The social use of space in a shell midden: testing ethnoarchaeological data from Tierra del Fuego (Argentina) with intra-site spatial analyses

Alberto García-Piquer
alberto.garcia.piquer@uab.cat

Jordi Estévez-Escalera

Department of Prehistory, Autonomous University of Barcelona, 08193, Catalonia, Spain.

*Corresponding author.

Abstract

This paper presents a part of an ethnoarchaeological research whose main objective is the development of methodological and conceptual instruments to advance the study of prehistoric hunter-gatherer societies. We have proposed ethnoarchaeological experimentation in order to contrast the relationship between spatial organization and social relationships for evaluate the resolution level of intra-site analysis combining the use of social categories (deriving from the socioeconomic analysis of an ethnographic documented Hunter-Gatherer society) with the systematic record recovered in a site of the same society, both from a quantitative and qualitative approach.

The processes of formation of the Túnel VII site have been differentiated from the interpretation of refitting analysis and spatial distribution maps and the detailed analysis of zooarchaeological data. However, the results presented in this paper have to be contrasted with an integrated analysis of lithic and bone technology remains in order to analyse the overall distribution of by-products from production and consumption activities. Moreover, results concerning the structure of spatial data point to the need to test spatial interpolation methods designed to overcome the geostatistical restriction on the homogeneity of the surface.

Keywords: Ethnoarchaeology, Hunter-Gatherers, Tierra del Fuego, Argentina, Intra-site spatial analysis, Geostatistics, Social organization

1. Introduction

The archaeological visibility of shell middens and favourable conditions for preservation of bioarchaeological remains have led to a long and rich history of research reaching back to the 19th century (see Andersen, 2000; Dupont et al. 2007; Pickard and Bonsall, 2014).

However, the stratigraphic analysis could be difficult by the heterogeneous nature and the successive depositional and postdepositional processes of these deposits, mainly made of shells and other remains of human activity. The traditional methods and techniques of excavation, as well as the character of undifferentiated coarse-grained palimpsest commonly
attributed to shell mounds, have prevented a good comprehension of the real extent and complexity of the midden, reduced the advantages of their potentially high-resolution record.

Great advances have been made through shell midden research in recent decades. The development of a range of new recovering methods and analytic techniques has been accompanied by a growing work on comparing shell midden sites over large geographical areas (from arctic regions to the tropics: Álvarez et al. 2011; Balbo et al. 2011; Milner et al. 2007; Roksandic et al. 2014) and among different chronologies and coastal communities worldwide (Bailey et al. 2013; Rick and Erlandson, 2008). All of this has resulted in a richer understanding of the large variability of this particular type of archaeological site both from the taphonomic and typological / functional perspectives.

Indeed, shell middens do not have a single function. Though generally interpreted as deposits of food remains and garbage, sometimes in association with activity/habitation areas, they have been also interpreted as burial monuments or as referential places for ritual and ceremonial activities (e.g. the huge Brazilian Sambaquis: Andrade Lima and López Mazz, 1999; Fish et al. 2000; Gaspar, et al. 1992; Gaspar and De Blasis, 1992; Klokler, 2008, Villagran, 2012). In fact, both functions are not exclusive. According to ethnographic literature, “domestic” and “ritual” activities could be alternately performed at a same site (Salius, 2013). Actually, separation between “ritual” and “domestic” life is in other societies not as separated as in our modern society (Mansur et al. 2007). Ideology and social norms are completely embedded in social and economic every day practices (Vila et al., 2004).

Variability also concerns the size and shape of the shell deposits, and the duration of the site’s occupation. Large shell middens are characteristic of Hunter-Gatherer societies with a low mobility frequency: the NW coast of North America (Ames, 1991, 2005; Arnold, 1992; Lightfood, 1993) or the aforementioned Brazilian Sambaquis. However, a series of short successive occupations over a long span of time can also produce this type of archaeological site, as seems to be the case with Australia (Catterall and Poiner, 1987; Faulkner, 2014; McNiven 1992) or Tierra del Fuego shell middens (Orquera et al. 2011). Shell middens may be the result of different social and economic strategies. Therefore, the scale and resolution of each particular type of shell midden have to be taken into consideration in order to achieve a comprehensive understanding of the aforementioned complex site-formation process (e.g. Cascalheira and Gonçalves, 2012; Colonese et al. 2011a; Duarte et al. 2017; Estévez et al. 2013; Gassiot and Clemente, 2015; Marchand and Dupont, 2017; Villagran, 2014).

