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Investigations on Archaeological *Cerastoderma glaucum* Population from Troia (Turkey) and Their Potential for Palaeoeconomical Reconstruction

CANAN ÇAKIRLAR
Inst. für Urgeschichte, Abteilung für Ältere Urgeschichte und Quartärökologie, Archäobiologie
Rümelinstr. 23. 72072. Tübingen, Deutschland
canancakirlar@yahoo.com

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ABSTRACT: The nature of shellfishing in the subsistence economy and the role of shellfish in the diet of Bronze Age Troia are questioned in this paper. A prominent feature of the archaeozoological assemblages of the site are remains of *Cerastoderma glaucum.* Relative abundance of taxa, mean valve height and estimated age range of *C. glaucum* populations were used as analytical tools to estimate the relative importance of this resource. Analyses indicate that shellfishing activity was more intense during the Early Bronze Age than in the Late Bronze Age, but shellfish consumed during the Late Bronze Age yielded more flesh per individual. Potentially, the average Late Bronze Age *C. glaucum* individual contributed more calories and protein to the diet than the average Early Bronze Age *C. glaucum.* Results from Middle Bronze Age samples are ambiguous. This ambiguity can be related to climatic changes that occurred at the time, but a bigger sample size is needed for a more satisfactory explanation of the patterns observed.

KEYWORDS: TROIA, SHELLFISHING, *Cerastoderma glaucum*, SUBSISTENCE ECONOMY, BRONZE AGE

RESUMEN: En este trabajo se cuestionan la naturaleza del marisqueo en las economías de subsistencia y el papel de los moluscos en la dieta de la Troya de la Edad del Bronce. Un rasgo característico de las colecciones arqueozoológicas de este yacimiento son los restos de *Cerastoderma glaucum*. La abundancia relativa de taxones, la altura media de las valvas y el rango de edad estimada en las poblaciones de este berberecho han sido utilizadas como herramientas analíticas para estimar la importancia relativa de este recurso. Los análisis indican que la actividad del marisqueo fue más intensa durante la temprana Edad del Bronce que durante la Edad del Bronce Tardío, si bien los moluscos consumidos en esta última etapa proporcionaron mayor aporte cárnico por individuo. En potencia el individuo promedio de *C. glaucum* de la tardía Edad del Bronce proporcionaba más calorías y proteínas a la dieta que el individuo promedio de esta especie procedente de la temprana Edad del Bronce. Los resultados de las muestras del Bronce Medio son ambiguos. Esta ambigüedad puede estar relacionada con cambios climáticos que ocurrieron en esos momentos si bien serán necesarias nuevas muestras de mayor envergadura para alcanzar una explicación mas satisfactoria a los patrones que se detectan.

PALABRAS CLAVE: TROYA, MARISQUEO, *Cerastoderma glaucum,* ECONOMIA DE SUBSISTENCIA, EDAD DEL BRONCE

INTRODUCTION

The peoples of the Aegean coast adopted the Neolithic way of life at the beginning of the 7th millennium BC and from then onwards developed a multi-faceted subsistence economy based on agriculture, animal husbandry, hunting, fishing, and shellfishing (Dickinson, 1994). Maritime trade and industrial activities flourished during the Bronze Age (3rd and 2nd millennia BC) (Dickinson, 1994). The frequent occurrence and ubiquitous presence of shell remains in the archaeological deposits of the region provides a firm analytical tool to explore the role and nature of shellfishing in the context of complex societies of the Aegean Bronze Age.

Shells of *Cerastoderma glaucum* (the lagoon cockle) are one of the most common and best preserved constituents of archaeomalacological assemblages across the basin (Rodden *et al.*, 1962; Gejvall, 1969; Shackleton, 1970; Becker, 1986; Shackleton, 1988; Peters, 1993; Buitenhuis, 1995; Sorrentino, 1997; Andreasen, 1998; Driesch, 1999; Karali, 1999; Prummel, 2005). Troia, a key archaeological site for the study of Aegean Bronze Age represents a settlement of urban characteristics (Korfmann, 2001). Numerous remains of *C. glaucum* constitute a prominent feature of the organic materials recovered from the new excavations (1988-present) at the site. This paper explores the potential of this material to understand the role of shellfishing in Troia as an example of advanced societies of the Aegean Bronze Age.

Relative abundance of taxa in the archaezoological record of a past society is considered to be a reflection of the dietary importance of different animal resources in that society. Relative abundance of species has been hitherto used in numerous occasions in archaeozoology and archaeomalacology (e.g. Uerpmann, 1982, 2003; Shackleton, 1988; Martin, 2004; Roselló-Izquierdo *et al.*, 2005). The indications of this method for assemblages representing animal diets involving both vertebrate and invertebrate resources is obscured by taphonomic factors (Roselló-Izquierdo *et al.*, 2005). For these assemblages inter- and intra-phylum variation in nutritional values is obviously great (Bailey, 1978; Claassen, 1998: 183). However, the differences between multi-phyla faunal assemblages between the different levels of the same site can be used to observe changes in dietary patterns. This method assumes that taphonomic processes active at different levels of the site are not significantly different. But taphonomic processes are highly unpredictable. It cannot be simply assumed that taphonomic processes were identical across a site during stratigraphic long sequences. Relative abundances of taxa alone might not reveal a true picture of the importance of shellfish gathering at a site with complex subsistence economy and a long occupational history.

