

21 - DEPOSITS OF TERRESTRIAL SNAILS: NATURAL OR ANTHROPOGENIC PROCESSES?

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Abstract: *In the archaeological sites of the southwestern Iberian Peninsula small dumps of land snails are frequently found. It is likely that these deposits are the traces of human activity. However, it could also be possible that these dumps were produced by a natural process at a period of time when these molluscs were inactive. We will try to explain the origin of these snail deposits by undertaking a statistical analysis to test hypotheses comparing biometric analyses from different groups of snails: those collected by people who usually consume snails in 2009, those found in plants where these molluscs accumulate at the end of the summer of 2009 and those registered in several archaeological sites: “La Gallega” (2,500 BC; Valencina de la Concepción, Seville), “El Carambolo” (ninth-sixth century BC; Camas, Seville), “Cerro de la Albina” (seventh century BC; Puebla del Río, Seville), “C/ San Felipe Neri” (second-third centuries BC; Carmona, Seville), “Hospital de las Cinco Llagas” (twelfth century AC; Seville), “La Almagra” (twelfth century AC; Huelva) and “C/ San Fernando” (twelfth century AC; Seville). The biometric analysis and the biostratigraphic observations have provided us a mathematical model to ascertain the origin of deposits of land snails in archaeological sites.*

Keywords: *Biostratigraphy, Taphonomy, Biometry, Terrestrial snails, Iberian Peninsula.*

Introduction

Taphonomy is the science which helps us to interpret the origin of the organic record associated with archaeological sites, and is supported on biostratigraphic analysis through which we can discern some of the characteristics of the current *post-mortem* processes that underpin taphonomic interpretations (Bernáldez 2009; Davies, Powell and Stanton 1989; Domínguez-Rodrigo 1998). Based on this theoretical framework it is essential to closely study the contents of deposits in order to describe their origin and outline the processes that acted upon them before they were buried. Here, we carry out a biometrical and biostratigraphic study of land snails from current deposits from southern Spain to infer these results and distinguish between natural and cultural deposits at archaeological sites. Several studies have already proved the importance of biometrical data (Bernáldez and García-Viñas 2010; Fradkin 2008; Gutiérrez 2009) and biostratigraphic analysis in a large number of paleobiological and archaeozoological analysis. In some cases the application of biometrical analysis can help to distinguish between natural and cultural deposits (Bernáldez *et al.* 2010; Hughes and Lampert 1977), but in other cases these studies are not enough (Rowland 1994) and we must support these

results with other features of the shell middens. Although we must not forget that uniformitarian research can help us to interpret ancient deposits through inference, we cannot ensure that ancient deposits have experienced the same events as the current ones. With regards to post-depositional processes, different results may be obtained from within the same deposit, or two separate deposits can yield the same results. In taphonomy, this is known as equifinality (Domínguez-Rodrigo, Egeland, and Pickering 2007; Lyman 2004; von Bertalanffy 1956). Thus, we must be careful with our statements about the interpretation of faunal deposits, but without a framework of comparison, our interpretations would be mere speculation (Bernáldez 2009).

Our research team has conducted similar studies with shells of genus *Glycymeris* as well as land snails. In the first case we interpreted the origin of the shells recovered from the floor of the Phoenician sanctuary of “El Carambolo” (Camas, Seville) (Bernáldez *et al.* 2010) and in the second, we deduced the human origin of different samples of land snails at “El Cerro de la Albina” archaeological site (La Puebla del Río, Seville) (Bernáldez and Bernáldez 2001). Archaeozoologists have found evidence of human consumption of land snails in many archaeological sites

