Fundamentals of Zooarchaeology in Japan and East Asia

Independent Administrative Institution
National Research Institute for Cultural Properties, Nara

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Cover photo: Red sea bream bones excavated from Osaka Castle Town Site (Osaka City Cultural Properties Association)
Chapter 1.
Techniques for retrieving of the ecofacts from archaeological sites
Preface
Interest in zooarchaeology has been increasing not only in Japan but in East Asian countries in general in recent years. The first step of zooarchaeology is to identify the species name and the elements of animal remains found in archaeological sites. However, in most cases animal remains from archaeological sites are broken into small fragments for various reasons, so identification involves great difficulties. For accurate species, elements, and right-left identification, reliable comparative skeletal samples of modern animals for reference are essential. Unfortunately, university laboratories and museums where researchers can compare faunal remains found in archaeological sites with skeletal specimens of extant animals are very few in East Asian countries, and zooarchaeologists have to secure necessary skeletal samples of extant animals by themselves. After 30 years of effort in preparing skeletal samples of extant faunal species that might be unearthed in archaeological sites, I finally became satisfied with the reliability of my skeletal collection. Although it may be an important training experience in a sense for those who study zooarchaeology to spend the same effort and time for preparing their own skeletal samples as I did, it is definitely not expedient for the further development of zooarchaeology. The primary goal of this book is to serve those who have no access to sufficient skeletal samples as a guide, offering information on excavation techniques, in addition to skeletal illustrations of major animals from fish to mammals so that readers can compare them with unearthed remains. I decided to compile this English version of the book that was originally written in Japanese for Japanese archaeologists, keenly realizing the necessity of a textbook in English for the dissemination of zooarchaeology in East Asia from my experiences as a lecturer of annual environmental archaeology seminars on the investigation and protection of cultural heritage at the Cultural Heritage Protection Cooperation Office, Asia/Pacific Cultural Center for UNESCO, as well as a zooarchaeology instructor invited to East Asian countries.
Many of the animal species included in this book are commonly found in East Asian archaeological sites. With some more species that are indigenous to each country, it will easily make a reference manual for skeletal identification of basic faunal species.
Zooarchaeology was born and grown in Europe in the 19th century, and studied mainly in the U.S. and Europe today. Nowadays zooarchaeological approach is required in the East Asian world as well with the almost infinite expansion of research areas, including the origin and development of agriculture and stockbreeding, the roles of cows and horses in the formation of ancient empires, and the techniques and history of animal use; the training of researchers and the development of researching facilities are immediately needed. I hope this book will be of some help for the improvement of the situation.

1. Why is Screening Necessary?
At most excavations in Japan archaeologists and their crews usually still collect lithics, pottery sherds, and fragments of bone and seeds by looking carefully at the place where they are digging with their spade or trowel. The finds collected are placed in plastic bags and brought back to be washed and classified. Bone, wood, and seeds are usually left to be identified by an appropriate specialist or company.
There are, however, many differences in the collection of this type of sample depending on the eyesight and care of the individual excavator, and on whether the soil is clayey or sandy, or is sifted mixed with pebbles. This means that the proportion of remains collected vary greatly from site to site and it is extremely difficult to make direct comparisons.
Excavations where only remains visible to the naked eye are collected are considered to be behind the times in countries where archaeological research is advanced. Archaeologists from Europe and America who visit Japan often ask why soil from excavations in Japan is not screened to search for small finds. It may be possible to reply to this question from the viewpoint of Japanese archaeology, but it is also true that we do not have sufficient data to reply properly to such foreign researchers.
One method of minimizing individual and soil differences in order to compare objectively the assemblages of finds left from soil and collect the remains left remaining in the screen. In Japan, the screening of soil from shell middens has become normal in most regions, but the soil from other sites is usually not screened in this way. As practical problems, much of the soil from excavations in Japan is clayey in nature and difficult to pass through screen mesh; also very large excavations using belt conveyors have become common-place and the quantity of soil requiring screening is much larger than in digs in Europe and America. Moreover a vicious circle is repeated whereby the absence of screening on large excavations makes it difficult to use that technique on small digs.
Let us first discuss three types of information that can be obtained from ecofacts related to environmental archaeology.
(a) Information relating to paleoenvironment: This can inform us about the general climate, environment and ecology of the site and its surrounding area.
(b) Information relating to economic activities: This helps us understand the economy of the site and its period. At the simplest level this involves identifying and listing animal and plant remains in order to determine what was used for food at the site. At the more complex level, the information can be used to reconstruct the agricultural economy of that period and to compare society, religion and so forth between or within sites.
(c) Information relating to human behavior: Through recent research it has become clear that the ecofacts contained in cultural layers, in pits and other features, or distributed right across the site are related in various ways to the activities of the people of the time. The clearest example of this is the remains of threshing and winnowing carried out in agricultural villages which can be seen in the plant assemblage. If the settlement produces remains of processing bone and adds, then the presence of craft or industrial activities can sometimes be assumed.

Many of these ecofacts related to environmental archaeology, including animal, plant and insect remains, are very small and there is no doubt that at excavations where these objects are collected with the naked eye, many of them are overlooked and quantitative analysis is impossible.

2. The Use of Screening
Carbonized materials are often found from dwelling floors, the area around hearths, and indoor storage pits. The fill of houses and other buildings is generally not suited to the preservation of organic remains, but if these remains are burnt and thus changed into inorganic material then their preservation is usually good. One example with which the
author has personal experience involved passing burnt soil found in hearths and the inside of pottery in Jomon dwellings through a 1mm screen. It soon became clear that burnt, dog salmon vertebrae and loose teeth were present in the soil. From this example it became clear that the previous scarcity of excavated salmon bones was due to the lack of screening in inland sites. In another example, the use of a 1mm screen on deposits from a rubbish pit at the Heian period Ushimichi site in Niigata Prefecture led to the identification of a type of stickleback that had previously been very rare from archaeological sites. Despite these examples, however, it cannot be said that soil screening for small finds has yet become the norm in inland sites and examples such as these are still the exception.

Another application of screening is in the collection of small artifacts from burial chambers and production sites of the Kofun period. Kofun grave goods include beads and other very small finds and it is very easy to overlook such artifacts in poorly-lit stone burial chambers. For this reason it has become common to screen the soil excavated from such chambers. In the case of bead-making and other production sites, it is also necessary to screen workshop and disposal areas for small remains.

Furthermore, in the excavation of cave sites the poor visibility also makes it very easy to overlook small finds. The quantity of soil produced by cave excavations is usually not that large so that if there is a stream nearby the soil can be wet sieved through a large, square screen.

3. The History of Techniques of Excavation of Micro Remains

(1) Washing Soil

The first report of soil from an archaeological site in Japan being washed to search for small finds is in the book Prehistoric Fishing in Japan by Kamakichi Kishinouye (1911). In this work, Kishinouye recounts how, when he washed fox bones from the Kuwagasaki shell midden in Iwate Prefecture in his sink at home, he noticed tiny fish bones that had been contained in the adherent soil. Nakao Sakazume made the following paraphrased comments regarding methods for collecting small artifacts: Soil containing cock shells (Rapania thomasonia) and moon shells (Neverita didyma) was brought back from a shell midden together with ash from hearths, placed in a white basin and mixed with water up to one eighth from the top. At this stage the small land snails float to the surface. If one gets close to these objects with a wet writing brush, they can be extracted by the brush through capillary action. After mixing several times until all floating objects have been removed, the water is thrown away and the soil examined. Soil is removed with the tip of the brush and anything that can be collected should be done so. It is unlikely that small fish such as sardines and dace would not have been used for food. Even if there is no method of directly identifying species at the moment, it is necessary to collect a sufficient quantity as samples for the future. Finally, Sakazume concluded that "in the near future, do doubt the day will come when such microscopic excavations will become essential."

