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Isotopes and Rocks: Geographical Organisation of Southern Patagonian Hunter-Gatherers

L. A. BORRERO,[a]* R. BARBERENA,[a] N. V. FRANCO,[a]
J. CHARLIN[a] AND **R. H. TYKOT[b]**

[a] *CONICET, IMHICIHU-DIPA, Universidad de Buenos Aires, Saavedra 15, 5° (1083), Buenos Aires, Argentina*
[b] *University of South Florida, Tampa, Florida, USA*

ABSTRACT We present an archaeological study of hunter-gatherer home ranges on the basis of two lines of evidence. Firstly, we discuss information related to the mobility of individuals, which was approached by stable isotope studies. Secondly, we present data related to the transport and discard of artefacts, since the distribution of these items may be determined by the movement of people. Our main goal is to integrate these two lines of research in the analysis of an archaeological case from southern Patagonia (Argentina and Chile, South America), that involves the hinterland, the Atlantic coast and the Strait of Magellan. Copyright © 2009 John Wiley & Sons, Ltd.

Key words: hunter-gatherers; stable isotopes; lithic procurement; Patagonia

Introduction

The archaeological evaluation of hunter-gatherer home ranges is the main goal of this paper. We use two lines of evidence that provide independent ways of measuring hunter-gatherer mobility and territorial organisation. Firstly, we present stable isotope information on human remains that constitutes a measure of the mobility of the sampled individuals. Secondly, we discuss data related to the transport and discard of lithic artefacts whose spatial distribution may be determined by the movement of people on the landscape. We compare both kinds of data in the analysis of an archaeological case from the steppes of southern Patagonia (Argentina and Chile, South America, Figure 1). Since these lines of research provide information that is different in many respects, a direct comparison can not be made. Therefore, we propose a methodological framework which is adequate to put this evidence on a fairly comparable level.

The main aspect that needs to be evaluated is the degree to which stable isotopes and lithic artefacts reflect human displacement within a given space or, in other words, whether they provide information about home range dimensions. Isotopic data interpreted on the basis of the available knowledge of isotopic ecology provides a quantitative estimation of the dietary importance of different classes of resources (Ambrose, 1993; Tykot *et al.*, 1996). When these resources can be sourced to specific procurement places, the dietary signals acquire a spatial meaning. In southern Patagonia marine foods meet this condition, so that we have a measure of the dimension of coastal–inland movements by measuring the distance from the coast where the samples that

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* Correspondence to: CONICET, IMHICIHU-DIPA, Universidad de Buenos Aires, Saavedra 15, 5° (1083) Buenos Aires, Argentina.
e-mail: laborrero2003@yahoo.com.ar

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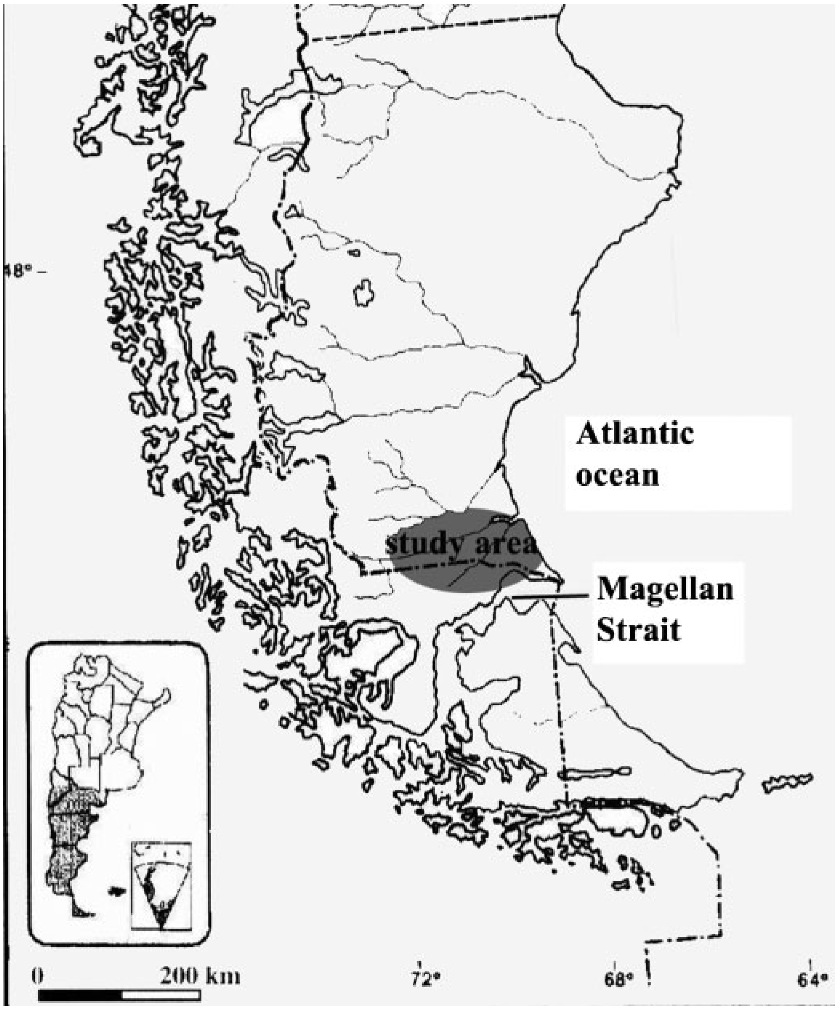

Figure 1. Map of southern Patagonia.

show consumption of marine foods appear (Sealy & van der Merwe, 1986; Borrero & Barberena, 2006; Sealy, 2006).

Lithic artefacts whose source is known can also be used to evaluate aspects of hunter-gatherer spatial organisation. Frequencies of raw materials alone cannot be directly used to infer the past extension of human home ranges, since lithic resources can be acquired in a number of different ways, including direct or indirect procurement tactics (Meltzer, 1989; Ingbar, 1994). We suggest that important clues can be obtained from the study of frequencies of raw materials combined with different reduction markers, like the size of artefacts, used angles of discarded tools, and frequencies of exhausted cores or tools, among others (Kuhn, 2004; Hiscock & Attenbrow, 2005). This analysis must take into account the existence of different technological strategies, like economy of raw materials (Odell, 1996). Regional information on the spatial distribution of potential lithic sources is a basic starting point (Ericson, 1984; Franco, 2002). In the Patagonian case there is a methodological difficulty in identifying those sources, given that most of them correspond to secondary deposits and are the product of widely occurring and successive glacial and glacifluvial events (Franco, 2002). It is important to stress that not all rock types are adequate to be used in this way. We suggest that

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types with a limited abundance on the landscape, that were therefore curated or economised, will be most informative about hunter-gatherer home ranges.

Given that all the analysed skeletal samples represent articulated individuals deposited on primary burials, there are no questions of fidelity of the depositional context with the isotopic signal (see Pate, 1995). Clearly, this record constitutes evidence of the home range of the populations involved. In terms of coverage, lithics provide a more continuous record than human bones, which constitute a smaller fraction of the archaeological record. Therefore, we are required to maximise the sample size of human remains. In order to do this, we use analytical time-averaging (*sensu* Behrensmeyer *et al.*, 2007: 7), combining Late Holocene samples from different locations that correspond basically to aeolian deposits.

