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Where Did They Go Fishing? A Multi-Scalar Spatial Analysis of Jomon Fishing Activities in the Tokyo-Yokohama District, East Japan

Abstract: This paper examines the spatial patterns of prehistoric net fishing carried out by the Jomon hunter-gatherers in Japan. It is a case study of a multi-scalar approach using a Geographical Information System (GIS) analyzing a large archaeological dataset. In the Tokyo-Yokohama district (1500 km^2 in area) of East Japan, 235 out of approximately 4000 Jomon sites have yielded a total of 3800 stone/clay sinkers, as a primary evidence of net fishing. GIS is employed for cataloguing this massive dataset and illustrating a series of sinker distribution maps in different scales – household (micro), settlement/occupation (semi-micro), site-catchment (semi-macro), and regional (macro) levels. A holistic interpretation of the archaeological patterns obtained from the analytical maps provides a better understanding of the diachronic changes, local variations, and possible venues of Jomon net fishing activities.

Introduction

Similar to its importance for the modern Japanese people, fish constituted one of the main parts of the daily diet of the Jomon people, or Neolithic hunter-gatherers, living in the Japanese archipelago from the early Holocene through to the middle of the first millennium BC. Ichthyological studies have revealed that the Jomon hunter-gatherers captured salmon and trout (Oncorhynchus sp.) running upstream during the autumn season, carps (Cyprinus sp. and Carassius sp.) in the freshwater zone, black sea bream (Acanthopagrus sp.) and sea bass (Lateollabrax sp.) in the estuarine water, and most interestingly, bonito (Euthynnus sp.) and tuna (Tunnus sp.) in the off-shore zone (Uchiyama 1997; Toizumi 1997). The archaeological evidence has also attested that the Jomon people were skilled fishers, operating a variety of fishing gears such as harpoons, fishhooks, nets, and fish traps. Among these, today, net fishing is the most common due to its high potential of fish catch.

The net fishing activities carried out in the past can be witnessed by the specific fishing gears such as nets, sinkers and floats that have been recovered from archaeological sites. However, organic nets and wooden floats have been badly preserved in the acidic soil environment of the Japanese archipelago. Therefore, stone/ceramic sinkers *(Fig. 1)* are held to be a primary indicator of net fishing by many Japanese researchers. According to their typological studies (for instance, Watanabe 1973; Kobayashi 1989; Terahata 1996), based on the retouch techniques, sinkers are classified into three subtypes – notched, incised, and grooved *(Fig. 1: 1–3)*. All ceramic sinkers have a pair (or two pairs) of incisions as attachments to fishing nets *(Fig. 1: 4–5)*.

The present status of research of the Jomon net fishing activities needs to be reconsidered to take into account new points of view. Since the first (and latest) nation-wide Jomon fishing study in the 1970s (Watanabe 1973), a dramatically increasing number of archaeological surveys and excavations throughout Japan have occurred due to the intensive urban development. This has added greater numbers to the Jomon net fishing evidence. Previously, archaeological studies of the Jomon net fishing have put a greater emphasis on the typological classification of sinkers and have paid less attention to the spatial contexts from which the sinkers were recovered. Therefore, the possible locations of Jomon net fishing areas still remain to be considered.

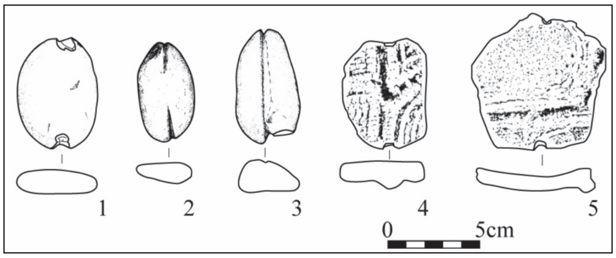

Fig. 1. Schematic illustration of typical Jomon sinkers
1: notched stone sinker, 2: incised stone sinker, 3: grooved stone sinker, 4: ceramic sinker (Katsusaka-type), 5: ceramic sinker (Atamadai-type.)

