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Stable isotopic analysis of prehistoric human diet in the Mariana Islands, western Pacific

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Stable isotopic analyses of human and faunal bones provide a valuable means to differentiate marine and terrestrial food use in prehistoric tropical island environments (Keegan and DeNiro 1988; McGovern-Wilson and Quinn 1996; Ambrose et al. 1997). Because stable carbon (δ¹³C) and nitrogen (δ¹⁵N) isotope values in bone collagen are quantitatively related to the isotopic composition of ingested foods (Schoeninger and Moore 1992; Pate 1994), isotopic analyses of archaeological human bone may provide quantitative information about past diet that enhances qualitative data derived from artefacts and floral and faunal remains.

As the majority of terrestrial plants and animals that were consumed in prehistoric Micronesia have stable carbon and nitrogen isotope values that are significantly different from marine foods (Ambrose et al. 1997), bone collagen δ¹³C and δ¹⁵N analyses can be employed to address percentage of marine vs. terrestrial foods in the diets of these Pacific islanders.

Human bone samples from two prehistoric sites on the northern coast of Rota, Mariana Islands, the SNM Hotel site (Craib 1992) and Vista del Mar (Craib 1998) were analysed for stable carbon and nitrogen in order to address relative use of marine and terrestrial foods.

Archaeological research in the Marianas

The Mariana Islands are located in north-western Micronesia, approximately 2230 km north of New Guinea, 1550 km southeast of Japan and 2500 km east of Luzon, Philippines. They consist of a group of fifteen islands extending north-south for approximately 700 km between 13°14' S - 20°33' S latitude and from 144°38' E - 146°05' E longitude. The island of Rota is located in the southern Marianas, approximately 48 km northeast of Guam (Fig. 1). The islands in this region consist of volcanic cores overlain by plateaus of marine limestone and fringing reefs. Rota has a narrow reef system and limited lagoons, unlike Guam and Saipan which have larger and more extensive reef systems and lagoons (Eldredge et al. 1977; Doan and Siegrist 1979; Kayanne et al. 1993).

The Marianas were first settled around 3500 BP (Butler 1994; Craib 1993). There was a significant increase in population sometime after AD 500 with dramatic increases after AD 1000, during the late prehistoric or Latte period, AD 1000 - 1521 (Moore 1988; Hanson and Butler 1997). The majority of prehistoric settlement sites are located along the coast or in adjacent inland areas. However, in the Latte period settlement sites are larger and they also occur in the interior regions of the islands (e.g. Hunter-Anderson 1994).

Distinctive rows of stone pillars, called Latte, are usually found at these sites. Latte sets are a primary locus for a diverse set of mortuary behaviours (Hanson and Butler 1997), though latte sets without burial associations have been reported for interior upland sites in Guam (Hunter-Anderson 1995). Latte period inhumations are predominated by single primary burials; other forms of burial include secondary burial with or without cremation and group burials consisting of skeletal elements from several individuals (Hanson 1988, 1995; Hanson and Gordon 1989).

In addition, the Latte period is associated with major changes in ceramic forms and increased representation of stone mortars, pounders and pestles. While plain shallow bowls and pans dominated the earlier ceramic assemblages, large, thick globular pots with constricted openings became dominant during the late prehistoric period. A greater emphasis on storage and boiling has been associated with the large pots (Butler 1988). As it has also been argued that dryland rice cultivation originated in the Latte period, it is possible that the pots were related to rice preparation (McGovern-Wilson 1989; Hunter-Anderson et al. 1995). Thus, it appears that Latte period population expansion was associated with agricultural intensification and diversification of mortuary practices.

Figure 1 Map showing location of Rota and Saipan, Mariana Islands (after McGovern-Wilson and Quinn 1996)
Faunal remains are dominated by marine fish and shellfish. Earlier (pre-1000 BP) prehistoric sites have a wide range of fish species from coastal reefs and lagoons and deep water habitats (Davidson and Leach 1988; Leach et al. 1989; Butler 1995). However, after about 1100 BP fishing practices appear to become more specialized with a concentration on reef and lagoon species (Leach et al. 1988; Craib 1990, 1998). Terrestrial fauna in the Marianas are restricted to land crabs, fruit bats, monitor lizards and several species of birds. Although pigs, dogs and chickens were common prehistorically elsewhere in the Pacific, their bones have not been recovered from unambiguous prehistoric deposits in the Marianas. The largest terrestrial mammal reported at the time of historic contact in the AD 1520s was the rat. At this time the majority of the diet was obtained from starchy tree and root crops including breadfruit, taro, giant swamp taro, yams, bananas, sugar cane, coconuts and rice. Arrowroot, cycad seeds, pandanus and seaweeds provided minor dietary supplements (Pollock 1986; Butler 1988; Ambrose et al. 1997).