In sum, isotope and lithic evidence can inform on spatial properties of past human adaptations at different scales. While the potential for refinement exists (i.e. Parkington, 2001; Sealy, 2006), isotopic analysis on human bones recovered at different sites in southern Patagonia provides the wider picture, indicating a differentiated use of the coast and a peri-coastal segment of land around 100 km wide, and the further hinterland, which shows no systematic connections with marine resources (Borrero *et al.*, 2001; Barberena, 2002). Lithic analysis, in turn, works with more abundant samples with a near-continuous coverage, and invites a finer-grained discussion of the use of space. The combined use of both markers is useful to discuss home ranges and, potentially, spheres of social interaction.

Southern Patagonia: climatic and ecological aspects

Southern Patagonia is a large territory located between 46° and 53°S (Figure 1) that constitutes the southernmost end of the South American continent. The Andean range dominates the topography in the western side of the continent, whereas dissected plateaus that give way to low steppe plains make up the eastern part (Clapperton, 1993; McCulloch *et al.*, 1997). During the middle Holocene, at *ca*. 6000 years BP, the sea approached its stabilisation phase near its present level (Rostami *et al.*, 2000). Given that the spatial distribution of archaeological samples in relation to marine coastlines is central in our discussions, it is important to stress that they reached their present level at *ca*. 5000 years BP (Isla, 1989). Since this study is focused on the Late Holocene record, it can be inferred that their past position in relation to the sea has not changed significantly since that time.

Atmospheric circulation patterns in southern Patagonia are controlled by westerly storm tracks that shift seasonally on a latitudinal axis (Lamy *et al.*, 2001). The interaction of the Andean topographic barrier and the westerly winds imposes a strong west–east gradient on precipitation and effective moisture. Precipitation in the western side of the Andes range reaches levels of 4000 mm/yr, whereas the eastern steppes show mean annual precipitation in the order of 200/300 mm (Oliva *et al.*, 2001). In the Pacific area that corresponds to the channels region of Chile there are evergreen forests composed of *Nothofagus betuloides*, and a few km to the east, as precipitation decreases, there is a deciduous forest dominated by *Nothofagus pumilio* and *Nothofagus antarctica* trees. As precipitation continues decreasing towards the east we reach the 400–200 mean annual precipitation area characterised by mesic and xeric steppe ecosystems (Oliva *et al.*, 2001). Most of the isotopic samples presented here come from this region.

All these southern Patagonian environments currently present cold-temperate climates, with mean annual temperatures between 8° and 5°C (Schulze *et al.*, 1996; Oliva *et al.*, 2001). Palaeoclimatic information indicates that despite the large variations recorded for the Late Holocene, southern climate always tended to be cold, with periods characterised by colder than current climate (Huber *et al.*, 2004; Haberzettl *et al.*, 2005; Mayr *et al.*, 2005). This is important for isotopic research (i.e. Cavagnaro, 1988), given that it conditions the photosynthetic pathways of the vegetal communities recorded at this latitudinal range, which show a C_3 pathway (Oliva *et al.*, 2001; see also Ehleringer & Cerling, 2001). These communities in turn determine the isotopic values of the subsequent terrestrial trophic chains (see discussion on isotopic ecology below).

The main food classes available for human consumption are terrestrial and marine species of mammals and birds. The guanaco (*Lama guanicoe*), a southern camelid, is the main terrestrial mammal in terms of its caloric content and its representation in the local archaeofaunal record, having been the main staple for hunter-gatherer societies throughout the Holocene (Borrero, 1986; Miotti, 1998; Mengoni Goñalons, 1999). The other important terrestrial species in terms of its caloric content is a flightless bird, the choique *Pterocnemia pennata* (Giardina, 2006). Nevertheless, the Patagonian archaeological record fails to show a signal of systematic human consumption of choique (Fernández, 2000). Marine species include birds such as the shag (*Phalacrocorax atriceps*) and the Magellan penguin (*Spheniscus magellanicus*), mammals such as the southern sea lions (*Arctocephalus australis*, *Otaria flavescens*), and several species of mussels (i.e. *Mytilus* sp., *Aulacomya* sp.). All these species are represented in the faunal record from coastal settings of the Magellan Strait and the Atlantic coast, although with variable frequencies (Barberena, 2008).

Methods and techniques

Isotopic methods

The human and animal samples were processed in the Laboratory for Archaeological Science at the University of South Florida. Bone collagen was extracted using well-established laboratory procedures (Ambrose, 1993; Tykot, 2004). Whole bone was demineralised in 2% hydrochloric acid (72 hrs), base-soluble contaminants were removed using 0.1 M sodium hydroxide (24 hrs each before and after demineralisation), and residual lipids were dissolved in a 2:1:0.8 mixture of methanol, chloroform and water (24 hrs). One milligram samples of the dried collagen pseudomorphs were analysed in duplicate for $\delta^{13}C$ and $\delta^{15}N$ in continuous flow mode using a CHN analyser coupled with a Finnigan MAT Delta Plus XL stable isotope ratio mass spectrometer. Visual assessment during collagen removal, the final yield, and %C, %N values were used to confirm the integrity of the collagen samples.

Bone apatite samples were prepared using procedures designed to remove non-biogenic carbon without altering the biogenic carbon isotope values (cf. Koch *et al.*, 1997). Powder samples were obtained by drilling from the centre of carefully cleaned bone samples. Approximately 10 mg of powder were immersed in 2% sodium hypochlorite to dissolve organic components (72 hrs for bone apatite). Non-biogenic carbonates were then removed in 1.0 M buffered acetic acid for 24 hours. The integrity of apatite samples is assessed through yields obtained in each stage of the pretreatment process. Sample loss is typically low while in sodium hypochlorite since much of the collagen in bone has dissolved. Samples weighing 1 mg were analysed on a Finnigan MAT Delta Plus XL stable isotope ratio mass spectrometer equipped with Kiel III individual acid bath carbonate system.

All results are reported using the delta (δ) notation, relative to VPDB for carbon and to AIR for nitrogen. The analytical precision is about ±0.1‰ for all measurements.

Regional isotopic ecology

As was mentioned previously, southern Patagonia is a high-latitude cold setting where the predominant low temperatures function as a limiting factor for the growth of vegetation showing the C_4 photosynthetic pathway (Ehleringer & Cerling, 2001). These species, altogether with others showing the CAM pathway, were recorded in central and northern Patagonia (Gómez Otero, 2007; Martínez *et al.*, 2009), but are not present below *ca.* 51°S (Boelcke *et al.*, 1985; Borrelli & Oliva, 2001). Therefore, the vegetal communities represented in forest and steppe settings show the typical C_3 photosynthetic pathway. This is an advantage for the isotopic discrimination of the consumption of terrestrial and marine proteins, as we demonstrate below (see Richards & Hedges, 1999; cw. Corr *et al.*, 2005). There is a relatively large $\delta^{13}C_{COL}$ database for southern Patagonia which is the product of ^{14}C AMS dating conducted on *Lama guanicoe* bones. This information confirms the expectations arising from the ecological and climatic data indicating that this is a C_3 isotopic ecosystem. Nevertheless, given that C_3 ecosystems may display a variable range of isotopic values (Tieszen, 1991; Heaton, 1999; van Klinken *et al.*, 2000), we proceed to characterise the range of $\delta^{13}C_{COL}$ values for guanaco, the main terrestrial herbivore.