This issue is relevant to the European Mesolithic period and the Mesolithic-Neolithic transition research. Unlike Mediterranean shell middens (Colonese et al. 2011b), the appearance of large accumulations of molluscs across Atlantic Europe during the Mesolithic seems to support a great reliance on littoral resources and the existence of economic intensification (see for a detailed synthesis Gutiérrez-Zugasti et al. 2011). In the case of the Ertebølle culture of Denmark, the availability of coastal resources has been used to propose high population
densities, a reduction in mobility and the development of complex hunter-gatherer societies (Rowley-Conwy, 1983; Rowley-Conwy, 1998). A considerable number of Mesolithic Atlantic European shell middens have been described as long-term, or even annually, large residential sites based on the size and thickness of their record, on average samples, or on the seasonality of faunal remains (Milner et al. 2007; Orquera and Piana, 1992). Portugal’s Muge shell middens were illustrative examples in this regard (Roche, 1989) though this perspective has been revisited (Bicho et al. 2010).

Previous studies have shown the potential of intra-site analysis of preserved spatial features, the distribution of lithic debitage and the refitting of lithics, bones or burnt stones for making proposals about the Mesolithic social organization, especially in northern Europe (Blankholm, 1987, 2008; Casati and Sørensen, 2011; Cascalheira and Gonçalves, 2012; Grøn, 1995, 2011, 2003; Loeffler, 2003; Martínez-Moreno and Mora, 2011; Price et al. 1987). Other studies have presented the importance of ethnoarchaeological and ethnographic data as a mechanism to generate hypothesis and methodological instruments (Grøn, 2017; Grøn and Kuznestov, 2003; Vila, 2011; Vila and Estévez, 2000). Despite this progressive quantitative and qualitative increase of spatial analysis in Mesolithic sites, there is still much to explore on the ability of intra-site analysis to archaeological reconstruct social relationships in a site.

This study presents a part of an ethnoarchaeological research whose main objective is the development of methodological and conceptual instruments to advance in the study of prehistoric hunter-gatherer societies. Our approach to Ethnoarchaeology (Estévez and Vila, 1995; Piana et al. 1992; Vila, 2011) differs from other ethnoarchaeological research (such as proposed originally by Kramer, Binford or Gould: cf. Whitelaw, 1983). Considering the assumptions that: 1) archaeological remains are mainly -structured- remains of social activity; 2) human activity is organized following patterns and social norms; and 3) the internal organization of a social unit translates into the management of the inhabited space (Dragicevich et al. 2012; Estévez et al., 1984), therefore archaeological investigation should intend to extract data regarding social relationships (Wünsch, 1992). This correlation of logic postulates has been contrasted in several ethnoarchaeological examples and even in a contemporaneous rubbish dump (Rathje and Cullen, 1992).

Therefore, we proposed an ethnoarchaeological experimentation to contrast the relationship between spatial organization and social relationships (Vila and Estévez, 2000). The aim of this research is to evaluate the level of resolution of intra-site analysis combining the use of social categories (deriving from the socioeconomic analysis of an ethnographic documented Hunter-Gatherer society) with the study of the remains archaeologically recovered in a site of the same society, both from a quantitative and qualitative approach. In addition, this methodological experiment should contribute to reach an understanding about the causes of the obvious variability observed in the archaeological record, in our case in a hunter-fisher-gatherer society with a subsistence based on similar resources as some coastal societies from the European Mesolithic (e.g. Ames, 2002; Pickard and Bonsall, 2014).
We present in this paper the results of a very fine-grained intra-site spatial analysis of archaeozoological data from Túnel VII site, a Yamana shell midden (Tierra del Fuego, Argentina) dated to the 18-19th century, and implications for understanding the variability in shell midden site-formation processes and its relationship with social use of space in Hunter-Gatherer societies.

1.1. Archaeological and ethnographic background

The Isla Grande of Tierra del Fuego and, specifically, the coast of the Beagle Channel (Fig. 1), is a privileged place for archaeological and ethnoarchaeological research. It has a relatively unaltered ecosystem, as well as a high-visibility and abundance of archaeological sites. Since 1975 the area has undergone extensive archaeological work which has allowed a chronological sequence up to six millennia old (e.g. Tunnel I, 6680 ± 210 BP, or Lancha Packewaia, 4020 ± 70 BP: Orquera and Piana, 2009).

![Map showing the location of Túnel VII on the Beagle Channel, 10 km from Ushuaia (Tierra del Fuego, Argentina).](image)

**Fig. 1** Map with the location of the site of Túnel VII on the Beagle Channel, 10 km from Ushuaia (Tierra del Fuego, Argentina).
As of the very first European contact, dating back to the 17th century, sailors and travelers reported the existence along the southern coastline of the archipelago of Tierra del Fuego of the hunter-fisher-gatherer groups later referred to—in the ethnographic literature—as *Yamana* or *Yaghan*. Considered as a paradigm for Prehistoric Hunter-Gatherer societies, these indigenous groups provided rich ethnographic data like the detailed descriptions of Hyades and Deniker (1891), the extensive ethnography of Gusinde (1937) or the abundant ethnographic objects that became part of American and European museums (for an overview of the main ethnographic collections see: Estévez and Vila, 2006a). Nevertheless, the impact on their lifestyles was limited until the mid-nineteenth century. After that date, “direct contact” resulted in a fast ethnic and demographic disintegration of the indigenous people (Piana and Orquera, 1995).

