Archaeol Anthropol Sci
DOI 10.1007/s12520-014-0188-1

ORIGINAL PAPER

The use of shells as tools by hunters-gatherers in the Beagle Channel (Tierra del Fuego, South America): an ethnoarchaeological experiment

Mary Malainey · Myrian Álvarez · Ivan Briz i Godino · Débora Zurro · Ester Verdún i Castelló · Timothy Figol

Received: 3 December 2013 / Accepted: 19 February 2014

Abstract This paper presents the results of the analysis of lipid residues extracted from two *Aulacomya atra* shells and a single *Mytilus edulis* shell found in the hunter-fisher-gatherer site of Lanashuaia II, a shell midden located on the Beagle Channel (Tierra del Fuego, Argentina). According to existing ethnographic information, the shells could have been used as receptacles (like spoons) or knives by the Yamana people that inhabited the region in the historical period (nineteenth and twentieth centuries). Yamana society is the final moment of a long history of hunter-fisher-gatherer societies present in the Beagle Channel and the rest of Fuegian Channels and islands. Higher concentrations of lipid residues were recovered from both *A. atra* shells than from the sedimentary control sample analyzed. This is consistent with existing accounts that these types of shells were used as containers to cook or melt fat-rich foods. The composition of lipids extracted from archaeological shell was significantly different from the degraded reference cooking residues prepared from modern *A. atra* shells.

Keywords Lipid residues · Shell midden · Hunter-fisher-gatherer · Ethnoarchaeology · Tierra del Fuego

M. Malainey · T. Figol
Department of Anthropology, Brandon University, 270-18th St, Brandon, Manitoba R7A 6A9, Canada

M. Álvarez · I. Briz i Godino (✉)
CONICET-CADIC, B. Houssay, 200, Ushuaia 9410, Tierra del Fuego, Argentina
e-mail: ibrizgodino@gmail.com

I. Briz i Godino
ICSE, Universidad Nacional de Tierra del Fuego, Ushuaia, Tierra del Fuego, Argentina

I. Briz i Godino
Dept. of Archaeology, University of York, York, UK

D. Zurro
CaSEs, Departament d'Arqueologia i Antropologia, IMF–CSIC, Barcelona Catalonia, Spain

D. Zurro
C/de les Egipcíaques, 15.08001 Barcelona, Spain

E. Verdún i Castelló
Departament de Prehistòria, Facultat de Filosofia i Lletres, Universitat Autònoma de Barcelona, GASA-(UAB), AGREST-(Generalitat de Catalunya), 08193 Bellaterra, Cerdanyola del Vallès, Spain

E. Verdún i Castelló
Edifici B Facultat de Filosofia i Lletres, Universitat Autònoma de Barcelona, 08193 Bellaterra, Cerdanyola del Vallès, Spain

Introduction

The majority of tools or artifacts identified and recovered from a large proportion of all hunter-gatherer archaeological sites are made of either stone/bone/antler/horn. Due to various reasons, studies of tools fashioned from other types of material in these kinds of sites are extremely scarce. Archaeological literature on perishable technologies refers to artifacts made with different types of plant materials (see Körber-Grohne 1988 or Vellanoweth et al. 2003, for references on plant remains). Sites with good preservation demonstrate that perishable materials were extensively used (e.g. hunter-gatherer sites from the Northwest Coast of North America; Croes 1997; Samuels 1991; Whelchel 2005).

We must consider the limitations related to how archaeologists approach contexts with poor preservation. Archaeologists do not always take advantage of techniques proficient in the recovery of information about poorly preserved materials (Zurro 2011). Over the last few years, our ability to analyze archaeological materials, as well as the spread of the use of different scientific techniques within our discipline, has evolved enormously. We now have enough

Published online: 13 March 2014

data from ethnographic and historical sources to generate and test hypotheses about the exploitation of many other materials that could have been used.

While the number of archaeological studies focused on the use of shells as tools for use in daily activities has increased recently (for example, Buc et al. 2010; Cristiani et al. 2005; Cuenca et al. 2011; Douka and Spinapolice 2012; Lammers 2008; Mansur and Clemente 2009; Szabó et al. 2007; Toth and Woods 1989; Vigie and Courtin 1986, 1987; Zubimendi 2010), in some cases, we may be prejudiced against considering material other than stone/bone/antler/horn and plants as suitable raw material for tools (Szabó 2008). Apart from dietary consumption, most studies of shell exploitation by hunter-gatherers have focused on the production of ornaments (Álvarez 2008; D'Errico et al. 2008; Salas 2007; White 2007). Mollusk shell may be overlooked as a raw material source for two reasons. First, it is not as resilient material as stone or bone. Second, in many archaeological contexts, the evidences of the use of shells as tools are not always easily observable, particularly in those pieces without traces of manufacture or intentional modification recovered in deposits formed by dense mollusk accumulation (shell middens). Nevertheless, in the case of littoral societies, shells could have been valuable and accessible raw material from which to fashion different tools. We aim to expand the record of artifacts employed in the processes of production and consumption within the sites we are studying, that is, to adjust this record to reflect the presumed reality. We are presenting results from the first study of what we suspect to be artifacts made from *Aulacomya atra* (Molina 1782) shell from the site Lanashuaia II (Beagle Channel, Tierra del Fuego, Argentina) employing lipids analysis.

Our ethnoarchaeological research in Tierra del Fuego is intended to achieve a more complete knowledge of societies by the critical use of comparative data from historically documented populations to develop applicable models and methods that can explain material culture variation related to social organization (Estévez and Vila 1996). Indeed, one of the goals is to broaden our view about how we approach the study of materials by improving different methodological aspects and open new avenues for research in hunter-gatherer archaeology (Briz et al. 2009, 2011; Estévez and Vila 1996).

Our ethnoarchaeological proposal (Briz 2010; Estévez and Vila 1996) relies on the dialectical contrast between the anthropological knowledge and the archaeological inquiry. This mutual confrontation between methods, sources, and outcomes between both fields of knowledge opens the possibility to readjust and reassess the ethnographical information while improving archaeological methods and techniques.

Most of the known archaeological sites in the region are shell middens, largely composed of layers of marine mollusks that were consumed as food (Orquera and Piana 1999). The layers may be combined with sediment mixed with shells in different proportions and different states of preservation along with lenses of humus containing small pebbles, charcoal fragments, and archaeological remains (Orquera 1996; Orquera and Piana 2000). It is important to note that a main feature of methodological development in Tierra del Fuego archaeology has been the recognition of stratigraphic units representing discrete depositional events (Balbo et al. 2010; Orquera and Piana 1992). Malacological studies have played an essential role in the archaeology of the region, not only for the possibility of obtaining information about subsistence strategies (Verdún 2010, 2011), but also because the identification of different species (and their state of preservation; Verdún et al. 2010) is used as a criteria for the stratigraphic isolation of different archaeological levels (Orquera and Piana 2000). In addition, the high calcium carbonate content of shell middens creates micro-environmental conditions that allow for the excellent preservation of organic remains (Álvarez et al. 2011). Consequently, these contexts offer a profitable scenario to explore the reliability of lipid analysis to unveil the context of use of shell tools.

Archaeological context and ethnographical sources

Tierra del Fuego is located on the southernmost end of South America; it constitutes the highest latitude in the Southern Hemisphere populated by hunter-gatherer groups during the Early Holocene (Fig. 1). The Beagle Channel separates Tierra del Fuego island from the southern group of islands of the Fuegian archipelago and connects the Atlantic and Pacific oceans. The climate of this region is cold and highly oceanic (Köppen 1936), and the modern vegetation corresponds to the Subantarctic Deciduous Beech Forest and the Evergreen Beech Forest including different species of *Nothofagus* such as *N. pumilio* (P. et E.) Krasser, *N. betuloides* (Mirb.) Oerst., and *N. antarctica* (G. Forster) Oerst.