Due to the poor archaeological preservation of plant remains in the tropics, it is difficult to determine the contribution of domesticated plants to the diets of prehistoric Pacific island inhabitants employing standard archaeological techniques. Thus, this provides an excellent case for the application of stable isotope palaeodietary techniques. Stable carbon and nitrogen isotope analysis of archaeological human bone offers a means to address the relative dependence on terrestrial plant and animal foods vs. marine foods in the prehistoric Mariana Islands.

Materials and methods

Bone specimens were obtained from prehistoric human burials from two archaeological sites on the mid-north coast of Rota, Vista del Mar (Craib 1998) and the SNM Hotel site (Craib 1992). Vista del Mar is located in the Uyulan region of Rota (Figure 2) adjacent to the Salug-Songton and Teteto-Guata archaeological sites and within the Unginao-Uyulan site (Butler 1988). Human bone samples from Butler's excavations have been analysed previously for stable carbon and nitrogen isotopes (Ambrose et al. 1997). The SNM Hotel site is located approximately 5 km northeast of the above sites straddling the Sagan-Gigani and Agusan regions of Rota. These sites date from 2000 - 250 BP, with most burials occurring in the Latte period. One burial excavated from the base of the cultural deposits at Vista del Mar dated to 1790 ± 60 BP (Craib 1998: 107).

The sample consisted of 10 individuals from Vista del Mar and 2 individuals from the SNM Hotel site. The age and sex of the skeletons were determined using standard morphological techniques (Buikstra and Ubelaker 1994). Burials occurred in distinct clusters within the sites.

A 1 - 1.5 g cortical bone specimen was taken from each individual. Sample preparation involved ultrasonic cleaning of whole bone specimens, demineralisation, and sodium hydroxide treatment. Whole bone chunks were demineralised in dilute HCl according to the methods of Sealy (1986). Humic acids and other base-soluble contaminants were removed using a 0.125 M NaOH solution. Extracts were soaked and washed thoroughly following acid and base treatments in order to remove dissolved contaminants. The remaining organic component was oven dried at 35°C and carbon and nitrogen concentrations were determined using an ANCA SL elemental analyzer. Stable carbon and nitrogen isotope values were determined by mass spectrometry. Analytical precision was better than ± 0.1% for carbon and ± 0.3% for nitrogen.

Controls for postmortem organic decomposition were implemented by excluding samples with 1) less than 5% collagen yield from whole bone, or 2) less than 5% carbon yield from collagen, or 3) less than 0.5% nitrogen yield from collagen (Schoeninger et al. 1989; Ambrose 1990; Pate 1997). When collagen yields were less than 5% upon initial demineralisation, additional whole bone samples were taken and demineralised until a specimen with adequate collagen yield was obtained.

Dietary percentages were calculated using bone collagen δ¹³C end-member values of -20.5% for a 100% C terrestrial diet and -9.0% for a 100% marine diet. Ambrose et al. (1997) determined these end-member values by analysis of modern marine and terrestrial foods collected from the Marianas.

Results

Raw data related to the Vista del Mar and SNM skeletal sample are presented in Table 1. Human bone collagen δ¹³C and δ¹⁵N means and ranges for the Vista del Mar and SNM sample are similar to those reported by Ambrose et al. (1997) for the sample obtained from the nearby Salug-Songton, Unginao-Uyulan and Teteto-Guata archaeological sites on the mid-north coast of Rota. Latte period burials from Saipan have more negative mean bone collagen δ¹³C and δ¹⁵N values than those from Rota. In comparison to the earlier prehistoric burials on

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Figure 2 Map showing location of the Vista del Mar (VDM) and SNM Hotel archaeological sites, Rota, Mariana Islands.
Saipan dating from 1500 - 1100 BP (McGovern-Wilson and Quinn 1996), the later Latte period burials have similar mean bone collagen δ²⁸⁴⁰ values but more negative δ¹⁵N values (Table 2).

**Discussion**

Mean bone collagen δ¹³C values for the Vista del Mar, SNM, Salug-Songton, Unginao-Uyulan and Teteto-Guata sites along the mid-north coast of Rota suggest that marine foods comprised on average 22 ± 8% of the prehistoric diet with a range of about 10% to 41%. Elevated (more positive) δ¹⁵N values for some individuals suggest consumption of large quantities of deep water fish. Other individuals with more negative δ¹³C and δ¹⁵N values appear to have had diets dominated by terrestrial foods. Thus, prehistoric diets on Rota were variable with some individuals having significantly greater access to marine foods than others. In addition, the stable isotope results suggest a similar range of diets for the inhabitants of this region of coastal Rota throughout the Latte period.

