Chronospatial variation of dental size of Holocene Japanese wild pigs (Sus scrofa leucomystax)

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The lower teeth of the Japanese wild pigs (Sus scrofa leucomystax) from various geographical locations both archaeological and modern were investigated. Buccolingual measurements of the lower third and fourth premolars, and first and second molars are used to compare the regional and temporal differences in dental size of pigs in the Japanese Archipelago.

Similar geographical variations in size of Jomon and modern wild pigs in Japan are observed in our study. The size of pigs from northern localities are larger compared to those from southern localities. Populations from Kyushu are distinctively small in dental size compared to the Honshu in both the Jomon and modern populations. A different pattern is observed in the Yayoi samples. The pigs from the Yayoi Period show a west–east cline in their size where the populations in the west being larger than those of east. Interestingly to note is that the size of pigs are significantly different between the sites in the northern Kyushu as well as in the western Honshu. The variation in a single region exceeds the geographical variations observed in the Jomon or in the modern samples. We can suppose that most of these individuals were brought in from outside the Archipelago. It is a necessity to understand the variation of the modern and archaeological pigs in the Asian continent in order to further discuss the issue morphometrically.

Keywords: Japanese wild pig, Sus scrofa leucomystax, geographical variations, temporal change, human interference

I. Introduction

This study focuses on Japanese wild pigs (Sus scrofa leucomystax) and the formation process of geographical variations in their size and morphology in the Japanese Archipelago. Today the Japanese wild pigs inhabit on main islands of Japanese Archipelago (Honshu, Shikoku, and Kyushu but not on Hokkaido). They show a large geographic variability in their size and also in their morphology. Most of the morphological studies on skulls and body of the mandibles of modern populations have been done by Hayashi (1974MS) and Endo et al. (1994, 1998 a, b, 2000). They stated that the populations in north show larger size compared to the ones in south and there seems to be a cline where the size of bones gradually becomes smaller from north to south of the Japanese Archipelago.

The comparison of size and morphology of
pigs between the Jomon and the Yayoi samples have been done by Nishimoto (1989a, b, 1990, 1991a, b, 1992a, b, 1993), Anezaki (1999, 2003), Nishinakagawa (1999) and Ozawa (2001). Nishimoto (1993) compared the mesiodistal and buccolingual crown measurements of upper and lower third molars of the pigs from the Jomon (Tagara, Sambu-ubayama, Torihama, Ikawazu) and the Yayoi (Asahi, Karako, Shimogori, Nabatake) sites. He stated that the size of third molar is basically larger in the Jomon specimens compared to the Yayoi and modern samples. He also noted that there were some exceptions in the Yayoi sites such as Nabatake and Yoshinogari in which the size of molars of pigs was larger than the Jomon comparatives.

The size of lower third molar gradually decrease in the size from the Jomon, Yayoi to modern specimens, whereas the rapid decrease in the size of upper third molar was observed from the Jomon to Yayoi Periods. The size of upper third molar from Yayoi sites was even smaller than the modern comparatives in many cases. Therefore, Nishimoto (1989a, b, 1990, 1991a) came to the conclusion that there were domesticated pigs during the Yayoi Period.

On the other hand, the variation in the size of third molar was also observed in the Yayoi sites; the size of Nabatake is especially noted because some of the specimens were larger than the Jomon comparative. Based on these results, Nishimoto (1989a, b, 1990, 1991a) concluded that it is highly possible that several types of pigs were introduced from the Chinese continent along with rice cultivation and during the Yayoi Period.

However, Nishinakagawa (1999) and Ozawa (2000, 2001) reported that the morphological variations of pigs from Shimogori, Nabatake and Asahi sites were within the range of the modern and Jomon comparatives from the Kyushu Island. They concluded that although there is a possibility of indigenous local domestication of pigs, no domesticated pigs were introduced to these sites from the Asian continent.

Pigs show a large geographic variability both in their size and in their morphology. It is needed to understand the geographical variations of both the modern and the Jomon specimens in the Japanese Archipelago in order to evaluate a nature of the Yayoi specimens. Selecting the measurements, such as buccolingual crown diameter, that are less affected by the age of an individual is also important, because the assemblage is comprised of mostly the individuals without third molar fully erupted at most of the sites (Anezaki, 1999, 2004MS).

Therefore, the primary aim of this study is to examine and compile data on the regional and temporal variations of the size and morphology of the Japanese wild pigs of the Jomon Period, the Yayoi Period, the Kofun–Heian Period and the modern populations. The regional variations in the size of pigs are investigated using pigs from the Jomon Period (10,000 – 2,500 calBP), the Yayoi Period (2,500 – 1,700 calBP) and the modern populations. The temporal change in the size of pigs is investigated using pigs from the Jomon Period, the Yayoi Period and Kofun–Heian Period (1,700 – 765 calBP) in the southern Kanto region of Japan. The long span of the occupation of humans in the region enables us to examine and evaluate the effect of human-animal interaction on the animals.

