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Application of biometric analyses on shell middens of hunter-fisher-gatherer societies of Tierra del Fuego (Argentina)

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ABSTRACT: The application of biometric analysis to archaeomalacological remains provides information about the management of coastal resources implemented by past societies. This paper presents the results obtained from applying biometric analyses to the archaeomalacological remains of the most abundant species recovered in the shell middens Túnel VII and Lanashuaia (Tierra del Fuego, Argentina): *Mytilus edulis*, *Nacella deaurata* and *Nacella magellanica*. These sites, which are related to an indigenous hunter-fisher-gatherer society (yamana), are located on the north coast of the Beagle Channel and belong to the period of European contact (end of 18th century-beginning of 19th century). These preliminary results of the biometric analyses suggest the existence of management patterns of the littoral resources.

KEYWORDS: SHELL MIDDENS, TIERRA DEL FUEGO, BIOMETRY, COASTAL RESOURCES MANAGEMENT

RESUMEN: La aplicación de análisis biométricos en restos arqueomalacológicos permite obtener información sobre el tipo de gestión implementada por las sociedades del pasado sobre los recursos litorales. En este trabajo se presentan los resultados obtenidos a partir de la aplicación de estos análisis a los restos arqueomalacológicos de las especies mayoritarias que componen los concheros Túnel VII y Lanashuaia (Tierra del Fuego, Argentina): *Mytilus edulis, Nacella deaurata y Nacella magellanica*. Estos yacimientos, que se relacionan con la sociedad indígena cazadora-recolectora-pescadora yámana, se encuentran en la costa norte del Canal Beagle y cronológicamente pertenecen a la época de contacto con los europeos (finales del s. XVIII-inicios del s. XIX). Los resultados preliminares obtenidos de los análisis biométricos sugieren la existencia de patrones de gestión de los recursos litorales.

PALABRAS CLAVE: CONCHEROS, TIERRA DEL FUEGO, BIOMETRÍA, GESTIÓN DE RECURSOS COSTEROS

INTRODUCTION

The Beagle Channel coast (in the southern part of South America), is a very particular place, because of the large amount of archaeological sites, which can be easily recognized along the beaches' relief (Figure 1). The majority of these sites are shell middens and present a similar structure: an annular rim surrounding a central excavated depression of 3-4m in diameter (Piana & Orquera, 2010; Orquera *et al*., 2011). The hut was located in the depression and a skirting rim surrounding it has been built as a result of the intentional accumulation of residues (Verdún-Castelló, 2010). Usually these sites were occupied several times, taking advantage of the previous structure. During the re-occupation the size of the skirting rim was increased as a protection against the wind (Verdún-Castelló, 2010; Orquera *et al*., 2011).

When European sailors and settlers arrived in the 19th century, indigenous groups of people, the yamana, were living in the area. One of the results of this contact between Europeans and indigenous people was the creation of a rich corpus of ethnographic information (chronicles, graphs, photographs…) about the yamana (e.g. Hyades & Deniker, 1891; Bridges, 1975 [1948]; Gusinde, 1986 [1937]).

The yamana were a hunter-fisher-gatherer society with a high level of consumption of coastal resources. They inhabited the coastal area from the Fuegian Channels in the north to the Cape Horn in the south and their economic system implied a high mobility within this entire area. Therefore the use of canoes was pivotal for the socio-economical relationships of these people.

The consumption of littoral resources was documented from 6400 BP in Túnel I and Imiwaia I sites (Orquera & Piana, 1999a, 2009) to the arrival of the European people in the 18th and 19th centuries. The consequence of the huge consumption of molluscs was the formation of a big amount of

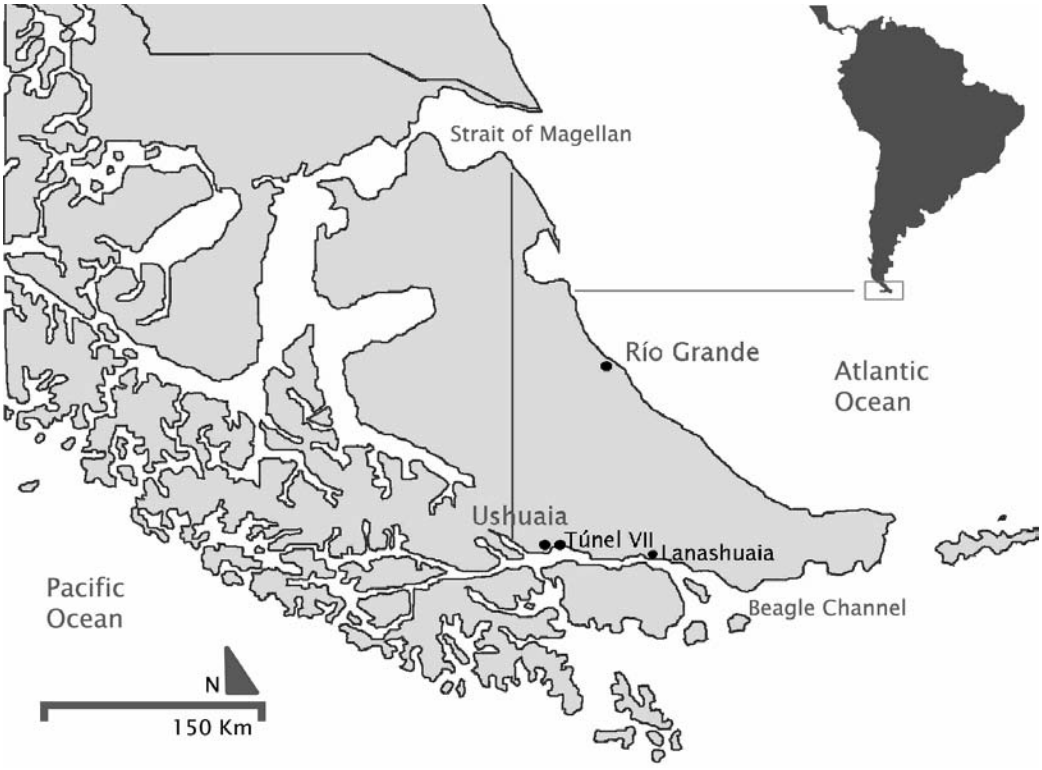

FIGURE 1

Map of the sites Túnel VII and Lanashuaia in the Beagle Channel.

shell middens along the Channel coasts. The economic system of this hunter-fisher-gatherer group was maintained without big changes during all the occupation period. However, some variations in the management of the resources have been documented (Álvarez & Briz, 2004; Tívoli & Zangrando, 2011).