(Aparicio 2001; Bernáldez and Bernáldez 2001; Lubell 2004a; Ruiz Cobo, Muñoz Fernández and Smith 1999), some of which are over 20,000 years old (Lubell 2004b). Also, nowadays these molluscs are on the menu of the most prestigious restaurants. Fernández-Armesto (2002) suggests in his book “History of Food” that land snails could be the first domesticated animals and that their importance is underestimated by archaeologists. While not pursuing the issue of domestication, it is true that most archaeologists only focus their efforts on studying the use of marine species for food and/or ornaments (Bar-Yosef 2005; González *et al.* 2010; Szabó and Quitmyer 2008) and that land molluscs are usually studied to characterize palaeoecosystems and environmental factors (Allen 2005; Davies 2008). However, archaeologists usually do not consider land snails as part of the economy of human communities. Nowadays the most commonly consumed land snail in the southwest of the Iberian Peninsula is *Theba pisana pisana* (Arrébola 1999; Arrébola and Álvarez 2001), being also the most common in ecosystems (Mayoral *et al.* 2007) and archaeological sites in this area.

Morphology and ecology of *Theba pisana pisana* (Muller 1774)

Theba pisana pisana is a land snail that belongs to the subfamily Helicinae. It has a moderately strong, opaque and bright shell with a uniform colour. Sometimes its shell has colour bands of varying thickness and regularity. Cowie (1983) has detected changes in the colour of the mantle, caused by differences in the age of individuals and by the amount of irradiation of the ecosystem where they live. Size ranges from between 12-22 mm in diameter and 9-19 mm in height and no significant changes are detected in relation to climatic variations (Cowie 1984b) as have been described for other species of land snails (Goodfriend 1986). This homogeneity of size in this species, not related to variations in temperature, can be explained by the characteristics of their preferred habitats. They often live in coastal areas (Kadmon and Heller 1998) and river valleys up to 600 m altitude, and the presence of water buffers these habitats from sudden temperature changes. *Theba pisana pisana* is a pioneer species which occupies different ecotones (e.g. agricultural fields, dune areas, scrublands, riparian vegetation, roadsides) and avoids hot and dry areas (Cowie 1985). It lives throughout the south of the Iberian Peninsula (Mayoral *et al.* 2007; Ruiz *et al.* 2006), as well as throughout the Mediterranean basin, Eastern Europe and the British Isles (Deisler and Stange 2001). This snail has become an invasive species in many parts of America, Australia or Africa because of its wide range of tolerance (Cowie *et al.* 2009; Odendaal, Haupt and Griffiths 2008; Rumi, Sánchez and Ferrando 2010). *Theba pisana pisana* can accumulate in dense groups and aestivate in diverse places (branches of plants, fence posts).

When identifying *Theba pisana pisana* by the features of its shell, it can be confused with *Cerzuela* (*Cerzuela*)

virgata (Da Costa 1778) or *Xerosecta* (*Xeromagna*) *promissa* (Westerlund 1893) which are of similar size and morphology (although we know that more than 95% of individuals in the study area are *Theba pisana pisana*). Nevertheless, in this analysis we have included all exoskeletons of these species (*Theba*, *Cerzuela* and *Xerosecta*) because we are interested in studying the range of size preferred by collectors (who may not discriminate between these species).

Study area

The biostratonomical and biometrical study of the land snails was carried out in the southwest of the Iberian Peninsula (Europe), near the city of Seville (fig. 21-1). We selected different areas near the archaeological sites studied at the Laboratory of Paleobiology of the Instituto Andaluz del Patrimonio Histórico (IAPH) to collect samples of current land snails.

Current ecosystems

We selected two ecosystems: “Loma del Acebuchal” (Alcalá de Guadaira, Seville) and an area near the Guadalquivir River (between Camas and Santiponce, Seville). Both ecosystems have permanent water sources: the first has an artificial lake and at the second the Guadalquivir River runs parallel to the sampling area. The flora includes typical Mediterranean species (e.g. *Pistacia lentiscus*, *Olea europea*), trees from riparian forests (e.g. *Populus alba*, *Populus nigra*, *Ulmus minor*) and ruderal vascular plants.

