Standardization of Shell Tools in the Haidai Region During the Dawenkou-Yueshi Culture Period: From the Perspective of the Whole Life Cycle

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Abstract. The period from the Dawenkou Culture to the Yueshi Culture in the Haidai Region was a critical stage of prehistoric social complexity. As widely used tools for production and daily life, shell tools are important evidence for revealing regional handicraft organization and resource utilization patterns. This paper takes shell tools unearthed from inland sites of this period as research materials, selects the Wangyin Site in Yanzhou, Sanlihe Site in Jiaoxian, Yuchisi Site in Mengcheng and Yinjiacheng Site in Sishui as typical cases, and systematically investigates the raw material preparation, processing production and use steps of shell tools from the perspective of the whole life cycle. The study finds that prehistoric shell tools in this region had formed a relatively standardized production system and stable application scenarios during this period, showing a limited level of standardization. At the same time, it is noted that the standardization level of shell tools cannot only rely on morphological quantitative indicators, but also needs to be comprehensively determined by combining the production organization characteristics of each stage of the operational chain.

Keywords: Haidai Region, Dawenkou-Yueshi Culture Period, Shell Tools, Standardization

1. Introduction

Prehistoric people in the Haidai Region carried out long-term and intensive exploitation of freshwater shellfish resources, which were mainly used as meat resources, raw materials for tool making, and temper for pottery. The stage from the Dawenkou Culture to the Yueshi Culture was a critical period in the process of prehistoric social complexity, manifested in rapid population growth, aggregation and hierarchy both within and among settlements, the emergence of private ownership, and intensifying social inequality [1]. Among these aspects, the organizational model, technological choices, and standardization degree of handicraft production serve as an important window into the civilization evolution process of this period.

At present, most academic studies on prehistoric aquatic resources focus on the utilization of shellfish as meat resources and the ecological features they reflect, while paying limited attention to shell tools made from mussel shells. Existing scholars have studied prehistoric shell tools using typology as a method, discussed their practical and decorative functions, and systematically sorted out relevant materials [2]. For specific sites, some studies have also conducted simulation

experiments on the raw material extraction steps of shell tools, thereby determining the basic operational techniques and raw material preferences [3].

Against this background, this paper focuses on the standardization level of shell tools in the process of social complexity in the Haidai Region, attempts to expand the research perspective to the dynamic standardization of the operational chain, and observes its characteristics from the perspective of the whole life cycle.

Most of the data on shell tools unearthed in the Haidai Region are disclosed in excavation reports. A large number of shell accumulations were found at the Guanqiaocunnan Site in Tengzhou [4], a large number of shell spades, shell knives, shell sickles, shell arrowheads, shell spoons and shell ornaments were unearthed at the Shangzhuang Site in Chiping [5], and a small number of Dawenkou Culture shell tools were also excavated at the Beiqian Site [6]. These findings indicate that shell tools were used for a long time in prehistoric Haidai Region and are important materials for studying prehistoric handicrafts. Despite the abundant data, discussions on cultural anthropological issues such as production technology, handicraft organizational models, and commodity circulation have not been in-depth.

In terms of research perspective, this paper restores the positioning of shell tools as production and daily life tools as well as ritual objects. In terms of temporal and spatial framework, it focuses on inland sites in the Haidai Region from the Dawenkou Culture to the Yueshi Culture period. In terms of research approach, it draws on the "operational chain" theory in the field of stone and bone tool research [7], and attempts to restore the whole life cycle of shell tools from "raw material preparation to manufacturing and use". At the same time, in view of the technological characteristics of shell tools that adopt "subtractive manufacturing" and are constrained by the size of natural raw materials, this paper calculates the coefficient of variation with "length, width and length-width ratio" as core parameters, and constructs a quantitative analysis approach suitable for shell tools. The above research approach reveals the resource utilization strategies of inland sites in the Haidai Region through the standardization degree and functional differentiation of shell tools, and provides support for exploring technological choices, division of labor in production and social needs under the background of prehistoric social complexity.

2. Materials and methods

2.1. Materials

The "shell tools" discussed in this paper specifically refer to finished artifacts made from the exoskeletons of freshwater shelled organisms through processes such as cutting, grinding and drilling. The raw materials, blanks and waste materials involved in the research process only serve as auxiliary evidence for discussing the use links of shell tools, and the core research objects remain finished shell tools.

