- RIGHTON, D. & ROBERTS, M. 2014: Eels and people in the United Kingdom. In: Tsukamoto, K. & Kuroki, M. (eds.): *Eels and Humans*: 1–10. Springer, Japan.
- ROBINS, C.H. & ROBINS, C.R. 1971: Osteology and Relationships of the Eel Family Macrocephalichthyidae. *Proceedings of the Academy of Natural Sciences of Philadelphia* 123(6): 127–150.
- ROBSON, H.; ANDERSEN, S.H.; CRAIG, O. & RITCHIE, K. 2013: Eel fishing in the late Mesolithic and the early Neolithic: A preliminary report from the stratified kitchen midden at Havnø, Denmark. *Archaeofauna* 22: 167–178.
- ROCHERS, K. de 1992: Women's fishing on Kosrae: A description of past and present. *Micronesica* 25(1): 1–22.
- ROSS, M.; PAWLEY, A. & OSMOND, M. (eds.) 2011: *The Lexicon of Proto Oceanic: The culture and environment of ancestral Oceanic society*. Volume 4: Animals. Pacific Linguistics 621. Canberra.
- RUSSWURM, C.F.W. 1855: Eibofolke oder die Schweden an den Küsten Ehtlands und auf Runö: eine historisch-ethnographische von der Kaiserlichen Akademie der Wissenschaften zu St. Petersburg mit einem demidowschen Preise gekrönte Untersuchung, Reval, Leipzig, Fleischer.
- SARFERT, E.G. 1919: Kosrae. In: Thilenius, G. (ed.): *Results of the 1908-1910 South Seas expedition*. II: Ethnography. L. Friederichsen and Co., Hamburg.
- SAUNDERS, T.V. 1965: The eels of Lake Wairarapa. *Te Ao Hou* 51: 36–38.
- SEERSHOLM, F.V.; COLE, T.L.; GREALY, A.; RAWLENCEC, N.J.; GREIG, K.; KNAPP, M.; STATF, M.; HANSENG,

