Indirect detection of changes in Seville population studying size changes in oysters?

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Detección indirecta de cambios en la población de Sevilla a partir de cambios de tamaño en ostras?

KEY WORDS: *Ostrea edulis*, Paleobiology, Paleodemography, Middle Ages, Modern Age.
PALABRAS CLAVE: *Ostrea edulis*, paleobiología, paleodemografía, Edad Media, Edad Moderna.
GAKO-HITZAK: *Ostrea edulis,* paleobiologia, paleodemografia, Erdi Aroa, Aro Modernoa.

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ABSTRACT

Shell middens contain important information on subsistence activity in human economies. The use of paleodemographic documentation can explain the importance of certain products in our diet. One of these products is oyster (*Ostrea edulis*) (Ladero 1989), also found in pictorial documentation of the studied centuries (See: Fig. 1). We have measured two hundred and eighty-three (N=283) right valves of *Ostrea edulis* (Linnaeus 1752), sampled from four archaeological deposits found in Seville that date back to the 14th and 18th centuries A.D. In this paper we present the hypothesis on the possible relationship between oyster consumption and demographic changes undergone in Seville during these centuries.

RESUMEN

Si bien los paleobasureros son un exponente de la actividad trófica del hombre en el pasado, la documentación paleodemográfica que conocemos puede explicar la importancia que tuvieron ciertos productos en nuestra alimentación. Uno de esos alimentos, descritos en la bibliografía (Ladero 1989) y en las pinturas de la época, es la ostra –por ejemplo fig. 1 -. Se han medido 283 valvas de *Ostrea edulis* (Linnaeus 1752) procedentes del registro paleobiológico de cuatro yacimientos arqueológicos localizados en la ciudad de Sevilla y datados entre los siglos XIV y XVIII d. C. En este trabajo se presenta una hipótesis de la posible relación que mantuvo el consumo de ostras con los cambios demográficos que experimentó Sevilla en este periodo histórico.

LABURPENA

Paleozabortegiak antzinako gizakiaren jarduera trofikoaren erakusgarriak badira ere, ezagutzen dugun dokumentazio paleodemografikoak azal dezake zer-nolako garrantzia izan zuten zenbait produktuk elikaduran. Elikagai horietako bat, bibliografian (Ladero 1989) eta garai hartako margolanetan deskribatua, ostra da –esate baterako, 1. irudia–. Ostrea edulisen 283 kusku neurtu dira (Linnaeus 1752), Sevilla hiriko lau aztarnategi arkeologikotako erregistro paleobiologikotik ateratakoak, K.o. XIV. eta XVIII. mendeen artean datatuak. Lan honetan, Sevillan periodo historiko hartan izandako aldaketa demografikoan ostren kontsumoak izan zezakeen eraginari buruzko hipotesi bat aurkezten da.

1. INTRODUCTION

Shell middens are a record of the use of natural resources and environment by humankind. These structures have become a reliable record that can be used to interpret the evolution of subsistence in a specific ecosystem and culture. Taking into account not only the contents but also the features and distribution of the container, middens stand for an indicator of the environmental impact of humankind on the different species from the exploited ecosystem (Bernáldez 1996, 2002).

Seville has a rich archaeological record dating back to the 8th century b.C. The frequent discove-

Figure 1. In this still life from Meléndez (17th and 18th centuries) called *"Ostras, huevos y un perol"* oysters are presented on a table without luxury. This shows that consumption of oysters is not only restricted to the wealthy.