The isotopic information currently available for vegetal species from southern Patagonia is very limited, and is one of the aspects that needs to be improved in future research. Tessone *et al.* (2009) provide very interesting information for the Salitroso Lake, located further north at latitude 47°S, indicating a mean $\delta^{13}C$ value of *ca.* −25‰, near the global mean for open environment C_3 communities (Heaton, 1999). The next step on the terrestrial trophic chains corresponds to the terrestrial herbivores, among which *Lama guanicoe* had the main dietary role throughout the human peopling of Patagonia. In this case there are a large number of local $\delta^{13}C_{COL}$ values associated with ^{14}C dates for archaeological samples of guanaco that offer an accurate evaluation of its isotopic variability through space and time (Table 1, Figure 2). There is currently an average value of −21.1‰ for a total of 25 samples, very similar to a previous value of −21.3‰ obtained on the basis of 19 samples (Barberena, 2002).

The analysis of the temporal distribution of $\delta^{13}C_{COL}$ values shows that there are no clear tendencies, displaying an almost neutral correlation in the distribution of samples from 9740 ± 50 to 160 ± 40 years BP (Table 1, Figure 2). There are three samples that show impoverished values of *ca.* −24‰. These samples come from western contexts (Rincón Amigo, Alice 1 and Lago Roca 3 sites) located closer to the eastern limit of the Andean forest, and these values may reflect some incidence of the so-called canopy effect (van der Merwe & Medina, 1991; Barberena *et al.*, 2008).

All this information suggests that southern Patagonia was characterised by comparable C_3 terrestrial ecosystems during the Middle and Late Holocene, and that the regional isotopic ecology employed for the interpretation of human samples is valid for this span.

Working at a larger spatial scale that includes the whole of continental Patagonia, from *ca.* 35°

Table 1. $\delta^{13}C_{COL}$ values for *Lama guanicoe* samples from southern Patagonia

#	Site	Sample	Lab code	$\delta^{13}C_{COL}$	^{14}C date
1	Cabo Vírgenes	Cervical vertebrae	USF-582	−21.0	—
2	Cerro Verlika 1	Humerus epiphysis	GX-25277	−21.3	1685 ± 70
3	Alero del Bosque	Metapodial	Beta-91301	−22.0	3110 ± 50
4	Lago Roca 3	Diaphysis	Beta-91302	−24.0	170 ± 30
5	Alice 1, 1	Tibia epiphysis	Beta-112231	−22.0	1420 ± 70
6	Alice 1, 2	Metapodial diaphysis	Beta-112232	−24.9	1480 ± 70
7	Alice 2	Mandible	GX-27174	−20.4	740 ± 60
8	Chorrillo Malo 2, 1	Humerus diaphysis	Beta-148743	−19.0	3790 ± 80
9	Chorrillo Malo 2, 4	Humerus diaphysis	GX-25279	−22.1	9740 ± 50
10	Rincón Amigo	Distal metapodial	Beta-138991	−24.6	1840 ± 40
11	El Sosiego 2	Femur diaphysis	GX-25278	−20.5	1920 ± 40
12	A. Piedra Quemada	Humerus diaphysis	GX-26196	−20.8	650 ± 40
13	V. Piedra Quemada 2	Femur diaphysis	GX-25775	−20.3	520 ± 40
14	Cabo Vírgenes 7	Metapodial diaphysis	GX-25773	−20.1	160 ± 40
15	Cabo Vírgenes 8	Radius-ulna	GX-27868	−21.0	240 ± 40
16	Cabo Vírgenes 4	Radius-ulna	GX-27864	−21.0	2000 ± 40
17	Cabo Vírgenes peat	Cervical vertebrae	GX-27865	−22.3	1510 ± 30
18	Cerro León 1, 1	Humerus epiphysis	GX-27863	−20.8	4340 ± 40
19	Cerro León 1, 2	Femur epiphysis	GX-27866	−19.8	2850 ± 40
20	Orejas de Burro 1, II	Tibia diaphysis	Ua-21902	−19.8	3490 ± 50
21	Cóndor 1, 4E, II	Tibia	Ua-24658	−20.3	965 ± 40
22	Cóndor 1, 4E, III	Radius-ulna	Ua-24658	−19.5	1360 ± 65
23	La Carlota	Radius-ulna epiphysis	Beta-215184	−20.1	1070 ± 40
24	Cabo Vírgenes 22	Tibia diaphysis	GX-32586	−21.3	660 ± 50
25	Cerro León 3	Femur distal epiphysis	GX-32583	−19.7	4370 ± 50
Minimum value				−24.9	
Maximum value				−19.0	
Mean value				−21.1	
Standard deviation				1.5	

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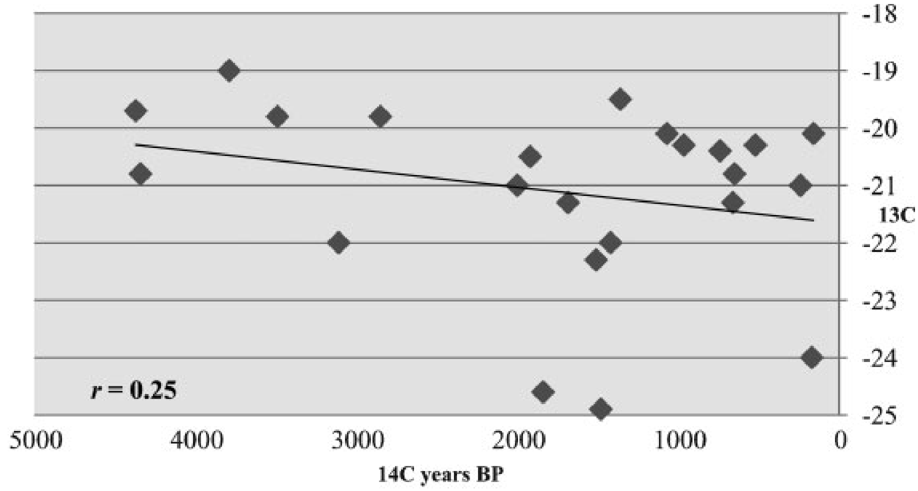

Figure 2. Temporal tendencies in $\delta^{13}C_{COL}$ values for guanaco (*Lama guanicoe*).*Note*: We exclude the sample from Chorrillo Malo 2 site (9740 ± 50 BP), since it is earlier than the span considered in our analysis.

to 52°S, we can compare the distributions of $\delta^{13}C_{COL}$ for guanaco and explore the differences in the dietary role of C_4 vegetation. Available evidence shows a gradual enrichment in $\delta^{13}C_{COL}$ values to the north[1] (Table 2), although this is not a unilineal pattern, since it is conditioned by several regional and local variables (Cavagnaro, 1988; Tieszen, 1994; Barberena *et al*., 2008). This pattern confirms the general expectations based on general climatic conditions, and confirms the absence of a C_4 component in the southern Patagonian herbivores' diet.