Molluscs seem to be a daily and very common resource among this community. Some ethnographic testimonies highlight their role in the diet and in the daily life (e.g. Lovisato, 1884; Hyades, 1885; Gusinde, 1986).

However, there are still some questions that should be answered to understand the real importance of marine resources in the social organization of the yamana groups. One of the main open problems is to understand whether yamana people implemented some sort of management system to this coastal resource in order to avoid the depletion of the shell beds, since the consumption of large amount of molluscs has been documented in shell middens from a long time (Orquera & Piana, 2001).

As biometric studies on shells testify, the variance of the size of the consumed molluscs gives information about the impact on littoral resources by human societies. The decrease in mollusc size could be related to the intensive anthropic exploitation of the shell beds (e.g. Mannino & Thomas, 2001; Milner *et al*., 2007; Erlandson *et al*., 2008; Álvarez-Fernández *et al*., 2011). However, in order to pinpoint the anthropic impact, it is necessary to discriminate the changes in the mollusc population caused by environmental conditions (Campbell, 2008; Gutiérrez Zugasti, 2011).

ENVIRONMENTAL SETTING

The extreme climatic and geographic conditions of the area restricted the availability of resources and conditioned the social organization of the groups who lived there. The climate is cold and wet with a constant presence of wind (especially from SW). The average annual temperature is 5.3ºC. It ranges from 9ºC in summer to 1ºC in winter; however, the constant wind increases the chill factor. The rain is also constant and homogeneous along the year, with an annual average of 530 mm (Iturraspe & Schroeder, 1999; Orquera & Piana, 1999b).

The solar radiation varies in relation to the season: in summer sunlight can last up to 18 hours a day while in contrast with winter when the average sunlight is only 7 hours (Iturraspe & Schroeder, *op. cit*.; Orquera & Piana, *op. cit*.).

The vegetation is composed mainly by species of the genus *Nothofagus* (Orquera & Piana, 1999b; Piqué, 1999). Marine resources that can be found nowadays in Isla Grande include fish, molluscs, pinnipeds and cetaceans. Among terrestrial animals there are foxes, guanacos and some rodents (mainly coming from the north of the Island). The avifauna is also very rich in the area (Massoia & Chebez, 1993; Tívoli & Zangrando, 2011).

STUDY AREA

The archaeomalacological remains analysed in this study were recovered from two archaeological sites from the north coast of the Beagle Channel: Túnel VII and Lanashuaia. The sites are 60 km away from each other (Figure 1). Both sites present similar characteristics: they are shell middens with an annular rim about 3-4 m of diameter surrounding a central depression (Piana & Orquera, 2010). They have been dated to the arrival of the first European settlers (18^{th}-19^{th} centuries) (Piana & Orquera, 1995; Piana *et al*., 2000).

Túnel VII is composed by 10 successive occupation events, produced in different seasonal moments (Figure 2). Dendrochronological data have placed the occupation events between the end of the 18^{th} and the end of the 19^{th} century (Estévez & Vila, 2006). The different occupation events are registered on the basis of the existence of discontinuity layers (composed by sediment) which reflect non-occupation events. They are recognized mainly in the hearths (*op. cit*.).

In Lanashuaia, no discontinuity layers were identified. This led the researchers to conclude that probably the site was produced by a single occupation event related to the consumption of a stranded whale (Figure 2) (Piana *et al*., 2000; Briz *et al*., 2009).

Both sites have a similar formation process. The stratigraphy of the shell middens in the Beagle Channel is composed by groups of stratigraphic layers (subunities) which form the *Occupation Episodes*. They are the «*minimal unities of stratigraphical deposition*» that can be isolated, form-

