Reconstructing Prehistoric Japanese Diet Using Stable Isotopic Analysis

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1. Introduction

In 1983, at the International Congress of Anthropological and Ethnological Sciences in Vancouver, a number of Japanese researchers expressed interest in stable isotope studies of prehistoric diet. Discussion with them revealed differing opinions on just exactly what Jomon diet in particular included. Some said that Jomon diet was based heavily on marine resources, others said that it was based more on nuts, wild boar and deer. Clearly we did not have all of the answers. As a result it was decided that the use of stable isotopic analysis, then a new approach to paleodiet studies, might be a useful tool in dealing with this question.

2. History

The analysis of the stable isotopes of carbon and more recently nitrogen, from preserved human bone collagen has provided useful information about the presence of maize versus other terrestrial foods (van der Merwe and Vogel 1978; van der Merwe *et al*. 1981; Bender *et al*. 1981; Bumsted 1984; Lynott *et al*. 1986; Schwarcz *et al*. 1985; Katzenberg and Kelley 1991), and also about the proportions of marine versus terrestrial food alternative groups as protein sources in local prehistoric diets, and of dietary change through time (Chisholm *et al*. 1982, 1983; Hayden *et al*. 1987; Hobson and Collier 1984; Koike and Chisholm 1988; Schoeninger and DeNiro 1984; Schoeninger *et al*. 1983; Sealy and van der Merwe 1985, 1986; Tauber 1981; Walker and DeNiro 1986; and others). In Japan, stable isotope studies of prehistoric diet have been carried out by Minagawa and Akazawa (1992), Roksandic *et al*. (1988), Takamiya and Goldberg (1993), and by the present authors (Koike and Chisholm 1988, Chisholm *et al*. 1992).

The isotopic method has the advantage that the data are obtained directly from the individuals being examined and not by inference from associated faunal, floral and other archaeological materials. When combined with data obtained from other sources isotopic data can provide a more complete picture of prehistoric subsistence.

3. Methods

The isotopic techniques are relatively well known by now, so only a few important details are mentioned here. Materials measured in isotopic studies of paleodiet are of two types, edible tissues from the food species and bone collagen from the consumer. Samples for analysis are prepared by removal of contaminant carbon and nitrogen. Purified samples are combusted to obtain CO_2 and N_2 for mass spectrometric analysis. Analytical results are expressed, as del values, in parts per mil (‰), as follows:

$$\delta(‰)= \{ [Rsample / Rstandard] - 1 \} \times 1000.$$

Where $R = (^{13}C/^{12}C)$ or $(^{15}N/^{14}N)$. The carbon standard referred to is the internationally used PDB standard, the nitrogen standard is N_2 in air.

3.1 Carbon and nitrogen-basic isotopic patterns

Numerous isotope measurements, taken over the years, have allowed us to divide plants into four groups upon which we may base dietary studies (see Figure 1). The Calvin-Benson, or C_3 group, including most flowering plants, trees, shrubs, and temperate zone grasses, is characterized by $\delta^{13}C$ values averaging about −26.5‰while C_4, or Hatch-Slack, plants, the majority of which are xeric environment grasses, including maize, some millets, some sorghums, cane sugar, some amaranths and chenopods, are characterized by values averaging about −12.5‰ (Smith and Epstein 1971; Vogel 1978; O'Leary 1981; van der Merwe 1982; and others). A third group, the Crassulacean Acid Metabolism (CAM) plants, is made up of succulents, with values that usually reflect their growth environment. Luckily, for paleodiet reconstruction, they are not common in the diet of herbivores or humans. Marine plants and plankton approximate the C_3 cycle but obtain their carbon from dissolved oceanic bicarbonates which have isotope ratios, of about 0‰ (differing from atmospheric CO_2 by about −7‰, thus their values average about −19.5‰ (Brown *et al*. 1972, Degens *et al*. 1968, Deuser *et al*. 1968, Sackett *et al*. 1965, and others).

We also know that when animals eat their metabolisms recombine food-derived chemicals that contain carbon and respire CO_2, resulting in further fractionation of the carbon isotopes, producing trophic level differences of about 1‰ (DeNiro and Epstein 1978; McConnaughey and McRoy 1979; Bender *et al*. 1981;

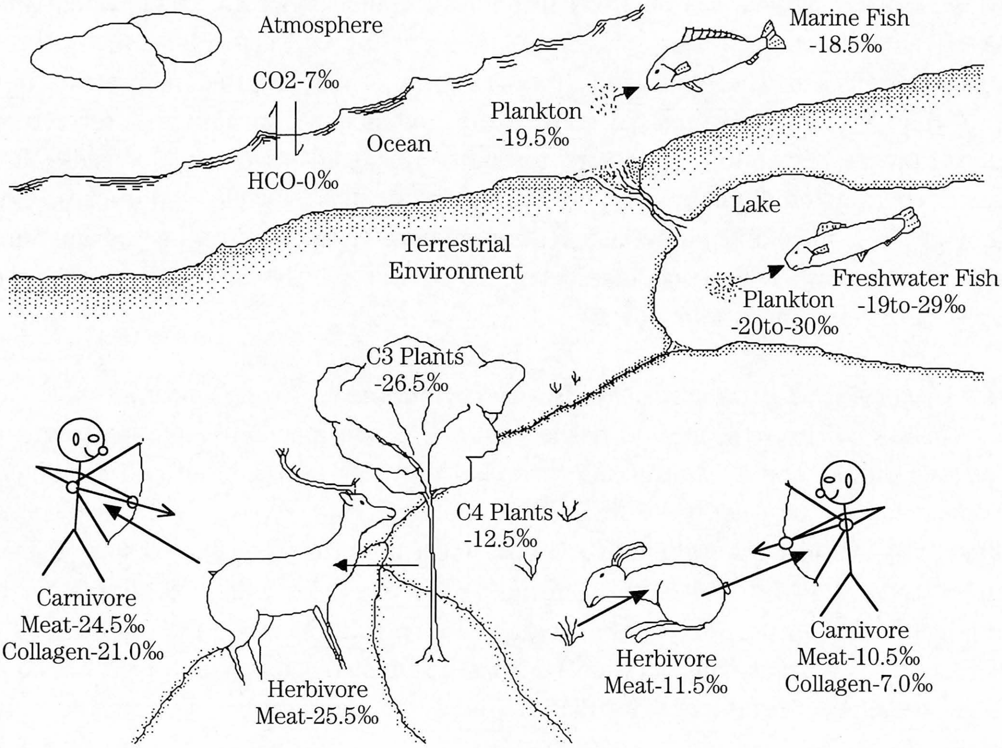

Fig. 1 Food chain relationships and δ^{13}C values

Tieszen *et al*. 1983; Schoeninger 1985). Consequently, the values for meat are only slightly displaced from those of the foods that the animals eat, which may allow us to average meat and plants from the same food chains together to form human's alternative food groups.