(2) The problem of sample size

The most commonly used method for sampling shell middens, the column sample, was mainly developed in midden excavations conducted by the British archaeologist Sebastian Payne. He compared the number of artifacts collected from midden deposits. An attempt at a quantitative comparison of shellfish from shell layers was made by Ichiro Yawata at the Yamazaki midden in Chiba Prefecture. Examining the shell deposits at three excavation areas—those dug by the Department of Anthropology, Tokyo University (1), the Shizhengaku Kenkyukai (II), and the intervening area III—Yawata used sections of the shell layers that contained relatively few other objects, counted all the collected shells, worked out their percentages and linked them with sea level changes.

The first use of a screen to collect small finds seems to have been at the Natagiri Cave in Chiba Prefecture. From the deposits in a trench outside the cave, 40cm blocks of soil were collected from Layers 3 and 4 and screening produced large quantities of Japanese pilchard (Sardinops melanosticus) (160 vertebrae from Layer 3, 311 from Layer 4), anchovy (Engraulis japonica) (296 vertebrae from Layer 3, 1145 from Layer 4), and chub mackerel (Scomber japonicus) (53 vertebrae from Layer 3, 44 from Layer 4). Estimates were also made of actual fish size using measurable elements of moray (Gymnothorax kiauke), black sea bream (Acanthopagrus schlegelii), and read sea bream (Pagrus major).

The British archaeologist Sebastian Payne was the first to clarify the correlation between screen mesh size and sampling error. He compared finds of obsidian from four sites, looking at (1) materials collected at the time of excavation, (2) materials collected during washing, and (3) compared the number and weight of finds found before screening (Tab. 1). As a result, he found that where screening was not used the number of obsidian artifacts that were found ranged from 0 to more than 27%, while in terms of weight the range was from 0 to 82%. Payne emphasized the dangers of statistical analyses on assemblages collected

Tab. 1. Sampling errors by number and weight at several sites.

<table>
<thead>
<tr>
<th>Site and stratigraphic unit</th>
<th>No. of fragments</th>
<th>Weight</th>
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<tr>
<td></td>
<td>Collected in trench</td>
<td>Collected by screening</td>
</tr>
<tr>
<td>Franchthi Cave F/B bank. Unit 49</td>
<td>7</td>
<td>81</td>
</tr>
<tr>
<td>Can Hasan III 49L 105.6 + 105.7</td>
<td>210</td>
<td>557</td>
</tr>
<tr>
<td>Can Hasan III 49L 109.1 + 109.4</td>
<td>27</td>
<td>620</td>
</tr>
<tr>
<td>Sitagroi ZA47</td>
<td>0</td>
<td>153</td>
</tr>
</tbody>
</table>

Dangers of statistical analyses on assemblages collected
In Japan, during the excavation of the Kamitakatsu shell midden in Ibaraki Prefecture, Kimio Suzuki and his colleagues noticed that the midden contained a large number of small fish bones and reported that with the use of screening they could collect small fish bones that were not visible to the naked eye [K. Shimizu, K. Suzuki and H. Fujimura et al., "Kaiizu ni okeru dobutsu izonai no saishu hoho to sono mondaiten", abstract of paper presented at the 39th meeting of the Japanese Archaeological Association, 1973]. These authors emphasized that existing excavations where only large bones were collected by hand had probably overlooked small animal and fish bones. Some years prior to this, Takeru Akazawa had taken three excavations used by Akazawa had employed screening, smaller fish had probably been overlooked. During their excavations at the Miyano shell midden in Iwate Prefecture, Suzuki and Komiya used screening to demonstrate that the Jomon people had actually caught small red sea bream, black sea bream and sea bass—and measured the premaxilla which tends to be the best preserved part of the head. Comparing his results with modern fish, Akazawa had argued that the shell midden people had concentrated on capturing large specimens.

Takafumi Suzuki, however, argued that because none of the excavations used by Akazawa had employed screening, smaller fish had probably been overlooked. During their excavation at the Miyano shell midden in Iwate Prefecture, Suzuki and Komiya used the same screen method to compare fish body lengths based on samples without sampling error. As a result it was shown that, whereas the red sea bream at Miyano were said to be bigger than at Shomyodai and that red sea bream under 30cm long were not present at Miyano, fish under 30cm occupied the major part of the red sea bream assemblage at Shomyodai. This difference clearly reflects fishing behavior in the Kanto and Tohoku regions in the Late Jomon.

During their excavations at the Tagara shell midden, Miyagi Prefectural Board of Education also screened soil after bones had been excavated by hand in order to investigate what proportion of remains had been overlooked with the naked eye. According to this report, 291 stone arrowheads were carefully collected by hand but with screening this number increased 1413. Naturally it was shown that comparisons of arrowhead weight and size with the naked eye less than 2/3 of red sea bream are smaller fish. The fewer remains remain on the screen, In the case of shell middens, circular screens with a diameter of 20cm are often used; these have meshes of 9.52, 4, 2, 1.5 and 0.5mm and are made by Iida Manufacturing Co. Ltd. and other companies (Fig. 2). Equipment especially designed for water deposits it is necessary to estimate the quantity of nut shells contained therein and if the quantity of soil is not that great, then the whole deposit should be removed for sampling. Where quantities are large, the Museum of London manual recommends 75 liters as a basic soil sample.

Depending on the objectives of the analysis, it is necessary to change the amount of soil sampled in order to obtain at least 100 examples of the remains concerned. In the case of seeds, however, current European standards recommend a combined total of at least 500 crop and weed seeds.

4. Dry Screening

In dry screening, soil from the excavation is placed on a square screen and the soil passed through leaving remains on the surface which can then be collected. This method is effective for shell middens, cave sites, and for sandy and silty soils. The smaller the screen mesh, the fewer remains are overlooked but at the same time the more pebbles and other debris remain on the screen making the sorting process harder. Generally speaking, 10mm and 5mm screens are the most effective here. Most pottery sherd, stone tools and mammal bones can be collected with a 10mm mesh, but stone chips, fish bones and damaged fragments of bone and stone tools need a 5mm mesh. Shell midden strata are usually divided into pure shell layers (here defined as more than about 9/10 shell), mixed soil-shell layers (more than about 2/3 are shell), mixed soil-shell layers (less than 2/3 are shell), and mixed soil-shell layers (using the naked eye less than 2/3 shell). When digging pure shell layers by hand it is also easy to overlook large remains hidden by shells. As noted already, it is essential to use large screens for all of these shell and mixed shell and soil layers.

Peat, gleyed, deoxidized clay and sand form the main deposits at wetland sites. None of these soils are suited for dry screening. As found at the Korekawa Nakai site, "special peat layers" are sometimes found with the remains of foods consumed by humans. In the case of such artificial
separation is also commercially available from the Daiichi Gosei Co. Ltd., with mesh sizes of 5, 2.5 and 1 mm (Fig. 7). If the quantity of soil is not that large, however, then customary screens are sufficient. Plant remains are often poorly preserved, and when they are very small they are often damaged and difficult to separate using dry screening. The use of water makes it easier to clearly separate ecofacts and soil, and differential flotation also helps in separating lighter objects such as seeds which float and heavier objects like bones that do not. Small remains obtained in this way are important materials for reconstructing past diets and determining the nature of archaeological features.

2) Sampling methods at sites

Soil sampling methods generally undertaken during excavations include (1) column samples taken at random points, and (2) discretionary samples from features.