The size ranges of archaeological shells are considered to be measures of the mode and intensity of shellfishing practiced by the society who gathered them. Mean size of archaeomalacological specimens has been used as a tool to estimate the intensity of foraging activity (e.g. Yesner, 1984; Ballbè, 2005; Prummel, 2005). Some researchers have been critical about using size as a criterion to measure the level of activity, based on the method's negligence of the environmental factors affecting shell size (Claassen, 1998: 49). It is very well known that the coastal environments of the world's seas went through substantial morphological changes throughout the Holocene (Roberts, 1991). It is also widely accepted that the climate of the Middle and Late Holocene was affected by abrupt fluctuations in the global climatic system (e. g., Mayewski *et al.*, 2004). For these reasons alone it would be erroneous to assume that environmental factors were stable throughout millennia or environmental changes did not influence the shell morphology of mollusk populations. Claassen's suggestion that the differences in the mean age of populations can be used as a measure of human mode of exploitation only, when there are no notable differences between the mean amount of shell growth per age year (1986), was put into practice by Mannino & Thomas (2001, 2002). These researchers quantified shell size together with age estimations using growth rings visible on the shell surface and successfully attested the intensification of shellfishing activity in Mesolithic Britain.

This study analyzes the relative abundance of species, size range and age of archaeological *C. glaucum* at Troia as a basis for an interpretation of the mode of shellfish gathering, role of shellfishing in the economy and intensity of this activity in Bronze Age Troia.

THE SITE AND ITS ENVIRONMENT

Troia is located in Northwestern Anatolia at the southern end of the Dardanelles (Figure 1). The settlement was formerly overlooking a marine embayment, which has been gradually silted up by alluvial sediments during the Holocene (Rapp & Gifford, 1982; Kayan *et al*., 2003; Kraft *et al*., 2003) (Figure 2). Sedimentation process has already begun around 6000 BP (Kayan *et al*., 2003). The lagoons created by the deltas of the rivers feeding the plain were located immediately to the east and west of the settlement at the beginning of the occupational history at Troia, around 5000 BP. The deltas gradually shifted to the north during the Bronze Age and afterwards (Kayan, 1996; Kayan *et al*., 2003) By the end of the Bronze Age (ca. 3000 BP), marsh land and deltaic lagoons as filling the 1-2 km distance between the site and the marine embayment proper (Kayan *et al*., 2003). Today the lagoons and estuaries of the Trojan Plain are located ca. 6 km north of the site, adjacent to the Dardanelles.

The site falls within the temperate climatic zone in a region where Mediterranean climate prevails. Mediterranean climate can be characterized by its seasonality; in most basic terms, by winter rains and summer droughts (Bolle, 2003). Mean annual precipitation totals in Western Anatolia reach 700 mm, with the seasonality of precipitation deviating from the winter rain/summer drought pattern towards the north (Türkeş, 2003). The mean temperature in the Troad increases up to 20-25°C during the summer months (June, July and August) as