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ries of organic material in archaeological deposits, either as rubbish from other periods (Bernáldez and Bernáldez 1998), as an offering (Minniti and Peyronel 2005; Bernáldez and Bernáldez 2005a, Álvarez-Fernández, 2006) or because of its use in constructions (Bernáldez & Bernáldez, 2002, Bernáldez *et al*. 2009 in press, Niveau de Villedary 2006, Arruda and De Freitas 2008, Abad and Sala 2007, Arancibia and Escalante 2006) contributes to the reliability of the paleobiologic interpretation of these deposits and, in some cases, show the overexploitation of natural resources (Swadling, 1976, Jerardino 1997, Mannino and Thomas 2002, Milner *et al.* 2007, Erlandson *et al*. 2008). This is verified in present-day societies by actualistic pieces of research carried out in different places (Catterall *et al*. 1987, Hockey and Bosman 1986, Keough *et al*. 1993, Nagaoka 2002).

One of the most common species identified in archaeological deposits from the end of the 14th century till the 18th is *Ostrea edulis* (Linnaeus 1952). During this 400 year period, changes in the average size of valves have been observed. Some of these changes correspond, at least in this city, to human demographic changes. The importance of this type of food for the 17th century population is described by Morales (1989:146). In 1562, a pair of oysters cost four *maravedíes*, a reasonable price for salary earners in those times, taking into account that a stevedore earned 350 *maravedíes*. Also, 17th century still lifes from the Netherland and Spanish pictorial schools seem to show the relevance of this food, the difference between these two being that in the former this element appears on wealthy family tables while in Spanish still lifes, oysters can be seen in common people's kitchens (Fig.1).

As a conclusion, oyster value in the 16th and 17th centuries can be deduced through archaeological discoveries, bibliographical quotes and paintings.

2. POPULATION ECOLOGY OF *OSTREA EDULIS*

The genus *Ostrea* has been an important food source over the centuries (Zobele and Negra 2009). *Ostrea edulis* is a Mediterranean species, living in rocky bottoms of medium and low depths and feeding on phytoplankton and other particles through microfiltration. This species is highly adapted to its environment (Zobele and Negra 2009). It inhabits environments with salinity levels ranging between 16% and 34%, and temperatures between 5 and 25ºC (Hutchinson and Hawkins 1992), which makes them capable of living in a wide spectrum of habitats. The size of an adult specimen ranges between 100 and 120 mm, although the minimum size allowed for its consumption in the South of Spain is around 80 mm (Consejería de Agricultura y Pesca 2001). Oysters find several difficulties to their development; the presence of parasites such as *Bonamia ostreae* and *Marteilia refringens* detected in the 60's, and abrupt drops of temperature (Lapègue *et al*. 2006).

Finally, it is worth mentioning that reproductive processes in this species are highly efficient, because of the high synchronization between individuals and of the large number of gametes freed into the environment (Zobele and Negra 2009), together with their protandric hermaphrodite character (Lapégue et al, 2006). Even being eurohalyne organisms, for younger specimens the salinity range is narrower (Hill, 1980), from 20% (optimum) to less than 15% (Lapégue *et al*. 2006).

3. SEVILLE DEMOGRAPHIC EVOLUTION BETWEEN THE 14TH AND 18TH CENTURIES

Seville has undergone great population variations through its history (Collantes de Terán 2002, Fernández 2002), such as the presence of other important European populations. These differences lead to changes in the use of territory and the exploitation of natural resources. Molluscs are one of the elements having experienced these changes, which could be the reason for the changes in oyster size through the city's history. The record of *Ostrea edulis* in Sevillian archaeological sites increases from the 14th century onwards, and it is now that enough valves have been collected to carry on a statistically reliable research on oyster biometric trend. Before this period, Seville was inhabited by Muslims, whose culture forbids the consumption of shellfish (Coram 35, 13). Despite this, and although scarce, some records of this animal group have been found in Seville and Huelva deposits studied by our team (Bernáldez and Bernáldez 2005b, Bernáldez and García-Viñas 2008).

