^{14}C DATING HUMAN SKELETONS FROM MEDIEVAL ARCHAELOGICAL SITES IN KAMAKURA, JAPAN: WERE THEY VICTIMS OF NITTA YOSHISADA'S ATTACK?

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ABSTRACT. We investigated the radiocarbon ages and carbon and nitrogen isotope ratios of human skeletal remains from burials at the Yuigahama-minami and Chusei-Shudan-Bochi sites in the Yuigahama area (Kamakura, Japan), which we believe are associated with the great attack on Kamakura by Nitta Yoshisada in AD 1333. The human bones produced enriched $\delta^{13}C$ and $\delta^{15}N$ values that could be affected by consumption of protein from marine fish and/or mammals with high $\delta^{13}C$ and $\delta^{15}N$, and therefore older apparent ^{14}C ages. We thus estimated the marine reservoir effect on human skeletons to determine their true ages. The IsoSource isotope mixing model was employed for reconstructing percentages of marine protein in the human diet, and calibrated calendar dates for the ^{14}C ages were calculated using the marine percentages. At the Yuigahama-minami site, most skeletons from individual burials now date to the last phase of the Kamakura period or the early part of the Muromachi period, while skeletons from mixed human-animal multiple burials date to the latter part of the Kamakura period. The humans from the individual burials, consisting of normal ratios of adult males, could have died a natural death, though the site could also have been used to inter victims of the battle of 1333. The humans from mixed human-animal burials, consisting of a high proportion of infants, were not victims of the 1333 battle, but the site may have been used to inter victims of the Kamakura earthquake in 1293, which resulted in a catastrophic tsunami. On the other hand, the skeletons from multiple burials in the Chusei-Shudan-Bochi site all date to the middle Kamakura period. Coupled with the fact that most humans in the site are male but show no evidence of injuries by sword cuts, it is likely that burials of the Chusei-Shudan-Bochi site could have been a collective interment following the Jinji earthquake in 1241, the Shoka earthquake in 1257, or the Shoka famine in 1258 in the middle Kamakura period. The results of this study indicate that humans from burials in the Yuigahama region were not necessarily victims of the attack by Nitta Yoshisada on Kamakura, but instead were likely victims of natural disasters such as large earthquakes and severe famines, which often occurred in the middle Kamakura period.

INTRODUCTION

The Medieval period of Japan spans about 400 yr, from AD 1200 to 1600. The period is characterized by a rise of its warrior class to political power and the establishment of military government. Kamakura (Figure 1) was an ancient capital with dense population where a military government, the Kamakura shogunate, was established in AD 1185 and lasted until the last great attack on Kamakura by Nitta Yoshisada in AD 1333. The most severe events documented at Kamakura in the Kamakura period are summarized in Table 1. Besides the attack on Kamakura by Yoshisada Nitta in 1333, other major battles fought within the city of Kamakura include Wada Yoshimori's battle of 1213, Miura Yasumura's rebellion of 1247, and the attack on Kamakura by Ashikaga Takauji in 1352. Moreover, extreme weather events (e.g. drought and strong rain), climate events (e.g. global cooling), and natural disasters (e.g. earthquakes) occurred in the Kamakura period, which caused many severe famines (e.g. the Kangi famine in 1231 and Shoka famine in 1258; see Saito 2010). Some major earthquakes also occurred in the Medieval Kamakura period. Records show large earthquakes occurring in 1241 (Jinji), 1257 (Shoka), and 1293 (Kamakura) with magnitudes of M7, accompanied by catastrophic tsunamis on the coast at Kamakura (Iida 1984). According to the "Kamakura Oh Nikki," which recounts significant incidents from 1180 to 1589, the Kamakura earthquake left between 20,000 and 30,000 people dead. The "Azuma Kagami," a Japanese Medieval chronicle, describes the Kamakura of those days in which natural disasters, famines, and an epidemics occurred frequently, and where dead bodies of humans, cows, and horses, etc., filled the roads. After the Kamakura shogunate fell, the Muromachi shogunate was established

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in 1338 and lasted until 1573. The capital was moved to Kyoto from Kamakura, and ancient Kamakura gradually reduced in significance.

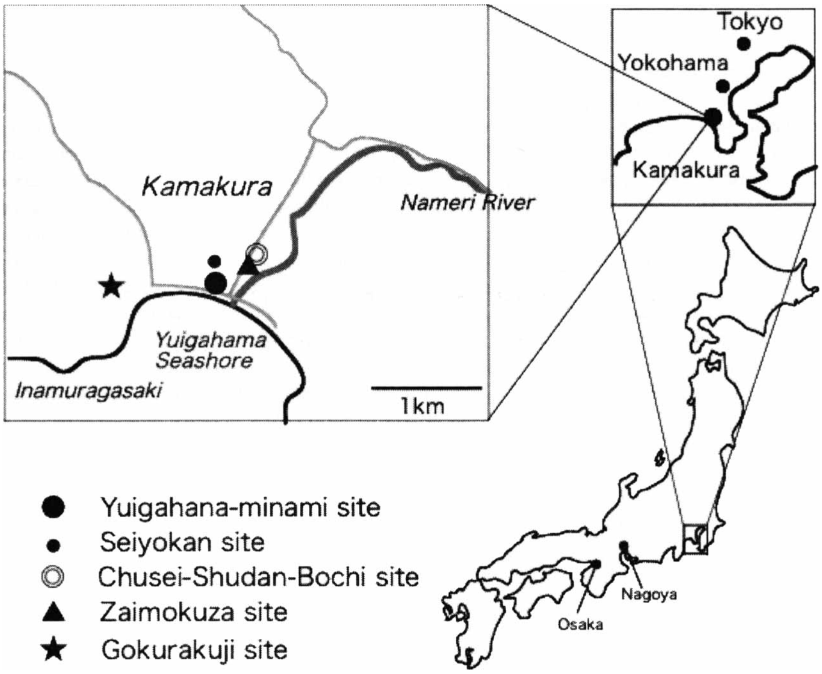

Figure 1 Map indicating geographical locations of Medieval sites of Zaimokuza, Gokurakuji, Yuigahama-minami, and Chusei-Shudan-Bochi in the Yuigahama area, Kamakura.

Table 1 Main incidents at Kamakura in the Kamakura period.