- A.J.; LUKE, J.; EASTON, L.J.; SHEPHERD, L.; TENNYSON, A.J.D.; SCOFIELD, R.P.; WALTER, R. & BUNCE, M. 2018: Subsistence practices, past biodiversity, and anthropogenic impacts revealed by New Zealand-wide ancient DNA survey. *Proceedings of the National Academy of Sciences* 115(30): 1-6.
- SHORTLAND, F.B. & RUSSELL, J. 1948: Observations on the oil content of New Zealand freshwater eels. *New Zealand Journal of Science and Technology* 29B(4): 164-200.
- SMITH, I.W.G. 1985: *Sea Mammal Hunting and Prehistoric Subsistence in New Zealand*. Unpublished PhD Thesis, Anthropology, University of Otago.
- 1989: Maori impact on the marine megafauna: pre-European distribution of New Zealand sea mammals. In: Sutton, D.G. (ed.): *Saying So Doesn't Make it So: Papers in Honour of B. Foss Leach*: 76-108. *New Zealand Archaeological Association Monograph* 17.
- SNEDECOR, G.W. & COCHRAN, W.G. 1967: *Statistical Methods*. Iowa University Press, Iowa.
- SPEITH, J.D. 1983: *Bison Kills and Bone Counts. Decision Making by Ancient Hunters*. University of Chicago Press, Chicago.
- 1990: Seasonality, resource stress, and food sharing in so-called 'egalitarian' societies. *Journal of Anthropological Archaeology* 9: 148-188.
- 2020: Paleoindividual Bison Hunting on the North American Great Plains –Two Critical Nutritional Constraints. *Paleo Anthropology* 2020: 74-97.
- SPEITH, J.D. & SPIELMANN, K.A. 1983: Energy source, protein metabolism, and hunter-gatherer subsistence strategies. *Journal of Anthropological Archaeology* 2: 1-31.
- STEFANSSON, V. 1957: *Arctic Manual*. Macmillan, New York.
- STOKES, J. F.G. n.d: *Ethnology of Rapa Island*. Unpublished draft of B.P. Bishop Museum Bulletin of the Bayard Dominick Expedition. Honolulu: Bishop Museum Press.
- STRICKLAND, R.R. 1990: *Nga tini a Tangaroa: A Maori-English, English-Maori Dictionary of Fish Names*. *New Zealand Fisheries Occasional Publication* 5.
- SUMNER, J.L. & HOPKIRK, G. 1976: Lipid composition of New Zealand eels. *Journal of the Science of Food and Agriculture* 27: 933-938.
- SUTTON, D.G. 1979: The prehistoric people of eastern Palliser Bay. In: Leach, B.F. & Leach, H.M. (eds.): *Prehistoric Man in Palliser Bay*: 185-203. *National Museum of New Zealand, Bulletin* 21.
- 1986: Maori demographic change, 1769-1840. *Journal of the Polynesian Society* 95: 291-339.
- 1989: Mori fishing: intensive exploitation of the in-shore zone. In: Sutton, D.G. (ed.): *Saying So Doesn't Make it So: Papers in Honour of B. Foss Leach*: 116-131. *New Zealand Archaeological Association Monograph* 17.
- SVANBERG, I. 1999: The brother of the snake and fish as kings. *Fröðskaparit* 47: 129-138.
- SVANBERG, I. & LOCKER, A. 2020: Ethnoichthyology of freshwater fish in Europe: a review of vanishing traditional fisheries and their cultural significance in changing landscapes from the later medieval period with a focus on northern Europe. *Journal of Ethnobiology and Ethnomedicine* 1668: 1-29.
- SZABO, K.; VOGEL, Y. & ANDERSON, A.J. 2012: Marine resource exploitation on Rapa Island: Archaeology, material culture and ethnography. In: Anderson, A.J. & Kennett, J. (eds.): *Taking the High Ground: The archaeology of Rapa, a fortified island in remote East Polynesia*: 145-166. *Terra Australis* 37, Canberra.
- Taylor, N.M. (ed.) 1959: *Early Travellers in New Zealand*. Clarendon Press, Oxford.
- TEAL, F. J. 1974: Once upon a tail. A consideration of the significance of the freshwater eels (*Anguilla dieffenbachii* Gray and *Anguilla australis schmidtii* Phillips) as a food resource in the proto- and prehistoric New Zealand economy. Unpublished Anthropology Stage 3 assignment, University of Otago.
- TITCOMB, M. 1951, 1953: Native use of fish in Hawaii. *Journal of the Polynesian Society* 60: 1-146; 62: 147-162. (Memoir 29).
- 1982: *Native use of fish in Hawaii*. University of Hawaii Press.
- TORRENTE, F. 2015: *Ancestral fishing techniques and rites on 'Anaa Atoll, Tuamotu Islands, French Polynesia*. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* 35: 18-15.
- VOGEL, Y. 2005: *Ika*. Unpublished MA thesis, Department of Anthropology, University of Otago.
- VOGEL, Y. & ANDERSON, A.J. 2012: Prehistoric Fishing on Rapa Island. In: Anderson, J. & Kennett, D.J. (eds.): *Taking the High Ground: the Archaeology of Rapa, a Fortified Island in Remote Polynesia*: 115-133. *Australian National University Press, Canberra*.
- WAKE, T. 2021: *Vertebrate Remains from EISP Rano Raraku Excavations, with an emphasis on fish*. In: Van Tilburg, J. (ed.): *Easter Island An Illustrated Encyclopedia and Archaeological Compendium*. *Cotsen Institute of Archaeology Press, University of California, Los Angeles*. In press.
- WALSH, D.S. & BIGGS, B. 1966: *Proto-Polynesian Word List I. Te Reo monographs*. *Linguistic Society of New Zealand*.
- Archaeofauna 31 (2022): 11-56