Nitrogen is also metabolized and recombined by the body subsequent to dietary intake, with some being incorporated into bone protein, also reflecting the food source that provided it. As Ambrose (1986) and others have observed, marine plants have δ^{15}N values about 4‰ higher than terrestrial ones. Species from the equivalent trophic levels in marine and terrestrial food chains maintain this difference. What is particularly useful about nitrogen values is that the inter-trophic level difference between similar tissues is about 3 to 4‰ (Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Ambrose 1986; Schwarcz 1991; Schoeninger and Moore 1992), which provides for better discrimination of trophic levels than does carbon, with its inter-trophic level increment of about 1‰.

Unfortunately little is known about the behaviour of nitrogen in fresh water systems. However, data reported by Minagawa and Wada (1984) and Yoshinaga *et al*. (1992), as well as some of Chisholm's unpublished data, suggest that the δ^{15}N values for fresh water species are the same as, or very similar to those of marine species of the equivalent trophic levels. It may be that nitrogen is not providing a marine - terrestrial comparison, but instead an aquatic - terrestrial one. Further research is necessary to clarify this point, and must consider the many environmental factors that are known to affect δ^{15}N values (Ambrose 1986, and others), including potential fertilizer effects. However, for the present discussion we may accept that marine and fresh water δ^{15}N values are similar for species of the same trophic levels.

3.2 Carbon and nitrogen - the diet to consumer collagen increment

While the average muscle tissue value of a consumer is displaced from its average diet by about 1‰ the difference between the average diet and extracted bone collagen (or gelatin) of the consumers (including rodents, cats, and monkeys) appears to be around 4.5 (±0.4)‰ when lipid free food samples are measured (Chisholm 1986; Koike and Chisholm 1988) and about 5‰ for samples with lipids left in (van der Merwe and Vogel 1978; van der Merwe 1982; and others). This is an important consideration because in archaeological situations extracted bone collagen, a protein, is the material analyzed because it is usually the only

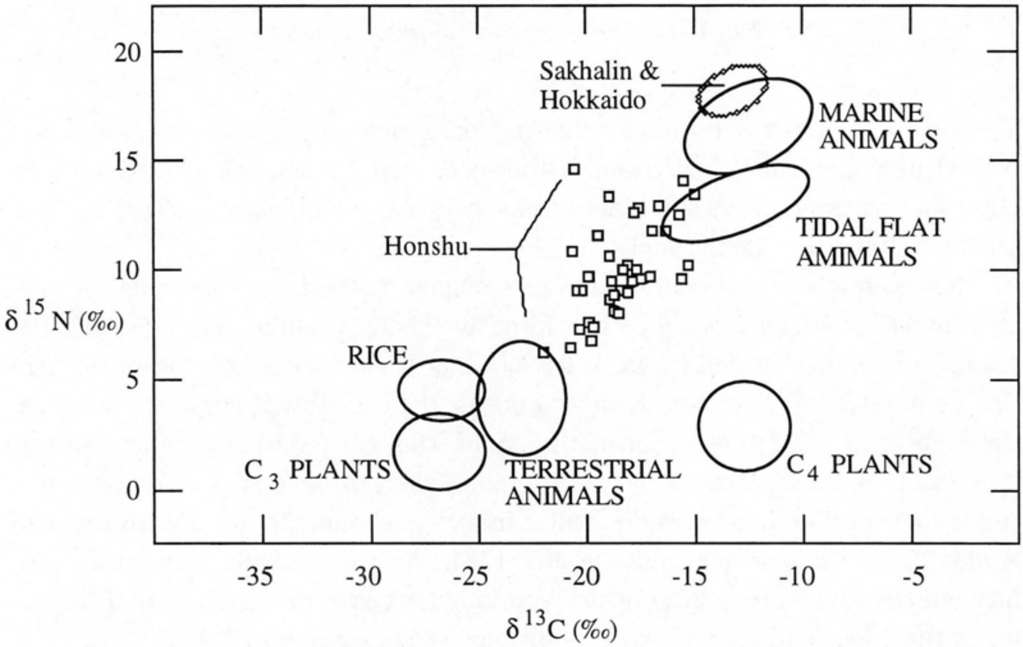

Fig. 2 Distribution of various potential food groups according to carbon versus nitrogen values, showing results for Japanese Jomon Period individuals.

organic tissue that is reliably preserved in sufficient quantity for analysis.

For nitrogen, the increment between diet and consumer gelatin is not quite as well understood, but seems to be about 4 to 5‰. The information on both carbon and nitrogen isotopes in food species is summarized in Figure 2.

3.3 Carbon - protein food chains and the role of carbohydrates

The amino acids from which collagen is assembled are obtained from dietary materials. While seven of these amino acids are considered essential in the human diet since humans cannot synthesize their carbon skeletons, the remaining ones are considered non-essential because their precursors have been shown, in laboratory experiments, to be derivable from the carbohydrate metabolism (Falconer 1969; Mahler and Cordes 1966; Meister 1965; White *et al* 1978: 329ff., 678 ff.). However, in normal circumstances protein intake is sufficient to provide non-essential amino acids as well as essential ones and little or no synthesis is necessary (White *et al*. 1978: 678). The presence of protein deficiency diseases in humans also suggests that protein in the diet is the precursor to protein in the body, and that carbohydrates and lipids do not normally provide alternative sources of protein components.

If this is the case, then the majority view, that all ingested carbon was deposited in a pool from which the carbon necessary for forming amino acids and thence protein was drawn, is erroneous. Instead, when measuring collagen, we are concerned with only the protein components of the food chain (Chisholm 1986; Chisholm *et al*. 1982, 1983; Ambrose and Norr 1993). If we are interested in making estimates of the role of different carbohydrate sources, sometimes called energy sources, in the diet, there is increasing evidence that it may be possible to do so through the analysis of the inorganic / apatite portion of bone.

3.4 Geographic variation in food species

Data from British Columbia (Table 1) show that we may expect geographic differences in food species values. In that case there is a difference of 0.9‰ between the averages for populations of terrestrial species in northern interior and southern interior areas of British Columbia. Schoeninger and DeNiro (1985) also present data that show geographic differences in a number of similar species collected from various areas around the world. Clearly, geographic differences in the isotope ratios of food species must be accounted for when determining the average isotope ratios for the local diet alternatives.