In order to solve these issues, a Geographical Information System (GIS) was used which has two important features. Firstly, GIS is well designed to analyze a large dataset to prepare a variety of thematic maps. Secondly, and more importantly, GIS is capable of displaying a map in any scale. This helps us to analyze the archaeological patterns in changing (or multi-)scales. On the basis of these two functions, this paper aims to achieve a new insight into the topographical nature of Jomon net fishing activities in the Tokyo-Yokohama district, East Japan, through GIS-aided spatial analyses of fishing gear distribution in different scales. This study also aims to present a case study of a multi-scalar approach towards a dense cluster of archaeological data.

Study Area

The Tokyo-Yokohama district, known as the capital region of Japan, is located at the southeast corner of Honshu, the largest island in the Japanese archipelago. The study area comprises Tokyo Metropolis and the northeast part of Kanagawa Prefecture. The area covers approximately 1500 km^2, stretching 55 km from east to west and 37 km from north to south.

The Tama River, flowing eastward into the Tokyo Bay, geographically divides this region into two parts: the Musashino Upland to the north and the Tama Hills to the south *(Fig. 2)*. From the hydrological point of view, the Musashino is a large alluvial fan resulting from the Tama drainage system, whose underground water has given rise to numerous springs and streams. The eastside of the Musashino Upland and Tama Hills faces the Paleo-Tokyo Bay, which used to penetrate further north

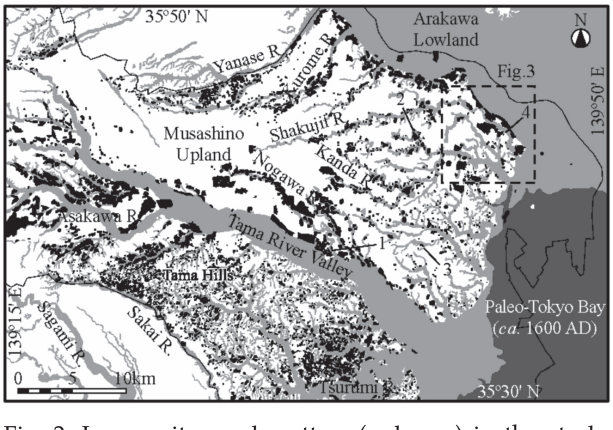

Fig. 2. Jomon sites and scatters (polygon) in the study area. Sites mentioned in the text are also indicated. 1: Benzaiten-ike, 2: Kita-egota, 3: Meiji-yakkadai, 4: Dosaka.

compared to present days due to the Holocene great transgression (Toizumi 1999).

On these lands, more than 4000 Jomon sites have been documented by rescue excavations. When these sites are illustrated with polygon, they appear to be concentrated on the riverbanks; on the other hand, no sites have been discovered in the midland regions *(Fig. 2)*. This pattern clearly indicates that water and aquatic resources were the main concerns of the Jomon people.

Multi-Scalar Methodology

The concept of scale can be applied to time, space and dimension (Lock / Molyneaux 2006). Among them, the spatial scale is mainly discussed in this paper. Hence the term multi-scale (multi-scalar) can be defined as a series of analytical scales. Since David Clarke's earliest attempts to classify the archaeological units into micro, semi-micro, semi-macro, and macro scales (Clarke 1977), the majority of the spatial approaches have focused on a singular analytical scale. However, it should be noted that the scale itself is principally relative and seamless, and thus, it could be multiple in nature. Therefore, in my view, the GIS-based multi-scalar spatial analyses should be applied to interpret distributional patterns in archaeology.

Tab. 1 presents a theoretical framework of multi-scalar spatial analysis. The ideal scale for browsing printed maps on a desk is indicated by the logarithmic basis. Each scale is relevant to a spatial unit as well as to an analytical method. For example, the scale 1:100 corresponds to household structure level analysis; in other words, micro-scale spatial analysis. GIS is particularly suited to analyze the distributional maps at this and larger scales. The larger the scale, the wider the area that can be analyzed. At a scale of 1:10,000, the traditional method of site-catchment analysis is employed to a selected site and its neighboring topographic features. A scale 1:100,000 and larger corresponds to regional or macro level analysis. Again, the scale levels are temporal, and thus, the transformation between different scales is quite seamless in GIS-based mapping. It is also noteworthy that at each scale, both qualitative and quantitative approaches can be chosen for analysis because GIS is capable of using both approaches.