Hunter-fisher-gatherer societies specialized in the exploitation of marine resources were first established on the coasts of the Fuegian archipelago around 7,000 BP (Orquera et al. 2011; Fig. 2). These groups moved along this archipelago using some kind of nautical craft and made a profitable use of most food available in the area, with marine resources, such as mollusks, fishes, and sea mammals being especially important (Estévez et al. 2001; Orquera and Piana 1999; Zangrando 2009). Mussels (*Mytilus edulis*), limpets (*Nacella deaurata* and *Nacella magellanica*), whelks (*Trophon geversianus*, *Xymenopsis muriciformis*, etc.) and chitons (Polyplacophora) (Orquera and Piana 2000; Verdún 2011) were the main species recovered from these archaeological sites and are still abundant in the area today. Guanacos (*Lama guanicoe*) and sea birds were also consumed (Mameli and Estévez 2004;

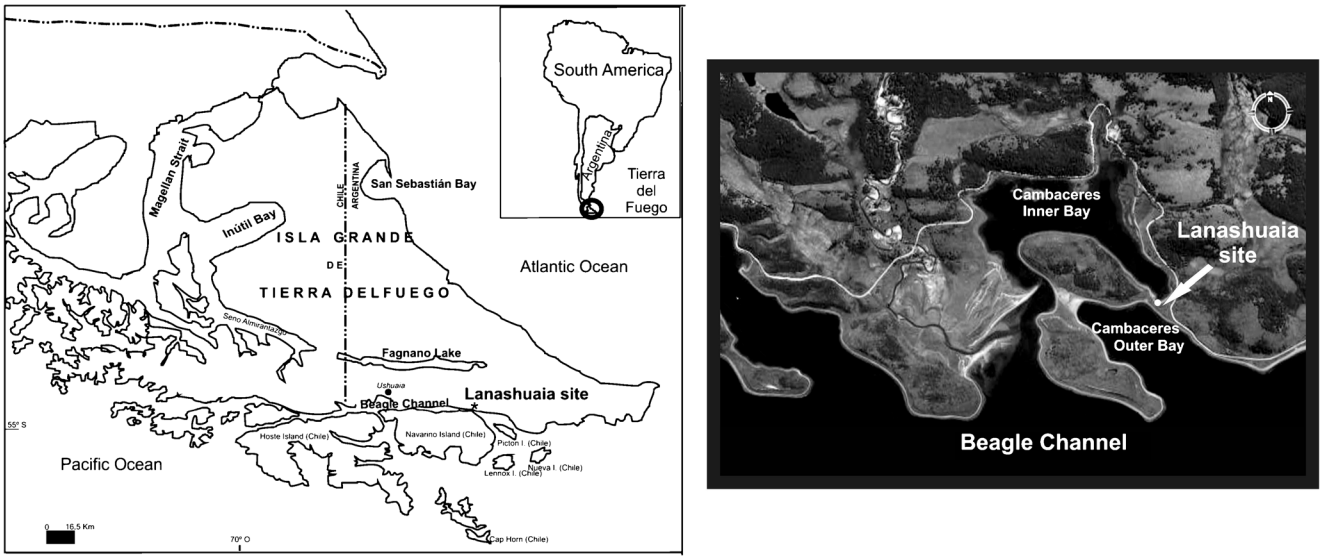

Fig. 1 Map of Tierra del Fuego with the location of Lanashuaia II site

Orquera and Piana 1999; Tivoli 2010); plant foods were eaten as snacks, rather than dietary staples (Zurro 2011).

Most tools recovered from the archaeological sites of the Beagle Channel were made from either stone or bone. In contrast, evidence of shell instruments are extremely rare; a few shell artifacts with a polished edge were found in Túnel I (n=7) (Orquera and Piana 1999) and Túnel VII sites (n=3) (Clemente 1997; Piana and Estévez 1996). However, surface post-depositional alterations on these pieces prevented the identification of use-wear traces (Clemente 1997).

Most archaeological evidence of shell artifacts is related to ornamental use such as beads (Orquera and Piana 1999). On the other hand, it is important to note that patterns of natural and intentional modification are sometimes hard to distinguish in a shell midden layer.

These sea nomad societies still inhabited the Magellan-Fuegian archipelago during the historic period, but their long-standing society collapsed due to the arrival of the Europeans. Their lifeways and social organization are known from ethnographic accounts, photographs, engravings, and even objects in museum collections. Written sources about these natives existed since the sixteenth century, although the most relevant corpus of information was documented in 1883 (Hyades and Deniker 1891) and later in the 1920s by the ethnologist M. Gusinde (1986). Although there could be some discussion in relation to the identification of various ethnic groups of the region (Gusinde 1986), the society that inhabited most of the area around the Beagle Channel in the nineteenth and early twentieth century were known historically as either Yamana or Yaghan (Gusinde 1986).

Fig. 2 Landscape from the Beagle Channel region from the Northern coast, near Lanashuaia site

According to the historical documents, shells provided a valuable source of raw material for production-consumption activities carried out by Yamana people. Accounts of the use of shell tools most frequently relate to their utility either as containers or as knives. For accomplishing the first purpose, the Yamanas took advantage of those species with the largest dimensions in the families *Mytilidae*, *Veneridae*, and *Volutidae*. There is documented use of marine shell as containers for the following:

- Cooking: according to Lovisato (1884) and Gusinde (1986), sometimes *Mytilidae* shells, such as *A. atra*, were used as containers for cooking small fish with pinniped or whale fat. The shell was placed on the fire, and the fish-fat mixture was covered with stones. Berries, such as strawberries, were mixed with fats or oils and cooked in shells over the fire.
- Melting fat: *Mytilidae* or *Volutidae* shells were placed on a hot stone or in the hot ashes. They would also have been used for collecting fat that dripped from the meat during roasting. This fat could be consumed directly or stored inside animal intestines (Bridges 1933; Gusinde 1986).

- Pigment processing: pigments with which the Yamana people painted their bodies were mixed with fat in large mussel shells, probably *A. atra* (Bridges 1897; Gusinde 1986; Koppers 1997; Lovisato 1884).
- Food and water containers: *Volutidae* shells were used to drink water (Bridges 1897; Bridges 1933; Gusinde 1986). Shells were also used to collect cambium "sap" from *Nothofagus* trees (Gusinde 1986).

There is also rich ethnographic information about complex knives, scrapers, and chisels made from shell being used for different activities, such as woodworking (Gusinde 1986; Hyades and Deniker 1891). These tools consisted of a large mussel shell (with a length of approximately between 100 and 120 mm), and a pebble serving as a handle. A piece of leather was used to join these two sections, with the addition of wood shavings or moss to adjust the handle of the knife/scraper (Fig. 3). This tool was used for different purposes as it was able to carry out precise and delicate tasks.

No evidence of manufacture or use modification was observed on the whole *A. atra* shells (Fig. 4) recovered from the Lanashuaia II archaeological site: the margins looked fresh and conserve all the distinctive features of the species, such as the growth lines. Consequently, we propose that they may have been used as containers (and not as knife-scrapers). Following an ethnoarchaeological perspective, lipid residue analysis was the most suitable method for testing this hypothesis. Four types of samples were analyzed: (1) the archaeological *A. atra* shells that may have been utilized, (2) the sediment that surrounded a specimen to assess the possible effects of contamination from the burial environment, (3) a group of *M. edulis* from the midden layer where the *A. atra* shell was recovered to compare the compositions of lipid residues extracted from different species, and (4) modern specimens of *A. atra* shells to determine the composition of natural lipid residues.