In comparison, bone collagen δ¹³C values for nearby Saipan (McGovern-Wilson and Quinn 1996; Ambrose et al. 1997) suggest prehistoric diets averaging 16 ± 6% marine foods with a range of about 10% to 42%. Thus, during the Latte period, individuals on Rota appear to have included greater proportions of marine foods in their diets in comparison to those on Saipan. Furthermore, the earlier prehistoric burials (1500 - 1100 BP) on Saipan have elevated δ¹⁵N values relative to Latte period burials, suggesting a greater proportion of seafoods derived from open ocean or deep sea environments vs. coastal marine habitats. In this case, the stable nitrogen isotopes provide independent evidence for changes in fishing practices in the northern Marianas that are reflected in the archaeological faunal remains. Fish bones found in archaeological sites prior to 1100 BP represent a wide variety of families from both coastal and open ocean or deep water habitats, while those from the later Latte period sites indicate a reliance on a limited range of fish primarily from coastal reef and lagoon habitats (Leach et al. 1988; Craib 1990, 1998).

In conclusion, bone collagen stable isotope analyses indicate 1) a similar range of diets along the northern coast of Rota during the Latte period, 2) differences in quantities of marine vs. terrestrial foods consumed on Rota and Saipan during the Latte period, 3) variability between individual diets in the northern Marianas from at least 1500 - 250 BP, with some individuals having significantly greater access to marine foods than others, and 4) changes in the types of marine foods consumed from the earlier prehistoric to the Latte period on Saipan.

**Acknowledgements**

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**Table 1 Stable carbon and nitrogen isotope results for prehistoric human bone excavated at the SNM and Vista del Mar (VDM) sites, northern Marianas archipelago, Micronesia.**

<table>
<thead>
<tr>
<th>Sample number</th>
<th>AARC Lab ID</th>
<th>Age at death (yrs)</th>
<th>Sex</th>
<th>Collagen yield (wt %)</th>
<th>C/N (wt %)</th>
<th>Collagen δ¹³C (‰)</th>
<th>Collagen δ¹⁵N (‰)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNM-1</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>14.3 ± 2.8</td>
<td>-17.8</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>SNM-2</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>6.9 ± 2.8</td>
<td>-17.8</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>VDM-1</td>
<td>F2-B1</td>
<td>Adult</td>
<td>I</td>
<td>21.3 ± 3.6</td>
<td>-18.0</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>VDM-2</td>
<td>F3-B1a</td>
<td>30-40</td>
<td>F</td>
<td>6.0 ± 3.3</td>
<td>-19.4</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>VDM-3</td>
<td>F3-B1b</td>
<td>Adult</td>
<td>M</td>
<td>9.4 ± 3.3</td>
<td>-18.5</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>VDM-4</td>
<td>F4B-B1b</td>
<td>7-9</td>
<td>I</td>
<td>21.3 ± 3.8</td>
<td>-18.5</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>VDM-5</td>
<td>F4B-B1c</td>
<td>5-6</td>
<td>I</td>
<td>5.3 ± 2.8</td>
<td>-18.6</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>VDM-6</td>
<td>F4B-B2</td>
<td>17-19</td>
<td>F</td>
<td>25.1 ± 3.8</td>
<td>-17.9</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>VDM-7</td>
<td>TP1a-B1a</td>
<td>35-50</td>
<td>M</td>
<td>23.1 ± 3.6</td>
<td>-17.4</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>VDM-9</td>
<td>TP2-B1a</td>
<td>6-7</td>
<td>I</td>
<td>5.8 ± 2.8</td>
<td>-15.8</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>VDM-10</td>
<td>TP2-B1b</td>
<td>7-8</td>
<td>I</td>
<td>18.2 ± 3.2</td>
<td>-18.3</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>VDM-11</td>
<td>TR2-B1</td>
<td>50</td>
<td>M</td>
<td>5.8 ± 3.0</td>
<td>-19.3</td>
<td>8.1</td>
<td></td>
</tr>
</tbody>
</table>

Key: n.d. = no data, I = indeterminate, F = Female, M = Male

**Table 2 Comparison of stable carbon and nitrogen isotope data for prehistoric human bone excavated at various archaeological sites in the northern Marianas archipelago, Micronesia.**

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>δ¹³C (‰)</th>
<th>Range</th>
<th>δ¹⁵N (‰)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rota</td>
<td>10</td>
<td>-18.05 ± 1.08</td>
<td>-19.4, -15.7</td>
<td>9.00 ± 1.34</td>
<td>7.3, 11.3</td>
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<td></td>
<td>12</td>
<td>-18.11 ± 0.94</td>
<td>-19.4, -15.8</td>
<td>8.97 ± 1.12</td>
<td>7.7, 10.6</td>
</tr>
<tr>
<td>Saipan</td>
<td>8</td>
<td>-18.58 ± 0.32</td>
<td>-19.4, -15.7</td>
<td>7.82 ± 0.94</td>
<td>6.1, 9.2</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>-18.66 ± 0.83</td>
<td>-19.3, -16.6</td>
<td>9.45 ± 0.86</td>
<td>8.3, 11.0</td>
</tr>
</tbody>
</table>

* Ambrose et al. 1997
* This study
* Ambrose et al. 1997
* McGovern-Wilson and Quinn 1996
References


Pate, F.D. 1997 Bone collagen diagenesis at Roonka Flat, South Australia: Implications for isotopic analysis. Archaeology in Oceania 32:170-175.