3.4.1 Food species variation in Japan

In view of these potential sources of variation, the first step of any complete

Table 1 Summary of modern diet sample results for British Columbia: showing geographic differences

Description of samples	n	$\delta^{13}C$ (‰ ± 1s.e.)
A) The marine diet alternative:		
POPULATION MEAN	46	−17.7 ± 0.2
B) The northern terrestrial diet alternative:		
POPULATION MEAN	26	−26.1 ± 0.3
C) The southern terrestrial diet alternative:		
POPULATION MEAN	21	−25.2 ± 0.4

paleodiet study must be the determination of local values for the archaeologically indicated dietary alternatives. Isotope ratios for Japanese food species have been presented and discussed elsewhere (Chisholm *et al* 1988, Koike and Chisholm 1988). Those results indicated that there are minor differences between Japan and other regions in plant species values, but that the differences, of about 14‰ between C_3 (average=−25.0±1.38‰ and C_4 plant species (average=−11.1±0.4 ‰), and of about 7 to 8‰ between the terrestrial and marine (average=−16.3± 2.06‰) food alternatives are maintained.

With a few exceptions, the values for herbivores in Japan are very similar to those of the C_3 species that they seem to be eating. This means that the herbivores and C_3 plants may be grouped as one diet alternative, which can be compared to the C_4 plants and marine species alternatives (Figure 3). C_4 intake is not likely very high, as there are only three known species of C_4 plants preserved in Jomon sites. This low C_4 presence has also been observed by Minagawa and Akazawa (1992).

One significant result of the diet species measurements is that the fish species produced quite varied results, with a range of values from −20.2 to −13.0 ‰ This degree of variation in results is sufficiently large that it is difficult to derive a good average value for marine foods. However, the marine species are clearly different than the terrestrial ones and on average are generally similar to those from elsewhere, so it will be possible to detect overall patterns and trends, and to make crude estimates of diet proportions that will be subject to correction as new data become available. Nitrogen data are not yet available for the food samples, so comparisons of nitrogen data must be made via the $\delta^{13}C$ versus $\delta^{15}N$ chart (Figure 2).

One complication that arises from this range of variation in fish values is that unfortunately we cannot rely on Monte Carlo simulations, such as those used by Minagawa and Akazawa (1992), to provide estimates of the relative proportions of various foods in the local diet. To do this we need better, and more localized

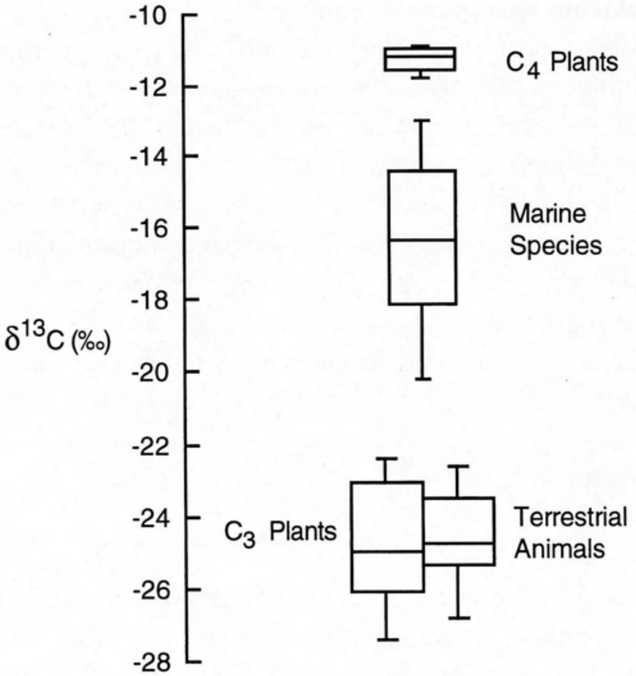

Fig. 3 Distribution of carbon isotope results values for Japanese food species.

information on the diet alternatives and their isotope ratios. In the present situation we can still look for changes in diet through time within a region, and for general trends in the diet over time and space, and thus compare human results from different sites and time periods within Japan.

3.5 Uncertainties - error estimation

The uncertainty on proportion estimates is determined by combination of the uncertainties associated with the sample measurement and the two endpoints between which the consumer value is interpolated. Most studies have not stated the uncertainties associated with their results, but for preliminary marine versus terrestrial comparisons on the British Columbia Coast, the reported uncertainty on proportion estimates was about ±8% (Chisholm *et al.* 1983). In the case of Japanese data the uncertainty is likely to be much higher, around ±30% or in some cases more, because of the variation in marine diet species results, and because there may be three diet alternatives to consider, the C_3, C_4 and marine groups.

4. Questions relating to Japanese contexts

When this study began there were a number of questions that we hoped to address, for example: 1) what were the relative marine - terrestrial proportions in dietary protein intake throughout Japanese prehistory? Did the reliance on marine foods change through time? 2) Was the diet of both interior and coastal people in Japan the same in the Jomon? 3) Can we see seasonal patterning at any time, particularly in the Jomon? 4) Can we see the introduction of rice? 5) Is there any isotopic evidence for status, or gender, differences in Japanese diet? Unfortunately, appropriate samples for addressing all of these questions were not available, however, we can provide partial answers to some of them.

5. Japanese Results

5.1 Procedures

The method used for collagen extraction in this study was a modification of Longin's (1971) technique. Bone samples, of about 1 - 2 gm, were ground to about 1 mm. and then demineralized with 0.2 - 0.25N HCl. The residue was heated to 60℃ for at least 10 hours while maintaining an acid pH of about 3, in order to denature the collagen and recover it as gelatin

About 10 mg of freeze dried sample were combusted for 2 hr with about 1 gm of pure CuO (wireform) in sealed tubes to obtain CO_2 for analysis, at either 520℃ in a preheated oven in Pyrex, or 900℃ in quartz tubes. The samples were then purified cryogenically for analysis. Comparison of the two combustion methods produced no differences in results.

Measurement of the resultant CO_2 was carried out on a Varian MAT CH7 instrument in the Laboratory of Geochemistry, Department of Earth Sciences, School of Science, Nagoya University. The precision of analyses for this instrument is ±0.1‰, or better. Nitrogen analyses were carried out on a Finnegan MAT Delta F instrument by Shoko Tsushou Ltd. The precision of analyses for this instrument was ±0.2‰, or better. Instrumental error therefore does not contribute noticeably to uncertainties in the results.