Column samples at random points are mainly used for shell layers and caves, but at sites where remains are not associated with clear features several points for sampling are chosen from across the site. With column sampling, several samples of 30 x 30 cm or 50 x 50 cm are usually taken. Samples are either taken in splits of 5 or 10 cm (Figs. 4 and 5) or else taken from each stratigraphic layer (Fig. 6). The former method is often used where samples cannot be taken by professional archaeologists at the site or where there is not enough light to distinguish strata (in caves, for example). This method has the advantage of making it possible to take a series of identical samples from one area, but where the deposits are sloping or each layer is very thin, several stratigraphic layers may be contained in the same sample—a problem which often occurs at shell middens. The second method has the advantage that each sample corresponds to one stratum, but depending on the thickness of the layers differences can occur in sample quantities (Fig. 6). When column sampling is conducted at a site, consideration needs to be given to the nature of the deposits and the organization of the excavation in order to choose the most appropriate sampling method.

Sampling soil at predetermined points during horizontal excavations is a useful method where overlapping lens-like patches cannot be sampled using column samples or where soil needs to be taken from ecofacts clusters, hearths and pits or from inside pots. The quantity of the sample depends on the number of ecofacts contained in the feature or the area surrounding the sample, but where the quantity is small it is best to collect all of the soil.

3) Water separation using soil analysis screens

Samples collected at the site should be placed in a separate bag for each sample. Water separation is carried out after they have been entered in a register (Fig. 7). The register should contain details of where the sample was taken, date, volume, weight, and sampling method. For the soil separation, a series of screens are placed on top of each other with the largest mesh at the top; water and remains are then passed down until the latter are collected on one of the screens. Water can be sprayed onto the soil using a hose or tap, or alternatively the screens can be placed in a tank of water and then rotated and snapped upwards with the wrist to collect ecofacts. In this case it is effective to remove the screens one by one from the top downwards while collecting finds.

If the soil to be washed is clayey, it becomes difficult to separate ecofacts and the screen tends to get blocked. Placing the soil in water overnight and careful brushing during washing can help in this case.

In particular, plant remains and small fish bones are very easily damaged and care is needed. About two trowels of soil are placed on the top screen and gradually broken up while being sprayed with water. Small ecofacts and particles of soil then pass down to the next screen. A brush can be used to help separation of soil and ecofacts. The same process is repeated on the second screen until the last one is reached. As the screen mesh gets smaller it becomes clogged more easily and it is important to not just to wash the ecofacts but to scrub the screen itself. When clogged, scrubbing the underside of the screen with a brush while water is sprayed from above makes it easier for water to pass through. When the washing has finished the finds are dried on newspaper in shallow containers. At this time it is important to check that no ecofacts are left in the screens mesh. It is best to dry finds indoors to avoid contamination from dust, plants and so forth. The soil that did not pass through the smallest mesh may possibly contain very small finds and a sample of about 100 cc should be retained. Samples of about 100 cc from each
layer should also be kept unwashed for later microscopic and chemical analyses. This is because when such samples are retained it becomes possible to quickly support advances in the analysis of parasites, diatom, pollen, and so forth. There are quite a few cases where soil samples for new analytical methods are collected from excavations in progress.

After the whole process has been completed the equipment should be washed carefully ready for the next sample. If remains are still clogged in the mesh then they could cause contamination problems later on. After the remains have been thoroughly dried, they should be bagged ready for identification, weighing, measuring and other analyses

6. Flotation
1) Objectives and general methods
Flotation refers to methods whereby soil is added to water or another liquid and the lighter finds float to the surface to be collected by the archaeologist. Soil is usually placed in a tub of water and then agitated until light seeds and carbonized materials can be collected. In the case of dry, sandy soils found in arid regions or dry caves, small remains are easily separated from the soil matrix, but with clayey soils like those in Japan the soil needs considerable agitation before small plant and insect remains will float to the surface. When the quantity of soil is small, it is added to a liquid with a high specific gravity and then plant and insect remains are collected (usually liquid zinc chloride with a specific gravity of two but because this is an organic chemical compound it cannot be poured down the drain after use and disposal poses problems). This same method is used by palynologists to separate pollen from soil in test tubes. Beetles and other insects can be collected by placing the soil into warm water with kerosene or dissolved paraffin wax. All of these methods pose problems of disposal; they are effective for treating small quantities of soil but difficult for amounts over 100 cc.

A 10 mm screen is sufficient for collecting nuts and large seeds but 0.5 mm or 0.3 mm screens are needed where small seeds like millets or grasses are expected. A simple kitchen strainer or tea strainer can be convenient here. Gauze is also easily obtained, but without a frame care is needed that small remains do not slip off the gauze and remain can also become clogged in the mesh and time-consuming to collect.

Soil samples are washed a little at a time.

Water is poured form above or the soil is added to a container of water. If too much soil is added, care needs to be taken that the screen dose not clog and water overflow.

Remains are collected according to the size of the screen.

2) Flotation of about 10 liters of soil
A 5 liter stainless steel beaker with a single spout is the most useful here (Fig. 8). Where a beaker is hard to obtain, a bucket will serve but without a pouring spout it is difficult to control finds floating on the surface.

(a) Fill the beaker with water and then add two or three trowels of soil (500 cc - 1000 cc) and stir. If the soil is clayey, it can be presoaked in water from the previous day and kitchen mixers or beaters are effective for stirring the soil.

(b) Floating finds are first removed with a tea strainer or similar device and then separated in a tray filled with water.

(c) Place a hose in the beaker and add water. The current from the hose can be used to float lighter artifacts to the surface. A net or strainer and a 20 cm diameter 0.3 or 0.5 mm mesh screen should be placed to catch water that overflows.

(d) The screening is completed when the number of floating artifacts becomes small and impurities disappear. Stone tools, potsherds, bones and other artifacts may, however, be contained the grid that falls to the bottom of the beaker and this should either be placed in a separate tray and the artifacts collected or else wet screened as described below.

(e) The seeds collected in the screen can, like wooden artifacts, be subject to shrinking, cracking and other damage during drying and they should be kept in a tightly sealed container until they can be identified.

3) Floation using a Chip purifier
Soil from latrines which contains large quantities of seeds, insects and so forth requires a Chip purifier used in scientific experiments (Fig. 9). Tap water pumped in at the bottom of the machine causes a current and the soil is agitated by the blade attached to the top. The light fraction flows with the water through the hole at the side, though larger objects can be collected directly with a strainer. In my experience, about a liter of soil can be floated in about 15 minutes.

7. Other Wet Screening Methods
1) Effective wet screening of large quantities of soil
If large quantities of soil need to be screened for valuable ecofacts, then use of an electric sieve is effective. With the electric sieve made by the Dalton Company, soil is inserted
through the funnel at the top and is passed through 10, 4, 2 
and 1mm screens while receiving vibrations that cause radial 
eddies; finds are then collected with pebbles and debris 
according to the size of each screen. This is suitable for shell 
midden layers or bead-making sites where the soil is not 
clayey and where there are small but important ecofacts.

In the case of clayey soils, soaking in water for several 
days makes processing easier. With actual clay, however, 
even this is often not enough. Where large quantities of very 
heavy soil need to be water screened, an electric cement 
mixer is effective (Fig. 10). This method was used by the 
Museum of London when excavating alluvial deposits from the 
River Thames. Sites formed on alluvial deposits of large 
rivers are often comprised of many layers of heavy clay 
soils. With limited time and resources, this type of machine 
is probably necessary to maintain the same standards as at 
other sites.

If 50-100 liters of clayey soil are placed in the mixer drum 
and rotated, the blades inside break up the soil and make it 
easier to dissolve in water. The use of concrete mixers and 
electric sieves are thus effective ways to collect small finds 
from heavy soils.