Year (AD)	Incidents[a]
1181	Yowa famine
1185	Establishment of the Kamakura shogunate
1192	Minamoto No Yoritomo becomes the shogun
1213	Wada Yoshimori's battle
1214	Strong wind and rain
1221	Jokyu disturbance
1231	Kangi famine
1241	Jinji earthquake (M7.0)
1247	Miura Yasumura's battle
1257	Shoka earthquake (M7.0)
1258	Shoka famine
1293	Kamakura earthquake (M7.1)
1333	Nitta Yoshisada's battle
1352	Ashikaga Takauji's battle
1433	Sagami earthquake (M7.1)

[a]M = magnitude of an earthquake.

Yuigahama is a beach of Kamakura city (Figure 1). Skeletons of more than 5000 individuals have been excavated from these Medieval archaeological sites in the Yuigahama area over the past 60 yr. The first systematic excavation was made in 1953 by the Anthropology Department, Faculty of Science, University of Tokyo, on the burial site at Zaimokuza. It was reported that more than 910 human skeletons were discovered in this excavation (Suzuki et al. 1956). Outside the old town of Kamakura, in Inamuragasaki, the remains of multiple burials were discovered at the Gokurakuji burial site, and about 1000 human skeletons were found (Suzuki 1998). Analysis of the human skeletons from the Zaimokuza and Gokurakuji sites revealed the following: 1) many skulls had cuts from swords or were pierced by arrowheads; 2) most of the dead were male adults; 3) females and children are also represented in the burial population, and these skeletons show evidence of sword cuts; and 4) there is evidence that the bodies were not buried immediately after death, and may have been lying exposed to rain and wind probably for a few weeks or a month until being reduced to a skeleton. From these observations, Suzuki et al. (1956) concluded that a battle occurred here on a very large scale. These human skeletons were presumed to belong to the ~6000 people who died in the attack by Nitta Yoshisada (Suzuki et al. 1956; Suzuki 1996, 1998). After the battle in 1333, Kamakura was temporarily in ruins, so the several thousand dead could not be buried and were left exposed. Their skeletal remains are thought to have been interred together in the Yuigahama area.

In recent years, further excavations have been carried out in this region: Seiyokan (excavated in 1992); Yuigahama-minami (excavated 1995–1997), a southern coastal Yuigahama site; and Chusei-Shudan-Bochi (excavated 2000–2001), a Medieval cumulative burial site (Figure 1). The burials can be divided roughly into 3 types: individual burials; multiple burials consisting of human skulls and whole bodies; and multiple mixed burials of human and animal skeletons (Figure 2). Based on the types of burials and their quantities among the sites, it has been suggested that individual burials may be related to status, while multiple burials could be those where a great number of bodies had to be buried due to epidemics, warfare, or natural disasters. In order to clarify the differences between the types of burial, it was necessary to study the morphology of the skeletons and conduct biomolecular studies (i.e. $\delta^{13}C$, $\delta^{15}N$), as well as to determine the radiocarbon ages of the skeletons. The purpose of the current research was to date human skeletons excavated from individual burials and mixed human-animal burials at the Yuigahama-minami site, and the multiple burials at the Chusei-Shudan-Bochi site. Our original questions were whether the dates of the skeletons differed by site, or whether the dates varied according to the type of burial at the same site, and whether the human skeletons excavated from sites in the Yuigahama area were those of the victims of Nitta Yoshisada's attack on Kamakura. However, the results of our $\delta^{13}C$ and $\delta^{15}N$ analyses suggest that a dietary offset may affect our ^{14}C dates. We also discuss the way in which we address marine effects on ^{14}C dating in the sites.

HUMAN SKELETON SAMPLES

The samples analyzed in this study were human bones excavated from individual burials and human and animal bones from mixed human-animal multiple burials of the Yuigahama-minami site, and human bones from multiple burials of the Chusei-Shudan-Bochi site.

The Yuigahama-minami site is located on the west bank of the Nameri River (Figure 1). It was excavated by the Kamakura Yuigahama Archaeological Research Group from 1995 to 1997 during construction of underground parking at the Kamakura Beach Park, adjacent to the coast of Yuigahama. Individual burials yielded 667 human skeletons, and injuries by sword cuts were found in 9 skeletons, 1.3% of the total (Hirata et al. 2002; Matsushita 2002). The human remains from individual burials are thought to have been buried immediately after death, or before the bones could be scattered (Hirata et al. 2004). The male to female ratio is 1:1, and the ratio of adults to subadults/children

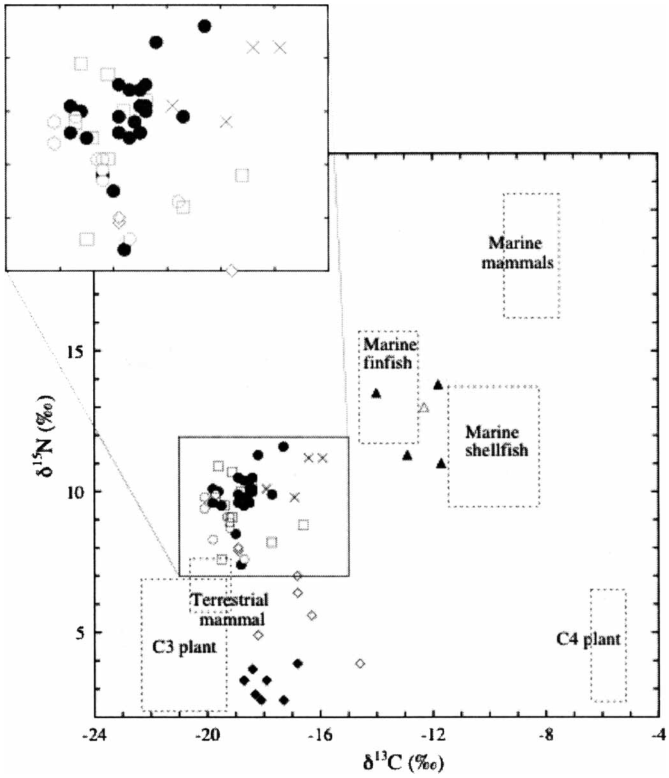

Figure 2 $\delta^{13}C_{VPDB}$ and $\delta^{15}N_{AIR}$ values for human and animal bones excavated from the Yuigahama-minami site and human bones from the Chusei-Shudan-Bochi site. Yuigahama-minami site: human bones from individual burials (open circle); human bones from mixed human-animal multiple burials (closed circles), horses (closed diamonds), cows (open diamonds), dogs (crosses), dolphins (closed triangles), and whale (open triangles). Chusei-Shudan-Bochi site: human bones from multiple burials (open squares).

is 2:1 (Nagaoka et al. 2006). There are also bones of elderly people, suggesting that the burials reflect the population at the time to some extent. The samples used for analysis from individual burials were human ribs.