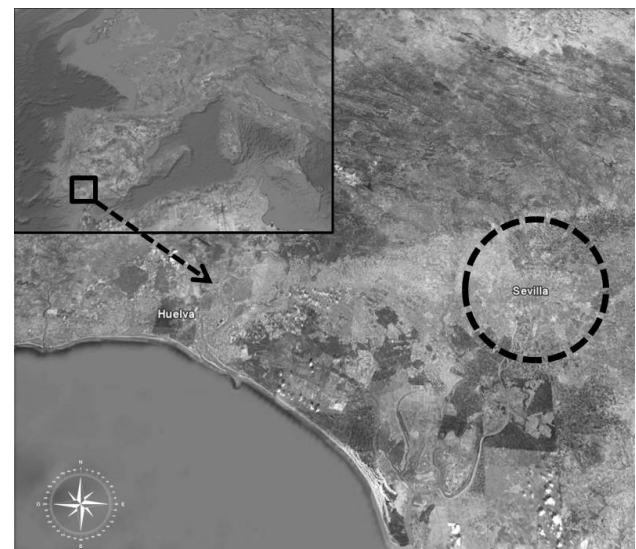


Figure 21-1. The study area is located near Seville, in the southwest Iberian Peninsula (Europe). Source: Google Earth.

Archaeological sites

Seven archaeological sites from southern Spain have been selected to compare with the results obtained in the current

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biometrical analysis:

- “La Gallega” (2,500 BC; Valencina de la Concepción, Seville). At this site there are different subsurface structures from the Copper Age. This archaeological site is located on a hill on the right bank of the Guadalquivir River and belongs to the larger archaeological site of Valencina de la Concepción-Castilleja de Guzmán. This site is classified as BIC (“Bien de Interés Cultural”), which means it is registered as of cultural interest by the Junta de Andalucía for being considered one of the most important Chalcolithic settlements in the Southern Peninsula. This recognition is based on the fact that the site consists not only of a huge populated area, but also contains an important megalithic area with numerous dolmens (the most notable are La Pastora, Montelirio, Matarrubilla and Ontiveros (Vargas 2004).
- “El Carambolo” (ninth-sixth centuries BC; Camas, Seville). This site is a landmark for specialists studying the legendary Tartessos when in the mid-1970s an important treasure related to this culture was found (Álvarez 2010; Carriazo 1978). Between the years 2002-2005 several excavations were carried out which clarified site function and the culture associated with it (Phoenician). In the 1970s this archaeological site was treated as a cabin, but recently new research defined this site as a pit. It is assumed that this pit was used to dispose of the remains of animal sacrifices to the gods *Baal* and *Astarte* made in a near Phoenician sanctuary (fig. 21-2) (Escacena Carrasco, Fernández Flores and Rodríguez Azogue 2007; Fernández and Rodríguez 2006, 2007).
- “Cerro de la Albina” (seventh century BC; La Puebla del Río, Seville). At this site only one structure was found, probably of Tartessian origin, which was possibly used temporarily on several occasions; Escacena and Henares 1999). The archaeologists recorded several deposits of shells with approximately 1,500 land snails in each one (Bernáldez and Bernáldez 2001) buried deliberately in holes. The origin of these deposits of snails could be related to metallurgical activity (Escacena Carrasco, Feliu Ortega and Izquierdo de Montes 2010).
- “C/ San Felipe Neri” (second-third centuries BC; Carmona, Seville). In 2000 archaeologists found a Roman temple in “La Ladera del Corcho”, which is currently located 8 m below the surface. The building boasts several galleries filled with a matrix of earthy bricks, pottery fragments, bones and millions of land snails.
- “Hospital de las Cinco Llagas” (twelfth century AD; Seville). When the current Parliament of Andalusia was being built (1998) an archaeological

excavation revealed some Roman and Islamic remains of great interest (Tabales *et al.* 2003). The medieval deposits had accumulations of land snails whose average size was less than 10 cm (Bernáldez and Bernáldez 2003a).