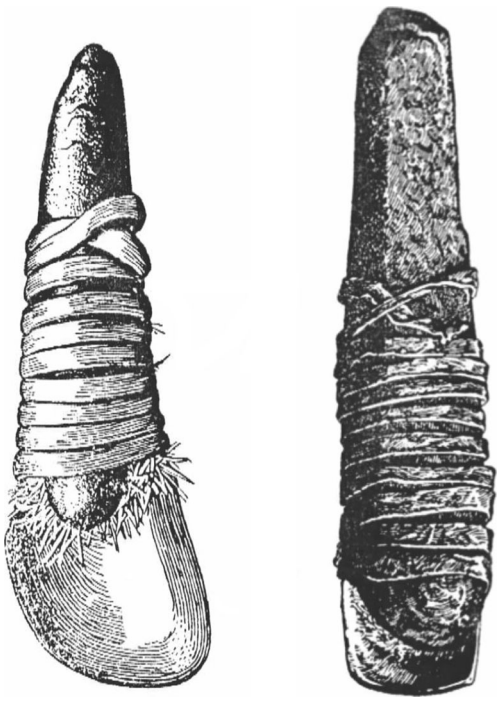

Fig. 3 Drawing of a shell knife/scraper (Gusinde 1986). Actual size of tool is ca. 12.75 cm×3.75 cm

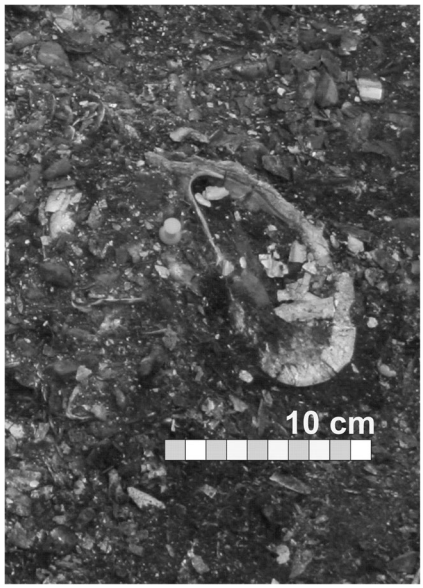

Fig. 4 *Aulacomya atra* shell from layer C20, Lanashuaia II (fieldwork season 2009)

Analyses of the midden sediment and modern *A. atra* were needed to determine whether or not the shell was actually used. If the lipid residues extracted from the archaeological *A. atra* and *M. edulis* shells resembled that of the adjacent midden sediment, this would suggest that the lipids arose from the depositional context. If the lipids extracted from the archaeological *A. atra* resembled those extracted from the degraded cooking residues of modern specimens, this would suggest that archaeological mollusk was cooked, and the shell was simply discarded after the flesh was eaten.

Material and methods

Lanashuaia is an archaeological locality on the isthmus that separates the inner and outer Cambaceres bays (see Fig. 1) on the northern coast of the Beagle Channel (Piana et al. 2000). A series of ring-shaped shell middens, evenly spaced in a linear distribution, lay along the shoreline next to the inner bay (Figs. 5 and 6). The on-going excavation of one of these structures, Lanashuaia II, began in 2009 (Briz et al. 2009).

Fig. 5 Cambaceres Interior Bay

The 55-m^2 area excavated to date (fieldwork seasons: 2009, 2010, and 2011) has revealed rich deposits that could be stratigraphically separated into different units according to shellfish size and species, level of shell preservation and thin lenses of pebbles and humus (Fig. 7).

Mussels dominate most of the layers, but limpets also occur in high frequencies; chitons and whelks are present in lower proportions. The shell midden layers were superimposed forming a ring structure around a central depression composed of humus deposits. Faunal remains also include sea lions (*Arctocephalus australis* and *Otaria flavescens*), guanacos (*Lama guanicoe*), whales (*Balaenoptera bonaerensis*), sea birds (*Phalacrocorax*, among others), and fishes. The lithic assemblage comprised flakes, cores, and retouched artifacts made on local raw materials. Bone tools such as harpoons, chisels, and awls were also recovered.

During the 2009 field season, two whole *A. atra* shells were found in a shell midden layer consisting mainly of large limpets (*Nacella* sp.), mussels (*M. edulis*) and abundant charcoal remains in a fine matrix of lime sediment. The *A. atra* shells each measured approximately 120 mm in length and 45 mm in width, and were the only examples of this species recovered from this stratigraphic unit (Fig. 8). An uncalibrated radiocarbon date on charcoal obtained from this layer yielded a date of 1385±25 years BP (CNA-590).

Fig. 6 Lanashuaia site with detail of the shell midden alignment in the beach of Bahía Cambaceres Interior

The species *A. atra* is a bivalve that it is mostly found in benthonic rocky areas, reaching a depth of 25 m; it can also be found in soft sediments or in seaweed banks (particularly those formed by *Macrocystis pyrifera* [(L.) C. Agardh]). At present, this species is found along the Argentinean Atlantic coast, from Tierra del Fuego and Patagonia to Buenos Aires province (Forcelli 2000; Gordillo 1995). It is common to find shells along beaches as well. Its relatively large size is note worthy because the average length of other species in the area is much smaller, about 85 mm for *M. edulis* (Forcelli 2000). *A. atra* shell is also harder than most other mussel species. These characteristics make it particularly useful as a tool or raw material for a tool.

As indicated above, two *A. atra* and *M. edulis* shells (that formed part of the archaeological deposit) were collected for analysis together with a sedimentary control sample directly associated with one of the *A. atra* shells (Table 1). If any of these archaeological *A. atra* shells were used as receptacles, such as spoons for melting fat, the residue extracted from the shell should differ in composition from a shell simply discarded after the cooked flesh was consumed. Modern *A. atra* specimens were collected from the same area and preserved by drying; reference cooking residues of shellfish were then prepared from them. Mollusks were first rehydrated in 50 mL of ultrapure water then steamed in a sealed beaker in a 350 °C oven for 1 h. After a cooling period of 30 min, the edible flesh was removed from the shell. In order to simulate the effects of oxidative decomposition over time, the shell was stored in an oven at 75 °C for a period of 60 days. The compositions of lipid residues extracted from archaeological shells were compared to the reference residues prepared from modern *A. atra* specimens.

Lipid analysis methods

Lipid extracts were analyzed using gas chromatography (GC), high temperature GC (HT-GC) (Evershed et al. 1990), and high temperature gas chromatography with mass spectrometry (HT-GC/MS) (Malainey et al. 2010). The residues were identified on the basis of fatty acid decomposition patterns of reference cooking residues (Malainey 2007; Malainey et al. 1999a, b, c), lipid distribution patterns, and through the presence of biomarkers (Dudd and Evershed 1998; Evershed 1993; Evershed et al. 1997, 2001; Malainey et al. 2010).

Lipids were extracted using a variation of the method developed by Folch et al. (1957). The shell and sediment samples were each placed in a 2:1 mixture, by volume, of chloroform and methanol (2×25 mL) and subjected to ultrasonication (2×10 min). Solids were removed by filtering the solvent mixture into a separatory funnel, and the lipid/

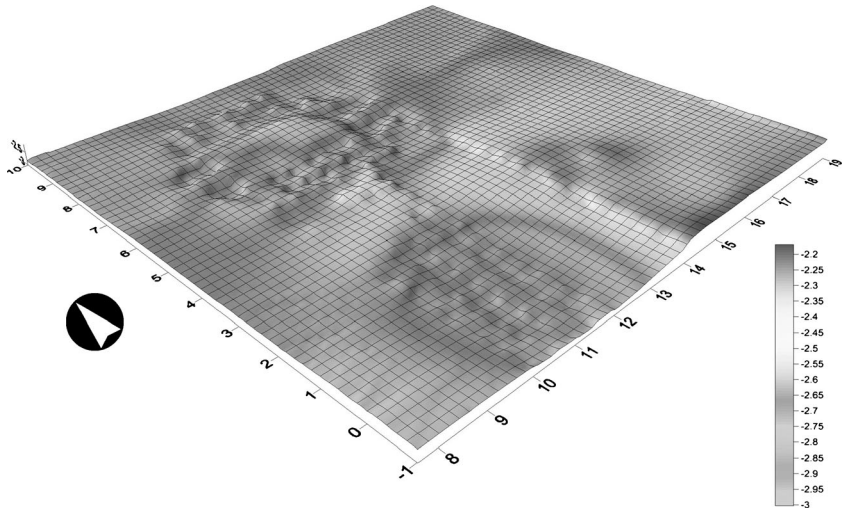

Fig. 7 Surface map of Lanashuaia II (2009, 2010, and 2011)

solvent filtrate was washed with 13.3 mL of ultrapure water. Once separation into two phases was complete, the lower chloroform-lipid phase was transferred to a round-bottomed flask and the chloroform removed by rotary evaporation. Any remaining water was removed by evaporation with 2-propanol (1.5 mL); 1.5 mL of chloroform-methanol (2:1, *v*/*v*) was used to transfer the dry total lipid extract to a screw-top glass vial with a Teflon®-lined cap. The sample was flushed with nitrogen and stored in a −20°C freezer.