Ethnography describes Yamana groups as high-mobile small social units that, throughout almost the whole year, lived on the exploitation of coastal resources—shellfish, fish, seabirds, marine mammals—by means of canoe sailing (Gusinde, 1937; Hyades and Deniker, 1891; for an exhaustive review of ethnographic reports and descriptions see Orquera and Piana, 1999). Despite a large variability in resource exploitation according to local availability (Estévez and Vila, 2006b), intertidal shellfish were the most predictable and abundant resource (Orquera and Piana, 2000, 2001). Therefore, archaeological sites of the Beagle Channel are mainly composed of shell midden (Orquera and Piana, 1991; Piana and Orquera, 2010). They have a similar structure: an annular ring of intentional accumulations of shellfish and other food-waste surrounding an excavated central depression of 3-4 m diameter. The hut is located in the central depression. These sites were occupied several times, taking advantage of previous structures. Modern replicas of native huts indicate that they could be used for four or more years (Piana and Orquera, 2010). During the reoccupation, the size of the shell midden border might increase to give protection against wind (Orquera et al. 2011; Verdún et al. 2010). Rapid site-formation process, neutralization of sedimentary acidity because of calcium carbonate and the absence of human-related post-depositional problems have favored an excellent preservation of those sites (Orquera and Piana, 1989).

The ethnographic record of Yamana groups reports a strict sexual division of labour as well as an undervaluation of women, stressed by means of initiation ceremonies and myths (Gusinde 1937; Orquera and Piana, 1999; Pedraza, 2013). Thus, despite being sometimes biased, shallow or controversial, ethnographic data can be depurated critically, providing information not only about *subsistence* exploitation—which productive and consumption activities were carried out—but also about Yamana social norms concerning tasks: the sexual-restriction associated to them, their location at the settlement area, the work-time required or even their social valuation (Pérez-Rodríguez et al. 2016; Vila and Ruiz, 2001). All the characteristics made Tierra del Fuego an excellent ground for developing under controlled conditions Ethnoarchaeological experimentation.
Previous work in the area have shown the utility of intra-site spatial analysis studies in setting high-resolution analyses about resources management, hut arrangements and organization of tasks (Briz et al. 2013; Estévez and Vila, 2006b; Negre Pérez et al. 2015; Wünsch, 1995; Zurro et al. 2017)

2. MATERIAL AND METHODS

2.1. The site of Túnel VII

The site of Túnel VII is a shell midden located in the northern shore of the Beagle Channel, 10 Km far from Ushuaia, Argentina (54˚ 49’ 15” S, 68˚ 09’ 20” W). Archaeological work was carried out by a Spanish-Argentinean research team within the framework of several “Experimental Ethnoarchaeological” projects.

Initial excavation area was 72 m², but later was resized to a smaller area of 32 m². Large area excavation was carried out with 1 m² sectors divided in turn in 0.50 m² sub-sectors. Remains larger than 1 cm were coordinated and the whole sub-sectors sediment was sieved with a 1 mm mesh-sized. Orquera and Piana (1992) methodology was implemented and developed in order to isolate and extract each of the stratigraphic sub-unities result of the characteristic rapid deposition of Tierra del Fuego shell middens.

Archaeological work revealed an area with a ring of shell middens surrounding a deep central area composed of dark humus and several overlapped fireplaces (Fig. 2). Periphery was composed of the repeated deposition of food waste, mainly shells, but also of flakes and lithic debris. Moreover, small concavities were located at the periphery of the central area and are interpreted like postholes, enclosing an approximately circular area of 3.5 m diameter (Estévez and Vila, 2006b). These structures are typical of the ethnographically documented Yamana huts (Gusinde, 1937; Piana and Orquera, 2010).

Túnel VII was 14C and dendrochronology methods dated to 1776-1792 CE and 1863-1898 CE (Piana and Orquera, 1995). Consequently, Túnel VII is fully representative of the morphology and the site-formation processes of archaeological sites concerning the later Yamana groups before their decomposition.