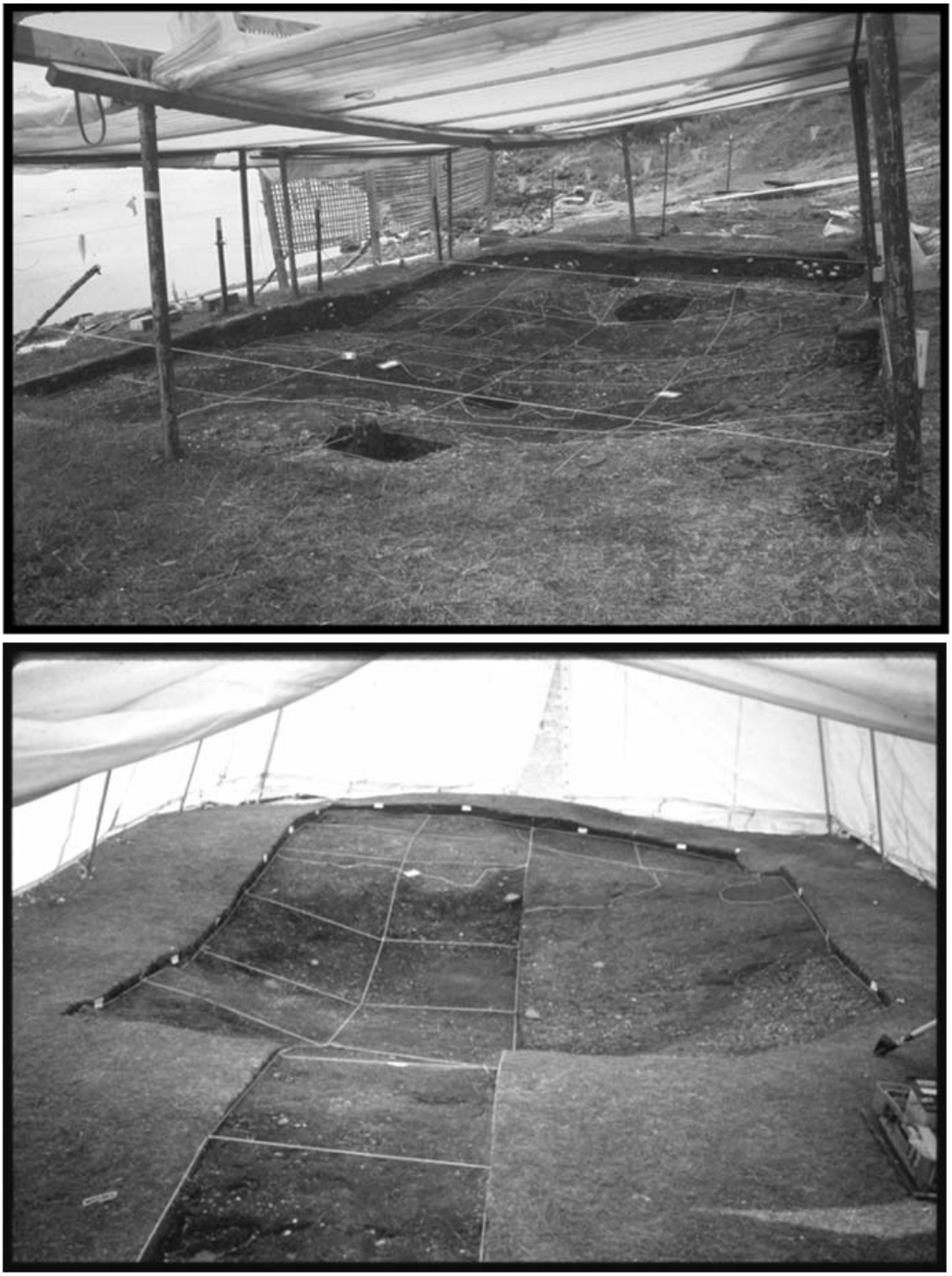

FIGURE 2

Túnel VII (above) and Lanashuaia (below) sites during the excavation process. Circular structures composed mainly by shells can be observed.

ing the *microstratigraphy* of the site (Orquera & Piana, 1992: 28). The differentiation among them is achieved through the identification of stratigraphic layers (compact layers, discontinuities on the sedimentary structure, etc.) and by the recognition of variances in some aspects of the deposit (*op. cit.*). Each subunit represents a concrete period of time (a single moment or a long period of continuous deposition).

MATERIALS AND METHODS

The archaeomalacological samples were obtained from each subunit identified during the excavation. This allowed generating a detailed and complete record of the composition of malacological assemblages at the sites.

In order to study the archaeomalacological remains of the shell middens, a sampling strategy was applied. A sedimentary sample of 4 dm^3 of each subunit was selected. Each sample represents the composition of a whole layer (Orquera & Piana, 2000). The mollusc remains were sorted out at the Laboratory of Archaeozoology of the Universitat Autònoma de Barcelona (Spain).

To quantify the MNI, the non-repetitive elements of the shells were considered, following and adjusting Moreno's (1994) and Gutiérrez Zugasti (2009) methodology: the apices, columella areas and the last whorl/aperture were considered for whelks; the apices and the whole basal rings, for limpets and the umbos and the whole margin areas, for bivalves. The largest value of each species in each layer was accepted as MNI.

The taxonomic identification was done following the information obtained from Otaegui, (1974), Ageitos de Castellanos & Landoni (1993), Gordillo (1995), Forcelli (2000), Aldea & Valdovinos (2005) and Valdovinos & Rüth (2005).

During the excavation process the total volume of each subunit was registered. This permitted the calculation of the total amount of molluscs that composed each subunit.

The biometrical data were obtained from the individuals recovered in these samples. Even though all the individuals were measured, only the most abundant taxa were exhaustively analyzed for both sites: the mussel *Mytilus edulis* Lamarck 1819, and the limpets *Nacella deaurata* (Gmelin 1791) and *Nacella magellanica* (Gmelin 1791).

The measurements taken in limpets were: maximum length (L) (maximum diameter) and maximum width (W). In relation to mussels, the measurements taken were the maximum height (H) (from the margin to the umbo) and the maximum width (W). A digital vernier callipers with accuracy to 0.01mm was used for taking measurements. However, in order to make biometrical inferences we considered only the length in limpets and the height in mussels. Moreover, to avoid repetitions in the bivalves only data from the most abundant side (right or left valve) from each stratigraphic subunit of each occupation period was considered.

The archaeological data were compared with measurements from modern individuals collected on the shores in front of each site. In Túnel VII the modern limpet (*N. deaurata* and *N. magellanica*) specimens were collected on October 2005, December 2005 and April 2006. The modern mussels (*Mytilus edulis*) samples were collected on December 2005. In Lanashuaia the limpet samples were collected in the outer Cambaceres Bay on December 2005 and the mussels were obtained from the inner and outer Cambaceres Bays on December 2005 and January 2006. Nowadays in the Beagle Channel the consumption of mussels is not allowed because of the presence of red tide (algal bloom), which implies that these populations are not affected by anthropic pressure.

Statistical tests were applied to the data using PAST 1.92 (Hammer *et al*., 2001): the Shapiro-Wilk test for normality, the one-way ANOVA analysis of variance for parametric data or the Kruskal-Wallis test for non-parametric data.

It should be noted that due to the high degree of fragmentation in both sites (more than 90% of the recovered individuals were broken) the number of measured shells is not abundant.

RESULTS

1. TÚNEL VII

In Túnel VII the molluscs coming from three occupation periods (B, C and D) have been quantified. Occupation phase B presented a MNI of 15,508. In the occupation phase C the presence of 11,876 molluscs has been estimated and in the occupation phase D, 68,164 individuals were counted. In all occupation events the taxonomical composition was similar: mussels (*Mytilus edulis*)

represented almost 90% of the molluscs of the site. Limpets (*Nacella deaurata* and *Nacella magellanica*) represented an amount between 2% and 7% of the individuals of each occupation event and the third taxon in order of importance, was whelks (*Trophon geversianus*, *Xymenopsis muriciformis* and *Acanthina monodon*) (Table 1). Measurements however, were obtained from individuals from every occupation period of the site (B, D, E, F, G, H, J, where B is the oldest and J the most recent).

