Bennett's wallaby marrow quality vs quantity: Evaluating human decision-making and seasonal occupation in late Pleistocene Tasmania

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Keywords: late Pleistocene Tasmania; fatty acid composition; bone marrow; Bennett's wallaby; zooarchaeology

DISCUSSION

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This paper investigates possible mechanisms as to why the medium-sized macropod the Bennett's wallaby (*Macropus rufogriseus*) remained the favourable prey item in southwest Tasmania, Australia, between 35,000 and 10,000 years ago, despite climatic fluctuations during the Last Glacial Maximum (LGM). It aims to examine the fatty acid composition of the bone marrow, brain tissue and muscle (flesh) of the Bennett's wallaby and explore why humans frequently selected and transported the wallaby hindquarters, breaking open their longbones and metatarsals to expose the marrow cavity, when these animals could easily have been transported whole.

The photo in this slide is Pine Lake in the alpine Western Lakes region of the Tasmania, and illustrates what the southwest may possibly have looked like during the lake Pleistocene.

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The archaeology of southwest Tasmania was first recognised by the discovery and subsequent excavation in 1981 at Kutikina Cave. Kutikina was first identified during the late 1970s, when, partly motivated by plans by the Tasmanian Hydro-Electric Company's plans to dam the Gordon River below its junction with the Franklin River; several expeditions were made into Tasmania's south-west to record the caves and rock shelters that would be destroyed by the impending dam.

The initial observations by Jones and his colleagues at Kutikina were the catalyst for more than a decade of concentrated archaeological fieldwork by La Trobe University in south-west Tasmania under the umbrella of the Southern Forests Archaeological Project (SFAP), which has seen human habitation of this region extended back to approximately 35,000 years ago. The results from Kutikina and SFAP, indicate that many of the caves in the south-west were occupied between 35,000 and 13,000 years ago, being abandoned during the terminal Pleistocene when the rainforest returned, while during the LGM grass and heath taxa dominated the Tasmanian vegetation.

This study also takes into consideration the results from the recent Bennett's wallaby teeth annuli (ondtochronoloigcal) study by Pike-Tay et al. (2008) to see if the investigation of the nutritional quality of the Bennett's wallaby can better help explain the apparent seasonal occupation of caves.

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The eight main sites from late Pleistocene are outlined here with the uncalibrated radiocarbon dates. Kutikina is in yellow and indicates that the assemblage accumulated over a 5,000 year period that spanned the height of the Last Glacial Maximum.

All of these SW sites have several things in common, including: the presence of Darwin glass (natural glass from an impact crater occurring in SW Tasmania), similar stone tools; and similar animal skeletal remains. There are now more than 950,000 bones analysed from southwest Tasmania providing a substantial database to examine human hunting and subsistence practices in late Pleistocene SW Tasmania.

The late Pleistocene pollen record indicates alpine/sub-alpine herbfields, moorlands and conifer forests dominated the region, with the patches of grasslands and sedgeland concentrated along the fertile valley floors. It is thought that during this time the Bennett's wallabies were 'ecologically tethered' to these fertile patches, with human hunters moving between and targeting these refugees.

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The excavation at Kutikina Cave was very rich with approximately 40,000 stone tools and 250,000 bone fragments collected from less then a cubic metre (Jones, 1987). It was estimated that this might only represent 1% of the entire artefact bearing deposit making Kutikina one of Australia's prolific archaeological sites (Kiernan et al., 1983).

The fauna at Kutikina was dominated by Bennett's wallaby (*Macropus rufogriseus*), and to a minor degree the Common wombat (*Vombatus ursinus*). Radiocarbon dates indicated that the site was occupied between 14,840 $\pm$ 930 and 19,770 $\pm$ 850BP; the first indication that people were able to penetrate and survive in the mountainous south-west interior during the last ice age (Kiernan et al., 1983), when winter temperatures may have dropped to -15^{o}C, while summers were cool and short, and enormous ice sheets were approximately 1000 kilometres south (Garvey, 2007).