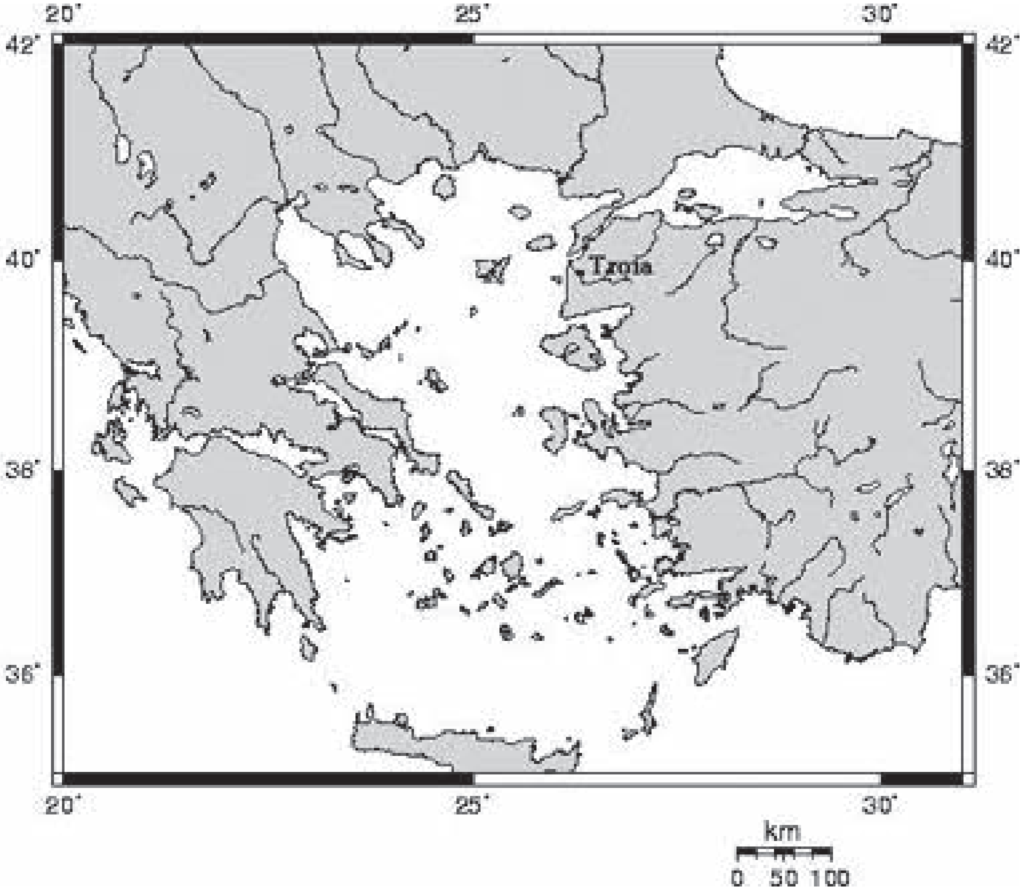


FIGURE 1
Location of Troia in the Aegean.

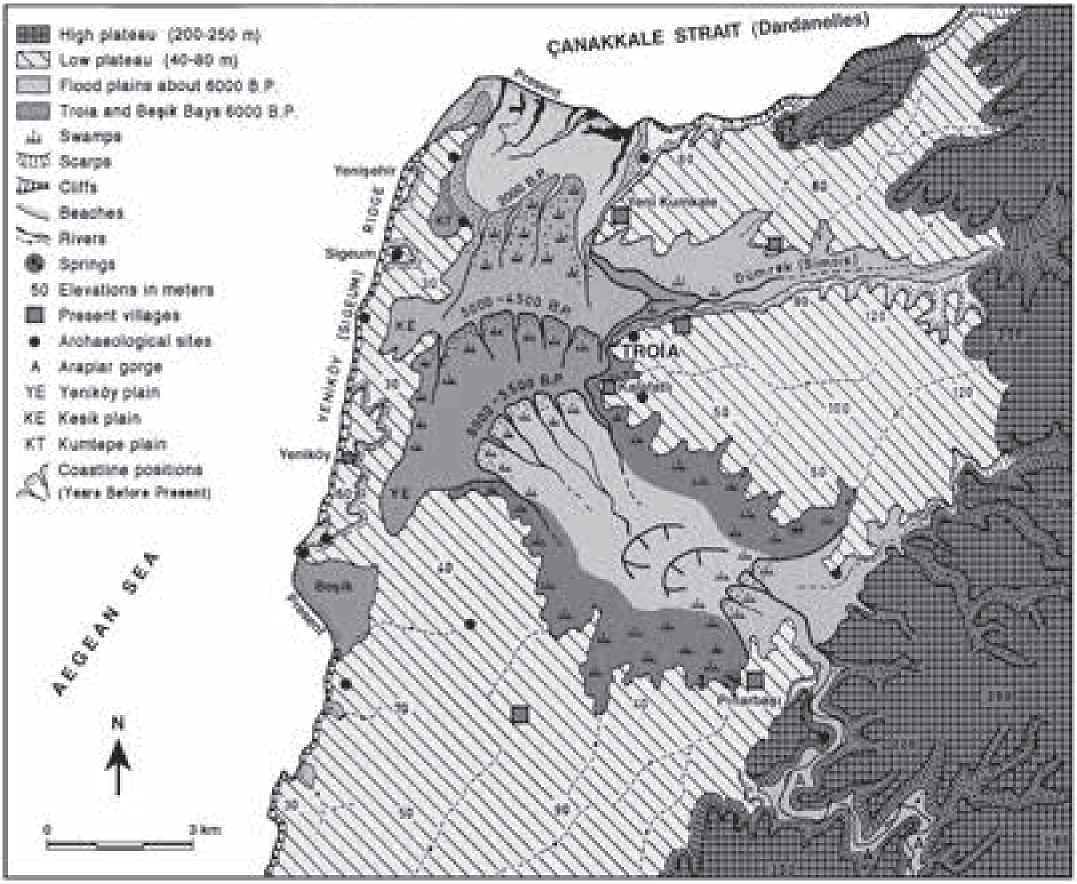


FIGURE 2

Geological characteristics of the Troad and Holocene development of the Trojan Bay (After Kayan *et al.*, 2003).

precipitation falls down to 10-25 mm. Coldest and wettest months are December, January and February, during which mean temperature decreases down to 5-7°C and precipitation rate is as high as 110 mm.