Marine animals are the second main class of food resources in the southern Patagonian environment, and we have isotopic values for some of these species which appear to be the most usually consumed. There is also available isotopic information presented by colleagues for other areas of the Patagonian coast (Orquera & Piana, 1996; Gómez Otero, 2007). We suggest that in the case of marine mammals, like the pinnipeds, that demonstrably have very large home-ranges, isotopic values from neighbouring areas can be considered for the reconstruction of the local isotopic ecology. Although the sample size is small, the homogeneity recorded in the values from different regions supports this decision (Table 3) and highlights the differences in the spatial scale of the variability recorded in terrestrial and marine trophic chains respectively. There are isolated values for penguin (*Spheniscus magellanicus*) and shag (*Phalacrocorax atriceps*), the two most important species of marine birds, which are indicative of a clear enrichment in $\delta^{15}N$ (17.1‰ and 16.8‰ respectively). The shag sample also shows an equally enriched $\delta^{13}C_{COL}$ value of −11.4‰; on the other hand, the penguin sample has an impoverished $\delta^{13}C_{COL}$ of −19.8‰,

Table 2. Descriptive statistics on *Lama guanicoe* $\delta^{13}C_{COL}$ values from Patagonia

	Southern Patagonia (50/52°S)	Lago Salitroso (49°S)	Lower Colorado River Basin (39°S)	Southern Mendoza (30/32°S)
n	25	13	7	11
Minimum value	−24.9	−20.59	−23.9	−19.4
Maximum value	−19.0	−18.55	−16.2	−14.7
Mean value	−21.1	−19.59	−21.04	−18.3
Standard deviation	1.5	0.51	3.1	1.4
References	This paper	Tessone *et al.* (2005, 2009)	Martinez *et al.* (2009)	Gil *et al.* (2006, 2009)

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Table 3. Isotopic values for Patagonian marine species

Species	Region and site	Element	Lab code	$\delta^{13}C_{COL}$	$\delta^{13}C_{APAT.}$	$\delta^{15}N$	Source
Otaria flavescens	Cabo Vírgenes	Femur	USF-581	−8.8		18.1	This paper
Otaria flavescens	Punta María 2 (Tierra del Fuego)	Radius	USF-387	−11.8	−9.7	15.1	This paper
Otaria flavescens	Cabo Vírgenes 2	Scapula	GX-25276	−11.2			Borrero *et al.* (2006)
Pinniped	Cabo Vírgenes 6	Femur and tibia	Beta-155999	−12.8			Borrero *et al.* (2006)
Otaria flavescens	North coast of Chubut		USF-109	−11.1	−9.6	16.1	Gómez Otero *et al.* (2000)
Arctocephalus australis	Shamakush I (Beagle Channel)		AC-698	−11.8			Orquera & Piana (1996)
Arctocephalus australis	Shamakush I (Beagle Channel)		AC-705	−14.5			Orquera & Piana (1996)
Minimum value				−14.5			
Maximum value				−8.8			
Mean value				−11.7			
Standard deviation				1.75			

which is inconsistent with both its maritime diet and its δ^{15}N value. This is the only modern sample used to build the isotopic ecology and this may explain part of the poor δ^{13}C value, but evidently there are other unknown factors and we suggest that only this sample would not be adequate.

In Figure 3 we present the distribution of isotopic values for guanaco (*Lama guanicoe*) and the two sealion species (*Otaria flavescens* and *Arctocephalus australis*), which are the main dietary staples in southern Patagonia as informed by the zooarchaeological record from coastal and hinterland settings (i.e. Mengoni Goñalons, 1999; Barberena *et al.*, 2004). The wide spacing observed between the two sets of $\delta^{13}C_{COL}$ values supports the isotopic evaluation of the role of marine and terrestrial proteins in human diets. Although the sample is very small, the same separation can be done on the basis of δ^{15}N values, since available determinations for guanaco reach *ca.* 5‰ (see Tessone *et al.*, 2009), and the average value for five samples of marine mammals is 16.4‰. The integration of $\delta^{13}C_{COL}$ and δ^{15}N values in the local isotopic ecology allows for an accurate reconstruction of the protein fraction of human diets.

In the archaeological case that we present here, a quantitative isotopic analysis is not so important as the qualitative identification of the consumption of marine foods, which will be used as evidence of systematic contact with coastal settings. Therefore, we have been concerned with the identification of an *isotopic threshold* beyond which the ingestion of marine foods can be positively suggested (this key methodological issue has been recently argued: see Hedges, 2004; Corr *et al.*, 2005; Richards *et al.*, 2005, 2006; Bocherens & Drucker, 2006). This can only be done on the basis of the local isotopic ecology, which provides the end-lines for terrestrial and marine proteins. Given the wide spacing recorded between the average values for terrestrial and marine resources (8.8‰ for $\delta^{13}C_{COL}$ and 7.4‰ for δ^{15}N), and since there are no plants showing the C_4 photosynthetic pathway, as we already argued, their isotopic discrimination is relatively straightforward. Nevertheless, the isotopic variation recorded for these food classes imposes some limits in the quantitative resolution that can

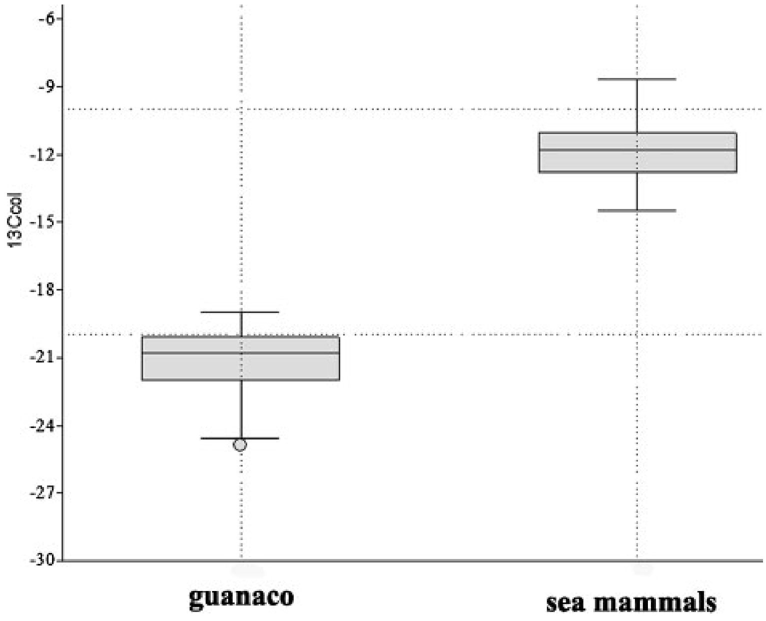

Figure 3. Distribution of isotopic values for guanaco and pinnipeds.

be achieved, and this is particularly relevant for those samples that show a low input of marine foods. We suggest that the local dietary threshold beyond which we can substantiate the ingestion of marine foods is located around 20% of the total diet (Figure 4). This includes $\delta^{13}C_{COL}$ values that are higher than *ca.* −18‰, although this is by no means a sort of 'magic number'. $\delta^{15}N$ values provide an additional criterion in dubious cases (Richards & Hedges, 1999; Yesner *et al.*, 2003; although see Hedges & Reynard, 2007).