1.1. *Nacella deaurata* and *Nacella magellanica*

The average size recorded of each species considering the whole site Túnel VII, is 32.7±6.1 mm in length (L) and 23.4±4.6 mm in width (W) for *Nacella deaurata*. For *Nacella magellanica* the average size is 32.2±5.8 mm (L) and 25±4.5 mm (W). In both species the sizes recorded are very similar. In order to recognize variations in the results we considered the length data and they are normally distributed for both species ($p>0.05$) (Table 2).

Due to the high degree of fragmentation, few individuals of *Nacella magellanica* could be measured. In this sense, *Nacella deaurata* offers more confident results because of the higher sample size (Figure 3).

Analysis of variance (one-way ANOVA) was applied to *N. deaurata* length data (occupation B was excluded because of the small sample size). No significant variations were documented between them (p (same) = 0.2468 >0.05).

In relation to *N. magellanica*, since the data of occupation J were not normally distributed, Kruskal-Wallis non-parametric test was applied to the occupations with more specimens (D, H, J). No significant differences were recorded between the different phases (p (same) = 0.9206>0.05).

In general terms though, both species present similar results and there are not statistically significant differences between them (one-way ANOVA p (same) = 0.5911>0.05). Most of the limpets in

Taxa	Túnel VII						Lanashuaia	
	Occupation B		Occupation C		Occupation D			
	MNI	%	MNI	%	MNI	%	MNI	%
Limpets (*Fissurella* sp.; *Nacella deaurata*, *Nacella magellanica*)	638	4.1	202	1.7	4,584	6.7	29,852	8.6
Whelks (*Trophon geversianus*, *Trophon* sp., *Xymenopsis muriciformis*, *Xymenopsis* sp., *Acanthina monodon*)	574	3.7	504	4.2	1,604	2.4	3,271	1
Mussels (*Mytilus edulis*, *Aulacomya atra*, *Brachidontes purpuratus*)	14,241	91.8	10,968	92.4	60,888	89.3	258,849	75
Poliplacophora (*Plaxiphora aurata*, *Tonicia chilensis*, Ischnochitonina)	-	-	101	0.9	577	0.9	12,457	3.6
Others	55	0.4	101	0.8	511	0.7	40,736	11.8

TABLE 1

MNI and frequencies of mollusc composition of Túnel VII and Lanashuaia sites.

Gastropoda

	N. deaurata		*N. magellanica*	
TÚNEL VII	**L**	**W**	**L**	**W**
B	29.3	21.1	33.1	26.6
	N=1	N=1	N=1	N=1
D	33.7±5.6	24±4.4	32.7±5.7	25.5±4.8
	N=20	N=19	N=12	N=13
	S-W p=0.328	S-W p= 0.2155	S-W p=0.4063	S-W p=0.3726
E	29±6.5	20.3±5.3	32±1	25.6±0.6
	N=10	N=9	N=2	N=2
	S-W p=0.5635	S-W p=0.7769		
F	31.4±5.2	22.4±3.8	24.4±6.6	19.8±5.2
	N=24	N=24	N=5	N=5
	S-W p=0.4751	S-W p=0.1363		
G	32.8±5.9	22.9±4.8	32.3±4	25±2.5
	N=11	N=11	N=8	N=8
	S-W p=0.4579	S-W p=0.2129		
H	33.7±7.5	24.3±5.4	33.4±5.8	25.4±4.8
	N=30	N=31	N=15	N=15
	S-W p=0.2419	S-W p=0.1275	S-W p=0.9423	S-W p=0.9893
J	33.7±4.9	24.4±3.3	33.2±5.6	25.7±4.6
	N=20	N=21	N=12	N=16
	S-W p=0.3259	S-W p=0.3428	S-W p=0.001559	S-W p=0.2077
Total	32.7±6.1	23.4±4.6	32.2±5.8	25±4.5
	N=116	N=116	N=55	N=60
	S-W p=0.178	S-W p=0.1428	S-W p=0.1359	S-W p=0.2772
LANASHUAIA	37.9±7.4	28.8±5.8	41.9±8.4	31.7±5.9
	N=39	N=61	N=67	N=76
	S-W p=0.09737	S-W p=0.1739	S-W p=0.09746	S-W p=0.09288

TABLE 2

Average size of *Nacella deaurata* and *Nacella magellanica* of each occupation event in Túnel VII and Lanashuaia sites (N=Number of measured specimens; L=length; W=width; S-W= Shapiro-Wilk normality test probability).

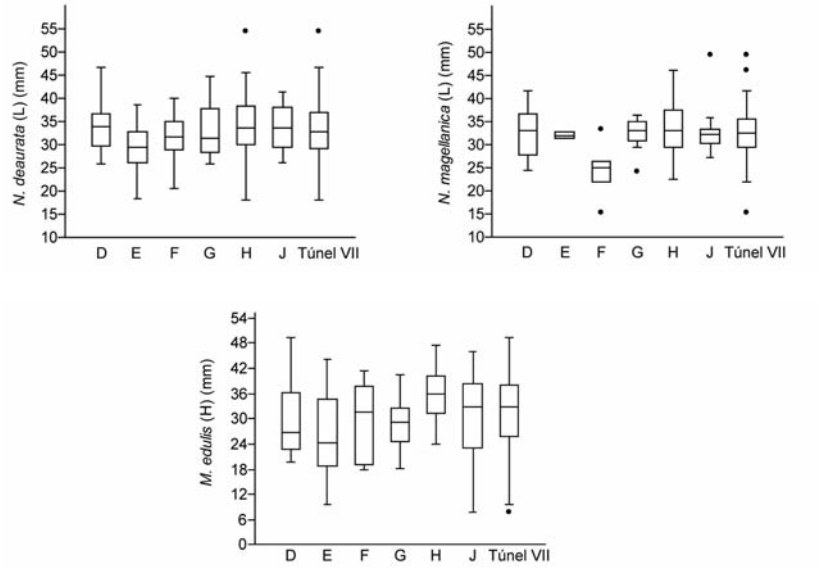

FIGURE 3

Box plot of *Nacella deaurata* and *Nacella magellanica* length and *Mytilus edulis* height of Túnel VII site in each occupation period and together (Túnel VII).