As mentioned, global climatic conditions were not always stable during the Holocene. Cyclical cooling events interrupted the continuity of climatic patterns during the Holocene (Bond *et al.*, 1997, 1999). Two cool episodes, both of which brought cooler climates to higher latitudes and dryer climates to lower latitudes, are roughly covered by the period under question in this study: 4200-3800 and 3500-2500 BP (Mayewski *et al.*, 2004). It is now widely accepted that these cooler periods influenced human cultures and activities to varying degrees in different parts of the world, including the Eastern Mediterranean region (de Menocal, 2001; Fagan, 2004; Issar & Zohar, 2004). Whether these changes in the global climate were factors affecting the environment and occupational history at Troia is still a matter of investigation and debate (pers. com. with E. Marinova and S. Riehl). It has been suggested that the first of these cool episodes may have affected the environment and the mammal sector of the subsistence economy at Troia (Uerpmann, 2003). In addition to this, independent of the global climatic changes that might have influenced the environment in the Troad, archaeobotanical investigations on the macrobotanical remains of the site suggest that beginning with the early phases of the Bronze Age, intensive use of landscape for agriculture and forest cleaning affected the climate at a local level (Riehl, 1999).

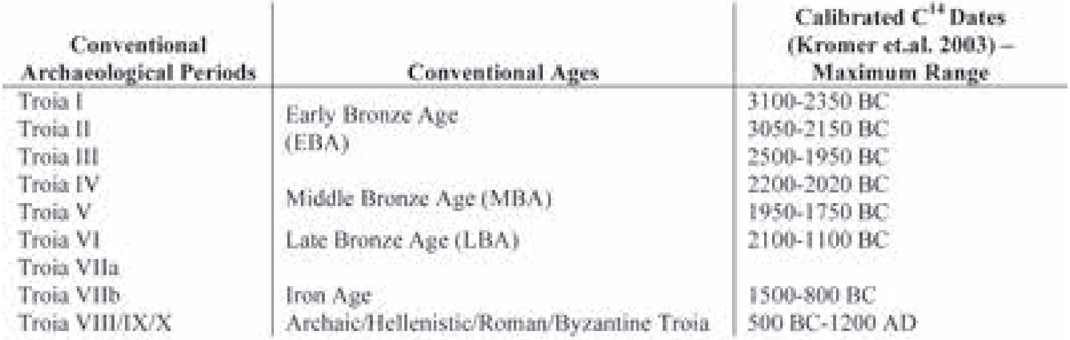
A generalized chronology of the site is provided in Table 1. All architectural phases in Troia are represented by substantial stone and mudbrick architecture and defensive walls. Material culture of the Early Bronze Age (EBA) shows strong parallelism with the cultures of the Aegean, while the artifactual assemblages of the subsequent Middle and Late Bronze Age (MBA and LBA) periods show strong ties with the Anatolian realm (Korfmann, 1996). Troia may have been an ally of the Hittite Empire, called by the Hittites under the name «Wilusa» (Starke, 1997). The Iron Age in Troia is represented with a single architectural layer (Troia VIIb). The material culture of this period, marked by Balkan elements, is different from the previous Bronze Ages. This situation possibly indicates the arrival of a new people (Korfmann, 1996). The Aegean world enters the so-called Dark Ages at the end of this period (Drews, 1995). Substantial Hellenistic, Roman and Byzantine towns represent the Post-Iron Age settlements at Troia (Korfmann, 2001).

MATERIALS AND METHODS

The Bronze Age faunal spectrum of Troia is dominated by domestic mammals such as cattle, sheep, goat and pig (Uerpmann, 2003). Fish remains make less than 1% of all faunal remains (according to number of identified specimens –NIS) excavated from Bronze Age Troia (Uerpmann & Van Neer, 2000). Mollusk remains constitute 37.4% (=51325 specimens) of the NIS coming from the Bronze Age layers. Ca. 75% of these belongs to shells of *C. glaucum*. Other important species represented in the assemblage are the gastrapod *Hexaplex trunculus* mainly used for dye production, epifaunal bivalves *Mytilus galloprovincialis* and *Ostrea edulis,* and the infaunal bivalve *Solen marginatus.*