Estimation of age at time of death for each human skeleton (Table 2) was by the macroscopic observation of crania, teeth, ribs, pelvis, and limb bones (Nagaoka et al. 2006). Skeletons were classified into 11 age categories: <1; 1–4; 5–9; 10–14; 15–19; 20–24; 25–34; 35–44; 45–54; 55–64; and 65 yr and over. Analysis of 260 human skeletons shows 98 subadults (<20 yr old) and 162 adults, indicating the short lives of the Yuigahama-minami humans. Sex determination of individuals aged 15 yr and older was carried out based on macroscopic assessment of pelvic features (Nagaoka et al. 2006).

In the mixed human-animal burials at Yuigahama-minami, 3108 skeletons of humans were recovered. Injuries were found in 68 skeletons, 2.2% of the whole (Matsushita 2002). Of the human skeletons, there are few torso bones, while the proportion of limb bones is high. The male to female ratio is about 2:1, and the burials are characterized by a high proportion of infants (Nagaoka and Hirata 2006). The human skeletons have bite marks from dogs at either end, suggesting that the corpses were exposed for some time after death. The skeletons are thought to have been scattered by dogs

Table 2 $\delta^{13}C_{VPDB}$ and $\delta^{15}N_{AIR}$ values and ^{14}C ages for human bones excavated from individual burials and mixed human-animal multiple burials of the Yuigahama-minami site. ^{14}C ages were calibrated using the Mixed Curves function in OxCal v 4.1 (Bronk Ramsey 2009) using the IntCal09 and Marine09 curves (Reimer et al. 2009), and the Marine% values estimated from IsoSource (Phillips and Gregg 2003).

Sample #	Sex	Age group	Gelatin yield (%)	C/N	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)	^{14}C ages (BP)	Lab # (NUTA2-)	Marine%	cal AD (1σ)
Human bones excavated from individual burials										
5A	M	15–19	7.7	3.2	−18.9	9.6	709 ± 40	12406	31	1320–1425
18B-1	F	25–34	9.2	3.2	−19.5	9.5	819 ± 39	12414	24	1260–1380
18B-2	M	25–34	7.8	3.2	−18.6	9.8	758 ± 40	12415	29	1301–1393
34	F	25–34	5.0	3.2	−19.2	8.8	649 ± 40	12416	24	1326–1439
63	F	25–34	4.9	3.2	−18.9	9.9	662 ± 41	12407	28	1329–1441
69	M	25–34	4.8	3.2	−18.7	9.5	691 ± 40	12408	28	1321–1426
94	F	25–34	4.7	3.2	−18.5	10.1	696 ± 39	12410	31	1325–1432
95	F	15–19	2.5	3.2	−18.4	10.1	793 ± 40	12430	31	1287–1390
100	F	25–34	2.5	3.2	−18.2	11.3	767 ± 30	10189	36	1315–1403
133	F	n.d.	2.4	3.2	−18.8	7.4	616 ± 39	12431	25	1404–1450
144	F	20–24	3.2	3.2	−18.5	9.6	624 ± 39	12411	29	1408–1455
150	F	35–44	4.2	3.3	−19.8	10.1	676 ± 31	10190	24	1322–1421
187	n.d.	10–14	3.7	3.2	−19.0	8.5	699 ± 40	12412	24	1314–1410
205	M	35–44	3.5	3.2	−17.7	9.9	695 ± 30	10191	35	1394–1441
249B	F	35–44	3.1	3.2	−19.6	10.0	684 ± 30	10192	24	1320–1415
255	F	54–64	3.1	3.2	−18.9	10.5	714 ± 30	10193	30	1320–1416
dupl.							724 ± 31	10222		1318–1411
259	n.d.	n.d.	8.3	3.2	−18.5	9.6	667 ± 39	12417	29	1325–1438
263	F	25–34	4.0	3.2	−19.8	9.6	635 ± 40	12419	22	1327–1440
272	F	54–64	3.8	3.2	−18.9	n.d.	780 ± 31	10194	n.d.	n.d.
279	M	15–19	4.9	3.2	−17.3	11.6	851 ± 39	12420	43	1288–1390
1030A	F	45–54	3.8	3.2	−18.7	10.4	829 ± 31	10207	30	1271–1382
1070	F	25–34	2.9	3.2	−18.5	10.4	680 ± 31	10198	32	1394–1441
1093	M	45–54	2.0	3.3	−18.4	10.5	706 ± 31	10199	32	1325–1427
5654	F	54–64	7.3	3.3	−18.4	10.0	739 ± 30	10200	31	1316–1405
dupl.							722 ± 31	10213		1319–1415
Human bones excavated from mixed human-animal multiple burials										
43B-207	n.d.	n.d.	6.3	3.2	−19.3	9.1	787 ± 32	10497	24	1278–1385
43-251	n.d.	n.d.	4.4	3.3	−20.1	9.4	785 ± 40	12386	21	1270–1385
44C-104	n.d.	n.d.	3.4	3.2	−19.2	8.7	792 ± 32	10498	23	1274–1383
44C-121	n.d.	n.d.	3.7	3.3	−18.7	7.6	804 ± 32	10499	26	1274–1384
44C-144	n.d.	n.d.	5.6	3.3	−20.1	9.8	824 ± 40	12387	22	1240–1303
44C-147	n.d.	n.d.	4.8	3.3	−19.8	8.3	767 ± 32	10503	31	1303–1392
270-51	n.d.	n.d.	5.9	3.3	−19.2	9.1	726 ± 32	10504	24	1306–1394
270-54	n.d.	n.d.	3.2	3.3	−19.7	9.9	766 ± 39	12388	24	1285–1388
270-55	n.d.	n.d.	5.0	3.3	−19.2	8.9	788 ± 32	10505	24	1277–1385

and other scavengers and the remaining fragmentary skeletons were buried together (Uzawa 2002; Ishida et al. 2003).