This paper limits the temporal and spatial scope to the Dawenkou-Yueshi Culture period in the Haidai Region, and focuses on shell tools unearthed from inland sites in this region as research objects. Spatially, the Haidai Region is located in a coastal location, where prehistoric people had a high degree of exploitation and utilization of freshwater and marine shellfish resources, and its application mode of shell tools is representative. Temporally, the region has a continuous and complete cultural lineage. The period from the Dawenkou Culture to the Yueshi Culture basically completed the evolution from ancient states to early states, and changes in the organizational form of handicraft production reflect a highly active process of social complexity. At the same time, shelled organism resources in inland sites have a relatively single source, and the utilization mode of shell

tools has strong stability, which is more suitable for quantitative and qualitative analysis in archaeology.

Under the above temporal and spatial framework, this paper further selects the Wangyin Site in Yanzhou, Sanlihe Site in Jiaoxian, Yuchisi Site in Mengcheng and Yinjiacheng Site in Sishui as typical cases. The Wangyin Site dates from the late early to middle Dawenkou Culture [8]; the Sanlihe Site is mainly a site of the middle and late Dawenkou Culture [9]; the Yuchisi Site covers the late to final Dawenkou Culture [10]; and the Yinjiacheng Site spans from the late Dawenkou Culture to the Yueshi Culture period [11]. The chronological sequences of these sites are successive, forming a complete time chain from the late early Dawenkou Culture to the Yueshi Culture. At the same time, they are respectively located in the hinterland of south-central Shandong, Jiaodong Peninsula, northern Anhui region and the edge of the south-central Shandong mountains. Their distribution locations intuitively reflect the core scope of the Haidai Cultural Area and its different radiating areas, and the organic connections formed in temporal and spatial dimensions can mutually confirm and complement each other.

2.2. Methods

The "whole life cycle" perspective is the core entry point for this paper to observe the shell tools unearthed from the above typical sites. Generally speaking, this cycle covers the complete chain from raw material acquisition, storage, processing and manufacturing, to use, circulation and abandonment [12]. Restoring its production process can reflect the social organizational form at that time to a certain extent. However, since shell products are mostly used as basic utensils, their functional positioning has led to the degeneration or even absence of some links in the life cycle (such as circulation). Therefore, this paper adaptively reconstructs the "whole life cycle" in the study of shell tools, and refines its core processes into three stages: "resource acquisition", "processing and manufacturing" and "use and utilization".

After establishing the basic framework of phased investigation, this paper further discusses the two core concepts of "specialization" and "standardization" in the organizational form of handicraft production and their relationship. Specialization in handicraft production refers to the organizational method of systematically organizing different production activities [13], and this process shows different degrees in different stages of human society [14]. The evaluation of specialization degree can be based on three dimensions: production background, direct evidence and indirect evidence [15]. Physical products as indirect evidence are the most accessible and intuitive materials among the above. Therefore, existing studies mostly retrospectively investigate the specialization degree of production by analyzing the standardization, diversity and spatial distribution of products. The core lies in the consistency presented by products in physical attributes such as shape, size and proportion. This consistency directly reflects the producers' depth of perception and control ability over the physical attributes of artifacts. That is, the higher the uniformity of the product, the more proficient the technical standards and professional literacy the producers usually have.

In practical operation, the Coefficient of Variation (CV for short) is a key indicator for quantifying the level of standardization, which is used to characterize the degree of dispersion of data. The higher this value, the greater the specification difference of products, that is, the lower the degree of standardization. The calculation formula is as follows:

$$CV = (S/\overline{X}) \times 100\%$$

where S is the sample standard deviation and $\bar{X}$ is the sample mean. When the sample size is less than 30, the correction formula can be used to optimize the results, and the formula is as follows:

$$CV=(1+1/(4n))\ CV'$$

where CV is the original coefficient of variation and CV' is the corrected coefficient of variation.

This method was mostly applied to the study of pottery standardization with large sample sizes in the past, and calculations were mainly based on absolute values such as caliber, base diameter and maximum abdominal diameter [16]. Relevant statistical studies point out that in the absence of clear reference standards, the minimum variation rate that human handmade products can achieve is about 1.7%, while if there are significant artificial manufacturing differences in products, their coefficient of variation usually exceeds 57.7% [17]. In addition, when the coefficient of variation of pottery is less than 3%, it corresponds to a highly intensive production mode; when it is between 3% and 6%, it is difficult to judge whether it is large-scale or small-scale production; when it is between 6% and 9%, it usually corresponds to small-scale production [18].