C. glaucum is an equivalve. Shell sculpture consists of ribs and prominent «growth rings» on the outer surface (Sabelli, 1979). Specimens can reach up to 50 mm in height, ca. 20 mm of growth taking place during the first 12 months of shell secreting (Boyden, 1972; Zaouali, 1979; Gontikaki *et al.*, 2003). The species is infaunal and inhabits muddy, sandy and coarse sandy bottoms in large communities (Poutiers, 1987). Juveniles with valve heights between 2 and 14 mm suspend to floating weed by means of a bysuss (Ivell, 1979b). Adults usually live buried just beneath the surface of the bottom (Boyden & Russel, 1972). *C. glaucum* is very tolerant to fluctuations in temperature and salinity. Around the British Isles populations were found in waters with temperature fluctuations between 0-25°C and salinities that range between 5 and 38‰ (Boyden & Russel, 1972). In the Mediterranean they were found in lagoons where salinity records reach up to 60‰ (Koutsoubas *et al.,* 2000). It inhabits predominantly closed or semi-closed lagoons (Boyden & Russel, 1972). The species' preference for sheltered areas with very limited wave action is the sole limiting factor in its colonization. *C. glaucum* spawning takes a polycyclic rhythm in the Mediterranean, with three spawning periods a year (Ivell, 1979a; Zaouali, 1980; Gontikaki *et al.,* 2003).

The incremental growth pattern of *C. glaucum* changes throughout the year. 50% of the specimens observed in a lagoon in the Northern Atlantic



Conventional Archaeological Periods	**Conventional Ages**	**Calibrated C^{14} Dates (Kromer et.al. 2003) – Maximum Range**
Troia I	Early Bronze Age (EBA)	3100-2350 BC
Troia II		3050-2150 BC
Troia III		2500-1950 BC
Troia IV	Middle Bronze Age (MBA)	2200-2020 BC
Troia V		1950-1750 BC
Troia VI	Late Bronze Age (LBA)	2100-1100 BC
Troia VIIa		
Troia VIIb	Iron Age	1500-800 BC
Troia VIII/IX/X	Archaic/Hellenistic/Roman/Byzantine Troia	500 BC-1200 AD

TABLE 1

Chronology of Troia.

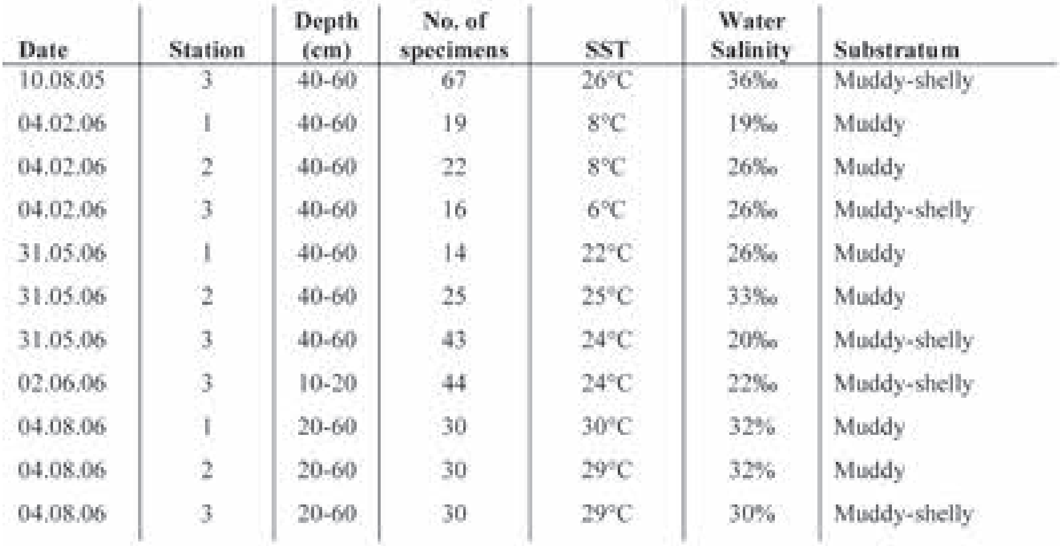
produced «winter rings» (Ivell, 1979b). The increments of populations living in a lagoon in Italy were considered too ambiguous to establish growth pattern (Ivell, 1979a). Populations in Tunisia form a «ring» during summer (Zaouali, 1979).

All archaeological *C. glaucum* specimens that are dealt with in this study were retrieved through hand-collecting methods from various architectural contexts, pits, floors and fill deposits. Live specimens were collected periodically using a sieve and shovel or simply by hand picking from the delta areas of the Trojan Plain in 2005 and 2006 from three isolated stations. Depth, characteristics of substratum, water salinity, and surface temperature at the time of collection were recorded (Table 2).

Valve heights (VH) of 4161 archaeological and 350 modern specimens (only right valves) were measured using a digital verniers caliper to 0.1 mm. precision. The measurement is as shown in Claassen (1998: 109, fig. 20).