Lithic methods

The availability of lithic resources in the Pali Aike volcanic field provides the frame of reference for the evaluation of the reduction of lithic artefacts and, more generally, of technological strategies on a regional scale. Following the methodology outlined by Franco & Borrero (1999; Franco, 2002), we sampled the glaci-fluvial deposits at about 60 locations in order to study the distribution and abundance of different rock

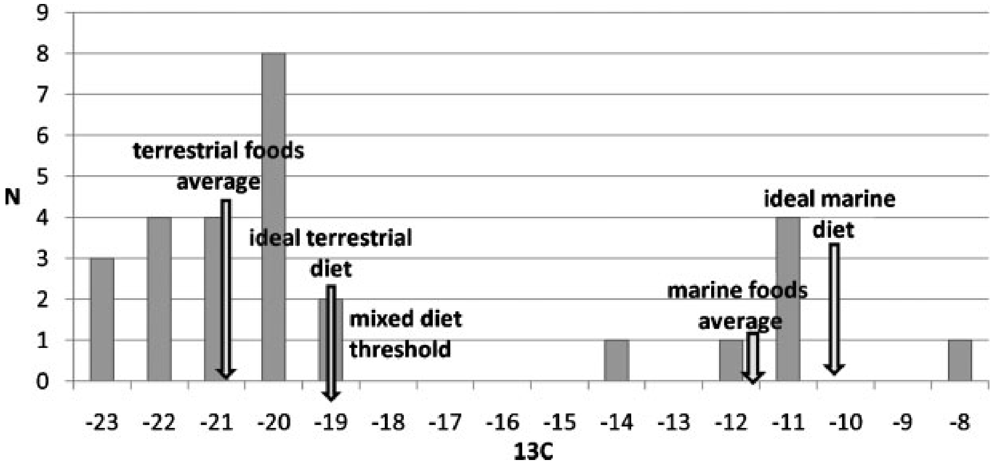

Figure 4. Frame for the dietary interpretation of isotopic values from southern Patagonia.

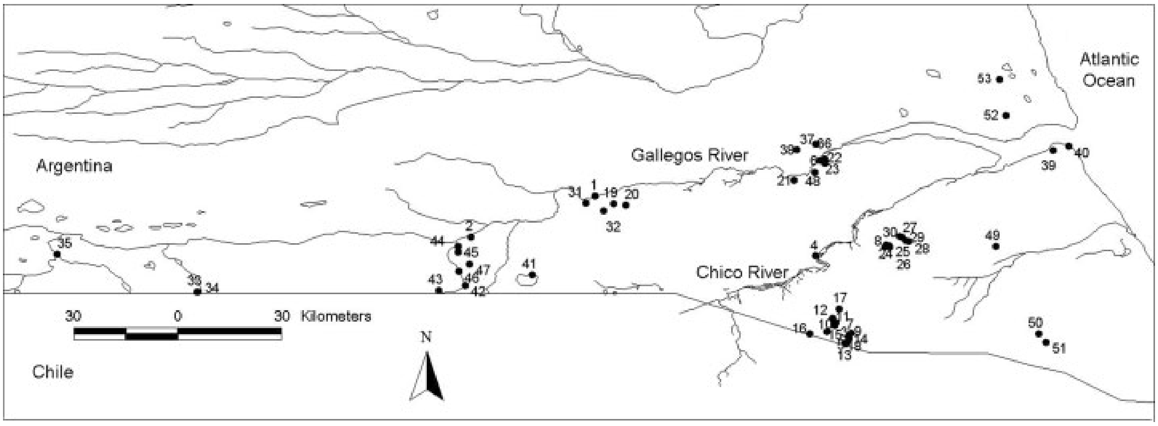

Figure 5. Sampling locations for the study of lithic materials availability.

types in the landscape (Figure 5). This sampling strategy was designed to deal with the predominance of secondary lithic deposits (*sensu* Nami, 1985) in the region, which were the main source for the procurement of lithic raw materials (Charlin, 2008). This survey methodology consists of a given number of people sampling each selected location during a controlled amount of time, collecting the appropriate rocks available (Franco & Borrero, 1999). It contributes to estimating the return of different potential lithic sources, analysing the diversity in terms of petrography, nodule size and rock quality for the manufacture of artefacts, among other factors. Even when secondary sources appear to be affected by differential visibility, it must be stated that the study of regional lithic technology strongly indicates that their distribution has not changed significantly through time.

In the analysis of lithic artefacts we follow a materialist and non-typological perspective (Hiscock, 2007). We evaluate the degree of exploitation of different lithic raw materials according to several reduction variables (Hiscock & Attenbrow, 2003, 2005). The unit of comparison is the rock-type by class of artefact (debris, unifacial tools, bifacial tools and cores). We used several reduction indexes including the following: flake-scar density in debris (Ingbar *et al.*, 1989) and cores; residual length in tools (Kuhn, 2004); geometric index of reduction (Kuhn, 1990), and estimated wear angle of retouched edges in unifacial tools (Aschero, 1983); reactivation index in bifacial tools (Iriarte, 1995); and rate of retouched edges and points by artefact.

Results for human samples and lithic assemblages

Stable isotopes in human remains

The multi-isotopic perspective that we develop provides better resolution and confidence for the dietary interpretations (i.e. van der Merwe *et al.*, 2000). Isotopic values do not have an intrinsic subsistence meaning and need to be interpreted contextually. The local isotopic ecology provides that context, which in this case is based on the characterisation of the range of variability of the main terrestrial and maritime resources. Although it needs refinements in relation with the ecology of certain species, like penguin and choique, the isotopic ecology database presented for southern Patagonia constitutes a solid baseline for the estimation of the dietary importance of marine foods. This consumption must be accurately determined in order to substantiate the reconstruction of the geographical organisation of the hunter-gatherer societies that inhabited southern Patagonia during the Late Holocene. In Table 4 we present the isotopic values for human samples indicating the distance from the coast at which they were recovered.

On the basis of the previous comments, we can identify with some degree of certainty which of