Túnel VII have length comprised between 28 and 35 mm (Figure 4) and no individuals smaller than 15 mm in length have been recorded.

The modern individuals collected in the shore in front of the site reached an average size of c. 40 mm in length. This means that in general, modern limpets are c. 10 mm longer than archaeological limpets from Túnel VII (Table 3).

Analyses of variance showed that significant differences exist between the sizes of archaeological specimens of both species and modern individuals from the same shores: *N. deaurata* (one-way ANOVA p (same) = 5.052E-05<0.05); *N. magellanica* (Kruskal-Wallis p (same) = 9.577E-17<0.05).

1.2. *Mytilus edulis*

Mytilus edulis is the most abundant species in the intertidal area of Tierra del Fuego (Ríos & Mutschke, 1999; Aldea & Rosenfeld, 2011). It is also the most abundant mollusc in the Beagle Channel's shell middens: this species represent c. 90% of the consumed molluscs.

Due to the high fragmentation degree (more than 95% of the individuals are broken); just a few individuals could be measured. The average size of the mussels documented in the entire Túnel VII site is 31.5±9 mm in height (H) and 17±4.9 mm in width (W). The data are normally distributed (p>0.05) (Table 4).

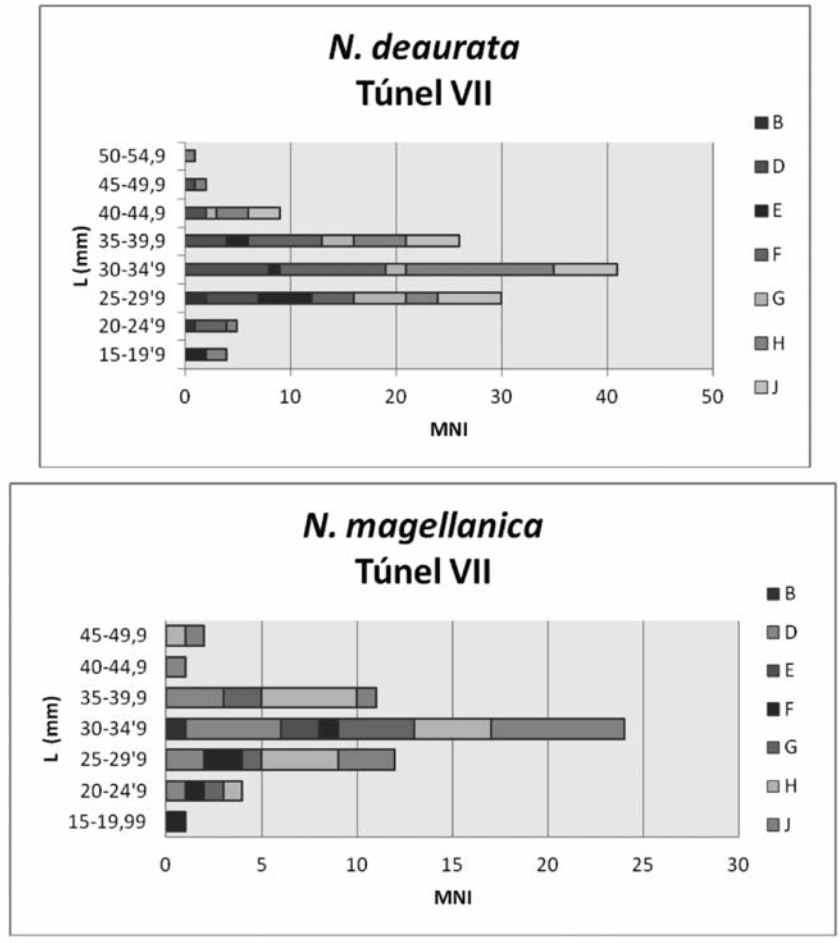

FIGURE 4

Composition and distribution of limpets (*N. deaurata* and *N. magellanica*) in each occupation event in Túnel VII site.

Gastropoda	Collecting area	Date	N	L	W
Nacella deaurata	Estancia Túnel	30/10/2005	2	39,8±6,3	28,3±4,9
		14/12/2005	5	39,0±2,5	29,1±1,1
		30/04/2006	3	45,2±4,2	33,0±2,9
		total	10	41,0±4,4	30,1±3,0
	Outer Cambaceres Bay	09/12/2005	17	43,3±4,4	33,2±3,6
Nacella magellanica	Estancia Túnel	30/10/2005	37	37,9±5,5	31,9±5,0
		14/12/2005	34	44,8±6,2	37,6±5,7
		30/04/2006	42	46,1±5,2	38,0±4,4
		total	113	43,0±6,6	35,9±5,7
	Outer Cambaceres Bay	09/12/2005	22	50,2±8,9	41,0±6,5

Bivalvia	Collecting area	Date	N	H	W
Mytilus edulis	Estancia Túnel	14/12/2005	51	55,0±5,8	28,4±3,2
	Inner Cambaceres Bay	09/12/2005	48	63,5±11,0	30,4±5,0
		08/01/2006	39	52,9±5,6	26,6±2,8
		total	87	58,7±10,4	28,7±4,5
	Outer Cambaceres Bay	09/12/2005	56	55,2±14,8	29,3±7,1
		08/01/2006	30	45,9±9,0	26,2±3,9
		total	86	51,9±13,8	27,5±6,6
	Cambaceres Bay (inner and outer)	total	173	55,4±12,6	28,1±5,7

TABLE 3

Modern individuals collecting areas and sizes.