Preparation of FAMES

A 400-μL aliquot of the total lipid extract solution was placed in a screw-top test tube and dried in a heating block under nitrogen. Fatty acid methyl esters (FAMES) were prepared by treating the dry lipid with 5 mL of 0.5 N anhydrous hydrochloric acid in methanol (68 °C; 60 min). Fatty acids that occur in the sample as di- or triglycerides are detached from the glycerol molecule and converted to methyl esters. After cooling to room temperature, 3.4 mL of ultrapure water was added. FAMES were recovered with petroleum ether (2.5 mL) and transferred to a vial. The solvent was removed by heat under a gentle stream of nitrogen; the FAMES were dissolved in either 75 μL (archaeological samples) or 200 μL (modern samples) of *iso*-octane then transferred to a GC vial with a conical glass insert.

Fig. 8 C20 layer during 2009 fieldwork season

Preparation of TMS derivatives

A 200-μL aliquot of the total lipid extract solution was placed in a screw-top vial and dried under nitrogen. Trimethylsilyl (TMS) derivatives were prepared by treating the lipid with 70 μL of *N,O*-bis (trimethylsilyl) trifluoroacetamide (BSTFA) containing 1 % trimethylchlorosilane, by volume (70ºC; 30 min.). The solvent was removed by heat under a gentle stream of nitrogen; the TMS derivatives were dissolved in 100 μL of hexane then transferred to a GC vial with a conical glass insert.

Solvents and chemicals were checked for purity by running a sample blank. Traces of contamination were subtracted from sample chromatograms. The relative percentage composition was calculated by dividing the integrated peak area of each fatty acid by the total area of fatty acids present in the sample. In order to identify residues on the basis of fatty acid composition, relative percentage compositions were determined first with respect to all fatty acids present in the sample (including very long chain fatty acids) (Table 1), and secondly, with respect to the ten fatty acids originally utilized in the development of the previously established identification criteria (C12:0, C14:0, C15:0, C16:0, C16:1, C17:0, C18:0, C18:1w9, C18:1w11, and C18:2) (Malainey 2007; Malainey et al. 1999b). High temperature gas chromatography and high temperature gas chromatography with mass spectrometry was used to further clarify the identifications.

Table 1 Sample descriptions and lipid composition of archaeological shell and midden sediment residues

Fatty acid	9SP 7		9SP 8		9SP 9		9SP 10	
	A. atra		*M. edulis*		*A. atra*		Midden sediment	
	Area	Rel%	Area	Rel%	Area	Rel%	Area	Rel%
C12:0	1,046	0.03	2,739	0.20	4,509	0.16	0	0.00
C14:0	19,655	0.50	14,571	1.07	48,842	1.70	10,014	1.80
C14:1	2,106	0.05	2,533	0.19	0	0.00	0	0.00
C15:0	22,175	0.57	8,933	0.66	37,113	1.29	7,989	1.44
C16:0	892,069	22.83	337,136	24.73	935,242	32.48	64,700	11.65
C16:1	76,298	1.95	18,195	1.33	46,716	1.62	20,599	3.71
C17:0	19,254	0.49	0	0.00	0	0.00	0	0.00
C17:1	0	0.00	4,655	0.34	8,049	0.28	0	0.00
C18:0	304,998	7.81	333,868	24.49	603,363	20.95	0	0.00
C18:1s	1,587,558	40.64	443,075	32.50	907,712	31.52	359,837	64.79
C18:2	734,811	18.81	171,774	12.60	283,693	9.85	92,219	16.61
C18:3s	107,978	2.76	25,758	1.89	0	0.00	0	0.00
C20:0	49,209	1.26	0	0.00	0	0.00	0	0.00
C20:1	15,880	0.41	0	0.00	0	0.00	0	0.00
C24:0	63,912	1.64	0	0.00	0	0.00	0	0.00
C24:1	9,834	0.25	0	0.00	4,370	0.15	0	0.00
Total	3,906,783	100.00	1,363,237	100.00	2,879,609	100.00	555,358	100.00
Biomarkers		β-Sitosterol, stigmasterol, cholesterol, dehydroabietic acid, azelaic acid		Azelaic acid		Cholesterol, stigmasterol		Cholesterol, β-sitosterol, stigmasterol
Peak ratios of C48, C50, C52, and C54 triacylglycerols (TAGS)		1:1.8:4.4:3.3, most similar to reference terrestrial mammals		2:1.6:2.6:1, most similar to the reference shellfish residue		1:3.5:9.4:9, strongly resembles reference terrestrial mammal		1:1.6:3.4:3.5, most similar to reference t errestrial mammal
Identification		High fat content		Moderate-high fat content		Moderate-high fat content		Very high fat content; lipid recovery comparatively low
Mass (g)		5.464		5.377		11.410		5.384
Cat. no./provenience		Cuad I12 C20		I111b C20		I111b C20		I111b C20

Gas chromatography analysis parameters

The GC analysis was performed on a Varian 3800 gas chromatograph fitted with a flame ionization detector connected to a personal computer. Samples were separated using a DB-23 fused silica capillary column (30 m×0.25 mm I.D.; J&W Scientific; Folsom, CA). An autosampler injected either a 1 μL (archaeological) or 3 μL (modern) sample using a split/splitless injection system. Hydrogen was used as the carrier gas with a column flow of 1.0 mL/min. Column temperature was held at 80 °C for 1 min then increased to 140 °C at a rate of 20 °C per minute. It was then programmed from 140 to 230 °C at 4 °C per minute. The upper temperature was held for 17 min. Chromatogram peaks were integrated using Varian MS Workstation® software and identified through comparisons with external qualitative standards (NuCheck Prep; Elysian, MN).

High temperature gas chromatography and gas chromatography with mass spectrometry

Both HT-GC and HT-GC/MS analyses were performed on a Varian 3800 gas chromatograph fitted with both a flame ionization detector and Varian 4000 mass spectrometer connected to a personal computer. For HT-GC analysis, the sample was injected onto a DB-1HT fused silica capillary column (15 m×0.32 mm I.D.; Agilent J&W; Santa Clara, CA) connected to the flame ionization detector, using hydrogen as the carrier gas. The column temperature was held at 50 °C for 1 min then increased to 350 °C at a rate of 15 °C per minute and held for 26 min. For HT-GC/MS analysis, samples were injected onto a DB-5HT fused silica capillary column (30 m× 0.25 mm I.D.; Agilent J&W; Santa Clara, CA) connected to the ion trap mass spectrometer in an external ionization configuration using helium as the carrier gas. After a 1-min hold

at 50 °C, the column temperature was increased to 180 °C at a rate of 40 °C per minute, then ramped up to 230 °C at a rate of 5 °C per minute, and finally increased to 350 °C at a rate of 15 °C per minute and held for 27.75 min. The Varian 4000 mass spectrometer was operated in electron-impact ionization mode scanning from m/z 50–700. Chromatogram peaks and MS spectra were processed using Varian MS Workstation® software and identified through comparisons with external qualitative standards (Sigma Aldrich; St. Louis, MO and NuCheck Prep; Elysian, MN), reference samples, and the National Institute of Standards and Technology (NIST) database.