Many remains of various animals, including horses, cows, dogs, dolphins, and whales, in addition to humans, have been excavated from mixed human-animal burials (Nishimoto et al. 2002). In Medieval Kamakura, horses and cows were valued as a means of transportation and battle, and Buddhist practices limited the eating of terrestrial animal meat. Therefore, the Medieval Kamakura population was unlikely to have consumed the animal meats. Meanwhile, dolphins and whales could have been consumed when found stranded on the coast at Kamakura, though there was no custom of whaling. This is assumed from evidence of sword cuts and processing traces for some bones (Uzawa 2002).

The Chusei-Shudan-Bochi site is located northwest of the Nameri River mouth, and was excavated before the construction of apartments. The Zaimokuza site is located 100 m south of this site. The Chusei-Shudan-Bochi burial site was surveyed by the Archaeological Research Group of Yuigahama Chusei-Shudan-Bochi from 2000 to 2001, and 592 skeletons were excavated. Injuries were found in 8 skeletons, 1.4% of the whole (Hirata et al. 2002). The samples used for analysis were human skeletons excavated from multiple burials at sites 1, 3, 4, 6, and 7. The multiple comingled skeletal remains suggest that the bodies were exposed after death prior to formal burial. The ratio of males to females is 2:1, while that of adults to subadults is 5:1 (Nagaoka and Hirata 2006). Males comprise the larger proportion of remains, with fewer elderly represented.

It is worth noting that human skeletons excavated from the Yuigahama-minami and Seiyokan sites, located on the west bank of the Nameri River (Figure 1), and the Chusei-Shudan-Bochi and Zaimokuza sites, located on the east bank of the Nameri River (Figure 1), have different ratios of age and sex, as well as different type of burials.

ANALYTICAL METHODS

For accurate ^{14}C dating and measurement of stable carbon and nitrogen isotope ratios of fossil bones, it is necessary that the original isotope ratios of the bones are preserved, and that contaminating material from the soil surrounding the burial is eliminated. Bone carbonate is easily broken down in acid soil, and exogenous carbon from humic acids in burial soil can contaminate bone protein. Therefore, chemical treatment of the bone samples prior to dating is important. The following describes the method used to prepare the bone samples.

After stains were removed from the surface of the bone samples with a dental drill, the samples were subjected to repeated ultrasonic cleaning in ultrapure water. After further ultrasonic cleaning in 0.2M sodium hydroxide (NaOH) in aqueous solution, samples were washed in ultrapure water and freeze-dried. The bone samples were then pulverized using a stainless steel mortar, and the powdered bone samples were placed in plastic tubes for decalcification using 0.6M hydrochloric acid (HCl). The contents were centrifuged, and the insoluble decalcified components were treated with 0.1M NaOH aqueous solution to remove exogenous carbon such as humic acids (Minami et al. 2004). Gelatin was then extracted from the insoluble components for 12 hr with slightly acidic (pH ~3) water at 90 °C. The solution was centrifuged, and the supernatant fluid was separated and freeze-dried to obtain the gelatin component.

The gelatin was combusted in vacuum-sealed glass tubes (4 hr at 850 °C). N_2 gas produced from the combustion reaction was collected over molecular sieves (Minami et al. 1998). The CO_2 gas produced was purified cryogenically, and then an aliquot of the CO_2 gas was reduced to graphite by H_2 with Fe catalyst at 620 °C for 8 hr in a sealed quartz tube. The graphite was pressed into an aluminum target and ^{14}C dated using an accelerator mass spectrometer (HVEE Tandetron AMS) at Nagoya University. The other aliquots of the CO_2 and N_2 gases were used to measure the carbon and nitrogen stable isotope ratios ($\delta^{13}C_{VPDB}$ and $\delta^{15}N_{AIR}$ values) with a gas mass spectrometer (Finnigan MAT-252). The C/N ratio was measured using an elemental analyzer (Thermo Quest NA25009) with the subsamples of gelatin sealed in a tin capsule. For ^{14}C dating, the $^{14}C/^{12}C$ isotope ratio contained in the sample carbon was standardized against the $^{14}C/^{12}C$ ratio of the reference sample oxalic acid (NIST SRM 4990C). Correction of carbon isotopic fractionation was performed using the $\delta^{13}C_{VPDB}$ value measured by AMS.

RESULTS AND DISCUSSION

Tables 2, 3, and 4 present atomic C/N ratios, $\delta^{13}C_{VPDB}$ and $\delta^{15}N_{AIR}$ values, and ^{14}C ages for human bones excavated from individual burials and mixed human-animal multiple burials of the Yuigahama-minami site, human bones excavated from multiple burials of the Chusei-Shudan-Bochi site, and animal bones excavated from mixed human-animal multiple burials of the Yuigahama-minami site, respectively.

Table 3 $\delta^{13}C_{VPDB}$ and $\delta^{15}N_{AIR}$ values and ^{14}C ages for human bones excavated from multiple burials of the Chusei-Shudan-Bochi site. ^{14}C ages were calibrated using the Mixed Curves function in OxCal v 4.1 (Bronk Ramsey 2009) using the IntCal09 and Marine09 curves (Reimer et al. 2009), and the Marine% values estimated from IsoSource (Phillips and Gregg 2003).

Sample #	Gelatin yield (%)	C/N	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)	^{14}C ages (BP)	Lab # (NUTA2-)	Marine%	cal AD (1σ)
1–83	2.4	3.2	–19.4	9.5	859 ± 30	10201	24	1240–1285
2–116	5.3	3.2	–19.7	9.8	934 ± 40	12400	23	1171–1257
3–116	5.6	3.2	–18.4	10.2	911 ± 40	12402	32	1224–1281
3–117	3.2	3.2	–19.6	10.9	884 ± 31	10202	27	1230–1280
4–146	2.1	3.2	–17.7	8.2	866 ± 40	12403	32	1241–1309
4–160	4.0	3.3	–19.1	10.7	864 ± 30	10205	29	1253–1297
5–170	3.6	3.2	–18.8	10.0	911 ± 40	12404	29	1218–1277
6–210	2.4	3.2	–16.6	8.8	889 ± 31	10206	38	1259–1308
6–217	3.2	3.2	–19.5	7.6	737 ± 40	12405	21	1291–1391
7–23	2.1	3.2	–19.1	9.1	864 ± 31	10197	25	1238–1285

C/N ratios for the bone were between 3.2–3.3, and thus within the acceptable range of 2.9–3.6 for well-preserved protein (DeNiro 1985). The collagen yields were acceptable at more than 1% (cf. van Klinken 1999; Minami et al. 2004) with a mean value of 4.6 ± 2.0% for individual burials, 4.7 ± 1.1% for mixed human-animal multiple burials from the Yuigahama-minami site, and 3.4 ± 1.3% for the Chusei-Shudan-Bochi site burial (at 1 SD). This suggests that well-purified collagen was extracted through our chemical treatment of bones and that diagenetic effects did not influence the $\delta^{13}C_{VPDB}$ values, $\delta^{15}N_{AIR}$ values, and ^{14}C ages.