During the research process, the archaeological data associated with net fishing gears, particularly stone / clay sinkers, are obtained from the excavation

SCALE	LEVEL	TARGET	GIS
≤ 1:1	super-micro	artefact	
1:10	micro	locus	applicable
$1:10^2$	micro	built structure	good fit
$1:10^3$	semi-micro	site	good fit
$1:10^4$	semi-macro	site-catchment	good fit
$1:10^5$	macro	region	good fit
$\geq 1:10^6$	super-macro	supra-region	good fit

Tab. 1. Framework of multi-scalar spatial analysis.

reports. These data are recorded in the GIS-compatible database that is composed of the sinker database in which the provenance, context, size, weight, material, typological class and dating are recorded for each specimen, and the site database in which the site code, local name, geocoordinates, topographical feature, occupational period and periodical/typological summary of the reported number of Jomon sinkers are input. Then, using the latter, in accordance with different scales such as locus/built structure (micro), settlement/occupation (semi-micro), site-catchment (semi-macro) and regional (macro) levels, a variety of sinker distribution maps are prepared by GIS.

Multi-Scalar Mapping

Locus Level (Micro Scale)

In the study area, the contextual information about the net sinkers at the locus/architectural level has been well documented. Sinkers are recovered from house floor, house fill, pit, oven, garbage, shell midden, and natural deposits. With regard to the household context, the Middle Jomon (third millennium BC) village site of Benzaiten-ike, located on the left bank of the Tama River *(Fig. 2: 1)*, provides interesting evidence on fishing net keeping. In three round pit dwellings (about 5 m in diameter on average) at this village, several ceramic sinkers have been found in situ on their floors. Particularly, from the House J23, dated to the later phase of the Middle Jomon, five ceramic sinkers, headed in the same direction, were recovered on the clay floor (Terahata 1996). The excavator reports that one of the sinkers shows traces of bitumen on its surface (Terahata 1996). These proofs indicate that the sinkers were attached to fishing nets used in the aquatic environment.

Site Level (Semi-Micro Scale)

The above-mentioned archaeological contexts of net sinkers (house, midden, etc.) can be classified into settlement (on-site) and non-settlement (off-site).

With regard to the settlement level, the intrasite spatial analysis well illustrates sinker disposal patterns. For instance, in the Middle Jomon village of Meiji-yakkadai *(Fig. 2: 3)*, 43 of the total 96 pit dwellings documented thus far have yielded one to eight sinkers (Meiji-yakkadai Iseki Chosakai 2000). The pottery-based chronology indicates that the site had been continuously occupied from the middle to later parts of the Middle Jomon period. Thus, the sinker distribution pattern at Meiji-yakkadai indicates the continuous production, maintenance, and disposal of net fishing gears at the fishing station.

Another disposal pattern has been unraveled at non-settlement sites. In the inland low-wetland sites around Kita-egota *(Fig. 2: 4)*, about a hundred ceramic sinkers have been recovered from the alluvial deposits. There is no residential architecture in these sites, except for a number of wet storage pits (Kita-egota Iseki Chosakai 1987). Sinkers from such a low-wetland context may also reflect their usage and disposal at a fishing point.

Site-Catchment Level (Semi-Macro Scale)

The site-catchment area, or the isochrone buffer zone around a given fishing station, is analyzed in order to estimate the potential fish catch (fishing potentiality). Since the natural settings of the study area are rather homogeneous, the fishing potentiality can be influenced by the area of aquatic environment around the fishing station. In this paper, the area of the aquatic zone within an hour's walk from a given departure point is considered as a fishing potentiality. This assumption is based on Taniguchi's estimation (2003) that the ideal territory of a Middle Jomon base settlement in the study area would measure 4.2 km in radius.

Then, the 60-minute-isochrone zone is calculated by using the Hiking Function (Tobler 1993), with placing additional costs on the lowland and water zone as below:

$$T = \frac{0.06b}{6\exp\left(-3.5\left|\frac{\pi}{180}\theta + 0.05\right|\right)}$$

where T is the lap time for moving one meter on the grid surface; θ, the slope angle; and b, an additional barrier coefficient (water zone = 3, lowland = 2, and others = 1). By using the 50 m-grid cost surface that is based on this equation, the 60-minute-isochrone area of a given fishing station is calculated.