Results

The compositions of lipid residues extracted from archaeological shell and midden sediment are presented in Table 1; the compositions of the degraded *A. atra* cooking residues extracted from the shell are presented in Table 2. The term *Area* represents the area under the chromatographic peak of a given fatty acid, as calculated by the Varian MS Workstation® software minus the solvent blank. The term *Rel%* represents the relative percentage of the fatty acid with respect to the total fatty acids in the sample. High temperature GC and GC/MS were used to verify the identification of the separated components and detect lipid biomarkers.

It must be understood that the identifications given do not necessarily mean that those particular foods were actually prepared because different foods of similar fatty acid composition and lipid content would produce similar residues. It is possible only to say that the material of origin for the residue was similar in composition to the food(s) indicated. High temperature gas chromatography and high temperature gas chromatography with mass spectrometry is used to further clarify the identifications.

Archaeological residues

Lipid residues were recovered from all archaeological shell and midden samples, but there were differences in their composition with respect to fatty acids, sterols, and triacylglycerols and relative amounts of fatty acids extracted. The amount of fatty acids recovered is of particular importance owing to differences in sample

Table 2 Relative percentage composition of cooking residues prepared from modern *Aulacomya atra* shell and saturated and monounsaturated fatty acids in fresh oyster

Fatty acid	Cooking residue from *Aulacomya atra* shell after 1 month oven storage	Cooking residue from *Aulacomya atra* shell after 2 months oven storage	Saturated and monounsaturated fatty acids in fresh oyster (from Ackman 1992)
C12:0	0.00	0.00	0.00
C14:0	4.01	4.40	7.16
C14:1	0.00	0.00	0.00
C15:0	0.85	0.93	0.00
C16:0	37.18	38.73	45.81
C16:1	11.72	11.89	6.95
C17:0	1.09	1.07	0.00
C17:1	0.52	0.00	0.00
C18:0	8.03	7.91	10.63
C18:1s	13.12	12.53	14.11
C18:2	3.71	3.15	3.48
C18:3s	1.00	0.91	0.00
C20:0	0.00	0.00	0.00
C20:1	5.60	5.84	6.95
C22:0	0.00	0.00	0.00
C22:1	8.95	8.64	4.91
C24:0	0.00	0.00	0.00
C24:1	3.27	3.05	0.00
Total	100.00	100.00	100.00
Lipid biomarkers	Cholesterol	Cholesterol	Not available
Peak ratios of C48, C50, C52, and C54 triacylglycerols (TAGS)	5.5:5.6:6.3:1	Not detected	Not available

surface area; the archaeological shell was intact, whereas the midden sediment consisted of loose particles. While all fatty acids were likely extracted from the sediment, this may not be true for the shell samples.

Residue 9SP 7 from archaeological *A. atra*

Residue 9SP 7, from fragments of *A. atra* shell, has a level of C18:1 isomers that exceeds 40 %. Foods known to produce similar residues include high fat nuts and seeds and the rendered animal fat. The animal sterol cholesterol and the plant sterols stigmasterol and β-sitosterol were all detected in the residue, indicating a combined animal and plant origin. Azelaic acid occurs as well as the diterpenoid, dehydroabietic acid, which indicates the presence of conifer products (Shackley 1982; Heron and Pollard 1988). Triacylglycerides (TAGs) were detected, and their levels increase with the numbers of carbons atoms from the C48 TAG to the C52 TAG then decrease slightly. As noted above, this pattern is most similar to that observed in the lipid residues of mammals and birds. The concentration of fatty acids in residue 9SP 7 was three times higher than that of the control residue 9SP 8, extracted from the *M. edulis* shell. The level of C18:2 is high in this residue, 18.81 %.

Gusinde (1986) indicated that shell receptacles were employed by the Yamana to mix pinniped or whale oil with either plant or animal foods. The oil was added in order to moisten and tenderize dried bird flesh, dried mushrooms, berries, and sardines prior to consumption. Based on the lipid composition of the extracted residue and faunal assemblage, a combination of sea lion fat and berries is a possible source.

The origin of the dehydroabietic acid is more intriguing as conifers do not occur in the region. Bridges (1897), Gusinde (1986), and Hyades and Deniker (1891) all indicate that Yamana people sucked the sap of the "notro" tree (*Embothrium coccineum* J.R. Forst. and G. Forst. 1775). According to Bridges (1933), during the summer the Yamana scraped and consumed a white, sweet substance that was under the bark of trees. Bridges (1897) stated the Yamana preferred the sap of the "lenga" tree (*Nothofagus pumilio* (P. et E.) Krasser). The sap and tree scrapings were gathered in another piece of bark or, as Gusinde (1986) reported, in a shell. Dehydroabietic acid is mainly produced by conifers in temperate regions; while it occurs in the smoke of conifers, it was not detected in the smoke of deciduous trees from tropical zones (Simonelt et al. 1993). Further research is required to determine if this or a structurally similar compound is biosynthesized by *N. pumilo* (a deciduous tree), *Embothrium coccineum* (J.R. Forst. and G. Forst. 1775) (an evergreen tree), or another locally available temperate zone species, such as Winteraceae trees (*Drimys winteri* J.R. Forst. and G. Forst. 1776).

Residue 9SP 8 from archaeological *M. edulis*

Residue 9SP 8, extracted from fragments of *M. edulis* shell, had a C18:1 isomer level of 32.50 % which is similar to the levels observed in residue 9SP 9 discussed below. The level of C18:0 in residue 9SP 8 is quite high, over 24 %, which suggests an animal origin, and cholesterol was detected in the residue. The plant sterol β-sitosterol was present; azelaic acid was also detected. TAGs occur in this residue, and the distribution pattern is consistent with that of a combined plant and animal residue. The level of the C52 TAG is highest, suggesting an animal residue; but the level of the C48 TAG is also elevated. The level of C18:2 is quite high in this residue, 12.60 %.

Residue 9SP 9 from archaeological *A. atra*

Residue 9SP 9, extracted from fragments of archaeological *A. atra* shell, has a C18:1 isomer level exceeding 31 %. The decomposed cooking residues of fat-rich plants, such as nuts and seeds, fatty mammals, and game birds are similar in composition. In particular, Texas ebony seeds, the fatty meat of medium-sized mammals (such as beaver) and the flesh of certain birds (such as grouse) also have similar levels of C18:1 isomers.

There is evidence that the residue is of both animal and plant origin. The level of C18:0 is quite high, about 21 %; the animal sterol cholesterol and the plant sterols stigmasterol and β-sitosterol are also present. Triacylglycerides (TAGs) were detected, and their levels increase with the number of carbons atoms from the C48 TAG to the C52 TAG then decrease slightly. This pattern of TAGs has been observed in the decomposed reference cooking residues prepared from mammals and birds, as well as archaeological lipid residues derived from mammals (Malainey et al. 2010). The level of the polyunsaturated fatty acid C18:2 is elevated in this residue, 9.85 %, which is likely due to the relatively young age of the site and cold environment.

Azelaic acid was detected; this short chain dicarboxylic acid is associated with the oxidation of unsaturated fatty acids (Regert et al. 1998). While often associated with plant materials, azelaic acid can be produced from mixtures of fatty acids obtained from fish and marine oil, as well as from animal fats and greases (Goeble et al. 1953). As such, locally available fish, birds, and marine mammals must be considered as possible sources. Although plant sterols were present, the elevated level of C18:0 and cholesterol together with the TAG distribution pattern indicate that lipids from animal sources are dominant in the residue. Albatross (*Diomedea exulans*, *D. crhysostoma*, *D. melanophrys*) is the most likely source of the residue. Several albatross bones were recovered from the same layer and very close to the *A. atra* shell. Because we were not able to obtain albatross flesh for analysis or locate a

publication that presents the fatty acid composition of its flesh, this hypothesis cannot be tested at this time.