- WEISLER, M.I.; BOLHAR, R.; MA, J.; ST PIERRE, E.; SHEPARD, P.; WALTER, R.K.; FENG, Y.; ZHAO, J-X. & KIRCH, P.V. 2016: Cook Island artifact geochemistry demonstrates spatial and temporal extent of pre-European interarchipelago voyaging in East Polynesia. *Proceedings of the National Academy of Sciences* 113(29): 8150-8155.
- WHITE, J. 1887: *The Ancient History of the Maori. Volume 2.* New Zealand Government Printer, Wellington.
- WILLIAMS, H.W. 1971: *A Dictionary of the Maori Language.* Government Printer, Wellington.
- WILLIAMSON, R.W. 1924: *The Social and Political Systems of Central Polynesia.* Cambridge University Press. 3 vols.
- WILMSHURST, J.M.; ANDERSON, A.J.; HIGHAM, T.F.G. & WORTHY, T.H. 2008: Dating the late prehistoric dispersal of Polynesians to New Zealand using the commensal Pacific rat. *Proceedings of the National Academy of Sciences* 105(22): 7676-7680.
- YONEKURA, N.; ISHII, T.; SAITO, Y.; MAEDA, Y.; MATSUSHIMA, Y.; MATSUMOTO, E. & KAYANNE, H. 1988: Holocene fringing reefs and sea-level change in Mangaia Island, Southern Cook Islands. *Palaeogeography, Palaeoclimatology, Palaeoecology* Volume 68 (2-4): 177-188.

INFORMACIÓN A LOS AUTORES

a) Los originales pueden redactarse en español, inglés, alemán o francés. Los editores pueden considerar, en determinadas circunstancias, la publicación de originales en otros idiomas. En cualquier caso se proporcionará un resumen y palabras clave en español y en inglés.

b) Los originales no deberían sobrepasar 20 páginas A4 (29,5 x 21 cm) incluyendo tablas y figuras. En caso de trabajos más extensos contáctese con el editor. Los manuscritos deberán remitirse a arturo.morales@uam.es.

c) Las figuras y tablas deberán ser originales y de gran calidad. Las leyendas de figuras y de tablas deberán remitirse, numeradas, en ficheros independientes y serán concisas e informativas.

d) Estructuración del manuscrito. El orden requerido en los manuscritos de carácter experimental es el siguiente: Título del trabajo; Autor(es) y Centro(s) de trabajo; Resumen y Palabras Clave; Abstract y keywords; Introducción; Discusión; Conclusiones; Agradecimientos (optativo); Referencias. Si el trabajo así lo requiere, resultados y discusión pueden agruparse en el mismo epígrafe. En manuscritos no experimentales, la estructuración del trabajo se deja a la libre decisión del(de los) autor(es).

e) las citas bibliográficas en el texto incluirán autor y año de publicación, por ejemplo (Smith 1992) o (Smith & Jones, 1992). En trabajos con tres o más autores usar (Martín *et al.*, 1993). En trabajos del(de los) mismo(s) autor(es) y año, se procederá a identificar cada trabajo con letras (a, b, c, etc...) tras la fecha.

f) Referencias. Sólo se incluirán aquellas citadas en el texto y se hará del siguiente modo:

PÉREZ, C.; RODRÍGUEZ, P. & DÍAZ, J. 1960: Ecological factors and family size. *Journal of Bioethics* 21: 13-24.

RUIZ, L. 1980: *The ecology of infectious diseases*. Siglo XXI, Madrid.

g) Los autores son los únicos responsables de los contenidos de sus artículos.