Ten short successive occupations episodes during the 80-years span have been identified (Estévez and Vila, 2006b). They have been identified primarily in the central area and the fireplaces by means of micromorphology techniques (Villagran et al., 2011), shell remains analysis (Verdún-Castelló, 2014) and the stratigraphic assembly of shell midden units in the immediate surroundings (Vila et al., 2009). Technologic and use-wear analyses evidenced exploitation of local raw materials as well as flaking and tool retouching activities, either inside or outside the “hut” (Clemente, 1995; Terradas, 1996). Phytoliths and fatty acid analyses were also carried (Zurro et al., 2009).
2.2. Sampled specimens

The archeozoological analyses concluded consumption of *Arctocephalus australis* and *Otaria flavensis* (NISP = 3.632), the two species of marine mammals in the region, and especially the juvenile male ones (Schiavini, 1993). However, the first taxon concerns bird species (NISP = 4.857), evidencing an important consumption of big and small seabirds, *Phalacrocorax sp.* and medium-sized penguins, and even of parrots, ducks and other small terrestrial birds (Mameli and Estévez, 2004). Eventually, unidentified cetacean remains were documented (NISP = 580), as well as a few remains of the endogenous camelid *Lama guanicoe* that evidence its sporadic consumption (NISP = 108). Furthermore, thousands of fish remains were recovered. Their number was calculated based on a density calculation on samples of every sub-unit (Juan Muns, 1992).

As expected in a Yamana context (Álvarez et al. 2013; Fiore et al. 2013; Orquera and Piana, 2000, 2001; Tivoli and Zangrando, 2011), a general trend is coastal resource exploitation (intertidal shellfish, fish, marine mammals). Notwithstanding, variability has been observed during the successive short different occupation episodes in the site of Túnel VII (Estévez and Vila, 2006b). First and foremost, bird consumption increases as marine mammal remains decreases. This pattern is also observed in fish (Juan Muns, 1992). Variability among episodes is neither related to a seasonal pattern, nor to changes in the environment, but of what has
been called an “opportunistic specialization” regarding resources exploitation (Estévez and Vila, 2006b).

In addition to species identification and seasonality, archaeozoological analyses focus on the recognition of butchery marks (cuts, chops, slicing and scraping marks), burning, bone fractures and fragmentation, as well as taphonomic modifications as weathering. Analyses intended to relate each of these markers to food-processing activities (Estévez et al., 2001). In the case of marine mammals, documentation of all anatomical elements supported ethnographic data regarding marine mammal transportation to the proximity of the hut (Gusinde, 1937; Orquera and Piana, 1999). The lower bone density of the smallest bird remains shades the analyses, although complete presence of all larger bird elements supports the assumption that they were transported from kill-sites (Mameli and Estévez, 2004). Finally, cetacean and guanaco remains show a differential processing (Estévez and Martínez, 1997).

2. 3. Method

2.3.1 Developing interpretative models (Yamana)

The first stage of the research consisted of the development of appropriate conceptual instruments. Ethnographic data concerning modern Hunter-Gatherer groups was critically analyses to assess material and social variability of these type of societies (Brumbach and Jarvenpa, 1997; Fisher and Strickland, 1989; Grøn, 1989; Heyman, 2009; Kelly, 2013; Lee and Daily, 1999; Waguespack, 2005) that are the closest to Yamana groups, at least in terms of subsistence strategies. Yamana ethnographic literature (Gusinde, 1937; Hyades and Deniker, 1891; Martial, 2005; Orquera and Piana, 1999), photographs and American and European museum collections (Estévez and Vila, 2006a) were examined in detail and from an archaeological perspective. Finally, conclusions extracted from several experimentations performed during the research projects in Tierra del Fuego and regarding manufacture and use-wear of lithic and bone tools, formation and alteration of fire structures, or carcass decomposition (Estévez et al. 2013, 2014; Mameli et al., 2002), were revised.

Based on a theoretical proposal of “objective value calculation” in Hunter-Fisher-Gatherer societies (Barceló et al., 2006; Pérez-Rodriguez et al., 2016; Vila et al., 2010) a standardised work-sequence was realized. It started from natural resource socialization until consumption and maintenance activities, including all the intermediate and successive stages of raw material transformation. Stress is laid on different by-products (waste and rejects) resulting for each of these stages: actually, it is the significate association of by-products that becomes in an archaeological marker, constituting the archaeological record. On the other hand, a consumption value index has been calculated with archaeozoological remains and direct consumption products (food). This index is based on meat yield per anatomical element of modern individual of each identified species (Savelle et al., 1996; Savelle and Friesen, 1996; Schiavini, 1993). In the case of birds remains, were meat yield research is still in progress,
values were extracted from the only suitable work and applied according to the wing: body ratio of each species (Tivoli and Pérez, 2009).

2.3.2 Modelling and visualizing Túnel VII formation-process

A second stage of the research consisted in 2D and 3D modelling of Túnel VII in order to study both horizontal and vertical spatial relations. The 271 micro-stratigraphic units (Orquera, 1995) were transformed into two-dimensional and three-dimensional shapefiles, with stratigraphic information and sedimentological properties as attributes, using ET GeoWizards 12.0 and ArcGIS 10.3 software by ESRI.