Residue 9SP 10 from archaeological midden sediment

Residue 9SP 10 was extracted from a disaggregated sediment sample from C20 layer. The composition of the residue can be characterized by C18:1 isomer levels approaching 65 %. Similar residues are associated with the fresh, uncooked residues of nuts and seeds and fresh rendered fat of animals. Cholesterol, stigmasterol, and β-sitosterol were confirmed in the sediment residue, proving the presence of both animal and plant products in the midden sediment. Azelaic acid was also detected. TAGs were present, and their distribution is most similar to that of mammals and birds. It is important to note, however, that the concentration of lipids extracted from the sediment was very low compared to that extracted from fragments of *A. atra* shell. The concentration of fatty acids in the residue extracted from 5.384 g of loose sediment was 12 % (1/8th) of that in residue 9SP 7, extracted from 5.464 g of intact archaeological *A. atra* shell. The level of C18:2 was quite high in the residue extracted from the sediment, 16.61 %.

Degraded reference cooking residues

The composition of lipid residues extracted from the shells of modern *A. atra* after 1 and 2 months of oven decomposition are presented in Table 2. With respect to fatty acid composition, both of the resulting residues had levels of C18:1 isomers of about 13 %. Polyunsaturated fatty acids are highly unstable and rapidly degrade during cooking (thermal degradation) and oven storage (oxidative degradation). The remaining saturated and unsaturated fatty acids are more stable, so there is little difference in the fatty acid composition of the cooking residue after 1 or 2 months of oven storage. Although the reference cooking residues were prepared from mussels that were dried and rehydrated, it is likely that their compositions would not significantly differ from cooking residues prepared from fresh specimens. As shown in Table 2, the composition of degraded *A. atra* cooking residues compare favorably with the relative amounts of the more stable fatty acids found in oyster (recalculated from Ackman 1999). Only the animal sterol cholesterol was detected in the degraded *A. atra* cooking residues. Triacylglycerols occur in the degraded cooking residue after 1 month of oven storage but were not detected in the residue exposed to 2 months of oven storage. Levels of C48 and C50 TAGs were nearly identical; the level of C52 TAGs was marginally higher, but the level of C54 TAGs was low. The C48:C50:C52:C54 ratio of TAGs in the reference residue is 5.5:5.6:6.3:1.

Discussion

Production-consumption strategies including raw material management are salient aspects of hunter-gatherer archaeology. Temporal variations in such dimensions of social development are key elements to explain tendencies and changes in the evolution and historical development of hunter-gatherer societies. Nevertheless, poor preservation of organic remains is an inherent problem in many archaeological contexts and can make it difficult to achieve a deeper understanding of the factors that lead to social transformations. Consequently, the improvement of novel methodologies has a paramount importance to fulfill this gap. Following this reasoning, the implementation of lipid residue analysis opens a new avenue of research to detect biomarkers of past activities and to deal with the difficulties related to the identification of tools or consumption processes that have low visibility in the archaeological record.

Specifically, this study provides an insight into the implementation of lipids analysis to the archaeological contexts of the Beagle Channel. The preservation state of the archaeological residues is excellent; this is likely due to rapid burial and the cool environment. In this study, lipid residues extracted from shells recovered from the Lanashuaia II site were analyzed to determine if the previous hunter-fisher-gatherer occupants used the shells as tools or receptacles. In order to demonstrate this, it is necessary to consider first the possibility that they were not used as tools. If the shells were simply discarded after the flesh was consumed, the lipids retained in the shell should reflect those produced when the mollusk was cooked. The composition of lipids extracted from the archaeological shell should resemble that of the degraded cooking residues produced from modern *A. atra* specimen. The fatty acid composition of the degraded reference residue retained in the shell of cooked mollusks is characterized by levels of C18:1 isomers of about 13 % and conforms to the previously published criteria for fish, corn, and similar foods when relative fatty acid composition is calculated with respect to the ten fatty acids utilized in the development of the established identification criteria (Malainey 2007; Malainey et al. 1999b). The degraded *A. atra* cooking residues are generally similar in composition to the decomposed cooking residue of freshwater fish (Malainey 2007). As with the decomposed cooking residues of freshwater fish, the degraded *A. atra* cooking residues have elevated levels of C14:0 and C16:1 (Malainey 2007); levels of C20:1 and C22:1 are also quite high in the degraded *A. atra* cooking residues. Based on the distribution of more resilient fatty acids in fresh oyster reported by Ackman (1992), elevated amounts of all four of these fatty acids may be expected in well-preserved marine mussel residues.

In terms of fatty acid composition, the degraded reference cooking residue extracted from modern *A. atra* shell is very

different from those extracted from the archaeological shell and midden sediment. The level of C18:1 isomers of the two reference cooking residues is much lower than that observed in the archaeological residues. The archaeological shell residues did not include elevated levels of C14:0 or C16:1; the fatty acids C20:1 and C22:1 were not detected. While only cholesterol was detected in the reference cooking residues, both plant and animal sterols were detected in the archaeological *A. atra* shell and in the midden sediment; no sterols were detected in the archaeological *M. edulis* shell. With respect to the distribution of TAGs, the reference *A. atra* cooking residue differs in that it does not resemble that of terrestrial mammals, plant, or a plant and animal combination. The lipid composition of the reference *A. atra* cooking residue does not resemble either the residues extracted from archaeological shell or the midden sediment.

Another possibility is that the lipids in the shells arose from the depositional context. This hypothesis was tested by analyzing the lipids that occur in the adjacent sediment. Lipids were extracted from midden sediment in direct contact with the *A. atra* shell from which residue 9SP 9 was extracted; the sediment was also in close proximity to the *M. edulis* shell from which residue 9SP 8 was extracted. The compositions of the residues extracted from the archaeological shells differed from the midden sediment in many aspects. Both archaeological shell residues were characterized by C18:1 isomer levels of about 32 % and similar with respect to the distribution of all fatty acids. By contrast, the residue extracted from midden sediment residue had C18:1 isomer levels of almost 65 % with a completely different distribution of fatty acids. No sterols were detected in the residue extracted from the *M. edulis* residue; both animal and plant sterols were detected in the *A. atra* residue and the midden sediment. The distribution of TAGs in each of the archaeological shells and the midden sediment was unique. Another consideration is that the lipid recovered from the midden sediment was a small fraction of that recovered from the intact archaeological shells. This is of particular importance owing to differences in sample surface area; the archaeological shell was not crushed prior to extraction, whereas the midden sediment was broken into small particles. The recovery of fatty acids from the sediment may have been more complete than from the shell. If the shell lipids were absorbed from the depositional environment, one would expect more fatty acids to have been recovered from the sediment than from the archaeological shell on a per gram basis. The opposite is true. For these reasons, we conclude that it is unlikely that lipids in the archaeological shell represent contamination from burial environment. This finding is consistent with the work of Condamin et al. (1976) and Heron et al. (1991) who found no transfer of lipids between archaeological material and the surrounding soil.

Ethnographic accounts show the Yamana valued the relatively large *A. atra* shells and employed it as a food container or tool. Based on the amount and composition of lipid recovered, the archaeological *A. atra* shell from which residue 9SP 7 was extracted may have been used as a receptacle in which to melt fat, like a spoon. Ethnographic accounts even describe how berries were sometimes added to the melted fat (Gusinde 1986). On a per gram basis, three times more fatty acids were extracted from this *A. atra* shell than from the *M. edulis* shell; eight times more fatty acids were extracted from this *A. atra* shell than the midden sediment. The presence of plant and animal sterols in both archaeological *A. atra* residues and dehydroabietic acid in one suggests that both mussel shells may have been used for plant processing. Azelaic acid, the decomposition product of unsaturated fatty acids, was detected in one archaeological *A. atra* shell and the archaeological *M. edulis* shell. Given the coastal setting and the abundance of marine resources, unsaturated fatty acids from locally available fish or marine mammals must be considered as the probable source. There are no local plants that produce seeds that are worth consuming (e.g., cereals or spices) in the region. Berries, which are known to have been consumed, were eaten whole.