5.2 Discussion - summary of results

Samples prepared for analysis in this study were from well preserved bone, and when purified had the appearance of good collagen, so there was little likelihood of sample contamination. Collagen yields were all over about 5%, enough for the analysis. To date, about 550 human samples have been analyzed for carbon isotope ratios, while only about 70 samples have been analyzed for nitrogen

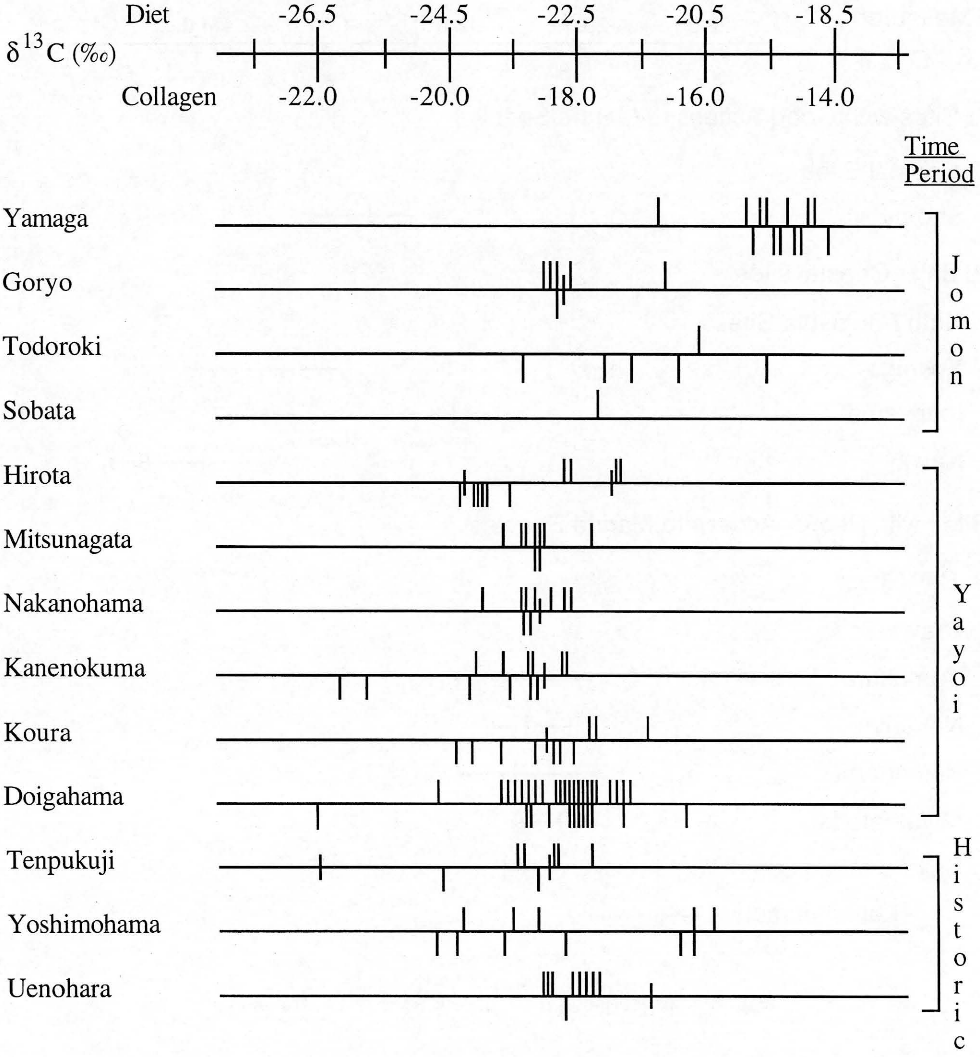

Fig. 4 Carbon isotope results for western Japan Jomon sites.

ratios. Therefore, the following discussion will be based primarily on carbon isotope ratio data. The nitrogen analysis is still progressing.

Individual human carbon isotope ratio values from Japanese samples range from −22.0 to −11.7‰, indicating diet values ranging from −26.5‰ (purely C_3) to −16.3‰, (purely marine). Some sites gave outlying values that make use of overall mean values misleading, so the outliers should be considered separately.

In western Japan, except for the site of Yamaga, the average reconstructed diet values at different sites ranged from −23.5 to −21.4‰with a few outliers (Figure 4). Central Japan sites have diet values ranging from as low as −26 to