While preliminary statements concerning the Kutikina faunal collection were made, the only analysis was an unpublished small pilot study by Geering (1983). In 2005 the rest of the faunal assemblage from Kutikina was analysed at the Tasmanian Museum and Art Gallery, Hobart.

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During the Kutikina excavation Rhys Jones (Kiernan et al., 1983; Jones, 1987) saw immediate parallels between the most southerly population on earth during the Last Ice Age at Kutikina, and northern ice age communities. In particular, he argued that humans in south-west Tasmania employed a similar strategic and specific hunting strategy of a main prey item by focusing on the Bennett's wallaby, similar to the tight targeting strategy focusing on reindeer in the Northern Hemisphere during this period (Kiernan et al., 1983). While preliminary statements concerning the Kutikina faunal collection were made, the only analysis was an unpublished small pilot study by Geering (1983).

Despite subsequent archaeological investigation in this region following the discovery of Kutikina, this original collection has remained unanalysed, and therefore could not be compared to the zooarchaeological assemblage from other caves and rock shelters from south-west Tasmania, nor could Jones's initial observations be tested. Now some 25 years after Kutikina Cave was excavated the faunal material is being studied, providing a more detailed insight into lives of the ice age hunters in south-west Tasmania.

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The Bennett's wallaby or red-necked wallaby belongs to the Genus *Macropus*, which includes the kangaroo, wallaby and wallaroo. It is a common large wallaby of south-eastern Australia, extending from the mainland across the Bass Straight Islands to Tasmania. In Tasmania the Bennett's wallaby is smaller than on the mainland. It shows moderate sexual dimorphism with males averaging 15 kg and females weighting 11 kg. The Bennett's wallaby is widespread and abundant; occurring across Tasmania and many of the smaller offshore islands, with their range spanning from coastal plains to the highest alpine zones of >1200 m (Garvey 2010). It is a grazing animal subsisting on grasses and herbs preferring plants that are low in fibre and high in nitrogen, inhabiting areas with open understorey and is particularly abundant in natural vegetation close to pastoral land. They are essentially solitary animals, but groups of 30 or more individuals may congregate together at night to graze. During the day they prefer to rest within the protection of dense shrubs within the forest, emerging during the late afternoon to graze along the forest edge. The mainland and Tasmanian species' differ in that females on the mainland give birth throughout the year while in Tasmania birthing occurs between late January and July, usually peaking in February, with 80% of births occurring in February and March (late summer to early autumn (Garvey 2010).

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This is a typical bag of skeletal material from Kutikina Cave. Wallaby hindlimb longbones dominate, with numerous helical fractures to the diaphyses and percussion marks from stone tools recorded. There is very little evidence of burning, and no indication of boiling of the material. There are a few cranial, rib and girdle fragments, while the metatarsals and phalanges of the pes or foot were also occasionally cracked longitudinally to access the marrow cavity.

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Preliminary results from this project were recently published (Garvey, 2006, 2007) and indicate that there were approximately 256,200 bone fragments weighing 40.8 kg excavated. About 10% of the assemblage, or 25,821 fragments weighing 18.4 kg were identified to either species and/or skeletal element. The bulk of the material were unidentifiable fragments of <1 cm in size. Interestingly both grey or Forester kangaroo and emu, both rare taxa in the late Pleistocene SW Tasmanian assemblages were both identified in very small numbers at Kutikina.

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The detailed analysis of the Kutikina material meant that several different taphonomic pathways or vectors were identified. The complete bones of several taxa of small mammals (<500gm) were identified from Kutikina (Garvey 2006). The excellent preservation, completeness and species indicate that owls, probably the Barn Owl *Tyto alba*, was most likely responsible for the presence of these animals at Kutikina.

There were several medium mammals (501gm-10kg) identified from Kutikina. Unfortunately there was insufficient material to determine the agent responsible for their accumulation, although humans, non-human predators (i.e. Tasmanian devil or Thylacine), as well as natural death may have been a contributing factor.