- “La Almagra” (twelfth century AD; Huelva). In 2002 an archaeological site was excavated in the “Campus del Carmen” (University of Huelva). There were structures spanning from the Roman period to the present (Campos Carrasco, de la O Teruel and Gómez Rodríguez 2005). We focus on a series of holes excavated in an Islamic kitchen dated from the 12th century. Bernáldez and Bernáldez (2005) described these features as clambakes, in light of the palaeobiological and taphonomic studies. In this paper we will only include groups of land snails recovered from inside these holes.
- “C/ San Fernando” (twelfth century AD; Seville). This archaeological excavation was carried out in the old quarters of Seville. Part of the Islamic wall (twelfth-thirteenth centuries) of the city and other structures dating from the Roman period to the present were discovered due to the tram works on this street (2004).

Both the conservation status of the material and the methodology used during the archaeological excavation ensure that the samples are significant (with small element loss prevented by screening).



Figure 21-2. Aerial view of the Phoenician sanctuary of “El Carambolo”. Throughout the entire Phoenician period the building changed its structure and distribution four times. The final state of the building is shown in this image (provided by Álvaro Fernández and Araceli Rodríguez).

Objectives

The main objective of this study is to detect and quantify significant differences between cultural and natural deposits of land snails. We will compare the sizes of the shells in both types of deposits and we will try to define a

set of features that allows other researchers to distinguish between the two deposits quickly and easily.

Methodology

To carry out this study different groups of land snails were selected: modern snails collected for consumption, snails from aestivation areas and snails from archaeological sites. The identification of different species was carried out using dedicated literature (Arrébola 2002; Ruiz *et al.* 2006) and the malacological collection of the Laboratory of Paleobiology (Instituto Andaluz del Patrimonio Histórico). All snails were measured by height (LM) and width (AM) in millimeters (fig. 21-3).



Figure 21-3. Ventral and dorsal view of the shell of *Theba pisana pisana*. We measured width (AM) and height (HM) in mm.

Modern snails gathered for consumption

Each sample of snails was collected by a person or group of people who usually use these molluscs for food. This allowed us to analyze the preferences of the collectors with specific reference to the size of the snails. We studied samples from different collecting seasons in the southern section of the Iberian Peninsula (from April to July) and at different places (see study area) to check if there were changes over time and/or within the collection area. We obtained three samples: two from the “Loma del Acebuchal” (Alcalá de Guadaira, Seville) in April and May of 2009 and one collected near the Guadalquivir river in Camas (Seville) in May of 2009. Once the snails were consumed, they were washed and dried. Afterwards we identified the snails and undertook the biometrical analysis.

Deposits of snails from areas of aestivation

The snails were collected at the “Loma del Acebuchal” (Alcalá de Guadaira, Seville) at the end of July 2009. Most were measured *in situ* and then released into the environment. We collected data from seven groups of this type located in the branches of different trees (*Olea europea*, *Pistacia lentiscus*, *Populus nigra*) and fence posts (fig. 21-4).



Figure 21-4. A group of snails during aestivation on top of a fence post at “La Loma del Acebuchal” (Alcalá del Río, Seville).

Archaeological deposits of land snails

We have deposits of shells from different archaeological sites in the southwest of the Iberian Peninsula, ranging from the Bronze Age to the twelfth century: “La Gallega”, “El Carambolo”, “Cerro de la Abina”, “C/ San Felipe Neri”, “Hospital de las Cinco Llagas”, “La Almagra” and “C/San Fernando”. These snails were cleaned using a combined system of ultrasound, air and water to remove the sediments inside the shells without causing damage to them (fig. 21-5). Once cleaned and dried, the shells were identified and measured with a digital caliper.

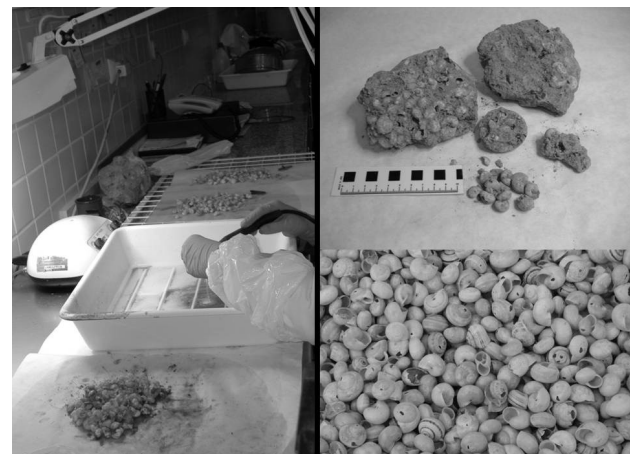


Figure 21-5. The snails recovered from archaeological sites were cleaned using a technique that combined air, water and ultrasound to remove all traces of sediment from inside the shells.