2) The problem of sample size

If, for example, you are interested in determining the ratio 
of shell types in a shell layer, there will be cases where it is 
sufficient to screen 1000cc of soil from each stratum through 
a 1mm screen, whereas in other cases 10,000cc will not be 
enough to get the full number of individual species. To 
obtain numbers for boar and deer, all the soil from the 
excavation needs to be passed through a 10mm or 5mm 
screen, but that might not be enough to get reliable data. In 
contrast, while studying pollen, diatoms, parasite eggs and 
other microfossils it is usually sufficient to have 500cc or the 
equivalent of a 35mm film case from each layer. For this 
reason, when taking soil samples from a site the 
archaeologist needs to think about what sort of analyses will 
be conducted at the site and thus what sample sizes, screen 
size, and so forth will be necessary.

8. Practical Aspects of Soil Screening

1) The example of the Mawaki site

Here I would like to discuss the example of the soil 
sampling, screening and ecofacts collection carried out by 
Yumiko Tanabe during the 1999 excavations at the 
nationally designated Mawaki site by the Noto Townshup 
Board of Education in Ishikawa Prefecture. The 360m² 
excavation area adjoined the central part of the site where 
Middle Jomon pit dwellings had been found in the past.

The excavations produced cultural layers and features 
from the Late and Final Jomon. Three strata were recognized 
with an accumulation of 10-30cm across the whole 
excavation area. In excavations the previous year, the black 
cultural layers at Mawaki had produced a large quantity of 
burnt, white bone fragments, but small finds had been so 
numerous that collecting them by hand had been difficult. 
Furthermore, because of the dark color of the cultural layers, 
no clear features had been confirmed and finds of pottery, 
lithics and bone had been scattered across the whole 
excavation area. Sampling points thought to represent the 
excavation area were thus chosen and 30 x 36cm column 
samples taken (Fig. 11:1-17).

Generally speaking, soil samples are often taken from 
baulks after excavations have finished, but on this occasion 
the following measures were taken while the dig was in 
progress.

1) Sampling points were left undug until the excavation 
of each stratum had been completed.

2) The elevation of the top and bottom of each stratum 
was taken (a total of 6 points) and recorded on the site plans. 
Following this a sample of 5 liters of soil was taken from the 
vertical column from each stratum.

3) In order to prevent contamination of the sample, 
wherever possible the column was cleaned and samples 
taken from a clean face. As each stratum was about 10cm 
thick, a 10 liter sample was theoretically possible and 
looking back the surfaces would still pose no problem for 
collecting 5 liters of soil. As each stratum was basically a 
dark clay soil, it was difficult to separate strata on soil color, 
inclusions, structure and so on and this method also helped
1. Sampling points are chosen.

2. The sample is left while the surrounding area is excavated.

3. Measuring elevation. Six points are recorded at the top and bottom.

4. The location of the sample, the elevations and other information is recorded on the site plans.

5. The sample is cleaned back.

6. The soil sample is taken. Where stones, potsherds be removed.

7. The soil samples are placed in bags. Sandbags may be used when drying is not a problem.

8. Weighing. The sample does not need to be dried first.

9. The soil should be placed in water to soften it until the day of flotation. Each time about 500-1000cc of muddy soil should be placed in a beaker ready for flotation and water separation.

Fig. 11. The collection and screening of soil samples from archaeological sites.
13. With the largest (9.52mm) screen at the top, water is poured on the soil. Water can also be placed in a shallow container and the screens agitate inside. In the latter case, a wrist snapping motion should be used to concentrate silt and remains at the center.

14. Old newspaper are placed in a container and the finds put on top. Where possible drying is best conducted outside, but care should be taken to avoid contamination.

15. After drying the finds are placed in bags.

11. Seeds, carbonized materials, wood fragments, insects and other light finds are caught in the net while objects smaller than 0.5mm pass through with the silt.

16. Later the bags are sored and classified by remains type.

12. After the flotation, water separation is conducted to collect heavier finds in the accumulated silt.

17. Numbers and weights are recorded.
to prevent collection of soil from several different layers at the same time.

The stratigraphy at the Mawaki site had been difficult to differentiate visually or by trowel during excavation and the soil sampling was also an attempt to see if strata could be distinguished by plotting objective, quantitative measures of grain size and relative proportions of ecofacts.

(4) A 5 liter stainless steel measuring beaker was used to obtain the approximate weight and volume of soil samples collected at the site (there is no need to worry about whether the soil is wet or dry). Flotation was then carried out by hand (Fig. 11:10) and after seeds, carbonized materials and wood fragments were removed, the remaining soil was wet screened. As the soil was clayey, it was pretreated by being placed in a container of water the day before to make screening easier. When samples are small (5-10 liters) flotation can be carried out using a measuring beaker and a plastic storage tray. A bucket may be used instead of a stainless steel beaker, but a spout makes it easier to pour water. Soil is placed in the beaker a little at a time and is mixed by strong water pressure from a hose. Where blocks of soil still remain, they can be broken up with a bamboo spatula or by hand. A kitchen beater is also useful here. The pressure and quantity of water should be adjusted so that light objects flow out with the water and heavier ones do not sink to the bottom of the beaker. The ecofacts that flow out with the water should be collected on a fine mesh net or a piece of cloth. At Mawaki, in addition to a 300 micron nylon sieve (made by the America Flotech Co.) of the type used in flotation in the West, Japanese nets for catching goldfish and cleaning tanks were also utilized. The water and soil that passed through the cloth were put back in the container and the water was poured off leaving the soil to settle at the bottom. Many of the ecofacts isolated in this way are small organic objects which may crack or be damaged if dried; they should be kept in a wet condition until analysis.

In stage two, water separation is carried out on the soil and finds remaining at the bottom of the beaker (Fig. 11:17). Circular screens of around 20cm diameter are used with 4, 1 and 0.5mm mesh. The screens should be placed on planks on top of the container that was used in the flotation. The soil remaining after the flotation is put on the uppermost, 4mm screen and water is sprayed from a hose, forcing down soil and finds while the screen is cleaned with a brush. Soil becomes encrusted inside fish vertebrae and within incised designs on pots so thorough cleaning is necessary. After the 4mm screen, the same process is repeated with 1mm and 0.5mm screens. If the lower screens become clogged, water may run up inside the screens so it is important to make sure that water can flow easily at all times. Once washing is completed, the finds should be dried on newspaper in a suitable flat container. Care needs to be taken that there is no contamination from foreign objects, but in the summer the finds should dry in about 8 hours outside. The mud remaining in the bottom of the container should ideally be dried and kept, but this was not possible at Mawaki due to space and other problems; some samples were retained and the rest thrown away. After the washing of one soil sample had been totally completed, the screens, containers and brushes were carefully cleaned and preparations made for the next sample. Once dried, the finds were placed in plastic bags and classified according to ecofacts type and animal species. Each sample is separated by flotation, and 4mm, 1mm and 0.5mm screens and should be carefully recorded on the labels.

At Mawaki, there was only one set of screening tools and only one archaeologist performing the work, but it was possible to process four samples per day.

2) The analysis of latrine soils

With latrine features the quantity of objects in the soil differs between pit and flushing types. In the former case, the quantity of ecofacts per unit of soil is very high and even a small sample should be sufficient for quantitative analysis, but with flushing latrines many of the contents are washed away. Particularly in the case of medieval and early modern latrine pits, it can be argued that the use of urine and feces as fertilizer was furthered by the addition of untreated garbage to increase decay and various food remains are found in such deposits, as at the Asakura homestead and other sites.

When digging by hand, chugi (wooden sticks used after defecation) and melon seeds can be seen with the naked eye and chugi can be actually excavated by hand. When a building is torn down, it is not uncommon for latrines to be filled with architectural elements or other remains of daily life. Generally speaking, the amount of soil that can be collected from a latrine pit is not that large, ranging from 50 to several hundred liters. Individual samples can be removed and placed in sealable plastic buckets. Coprostanol and other chemical analyses, however, require storage in a cool dark place to avoid oxidation and other changes after excavation. Such samples should then be analyzed quickly.