As mentioned in the previous slide, Kutikina is unusual amongst the SW Tasmanian sites in the presence of both the large (>10.1kg) grey or Forester kangaroo and the emu. Given these species ecological niches and size, it is most likely that humans were responsible for their presence in Kutikina, although again, there was insufficient material to identify their taphonomic history.

Finally, given the systematic helical fractures, longitudinally split bones, percussion marks and known taphonomic patterns of Tasmania's non-human predators, the Bennett's wallaby and wombat were brought to Kutikina by humans. However, the distribution of body parts indicates that sometimes they were brought whole to the cave, whilst other times the larger hindlimbs and pes were selected.

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Body part analysis (Garvey, 2006) indicates that wallaby longbones were favoured, particularly the hindlimb (femora, tibiae, fibulae), while very few axial and cranial elements recorded. However, given the presence of cranial, axial and girdle material some complete wallabies would have been brought into the cave. The majority of the long bones, and many phalanges and metatarsals, were longitudinally split to extract the highly nutritious bone marrow. There were also numerous cut marks on many of the long bones, which are likely to have been made by stone tools when the bones were being processed. Future analysis of these cut marks should identify specific butchering techniques.

The graph in the bottom figure illustrated that distribution of the 10 major body parts across the three excavated units at Kutikina. If the wallabies were brought back to the cave whole then you would expect the distribution to concentrate along the '0' line. However, it can be seen that in all unis there is a large overrepresentation of hindlimbs, and underrepresentation of manus and axial elements.

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These are examples of the types of wallaby bones found in Kutikina. There are lots of bones with cut marks, with the position and number of cut marks specifically recorded. The majority occur on the hindlimbs. All of the hindlimbs and many of the pes elements were split open to extract the highly nutritious bone marrow. A variable size range of Bennett wallaby bones was also recorded indicating that the species may have been larger during the late Pleistocene than it is today.

Another characteristic of late Pleistocene SW Tasmania is the presence of bone points, commonly made on the proximal fibula, although there is also an example of a radius bone point also known from Kutikina. Kutikina has also produced the only possible chop marked bone.

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So why does split Bennett's wallaby hindlimbs dominate the Kutikina and other faunal assemblages from SW Tasmania? There are several possibilities:

1. Marrow/meat quality and/or;
2. Marrow/meat quantity and/or;
3. Processing time?

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The Bennett's wallaby meat and marrow quantity was recently tested by Garvey (2010). It was found the posterior parts of the animal, especially the femur, tibia/fibula, sacral vertebrate and pelvis were the highest ranked body parts, while the cranium, pectoral girdle, forelimbs and manus were of little economic value. However, when compared to the distribution of wallaby material at Kutikina it was found that humans ignored some of the larger 'meaty' elements such as the sacrum, preferring the hindlimbs which were found to not only carry large amounts of flesh but also the greatest volume of bone marrow.

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This figure illustrates the Meat Utility Index (MUI) following Lyman *et al.* (1992). It considers the weight of meat associated with the 18 specific wallaby anatomical units from four dissected wallabies and the mean. The MUI meat weights were then normed on a scale of 1-100 to calculate the %MUI (see Binford, 1978; Lyman *et al.*, 1992). The red stars indicate the body parts with the highest MUI ranking. For each wallaby this was found to be the: femur; sacral vertebrate; tibia and fibula; lumbar vertebrate; and the ribs.

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The Bennett's wallaby Meat Utility Index was then compared to the faunal assemblage from Kutikina Cave. The Minimum Number of Animals (MAU) was calculated for the Kutikina faunal assemblage following Binford (1978) and Lyman *et al.* (1992), by dividing the observed minimum number of skeletal parts by the frequency that it occurs in an individual Bennett's wallaby. The scatterplot of the Kutikina MAU verses the %MUI is shown.