At the beginning of 13th century (1248) Fernando III conquered Seville, establishing the end of *Isbiliya* and the beginning of Seville (Collantes de Terán 2002). This brought an important increase in the commercial activities between the Atlantic Ocean and the Mediterranean Sea, which made Seville one of the most important and most populated cities in the Kingdom of Castile. The population of Seville was of 20,000 inhabitants at the end of 14th and beginning of 15th century, and of 40,000 at the end of 15th century. While Seville was the centre of commercial relations with

America its population continued growing; from 50,000 inhabitants in 1530 to 125,000 (150,000 according to Fernández (2002) and 140,000 in 1588 according to Domínguez (1989)).

However, several disasters, such as the bubonic plague in 1649, decimated the population, which reduced the number of inhabitants by 50%, resulting in an estimated population of between 60,000-80,000 inhabitants (Fernández 2002), and 63,000 in 1655 (Domínguez 1989). From this date onwards, the number of inhabitants varies between 75,000 and 80,000 (Dominguez, 1989), until the middle of the 19th century, when the number of 100,000 inhabitants was surpassed.

4. METHODOLOGY

For the purposes of this research we have used 213 *Ostrea edulis* right (upper side) valves in good condition from four Sevillian archaeological deposits. Two of these archaeological sites -Plaza de la Encarnación (Encarnación Square) and La Catedral (The Cathedral)- are located within the ancient wall of the city, and the other two -Las Reales Atarazanas (The Royal Shipyard) and El Castillo de San Jorge (Saint George's Castle)- are found outside the ancient walls (See: Fig. 2).

The location of these deposits –except for the one in Plaza de la Encarnación- in the seaboard area of the city between the late 14^{th} and 16^{th} century, could stand for their presence, although they are also found in different places with a different economic tradition.

We have used subfossil material extracted from 25 samples taken from three of the seven naves of the current building of Las Reales Atarazanas archaeological site. This material originates from urban activity between the 13^{th} and 18^{th} centuries (Bernáldez and Bernáldez 1997). In the archaeological site of La Catedral (Tabales *et al*. 1996, Tabales and Jiménez 1997) we have analysed three different cuts with paleorganic records dating from the 11^{th} to the 18^{th} centuries. In this case middens were formed by organic waste used for building the Cathedral (Bernáldez and Bernáldez 2002). Also, we have rescued material dating from the 4^{th} to the 19^{th} centuries out of several cuts in El Castillo de San Jorge archaeological site (Hunt 1998). Finally, elements dating from the 1^{st} century to this day have been extracted from the Plaza de la Encarnación archaeological site. From a taphonomic point of view, the good condition of the specimens, together with the archaeologists' skills have prevented information losses due to fracturing, especially in smaller and more fragile elements.

After preparing the organic material at the IAPH Paleobiology Laboratory, the collected valves were subject to a biometric analysis, considering two measures: maximum length (LM) and maximum width (AM) in mm (See: Fig. 3), although only LM values are used for this research.

The Central Limit Theorem, defined by Laplace and Gauss in the 19^{th} century –which we are considering for this research- states that samples always follow a normal distribution which adjusts better as the number of data increases (Milton 2007, Ramos 2006). Following the verification of homoscedasticity (Levene's test), we have applied the ANOVA test in order to verify if there are significant differences between the groups and, if so, we have used the Scheffé and Bonferroni's tests to determine during which concrete period or periods can they

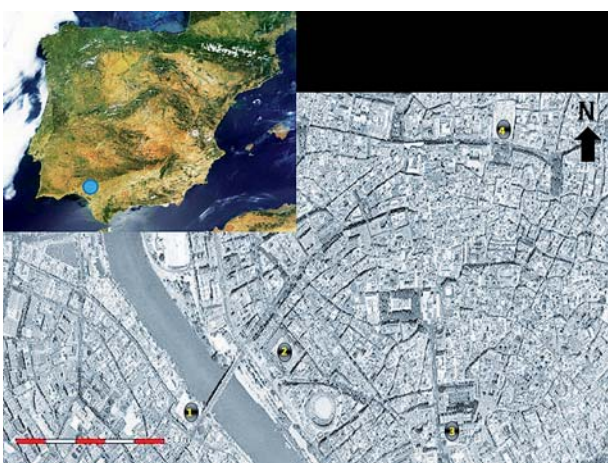

Figure 2. Settlement of the studied deposits in Seville (South of Spain): 1. Castillo de San Jorge (Triana market), 2. Reales Atarazanas, 3. Catedral, 4. Plaza de la Encarnación.