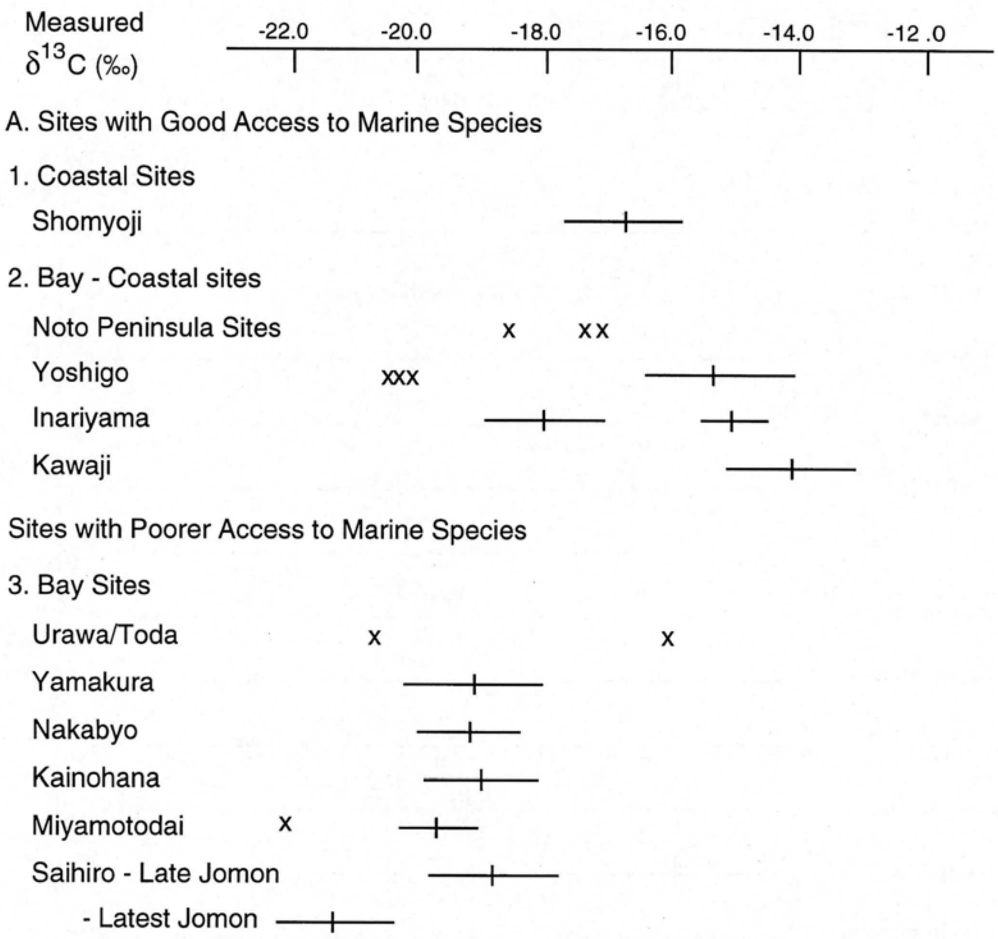

Fig. 5 Carbon isotope results for sites in Central Japan

−17.8‰ (Figure 5); but with values that are generally more positive (marine) than in western Japan. Hokkaido site average diet values are somewhat more positive (marine) than those for central Japan, and noticeably more positive (marine) than those for western Japan, ranging from −20.3 to −17.3‰, also with a few outliers (Figure 6). In general, results indicate that people from all of the sites sampled had a substantial intake of marine protein in their diets, generally less than about 50% in western Japan, while in Central Japan and Hokkaido it was generally between about 40% and 80%.

When nitrogen data are introduced for the Central Japan (Honshu) samples (Figure 7) we can more clearly locate them with respect to the diet alternatives. The first observation is that there is a reasonable spread in the results. This indi-

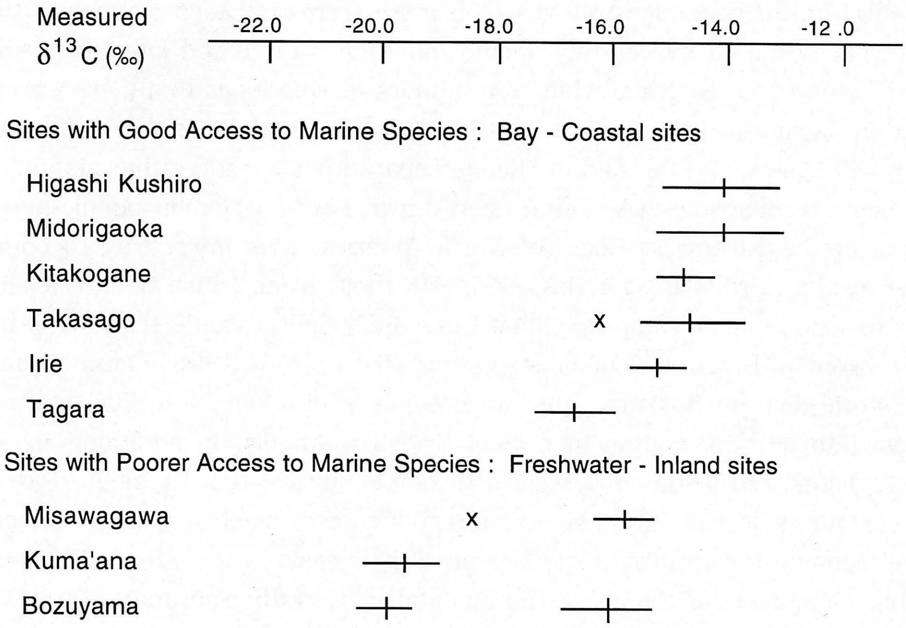

Fig. 6 Carbon isotope results for Northern Japan sites.

cates that there is a reasonable amount of variation in the diets of the individuals examined. When the data are compared with diet alternatives it is clear that, for both nitrogen and carbon, the average diet contained about 50% marine and 50% terrestrial species. The effect of C4 species, if present at all, was minimal.

Variation within a site ranges from a minimum of ±0.3‰ for the Edo Period cemetery site of Jisho-in, near Shinjuku in Tokyo, to ±1.6‰ at Minami Usu in Hokkaido. We know from other studies (Chisholm *et al.* 1983) that the variability within one population where everyone is eating the same food is quite small (about ±0.3‰) so variability that is greater than this will represent differences in diet for the people examined, suggesting that the Jisho-in individuals must have been eating a virtually identical diet. The higher variability for sites such as Minami Usu suggests considerable local diet variation.

Examination of the data reveal some trends in food resource exploitation. For Hokkaido populations, average diet values through the Jomon Period were around −18.5‰, followed by a shift to more positive values around −17.5‰ (85−90% marine) for the sea mammal hunting Okhotsk people, and then to more negative (terrestrial) values, around −19.5‰ in the Satsumon Period, and around −20.2 for the Ainu.

In the Kanto region, the data we have are mainly from Jomon sites, so temporal shifts cannot be determined. In Kyushu and western Japan, the diet seems to shift from a more marine focus to a more terrestrial focus, although this is somewhat obscured by coastal - inland differences discussed later. It is safe to say that there was a general shift from a more marine focus to a more terrestrial focus in Japanese diet over time, although the magnitude of the shift was not necessarily great, and the rate of change apparently slow and rather gradual.

Since comparisons have often been drawn between Jomon populations and people of the Northwest Coast of North America, it is interesting to compare these results, particularly for Hokkaido, with those from British Columbia. Generally, Hokkaido human samples exhibit isotopically lighter values than found in the coastal zone of British Columbia, suggesting that there was less marine protein in prehistoric diets in Hokkaido, the range being from about 50 to 70% marine, as opposed to 85±8% marine in coastal British Columbia. In addition, the more widely distributed results observed in Hokkaido suggest that the menu was more varied than in British Columbia - the possible choices used were more numerous. If we examine the terrain of the two areas it is easy to see why. In British Columbia, along most of the coast, the mountains rise rather abruptly from the sea, leaving little area for human habitation and hunting. Access to game animals is often difficult, particularly when compared with access to marine species. In Hokkaido the land slopes more gradually up from the sea, allowing much better access to species such as deer and bear, which were certainly hunted by the Ainu people. Thus, terrain is one of the determining factors in land animal exploitation differences between the two areas, and this is reflected in the isotopic record.

Samples from Sakhalin and Hokkaido, measured by Minagawa and Akazawa (1992) show a higher marine protein intake than do the ones we examined, from Honshu. This is what we would expect for two reasons: 1) the marine intake likely was higher, as indicated by archaeological materials, including fauna, from the sites in the area, and 2) the isotope ratios for marine species from the northern areas of Japan are more negative (more marine) than those from around the Tokyo Bay area.

5.3 Inter-site differences in the Jomon - can we see seasonal patterning?

During the Jomon Period there are differences in isotope ratios between coastal and interior dwellers from a number of sites. Where such differences are seen, as expected, the coastal dwellers used more marine foods.