II. Materials and methods

The materials used in this study are the archaeological pig remains from the Jomon Period to the Kofun–Heian Period sites and the modern pig specimens in the island of Honshu and Kyushu of the Japanese Archipelago (Fig. 1).

Crown width diameter were taken on the third and fourth premolars (P3W, P4W) and on the mesial cusp (M1M, M2M) and distal cusp (M1D, M2D) of first and second molars of the mandible (Fig. 2). The buccolingual measurements are less influenced by the attrition between teeth where as mesiodistal measurements become significantly small through age (Kuşatman, 1991; Anezaki, 2002).

The each of the crown width diameter was compared to the corresponding dimensions of a standard population using logarithmic ratio technique (LSI value : Simpson, 1941). The “standard” population used in this study is a collection of 26 modern wild pig specimens from Kanagawa Prefecture, southern Kanto region, currently stored at Kanagawa Prefectural Museum of Natural History. LSI value of the
Chronospatial variation of the Japanese wild pigs

Measurement is positive, the size of the specimen is larger than the standard, and if negative, the size is smaller than the standard.

First, the regional variation in the size of pigs in the modern specimens (specimens from The University of Tokyo, National Museum of Nature and Science, National Museum of Japanese History, and Gunma Museum of Natural History) is investigated using 10 populations from the island of Honshu and Kyushu. Then, the regional variation in the size of pigs is investigated in the Jomon and the Yayoi Periods using materials from 25 sites and compared with the modern wild populations. The temporal change in the size of pigs from the Jomon to Kofun–Heian Period is investigated using ma-
materials from 10 sites in the southern Kanto region. Since modern pig populations show a large geographic variability in their size and also in their morphology (Endo et al., 1994, 1998 a, b, 2000), it is important to select study materials that are less influenced by climatic and geographic factors. The southern Kanto region is selected because it is well known for the richness of both dry and wet sites.

III. Results

1. The geographical variation in the modern specimens

Figure 3–a summarizes the log index data of pig teeth measurements of the modern specimens. The regional variation is observed in the modern populations. The size of pigs from Kyushu is significantly small ($t = -20.546, p = 0.000$) compared to those of Honshu.

2. The geographical variation in the Jomon remains

A similar cline is observed in the Jomon specimens (Fig. 3–b). The specimens from the Earliest Jomon and the Early Jomon Periods were used to investigate the regional variation.

The specimens from the northern Tohoku region are the largest in size compared to any other samples from the Honshu and Kyushu. On the other hand, the specimens from northern Kyushu are significantly smaller (Tohoku: $t = 9.353, p = 0.000$, Hokuriku: $t = 5.825, p = 0.000$, southern Kanto: $t = 4.052, p = 0.000$, Kinki: $t = 4.507, p = 0.000$) compared to any specimens from the Honshu region.

Pigs from Hokuriku are significantly larger than the pigs from southern Kanto region ($t = 5.237, p = 0.000$), and the specimens from Kinki and southern Kanto are similar in size.

3. The geographical variation in the Yayoi remains

Figure 3–c shows variation in the size of pigs during the Yayoi Period across the Kyushu and Honshu islands of the Japanese Archipelago.

Significant variation in the size of pigs is observed in both the northern Kyushu and the western Honshu regions. In the northern Kyushu region, the specimens from Yoshinogari are significantly larger compared to those from Sasai ($t = 3.751, p = 0.001$) and Shimobayashi ($t = 3.982, p = 0.000$). Nabatake and Shimogori specimens fall within the range of the Jomon samples from northern Kyushu region (cf. Fig. 3–b), and Sasai and Shimobayashi specimens fall outside the range of the Jomon samples from Kyushu.

In the western Honshu region, the specimens from Shimpo are significantly larger compared to those from Kadota ($t = 4.136, p = 0.000$, Tsuboi ($t = 6.033, p = 0.000$), and Asahi ($t = 5.223, p = 0.000$).

All of the specimens from western Honshu are significantly larger (Kadota: $t = -5.794, p = 0.000$, Shimpo: $t = -11.375, p = 0.000$, Tsuboi: $t = -2.637, p = 0.000$, Asahi: $t = -7.459, p = 0.000$) than the modern specimens from Hyogo Prefecture (Fig. 3–a). Shimpo specimens fall within the size range of Sasai and Shimobayashi of northern Kyushu. On the other hand, Kadota and Asahi specimens fall within the size range of Shimogori, and Tsuboi falls within the range of Nabatake from northern Kyushu.