Bivalvia		
	Mytilus edulis	
TÚNEL VII	H	W
B	28.2	15.9
	N=1	N=1
D	29.7±9.3	17.5±5
	N=10	N=10
	S-W p=0.2343	S-W p=0.08235
E	25.8±12.4	12.3±4.5
	N=6	N=5
F	29±9.7	16.5±4.7
	N=7	N=6
G	28.8±6.8	14.5±5.4
	N=8	N=7
H	35.8±6.5	18.7±4
	N=26	N=25
	S-W p=0.803	S-W p=0.6295
J	30.2±10.9	16.6±5.9
	N=12	N=10
	S-W p=0.5277	S-W p=0.359
Total	31.5±9	17±4.9
	N=70	N=64
	S-W p=0.4444	S-W p=0.4016
LANASHUAIA	35.3±7	20.1±3.7
	N=97	N=105
	S-W p=0.0005847	S-W p=6.716E6

TABLE 4

Average measurements of *Mytilus edulis* obtained from each occupation event in Túnel VII and Lanashuaia sites (N= number of measured individuals; H= height; W= width; S-W= Shapiro-Wilk normality test probability).

One-way ANOVA test was applied to the height data of D, H, J occupation events. The occupation B has been excluded because of the low number of measurable individuals. Even though the test did not show a statistically significant difference (p (same) = 0.06643>0.05) the p value is very low, which is probably due to the small sample size.

In general, in all occupation events the average height is c. 30 mm. However, occupation E presents the smaller sizes, as well as in limpets, with 25.8±12.4 mm of average height. On the other extreme, occupation H has the largest sizes, which reach an average height of 35.8±6.5 mm. It must also be noted that there are some small individuals, shorter than 15 mm in height. The size of the most of the mussels recorded in Túnel VII ranged from 25 mm to 40 mm (Figure 5).

Comparing archaeological data and modern individuals, it is clear that the archaeological mussels are smaller than the modern ones. The average height of modern individuals is 55±5.8 mm, much larger that the size of the archaeological material recorded in Túnel VII (31.5±9 mm) (Table 3). The non-parametric Kruskal-Wallis test show that there are statistically significant variation between archaeological and modern sizes (p (same) = 1.495E-15<0.05).

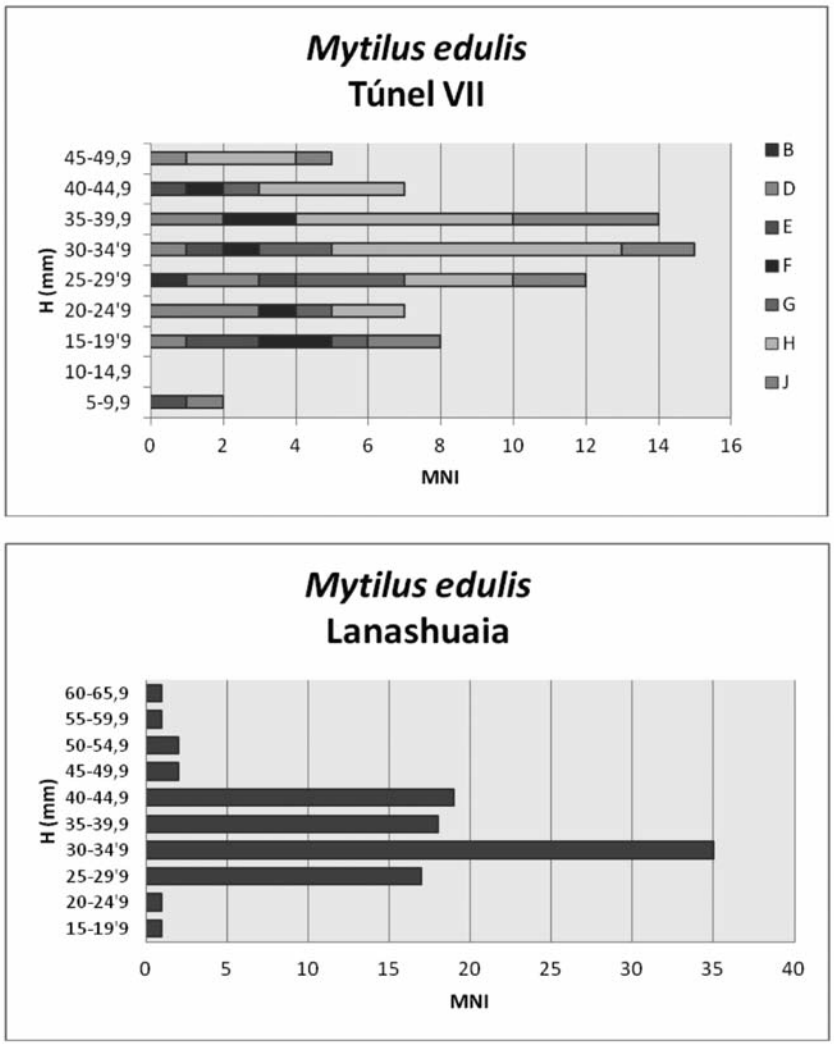

FIGURE 5
Composition and distribution of *Mytilus edulis* in each occupation event in Túnel VII and Lanashuaia sites.

2. LANASHUAIA

The MNI estimated at the site was 345,165 individuals. The taxonomical composition of the site is very similar to other archaeological shell middens in the Beagle Channel (Orquera & Piana, 2001). The most important taxa are *Mytilus edulis* (73.8%), limpets (*Fissurella* sp., *Nacella deaurata, Nacella magellanica*) (8.7%) and chitons (3.6%) (Table 1). Since the site is composed by a single occupation event, it was analysed as a whole.

2.1. *Nacella deaurata* and *Nacella magellanica*

The average size documented for *Nacella deaurata* is 37.9±7.4 mm in length and 28.8±5.8 mm in width. *Nacella magellanica* reached 41.9±8.4 mm in length and 31.7±5.9 mm in width (Table 2).