Interestingly the femur and tibia (circled here in red) which ranked highly in the utility index and the MAU, also had the largest volume of bone marrow. This may be not be just a coincidence, as these elements were systematically broken with numerous percussion marks and helical fractures to the diaphyses in the zooarchaeological assemblages indicating the deliberate extraction of bone marrow. However, other relatively high ranking MUI body parts the sacrum, lumbar and ribs (circled here in blue), all ranked low in Kutikina. These three body parts also have low abundances of bone marrow.

The economic utility analysis of the wallaby and its comparison to the Kutikina MAU implies that humans were not under selective pressure concerning which parts of the animals they transported. Rather, it seems that humans ignored some of the large 'meaty' elements and selected the hindlimbs which were found to not only carry large amounts of flesh, but also the greatest volume of bone marrow. Hence, humans may not have been targeting elements with the largest quantity of meat, but rather the largest amount of marrow, with meat as a by-product (Garvey 2010).

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To test whether it was the quality of the wallaby bone marrow that humans were seeking it was decided to examine the fatty acid or nutritional value of the marrow throughout the animal.

Binford (1978) argued that oleic acid an omega-9 monounsaturated fatty acid was a good indicator of marrow quality. Moring (2007) further developed this idea introducing the Unsaturated Marrow Index (UMI) arguing that it was all of the unsaturated fatty acids that were important. In caribou, and ungulates in general, unsaturated fats increase as you move away from the body core temperature or the heart (Meng *et al.* 1969; West and Shaw 1975). Such a high percentage of unsaturated fatty acids in the extremities cause oiler marrow with a lower melting temperature, ensuring that the marrow remains fluid in climatic extremes.

However, while much is known about the fatty acid composition of ungulates and other placental mammals, very little is known concerning the physiology of the Bennett's wallaby or macropods in general. Therefore, the fatty acid composition of the wallaby needs to be tested and compared to what we know about placental mammals.

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A single Bennett's wallaby had several bone marrow, muscle and brain tissue samples extracted. These had their Total Fat (FOLCH) and Fatty Acid Profile (FAMES) determined, with 14 fatty acids measured per sample. It was found that similar to the placental ungulate the fatty acid concentration of the wallaby bone marrow decreased in saturated fats distally away from the body core temperature or the heart towards the hands and feet. Also similar to placental mammals it was found that the largest fatty acid changes occurred in the monounsaturated Oleic acid (C 18=1) and Palmitoleic (C16:1) both increasing distally, and saturated Palmitic acid (C16:0) and Stearic acid (C18:0) both decreasing accordingly.

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Overall it was found that the fatty acid concentration in the wallaby bone marrow decreased in saturation distally, with the greatest changes occurring between the humerus and the proximal ulna in the forelimb, and the between the proximal and medial regions of the tibia in the hindlimb (indicated by the blue arrow on the wallaby skeleton, and shown in the graph below it). This is similar to that identified in the caribou by Meng et al. (1969).

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These changes are associated with a dramatic change in the colour of the bone marrow. As can been seen in the photo the bone marrow undergoes an abrupt colour change from a dark red in the femur where it is more saturated (labelled A), to a lighter red in the proximal region of the tibia (labelled B), to a much paler red towards the medial region of the tibia where it is much higher in unsaturated fatty acids (labelled C), and then quickly turns white towards the distal end (labelled D). A similar colouration change was noted in the forelimb between the heavily saturated marrow in the humerus, and the unsaturated marrow in the ulna/radius. This sudden colour change is probably also associated with a shift in the palatability of the marrow. This colour change has also been associated with the hardness and texture of caribou marrow, which is directly linked to its melting point, palatability, and the rate at which is becomes rancid (Morin, 2007). Because distal marrow has a lower melting point it will be softer and oiler, and hence more palatable and will not remain fresh for very long. It appears that a similar pattern is occurring in the macropod marrow.