We can see (Figure 4) that in western Japan there is a tendency for inhabitants of sites with poorer access to marine resources to be more negative (terrestrial) in value than the coastal shell midden site of Yamaga. However, this is not a strong pattern. Calculated diet values for people from Yamaga, averaging

−19.2±0.5‰, were more positive (more marine) than for people from the more inland site of Goryo, at −22.7‰, as well as at Todoroki and Sobata. This indicates that the Yamaga people were getting about 65 to 70% of their protein from marine species, compared to 25 to 45% for other Kyushu Jomon people.

Human results for Central Japan regions (Figure 5) reinforce the inland versus coastal pattern, wherein the coastal sites do reflect a more positive (marine oriented) set of results than do sites with poorer access to marine resources. Results of Minagawa and Akazawa (1992) for the Kosaku and Kitamura sites also show a difference between inland and coastal sites, although of slightly less magnitude than seen here.

A similar pattern is seen in our results for Northern Japan (Figure 6), as well as in those of Minagawa and Akazawa (1992) for Kitakogane and Sanganji. This pattern is most strongly observed for the coastal site of Tagara, with an average diet value of −20.9±0.7‰ (also reported by Minagawa and Akazawa 1992) and the inland cave site of Kuma'ana, with an average value of −23.7± 0.8, which are within a few kilometers of each other. The inhabitants of Kuma'ana, the inland site, were obviously more terrestrial in diet orientation than were the people of Kuma'ana, which while slightly inland, is more of a coastal site. In addition, these results indicate only a moderate reliance on marine species, thus supporting the idea that people of the region had a diet that was heavy in terrestrial protein species.

In Hokkaido, the sites of Bozuyama and Misawagawa give slightly more negative (terrestrial) results than the other Jomon period sites. At present we have no definite explanation for the Bozuyama sample bias, although we may speculate that the three more negative values are from individuals who were predominantly terrestrial hunters. Faunal remains from Misawagawa include deer and corbicula (a fresh water species), unlike other Hokkaido Jomon sites such as Higashi Kushiro or Kitakogane, perhaps explaining the more terrestrial bias in that case.

These differences are of interest because they indicate that while the Jomon people may have followed a seasonal round, as suggested by Kobayashi (Aikens and Higuchi 1982) and other researchers, and that they did consume a mixture of marine and terrestrial foods, they did not all exhibit the same pattern. While this is no surprise, it does suggest that people who lived on the coast spent more time there, eating marine foods, than did people from inland areas. In other words there were at least two populations, one primarily coastal and the other primarily inland dwellers. While these two populations may have followed similar seasonal exploitation patterns, or perhaps exchanged foods, they did not do so to a sufficient extent that their dietary protein intake was identical.

5.4 Temporal patterns - Can we see the introduction of rice?

In addition to the general temporal patterns just outlined, there are a few details that may allow us to address the question of when rice was introduced. In Kyushu, the Jomon Period results show slightly more inter-site variation than do those for later period sites, in that coastal and inland sites differ in average diet values (e.g., Yamaga at −19.2‰ and Goryo at −22.7‰. This suggests that people inland and on the coast of Kyushu had slightly different menus, and that those menus were not as extensive as in later periods when the intra-site variation was greater. The Yayoi Period site results seem more consistent, with diet average values between −24.1 and −22.8‰, but they show slightly higher intra-site variation, and a decrease in the coastal - inland difference. Historic period sites follow this trend with average values between −22.6 and −21.5‰. These results suggest that the Yayoi people selected a wider variety of foods, but that the alternatives chosen for each site were similar. This is consistent with the widespread adoption of a common staple food, such as rice, and would be expected with a shift from a hunter-gatherer subsistence base to an agricultural one. This pattern continued into historic times, with the percentage of marine protein in the diet ranging between about 15 and 40%. Nitrogen values for Yayoi sites such as Doigahama and Kanenokuma average 10.8 and 9.9‰ respectively as compared to values of 13.7 and 14.2‰ for two individuals from Yamaga. The shift in nitrogen results can be explained in a number of ways: there was a shift from animals to plants in the local diets - but retaining an overall C^3 bias - thus not affecting the carbon results; there was a shift from marine to terrestrial foods in the local diets - which would affect the carbon results; or there was a shift towards plants grown in wet field environments - such as rice, which are known to have higher δ^{15}N values than other plants. The latter explanation is more consistent with other archaeological evidence about the introduction of wet rice agriculture in the region. The nature and magnitude of the change in western Japan, while indicating a shift to rice as a staple food, do not match the strong shift in isotopic values observed when maize agriculture was introduced to various areas of North America (Bender *et al* 1981, Lynott *et al*. 1986, van der Merwe 1978). Further, the samples available for analysis were not sufficient for a fine grained analysis of the changes over time. If sufficient samples can be analyzed it may be possible to determine not only the time of the introduction of rice agriculture, but the rate at which it appeared throughout Japan.

5.5 Intra-site differences - Can we see status and / or gender differences ?

5.5.1 Jomon and Yayoi people

Gender and status related differences in diet are not commonly observed, at least isotopically, for hunter - gatherer - fisher groups throughout the world. Isotopic paleodiet evidence, when it does appear in such groups, may perhaps mark the beginnings of the status and role differentiation found in more complex societies.