Conclusions

We believe that the evidence supports our interpretation of the whole *A. atra* shells recovered from Lanashuaia II as tools used by the former inhabitants of the site. In terms of quantity, substantially more fatty acids were recovered from the archaeological shells than from the associated midden sediment, which discounts the possibility of contamination from the burial environment. The residue extracted from one of the *A. atra* shells yielded three times more than the residue extracted from a *M. edulis* shell. In terms of composition, both archaeological *A. atra* residues differed from the residue extracted from the *M. edulis* shell in that sterols from both plant and animal sources were detected in the former. The distribution of TAG peaks in the archaeological *A. atra* residues resembled that observed in the cooking residues of terrestrial mammals, whereas the distribution in the *M. edulis* shell residue was most similar to that of the degraded mollusk cooking residue we prepared. Differences between the composition of the ancient and reference *A. atra* residues seem to relate to the use of the archaeological shell as a tool, likely a container in which animal fat was melted and possibly as a spoon in which sap was collected. This is consistent with existing ethnographic information indicating the Yamana selected the relatively large and hard *A. atra* shells for use as receptacles.

The ethnoarchaeological approach adopted in this research has allowed us to empirically test the use of mollusks as food containers, a practice acknowledged in ethnographic sources, but had not be already proven in the archaeological

record. Ethnoarchaeology not only provided the general dataset to build the hypothesis but also lead the selection, adjustment, and improvement of the accurate method for undertaking this study. Thus, the temporal depth of this practice was assessed: the data presented here have showed that the use of *A. atra* as tools for gathering grease, at least can be dated back to *circa*. 1,000 BP. Consequently, this study offers novel information about temporal trends in hunter-fisher-gathering strategies.

Acknowledgements This research was supported by The Wenner-Gren Foundation for Anthropological Research (Project: "Social aggregation: a Yámana Society's short term episode to Analyse Social Interaction"), Ministerio de Ciencia e Innovación, Spain (Project: "Marcadores Arqueológicos de Relaciones Sociales: etnoarqueología de cazadores-recolectores en el Canal Beagle"-HAR2009-06996), and Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina (Project: "Procesos de agregación social entre las sociedades cazadoras-recolectoras del canal Beagle: nuevas metodologías de análisis"-PIP 0706). Lanashuaia is located within the boundary of Estancia Harberton (Tierra del Fuego, Argentina), we wanted to thank the Goodall family, especially to Dr. Natalie Goodall and the staff of Acatushum Museum. We are also grateful to Lorena Salvatelli, Adriana Lacrouts, Marina Iwanova, and Nélida Pal, and to Bernardo Rondelli for his help with cartographic data. We thank the anonymous reviewers for their suggestions for improving this paper.

References

Ackman RG (1992) Fatty acids in fish and shellfish. In: Chow CK (ed) Fatty acids in foods and their health implications. Marcel Dekker, New York, pp 169–184

Álvarez E (2008) The use of *Columbella rustica* (class: Gastropoda) in the Iberian Peninsula and Europe during the Mesolithic and the Early Neolithic. In: Hernández M S and Soler López J A (eds) IV Congreso del Neolítico Peninsular. Museo Arqueológico de Alicante-Diputación de Alicante, Alicante, II, pp. 103–111.

Álvarez M, Briz I, Balbo A, Madella M (2011) Shell middens as archives of past environments, human dispersal and specialized resource management. Quat Int 239(1–2):1–7

Balbo AL, Madella M, Vila A, Estévez J (2010) Micromorphological perspectives on the stratigraphical excavation of shell middens: a first approximation from the ethnohistorical site Tunel VII, Tierra del Fuego (Argentina). J Archaeol Sci 37:1252–1259

Bridges T (1897) An account of Tierra del Fuego (Fireland) its natives and their languages. Ms.

Bridges T (1933) Yamana-English, a dictionary of the speech of Tierra del Fuego. Hestermann F-Gusinde M Eds., Mödling

Briz I (2010) Etnoarcheologia: che cosa, come, verso dove? Quaderni di Thule IX 549–559

Briz I, Álvarez M, Zurro D and Caro J (2009) Meet for lunch: a new ethnoarchaeological project. *Antiquity* 083(322), http://www.antiquity.ac.uk/projgall/briz322/. Accessed 1 December 2013.

Briz I, Álvarez M, Balbo A, Zurro D, Madella M, Villagrán X, French C (2011) Towards high-resolution shell midden archaeology: experimental and ethnoarchaeology in Tierra del Fuego (Argentina). Quat Int 239(1–7):125–134

Buc N, Silvestre R, Loponte D (2010) What about shells? Analysis of shell and lithic cut-marks. The case of the Paraná wetland (Argentina). Munibe-Supl 31:252–261

Clemente I (1997) Los Instrumentos líticos de Túnel VII: una aproximación etnoarqueológica. Treballs d'Etnoarqueologia, 2, UAB-CSIC, Madrid.

Condamin J, Formenti, F, Metais MO, Michel M, Blond P (1976) The application of gas chromatography to the tracing of oil in ancient amphorae. Archaeometry 18:195–201

Cristiani E, Lemorini C, Martini F, Sarti L (2005) Proceedings of the 4th meeting of the ICAZ Worked bone Research Group at Tallinn. Scrappers of Callista chione from Grotta del Cavallo (Middle Paleolithic cave in Apulia): evaluating use-wear potential. In: Luik H, Chayke AM, Batey CE, Lougos L (eds) From hooves to horns, from mollusc, to mammoth. Manufacture and use of bone artefacts from prehistoric times to the present. Tallinn Book Printers Ltd, Muinasaja Teadus, 15, Tallinn, pp 319–324

Croes DR (1997) The North-Central cultural dichotomy on the Northwest Coast of North America: its evolution as suggested by wet-site basketry and wooden fish-hooks. Antiquity 71(273):594–615

Cuenca D, Gutiérrez I, Clemente I (2011) The use of mollusc shells as tools by coastal human groups. The contribution of ethnographical studies to research on Mesolithic and early Neolithic technologies in Northern Spain. J Anthropol Res 67:77–102

D'Errico F, Vanhaeren M, Wadley L (2008) Possible shell beads from the Middle Stone Age layers of Sibudu Cave, South Africa. J Archaeol Sci 35(10):2675–2685

Douka K, Spinapolice EE (2012) Neanderthal shell tool production: evidence from Middle Palaeolithic Italy and Greece. J World Prehistory 25(2):45–79

Dudd SN, Evershed RP (1998) Direct demonstration of milk as an element of archaeological economies. Science 282:1478–1481

Estévez J, Vila A (1996) Etnoarqueología: el nombre de la cosa. In: Encuentros en los conchales fueguinos. Treballs d'Etnoarqueologia, 1, CSIC-UAB, Madrid-Barcelona, pp 17–23

Estévez J, Piana E, Schiavini A, Juan-Muns N (2001) Archaeological analysis of shell middens in the Beagle Channel, Tierra del Fuego Island. Int J Osteoarchaeol 11:24–33

Evershed RP (1993) Biomolecular archaeology and lipids. World Archaeol 25(1):74–93

Evershed RP, Heron C, Goad LJ (1990) Analysis of organic residues of archaeological origin by high temperature gas chromatography and gas chromatography-mass spectroscopy. Analyst 115:1339–1342

Evershed RP, Mottram HR, Dudd SN, Charters S, Stott AW, Lawrence GJ, Gibson AM, Conner A, Blinkhorn PW, Reeves V (1997) New criteria for the identification of animal fats in archaeological pottery. Naturwissenschaften 84:402–406

Evershed RP, Dudd SN, Lockheart MJ, Jim S (2001) Lipids in archaeology. In: Brothwell DR, Pollard AM (eds) Handbook of archaeological sciences. Wiley, New York, pp 331–349

Folch J, Lees M, Sloane-Stanley GH (1957) A simple method for the isolation and purification of lipid extracts from brain tissue. J Biol Chem 191:833

Forcelli DO (2000) Moluscos magallánicos. Guía de moluscos de Patagonia y sur de Chile. Vázquez Mazzini Eds, Buenos Aires

Goeble C G, Brown A C, Oehlschlaeger H F and Rolfes R P (1953) Method of making azelaic acid. United States Patent No. 2813113. Issued November 12, 1957.