Statistical normality test Shapiro-Wilk was applied to the length data and it shows that *N. deaurata* data are not normally distributed, but it is not conclusive because p value is very low (p=0.09737>0.05). The data of *N. magellanica* are normally distributed (p=0.9746>0.05) (Table 2).

N. deaurata individuals are, in general, smaller than *N. magellanica*. However, it should be noted that individuals smaller than 25 mm in length are not present and that most of the limpets have a size between 30 and 50 mm in length.

Comparing the archaeological data to actual size of modern specimens obtained in the beach surrounding the site, it can be observed that in both species the modern limpets are larger than the archaeological ones (Table 3, Figure 6). The mean length size (L) documented for modern individuals is c. 40 mm for *N. deaurata* and c. 50 mm for *N. magellanica*. The difference between the archaeological and the modern individuals for *N. deaurata* is c. 5 mm. For *N. magellanica*, which is located in the upper intertidal area, the difference is larger. The modern specimens are c. 10 mm larger than the archaeological specimens. The same variation was detected in Túnel VII site.

The non-parametric test Kruskal-Wallis shows that exists significant variations between archaeological and modern population in both species: *N. deaurata* (p (same) = 0.005291<0.05); *N. magellanica* (p (same) = 0.0003126<0.05).

2.2. *Mytilus edulis*

The average height recorded in the site is 35.3±7 mm (Table 4) and most of the individuals have sizes comprised between 25 mm and 40 mm. It also has to be highlighted that no individuals smaller than 20 mm in height have been registered (Figure 5).

The comparison between the archaeological and modern molluscs shows that the modern individuals are significantly larger than the archaeological ones (Table 3, Figure 5). The Kruskal-Wallis test reveals that significant differences exist between the two populations (p (same) = 1.639E-28<0.05). The average height of the modern individuals is 55.4±12.6 mm. Many individuals from the inner and outer Cambaceres bays can easily

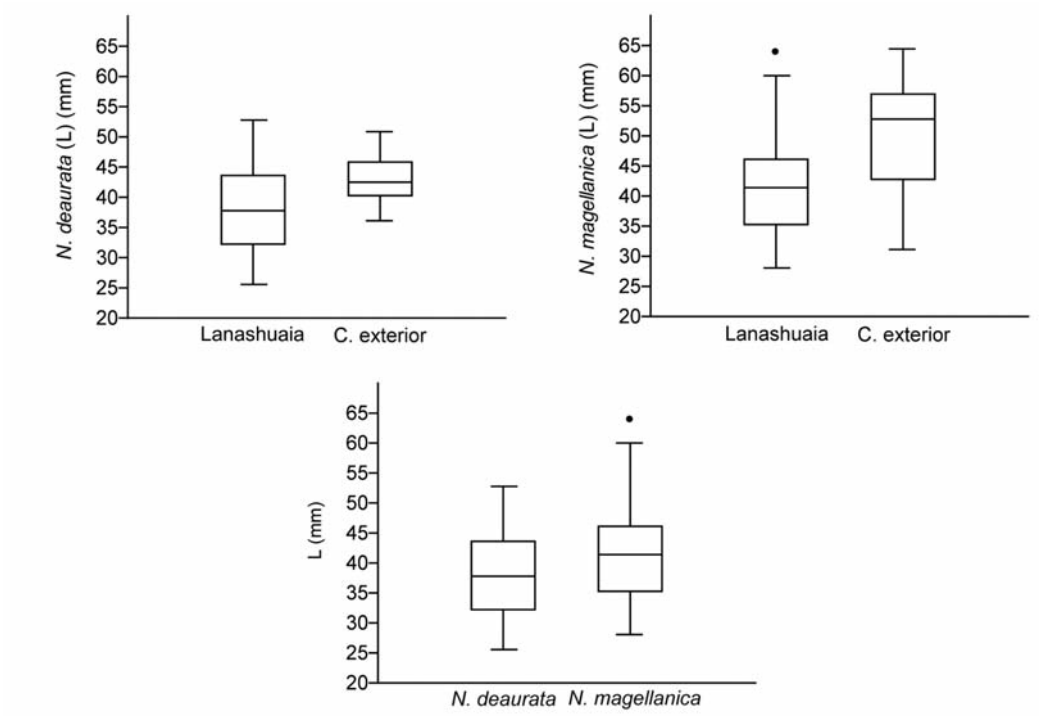

FIGURE 6

Left: Comparison between *Nacella deaurata* and *Nacella magellanica* length of Lanashuaia archaeological individuals and modern individuals obtained in outer Cambaceres Bay (C. exterior). Right: Box plot of *Nacella deaurata* and *Nacella magellanica* length data of Lanashuaia site.

reach sizes larger than 50 mm. The difference between the modern and the archaeological specimens can be c. 20 mm.

DISCUSSION

The predominant species at the sites of Túnel VII and Lanashuaia are mussels (*Mytilus edulis*) and limpets (*Nacella deaurata* and *Nacella magellanica*), as it also happens in the most of shell middens in the Beagle Channel (Orquera & Piana, 2000, 2001). These species, as well as other species recorded at both sites, inhabit in the rocky intertidal areas. This shows a predominant exploitation of these zones.

Biometric analyses were performed on these species, since the most abundant taxa are the best to reflect the management implemented on them. Even though the sample size is small it allowed reaching preliminary but significant results.

Túnel VII is composed by 10 occupation events. The results show a recurrence in the size of the consumed molluscs in the biometric record obtained from both limpets and mussels. In all the Occupation Events, the size of the limpets is c. 30 mm and the two limpet species present similar sizes.

It should be noted that both species inhabit different intertidal zones (*N. deaurata* lives in the lower intertidal zone and *N. magellanica,* in the middle and upper intertidal zone) (Morriconi, 1999, 2005). Therefore, the recording of the same sizes in both species suggests that the degree of exploitation of resources would be similar across the intertidal gradient.

The size of the mussels presents also a recurrence along the occupation sequence. They present an average height of c. 30 mm. The repetition in the size of the molluscs from the different occupation events of Túnel VII, could be indicative of the management implemented on these resources, since smaller sizes are under-represented and there are not large individuals.