For data analysis we used SPSS 14 and we studied normality and homoscedasticity of the different groups. Then we performed mean and variance contrast studies (ANOVA and Scheffé) as parametric contrasts and Kruskal-Wallis and Tamhane as nonparametric. After this, we cross-checked the differences between groups using a distribution analysis and we obtained a formula of classification from the current samples. In order to

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validate the generated model the group of snails from archaeological sites was included in the analysis.

Results

We studied 7,049 land snails: 2,836 (40.23%) of these derived from the biostratigraphical study and 4,213 (59.76%) were selected from archaeological sites.

First we checked whether the differences in size between the groups collected in the actualistic study were statistically significant (three samples were gathered for current consumption and seven samples were selected in areas of aestivation) (fig. 21-6). We analyzed normality using a Shapiro-Wilk test, but it was negative; therefore we applied a non-parametric contrast (Kruskal-Wallis) to test whether these biometrical differences were significant. This one concluded that at least one of the 10 groups analyzed showed significant differences with the others (HM: $\chi^2 = 1329.538$, sig.=.00; AM: $\chi^2 = 1285.461$, sig.=.00). To find out which of the groups showed these differences, we decided to accept normality (depending on Central Limit Theorem which states that samples always follow a normal distribution which adjusts better as the size of the dataset increases until infinity (Milton 2007,

Ramos 2006) and applied the Levene test to check the homoscedasticity. The homoscedasticity test was not able to be successfully applied, probably because there were large differences in the sizes of the datasets, and therefore we had to apply a Tamhane test. We concluded that the differences observed between groups (current consumption vs. areas of aestivation) of land snails were significant.

Although the differences between the two groups were evidenced by a contrasting average, we cross-checked this through a discriminant analysis. This procedure also identified two groups of snails (Wilks' lambda = 0.481; sig.= .00 / M Box = 1591.700; sig.= .00) and we obtained the following classification formulas:

$$\text{Natural deposits} = -2.096\text{HM} + 3.155\text{AM} - 10.599$$

$$\text{Cultural deposits} = -1.545\text{HM} + 3.597\text{AM} - 20.94$$

After analyzing the differences between the groups of modern land snails, the 3 samples gathered for consumption were placed into a single group, and the same with the seven samples from areas of aestivation. In order to confirm these differences between the two new groups, we repeated the previous analysis (Kruskal-Wallis and Tamhane tests). These two new groups were compared with the land snails from archaeological sites.