The microfossils found in latrine deposits may contain pollen, diatom and parasites and samples for these analyses should be taken separately at the time of excavation. Several dozen cc are sufficient for each sample. Where possible samples should be taken stratigraphically; failing this, multiple samples should be taken from the upper, central and lower strata and from the central and peripheral areas. For comparison, samples should also be taken of soil outside the feature. A 35mm film case is the simplest container for taking samples. Where the soil is clayey, the lid can be removed and the film case inserted straight into the section, a method which also helps to avoid contamination.

9. Equipment

1) Flotation machines

Flotech is a specialist flotation machine designed in America which can process between 5 and 10 liters in 10-15 minutes (Fig. 12). Floating objects are collected on a 0.3mm nylon mesh and stones and ecofacts on a metal-framed 0.5mm screen. The advantage of this machine is that when once filled with water finds larger than 0.3mm are filtered onto one of the screens while floating objects and smaller clay and silt particles are circulated with the water. Until heavy deposits build up, there is no need to change the water.

2) Soil analysis screens

These can usually be found in catalogues selling equipment for scientific experiments. The screens can be washed but are prone to clogging unless small amounts of soil are used.

3) Metal trays for washing

Kitchen trays are quite sufficient here.

4) Tweezers

Anatomical tweezers with pointed tips are best for picking up small and fragile seeds, bones and insects. The tweezers made by the Tureto Company in Germany are best for small finds since pressure is not applied to the tips (imported by Rigoshia Co., Tel. 03-2811-1831).

5) Test tubes

Easily damaged seeds and insects should be sealed in a test tube in a 70% ethanol solution. Water is sufficient for short-term storage. Test tubes are not fully sealed and water often begins to evaporate after one or two years. Important specimens should be placed in water or alcohol in a test tube and then in a larger bottle or a styrofoam container filled with water.

6) Chemicals

The borax and boric acid usually used for preserving wooden artifacts are not recommended as they form needle-
like crystals when water evaporates from the surface. As long as mold does not form, these artifacts can simply be kept in water or alcohol.

7) Lights with magnifiers (Rakuso Co. etc)
These are useful for collecting finds from 2mm and 1mm screens and seeds and insects from flotation devices.

8) Binocular microscope
This is necessary for examining seeds, insects and small bones. A wide field of vision and a light lens are best.

9) Lighting
Sloping lighting which emphasizes shadows is best for examining the blades of stone tools under a microscope, but halogen lights with few shadows are best for seeds, bones and insects.

10) Photography
Excavated bones and seeds range in size from cattle and horse skulls and long bones over 50cm to fish bones, insects and grass seeds that are only 1-2mm. Many bones and seeds are dark or blackish in color. Furthermore, bones that produce Vivianite have rough surfaces and minor protuberances and depressions on joints can make identification difficult. In such cases it can be difficult to show the particular features with black and white photography.

A difference between the photography of environmental archaeology samples and other remains is that small finds often need to be photographed at a magnification. A macro lens of a 35mm single lens reflex camera is not sufficient for seeds and bones smaller than 5mm and photomicrographs are necessary. A photographic subject can be magnified with a macro lens and bellows. In this case, a camera with bellows and a close-up lens should be attached to a close-up photographic stand and the size and layout adjusted with the range finder. The lens should be stopped to f116 or f22 to obtain the best depth of field, but in most cases indoor natural light will not be sufficient and eocfacts lighting is required. Flash or studio lights should be positioned at angles from the left and right sides and adjusted to minimize any shadow. Lighting from below is also necessary to prevent shadows on the background. When using lighting from below, the artifacts should be placed on non-reflective photographic glass positioned about 10cm above the lights. When using medical close-up lenses (for example the Nikon Medical Nikkor) and close-up ring flashes, diffused light shows through even non-reflective glass and objects should be photographed on a cloth with low reflection such as black velvet.

Medium and large format cameras are not suited for photographing small objects at anything larger than actual size. A macro lens on a single lens reflex camera can be used for a subject-to-film ratio of from 1/4 to actual size; anything larger than actual size requires bellows to be attached between the camera body and the lens. In order to obtain a deep focal depth, however, the lens needs to be stopped down as far as possible which means a long exposure with natural light, requiring a robust photographic stand (Fig. 13).

The digital cameras that have quickly become very common in recent years have a high depth of focus and depending on how they are used they can produce sharp images that can be easily blown up. For further photography of the surface of seeds and so on, a camera can be attached to a low magnification microscope. These microscopes have attachments for 35mm or Brownie photography. Photography with existing film, however, has the disadvantages of sensitivity of exposure and focus, and of the time needed for developing and processing—prior to which the results cannot be seen. A CCD camera removes these disadvantages and also makes for simple photography whereby minor adjustments can be made during shooting; this type of camera is thus very suitable for the objectives discussed here.

As I have repeatedly stated, the methods and size of soil samples vary greatly depending on the objectives of the analyses to be performed. In other words, it is important that the archaeologist in charge of a site decide what analyses need to be employed to understand what problems and that
he or she collects soil samples with a clear idea of the
research strategy, analyzing samples by him/herself or
sending them off to relevant specialists. Table 2 summarizes
analytical methods and required soil samples used in
environmental archaeology. Using this table it is hoped that
archaeologists will carry out active sampling at excavations
and quickly process those samples once the digging is over,
thus reducing the mountains of unprocessed sandbags
containing soil samples that are found at many sites in Japan
today.

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Tab. 2. Materials, analyses and samples in environmental archaeology.
Developed from Craig Spence (Ed.), 1990.