2.3.3. Computing the spatial distribution of archaeozoological remains

Manipulation with the data took place in MS Access 2013 and Excel 2013 (Microsoft Corporation, 2013). Refitting analysis of the archaeozoological remains in order to assess the site-formation processes in each episode was performed by means of graph theory. Network analysis in archaeology reemerged recently along with the development of information technologies that provided environment for efficient modelling of complex relationships. Each refitted remain was converted into a node and refitted relations expressed as undirected edges. Data was imported into Social Network Analysis software PAJEK 5.01 (Batagelj and Mrvar, 1998, 2003) and spatial information (x, y, z) converted into vectors. Taphonomic categories (trampling and polishing marks, bone-cracking, and especially weathering degree) resulting from archaeozoological analysis (Estévez and Martínez, 1997; Mameli and Estévez, 2004) had visualized by means of nodes colour and shape; edges colour symbolized vertical relations among episodes. Results were incorporated to GIS models.

Coordinates remains (>1 cm) were scattered and visualized with ArcGIS software. Spatial interpolation procedures were used to estimate the distribution of coordinates and uncoordinated remains over the site surface. For this purpose, a grid of 64 centroids of 0.50 cm² each was designed and different algorithms to interpolate a gradient representation from x, y, z data were tested by means of Python-language scripts and ArcGIS software. Although recent experimentation has shown that deterministic interpolation methods are problematic dealing with the complex-heterogeneous spatial structure of archaeological data (Achino, 2016; Bevan and Conolly, 2009; Rondelli et al., 2014), this prior test revealed Inverse Distance Weighting (IDW) as an appropriate technique at this first exploratory stage. Moreover, as stated by Achino (2016: 177), “an interpolated scalar field should not be considered as a ‘visualization’ of spatial data, but as a predictive model of the most probable place where data of a particular category were deposited (discarded) in preference”. Thus, the gradient in this map should be understood as the amount of change in the probability of the observed archaeological category in some direction, usually the direction for which the amount of change is greatest. Consequently, input data was normalized with “normal score transformation” (NST) ArcGIS method, or transformed to weighted indices.
Spatial distribution maps were created using concrete categories as weight (z) in order to shape social-meaningful maps of the use of space. Cleaning-activities were defined based on presence of crushing, burning, and distribution of large (>15 cm), small (<5 cm) and medium-sized (5-15 cm) remains. Taphonomic “noise” was evaluated based on distribution of more weathered bones (≥3) and presence of trampling, cracking, polishing, and rounded archaeological categories. Finally, production and distribution maps were based on the consumption value index and the locations of rejects. Each of these spatial distribution maps was created for nine from a total of ten episodes, labeled with letters from the oldest (A) to the more recent one (J).

3. RESULTS

3.1. Determination of “vertical-pollution” degree

The three-dimensional modelling of Túnel VII episodes (Fig. 3), as well as the analysis of the refitting of archaeozoological remains by means of graph theory methods, has allowed to understand the complex formation processes and evaluate taphonomic disturbance, especially referring to the first occupations, before accumulation of shell midden deposits. In addition, spatial distribution maps of weathering and other post-depositional evidence have made possible the distinction between activities and circulation areas. This could help to locate the entrance of the hut and, thus, better understand spatial structure of every episode (Fig. 4).

Fig. 3 Three-dimensional modelling of the first sequence of occupation (above) and vertical plotting of Túnel VII faunal and lithic remains.
Spatial distribution maps of alteration per episode allow observing that faunal remains deposited around fire structures were more affected by dynamic occupations (trampling, cracking, rounded). First episodes also show alteration at the western sector of the site, as well as in the northern sector (the slope). This structure changes from F episode: shell middens of the previous episode (E) covered the northern area and a larger concentration of weathered bone remains in the central and north-eastern area is observed. At the end of the occupation (episode H) the few evidences of trampling are in the northern area. This pattern is opposite to what is observed in the first episodes.

![Spatial distribution maps of alteration per episode](image)

**Fig. 4** Two-dimensional representations of Túnel VII episodes, visualizing fireplace location, the proposed limits of the hut and the overlapping dynamics of shell midden.

The results of refitting analysis allowed to further unravel the taphonomic relations between episodes, identifying which faunal remains were related with early episodes of occupation (A, B and C) and which corresponded to middle (D, E and F) and later episodes (G, H and J). Refitting analysis indicated that faunal remains of the northern sector belonged to later episodes, and that middle episodes (probably winter occupations: Estévez and Vila 2006b) present an extensive use of all Túnel VII surface (Fig. 5).
Fig. 5 Three-dimensional representation of faunal remains refitting reveals difference in the use of the space across the episodes.