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Once it was found that the bone marrow distribution in the Bennett's wallaby had a similar pattern to that identified in ungulates the pilot study was extended to examine changes in the fatty acid composition of the bone marrow, flesh and brain tissue of the wallaby from different Tasmanian geographic, environmental and climate zones throughout the year. The regions of Maydena, Buckland and the Western Lakes were selected to investigate possible seasonal variation in the overall body and nutritional quality of the Bennett's wallaby that may help explain seasonal occupation and wallaby hunting discussed by Pike-Tay et al. (2008). It should also be noted that these are the same three regions from which the control sample of wallaby teeth used by Pike-Tay et al. (2008) were collected.

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Where possible marrow, muscle and brain tissue samples from fresh road-killed wallabies was collected. However, due to scavenging of the carcasses by Tasmanian devils, quolls or birds, it was not always possible to collect all the specimens required. In total 27 wallabies were collected: 8 from Buckland, 9 from Maydena and 10 from the Western Lakes. The red stars on the wallaby skeleton indicate where the three samples were extracted from; brain tissue, muscle from the femur region, and distal tibia marrow.

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These are the results from the year long trail. Bone marrow from the distal tibia of 27 wallabies; muscle from the hindquarter of 26 animals; and brain tissue from 20 individuals were collected. This is a relatively large sample size for seasonal, geographic, climate, rainfall, gender and age comparisons. The percentage of unsaturated fatty acids in the bone marrow (n=27), muscle (n=26) and brain tissue (n=20) for each wallaby are divided into the three collections zones (Buckland, Maydena and Western Lakes) per season (where S- summer, A- autumn, W- winter and Sp- spring). This is then compared to the average annual rainfall, and the maximum and minimum temperatures for each region. The results indicate that despite seasonal fluctuations in the maximum and minimum temperature, and the average rainfall for the three regions, the unsaturated fatty acids in the tissues tested did not alter greatly other than what may be expected from individual variation. Hence it appears that despite changes to their external environment, the fatty acid and hence body condition of the Tasmanian Bennett's wallaby, regardless of gender and/or age, remained stable. Whilst there are slight variations these are explained by individual variation, rather than a strong overall pattern of body condition or depletion of fats.

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This study on the bone marrow, muscle and brain tissue of the wallaby indicates that unlike the migratory caribou herds of the Northern Hemisphere, the dominate prey species in southwest Tasmania provided a stable and reliable protein and fat source throughout the seasonal fluctuations of the late Pleistocene. So what was motivating the seasonal exploitation and use of the landscape identified by Pike-Tay et al. (2008)? It does not seem as if the nutritional quality of the wallaby marrow, muscle or brain tissue was an influencing factor.

So what was motivating the seasonal exploitation and use of the landscape identified by Pike-Tay et al. (2008)? It does not seem as if the nutritional quality of the wallaby marrow, muscle or brain tissue was an influencing factor. Perhaps it was another resource that people were exploiting that was driving this seasonal habitation? To help better understand human habitation and use of the landscape in Tasmania during the late Pleistocene, future research needs to focus on what people were doing outside of the southwest zone during the last ice age.

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So then, how do we explain hunting, butchery and seasonal patterns observed in late Pleistocene SW Tasmania? Future work is required to:

1) Examine both experimental and ethnographic accounts of macropod hunting. Experimental work needs to focus on the time constraints and energy costs associated with hunting and butchery of the Bennett's wallaby and how these relate to the return.

2) Investigate the possibility that people may have been seeking other commodities besides bone marrow and/or meat such as bones for bone tools or fur.

3) Evaluate the bone density of the Bennett's wallaby to determine if the skeletal representation seen in the southwest caves is real and not just a reflection of the actual bone density. However, the presence of the complete small mammal bones indicates that the caves have excellent preservation.

4) Finally, need to explore the physiological benefits of the fatty acids in the marrow, meat and brain tissue as well as other organs in the wallaby. What are human requirements during periods of climatic and/or physiological stress and how would this effect the targeting of specific wallaby elements.

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Acknowledgements

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References