However, different from the "additive manufacturing" of pottery, the production of tools such as stone tools, bone tools and shell tools is limited by the shape of raw materials and belongs to typical "subtractive manufacturing". Therefore, we cannot directly apply the standardization evaluation method of pottery based on "absolute values", but must turn to the consideration of "relative values". Existing studies have analyzed the standardization differences among rough blanks, semi-finished blanks and finished products of stone tools by constructing three-dimensional indicators of "length, width and height" [19], and quantified the variation degree of bone tools to estimate the degree of production specialization [20]. However, among the three dimensions of length, width and thickness, the thickness data of shell tools has limited reference value. For this reason, this paper introduces the indicator of "length-width ratio", which converts the two independent absolute dimensions of length and width into a single relative indicator for measuring the shape of artifacts, and can more scientifically and accurately reflect the processing intentions of ancient people and the morphological standardization degree of shell tools.

It is worth noting that a high degree of production specialization does not necessarily correspond to a high level of standardization. This is because the manufacturing of products is deeply influenced by demand orientation: if products are designed to adapt to multiple usage scenarios or meet the diverse needs of specific social functions, producers will consciously retain or even create differences, resulting in a lower degree of standardization. This indicates that for products with multiple demand scenarios, their specialization level needs to be comprehensively judged by combining other evidence in the production and use processes. Based on this, when discussing the standardization of shell tools, this paper will not only calculate the coefficient of variation, but also fully combine multi-dimensional evidence from aspects such as raw material preparation, production and processing, and use and utilization.

3. Case analysis

The typical sites selected in this paper can be divided into two groups according to their research focuses: the Wangyin Site and Sanlihe Site, whose main remains belong to the early Dawenkou Culture, mainly reflect the raw material reserve, resource selection and multi-purpose utilization of shell tools, and are used to reveal the targeted development and management strategies of regional ancestors for shellfish resources; the relatively later Yuchisi Site in Mengcheng and Yinjiacheng Site in Sishui have unearthed a considerable number of shell tools with complete types, which can

intuitively present the production technical specifications and functional differentiation characteristics through the research on technological logic, artifact evolution and standardization quantification.

In addition, the shell tools unearthed from the above sites all contain relatively complete information on usage contexts and functional orientations, which can jointly support the comprehensive interpretation of the usage modes, functional differentiation and social connotations of shell tools.

3.1. Wangyin site in Yanzhou

A certain number of tool-type shell tools and concentratedly distributed remains of freshwater shelled organisms were found in the ash pits and cultural layers of the Wangyin Site in Yanzhou.

The shell tools unearthed from the strata and ash pits of the site are mainly practical production tools. Among them, shell spades are the most numerous, with a total of 14 pieces, all made from Lamprotula shells. During production, the nodules on the back of the shell surface were first ground flat, and then the periphery of the commissure area was trimmed; some specimens have flattened back nodules, notched blades and worn tips due to long-term use. A total of 3 shell sickles were unearthed, which are crescent-shaped as a whole with prominent curved backs, and some specimens have obvious use-wear traces [21].

In addition to finished shell tools, 54 pieces of shell materials were also found in the cultural layers of the site, some with cutting and grinding lines on the surface and some with perforations, which belong to blanks or waste materials in the shell tool manufacturing process; layered and pit-accumulated residual shells of mussels and snails can also be seen in the site, which should be intentionally stored raw materials [21]. Relics produced in all links of shell tool manufacturing have been found in this site in considerable quantities, indicating that the ancestors of Wangyin had formed a relatively complete shell tool production process including raw material storage and pretreatment, and could carry out production on a certain scale. Besides being used as food resources and raw materials for tool making, mussel shells are also an important source of temper in pottery making. Since the Beixin Culture period, shell-tempered pottery has always accounted for a high proportion of the unearthed pottery sherds at this site. It is speculated that the concentratedly stored remains of shelled organisms may be an important source of temper. It can be seen that in terms of resource utilization, the Wangyin Site realized multi-channel development of shellfish.

In terms of raw material selection for tool making, the site shows a clear species preference: the core practical tool, shell spades, preferentially uses Lamprotula species as raw materials. A total of 30 species of Bivalvia animal remains were found at the site, among which 16 species belong to the genus Lamprotula spp., accounting for 53.6% of the species abundance and occupying a dominant position [22]. Lamprotula species have high density and hardness in their shell structure, which meets the material requirements of spades as agricultural production tools. Abundant raw material sources and appropriate material specificity make Lamprotula species the preferred raw material for shell spade production at the Wangyin Site.

In summary, all the shell tools unearthed from the Wangyin Site retain clear use-wear traces, which intuitively reflect the actual application state of prehistoric shell tools; the complete preservation of shell materials, blanks, production waste and centrally stored shell raw materials in the site confirms that the local area had a shell tool production system including raw material reserve and pretreatment. In addition, the ancestors of Wangyin had a clear species preference for shellfish resources, selecting Lamprotula species specifically for making core production tools according to the functional requirements of artifacts and material properties, and applied shellfish resources to

multiple fields such as tool making, pottery making and food consumption, which fully reflects the efficient and diversified development and utilization mode of regional shellfish resources by the ancestors during the Dawenkou Culture period.