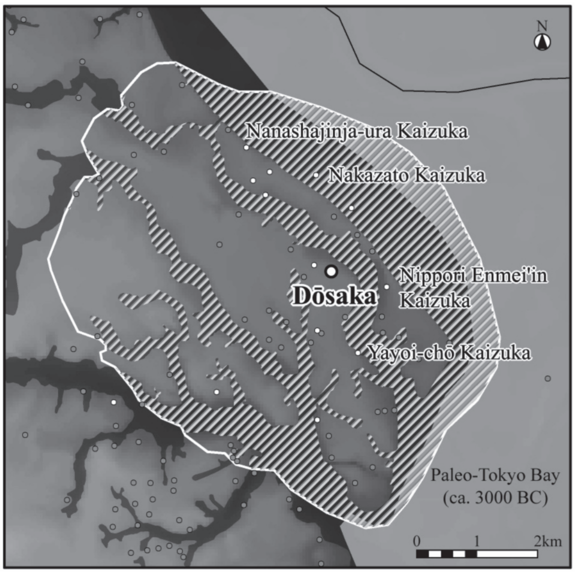

Fig. 3. 60min-isochrone fishing potential area (hatched zone; 18.0 km² in this case) of the Middle Jomon settlement of Dosaka.

Fig. 3 shows the 60-minute-isochrone of the Middle Jomon settlement of Dosaka, located on the edge of the upland, close to the paleo-coastline. The isochrone includes coastal shell middens, such as Nakazato Kaizuka, as well as inland streams. The fish remains of this site contain a high percentage of estuarine species such as black sea bream and sea bass in addition to the freshwater species such as carp (Dosaka Kaizuka Chosakai 1978). Therefore, it is likely that the Dosaka people carried out their fishing activities both in an inner-bay area and in a freshwater riverside.

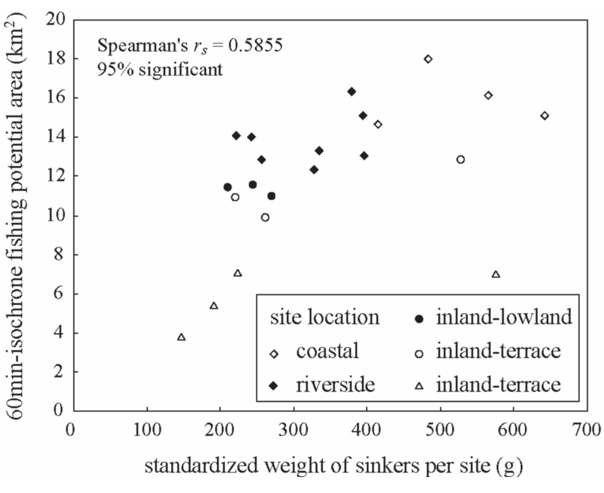

Fig. 4. Correlation between fishing potentiality and standardized weight of sinkers from the 23 selected sites in the Musashino.

According to their topographical nature that is quantitatively evaluated by GIS, the sites from which stone or clay sinkers have been recovered (hereafter mentioned as "sinker site") are divided into three classes. One group is principally closer to the Tokyo Bay, another is closer to the Tama River Valley and the other is located inland and therefore, it is relatively remote to both water zones. Each class can be subdivided into two location groups: low-wetland sites and terrace sites. According to this scheme, Dosaka is categorized as a coastal-terrace site.

The results of a site-catchment analysis of the 23 selected sinker sites in the Musashino Upland (northeast part of the study area) are shown in *Fig. 4*. Spearman's rank correlation coefficient indicates a significant correlation between standardized sinker weight (x) and the 60-minute-isochrone fishing potential area (y). Interestingly enough, this correlation is also associated with the site location. Both standardized sinker weight and fishing potentiality increases in the order of inland-terrace, inland-lowland, riverside and coastal sites. This pattern suggests that the Jomon people used to select appropriate net sinkers taking into account the conditions of their fishing area.