3.2. Evaluation of the impact of cleaning activities

The results show recurrence of the same pattern throughout the ten episodes. Larger bone remains (>15 cm) were concentrated in the western area of the site, outside the central area where firing structures were located. The smaller fragments (<5 cm) were homogeneously distributed throughout the site, although ostensibly they accumulated around the firing area or in
the western and – less frequently – of the eastern sector. Medium-sized bone remains (5-15 cm) were concentrated in the centre of the site along a north-south axis, or directly in the firing area. Especially in the case of otariid, graph theory analysis of refitting faunal remains evidences cleaning activities (Fig. 6).

However, there are differences between episodes. Cetacean refuse-remains associated with both first episodes (A-B) were located in a concentration at the eastern-side of the site. On the other hand, since episode C another concentration in the southeast area of the site is observed. Both concentrations appear to be intentional depositions of sub-products. The distribution of consumption waste (i.e. burned remains and/or crushing marks) corresponds during the beginning of the occupation (Episodes A-B-C) with the distribution of large skeletal remains, although from the D episode this distribution is concentrated inside the hut. In the episode E large and medium-sized bone remains are concentrated in the north-central area of the site, which seems to indicate a discard area.

Fig. 6 Refitting network of otariid remains (above). XY plot of nodes degree centrality evidences the connections between central area and refusal areas.
3.3. Localization and rating of production and consumption activities

Categories derived from the socioeconomic analysis have been applied to 134 products or material goods that are ethnographically or archaeologically recorded for the Yamana groups. Thus, it is possible to build a model of related production processes and the evaluation of the invested time. Application of the meat yield value to direct consumption products, considering Túnel VII identified animal species physiology, sex, age and even individual size in specific cases (e.g. marine mammals or penguins), resulted in meat-yield value index per species. The ratio was later normalized, resulting in an inter-species consumption value index \( (V_i = 1-5) \). Then, information about butchery and consumption marks allowed to distinguish rejected parts during the processing activity \( (V_i = 0) \) from consumed ones.

Therefore, the application of the index of consumption value to the anatomical elements according to animal species and individual has allowed distinguishing between those parts consumed and those rejected for consumption. The distribution is not arbitrary (Fig. 7). Consumption value is concentrated in all the episodes close to the firing area, but also in refuse areas, especially in the southwestern and northwestern areas. Interestingly, in several episodes it is possible to discriminate among waste depositions of high-value consumption remains from depositions of rejects consequence of carcass processing (Fig. 8). In the case of birds, spatial distribution maps show specific areas of rejects, as well as a general pattern: a bimodal accumulation (major \textit{versus} minor value) around firing areas.

![Fig. 7 Spatial distributions maps of earlier Episode A: a) weathering map; b) distribution of residues; c) distribution of high-valued consumed remains; d) distribution of rejects. Fireplace AC10 and proposed limit of the hut displayed.](image)
Fig. 8 Spatial distributions maps of Episode F: a) weathering map; b) distribution of residues; c) distribution of high-valued consumed remains; d) distribution of rejects. Fireplace AC6 and proposed limit of the hut displayed.

4. DISCUSSION

Archaeological sites are mainly the product of anthropic activities. The problem is to separate human component underlying site formation from non-human agencies. It is for this reason that studying processes underlying the formation of archaeological sites (Schiffer, 1972) has become a major concern of archaeologists.

Discussion about site formation processes in the 1980s introduced the concept of palimpsest to denote multiple, temporally sequential depositional episodes, emphasizing the impossibility of dissection of the archaeological record (Bailey, 1981; Binford, 1981; Foley, 1981). Shell middens became a paradigmatic example of archaeological sites with well-preserved evidence where later episodes of deposition variably obliterate the initial configurations of previous deposits. Since then, this concept is being used by different authors as antithetical to the term “living floor”, another key concept adopted from ethnographic research in the 1960s by different authors (Clark, de Lumley; Stekelis: cf. Malinsky-Bullet et al., 2011), and often taken to mean a discrete and undisturbed occupation surface, in which the spatial configurations of remains reflect primarily or exclusively the behaviors of prehistoric groups over a short-duration single episode (as defined in Dibble et al. 1997).

More recently, a less dichotomic view has emerged according to which ‘palimpsests are universal’ (Bailey, 2007: 209) and are central to understanding the archaeological record and
the historicity of the material world (Lucas, 2012: 119). Fundamentally recent discussion asserts that all archaeological deposits are palimpsests, and what varies is their temporal resolution. Bailey’s discussion of the varieties of palimpsest distinguishes between ‘true palimpsest’ (e.g., where all or most of the preceding evidence is removed by cleaning activities), ‘cumulative palimpsests’ (e.g. cave or shell midden deposits) and ‘spatial palimpsest’ (e.g. open-air sites or ‘living floors’). However, the boundary between them is not a sharp one (Bailey; 2007). Indeed, at Túnel VII cleaning activities are detected, providing the opportunity to link the central area with the ring-shaped shell midden, and thus to discriminate among deposits from different discrete occupation periods.