The low presence of smaller individuals (<20mm in limpets) could suggest a selection of the larger individuals, leaving the smaller for a later consumption. Limpets are collected by hand one-by-one, which easily allows the selection of preferred sizes. For *Mytilus edulis*, some small individuals (<20mm) have been documented. In this case, they are collected in clumps where they could be picked unintentionally, together with the bigger ones.

Compared to the modern specimens obtained from the same area where the sites are located, the archaeological molluscs are significantly smaller in both species. This fact together with the recording of similar sizes along the sequence, suggests an intensive exploitation of these resources.

Lanashuaia is probably composed by only one occupation event. The biometric data show similar results than Túnel VII. Most of the measured individuals (both limpets and mussels) present similar sizes that range from 30 mm to 45 mm in length and height respectively. Following the same trend observed in Túnel VII, the presence of small individuals (<20 mm) has not been documented.

The comparison with modern specimens also shows significant differences between the archaeological and the modern individuals. The data offered by the measured limpets (*Nacella deaurata* and *Nacella magellanica*) indicate a decrease in the sizes. However, the mussels show a higher difference which would represent a diminution between 32% and 40% of the sizes.

The recurrence in the sizes in all the occupation events in Túnel VII and in Lanashuaia would probably reflect the sizes of the molluscs used for consumption. Preliminary biometric data of other sites from the Beagle Channel corresponding to different chronologies (from 5,800 BP to 100 BP) show length averages in Patellidae that ranges from 19 mm to 45 mm (Orquera & Piana, 2000, 2001). Mussels (Mytilidae) height ranges mostly from 32 mm to 40 mm. Only two sites have larger averages, Imiwaia I (5,800 BP) and Shamakush X (500 BP) (*op. cit.*), while most of the sites present similar averages than the documented in Túnel VII and Lanashuaia.

The differences in the sizes are not directly related to the chronology of the sites. This could suggest that the sizes of the molluscs obtained at each site are not a consequence of the chronological variations and possible changes in the climatic conditions but to a similar resource management. The comparison with modern biometric data from specimens collected in the shores in front of the two sites prove that, in natural conditions, limpets and mussels can reach between 10 mm-20 mm more.

The ethological and biological studies about the composition and distribution of these species in

the Beagle Channel shores are scarce. In sheltered areas in the Beagle Channel as Lapataia Bay and Chica Bay a maximum length of 52 mm for *N. magellanica* was recorded. In exposed areas as Occidental Point and Conejo Island a maximum length of 71 mm was recorded (Morriconi, 2005). For *N. deaurata* a maximum length of 65 mm in exposed and sheltered zones was recorded (*op. cit.*). These variations are a response to the different exposure grade of the shores as a protection against the desiccation and the detachment (caused by the strong wave action) (Morriconi & Calvo, 1993; Morriconi, *op. cit.*). This data agree with the sizes recorded for the modern individuals recovered in front of the sites, which could be considered as sheltered (following Morriconi's description).

Although *Mytilus edulis* is the most abundant mollusc in the intertidal area along the Tierra del Fuego coasts (Ríos & Mutschke, 1999; Aldea & Rosenfeld, 2011), there is little information about the composition and distribution of modern populations in the Beagle Channel. The average size recorded in modern individuals collected in the intertidal of Lapataia bay show sizes ranging between 35.5 mm to 56 mm (Silva, 1996). The author remarks that the individuals from the upper intertidal zone are smaller than the individuals from the lower and subtidal zones. This difference is due to the influence of the stress conditions (e.g. desiccation, wave action) which are more stable in the lower intertidal zones (Bala, 1989; Silva, 1996).

Some recent isotopic analyses on shells from Túnel VII site registered isotopic values which might suggest lower summer sea surface temperature (SST) or lower rivers discharges than nowadays (Colonese *et al*., 2011). The isotopic values could indicate a decrease in the SST from c. 3.1ºC and 1.8ºC. These data agree with other similar analyses carried out in the area (Obelic *et al*., 1998), which indicate a mean annual SST at the end of 19th century about 1.1ºC lower than nowadays.

It is known that some local paeloenvironmental factors could affect directly the development of the intertidal mollusks (e.g. Morriconi & Calvo, 1993; Morriconi, 2005; Campbell, 2008; Gutiérrez Zugasti, 2011). However the coincidence of the sizes in different contexts showed by the present study (several occupation events in Túnel VII and also in different sites from different chronological contexts) would relegate those factors to a secondary role. This would suggest that the anthropic pressure on these resources would be a more important factor which could affect directly in the sizes registered in these sites.

Other biometrical study carried out the Strait of Magellan compares modern limpet specimens with archaeological shells (1,360±75 BP) and it show similar results (Thantje & Ríos, 2010). Small size classes are under-represented in archaeological record and there are not very large and old specimens. This was interpreted as a result of the anthropic regular exploitation of these resources that does not allow the natural development and growth of these populations.

CONCLUSIONS

During the last period of yamana occupation of the Beagle Channel, similar characteristics in the management of the molluscs as food resource have been detected at several archaeological sites. The archaeological molluscs have been subjected to a certain degree of anthropic pressure, which was recurrent in all the occupation events of Túnel VII and also in other sites as Lanashuaia without ever reaching the overexploitation. Indeed, the exploitation of molluscs of similar sizes along the entire occupation sequence in Túnel VII and also at different archaeological sites might suggests that some time elapsed between each occupation period. This would allow the recovering of the shell bed until the molluscs could reach an acceptable size for their consumption.

The data that we collected so far suggest that the yamana society implemented a sustainable system of exploitation of the shell beds. Due to the general smaller sizes compared to modern specimens, anthropic pressure over the resource might be suggested. However, yamana people also cared for the conservation and allowed the regeneration of the shell beds in order to avoid the overexploitation of the resource. More work is needed in order to strengthen these results, which should be considered preliminary due to the small sample size. However, the application of biometric analyses to archaeological molluscs assemblages from sites of this region has demonstrated a great potential in order to gain fundamental knowledge of past socio-ecological dynamics.

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