3.2. Sanlihe site in Jiaoxian

Shell products unearthed from the Sanlihe Site are mainly found in tombs and storage pits.

A total of 74 shell tools were unearthed from the Dawenkou Culture tombs at the site. The identifiable types of practical tools mainly include knives, sickles, arrowheads and spoons, and the ornaments include perforated shell tools made from large mussel shells and Meretrix meretrix, as well as round and square shell ornaments. Among them, there are 36 long strip-shaped shell tools with simply ground edges, and their perforation forms include double holes, single holes and no holes, and their specific functions remain to be further verified [23].

The number of shell tools in the Longshan Culture tombs of the site dropped sharply, with only 5 spoons and 1 long strip-shaped shell tool found. The above-mentioned shell spoons and long strip-shaped shell tools were mostly found near the hands of the tomb owners or directly held in their hands, indicating that the two may have similar practical functions. In addition, unprocessed shells of Thais clavigera were also unearthed in the coffins of tombs such as M214 and M240, and shells of Meretrix meretrix and Scapharca subcrenata were also found under the human bones of M275 [23]. The coexistence of these unprocessed remains of shelled organisms and finished shell tools that have been ground and perforated indicates that mussel shells may have certain ritual connotations.

In addition to finished artifacts, a series of special Dawenkou Culture ash pits (such as H128, H223, H217, etc.) were also found in the site. A large number of shells were accumulated in these ash pits, which were collected and piled up centrally, with obvious traces of artificial screening. In addition, most of the pits are wide at the top and narrow at the bottom, which were artificially trimmed and confirmed to be storage pits rather than ordinary garbage dumping ash pits [23]. It can be inferred that the shells in such storage pits were consciously stored as raw materials for making shell tools.

It can be seen that from the Dawenkou Culture to the Longshan Culture period, the shell tools at Sanlihe had both practical and ritual functions. At the same time, the discovery of storage pits dedicated to storing shell materials indicates that the shell tool production at this site already had planned raw material reserve and specialized production tendencies.

3.3. Yuchisi site in Mengcheng

The shell tools unearthed from the Yuchisi Site cover various types such as shell spades, shell knives, shell sickles, shell arrowheads, shell rings and pendants, which can be divided into two categories: production tools and decorative artifacts.

Observed from the morphological characteristics, the shell spades at this site are generally wide, flat and nearly square, with large and regular shapes, and their wide blades can meet the operational needs such as digging and turning soil. Shell knives and shell sickles are both long strip-shaped, suitable for cutting scenarios; the difference between the two types is that shell knives have straight blades or outwardly convex curved blades, while shell sickles have inwardly concave curved blades, adapting to their opposite force directions. Shell arrowheads have various shapes, including short and thick ones and long and thin ones, with basic structures such as tangs and shafts. As non-production tools, shell rings and pendants: the former are extremely narrow and long strips, presumed to be decorative rings or artifact components, possibly with the implication of imitating

jade artifacts; the latter have neat cutting traces on the edges and perforations in the middle, which should be ornaments hung with ropes [24].

Analyzed from the production technology, the design of practical tools at this site presents the technological logic of "form follows function and utilizes natural structures". Shell spades are made from large Bivalvia shells with a certain thickness, and the natural curvature of the exoskeleton of shellfish is used to adapt to the shoveling function; both shell knives and shell sickles use the ventral margin of the shell as the blade, and the structure of gradually thinning edges is used to improve cutting efficiency; some subtypes of shell arrowheads use the hinge groove (or hinge socket) of the hinge part of the mussel shell to process into a ridge, and the nearly triangular cross-section can increase lethality [25]. The sample size of non-practical tools is limited, but their coordinated structures reflect that the ancestors had mastered the processes such as cutting, grinding and perforating shell materials proficiently.

The published archaeological materials of the Yuchisi Site have detailed records of the sizes of typical specimens among the unearthed shell tools, based on which the ratio of length to width can be used to describe their shapes (the sample size of shell ornaments is too small, so it is not included for the time being). Taking subtypes with a sample size of 2 or more as the smallest unit, the above data were input into the software RStudio to calculate the coefficient of variation and generate a scatter plot (as shown in Figure 1). It is found that on the graph, spades, knives, sickles and arrowheads respectively form concentrated data clusters, and the values of agricultural tools on the vertical axis are significantly lower than those of fishing and hunting tools.