INFORMATION FOR AUTHORS

a) Manuscripts can be submitted in Spanish, English, German and French. Under certain circumstances papers may also be published in other European Community languages. All papers will include an abstract and keywords in English and Spanish.

b) Manuscripts should usually not exceed 20 A4 printed pages (29,5 x 21 cm), including figures and tables. For longer manuscripts, contact the editor. Manuscripts should be submitted to arturo.morales@uam.es.

c) Figures and tables must be original and high quality. Figure legends should be numbered with arabic numerals and given on a separate file. Figure and table legends should be concise and informative.

d) Papers should be organized as follows: Title, name and mailing address(es) of author(s). Abstract, Keywords, Introduction, Materials and Methods, Results, Discussion, Conclusions, Acknowledgements, References. Results and Discussion may be treated together if this is appropriate. Non-experimental works can be organized in the way which the author(s) think(s) is the most appropriate one.

e) Citations in the text should be with author and date of publication, e. g., (Smith, 1992) or (Smith & Jones, 1992) with comma between author and date; for two-author papers, cite both authors; for papers by three or more authors, use Martín *et al.*, 1993. For two or more papers with the same author(s) and date, use, a, b, c, etc., after the date.

f) References: only papers cited in the text should be included; they should be arranged as indicated in point «f» of the other column.

g) Authors are responsible for the contents of their manuscripts.

ÍNDICE / CONTENTS

N MEMORIAM: ANA FABIOLA GUZMÁN CAMACHO.....	7-9
Freshwater and Marine eels in the Pacific and New Zealand: Food Avoidance Behaviour and Prohibitions. <i>B.F. Leach, J.M. Davidson & F.J. Teal</i>	11-56
https://doi.org/ 10.15366/archaeofauna2021.31.001	
Subsistence strategies in the Inner Congo Basin since the 14 th century AD: the faunal remains from Nkile and Bolondo (DR Congo). <i>Laurent Nieblas Ramirez, Veerle Linseele, Wim Wouters, Hans-Peter Wotzka & Wim Van Neer</i>	57-75
https://doi.org/ 10.15366/archaeofauna2021.31.002	
Zooarqueología de todo un valle: cambios en el consumo de animales en los últimos 3.400 años en El Valle de Mauro, norte semiárido de Chile (31°s). All valley's zooarchaeology: changes in the consumption of animals in the last 3,400 years in El Mauro Valley, semiarid north of Chile (31°s). <i>Patricio López Mendoza, Daniela Villalón & Bárbara Rivera</i>	77-95
https://doi.org/10.15366/archaeofauna2021.30.003	
European Pond Turtle (<i>Emys orbicularis</i>) remains in Iron Age contexts of the Spanish Northern Iberian Peninsula. <i>Iratxe Boneta Jiménez, Corina Liesau Von Lettow-Vorbeck & Adán Pérez-García</i>	97-108
https://doi.org/ 10.15366/archaeofauna2021.31.004	
Gestión ganadera durante la Edad del Bronce Medio y Final en Mallorca (Islas Baleares). El caso del poblado de <i>Els Closos de Ca'n Gaià</i> . <i>Lua Valenzuela-Suau, Sílvia Valenzuela-Lamas, Bartomeu Salvà, Joan Fornés, David Javaloyas, Llorenç Oliver, Florent Rivals & Delphine Bosch</i>	109-132
https://doi.org/ 10.15366/archaeofauna2021.31.005	
Archaeozoological studies: new database and method based on alphanumeric codes. <i>Cristina Real, Juan Vicente Morales, Alfred Sanchis, Leopoldo Pérez, Manuel Pérez Ripoll†, Valentín Villaverde</i>	133-141
https://doi.org/ 10.15366/archaeofauna2021.31.006	
Mariscadores en las costas del Caribe colombiano en época prehispánica y moderna: una reflexión para evaluar el impacto humano en los ecosistemas marinos desde la arqueomacología y la etnoarqueología. <i>Diana Rocío Carvajal Contreras</i>	143-154
https://doi.org/ 10.15366/archaeofauna2021.31.007	
Étude ostéométrique des principaux os des membres et de la ceinture du membre thoracique chez le Faisan de Colchide (<i>Phasianus colchicus</i> L., 1758). Osteometric study of the main limb bones and of the thoracic limb girdle of the Common Pheasant (<i>Phasianus colchicus</i> L., 1758). <i>N. Mokrani, A. Borvon, A. Milla, C. Thorin & C. Guintard</i>	155-180
https://doi.org/ 10.15366/archaeofauna2021.31.008	
Announcements.....	181-185