Regional Level (Macro Scale)

In the study area, 235 Jomon sites have yielded a total of approximately 3800 net sinkers (Kondo 2007). The distribution maps of sinker sites show diachronic changes of net fishing patterns *(Fig. 5)*. Net sinkers appeared in the Initial Jomon period (ca. seventh to fifth millennia BC; *Fig. 5a*); however, the distribution density of the net sinkers had been relatively low until the Early Jomon (fourth millennium BC; *Fig. 5b*) and early (Goryogadai) phase of the Middle Jomon period. From the middle (Katsusaka) to later (Kasori-E) phases of the Middle Jomon period (the middle to later parts of the third millennium BC), ceramic sinkers suddenly became predominant. The distribution map of these stages *(Fig. 5c)* shows dense clusters of sinker sites along the western coast of the Paleo-Tokyo Bay and the lower reaches of the major river valleys. Afterwards, in the Late Jomon (second millennium BC; *Fig. 5d*) and Final Jomon (first millennium BC; *Fig. 5e*) periods, the ceramic sinkers were then replaced with their stone counterparts with a significant quantitative decline.

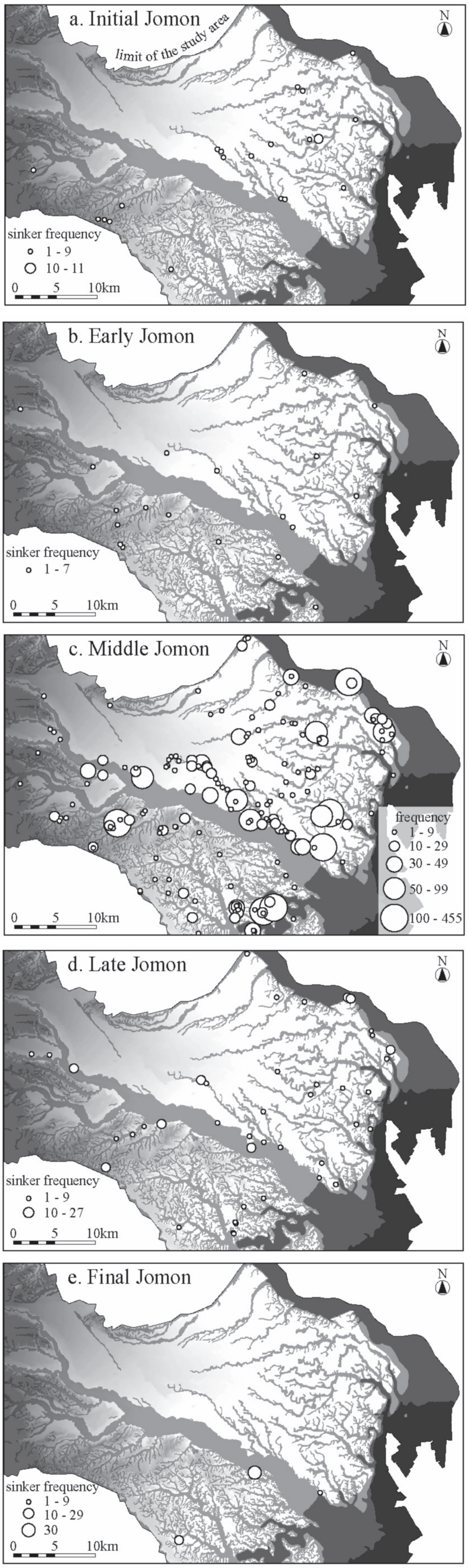

Fig. 5. Chronological sequence of the sinker sites.

As described, the Katsusaka phase of the Middle Jomon period is the beginning of the predominance of net fishing in this region. In this phase, it is said that two population groups – the Katsusaka people from central highlands and the Atamadai people from the eastern coastal zone – simultaneously inhabited the region (Kobayashi 1989). As most sinkers at this phase are made up of potsherd, it is possible to distinguish between the net fishing activities of the two groups by the ceramic typology. It is of interest that while the percentage of the Katsusaka type ceramic sinkers increases in the inland zone, that of their Atamadai counterparts increases in the littoral zone *(Fig. 6)*.

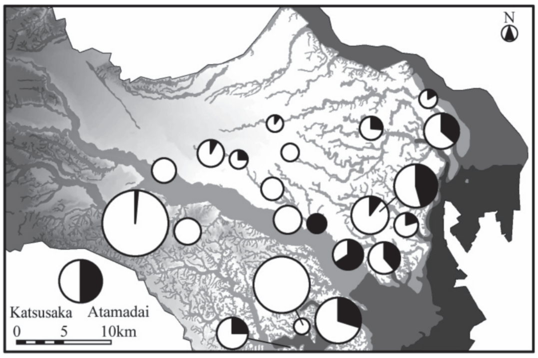

Fig. 6. Percentage of Katsusaka- and Atamadai-type ceramic sinkers at the 24 selected sites at the middle phase of the Middle Jomon period (middle of the third millennium BC).