Growth patterns and rates of 2245 archaeological and 323 modern specimens were examined by observing their cross-sections. Although surface «growth rings» are generally related to the incremental features observed on the cross-sections, in this study detailed observations on cross-sections were favoured over counts of growth rings for age estimations. Surface «rings» on *C. glaucum* have variable appearances and are not always clear, whereas the cross-sections offer the advantage of observing the extent of variations in incremental growth, which are currently being evaluated for studies of seasonality of shellfishing in Troia. Valves were cross-sectioned radially along the longest rib. The cross-sectioned surfaces were polished with 400- and 1200- grit emery paper. Translucent and opaque incremental zones were observed with the help of a light microscope, but often under normal light. Lengths of the increments were recorded using a digital verniers caliper to a precision of 0.1 mm. Each incremental zone is labeled with a number with respect to its sequence in secretion and with characters T and O, designating translucent and opaque increments. For example, the first translucent incremental zone from the umbo is labeled 1T, the opaque incremental zone that formed after 1T is called 1O etc. One opaque incremental zone, together with a translucent incremental zone is considered to form a growth stage. For example, the first opaque incremental zone (0O) forms stage 1 together with 1T. 1O, together with 2T, forms stage 2.

Data were recorded in KNOCOD and ACCESS. Measurements were quantified using EXCEL and statistical differences were calculated using JMP IN. This method of labelling sequential growth increments has been modified by Quitmeyer *et al.* (1997).



Date	Station	Depth (cm)	No. of specimens	SST	Water Salinity	Substratum
10.08.05	3	40-60	67	26°C	36‰	Muddy-shelly
04.02.06	1	40-60	19	8°C	19‰	Muddy
04.02.06	2	40-60	22	8°C	26‰	Muddy
04.02.06	3	40-60	16	6°C	26‰	Muddy-shelly
31.05.06	1	40-60	14	22°C	26‰	Muddy
31.05.06	2	40-60	25	25°C	33‰	Muddy
31.05.06	3	40-60	43	24°C	20‰	Muddy-shelly
02.06.06	3	10-20	44	24°C	22‰	Muddy-shelly
04.08.06	1	20-60	30	30°C	32%	Muddy
04.08.06	2	20-60	30	29°C	32%	Muddy
04.08.06	3	20-60	30	29°C	30%	Muddy-shelly

TABLE 2

Summary of modern collections.

RESULTS

It is already mentioned in the section above that mollusk remains make up ca. 37.4% of the entire Bronze Age faunal assemblage and that *C. glaucum* remains constitute ca. 75% of the mollusk assemblage in NIS. Material culture and subsistence economy change during the 1700 years representing the continuous Bronze Age occupation at the site (Korfmann, 1996; Riehl, 1999; Uerpmann, 2003). The relative abundance of mollusk remains in the faunal assemblages dating to the different periods within the Bronze Age also changes. Mollusk remains make up 46% (28129 specimens) of the EBA faunal assemblages, only 24% (3022 specimens) of the MBA assemblages and 31.7% (17687 specimens) of the faunal assemblage yielded from the LBA layers. The contribution of *C. glaucum* remains to the mollusk assemblages also changes through time. *C. glaucum* remains make up 85% (23904) of the mollusk assemblage in the EBA, 20% (617 specimens) of the mollusk assemblage in the MBA, and 70% (14127 specimens) of it in the LBA.

VH of archaeological *C. glaucum* are significantly smaller from those of the modern samples (p=0.000)[1] (Figure 3). Archaeological samples dating to different periods also show variation among themselves. The cockles gathered by EBA Trojans are significantly smaller than those eaten by the LBA Trojans (p=0.0000). The *C. glaucum* population represented by the valves from MBA layers of the site is similar to the EBA population (p=0.0506), but significantly smaller than the LBA sample (p=0.0001).

Observations on the cross-sections of modern *C. glaucum* showed that the rate and pattern of growth is similar among the individuals of the same population, i.e. that individuals secreted (translucent or opaque) incremental zones coevally. Variations in incremental growth pattern are not related to individual differences but on changing environmental parameters that influence the entire population. Results indicate that slow shell secretion takes place during the warm summer months.

Up to eight sequential growth stages are determined on archaeological and modern shells. Both the modern and archaeological assemblages represent individuals collected at different growth stages (Figure 4). Specimens represented by the modern sample are much older than archaeological populations. Specimens collected during the EBA are younger than those collected during the LBA. Ca. 44% of the shellfish consumed was only at growth stages 1 and 2 during the EBA, whereas in the LBA only 32% of the *C. glaucum* sample was made up of specimens at growth stages 1 and