The Ikego specimens from the southern Kanto region fall within the range of Kadota and Shimogori.

4. Temporal change in the southern Kanto region

Figure 3–d shows the temporal change in the size of pigs from the Early Jomon to the Kofun–Heian Period. For the Jomon Period, it is clear that the Earliest (Yoshii-Shiroyama, Kyama) and the Early Jomon (Haneo) specimens are the smallest. The size of pigs significantly increases ($t = -5.133, p = 0.000$) from Early Jomon (Haneo) to Middle Jomon Period (Shimot). The size of pigs remains relatively the same from Middle Jomon Period, Late Jomon Period (Shim-ota, Tabeta, Tonodai), Late/Final Jomon Period (Uchino) to Final Jomon Period (Sambu-ubayama). Of particular note is the significant decrease in the size of pigs in the Yayoi Period (Ikego) ($t = -9.657, p = 0.000$).

The size of pigs in the Yayoi Period is even smaller than the modern standard Kanagawa population. Interestingly, the size of pigs at this site significantly increase ($t = -6.453, p = 0.000$) again during the later Kofun–Heian Period (Ikego), with their mean value closer to the modern standard.

IV. Discussion
The contrast between the Jomon samples and the modern standard shows the degree that pigs changed in size, the result perhaps of several factors such as deterioration of habitat due to human activities and hunting pressure. Together with the geographical variation observed in the Yayoi remains, we could say that the major change in the size of suids had occurred only in the last 2,500 years.

A considerable and similar geographical variation in the size of Jomon and modern pigs in Japan were observed in our study. A clear east-west cline in the size of teeth was observed where the size of pigs from Kyushu is distinc-
tively small compared to those from Honshu. However, a different geographical variation was observed in the Yayoi samples. The pigs from the Yayoi Period have shown a west–east cline in their size where the populations in the west being larger than those of east. Interestingly to note is that the size of pigs were significantly different between the sites in the northern Kyushu as well as in the western Honshu (Fig. 3–c). The variation in a single region exceeds the geographical variations observed in the Jomon or in the modern samples. As for the temporal changes, a major change in the size of pigs were observed in the Yayoi and Kofun–Heian samples in southern Kanto region, where the size of pigs become extremely small in the Yayoi and the size become large in the Kofun–Heian Period (Fig. 3–d).

An east–west cline observed in the size of both the modern and Jomon samples is hardly surprising, given the considerable environmental differences within the Japanese Archipelago. It has been known that the body size of pigs is larger in colder regions compared to warmer regions (Endo et al., 2000). Endo et al. (2000) report a certain degree of geographical variation in the size among modern Japanese wild pig populations based on the statistical analyses of the mandibles which support this tendency.

The significant variations among Yayoi sites are noteworthy. It is the time in which the size of pigs shows a major change in the Kanto region. The size of pigs at some western sites, especially Yoshinogari, Sasai, Shimobayashi and Shimpo, is notably large compared to other sites. The variation is large within a single region which exceeds the range of variation of either the Jomon or the modern populations from the region. This suggests that these animals were introduced from outside the region.

Transportation of pigs from region to region seems to be a common practice since the Earliest Jomon Period (Matsumoto, 1918; Naora, 1938, 1939, 1971; Inukai, 1959; Kaneko, 1975; Nishimoto, 1979; Yamazaki et al., 2005) until present. The pigs were found from the sites in Hokkaido and Izu Islands which are outside their natural distribution. According to the results of mitochondrial DNA analysis of these specimens (Watanobe et al., 2001, 2002, 2004; Ishiguro and Watanobe, 2005), both in Hokkaido and Izu Islands pigs had haplotypes that are closely related to those of Japanese pigs in eastern and northern Honshu regions, which suggest that pigs were transported from nearby regions.

There are two possible explanations for the increase in the variation in the size of pigs in the Yayoi Period. By comparison of the size alone, the size of pigs from Yoshinogari is notably larger than those of Hokuriku and close to the size of northern Tohoku of the Jomon Period. The pigs from Yoshinogari, Sasai, Shimobayashi and Shimpo may have been transported from the regions of Tohoku, Kinki, southern Kanto or Hokuriku. However, taking into account that the cultivation of rice and other cultural elements were first introduced to the Japanese Archipelago from the west (northern Kyushu and western Honshu) at the beginning of the Yayoi Period, it is more likely to explain that pigs were introduced to the Archipelago from the Eurasian continent as stated previously by Nishimoto (e.g., 1989a, b, 1990, 1991a, b, 1992a, b, 1993).