Moreover, the results presented here show clearly that the application of a specific excavation methodology, adapted to a particular type of shell midden (Orquera and Piana, 1992), allow to disentangle the cumulative sequence of the shell midden. The study of the temporal relations between the isolated stratigraphic sub-units (and their archaeological evidence) allowed increasing spatial resolution without a considerable reduction in chronological control. However, the problem of the temporality of the sub-units themselves must to be addressed in future analysis in order to obtain a higher resolution.

The issue of the reconstruction of sequence or order is fundamental to intra-site spatial analysis. The possibility of a random nature of deposition should be demonstrated and explained in any case as a result of entropy introduced by accumulation of random human or taphonomic activity (Mameli et al. 2002). If we assume from the beginning a hazardous or non-structured distribution and if we use a consequent sample technique, then we can hardly discover the hidden organization nor can we demonstrate the actual performance of the sample we have taken.

Therefore, though randomness and variability are expected, human activity is the consequence of organized activities that are carried out by women and men in a particular temporal and spatial sequence (Estévez et al. 1998). The concrete configuration of these production and reproduction tasks has been called “organizational strategies” (Terradas, 2001: 19). It is a concrete “organizational strategy” regulated by social norms what defines every society. Consequently, social activities (temporal and spatial discontinuities) and social relationships (levels of aggregation and disaggregation of human interactions) are reflected in the archaeological materiality. The analytic challenge consists in differentiate discrete levels among the archaeological spatiotemporal structure (Wünsch, 1992). To apply intra-site spatial analysis at Túnel VII shell midden four analysis levels of the archaeological data were proposed: 1) production and 2) consumption processes; 3) refuse-management processes, and 4) sedimentation processes.

The impact of cleaning activities in the spatial arrangement of Túnel VII archaeozoological remains had been previously proposed by means of statistical and geostatistical comparison between bird and otariid remains of first and intermediate occupation episodes (Castillejo, 2007,
2012). Present results support prior identification of a western-refuse area in opposition to an empty-area around the fireplaces, in south-eastern direction.

Refuse-management practices involved the cleaning of the occupation area, either by relocating big-sized consumption-waste in the western area (toss-deposition *sensu* Binford, 1978) mainly of otariid and large seabirds or penguins; or by sweeping the hut area and displacing small-medium-sized consumption-waste against the inner perimeter of the hut. A key issue is that “wall-effect” is difficult to observer because of non-coordination of the smallest remains. In addition, the structure of a Yamana hut was made of branches and thin trunks, and covered with sea-fur hides, moss, leaves or mud, and thus its wall thickness is expected to be largely irregular (Plana and Orquera, 2010).

Nevertheless, the analysis of non-coordinated (small and medium-sized) bone fragments allows reaching a broader perspective of refuse-management processes. Cetacean and bird (mainly small-medium bird) waste remained in the occupation area, or it was relocated to the immediate periphery. Indeed, archaeological work in other yamana sites, as in Lanashuaia (60 km far from Túnel VII), revealed spatial-discrete areas near the hut dedicated to cetacean-processing (Verdún et al., 2015). On the other hand, the inversion of the ratio bird-otariid remains since episode D results in a clearer detection of bird refuse-management patterns, concentrated inside in the inner periphery of the hut area.

Although there is an association among general spatial structure, and resource exploitation or seasonality (e.g. presence of otariid butchery activities), the results also show some general patterns that should be related to spatial and labour social norms. As ethnography documents, location of the entrance/exit of the hut (and therefore paths connecting outside activities with the inner space of the hut) in each episode influences directly on the spatial distribution of consumption waste. Furthermore, small-sized consumption-waste distribution around fireplaces shows a redundant bimodal pattern in almost all the episodes. These results support prior assumptions of archaeozoological analysis about a differential exploitation of bird anatomy (Mameli, 2004; Tivoli, 2010, 2014). Regarding production and consumption processes, a differential discard pattern of anatomical parts is observed in the case of birds and otariids, although there is a similar distribution of the most valued parts in terms of meat yield.