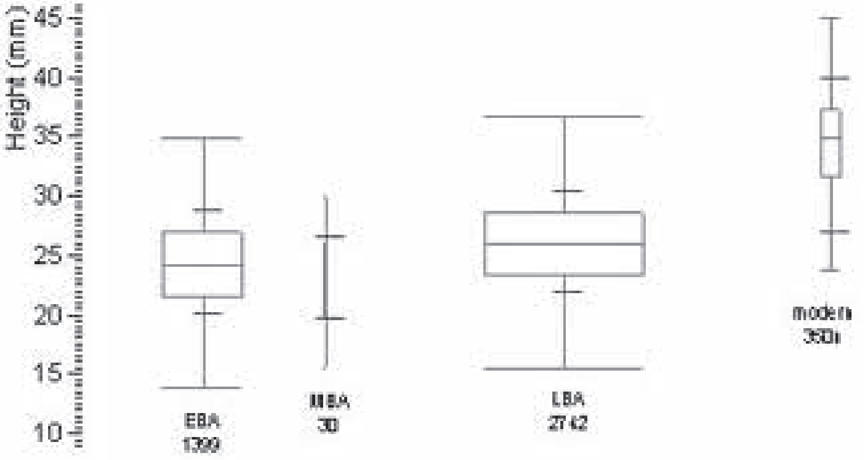


FIGURE 3

Valve height plots of archaeological and modern *C. glaucum.* The plots' breadths represent sample size, also indicated below the plots in numbers. The square box represents the interquartile range; long horizontal bars across the plot are the interquartiles. Short lines indicate the range of standard deviation.

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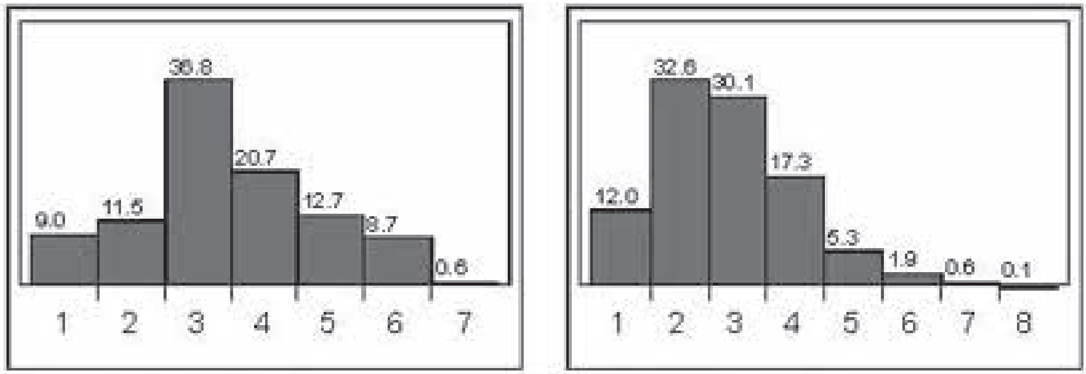
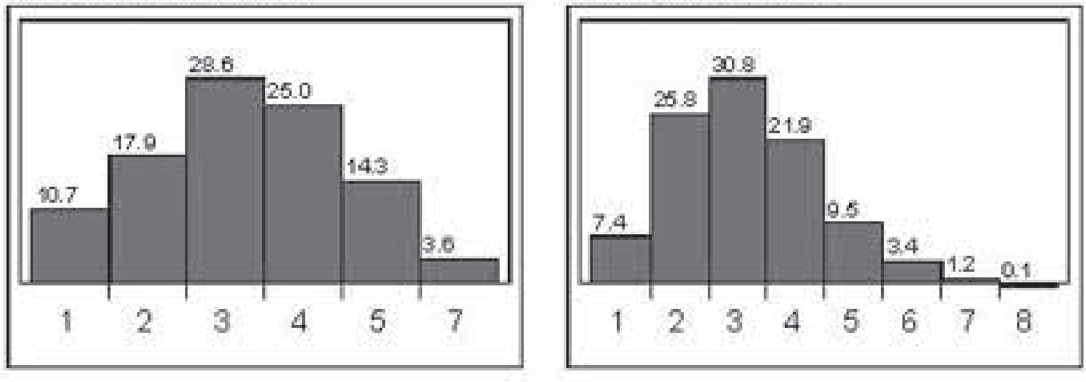
[1] Using student's t-test assuming unequal variances, in all cases at α=0.05 and p is tailed.

2. Ca. 14% of the specimens collected during the LBA have reached stage 5 and beyond, while only 7% of the EBA specimens were at stage 5 or above at the time of collection. The growth stage distribution of MBA specimens is not normal; probably due to limited sample size. Despite that, it is noteworthy that the smaller valves of this population represent specimens at advanced growth stages. Growth stage 8 is not represented in modern populations. Stage 7 is only very rarely represented in both modern and archaeological populations. This situation might indicate that stages 7 and 8 are not true stages, but over-estimated stages occurred by random disturbances in growth.



a. Modern (323 specimens)

b. EBA (936 specimens)



c. MBA (28 specimens)

d. LBA (1281 specimens)

FIGURE 4

Growth stages of modern and archaeological *C. glaucum* at the time of collection. Numbers below the bars represent growth stages. Numbers above the bars are percentages of specimens collected at the corresponding growth stage.