Table 4. Isotopic data on human remains from southern Patagonia

Sample	Km to coast	Chronology	Code (USF)	Sex	Age	$\delta^{13}C_{COL}$	$\delta^{13}C_{AP}$	$\Delta^{13}C$	$\delta^{15}N$	% MR[d]
Orejas de Burro1, 1	16	3565 ± 45	8323/8327	M	20–25 years	−18.1	−15.0	3.1	13.1	20
Orejas de Burro1, 2	16	3565 ± 45[b]	8326/8330	M	45–50 years	−18.5	—	—	13.7	20
Orejas de Burro1, 3	16	3565 ± 45[b]	8325/8329	?	8 ± 2 years	−19.3	−16.5	2.8	11.7	0
Orejas de Burro1, 4	16	3565 ± 45[b]	8324/8328	?	6 ± 3 months	−18.1	−12.7	5.4	13.6	—
Juni Aike 6[e]	70	—	371/228	M	<6 months	—	−15.6	—	12.8	0
Posesión Olympia 1	0	19–20th century	372/229	M	Adult	−14.4	−12.7	1.7	16.1	60
Posesión Olympia 2	<1	—	373/230	M	Adult	−19.4	−14.6	5.2	13.8	0
Bahía Santiago	<1	—	374/231	—	Adult	−16.3	−14.3	2.0	12.8	30
Punta Delgada	<1	—	375/232	F	Adult	−17.0	−13.6	3.4	14.2	25
Punta Dungeness 5	<1	16th century	388/233	—	Infant	−14.5	−12.3	2.2	16.8	50
Punta Daniel	<1	—	377/234	M	Adult	−15.0	−12.9	2.1	14.0	40
Fortaleza	90	630 ± 60	4512	—	Young	−17.6	—	—	15.1	20
Cerro Johnny	52	413 ± 41[c]	378/235	M	Adult	−19.2	−16.9	2.3	11.0	0
Las Horquetas	82	Modern	379/236	F	Adult	−21.6	−17.4	4.2	10.9	0
Cabo Vírgenes 17.1	<1	900 ± 40	4511	M	Adult	−16.8	—	—	11.4	30
Cabo Vírgenes 17.2	<1	—	4508	F	Adult	−14.0	—	—	13.2	60
Ea. La Costa	<1	—	4510	—	—	−18.1	—	—	16.5	20
Palermo Aike	40	1120 ± 50	370/227	M	Adult	−17.6	−13.9	3.7	12.0	20
Cerro Sota[a]	50	3380 ± 70	OxA	—	—	−19.9	—	—	—	0

[a] From Hedges *et al.* (1992).
[b] Deposited simultaneously with the OB1, 1 skeleton.
[c] Combined age of dates on different tissues associated to this individual (OxCal4).
[d] Minimum percentage of marine foods in diet.
[e] The Juni Aike 6 sample corresponds to a non-weaned subadult. We can use it as an indirect measure of its mother diet.

these values is indicative of the consumption of marine foods. There is a positive correlation between $\delta^{13}C_{COL}$ and $\delta^{15}N$ values (Figure 6). This set of data points is similar to what Schwarcz (1991) defined as 'linear distributions', which are usually associated with the consumption of two classes of resources with different intensities, in this case marine and terrestrial proteins. Most of the cases located on the right side of Figure 6 indicate the consumption of marine proteins. Taking into account the baseline value defined for terrestrial resources, and considering the fractionation value between food and bone tissue, we can arrive at a quantitative determination of the *minimum* intake of marine foods in each case (Ambrose, 1993; Ambrose *et al.*, 1997).

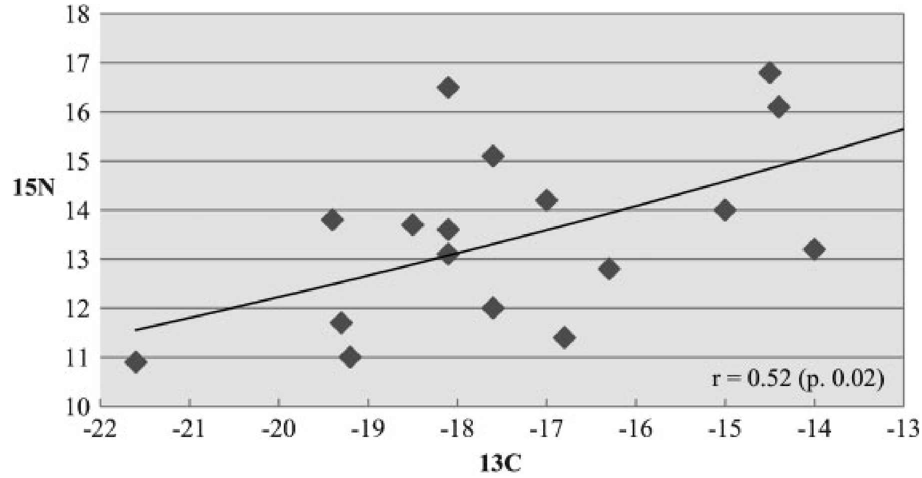

Figure 6. $\delta^{13}C_{COL}$ and $\delta^{15}N$ information on human remains.

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It is important to emphasise that we are not determining cases that may show a very low intake of marine foods (below 20% of the total diet), which may be isotopically mimicked by the ingestion of terrestrial proteins situated on the most enriched segment of their range. The human isotopic sample includes seven individuals who do not show the consumption of marine proteins, and 12 individuals who consumed them in percentages ranging from 20% to 60% of the total diet. As already mentioned, we do not wish to assign a precise quantitative accuracy to these reconstructions, since their main value resides in the accuracy of the qualitative inferences presented – whether or not any individual consumed marine proteins.

The information from C and N is concordant, reflecting a decrease towards the hinterland in the intensity of the consumption of marine foods. Although sample sizes are small, if we discriminate these cases in terms of their closer association with a particular coastline segment, we can see that interesting differences can be seen. In the case of the Atlantic Ocean, marine proteins are consumed up to a distance of 90 km from the coast, whereas in the case of the Strait of Magellan they are consumed within a smaller peri-coastal zone of *ca.* 20 km (Figures 7 and 8). This is also reflected in the R^2 values for these sets, which show a more positive relation in the case of the Strait of Magellan for both C and N values. This may suggest that, in the case of the Strait of Magellan, on a spatial scale of *ca.* 20–30 km from the coastline we reach the point where marine foods were not eaten on a systematic basis. On the other hand, in the case of the Atlantic coast this point is located at *ca.* 90 km from the nearest coast segment.

Given that the Atlantic sample is very small in comparison with the one from the Strait of Magellan, the evidence of a more spatially widespread consumption of marine resources in the Atlantic constitutes interesting evidence in itself. Although more information is clearly needed, the identification of this situation in the Atlantic sample despite its small size raises the possibility that in fact we are sampling a wider organisational phenomenon. This information may suggest that coastal–inland movements were wider in association with the Atlantic than with the Strait. In the first case these movements may have been associated with the large basins of the Santa Cruz and Gallegos rivers, with a west–east axis, that could act as corridors (Franco *et al.*, 2004; Carballo Marina, 2007).

Lithic distributions

We present a brief summary of the main spatial tendencies identified in the southern Patagonian lithic record (Charlin, 2008), in order to provide another perspective on the geographical trends identified on the basis of isotopic data. The study

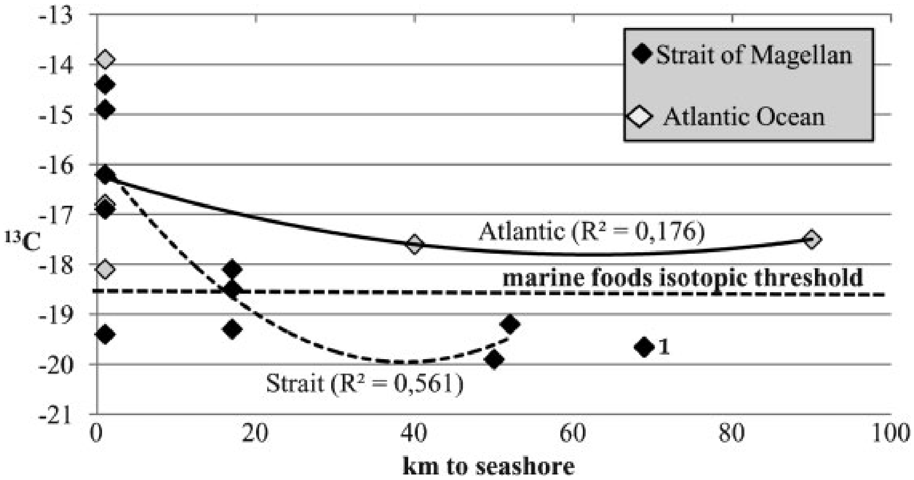

Figure 7. $\delta^{13}C_{COL}$ values and distance to the coast.