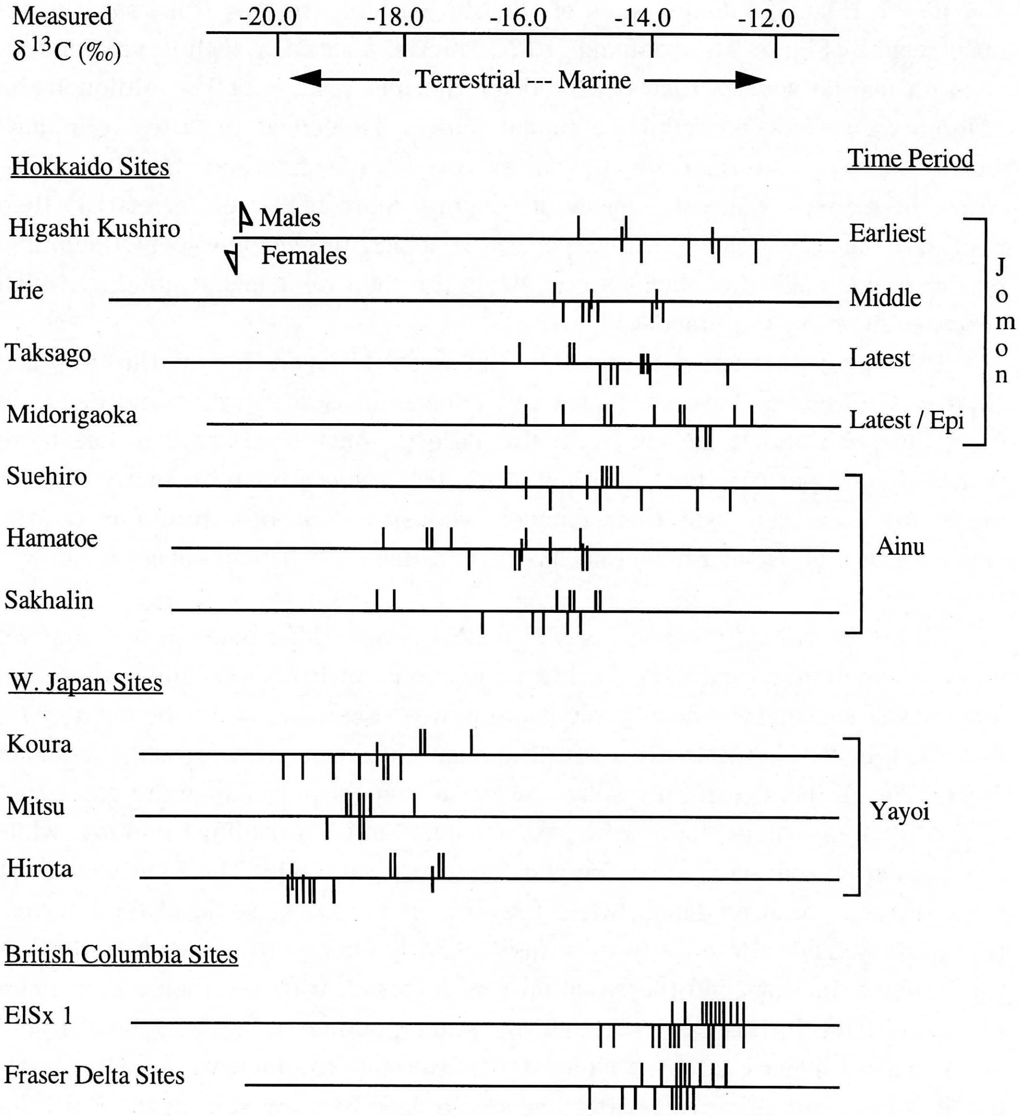

Fig. 7 Male - Female differences observed in various sites

In three western Japan Yayoi sites we saw a bimodal distribution of results (Figure 4). At Yoshimohama, 4 individuals, both males and females, were less negative than the other 7, but we have not yet been able to find any variables, such as burial status, tooth modification, or age that correlate with this difference. Hirota and Koura results will be discussed below. The site of Doigahama provided 40 individuals for analysis, some exhibiting tooth evulsion, some with notched and forked teeth, and many with differential burial goods, that presumably indicate some level of status differentiation. Unfortunately, we did not find any correlation between isotope ratios and either age or any of these indicators.

In the Hokkaido Jomon sites of Higashi Kushiro, Irie and Takasago the female results (Figure 7), averaging −13.2±0.8‰, suggest a slightly greater reliance on marine species than observed for the males, at −14.9‰, Although the differences are not as distinct, a similar pattern is seen at the sites of Midorigaoka, Suehiro, and Hamatoe, the latter two sites being Ainu. In all of these cases the average values for males are slightly more negative (terrestrial) than for the females, consistent with a pattern in which the women spent their time on the shores collecting shellfish etc., while the men went inland hunting, which seems to fit with Ainu practices.

This is an interesting contrast to the western Japan site of Hirota which showed a difference between males and females in isotope ratios and hence in diet (Chisholm and Koike 1987). In this case the males appeared to use more marine foods, perhaps because they were fishermen who took more of their meals from the sea than their families who stayed ashore. Hirota is on the smaller island of Tanegashima and has been a deep sea fishing village for a long time.

These are among the few cases of male - female differences in diet that we know of for hunter - gatherer - fisher populations. In British Columbia there are two coastal locales that show a minor difference (Figure 7), with the average female diet being slightly more terrestrial than the average male diet (Chisholm 1986). The British Columbia results and those from western Japan are consistent with a situation where the men were out fishing and sea mammal hunting, while the women stayed ashore and foraged for terrestrial foods. The men would eat some of their catch for lunch, while the women would eat some of their terrestrial harvest. The difference in diet was obviously enough to show up in the isotopic values. In Hokkaido the situation was reversed, with the men eating more terrestrial food. In this case, perhaps the women gathered, and ate shellfish and other marine species gathered along the shore while the men were inland hunting. It is interesting that this pattern seems to have been present in the Early Jomon at Higashi Kushiro, a site near both ocean and inland hunting areas.

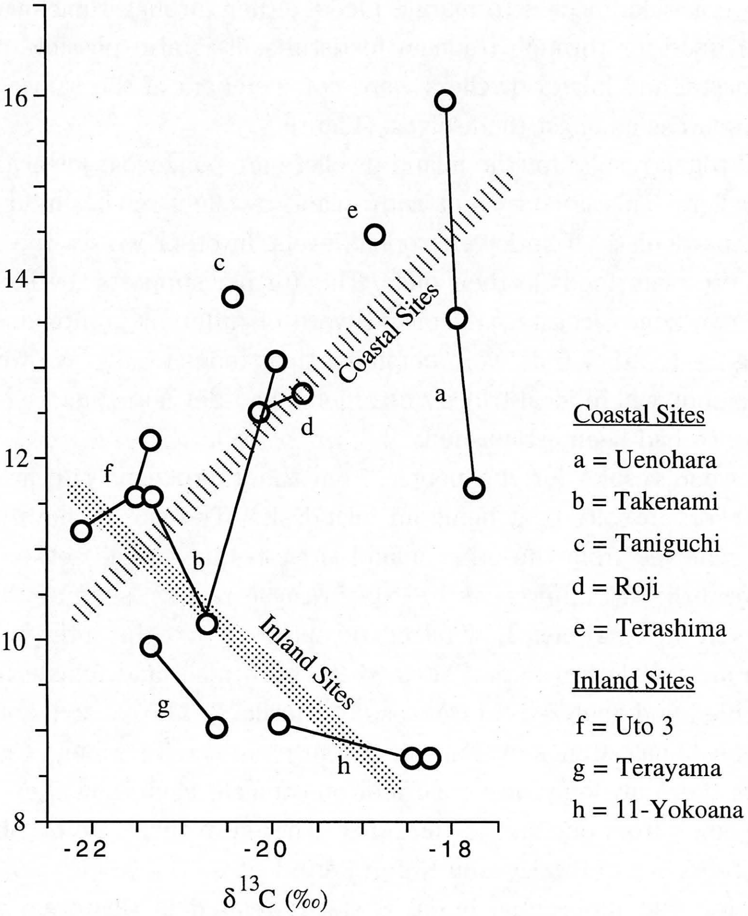

Fig. 8 Kyushu Kofun Period site results

The site of Koura in Shimane Prefecture on the Sea of Japan is misleading, showing evidence of male - female differences in carbon ratios, with seven females averaging −18.8±0.7‰, and three males, averaging −17.4‰. However, two males are Kofun Period burials, unlike the females who are from the Yayoi Period. Thus, we cannot determine if these results indicate gender or temporal differences in diet.