DISCUSSION

As stated, both the contribution of mollusk remains to the faunal assemblage and the contribution of *C. glaucum* to the mollusk assemblage are greater in the EBA than in the LBA. In the LBA mammals assume a more significant share of the faunal assemblage, while *Hexaplex trunculus* appears as a considerable component of the mollusk remains. In the MBA, both the share of mollusk remains and the share of *C. glaucum* are minimal. Whether the picture attained from the quantifications of relative abundance of taxa for the MBA assemblage have been biased by sample size, excavation techniques or the nature of the excavated areas is not clear. Nevertheless, the divergence from the chronological trend observed in the mollusk remains is in line with the archaeozoological (mammals only) and archaeobotanical results of the same period (Riehl, 1999; Uerpmann, 2003). Moreover, the assemblage consists of 12581 specimens; a sample size that easily outnumbers most archaeozoological samples used as basis for reconstructions of subsistence economy. The size of the sample is not small; it is smaller than EBA and LBA assemblages of the same site. The ambiguous divergence represented the MBA sample put aside, it could be suggested that shellfishing for dietary purposes and *C. glaucum* gathering became less frequent and intense over time.

Changes in the relative abundance of taxa indicates that shellfishing played a more important role in the diet and economy of the EBA settlement than in the subsequent LBA period. *C. glaucum* was still by-and-large the most important component of the shellfish section of the diet during the 2nd millennium BC. The new element in the mollusk assemblage, namely *H. trunculus*, was not part of the diet. The crushed specimens indicate that they were mainly used for dye industry.

The comparison of valve height and age ranges between archaeological samples controlled by valves of the modern samples gives more insight to shellfish exploitation in the Bronze Age settlement. Modern shells collected for this study represent an undisturbed population. The last record of *C. glaucum* procurement in the Troad dates to the period between 1932 and 1938 (Blegen *et al.*, 1951: 66-67). The lagoons and estuaries where the collection stations are located are parts of the Troia National Park, where fishing is forbidden by law. The modern sample could easily be established once the beds were located. Individuals of this sample are bigger and older than individuals in the archaeological samples. The impact of human consumption is evident in the size and age range of the archaeological populations. The shells brought to the EBA site were not only smaller than the ones consumed during the LBA, but they were also younger. In this case, it is certain that VH range of populations represented by the archaeological assemblages is not a reflection of environmental parameters causing populations to grow slower per time unit, but a reflection of the mode of human exploitation. EBA inhabitants' intense gathering behavior resulted in yields consisting of smaller and younger individuals, whereas the LBA inhabitants were collecting smaller amounts of bigger and older shellfish containing more flesh.

The VH range of the MBA sample falls within the VH range of the EBA sample. While the variability of estimated age in this sample is not normal, it is skewed towards older individuals. The results from this small sample are unsatisfactory and only ambiguous interpretations can be inferred from it.

CONCLUSIONS

A series of quantified data were obtained from the mollusk assemblage of Bronze Age Troia. Counts of NIS were used to calculate relative abundance of taxa. Periodic studies on extant *C. glaucum* populations in the Troad showed that growth varied coevally among the individuals of the same population. Age variations of modern and archaeological assemblages were estimated by examining the cross-sections. Results showed that the EBA specimens were not only smaller but also younger than the LBA specimens. Archaeological populations are altogether smaller and younger than the modern samples representing undisturbed populations.

Analyses of relative abundance of taxa, and size and age ranges of the archaeological *C. glaucum* populations suggest that shellfish was a valued resource for Early Bronze Age Troia. Shellfish was gathered more often in the EBA than it was in the subsequent LBA period. The analyses proved that shellfishing was a less intense activity in the LBA than it had been during the EBA. An important question is whether this change corresponded to a lesser shellfish contribution to the diet of LBA Troia. For the consumer, the bigger *C. glaucum* collected during the LBA offered more flesh per individual. The results of the analyses presented here do not answer this question satisfactorily.

However, there are ecological reasons to think that not only shellfishing became less intense, but also shellfish did not contribute to the diet of the population as significantly as it did during the EBA: Shellfishing grounds of Troia shifted northwards in the course of the Bronze Age. By 2nd millennium BC, the distance between the settlement and the areas where shellfishing took place was long enough to make shellfishing not as profitable as it was during the EBA. In the LBA, subsistence economy of the site was stabilized and secured by intensive agriculture (Riehl, 1999), the increasing importance of cattle in the diet (Uerpmann, 2003), and strong central organization. In this environmental and economic frame, shellfish as a dietary source and shellfishing as a means of food procurement may have lost some of their importance against more nutritious resources under immediate reach in the surplus.

The ambiguity of the picture created by the seemingly small-sized specimens collected at advanced growth stages can only be clarified with a bigger study sample. The divergence demonstrated by the sample might be related to the global climatic events occurring during this period. A more substantial sample can only be obtained by uncovering larger deposits dating to the period.

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