This phenomenon may be formed because agricultural production tools occupied a higher position in the lives of Neolithic ancestors, so a relatively mature production process was formed. As fishing and hunting tools, arrowheads, on the one hand, need to adapt to the rich application environments of catching different prey, and on the other hand, as "expedient tools", they have low sustainable utilization degree, so they have formed more diverse shapes.

It can be seen from the above that the shell tools at the Yuchisi Site were processed in accordance with local conditions by fully relying on the natural structure of shells, and practical tools followed the function-oriented production logic. The agricultural shell tools in the site have stable length-width ratios and similar shapes, and their variation degree is lower than that of the flexibly shaped shell arrowheads, reflecting that prehistoric society formed differentiated artifact production specifications according to production needs.

3.4. Yinjiacheng site in Sishui

Shell tools from the Yinjiacheng Site in Sishui have been found in both cultural layers and ash pits, including common types such as spades, sickles, knives, awls, arrowheads and shell ornaments.

First of all, there is a clear typological continuity of shell tools from the Longshan Culture to the Yueshi Culture period at the site. Specifically, Type A spades of the Longshan Culture are similar in shape to Type B spades of the Yueshi Culture, and Type B spades of the Longshan Culture are similar to Type A spades of the Yueshi Culture; Type A Form I knives of the Longshan Culture are identical to Type Aa Form I knives of the Yueshi Culture, and Type A Form II knives of the Longshan Culture correspond to Type Aa Form II knives of the Yueshi Culture; the shapes of Type A arrowheads, Type C arrowheads and Type A awls in both periods are also basically consistent.

Secondly, the ancestors had demonstrated a clear awareness of risk sharing in the production of shell tools. Type A Form I knives of the Longshan Culture and Type Aa Form I knives of the Yueshi Culture were both perforated at the umbo of the mussel shell and used this part as the handle [26]. The production risk of this type of shell knife was mainly concentrated at the perforation site of the

umbo, which is the thinnest part of the raw material, while the ventral margin with hard texture and large thickness was ground into the blade, effectively reducing the risk of breakage during processing. Type A Form II knives of the Longshan Culture and Type Aa Form II knives of the Yueshi Culture adopted the opposite strategy: the umbo was naturally formed into a thin blade, and perforations were made at the thicker ventral margin [26], concentrating the production risk in the area with higher requirements for drilling strength.

In addition to the above basic analyses of typology and operational chain, the Yinjiacheng Site, with abundant unearthed shell tools and relatively detailed records, can also support archaeological statistical research. Taking spades, sickles, knives and arrowheads as units to calculate the coefficient of variation of the length-width ratio and then generate a scatter plot (as shown in Figure 2), it is found that the cluster of the coefficient of variation of the length-width ratio of arrowheads is significantly higher on the vertical axis than that of spades, sickles and knives. This situation is consistent with that at the Yuchisi Site, and it is speculated that there are different procedural control concepts in the production of agricultural tools and fishing and hunting tools. In summary, the shell tools at the Yinjiacheng Site from the Longshan Culture to the Yueshi Culture stage have stable typological inheritance and evolution relationships. In the processing of shell tools, the ancestors could adjust the positions of perforation and blade opening in combination with the natural structure of shells, forming differentiated risk avoidance strategies. At the same time, relevant quantitative analysis shows that this site also presents the characteristics that agricultural shell tools have regular shapes, low dispersion and high standardization degree, while fishing and hunting shell tools have diverse shapes and large coefficients of variation. This is highly consistent with and mutually corroborates the analytical conclusions of the Yuchisi Site, jointly confirming that the prehistoric Haidai society had formed a hierarchical and differentiated standardization system for shell tool production according to the functional differences between agricultural tools and fishing and hunting tools.