It is true that some archaeological patterns are extracted from these distribution maps, but they may be biased by the different scales of excavation projects. In order to reduce such a bias and to detect possible net fishing areas, the sinker density is standardized by the following procedure. Firstly, the reported number of sinkers at a given site (TOTAL) is divided by the total excavated area (DIGAREA) to get an expected sinker number (EXP) per one hectare (10,000 m^2):

$$EXP = \frac{TOTAL}{DIGAREA} \times 10000$$

Then, in order to reduce the variability of excavation area, the expected number is converted into log value (S):

$$S = \log_{10} EXP$$

By using this, the adjusted standard deviation score of the estimated sinker number (D) is calculated:

$$D = \frac{S - \overline{S}}{\sigma} \times 100$$

where is $\overline{S}$ the arithmetic mean of S, while σ is the standard deviation of S. Finally, the kernel density per square kilometer is calculated to get a 1 km-grid standardized sinker density score.

In the study area, the highest density scores appear on the lower reaches of the Tama River as well as on the west coast of the Paleo-Tokyo Bay *(Fig. 7)*. It is strongly inferred that these are two major Jomon net fishing areas.

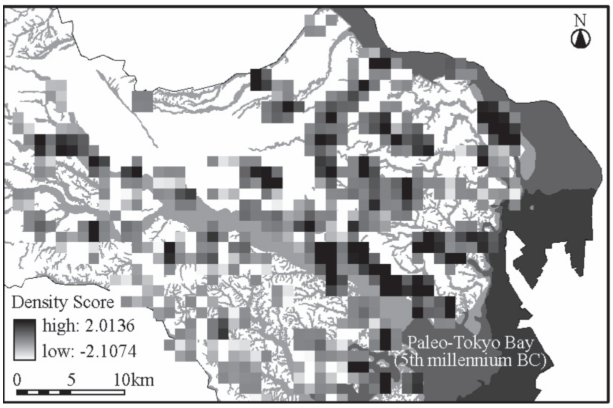

Fig. 7. 1 km-grid standardized sinker density score.

Holistic Interpretation

A holistic interpretation of the above-mentioned multi-scalar archaeological patterns of the Jomon net sinkers enables us to understand the diachronic changes and local variations of net fishing activities as well as possible fishing zones in the study area.

In the micro and semi-micro scales, the intrasite spatial analysis of the sinker context provides information on the techniques in which net fishing gears were prepared, used, maintained, and discarded. Firstly, as exemplified by the case of the House J23 at Benzaiten-ike, at the locus / architecture (micro) level, the net sinkers that were recovered from the house floor indicate that the net fishing gears were kept and maintained at base camps. Secondly, at the settlement / occupation level, the intermittent disposal of sinkers in the village of Meiji-yakkadai and low-wetland sites, including Kita-egota, indicates the frequent use of net fishing devices.

The site-catchment analysis in the semi-macro level well illustrates topographic potentiality of Jomon net fishing. Firstly, it reveals that the standardized weight of the net sinkers from a given fishing station is significantly correlated to the size of the neighboring aquatic zone *(Fig. 4)*. From this result, it can be strongly inferred that Jomon fishing activities were carried out in close proximity to settlements. Secondly, the fishing potentiality and standardized sinker weight increases in proportion to its proximity with the waterfront. This pattern can be explained by the interpretation that a variety of sinkers were prepared and used, taking into account fishing conditions, such as water depth, target fish, and expected fish catch. To effectively exploit the aquatic resources near settlements, in accordance with their population size and location, a variety of net fishing was conducted.

Finally, from the macro viewpoint, which took into account all parts of the study area, the chronological distribution maps *(Fig. 5)* and standardized density score *(Fig. 7)* in the region clearly indicate the presence of dense clusters of sinker sites along the coastline of Paleo-Tokyo Bay and the lower reaches of the Tama River Valley. In those stages, these areas could have served as major net fishing areas for the Jomon hunter-gatherer-fishers. Particularly, in the middle (Katsusaka) and later (Kasori-E) phases of the Middle Jomon period, the coastal and river fish resources were intensively exploited. In the Katsusaka phase, it appears that although the Katsusaka and Atamadai people were from different origins, they shared their fishing areas without imposing any territorial boundaries *(Fig. 6)*. The intensive net fishing activities also appear to be associated with the tremendously high-density population in that period (Imamura 1996, 93–99).