Current deposits of snails

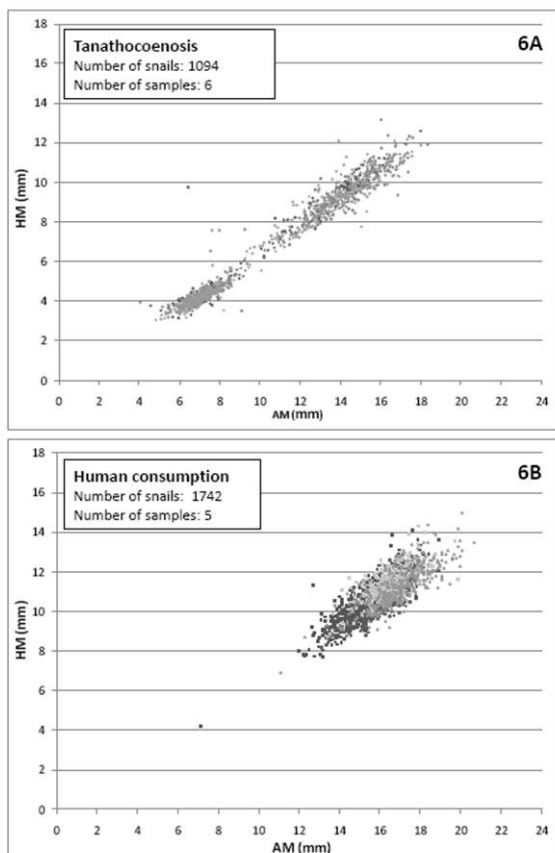


Figure 21-6. In this figure we show the biometrical measures (height and width) of all the land snails which were collected in the actualistic study. We highlight the studied groups: modern consumption and areas of aestivation.

A graph (fig. 21-7) of the biometrical data of the snails found in archaeological sites was similar to figure 21-6 (which represented the groups of current land snails). We thought that this result could be related to three potential origins:

- waste from human consumption,
- natural thanatocoenosis
- and mixed groups of the previous two.

Parametric tests should be applied in order to undertake statistical comparison of samples, but the normality was not proved and neither was the homoscedasticity, probably due to the difference in the number of elements of each group: 147 snails from “La Gallega”, 312 from “Cerro of the Albina”, 606 from “San Felipe Neri”, 481 from “La Almagra”, 1739 from “C/San Fernando”, 472 from “Hospital de las Cinco Llagas” and 457 from “El Carambolo”.

Due to these results we decided to implement the Kruskal-Wallis test, which confirmed that at least one of the groups showed differences with the rest in terms of height and width. The pair comparison test was conducted using the Tamhane test with which we obtained four groups according to the size of the snails:

- Group a: Composed of samples from “La Gallega”, it had the smallest average size (about 3 mm in HM and 6 mm in AM).
- Group b: Composed of current samples of aestivation and samples of “C / San Felipe Neri”.
- Group c: Composed of snails from “Cerro de la Abina”, “La Almagra”, “C/San Fernando”, “El Carambolo” and the current samples of snails collected by humans.
- Group d: Composed of the sample of “Hospital de las cinco Llagas”.

Archaeological deposits of snails

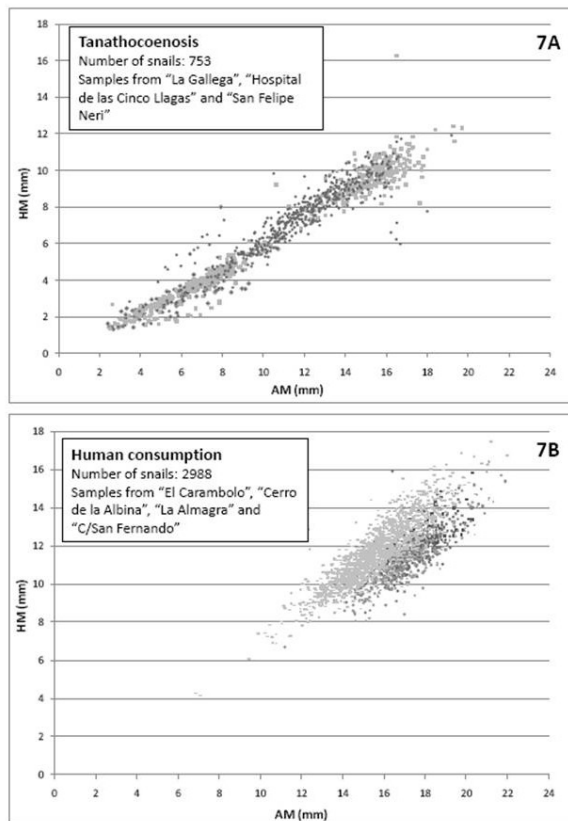


Figure 21-7. In the analysis of size-ranges of the snails from archaeological sites two groups were identified which is a similar result to that obtained in the actualistic study (fig. 21-6).