Therefore, graph theory and spatial distribution maps, in combination with a more detailed analysis of zooarchaeological data, have allowed to clarify site site-formation processes of Túnel VII. However, the results presented in this paper have to be contrasted with an integrated analysis of lithic and bone technology remains in order to analyse the overall distribution of by-products from production and consumption activities. Moreover, results concerning the structure of spatial data point to the need of test spatial interpolation methods designed to overcome the geostatistical restriction on the homogeneity of the surface. Geostatistical research with ethnoarchaeological case studies is presenting promising results in this respect (e.g. Negre et al., 2016). In any case, at this point of the research, results support preliminary assumptions
about spatial distribution in Túnel VII of lithic and bone manufacture activities (Estévez and Clemente, 2013), plant resources (Zurro et al., 2009) or fish remains (Juan Muns, 1992). Furthermore, results are consistent with those of nearby Yamana sites (Álvarez et al., 2013; Britz et al. 2013; Negre et al. 2015; Verdún et al. 2015; Zurro et al. 2017).

5. CONCLUSIONS

This ethnoarchaeological study offers new elements for discussing and opening new perspectives into intra-site spatial analysis and the implications for understanding the social use and management of space in Hunter-Gatherer societies, especially in shell midden deposits, which show a complex pre- and post-depositional history.

The ethnoarchaeological approach adopted at the beginning of the investigation aimed to build a middle range theory of social norms. Considering the materialization of social activity (i.e. social relationships) into the spatial distribution of production and consumption by-products, we tested the possibility of reaching the normative system of a society by means of an archaeological methodology. As previously discussed, results are encouraging.

Indeed, results show a general correspondence of the archaeological record of Túnel VII with the ethnographic descriptions of the Yamana groups. First, the circular arrangement of the dwelling and the settlement pattern, characterized by a high-mobility system and reoccupation of abandoned huts in the shorelines of the Beagle Channel. Second, the existence of refuse-management activity based on the existence of ‘clean’ areas versus refusal and waste areas. Third, the identification of several different activities that ethnography reports as performed inside the hut like preparation and consumption of food resources (whale blubber, shell food, fish, marine mammals or birds) or tool and weapon making (Estévez and Clemente, 2013); and outside the hut, as primary processing of animal carcasses (ostensibly of the largest marine mammals hunted). Moreover, ethnographers described the existence of a strict sexual division of labour in Yamana society, not only in resource-exploitation activities but in the organization of almost all daily activities (Gusinde, 1937; Hyades and Deniker, 1891; see a synthesis in Vila et al., 2010). Interestingly, this sexual division was translated also to the space: for example, men butchered marine mammals outside the hut, women butchered birds inside the hut. Although the archaeological record reveals a greater flexibility and variability than the ethnographic one, for example regarding the exploitation of resources (Mameli et al. 2005) or lithic tools production (Terradas, 2001), the essential social relationships are observable in the spatial distribution of Túnel VII. Future and more detailed analysis may reveal also patterns of differential consumption between social agents, as incipient results seem to indicate.

In this perspective, we advocate for a further increase in the use of social categories built from the analysis of the archaeological record, rather than archaeological categories derived from the description of remains. This is relevant to Mesolithic research in different ways. On the one hand, discussion about percentages in marine proteins consumed may have varied considering the size of the social unit, or the temporal extent of the occupation. Thus, obtaining a better
understanding the scale and the resolution of Mesolithic sites, and especially of Mesolithic shell middens, is necessary to discriminate among economic intensification of littoral resources, and changes in demographic pressure, mobility frequency or settlement patterns. On the other hand, and compared with Upper Palaeolithic sites, Mesolithic sites are smaller, with more hearths and/or more successive campsites, and spatial features seem vaguer (Rozoy, 1999). Differences could be explained in terms of redefinition of social relationships within and between social units. In this sense, the emergence of social inequalities regarding sexual division of labour has been suggested based on ethnographic analogies and Hunter-Gatherer theory (e.g. Estévez et al. 1998). However, much work is still required to test such hypotheses. Comparative studies about the use of space by different societies might allow us to build strong interpretative models to be applied at Hunter-Gatherer prehistoric sites.

Acknowledgements

We would like to thank David Cuenca, Igor Gutiérrez and Gregor Marchand for inviting us to participate in this special volume. This paper was presented in EAA (2016) in Vilnius, Lithuania. The authors would like to thank two anonymous reviewers for their help and comments. This paper was developed within the PhD research project of “Aproximación arqueológica al mantenimiento y la transmisión de las normas sociales en sociedades cazadoras-pescadoras-recolectoras” (2014FI_B916), funded by Catalonian Government, and was performed in the framework of research team AGREST (2014SGR1169).

References


Bicho, N., Umbelino, C., Detry, C., Pereira, T., 2010. The emergence of Mesolithic shellmiddens (central Portugal) and the 8200 cal yr BP cold event. Journal of Island and Coastal Archaeology. 5, 89-104.


Pedraza Marín, D., 2013. Las ceremonias y el mundo simbólico en la producción y reproducción socioculturales de las sociedades Yámana y Selk’nam de Tierra del Fuego. Revista Atlántica-Mediterránea de Prehistoria y Arqueología Social. 15, 141-164.