^{14}C age errors are reported at 1σ, while $\delta^{13}C_{VPDB}$ and $\delta^{15}N_{AIR}$ value errors are ±0.1‰. Calibration for the ^{14}C results was performed using the program OxCal v 4.1 (Bronk Ramsey 2009) and the Mixed Curves function, using the IntCal09 and Marine09 data set (Reimer et al. 2009). The value of Marine% in Tables 2 and 3 was estimated by the IsoSource program developed by Phillips and Gregg (2003) for reconstructing diet. We used IsoSource instead of the IsoConc concentration-weighted mixing model of Phillips and Koch (2002), which does well using isotopic composition, elemental concentrations, and biomass for each food source to determine the proportional dietary contributions of C and N, but only 3 diet sources can be used for the proportional estimation. Calibrated ^{14}C age ranges were calculated using the Mixed Curves method with calibration data from IntCal09 and Marine09 curves (Reimer et al. 2009) and a local reservoir offset (ΔR) of 80 ± 33 yr for the sea around Kamakura (Shishikura et al. 2007).

Investigating Diet with $\delta^{13}C$ and $\delta^{15}N$ Values

The isotopic ratios of carbon and nitrogen in bone collagen can be used to estimate the intake of food resources when a human or animal was alive. The carbon and nitrogen isotopic composition of biotic resources in nature are known to have a fairly wide distribution range. The variation in carbon is in part due to the isotopic fractionation from various photosynthesis cycles of plants (plant C_3,

Table 4 $\delta^{13}C_{VPDB}$ and $\delta^{15}N_{AIR}$ values and radiocarbon ages for animal bones excavated from mixed human-animal multiple burials of the Yuigahama-minami site. ^{14}C ages were calibrated using the mixed curves function in OxCal v 4.1 (Bronk Ramsey 2009) using IntCal09 and Marine09 curves (Reimer et al. 2009), and the Marine% values (closed shape) estimated from IsoSource (Phillips and Gregg 2003).

Sample #	Gelatin yield (%)	C/N	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)	^{14}C ages (BP)	Lab # (NUTA2-)	Marine%	Calibrated age range (1σ)
Terrestrial herbivore								
Horse								
43B-143	2.7	3.2	−16.8	3.9	793 ± 32	10490	0	1220–1264
44C(12)	1.5	3.3	−18.3	2.8	734 ± 30	12484	0	1261–1287
44C-65	1.9	3.2	−18.4	3.7	817 ± 30	12485	0	1210–1261
270-50	2.0	3.2	−17.3	2.6	818 ± 30	12487	0	1210–1261
5112	4.4	3.2	−18.7	3.3	793 ± 39	12395	0	1218–1268
Ta-174	2.5	3.3	−17.9	3.3	731 ± 30	12489	0	1262–1287
Ta-175	2.6	3.4	−18.1	2.6	709 ± 30	12491	0	1267–1295
Cow								
44C-161	2.8	3.2	−18.9	7.9	745 ± 30	12393	0	1253–1285
44C-14	3.0	3.2	−16.8	6.4	702 ± 32	10487	0	1270–1377
270-A	3.1	3.2	−18.6	3.9	731 ± 33	12486	0	1259–1290
5385-44	3.4	3.3	−16.8	7.0	682 ± 33	10495	0	1277–1383
5385-67	3.5	3.3	−18.9	8.0	766 ± 39	12396	0	1225–1277
Ta-20	1.9	3.3	−18.2	4.9	782 ± 39	12399	0	1222–1270
Ta-105	3.4	3.2	−16.3	5.6	749 ± 33	10486	0	1230–1284
Terrestrial carnivore (*Dog*)								
44C(16)	3.2	3.2	−16.9	9.8	990 ± 40	12394	42	1194–1274
44C-A18	3.5	3.3	−15.9	11.2	934 ± 32	10489	52	1267–1380
1018	2.7	3.3	−15.9	11.2	928 ± 33	10488	52	1270–1384
5385(19)	3.9	3.4	−17.9	10.1	917 ± 40	12397	44	1245–1315
Ta-96	2.4	3.3	−16.4	11.2	1031 ± 30	12488	50	1205–1270
Marine mammal								
Dolphin								
5385(8)	4.6	3.2	−14.0	13.5	1426 ± 32	10491	100	955–1185
5652	6.0	3.2	−11.7	11.0	1193 ± 39	12398	100	1185–1390
5685-7	5.0	3.3	−12.9	11.3	1279 ± 33	10496	100	1085–1294
Ta(1)	2.3	3.2	−11.8	13.8	1395 ± 33	10483	100	999–1210
Whale								
Ta(2)	1.2	3.2	−12.3	13.0	1350 ± 32	10484	100	1036–1242

plant C_4, plant CAM). For nitrogen, differences result from the ways that plants obtain nitrogen, as well as the isotopic enrichment in the foodchain (Minagawa 1993).

Figure 3 shows the distribution of $\delta^{13}C$ and $\delta^{15}N$ values for food resources and for bone protein from human and animal burials in the archaeological sites. The $\delta^{13}C$ and $\delta^{15}N$ values of regional food resources (based on Yoneda et al. 2004) have been adjusted by +4.5‰ $\delta^{13}C$ and +3.4‰ $\delta^{15}N$ (cf. Ambrose 1993) to reflect what the carbon and nitrogen values of these food resources would be after consumption and metabolic isotopic enrichment of the $\delta^{13}C$ and $\delta^{15}N$ values (DeNiro and Epstein 1981; Ambrose and DeNiro 1986). In Figure 3, these food ranges are enclosed in rectangles, and provide a reference for the $\delta^{13}C$ and $\delta^{15}N$ values for the gelatin extracted from the human and animal bones from the Yuigahama-minami site and the human bones from the Chusei-Shudan-Bochi burial site. The human bone samples from the sites plot between marine fish and C_3 plants, indicating that the people buried in the Yuigahama area ate marine foods as well as terrestrial vegetation.