For this study we were only interested in distinguishing between natural and cultural deposits, therefore those clusters whose average height was less than 10.64 mm, which is the minimum value of the sets associated with human consumption, were assigned as a natural thanatocoenosis. After processing the width data the results obtained were similar to those above, establishing 14.95 mm as the lower limit to consider a group of snails as having a cultural origin.

The average size of snail at “Hospital de las Cinco Llagas” archaeological site (HM=7.35 mm; AM=11.75 mm) is not included in any of the previous deposits (cultural or natural) and it could be an example of a mixed deposit. Nevertheless, these land snails were buried deliberately in a hole, so we think that they were probably collected for human consumption (which could be an exceptional case).

Discussion and conclusions

After the statistical analysis of the biometry of 7,049 shells of *Theba pisana pisana*, we found significant differences between cultural and natural deposits of land snails (fig. 21-9). Therefore, the first conclusion is that we can determine the origin of an accumulation of shells in the southwest Iberian Peninsula using a combined analysis of

biometrical and biostratonomical data.

The deposits of land snails were defined by their size (average width and height). A group of snails which measure over 10 mm in height and 15 mm in width could be interpreted as a cultural deposit (waste of human consumption), and those which have an average of about 7 mm in height and 10 mm in width could be related to natural thanatocoenosis (dead snails in aestivation zones). Bernáldez and Bernáldez (2001) suggested that snails over 11 mm in diameter can be selected for consumption, being the minimum and maximum sizes between 11 and 20 mm. These data provide a mean of about 15 mm, a value similar to that obtained in our case. In addition, we have defined two formulae to classify both groups (natural vs. cultural deposits) through a discriminant analysis. These are easy to use; simply replace the values of AM and HM and solve it. The highest result will be the solution which will help us to define the deposit. It is important to note that the formulae have been validated with the mean size of the snails collected in the biostratonomical study and at the archaeological sites (but we did not include the sample of the “Hospital de las Cinco Llagas” because this is a special case). In 100% of the cases the result obtained with this method is similar to that already obtained by the Tamhane test. Therefore, we believe that this tool can be a simple way to interpret deposits of land snails which present doubts as to their origin. The homogeneity of the data group should be checked if the group has biometrical characteristics associated with human consumption: a large number of individuals, a mean similar to the median and a low variance. In the case of natural populations these features are not expected, because the bimodality of the size of the snails from these groups (fig. 21-8), related to their biennial cycle of life (Cowie 1984a), prevents the values of mean, median and variance being as adjusted as is required (in fact, the bimodality is a feature which could be used to classify a deposit of snails as a natural thanatocoenosis).

Four deposits of land snails from archaeological sites have been statistically considered as a natural thanatocoenosis, something which has already been mentioned in previous studies (Bernáldez and Bernáldez 2002, 2003b). The rest have been interpreted as accumulations produced by human consumption, also classified in this way in previous analysis (Bernáldez and Bernáldez 2001, 2005). “Hospital de las Cinco Llagas” is an exceptional case, the taphonomic interpretation of this site (Bernáldez and Bernáldez 2003a) reveals that the average size of the snails is less than the size of the snails from a cultural deposit, but we are reluctant to identify the origin. Although the statistical analysis classifies this deposit as a natural thanatocoenosis, these snails were buried deliberately. Therefore, we could be facing a case of human consumption of *Theba pisana pisana* at a non-optimal time or, perhaps, these molluscs were used in an unknown manner (Bernáldez and Bernáldez 2001).