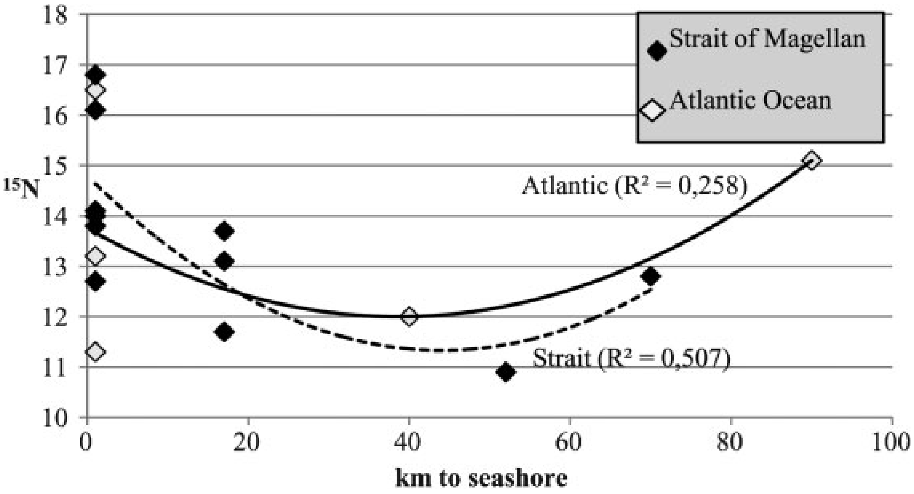

Figure 8. δ^{15}N values and distance to the coast.

of lithic artefacts from southern Patagonian sites has shown that a set of fine-grained dark rocks of very good quality are the most frequently used, constituting more than 50% of the artefacts recovered. This set includes different types of dark rocks, like basalt, dacite and chert, among others, that are very similar macroscopically (Charlin, 2005). The regional sampling of the available lithic sources indicates that these dark rocks are actually scarce and come from spatially restricted places. They are mainly available in the Gallegos River basin, in the margins of some lagoons between the Gallegos and Chico rivers, and on the northern coast of the Strait of Magellan (Figure 9; see Massone, 1984; Gómez Otero, 1986–1987; Nami, 1999; Carballo Marina, 2007).

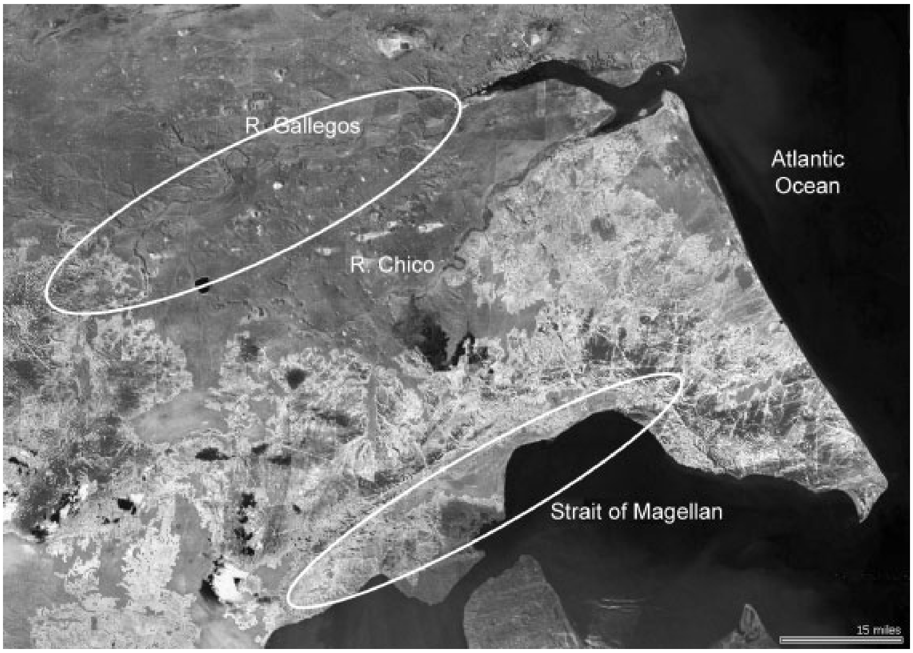

Figure 9. Availability of fine-grained dark rocks in Pali Aike.

The spatial patterns of core reduction in these dark rocks are presented here as an illustrative example. These spatial trends in the degree of exploitation of lithic resources are similar for other raw materials, like dacite and chalcedony, which follow dark rocks in terms of artefact proportion (30% and 15% respectively of the total artefacts recovered in the Pali Aike volcanic field). Other reduction variables that were measured in debris and tools also show the same patterns.

We present a least-squares regression analysis of flake-scar density in dark rock cores against distance from the Gallegos River in order to evaluate the patterns in lithic raw materials reduction. The Gallegos River, north of the Pali Aike, and the Strait of Magellan in the south, are the main permanent provisioning sources of dark rocks (Figure 9). The distance from one source is approximately inversely proportional to the other. In Figure 10 and Table 5 we can observe that the lineal regression model does not adjust well. There is a low mean flake-scar density (0.56 flake scar per mm^3) near the Gallegos River (0–5 km), with the majority of cores with $\leq$1 flake-scar per mm^3. Around 30 km from this source there is an increase in the mean flake-scar density (1.17 flake-scar by mm^3), reaching a maximum of 3.82 flake scar per mm^3 away from the source, as expected from principles of raw material economy (*sensu* Odell, 1996). However, there is important variability in the degree of core reduction within this area as well (between 0.13/3.82 flake-scar per mm^3). Beyond 45 km from the Gallegos River there is a decrease in the mean flake-scar density (0.38 flake scar per mm^3), breaking down this linear pattern. At this place we are about 18 km from the other important source of dark rocks that corresponds to the coasts of the Strait of Magellan. The latter should influence the observed patterns.