<table>
<thead>
<tr>
<th>Ecofacts</th>
<th>Favorable Locations for Preservation</th>
<th>Information That Can be Obtained</th>
<th>Sampling and Analytical Methods</th>
<th>Sample Size Required</th>
</tr>
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<tbody>
<tr>
<td>Human bones</td>
<td>Shell middens, caves, wet and non-acid soils</td>
<td>Diet, pathology, demography, lifestyles, mortuary customs, social stratification, kinship</td>
<td>Hand excavation / 5-10mm screen</td>
<td>All soil from the burial</td>
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<td>Large mammals</td>
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<td>All soil</td>
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<td>Small mammals</td>
<td>Shell middens, caves, and non-acid soils</td>
<td>Natural fauna, natural environment, ecology, human adaptations to the environment</td>
<td>1-2mm screen</td>
<td>All soil/ 75 liters</td>
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<tr>
<td>Bird bones</td>
<td>Shell middens, caves, and non-acid soils</td>
<td>Same as large and small mammals</td>
<td>2.5mm screen</td>
<td>All soil/ 75 liters</td>
</tr>
<tr>
<td>Fish bones, fish scales, otoliths</td>
<td>Shell middens, caves, and non-acid soils</td>
<td>Diet, fishing technology, history of fishing, seasonality</td>
<td>0.5-2mm screen</td>
<td>All soil/ 75 liters</td>
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<tr>
<td>Carbonized plant remains</td>
<td>All soils</td>
<td>Vegetation, diet, building materials, materials for wooden tools, fuel, construction technology</td>
<td>Hand excavation/ above sampling methods/ 0.3 mm flotation</td>
<td>All soil/ 75 liters</td>
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<tr>
<td>Uncarbonized plant remains (seeds, leaves, etc)</td>
<td>Wet and waterlogged soils</td>
<td>Vegetation, diet, building materials, materials for wooden tools, construction technology</td>
<td>Hand excavation/ 0.3 mm flotation</td>
<td>Features, 10-20 liters from each stratum</td>
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<td>Wood (charcoal)</td>
<td>Wet and waterlogged soils (all soils)</td>
<td>Dendrochronology, paleoenvironment, building materials, construction technology</td>
<td>Hand excavation/ above sampling methods and low power x10 and x100 microscopes</td>
<td>All soil/ 75 liters</td>
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<td>Features, 50cc from each stratum (a film case can be used)</td>
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<td>Ecofacts</td>
<td>Favorable Locations for Preservation</td>
<td>Information That Can Be Obtained</td>
<td>Sampling and Analytical Methods</td>
<td>Sample Size Required</td>
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<td>Pollen</td>
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<td>Features, 50cc from each stratum (a film case can be used), column samples</td>
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<td>Identification of rice and other cereals, vegetation, land use, agriculture, seasonality</td>
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<td>urnn samples</td>
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<td>Soil</td>
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<td>On-site examination by specialist/ soil sampling</td>
<td>Column sample, block cutting</td>
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<td>Stratigraphic formation processes, environment, agriculture, construction</td>
<td>Soil sampling with a kubiena box</td>
<td>Soil collected in a 5x10x5cm metal frame</td>
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<td>Large mollusks</td>
<td>Alkaline to neutral soils</td>
<td>Diet, subsistence, exchange, season of gathering, management practices</td>
<td>Hand excavation/ 5-10mm screen</td>
<td>All soils/ 75 liters</td>
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<td>Small mollusks</td>
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<td>Features, 10 liters from each stratum</td>
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<td>Features, 10-20 liters from each stratum</td>
</tr>
<tr>
<td>Insect remains (uncarbonized)</td>
<td>Wet and swampy soils</td>
<td>Climate, vegetation, growing environment, industry, human diet</td>
<td>As above</td>
<td>As above</td>
</tr>
<tr>
<td>Parasite eggs</td>
<td>Wet and swampy soils</td>
<td>Human and animal parasites, sanitation, identification of latrines, relations with intermediary hosts</td>
<td>Analyzed in the lab with a x400 microscope and other specialist equipment</td>
<td>Features, 0.05 liters from each stratum (a film case can be used)</td>
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<tr>
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<td>All soils</td>
<td>Human diet, identification of animals with degraded lipids, tool function, nutrition from latrine soils, sexing, distinguishing human and canine coprolites</td>
<td>Examined in the lab depending on the sample (lithic, pottery, soil, etc) and quantity of lipids: various specialist equipment required</td>
<td>For soil, approx. 1 liter. To avoid contact with petroleum based products, the sample should be wrapped tightly in aluminium foil and kept in a cool, dark place</td>
</tr>
<tr>
<td>Stable isotope analysis</td>
<td>Human and animal bones</td>
<td>Human diet, ratio of marine foods, distinguishing wild and domesticated animals</td>
<td>Analyzed in the lab with various specialist equipment</td>
<td>1-3 grams of bone avoiding the surface</td>
</tr>
</tbody>
</table>
Chapter 2.
Small and middle size mammals
1. The Significance of Compiling a Pictorial Review for Animal Skeletons

There are an increasing number of people in the field of archaeology who are interested in animal remains. This development is doubtlessly due to the diversification of the field of archaeology, that has promoted a focus on the value of shellfish and animal bones that are amenable to the direct discussion of ancient eating habits and livelihoods. In the past, animal remains were lumped together with natural stones and plant remains and referred to as “natural remains” that were considered to be material for studies in the field of natural science and, thus, outside the realm of archaeological research. Today, however, their importance as ecofacts reflecting important cultural behaviour and lifeways is recognized as a full-fledged sub-discipline of archaeology.

Nevertheless, in order to identify the species and body part of animal remains that are unearthed from archaeological sites, it is necessary to become thoroughly versed in complicated anatomical terminology, most of which is either in Latin or English and have access to skeletal specimens of a full range of modern animals in a zooarchaeological laboratory reference collection. In addition, there have been no facilities that have skeletal specimens of modern animals made available for archaeological researchers to use, a situation that has forced those who aspire to become zooarchaeologists, or zooarchaeologists, into collecting their own skeletal specimens and creating their own faunal osteology (animal bone) reference collections. Furthermore, if one wishes to come into contact with research at the forefront of zooarchaeology, there is a need to consult the academic literature, written primarily in English. These factors make for a road that is wildly convoluted and despairingly long.

Even though on the one hand, the demand for information provided by the zooarchaeologist has increased, on the other hand nothing has changed in terms of the difficulty of studying the discipline. Even if one were to teach oneself, the first obstacle is the absence of any decent introductory handbooks on animal bone osteology. At the National Research Institute for Cultural Properties in Nara, Japan, we have always incorporated lectures on zooarchaeology in our Environmental Archaeology training programs. We are now drawing on our experience to compile a series of pictorial reviews of animal osteology, designed for archaeological researchers with convenience of use in mind. This paper, "Environmental Archaeology 2: A Pictorial Review and Comparative Morphology of Small and Medium-Sized Mammalian Osteology," contains life-size illustrations of the major bones (for bones on both sides of the body, the left bone is shown) of ten animals:

1. Japanese macaque (Macaca fuscata)
2. Domestic dog (Canis familiaris)
3. Otter (Lutra lutra)
4. Fox (Vulpes vulpes)
5. Raccoon dog (Nyctereutes procyonoides)
6. Badger (Meles meles)
7. Japanese martes (Martes melampus)
8. Japanese weasel (Mustela leucurus)
9. Japanese hare (Lepus brachyurus)
10. Japanese giant flying squirrel (Petaurista leucogenys)

We have addressed the ox, the horse, the wild boar, and the Sika deer in upcoming issues, and hope to design reviews for birds and fish as well. It would be most gratifying for the authors if this series of pictorial reviews is of utility to all archaeological researchers who have an interest in the remains of animals from archaeological contexts.

2. Skeletal Structure

In describing the parts of an animal’s skeleton, there are several special terms that are used to identify the relative positions they originally occupy in the body. The bones excavated from archaeological sites are often broken into minute fragments. It is therefore an unavoidable necessity to use special terminology to describe which part of the original bone a given fragment corresponds to. The following is an explanation of the minimum vocabulary used in such descriptions.

When describing a portion of a bone, the portion closer to the head is referred to as “anterior” while the portion closer to the tail is called “posterior.” The portion closer to the axial skeleton (cranium and spine) is called the “proximal” end while the portion farther from the axial skeleton is referred to as the “distal” end. The side that is closer to the center of the body is called “medial” and the side farther from the center, “lateral.” In terms of morphology, the bones in an animal’s skeleton can be classified into the following long bones, short bones, sesamoid bones, flat bones, and irregular bones. Long bones are typically found in the appendicular skeleton (limbs), and consist of a bone shaft ("diaphysis") and the two extremities on either end ("epiphysis"). During growth and development of an animal, the diaphysis and the epiphyses are separated by epiphyseal cartilage, and bone growth takes place primarily in this cartilaginous layer. When the cartilaginous layer deteriorates and disappears, a markedly uneven surface with fine irregularities is generated between the shaft and the ends of the bone. As the animal matures, the bones cease their growth. The epiphyseal cartilage disappears, and the diaphysis and epiphyses fuse together (termed ossification) to form a single unit. The timing of ossification differs between animal species and between individual body parts. It therefore provides good clues for the assessment of age in animals whose permanent teeth have already completely erupted. However, in archaeological contexts, whole skeletons are rarely excavated and single bones or fragments are all that are left to work with, thus, it is necessary to age individual bones through this type of epiphyseal fusion.