Table 5 Food sources and isotopic data used in the IsoSource program: 1) Isotopic data of C_3 and C_4 plants, and modern marine finfish bone and shellfish cited from Yoneda et al. (2004: Table 3) and corrected for the Suess effect. 2) Isotopic data from bone for marine mammals, terrestrial carnivores, and terrestrial herbivores are averages of values for dolphins and whale, dogs and horses, and cows in this study. For the food sources, metabolic isotopic enrichment of +4.5‰ $\delta^{13}C$ and +3.4‰ $\delta^{15}N$ was taken into consideration.

Food source	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)
C_3 plant[1]	–25.4	1.2
C_4 plant[1]	–10.0	1.0
Marine finfish[1]	–18.2	10.4
Marine shellfish[1]	–14.3	8.3
Marine mammal[2]	–12.5	12.5
Terrestrial carnivore[2]	–16.6	10.7
Terrestrial herbivore[2]	–17.9	4.7

The $\delta^{13}C$ and $\delta^{15}N$ plots for the terrestrial carnivores (dogs) are distributed in a similar range to those of the Kamakura humans, suggesting that dog and human diets were similar. The terrestrial herbivores (cows and horses) have $\delta^{13}C$ that is enriched relative to the value range expected for terrestrial mammals as cited in Yoneda et al. (2004). The enriched $\delta^{13}C$ values for cows and horses suggest that their diet included C_4 as well as C_3 plants and is different from the consumption of almost only C_3 plants for humans in the same burials. Furthermore, cows have more enriched $\delta^{15}N$ values and could have been fed on marine-sourced plant foods in addition to C_4 and C_3 terrestrial plants. The feeding of seaweed as fodder for terrestrial herbivores is reported at coastal sites (e.g. Britton et al. 2008), and this may apply to the cows buried at the coastal site in Yuigahama. Further work on C and N isotope values for terrestrial herbivores in this region is needed to determine the apparent differences in diet between horses and cows, and the reason for the enriched $\delta^{15}N$ values for cows.

For the IsoSource analyses, 7 food sources (C_3 plants, C_4 plants, marine finfish, marine shellfish, marine mammals, terrestrial carnivores, and terrestrial herbivores) were used for reconstructing the paleodiet of the Kamakura human skeletons (Table 5). The $\delta^{13}C$ and $\delta^{15}N$ values for C_3 and C_4 plants, marine finfish, and marine shellfish are taken from Yoneda et al. (2004:103; Table 2). The isotopic data of marine mammals, terrestrial carnivores, and terrestrial herbivores used are averages of the measured values for dolphins and whale, dogs, and horses and cows from the sites under consideration. Marine% values given in Tables 2 and 3 were determined by the total % of marine finfish, marine shellfish, and marine mammal using the isotope mixing IsoSource program. The Marine% values for dogs in Table 4 were determined by the same method. The $\delta^{13}C$ and $\delta^{15}N$ values for the human bones of both the Yuigahama-minami site and Chusei-Shudan-Bochi site are distributed over a small range, but the $\delta^{15}N$ values of the bones from individual burials in the Yuigahama-minami site tend to be higher than those of the mixed human-animal multiple burials. The average values in the individual burials at 1 SD for $\delta^{13}C$ was −18.7 ± 0.6‰, and the average $\delta^{15}N$ value was 9.9 ± 0.9‰, while those of the mixed human-animal burials were −19.5 ± 0.5‰ and 9.0 ± 0.7‰. The estimated Marine% by the IsoSource model for human bone is 29 ± 5% from the individual burials and 24 ± 3% from the mixed multiple burials. Meanwhile, the average values of $\delta^{13}C$ and $\delta^{15}N$ in multiple burials in the Chusei-Shudan-Bochi site were −18.8 ± 1.0‰ and 9.5 ± 1.1‰, for carbon and nitrogen, respectively, and the estimated Marine% by the IsoSource model was 28 ± 5%. The values are similar to those of the individual burials in the Yuigahama-minami site, though the deviations are a little larger. These results suggest that the humans from the individual burials ate more marine-sourced food than the humans from mixed multiple burials, and more