5.5.2 Kofun people in Kyushu

With the exception of the 11-Yokoana site, people from Kofun sites in inland locations tend to yield carbon values that are about 1.5‰ ore negative (more terrestrial) than for people from coastal sites. This suggests that the diet of inland dwellers was less marine in protein content, as one would expect if people inland did not have as good access to marine foods, either through their own efforts to obtain such food, or through trade in foodstuffs. It is also possible to conclude that the coastal and inland dwellers were not members of the same group sharing food resources amongst themselves. (Figure 8)

The nitrogen results for the inland dwellers are somewhat lower than for the coastal dwellers. This is consistent with inland dwellers relying more on terrestrial foods, particularly from lower trophic levels. In other words, the inland people used more plant foods in their diets. This further supports the idea that people in the two zones, coastal and inland were of different groups and were not exchanging food, rather they were obtaining their foods locally. We would expect this in situations where local tribes / chiefdoms had developed and where territorial boundaries had been established.

The carbon results for the people from the 11-Yokoana site are more like coastal dwellers in spite of it being an inland site. The site is, however, located somewhat removed from the other inland sites in this sample set, so there may be some local dietary differences to explain these results, such as the presence of C_4 plants in the local diet. Low nitrogen values support this interpretation.

There are five Kofun Period sites where both male and female burials have been identified and analyzed. In the case of Kusaka 2, 11-Yokoana, and Uenohara the male and female values overlap. In the cases of the Terashima Cist and Takenami sites there are only one male and one female each, and the order of results is reversed from one site to the other. Therefore there are no obvious male - female differences in the Kyushu Kofun Period sites.

Assuming that differential burial is status related in this area, we can see some correlation between isotopic data and status. Higher ranking individuals were buried in key hole Kofun, middle rank individuals in round or square shaped Kofun, and lower ranked individuals in tunnel tombs. We did not have any non-tomb burials to examine in this study, and therefore cannot speculate on the diet of the common people. Samples from the higher ranked skeletons (Taniguchi and Roji - which are coastal sites) yielded results in the middle of the typical ranges for δ^{13}C and δ^{15}N values, not what we would expect if location was the determining factor in diet. The three middle ranked sites showed a correlation between diet and location, with Uto and Terayama reflecting a more terrestrial plant based diet, while the Terashima individual was at the marine end of the scale. On the other hand, no clear correlation was seen for the lower ranked groups (Uenohara, Takenami, 11-Yokoana). The previously discussed individuals from the 11-Yokoana tunnel tomb, and three from the coastal site of Uenohara, show values that seem to correlate with their locations, however, the individuals from Takenami, a coastal site, show a higher reliance on plant foods than would be expected. Further, the Uenohara individuals are somewhat unusual in that they yielded high carbon values suggestive of a high marine intake, however, they had lower nitrogen values than would be expected for a heavy marine intake, suggesting that perhaps C_4 plants were part of their diet, as may have been the case at 11-Yokoana. While it is difficult to make reliable conclusions from these data, it would appear that higher ranked individuals during the Kofun Period in Kyushu had slightly higher intakes of meat than did lower ranking people, although unfortunately, we cannot tell just what species they would have been eating. Further selective sampling will be required to resolve this question.

A correlation between isotope ratios and stature was observed for five male and five female skeletons, in which the taller individuals were lower in both δ^{13}C and δ^{15}N values, indicating that they relied less on marine species. This follows current conceptions that taller stature correlates with non-marine diets. Unfortunately we cannot see any correlation between status and stature in this sample.

6. Conclusions and recommendations

Although the variability of aquatic food species makes determinations of proportions difficult, it appears that Jomon Period coastal shell midden inhabitants obtained about 60 to 90% of their protein from marine species, while inland dwellers got only about 30 to 50% of their protein from the sea, which is somewhat lower than generally assumed for Jomon people. The Yayoi and historic period people appear to have obtained about 20 to 50% of their protein form marine sources, with no large differences between locations for these people. The Ainu people, who are known to use marine resources extensively, gave values similar to the Jomon coastal sites. In Kyushu, as the transition was made from Jomon to Yayoi, the range of variation between sites decreased slightly, while the range of variation within sites increased slightly, i.e., there was a shift to a more standardized, but larger menu, due no doubt to the introduction of a staple, or a few staple food species - such as rice.

In inland versus coastal site comparisons, some Jomon site results differ significantly indicating that it is unlikely that they were used by the same population. Both types of sites show evidence of the different diets, and are located in different resource exploitation areas, the difference suggests that the sites were not part of a uniform seasonal exploitation pattern for the same population, nor was there exchange of foods sufficient to provide the same menu in the two sites.

There are some cases in which male - female differences in diet are observed. The male - female differences can be attributed to role differences, in that men and women may sometimes carry out different subsistence related activities, that in some cases can be reflected in their diets. However, at this time it is not possible to identify status related differences.

Differential status evidence in the Kyushu Kofun Period is not clearly evident in our data, although there are hints that higher ranked individuals may have eaten more meat than middle and lower ranked individuals. Location seems to have been a factor in this period as it was in earlier times.

The results presented here show the potential of such studies in the reconstruction of Japanese paleodiet. It is clear that there is a need for subsidiary data, about the characteristics of the food species, and about the local archaeological situations, before accurate interpretations can be made. However, it is also evident that changes in diet across time and space, and according to status and gender, may be reflected in the isotopic analysis results. As far as Japanese diet studies are concerned, this is only a beginning, however, it has already produced a number of interesting observations. To fully understand the similarities and differences that may exist in Japanese prehistoric diet it will be necessary to carefully define the research questions and to select samples for analysis that will permit fine grained resolution of those similarities and differences, if they exist. Methodological requirements of such studies include local sampling of food species and proper analysis of errors and uncertainties if the data are to be reliably interpreted.

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