As discussed above, the GIS-based multi-scalar analysis provides different insights into the Jomon net fishing. A combination of the qualitative and quantitative approaches in different spatial scales enables us to recognize the prehistoric fishing strategies from a holistic perspective. Then, what will be the consequences if they are analyzed at a larger, supra-regional scale? In my view, archaeological patterns could be interpreted differently when the analytical scale is broadened. A more extensive survey conducted across the entire Japanese archipelago can provide an answer to that question; furthermore, it will also enable a detailed reconstruction of prehistoric fishing strategies from a wider perspective.

Acknowledgements

This research project is financially supported by the Sasakawa Scientific Research Fund and CAA 2007 travel grant. I am grateful to Gary Lock, as chair, and the other participants of the session, whose comments assisted me in the elaboration of my paper.

References

CLARKE 1977

D. CLARKE, Spatial archaeology (London 1977).

DOSAKA KAIZUKA CHOSAKAI 1978

[Dosaka Shell Midden Archaeology Unit] (Tokyo 1978).

IMAMURA 1996.

K. IMAMURA, Prehistoric Japan: New Perspectives on Insular East Asia (London 1996).

KITA-EGOTA ISEKI CHOSAKAI 1987

KITA-EGOTA ISEKI CHOSAKAI, Nakano-ku [Nakano City] (Tokyo 1987).

KOBAYASHI 1989

K. KOBAYASHI, Jomon jidai chuuki zen'yo dankai no dokihensui ni miru seigyo katsudou. [Ceramic sinkers and subsistence in the earlier part of Middle Jomon.] Kodai Bunka 41:4, 1989, 24–37.

KONDO 2007

Y. KONDO, Interpreting Archaeological Objects Using GIS: Spatial Analysis of the Jomon Sinker Distribution in the Tokyo-Yokohama District, East Japan. Bulletin of the Department of Archaeology, The University of Tokyo 21, 2007, 1–82.

LOCK / MOLYNEAUX 2006

G. LOCK / B. MOLYNEAUX, Confronting Scale in Archaeology (New York 2006).

MEIJI-YAKKADAI ISEKI CHOSAKAI 2000

MEIJI-YAKKADAI ISEKI CHOSAKAI [MEIJI-YAKKADAI ARCHAEOLOGY UNIT] (ED.), Setagaya-ku Kyoiku Iinkai [Setagaya City Education Board] (Tokyo 2000).

TANIGUCHI 2003

Y. TANIGUCHI, The Distribution of the Middle Jomon Central Settlements and their Territorial Model. Kokogaku Kenkyu [Quarterly of Archaeological Studies] 49:4, 2003, 39–58.

TERAHATA 1996

S. TERAHATA, Tokyo-to Setagaya-ku oyobi Komae-shi shutsudo no dosui to sekisui ni tsuite (jou). [Sinkers from Setagaya and Komae City, Tokyo Metropolis: Part 1.] Tokyo Kouko 14, 1996, 1–41.

TOBLER 1993

W. TOBLER, Three Presentations on Geographical Analysis and Modeling. Technical Report 93-1. National Center for Geographic Information and Analysis (Santa Barbara 1993).

TOIZUMI 1997

T. TOIZUMI, Spatial Relationship Between Jomon Fishery and Marine Resources around Tokyo Bay, Central Japan. Joho Kankyo Kagaku [Information and Environmental Science] 26:2, 1997, 21–26.

TOIZUMI 1999

T. TOIZUMI, Relationship Between Marine Environment in the Holocene and Jomon Shell Middens in the Tokyo Bay Area, Central Japan. Bulletin of the National Museum of Japanese History 81, 1999, 289–310.

UCHIYAMA 1997

J. UCHIYAMA, Jomon Fishing Activity in the Kanto District in the Late Phase (4000–3000 BP): Spatial Analysis of Prehistoric Subsistence Using GIS. Bulletin of the National Museum of Ethnology 22:2, 1997, 375–424.

WATANABE 1973

M. WATANABE, Jomon jidai no gyogyo. [Fishing in the Jomon Period.] (Tokyo 1973).

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