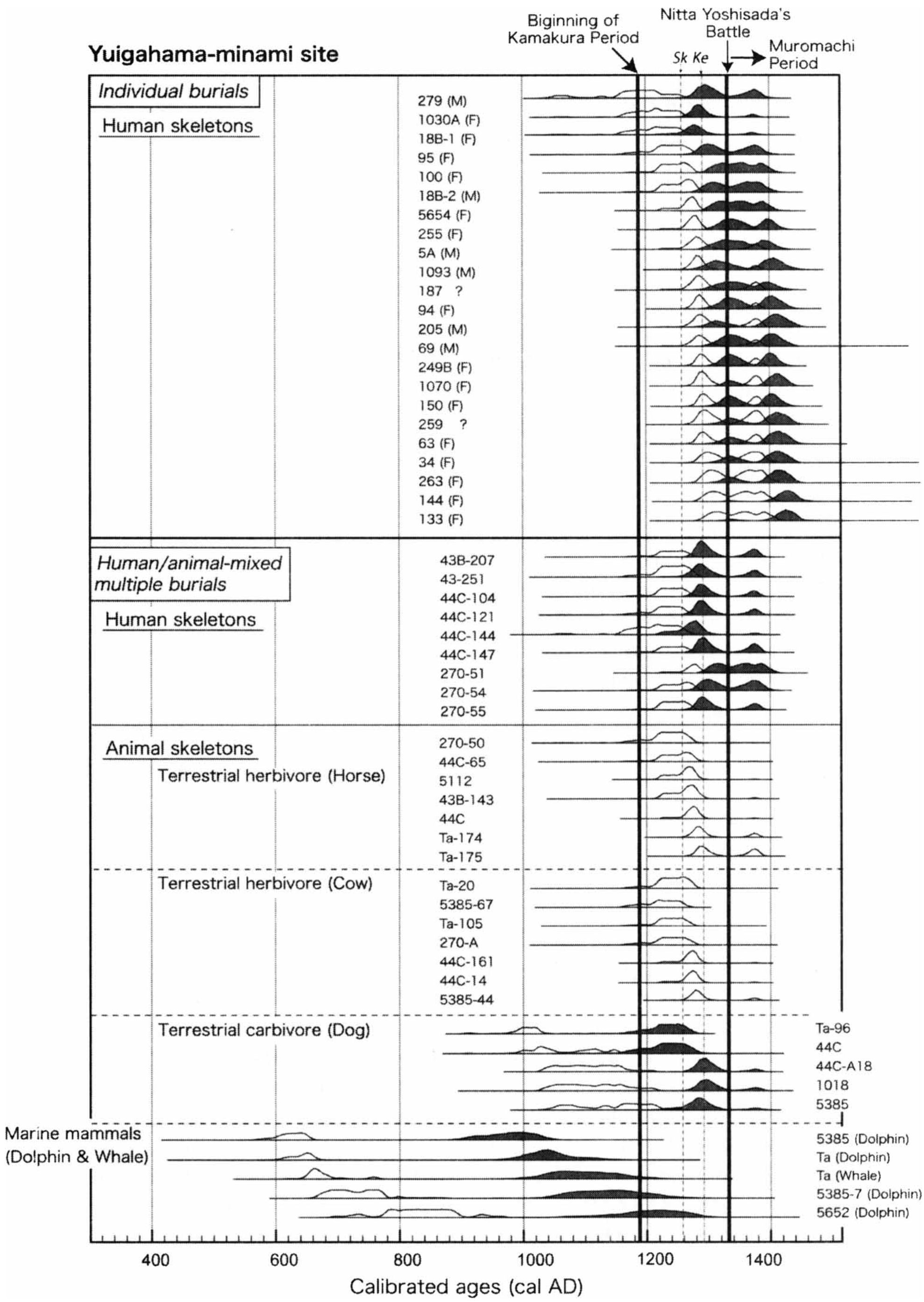

Figure 3 Calibrated ages for human and animal bones excavated from the Yuigahama-minami site. Calibrated ages determined using the IntCal09 data set (outlined), as well as calibrated ages determined by the Mixed Curves function in OxCal v 4.1 (Bronk Ramsey 2009) with a combination of IntCal09 and Marine09 curves (Reimer et al. 2009), and the Marine% values estimated from IsoSource (Phillips and Gregg 2003). "Sk" denotes the Shoka earthquake in AD 1257 and "Ke" marks the Kamakura earthquake in AD 1293.

importantly, that differences in diet in the humans appear to be associated with the type of burial (i.e. individual versus mixed burial) in the same site.

We also consider other factors, such as diagenesis, that might affect the isotopic values. The carbon and nitrogen percentages of the human samples from individual burials (24 and 9 wt% respective averages) are lower than for those from mixed burials (30 and 11 wt% respective averages). Visually, bones from the individual burials are thin and brown and bones from the mixed burials are robust and yellowish-white, and may indicate poor preservation in the bones from the individual burials. Diagenesis is known to degrade amino acids such that the light nitrogen is lost and the $\delta^{15}N$ value of the remaining amino acids can show enrichment (Silfer et al. 1992; Minami and Nakamura 2005). While there is less than 1‰ difference between the $\delta^{15}N$ values for the bones from individual burials and the mixed burials, we must consider that diagenesis could affect these values. Further research, such as analysis of the amino acid composition, is necessary in relation to this question.

From the IsoSource analyses, the humans buried in the Yuigahama region appear to have consumed mainly C_3 plants and marine-sourced protein (Figure 2). This diet estimation does have a basis in fact from the historical record. During the Medieval period in Japan, Buddhist practices limited the eating of meat and thus terrestrial animal protein was not a great part of the diet. The lack of terrestrial animal protein in the diet may also be found in skeletal evidence. Nagaoka and Hirata (2006) reported the Kamakura Medieval people have the smallest tooth size among the post-Jomon (Yayoi, Kofun, Edo, and modern period) people of mainland Japan, and suggested that this may be the result of diet (i.e. malnutrition) based on the observation that tooth size varies according to nutrition and hygiene (Suzuki 1993).

Radiocarbon Dating

Tables 2, 3, and 4 and Figures 3 and 4 show the calibrated ^{14}C results for bone gelatin samples from humans, terrestrial herbivores (cow and horse), terrestrial carnivore (dog), and marine mammals (dolphin and whale) excavated from the Yuigahama-minami and Chusei-Shudan-Bochi sites. The plotted results show the calibration of each age shown both as outlined shapes using only the IntCal09 data set, and the calibration of the human, terrestrial carnivore, and marine mammal bone results shown as filled shapes using the IntCal09 and Marine09 Mixed Curves method and the Marine% values with assumed errors of ±5%.

The dolphin and whale dates calibrated by IntCal09 are older than the human dates by 400 to 600 yr. When the dolphin and whale dates are calibrated by the Mixed Curves method using a Marine% value of 100% and ΔR of 80 ± 33 yr, the results are still older than the dates of humans and terrestrial herbivores by a up to ~200 yr. Our use of the average value of ΔR 80 ± 33 yr in this study for calibration of all samples could be the reason for this. Marine mammals such as dolphins and whales likely came from different ΔR regimes. There is a wide range of ΔR values for possible whale and dolphin migration areas than the one cited for our estimation of human diet; for example, Shishikura et al. (2007) reported various ΔR values of 40 to 250 yr in the sea around Kamakura.

When calibrated by the Mixed Curves function of OxCal v 4.1 (Bronk Ramsey 2009) and the IntCal09 and Marine09 curves (Reimer et al. 2009), the human skeletons from individual burials at the Yuigahama-minami site mainly date to the latter phase of the Kamakura period (~1290–1333) or the early Muromachi period (1394–1450). The humans could therefore be victims of the Kamakura earthquake in 1293 or Nitta Yoshisada's battle in 1333. We believe it is more likely that they died from a natural disaster due to the normal ratios of males to females and adults to subadults (<20 yr old) of the individual burials, rather than from a battle that may have shown higher incidence of male and fewer elderly.