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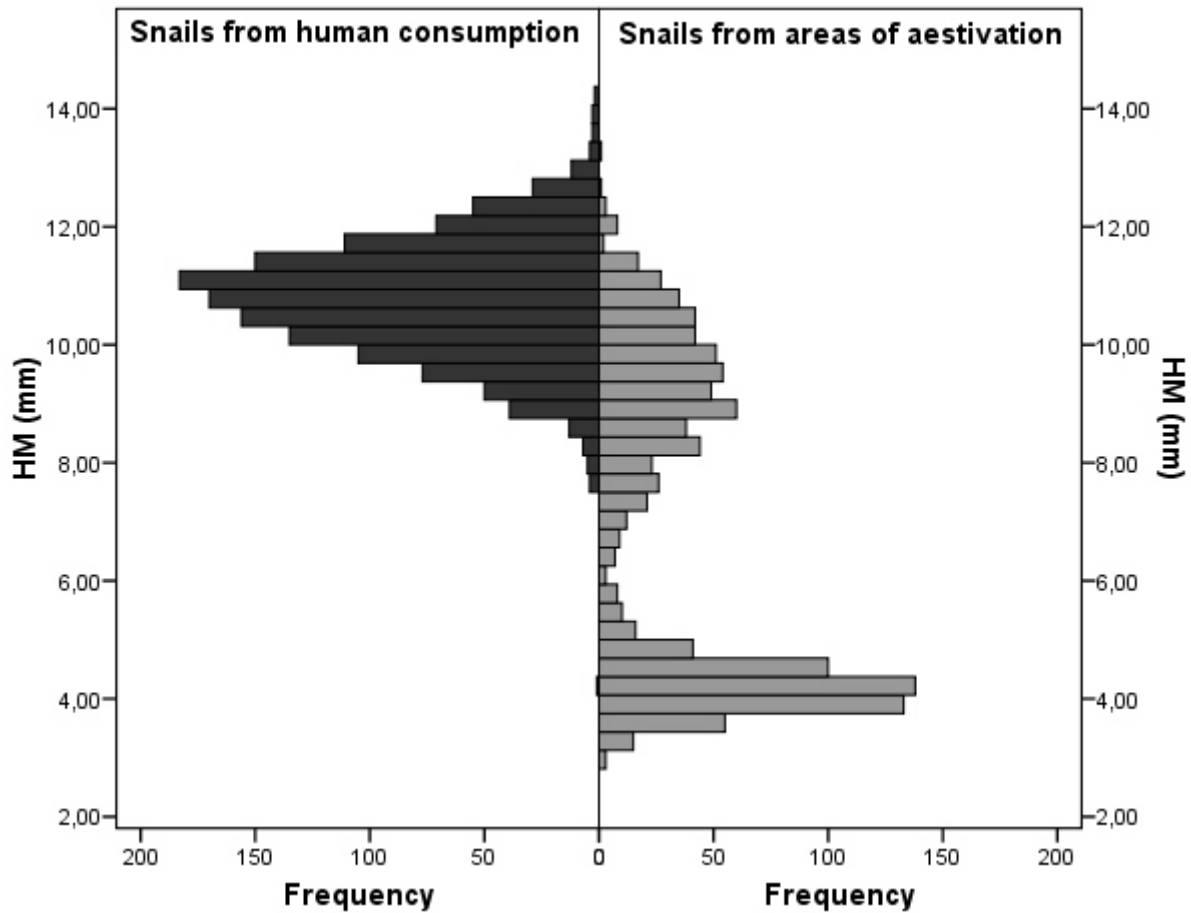


Figure 21-8. The bimodality in the size of the snails from areas of aestivation is explained by the two-year cycle of growth (Baker and Vogelzang 1988; Cowie 1984a).

Although the biostratonomical research could be a science-based tool to discriminate different types of deposits, researchers should be careful when applying the actualistic results in the interpretation of a taphocoenosis or oryctocenosis. A large number of agents may influence both the formation of the deposits (e.g. water, mudslides, animals) and the preservation of their components (e.g. trampling, erosion, dissolutions). In addition, the methodology applied by archaeologists to obtain samples may cause data loss, due to the fragmentation of the elements or the non-collection of some of them. For example, the smaller snails are harder to detect if the material is not sieved, therefore the results of the biometric study could be wrong (because the arithmetical mean could be overestimated). Consequently to complete this research we should study more samples and design biostratonomic experiments to quantify the snail loss during the pre-fossil diagenetic phase.

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Figure 21-9. Snails in an aestivation zone. During burial and the action of diagenetic processes several elements were lost through physical, chemical and biological vectors.

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