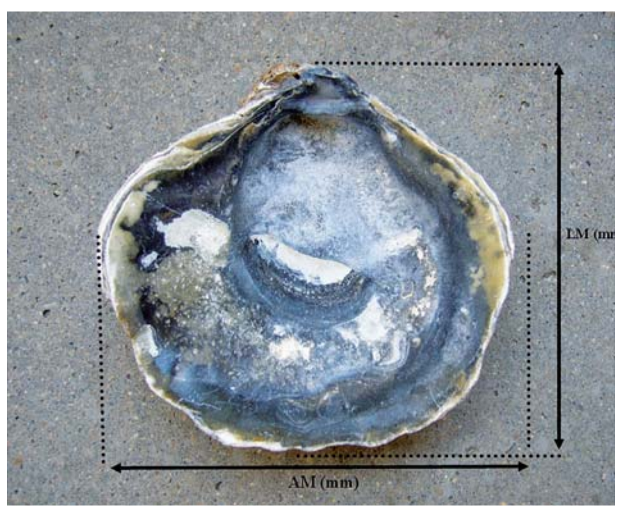

Figure 3. Measures (mm) of Ostrea edulis valves: LM (length) and AM (width).

be observed. In order to detect the existence of a relationship between oyster valves size and Seville's population through time we have applied Spearman's rank correlation coefficient.

5. RESULTS: VARIATION IN THE SIZE OF OYSTERS FROM SEVILLIAN ARCHAEOLOGICAL DEPOSITS DATING FROM THE 15TH AND 17TH CENTURIES

During the years of collection of malacological material, we have noticed that the average size of valves and snails reaches, at least, the optimum size when they are destined for consumption; and that, as has been proved in (Bernáldez *et al.* 2008), although the emplacement of the deposit can favour the mixture of elements from non anthropic activities, it is obvious that collectors picked the biggest elements if the energy balance –the ratio between the energy supplied by the food and the energy spent in obtaining it- is positive (Valverde 1967). Nowadays (2001), the Consejería de Agricultura y Pesca de la Junta de Andalucía (Andalusian Government on Agriculture and Fishing) determines the minimum consumption size for oysters from our coasts in 80 mm.

The first result observable in the biometric data base of oysters is that the average size is bigger than the current one stipulated by the Junta de Andalucía, and that it remains almost constant (see Figure 4) from the 15th to the 16th century (see Table 1). However, valves collected in late 16th century middens undergo an average reduction of 24 mm, only to rise up again in around 31 mm in 17th century middens. This detected decrease is statistically significant, and through the application of an ANOVA we obtain a p-value of 0.000, which makes us reject the H_0 of samples equity. Then, we compare the groups two by two through the application of the Scheffé and Bonferroni's tests, coming to the conclusion that the only group that is significantly different from the rest is the one made up of oysters dating from the late 16th century, with p-values of less than 0.05. In order to contrast this hypothesis, we have made two homogeneous subgroups (see Table 3), the first made up exclusively of valves from the 16th century. Even though the number of valves from this period at our disposal is low, available data allow us to show a tendency in this historical moment.