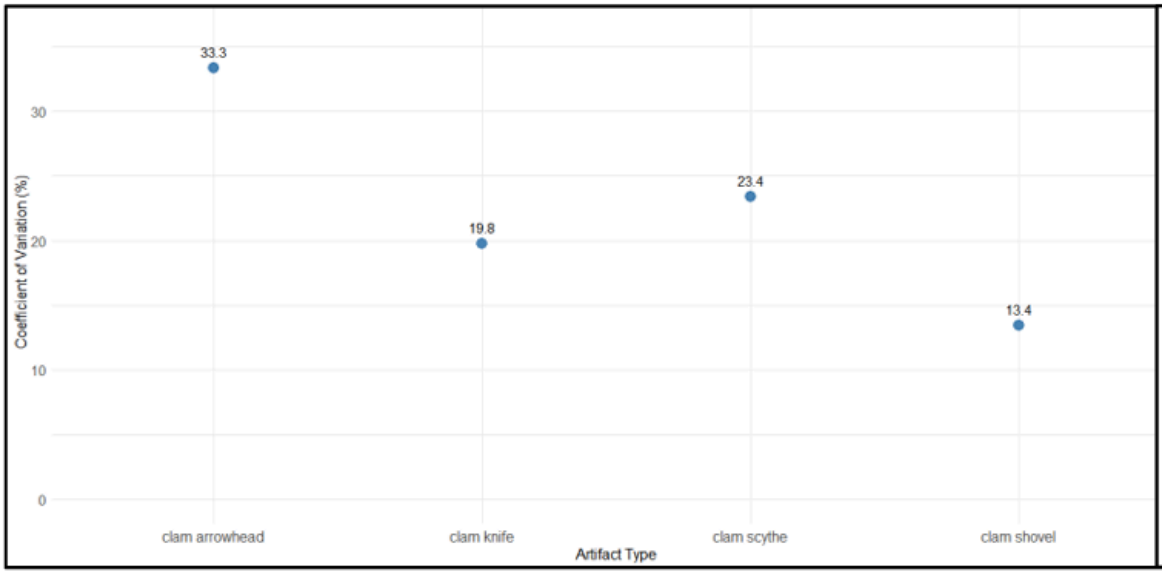

Figure 1. Scatter plot of the coefficient of variation of shell artifacts unearthed at the Weichi Temple site

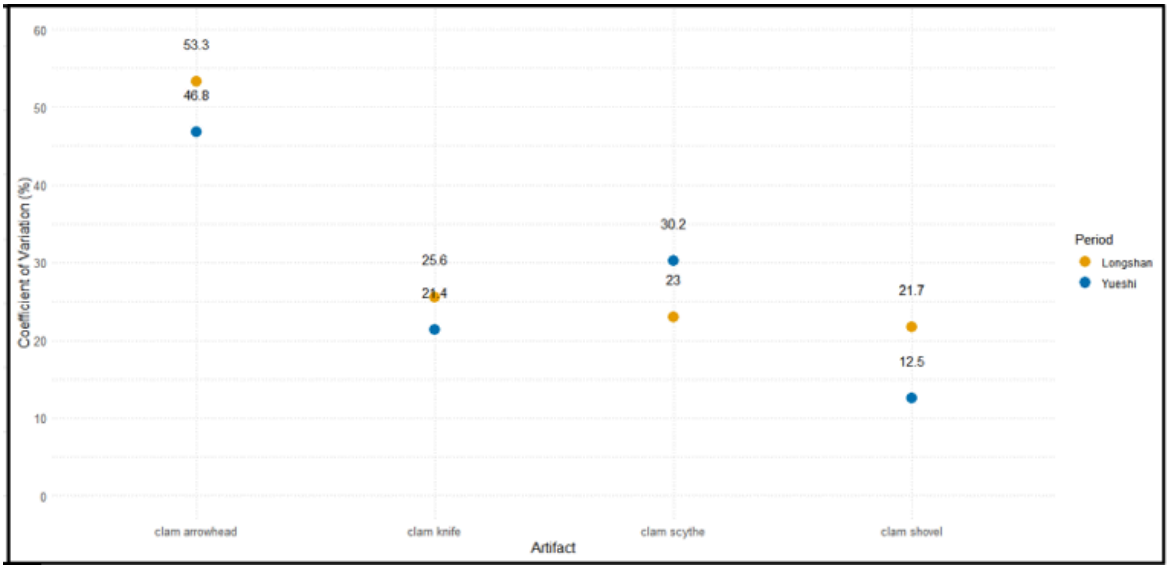

Figure 2. Scatter plot of the coefficient of variation of shell artifacts from the Longshan Culture and Yueshi Culture periods unearthed at the Yinjiacheng site [27]

4. Discussion

Through typological sorting, production process restoration and statistical analysis of shell tools unearthed from the four sites of Wangyin in Yanzhou, Sanlihe in Jiaoxian, Yuchisi in Mengcheng and Yinjiacheng in Sishui, it is found that the utilization characteristics of shell products in each site exhibit certain commonalities. That is, under the whole life cycle framework of "raw material preparation - production and processing - use and utilization", all stages of the shell tool utilization operational chain show a limited degree of standardization.

4.1. Raw material preparation: awareness of shell material resource management and control

During the Dawenkou-Yueshi Culture period, the ancestors in the Haidai Region had broken through the passive exploitation of aquatic resources in the links of selecting and storing raw materials for shell tools, demonstrating a high degree of resource management and control awareness and targeted utilization strategies.