Names of Major Bones in the Mammalian Skeleton

<table>
<thead>
<tr>
<th>Bone Name</th>
<th>Latin Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canine</td>
<td>Canis familiaris</td>
</tr>
<tr>
<td>Dog</td>
<td>Canis familiaris</td>
</tr>
<tr>
<td>Fox</td>
<td>Vulpes vulpes</td>
</tr>
<tr>
<td>Raccoon</td>
<td>Nyctereutes procyonoides</td>
</tr>
<tr>
<td>Badger</td>
<td>Meles meles</td>
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<tr>
<td>Japanese Martes</td>
<td>Martes melampus</td>
</tr>
<tr>
<td>Japanese Weasel</td>
<td>Mustela leucurus</td>
</tr>
<tr>
<td>Japanese Hare</td>
<td>Lepus brachyurus</td>
</tr>
<tr>
<td>Japanese Giant Flying Squirrel</td>
<td>Petaurista leucogenys</td>
</tr>
</tbody>
</table>

Japanese Sika Deer: Left Femur
3. Characteristics of the Skeleton by Body Parts

Cranium

The cranium is primarily divided into the visceral cranium, which comprises the face, and the neurocranium, which houses the brain; the mandible is not included in the cranium. The visceral cranium is mainly comprised of the premaxilla or incus bone, the maxilla, the nasal bone, the zygomatic bone, and the palatine bone. The neurocranium is primarily made up of the frontal bone, the parietal bone, the temporal bone, and the occipital bone. The eye socket forms the border between the visceral cranium and the neurocranium. The fundus of the occipital bone is comprised of the occipital condyle, which articulates with the spine, and the great foramen, through which the inferior medulla oblongata and the vertebral arteries gain passage to the spine.

In the Japanese macaque, the snout portion is short to the anterior and posterior. The neurocranium is large and round. The eye socket is independent of the temporal fossa and is oriented forward. The dentition, or 'dental formula', is the same as in humans: 2-1-2-3 and 2-1-2-3 (the dentition represents the right and left maxillary incisors; canines; premolars; and molars, and the mandibular incisors; canines; premolars; and molars, in sequential order). The first set of four numbers represents the 'upper' or maxillary dentition, while the second set of four numbers represents the 'lower' or mandibular dentition; both sets are only half of full complement of teeth in the skull, thus, for the macaque, the total number of teeth is: 32. Mammals in the same family typically have one set of four numbers representing the teeth in the mandible, and one set of four numbers representing the teeth in the maxilla. The dental formula is 3-1-4-3 and 3-1-4-3.

In the fox, the side view demonstrates a linear profile from the snout to the posterior. The eye socket is large, and the infraorbital foramen is somewhat developed. The external occipital protuberance is somewhat developed and juts out slightly from the occipital condyle. The dental formula is 3-1-4-2 and 3-1-4-3.

The front of the dog is significantly higher than its snout portion, and there is a well-developed stop (frontal-nasal depression) where the bone is depressed at approximately the border of the nasal bone and frontal bone (the Jomon dog is characterized by its small stop). The eye socket is large, and the infraorbital foramen is somewhat developed. The external occipital protuberance is somewhat developed and juts out slightly from the occipital condyle. The dental formula is 3-1-4-2 and 3-1-4-3.

In the raccoon dog, the neurocranium is smaller, broader, and shorter to the anterior and posterior compared to those of the dog and fox, which are fellow members of the family Canidae. The sagittal crest and the nuchal crest are somewhat developed. The dentition is 3-1-4(3)-2(3) and 3-1-4(3)-2(3), but there is a high incidence of abnormal arrangement in the dentition.

The marmot also has a more abbreviated skull to the family Mustelidae. It has a short snout portion and a low neurocranium. A top (superior) view demonstrates the following differences from the raccoon dog: a thicker snout portion, eye sockets located more to the anterior, and an extremely developed sagittal crest. The dental formula is 3-1-4-1 and 3-1-4-2.

The otter is also a member of the family Mustelidae. While the snout portion is short and the neurocranium is large, it is broad with a developed temporal fossa. It therefore gives a flattened impression. The naris and infraorbital foramen are extremely large, but the eye socket is small. The sagittal crest and the nuchal crest are well developed. The dental formula is 3-1-4(3)-2(3) and 3-1-4(3)-2(3).

The Japanese marten also belongs to the family Mustelidae, as does the Japanese weasel. In both animals, the visceral cranium is small, and the neurocranium is large. While the Japanese weasel is about 20 percent smaller than the Japanese marten, there are such large male-female differences in both species that it is hard to make generalizations. The naris and infraorbital foramen are extremely well developed, but the eye socket is small and the temporal fossa is large. A side view demonstrates that the neurocranium is low, the nuchal crest is developed, and the zygomatic arch is curved. The weasel has a shorter snout and a larger tympanic part of the temporal bone. The dental formula is 3-1-3-1 and 3-1-3-1 in the Japanese weasel, and 3-1-3-1 and 3-1-3-1 in the Japanese marten.

The bones of the Japanese hare are thin and delicate overall, and extremely characteristic in that there is a network of holes on the superior surface of the maxilla and the nasal bone. The neurocranium is large, and the external acoustic foramen is somewhat to the superior. The dental formula is 2-0-3-3 and 1-0-2-3.

The bones of the Japanese giant flying squirrel also have thin and delicate bone walls. The snout is short, and the cranial is large and round. The naris is large, but the infraorbital foramen is small. The zygomatic process of the frontal bone protrudes and forms a large eye socket. A top view indicates that the zygomatic arch forms a gentle curve and the entire cranial forms an ellipse. The anterior surface of the incisors are orange in color. The dental formula is 1-0-2-3 and 1-0-1-3.

Mandible

The mandible is divided into the mandibular ramaus, which articulates with the cranium, and the mandibular body, where the teeth are located. Generally speaking, a coronoid process occurs at the top of the mandibular ramaus, and posterior to that, an articular process that articulates with the cranium. A coronoid process may form in the posterior of the truncal portion of the mandibular ramaus. The angle of the mandible continues to the inferior, and forms the posterior portion of the mandible. The mandibular symphyses, where the right and left mandibular bodies make contact, fuses in the Japanese macaque as the animal ages, but rarely fuses in many other animal species. The mandibular body of the dog, fox, raccoon dog, and badger is long and slender, while that of the Japanese macaque, Japanese hare, and Japanese giant flying squirrel is high to the superior and inferior short to the anterior and posterior.

The alveolar crest is prominent in the Japanese macaque, but not very significant in the other animals. The coronoid process forms an isosceles triangle or a triangle that is close to isosceles in the fox, otter, Japanese marten, and Japanese weasel, while it is smaller in shape in the dog, raccoon dog, and badger. The articular process is located at about the same height as the mandibular body in the case of the dog, fox, raccoon dog, badger, otter, Japanese weasel, and Japanese marten. However, it is positioned higher than the mandibular body in the case of the Japanese macaque, Japanese hare, and Japanese giant flying squirrel.

The coronal process is extremely developed, and the border of the masseteric fossa distinct, in the dog, fox, raccoon dog, badger, otter, Japanese weasel, and Japanese marten. In the Japanese hare and the Japanese giant flying squirrel, there is a diastema between the incisors and premolars. The facial vascular notch is developed and the mandibular body can be readily distinguished from the angle of the mandible. The angle of the mandible is developed in a gnu-like shape. In the Japanese giant flying squirrel, the mandibular body and diastema are shorter, and short overall to the posterior and anterior. The coronal process and mandibular notch are more prominent, and the anterior surface of the incisors is colored. A superior (or top) view, with the right and left mandibular bodies joined together, indicates that the mandible of the Japanese macaque is curved, forming a U-shape, while those of the other animals are linear and V-shaped.