From the comparison of the size alone, we could suggest that most of the pigs from Yoshinogari, Sasai, Shimobayashi, and Shimpo were brought in from outside the region. Unfortunately, no genetic analyses have been done on most of the Yayoi sites used in this study; however, Watanobe et al. (2001, 2002, 2003), Morii et al. (2002), Ishiguro and Watanobe (2005) reported that pigs from some sites in the western Honshu (Agata: Final Jomon–Early Yayoi, Miyamaegawa: Late Yayoi–Early Kofun, Miyashita: Late Jomon) were closely related with the pigs from the continental China based on the ancient mtDNA analyses, which support the hypothesis that the pigs were transported to the Archipelago from the Asian Continent. These pigs were genetically closely related with the domestic breed of the modern comparatives from China. The samples from Shimogori and Asahi sites that are within the range of pigs from the Jomon, northern Kyushu, have been genetically analyzed as well (Ishiguro, 2000; Watanobe et al., 2003; Ishiguro and Watanobe, 2005), and were reported that they are closely
related with the wild pigs that are native to the Japanese Archipelago, *Sus scrofa leucomystax*. Shimogori was the first site that was reported with possibility of pig domestication based on morphological observation of the well preserved skull by Nishimoto (1989a).

It is said that there is a large variation in the size and shape of the pigs of the Eurasian continent, both wild and domesticated (Groves, 1981; Institute of Animal Science, Chinese Academy of Agricultural Sciences, 1986). According to Jing and Flad (2002), the size of pigs from the archaeological sites in China decrease steadily over time from Paleolithic to Neolithic. It is a necessity to understand the variation of the modern and archaeological pigs in the continent in order to further discuss the issue morphometrically.

Further investigation of both the morphology and the ancient DNA is necessary for the Yayoi Period, especially those sites that were outside the size range of the Jomon sites as well as comparison between the samples from the continental China. What we can say from the available evidence is that pigs were transported from one region to another by humans during the Jomon and the Yayoi Period as we see similar practice today. However, the distance of transportation and degree of selection on the animal may have been different between the Jomon and the Yayoi. During the Jomon Period, local pigs were likely to be transported to the nearby islands off the shore of the Japanese Archipelago. There may have been transportation of pigs within the main islands. In Yayoi, pigs were transported even further distance compared to the Jomon Period. There may have been some selections made on pigs that were exploited at the sites, as seen in their large variations observed in the Kyushu region and the western Honshu region. A similar variation pattern could have existed in the southern Kanto region, but we were able to analyze only one site, Ikego (Middle Yayoi Period). Some of the pigs were transported from the continental China as suggested by the result of ancient DNA analyses. The size increase observed in the Kofun–Heian Period in the Kanto region suggests that these pigs were assimilated into the wild population when the sites were abandoned. The effect of genetic disturbance of the wild population during the Yayoi Period could have been only limited in scale as well as geographically, because the similar geographical variation of east-west cline is still observed in the modern populations. In light of these results, it will be necessary in future to investigate the size range of pigs in the continent during the Yayoi Period and also investigate Japanese zooarchaeological evidence more closely in the other regions and periods as well as the modern populations on both morphologically and genetically to see if any of the preliminary conclusions outlined above can be further substantiated.

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完新世ニホンイノシシの臼歯サイズにみられる時空間的変異

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[要]

日本列島の本州、四国、九州に生息するニホンイノシシ（Sus scrofa leucomystax）の下顎骨臼歯サイズの地理的多様性と時間的変化について検討した。分析に用いた資料は、本州、九州より得られた現生資料と、縄文時代から平安時代の考古遺跡から出土したイノシシ骨である。分析では、下顎第 3、第 4 小臼歯の頸垂直径および第 1、第 2 大臼歯の頸垂直径を使用した。現生資料群と縄文時代の資料から、列島の東ではイノシシの臼歯サイズが大きく、西にいくにつれて小さくなる傾向が認められた。

九州の個体群は、現生・考古資料ともに本州に比べて顕著に小さい。

一方、弥生時代においては列島の西でイノシシの臼歯サイズが大きく、東で比較的小さい傾向が認められた。また、北部九州および本州西部では、遺跡間で臼歯サイズに顕著な差が認められ、その変異幅は縄文時代および現生資料の地理的変異幅を超える。弥生時代におけるこのような傾向の背景には、特定地域のイノシシを人為的に移動させるなどの影響があったことが推定される。

キーワード：ニホンイノシシ，Sus scrofa leucomystax，地理的変異，時間的変異，人為的影響

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