In sum, the regional analysis of core reduction shows an increase in the reduction intensity in relation to the distance from the main identified potential sources, the Gallegos River and the Strait of Magellan (Figure 11). Therefore, there is

Table 5. Values of least-squares regression analysis

Intercept (b_0)	0.69
Slope (b_1)	0.01
R-squared (R^2)	0.04
Correlation (r)	0.19
Mean square error	0.64

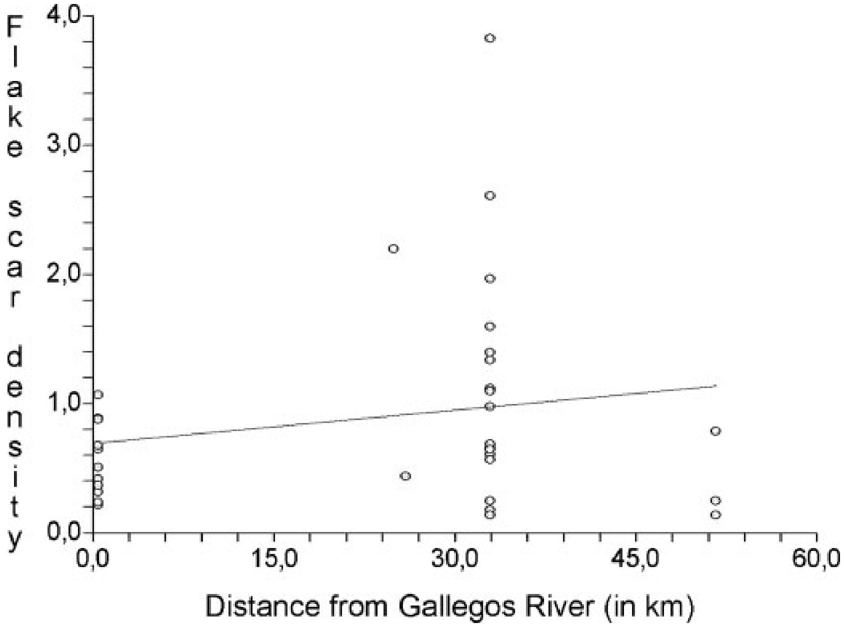

Figure 10. Least-squares regression analysis of flake-scar density by core against distance to the Gallegos River.

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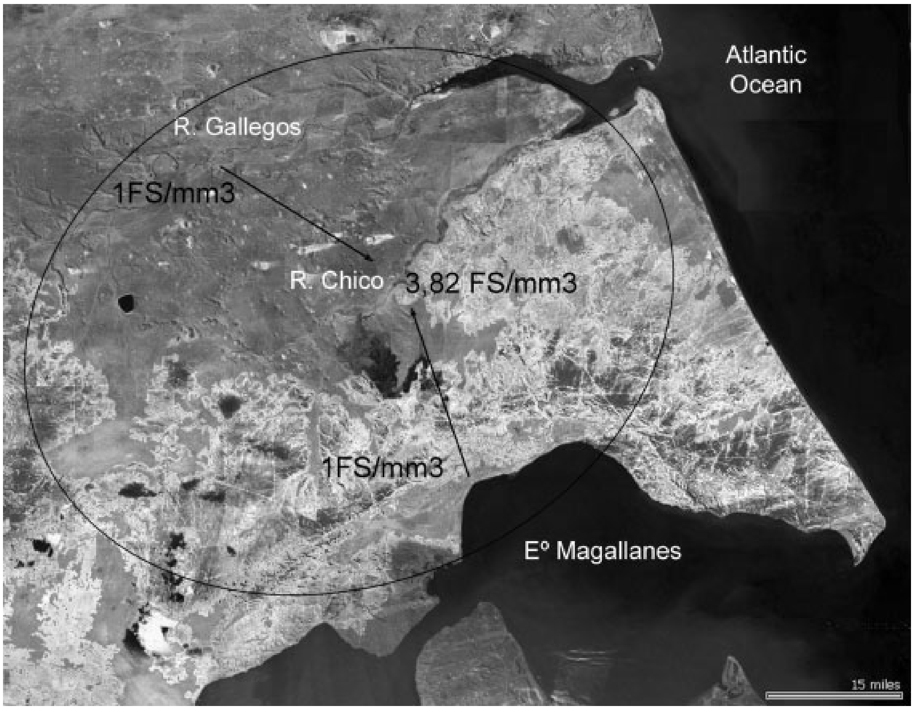

Figure 11. Tendencies in the reduction of lithic artefacts.*Note*: The arrows indicate an increment in the intensity of reduction of the different raw materials.

a central area located within 30–40 km of the Gallegos River and the Strait of Magellan that contains the most intense evidence of reduction in the lithic assemblages. However, the variability existing in the degree of reduction in this central region suggests that some rocks were obtained nearby, so probably the lagoons located between the Gallegos and Chico rivers also functioned as potential provisioning sources (Charlin, 2008).

Discussion and conclusions

The isotopic evidence of systematic marine protein consumption constitutes a proxy for the movement of individuals, and allows us to segment the southern Patagonian space in terms of the role played by these resources. This information does not support traditional historically based accounts (i.e. Casamiquela, 1991), which suggest that these hunter-gatherer societies had very large territories that included spaces from the Atlantic coast up to the Andean mountain range. The spatial circumscription recorded for the use of marine foods in relation to the distance from the coast suggests more restricted levels of mobility. The isotopic record shows differences in the consumption of marine proteins in relation to human samples spatially associated with the Atlantic, showing a wider dispersion of this practice than the samples related to the Strait of Magellan. This is the isotopic expression of differences in coastal–inland mobility.

The spatial structure of the lithic record is produced by processes of transport and discard of artefacts, and may thus constitute an indicator of hunter-gatherer spatial organisation. Nevertheless, for this evidence to be relevant for the analysis of home ranges, we have to identify and put aside those raw materials obtained through indirect means, like trade or exchange (Renfrew, 1977). We have done this in the Patagonian case, discriminating between obsidians, which have travelled hundreds of km through indirect mechanisms, and the dark fine-grained rocks

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discussed here (Charlin, 2008). The evidence briefly reviewed suggests the need to segment this large region on the basis of the reduction trajectories of the most commonly used raw materials. We record an increase in the intensity of raw material exploitation in relation to the distance from both the Magellan Strait and the Gallegos river basin. This is strong evidence for the existence of relatively restricted home ranges, being consistent with isotopic data of human remains. In particular, the gradual decrease from the Magellan Strait to the hinterland on average cores' flake-scar density and other reduction proxies replicates the spatial configuration of the isotopic record.

The contrast recorded in spatial organisation of the Patagonian societies may be related to the differential role played by marine and terrestrial resources in these different settings, given that both stable isotopes and the associated faunal record point to more regular consumption of marine foods in the Strait (Massone, 1984; Barberena, 2008). This may in turn be associated with differences in the carrying capacity of these marine environments (Magazzù *et al.*, 1996). We can suggest that the coastal environment of the central Strait of Magellan had the capacity to sustain human societies with higher demographic levels. This situation would be consistent with the differences recorded in the isotopic record that indicate the widespread consumption of marine foods on the Atlantic side of the continent. Other available evidence not developed here, like size of faunal assemblages and density of mortuary sites, also indicates that there is a demographic packing (*sensu* Binford, 2001) in the areas located to the north of the Strait of Magellan (Barberena *et al.*, 2007).

In this paper we have developed a scheme for the integration of isotopic and artefactual evidence in relation to geographical goals of research. On a regional scale, this evidence reflects different dimensions of the spatial organisation of human societies. While isotopic data are informative in terms of human movements, lithic artefacts relate to patterns in the transport, use life and discard of material objects. These differences may be seen as limiting the strength of the patterns observed, although we suggest that they provide a unique opportunity to explore some of the complexity inherent in hunter-gatherer spatial organisation.

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