There are several possible explanations to a species decreasing significantly: physic- chemical changes in the environment causing a lack of saturation of nutrients, an increase in the intraspecific or interspecific competence for space in population (which would eventually be induced by the previous cause or, as it is a rupicolous species, by the lack of rocky substrates), -a change in the environment temperature,…

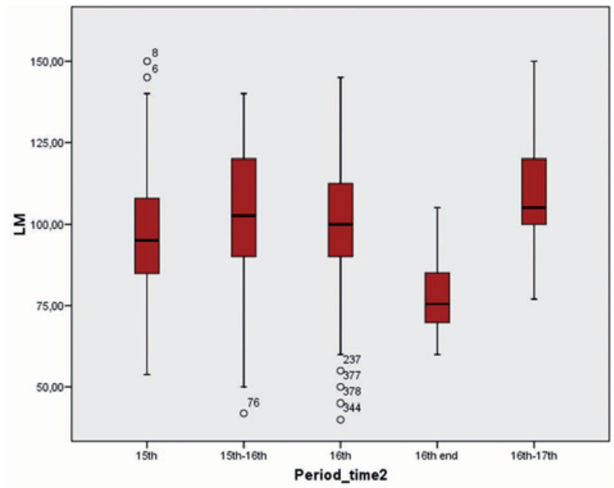

Figure 4. Size (LM in mm) of oysters from Seville archaeological sites in different periods of time. LM stands for the valves maximum length.

	DEMOGRAPHY
14th-15th	20.000
15th	40.000
15th-16th	40.000
16th	50.000
16th end	137.500
16th-17th	70.000
17th	70.000
18th	78.000

Table 1. Number of inhabitants in Seville in specific historical periods (Collantes de Terán, 2002; Fernández, 2002; Domínguez, 1989).

LM (MM)			
Levene's test	gl1	gl2	Sig.
1,778	4	380	0,132

Table 2. Test for homogeneity of variances. LM stands for the maximum length of the valve, gl for the degrees of freedom, and sig for the p-value Alpha=0.05.

LM (MM)				
	Period_time	N	Subgroup for alpha = .05	
		1	2	1
Scheffé (a,b)	16th end	14	77.8171	
	15th	63		97.8389
	16th	155		101.5275
	15th--16th	88		103.9443
	16th--17th	65		108.6723
	Sig.		1.000	.149

Table 3. Test of homogeneous subgroups. LM stands for the valves maximum length and N for the number of valves. Average measures for groups in homogeneous subgroups shown.

a. Using sample size of harmonic average = 41.493.

b. Groups sizes are not equal. Using harmonic average of groups' sizes. Type I error levels are not assured

Nowadays, the Guadalquivir River is undergoing a high index of salinity affecting faunal composition and the structure of its biocenosis; this situation will end up affecting the fishing of some species and the use of water in agriculture, two basic activities in the everyday life of Seville citizens in the studied centuries. The consequences have not been studied yet, but rice producers are demanding research on the causes of this extremely negative effect on food production. The same exact situation may have occurred in another historical moment of this river, as its low section is affected by tides. One of the consequences of this change could have become an advantage as the increase of salinity would make possible to install oyster beds close to the city, which, in turn, would have given oysters a reasonable price (Morales 1989: 146). The fact that oysters were not unaffordable for most of the inhabitants could stand for the existence of oyster beds -as in Roman Tarragona (Luján 1988), because travelling 70 km to the seaside (Arteaga and Roos 2005) to collect them would have increased their price considerably.

Besides, changes of temperature were generally drastic in those centuries, to such an extent that those times are called "the little Ice Age" (Fagan 2001), with four peak points in the middle of the 15th, end of the 16th and beginning of the 17th, end of the 18th, and middle of the 19th centuries (Martín & Olcina 2001). These changes would have altered salt and oxygen concentrations in the aquatic environment, but desalinating it, which, as a consequence, would not explain the installation of a close oyster bed. Even though Fagan (2003) establishes that there are not important changes in Europe to justify changes in biocenosis, he fails to explain if these justify size variations -in fact Sousa and García-Murillo (2003) point out that this period would have implied an increase in rainfall and floods in the South of the Iberian Peninsula. This, together with the capacity of absorbing temperature variations of the aquatic environments, and with the fact that peak points have been detected in periods other than those studied here, could justify the rejection of this theory as a justification of size change in studied oysters.