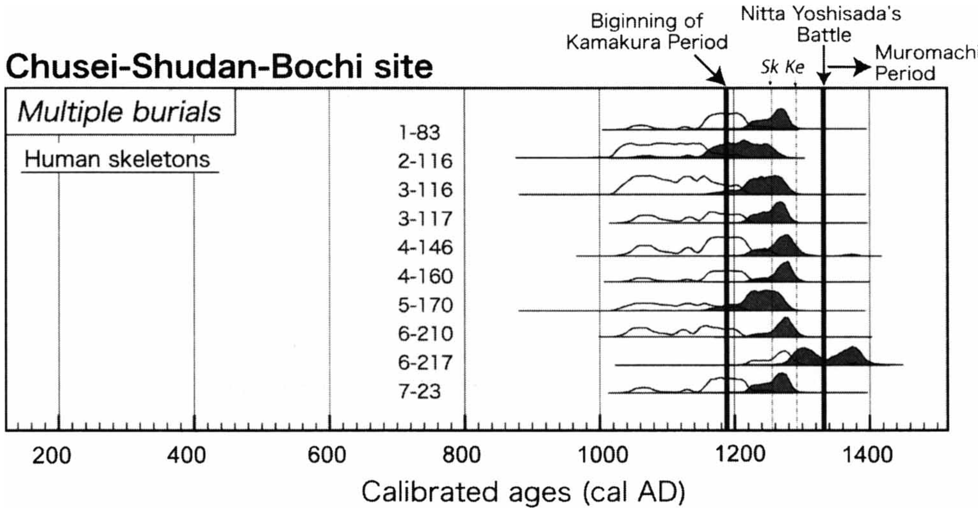

Figure 4 Calibrated ages for human bones excavated from the Chusei-Shudan-Bochi site. Calibrated ages only by IntCal09 data set (outlined) and the Mixed Curves function of OxCal v 4.1 (Bronk Ramsey 2009) using the IntCal09 and Marine09 curves (Reimer et al. 2009), with Marine% values (shaded) estimated from IsoSource (Phillips and Gregg 2003).

The humans from mixed human-animal burials date to the mid- to late Kamakura period. Their ^{14}C results can be combined by the "Combine" function of OxCal v 4.1, and give a combined date of AD 1288–1304 (68.2%). This suggests that the humans from the mixed multiple burials could be victims of the Kamakura earthquake in 1293. Because of the mass deaths due to the earthquake, Kamakura was temporarily in ruins, so many of the dead may not have been buried immediately. Another indicator that these burials are from a natural disaster is the sediment records in the Yuigahama region, Kamakura, which show that a catastrophic tsunami resulted from the Kamakura earthquake (Iida 1984). The terrestrial herbivores (horses and cows) have older ^{14}C ages than the humans in the mixed human-animal burials. The terrestrial carnivore (dog) also tends to have slightly older ages when calibrated by the Mixed Curves method (Figure 3). Therefore, some of the animals could have predated the human death. As described in "Azuma Kagami," dead bodies of humans and animals were scattered along the roads in Kamakura, especially after the Shoka famine in 1258. It is possible that a mass of victims from the Kamakura earthquake were buried together with scattered animal bodies that died before or after the earthquake.

The human bones excavated from the multiple burials at the Chusei-Shudan-Bochi site date to the middle Kamakura period, and may have been buried at nearly the same time. Excluding samples 2-116 and 6-217 that show poor agreement, the ^{14}C results for the human bones can be combined by the "Combine" function of the OxCal v 4.1 program, resulting in a date of AD 1238–1286 (68.2%). The result suggests that most of the bones in the multiple burials at the Chusei-Shudan-Bochi site are likely those of people who died in the large earthquakes in 1241 or 1257, or the Shoka famine in 1258–1260 in the middle of the Kamakura period. Multiple burials have a larger proportion of adult males (Nagaoka and Hirata 2006), but the ratio of skeletal injuries was small (Hirata et al. 2002). Therefore, it is more likely that they died did not die in battle but due to earthquakes or famines.

The different ^{14}C results from sites with both multiple and individual burial styles are not surprising due to the long-term human habitation of the area. Historical records such as "Shinpen Sagami no Kuni Fudoki" indicate that the Yuigahama area was used from before the Middle Ages as both a known settlement site and cemetery site (Saiki 2002). ^{14}C ages from the multiple burials at the

Yuigahama-minami and Chusei-Shudan-Bochi sites suggest that both sites were used intensively as a burial place for a short period of time, but that individual burials at the Yuigahama-minami site were used for burials for a relatively long time. In the Kamakura period, many catastrophic earthquakes occurred near Kamakura accompanied by big tsunami, and severe famines occurred repeatedly. Moreover, large numbers of deaths during catastrophic events (warfare, natural disasters, famines, and other causes) in the Yuigahama-minami and Chusei-Shudan-Bochi sites often resulted in mass-burial practices.

CONCLUSION

When ^{14}C results from individual burials and mixed human-animal burials from the Yuigahama-minami site and the multiple burials from the Chusei-Shudan-Bochi site are corrected for marine reservoir effects, the individual burials date to a wide date range of the last phase of the Kamakura period to the early Muromachi period. The mixed human-animal burials date to the latter of the Kamakura period, and multiple burials excavated from the Chusei-Shudan-Bochi site date from the middle Kamakura period. The human bones from the mixed human-animal multiple burials could be victims of the Kamakura earthquake in 1293, which was accompanied by a catastrophic tsunami. The bones in the multiple burials at the Chusei-Shudan-Bochi site could be those of people who died through earthquakes and famines, such as the Shoka earthquake in 1257 and the Shoka famine in 1258. The individual burials at the Yuigahama-minami site could be victims of Nitta Yoshisada's battle in 1333, but were more likely to have died natural deaths.

Within the same site, human bones in different burial types produce different dates. From the small range of ^{14}C ages in the human bones from mixed burials and multiple burials relative to the range of ages from individual burials, we believe that mixed and multiple burials show the interment of large numbers of victims from natural disasters or famines. Morphological examination of human bones excavated from multiple burials suggests the corpses were not immediately buried after death, and the bones were scattered by dogs or other animals. Human bones from multiple and mixed burials date from the time of known earthquakes and famines occurring in the Medieval Kamakura period. Stable isotope and ^{14}C results from the individual burials at Yuigahama-minami indicate that these people may have had a greater amount of marine-sourced food in their diets than people buried in mixed graves. Whether this was due to differences in status or in practice is an issue that requires further research.

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