In the raw material selection link, the phenomenon of "selecting materials according to artifact types" presented in some sites, and the high correspondence between specific artifact types and specific mussel genera reveal the standardization of the process. For example, shell spades at the Wangyin Site, as digging agricultural tools, centrally select Lamprotula species with thick shells and high hardness as raw materials, which meets the functional requirements of their high-strength physical properties. The stable corresponding mode of "specific species-specific artifact types" indicates that the ancestors in the Haidai Region, in the complex freshwater habitats, had the ability to consciously and directionally extract raw materials according to the mechanical requirements of different tools.

In the raw material storage link, the phenomenon of concentrated accumulation of shellfish remains in artificially specially processed storage pits has been found in multiple sites, and traces of artificial trimming and pretreatment can be seen on the surface of some mussel shells. This unified storage and preprocessing behavior indicates that before the discarded mussel shells after consumption became ordinary domestic garbage, the ancestors had already carried out secondary

sorting on them, which shows that the production and use of shell tools had been deeply integrated into the planning system of the daily economy of settlements.

In summary, the targeted selection and storage behaviors of shell materials by the ancestors in the Haidai Region during the Dawenkou-Yueshi Culture period were not accidental or fragmented immediate utilization, but presented procedural and organizational characteristics.

4.2. Production and processing: "contextualized" production strategy

The shape of finished shell tools is an important indicator for measuring the degree of standardization in the production and processing link. By calculating the coefficient of variation (CV) of the length-width ratio of various shell tools in the sites, this paper finds that there is a differentiation phenomenon among different artifact types: the coefficients of variation of shell knives, shell spades and shell sickles, which are typical agricultural tools, are generally low, while the coefficient of variation of shell arrowheads, which are fishing and hunting tools, is significantly high.

Agricultural production has a relatively fixed natural background and predictable operation modes. Such stable application scenarios impose unified and strict restrictions on the mechanical structure and ergonomics of tools. Therefore, it was a choice in line with agricultural needs for the ancestors to anchor the shape of agricultural tools within a specific range. However, fishing and hunting activities face more complex and changeable natural environments and target prey. The changeable hunting scenarios require tools to have high versatility, which has given rise to the high diversity of shell arrowheads in size and shape. It can be seen that the significant difference in the coefficient of variation between agricultural tools and fishing and hunting tools does not stem from the gap in the degree of production specialization, but is the result of the ancestors' precise control and technical adaptation to the needs of different application scenarios.

It can be seen from this that the ancestors in the Haidai Region during the Dawenkou-Yueshi Culture period could adopt different processing scale strategies according to the different use logics of agricultural tools and fishing and hunting tools, which confirms that a mature "contextualized" manufacturing concept had been formed in the production and processing link at that time.

4.3. Use and utilization: extension from practical tools to ritual objects

By observing the shapes and relative positions of shell tools unearthed from tombs, it is found that during the Dawenkou-Yueshi Culture period, the ancestors in the Haidai Region had broken through the single practical tool attribute of shell tools, showing a trend of extending to symbolic significance. This process is reflected in a kind of "behavioral standardization" that is separated from production and manufacturing.

Shell tools have formed relatively stable "standardization of usage contexts" in funeral scenarios. In the tombs of some sites, there is a persistent stable funeral custom of placing specific long strip-shaped shell tools or shell spoons in the hands of the tomb owners, accompanied by unprocessed snail and mussel shells. This indicates that specific shell tools have been transformed into utensils with fixed symbolic connotations. At the same time, ornaments such as perforated shell pendants and shell rings generally show an obvious imitation tendency of contemporary jade artifacts in shape, establishing a relatively fixed paradigm.

Whether it is the fixed posture of holding shell tools in tombs or the fixed shape of jade-imitating shell ornaments, these two phenomena jointly point to the formation of "behavioral standardization" of shell tools in the Haidai Region during the Dawenkou-Yueshi Culture period, which is separated

from the production and manufacturing links. Such fixed artifact combinations and behavioral norms used in funeral activities reflect that shell tools are one of the important carriers of regional consensus at the level of spiritual beliefs of the ancestors in the Haidai Region.