Scapula

Ready to use a model to identify identification of species, the scapula...
is a bone of archaeological significance. In the case of small and medium-sized mammals, the scapula is large in relation to the overall size of the animal, flattened in shape, and thin. Generally triangular in shape, it has a distinct morphology. However, due to soil pressure and gnawing by dogs, it is rare for the scapula to be unearthed complete. The spine of the scapula is an eminence that forms on the lateral side. It begins to inflate gradually from the area around the proximal dorsal margin and forms a stump at around the acromial notch, forming an acromial process and a tuberosity to which the deltoid muscle is attached. The scapula of the dog, fox, and raccoon dog are similar overall, but in the dog and the raccoon dog, the lateral surface view is somewhat long, while it is short in the fox. The lateral surface view is very similar in the otter, Japanese marten, and Japanese weasel, but the differences in size, as well as the shape of the acromial process, allows for species discrimination between the two animals. The acromial process is well developed in the Japanese macaque, Japanese hare, Japanese giant flying squirrel, Japanese marten, and Japanese weasel. This bone gives species-specific characteristics but because it is a relatively fragile bone, it is often missing in archaeological contexts. The coracoid process is well developed in the Japanese hare, Japanese giant flying squirrel, Japanese marten, and Japanese weasel. The coracoid processes of the Japanese giant flying squirrel and Japanese hare are very similar. Likewise, those of the Japanese marten and Japanese weasel are very similar.

Humerus

The proximal extremity of the humerus is divided into the greater trochanter and the head of the humerus. The articular portion of the head of the humerus is inflated and articulates, or connects, with the articular fossa of the distal extremity of the scapula. The distal extremity forms the condyle of the humerus. The articulation with the radius and ulna, and the troclear notch, are developed. The superior depression is called the radial fossa on the anterior surface and the olecranon fossa on the posterior surface. Depending on the species, this depression is perforated and forms the supratrochlear fossa. Out of the species covered in this issue, those that have a supratrochlear fossa are the dog, fox, raccoon dog, and Japanese hare; however, at times the supratrochlear fossa may not be present.

The greater trochanter is well developed and located somewhat superior of the head of the humerus in the dog, raccoon dog, otter, and Japanese hare. In the Japanese macaque, dog, Japanese giant flying squirrel, and Japanese hare, the head of the humerus is located roughly along the central line of the axis of the diaphysis. In the dog, fox, raccoon dog, otter, Japanese marten, and Japanese weasel, the deltoid tuberosity extends as far as the distal portion of the diaphysis. The trochanter of the humerus is located anterior of the central axis of the bone. The medial epicondyle protrudes to the medial, and lateral epicondylar crest and the lateral border of the trochanter of the humerus form a sharp crest. The medial epicondyle protrudes particularly prominently and forms the medial epicondylar foramen in the otter, Japanese marten, and Japanese weasel. In many species, the diaphysis is linear; however, it is strongly curved in the otter, with the lateral epicondylar crest markedly developed at the distal extremity. The diaphysis of the badger is very strongly curved, but not as prominent as that of the otter.

Radius

The radius is a weight-bearing bone that articulates distally to the humerus. In combination with the ulna, that is located posteriorly, it contributes to the rotation of the wrist. Because of its relatively thick bone wall, it is a part that is readily preserved. The proximal extremity is called the cycloidal surface, and forms the elbow joint together with the ulnar notch of the ulna. Generally, the radius is thicker and shorter than the ulna. The cross section at the proximal diaphysis is a strongly flattened ellipsoid, which becomes less flat and more thick toward the distal, and reaches maximum size at the border portion between the diaphysis and epiphysis.

The so-called articular surface of the wrist at the distal extremity is a rounded concave shape, and is where species-specific characteristics tend to manifest. In the dog, fox, raccoon dog, Japanese marten, and Japanese weasel, the proximal articular surface is rounded, kidney-shaped, and depressed slightly in the center. While the radius of the fox is very similar in morphology to that of the dog, it is more slender overall and a crest develops somewhat in the center of the posterior surface of the diaphysis. In the raccoon dog, the diaphysis is somewhat round from the diaphysis to the distal, and there is a developed styloidy process. In the Japanese macaque, the diaphysis curves broadly, there is a developed crest on the anterior surface of the distal, and the cross section is triangular. The radius of the Japanese hare is extremely slender and bends at the proximal, with a developed crest on the posterior surface of the diaphysis. In the Japanese marten, the radius is relatively linear. The radius of the otter and the Japanese weasel are strongly curved at the distal and similar in general appearance. However, in the Japanese weasel, the cross section of the distal portion of the diaphysis is characteristically long anteriorly and posteriorly.

Ulna

The ulna is located posterior to the radius. The olecranon forms the superior part, and a trochlear notch is formed between the olecranon process inferior to the olecranon and the coronoid process. The ulna articulates with the trochlear portion of the distal extremity of the humerus. Generally, the diaphysis becomes extremely slender and delicate from the truncal portion to the distal. In the dog, fox, raccoon dog, badger, otter, and Japanese marten, the olecranon process and coronoid process protrude to the anterior to roughly the same degree. However, the coronoid process protrudes farther anterior in the Japanese macaque, while the olecranon process protrudes farther anterior in the Japanese hare and the Japanese giant flying squirrel. In the Japanese macaque and otter, the diaphysis is extremely thick. However, in the fox, Japanese hare, and Japanese giant flying squirrel, the diaphysis is extremely slender and delicate from the truncal portion to the distal. The troclear notch process at the distal end is inflated in a characteristic pea-like shape in the Japanese macaque, otter, Japanese marten, and Japanese weasel. Archaeological sites often yield the relatively sturdy olecranon and the portion around the trochlear notch.

Pelvis

The pelvic girdle is comprised of the ilium, ischium, and pubis fused together, with the right and left ilia clasping the sacral vertebrae at the posterior. The anterior of the pelvis forms the pubic symphysis and the ischial symphysis, which fuse with age. Because of its association with birth, the pelvis is a bone in which the male-female differences are most prominent in many animals, including the human.

In the Japanese macaque, the ilium is extremely long. The obturator foramen has a protruding postpubic ramus and is close to heart-shaped. The ilioischial eminence is not significantly developed, but the ischial tuberosity is extremely well developed and is semilunar in shape. In the dog, the ilium is short, the ilioischial eminence is well developed, the ischial spine and ischial tuberosity are somewhat developed, and the obturator foramen is close to oval. With a developed ilioischial eminence and ischial spine, the pelvis of the fox is generally similar to that of the dog, but is distinguished by having a well-developed tuberosity to which the rectus femoris muscle is attached.

In animals such as the badger and the raccoon dog, the ilium is somewhat long and the ischial tuberosity somewhat developed, but while in the badger the sacral tuberosity and ilioischial eminence is somewhat developed, in the
Cranium

Japanese macaque

Otter

Dog

actual size
Cranium

Japanese marten

Raccoon dog

Japanese weasel

Badger

Japanese hare

Japanese giant flying squirrel

Fox
Scapula

Dog

Japanese macaque

Badger

Japanese marten

Japanese giant flying squirrel

Japanese hare

Otter

Fox

Raccoon dog
Humerus

Japanese macaque

Japanese hare

Japanese giant flying squirrel

Raccoon dog

Badger

Otter

Japanese marten

Dog

Fox

actual size
Radius / Ulna

Japanese giant flying squirrel

Japanese hare

Fox

Dog

Japanese macaque

Japanese weasel

Japanese marten

Otter

Badger

Raccoon dog actual size
Pelvis (Coxal bone)

Raccoon dog

Japanese hare

Dog

Japanese macaque

Japanese giant flying squirrel

Japanese marten

Badger

Otter

Japanese weasel (actual size)
### List of Measurements by Animal Species (Units: mm)

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