Finally, it could have happened that oyster size was marked by the degree of pressure exerted by predators on a population and that, as a consequence, the increase of captures reduced the regeneration time, limiting their size and vice versa. According to this theory, it is important to take into account changes in consumption preferences, marked either by culture or by the value of the product. That is, oysters have gone from appearing in archaeological sites before the 14th century to be found in -larger numbers in deposits after the Reconquista. The fact that large amounts of oysters have been found in the outskirts of the city means that this was a food for poor people, this theory being supported by documentation of those times. In order to strengthen the hypothesis posed to explain changes in oyster size, we shall study the amount of oysters collected indirectly, through demographic changes undergone by the city of Seville during this historical period, and for this purpose we are assuming that the bigger the number of inhabitants in a city, the higher is the probability that the consumption of this shellfish increases.

5. CONCLUSION AND DISCUSSION: HUMAN BEINGS AND OYSTERS: COHABITATION DURING 400 YEARS

If we compare the trend in oyster size variation to Seville demographic data in each historical period, it can be noticed that there is a coincidence between peaks of maximum number of inhabitants and minimum oyster size and vice versa. Although there is not a significative inverted proportional relation (Rho Spearman= -0.555, p-value= 0. 257 for α=0.05), possibly due to the small number of samples, it is not appropriate to reject the possibility of a relationship between demography in Seville and oyster size (see: Fig. 5).

This analysis shows size changes in these types of oysters between the 14th and 18th centuries, and their possible relation to demographic changes in the city of Seville. During the period of highest human population density, the late 16th century, valves average size was the smallest in comparison to other centuries. So, when the population of the city tripled, at the end of the 16th century, the average size of valves reduced by 23.71%, and in the 17th century, when there was a 50% decrease in the number of inhabitants, valves size increased by 23.89% (see figure 5). Although we also have data from the 17th and 18th century that follow this trend, they have not been included in the statistical analysis, as their number is smaller.

These trends entitle us to propose the existence of a relationship between oyster size and human population density from the end of 14th century to the 18th century, and we pose the hypothesis that the cause for these size variations may be human demand of this product when the population increases as spectacularly as as it did in Seville after the discovery of America, when it became the exit port for the colonization of that area, or to do business with emigrants. If this point was true, it would prove that paleobiologic records associated with human beings are an indispensable source of information to understand the evolution of the ecosystems and human behaviour called culture.

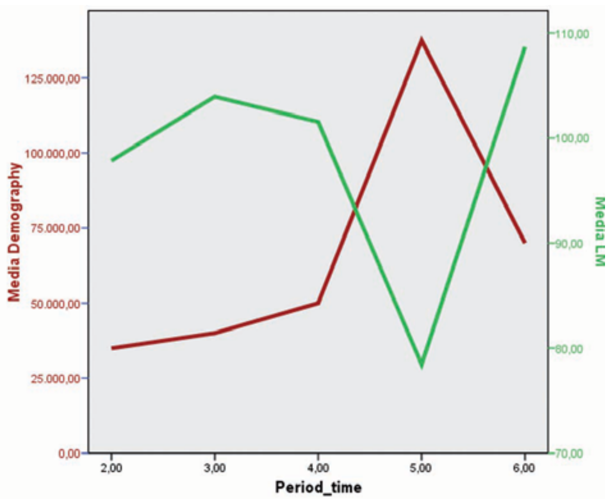

Figure 5. The graph represent the number of inhabitants in Seville and the LM of oysters from several archaeological sites related to a specific historical period. It can be noticed that there is a possible inverted relation in the late 16th century and the 17th century. 2: 14th -15th Centuries; 3: 15th Century; 4: 16th Century; 5: end of the 16th Century; 6: 16th-17th Centuries.

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