4.4. Limited procedural standardization: deconstruction of behavioral paradigms from the perspective of the operational chain

The level of standardization is an important indicator for measuring the degree of specialization of prehistoric handicraft products, and the most commonly used indicator for measuring the level of standardization is the coefficient of variation. If this indicator is used to quantitatively observe shell tools, it is found that their overall morphological dispersion is relatively high, and the corresponding standard for the relationship between the level of standardization and the degree of production specialization differs from the established indicators. However, this result cannot deny the maturity of their production organization: on the one hand, the shape of shell raw materials is random, and the high coefficient of variation is caused by material characteristics rather than loose production control. On the other hand, methods for qualitative and quantitative analysis of production organization forms also include the observation of production backgrounds, direct evidence and indirect evidence [28]. Indirect evidence includes the consistency of product raw materials, production technologies, specifications and sizes, as well as the diversity of product types and styles, etc. This is consistent with the concept proposed in this paper that the degree of standardization of shell tools should be measured by the behavioral norms in their production and use stages. That is, from the perspective of the whole life cycle, it can be found that the ancestors in the Haidai Region had formed stable and unified behavioral norms in the links of shell tool development, production and use.

Consistent with tools made of natural raw materials such as bone tools and stone tools, the specialization level of shell tools cannot be measured only by the morphological coefficient of variation, but must be comprehensively judged by combining the resource selection, processing strategies and usage contexts presented at each stage of the operational chain. The level of standardization is an efficient quantitative indicator of the degree of specialization, but the two are not sufficient and necessary conditions for each other: tools oriented to stable functional needs will show high morphological standardization, while tools oriented to complex usage scenarios will show low morphological standardization and high behavioral standardization. In addition, as practical tools with abundant materials and simple production, stone tools, bone tools and shell tools have the meaning of "expedient tools" in production and daily life. These tools occupy the ecological niche of basic practical utensils, and their motivation for specialization is definitely much lower than that of sensitive factors such as pottery and jade artifacts in the process of social complexity. This further explains that the generally high degree of variation of the above tools is the result of prehistoric ancestors' consideration based on input-output ratio.

The core of the limited procedural standardization proposed in this paper is to expand standardization from the convergence of static finished products to behavioral norms running through the entire operational chain. Overall, shell tools in the Haidai Region during the Dawenkou-Yueshi Culture period had reached a limited level of specialization. Its key manifestation is not the high regularity of finished products, but the stable, standardized and planned behavioral system in the production and use processes.

5. Conclusion

This paper places the shell tools of the Dawenkou-Yueshi Culture period in the Haidai Region in the macro context of the process of social complexity, breaking through the limitations of previous studies that only focused on shellfish as meat resources or static typological classification. By introducing the "whole life cycle" perspective, this paper expands the connotation of standardization from the static convergence of finished products to "procedural standardization" including targeted management and control of raw materials, contextualized processing and ritualized use. The above research attempts to deepen the understanding of the organizational forms of prehistoric shell tool handicrafts and provides a new micro perspective for understanding the resource utilization strategies in the Haidai Region.

In view of the particularity of quantitative evaluation of shell tools, the innovations in relevant quantitative methods in this paper are mainly reflected in two aspects: First, it converts the "absolute values" in traditional quantitative analysis based on pottery research into "relative values", minimizing the interference of inherent morphological differences of natural shell raw materials and effectively eliminating "pseudo-variation" caused by material characteristics. At the same time, it is noted that the subtractive manufacturing method of shell tools determines that the absolute values of their coefficients of variation are generally lower than those of pottery, that is, the CV values corresponding to shell tools are much lower than those of pottery under the same degree of specialization. Second, on the basis that relevant studies on stone tools and bone tools focused on single values such as length, width and thickness, this paper adjusts the calculation object to "length-width ratio". The transformation from one-dimensional independent data to two-dimensional shape skeleton compensates for the limitations of quantifying weakly correlated data, and can more accurately capture the producers' control intentions and technical logic over artifact shapes.

However, this paper still has limitations. Limited by the recording methods of early archaeological reports, there are few measurable valid data for some artifact types, resulting in that some coefficient of variation statistics in this paper have not reached the ideal significance level. At the same time, the judgment on the functions of shell tools in this paper mostly relies on inferences based on shapes and excavation locations, lacking direct evidence support from scientific archaeological methods such as use-wear analysis and residue analysis.

In view of the above deficiencies, future research can be deepened in three aspects: First, expand the material base, combine newly excavated data and 3D scanning technology to construct a more representative quantitative database; Second, introduce interdisciplinary methods such as use-wear analysis, bionic mechanics and isotope tracing to accurately verify the working efficiency and raw material sources of shell tools; Third, carry out macro comparisons, conduct horizontal comparisons between the standardization degree of shell tools and that of contemporary pottery, stone and jade artifacts, and comprehensively reveal the panoramic picture of prehistoric handicrafts in the Haidai Region during the process of social complexity.

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