Gordillo S (1995) Moluscos australes. Introducción al conocimiento de los bivalvos y caracoles de las costas del canal Beagle, Tierra del Fuego. Zagier & Urruty Ed, Buenos Aires

Gusinde M (1986[1937]) Los Indios de Tierra del Fuego, T III. Yamana - La vida económica. Centro Argentino de Etnología Americana. Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires.

Heron C, Pollard AM (1988) The analysis of natural resinous materials from Roman amphoras. In: Slaterand EA, Tate JO (eds) Science and Archaeology Glasgow 1987: Proceedings of a Conference on the Application of Scientific Techniques to Archaeology, Glasgow,

1987. British Archaeological Reports, British Series, 196(ii), Archaeopress, Oxford, pp 429–447
Heron C, Evershed RP, Goad LJ (1991) Effects of migration of soil lipids on organic residues associated with buried potsherds. J Archaeol Sci 18(6):641–659
Hyades PD, Deniker J (1891) Mission Scientifique du Cap Horn 1882–1883. Anthropologie et Ethnographie. Ministères de la Marine et de l'Instruction Publique. Gauthier-Villars et fils, Paris
Köppen W (1936) Das geographische System der Klimate. Handbuch der Klimatologie, Bd. 1, Teil C, Berlin
Koppers W (1997[1924]) Entre los Fueguinos. Ediciones de la UMAG, Punta Arenas.
Körber-Grohne U (1988) Microscopic methods for identification of plant fibres and animal hairs from the Prince's tomb of Hochdorf, Southwest Germany. J Archaeol Sci 15:73–82
Lammers YM (2008) Tracing traces from present to past. A functional analysis of pre-Columbian shell and stone artefacts from Anse à la Gourde and Morel, Guadeloupe, FWI. Leiden University Press, Leiden
Lovisato D (1884) Sulla collezione etnografica della Terra del Fuoco illustrata dal Dott. Colini Boll della Società Geogr Ital XXI:719–724
Malainey ME (2007) Fatty acid analysis of archaeological residues: procedures and possibilities. In: Barnard H, Eerkens JW (eds) Theory and practice of archaeological residue analysis. British Archaeological Reports, International Series, 1650. Archaeopress, Oxford, pp 77–89
Malainey ME, Przybylski R, Sherriff BL (1999a) The fatty acid composition of native food plants and animals of Western Canada. J Archaeol Sci 26(1):83–94
Malainey ME, Przybylski R, Sherriff BL (1999b) The effects of thermal and oxidative decomposition on the fatty acid composition of food plants and animals of Western Canada: implications for the identification of archaeological vessel residues. J Archaeol Sci 26(1):95–103
Malainey ME, Przybylski R, Sherriff BL (1999c) Identifying the former contents of Late Precontact Period pottery vessels from Western Canada using gas chromatography. J Archaeol Sci 26(4):425–438
Malainey M E, Innes P J and Figol T (2010) Taking a second look: results of the re-analysis of archaeological lipid residues from North America and beyond. Communication presented at the 75nd Annual Meeting of the Society for American Archaeology, St. Louis, MO.
Mameli L, Estévez J (2004) Etnoarqueología de aves: el ejemplo del extremo sur americano. Treballs d'Etnoarqueologia, 5, CSIC, Madrid
Mansur M E and Clemente I (2009) ¿Tecnologías invisibles? Confección, uso y conservación de instrumentos de valva en Tierra del Fuego. In: Oliva F de Grandis N and Rodríguez J (eds) Arqueología argentina en los inicios de un Nuevo Siglo. Publicación del XIV Congreso Nacional de Arqueología Argentina, 2. Laborde Libros, Rosario, pp. 359–368.
Orquera LA (1996) Túnel VII: la estratigrafía. In: Estévez J, Vila A (eds) Encuentros en los conchales fueguinos. Treballs d'Etnoarqueologia, 1, CSIC-UAB, Madrid-Barcelona, pp 83–103
Orquera LA, Piana EL (1992) Un paso hacia la resolución del palimpsesto. In: Borrero LA, Lanata JL (eds) Análisis espacial en la arqueología patagónica. Ed. Ayllu SRL, Buenos Aires, pp 21–52
Orquera LA, Piana EL (1999) Arqueología de la región del canal Beagle. Sociedad Argentina de Antropología, Buenos Aires
Orquera LA, Piana EL (2000) Composición de los conchales de la costa del Canal Beagle (Tierra del Fuego, República Argentina)-Primera parte. Relac Soc Argent Antropología XXV:249–274
Orquera LA, Legoupil D, Piana EL (2011) Littoral adaptation at the southern end of South America. Quat Int 239(1–2):61–69
Piana EL, Estévez J (1996) Confección y significación de las industrias ósea y malacológica en Túnel VII. In: Estévez J, Vila A (eds) Encuentros en los conchales fueguinos. Treballs d'Etnoarqueologia 1, CSIC-UAB, Madrid, pp 239–259
Piana EL, Estévez J, Vila A (2000) Lanashuaia: un sitio de canoeros del siglo pasado en la costa norte del Canal Beagle. In: Gómez J (ed) Desde el pais de los Gigantes. Perspectivas arqueológicas en Patagonia. Actas de las Cuartas Jornadas de Arqueología de la Patagonia. Universidad Nacional de la Patagonia Austral, II, Río Gallegos, pp 455–469
Regert M, Bland HA, Dudd SN, van Bergen PF, Evershed RP (1998) Free and bound fatty acid oxidation products in archaeological ceramic vessels. Philos Trans R Soc Lond 265(1409):2027–2032
Salas K (2007) Estudio tecnológico de 13 collares etnográficos patagónicos. Magallania 35(1):33–41
Samuels ESR (1991) Ozette archaeological project research reports. Volume 1. House structure and floor midden, reports of investigations, 63. Department of Anthropology, Washington State University. Pullman and National Park Service, Pacific Northwest Regional Office, Seattle
Shackley M (1982) Gas chromatographic identification of a resinous deposit from a 6th century storage jar and its possible identification. J Archaeol Sci 9:305–306
Simonelt BRT, Rogge WF, Mazurek MA, Standley LJ, Hildemann LM, Cass GR (1993) Lignin pyrolysis products, lignans and resin acids as specific tracers of plant classes in emissions from biomass combustion. Environ Sci Technol 27:2533–2541
Szabó K (2008) Shell as a raw material: mechanical properties and working techniques in the tropical Indo-West Pacific. Archaeofauna 17:125–138
Szabó K, Adam B, Bellwood P (2007) Shell artefact production at 32.000–28.000 BP in Island Southeast Asia. Thinking across media? Curr Antropol 48(5):701–723
Tivoli A (2010) Exploitation of bird resources among prehistoric seanomad societies of the Beagle Channel region, southern South America. Before Farming 2:1–12
Toth N, Woods M (1989) Molluscan shell knives and experimental cutmarks on bones. J Field Archaeol 16:250–255
Vellanoweth RL, Lambright MR, Erlandson JM, Rick TC (2003) Early New World maritime technologies: sea grass cordage, shell beads, and a bone tool from Cave of the Chimneys, San Miguel Island, California, USA. J Archaeol Sci 30:1161–1173
Verdún E (2010) Molluscs as sedimentary components. Another perspective of analysis. Munibe-Supl 31:294–301
Verdún E (2011) El consum de mol·luscs en societats caçadores-recol·lectores de Tierra del Fuego (Argentina). Dissertation, Universitat Autònoma de Barcelona
Verdún E, Briz I, Camarós E, Colonese AC, Estévez J, Zurro D (2010) Metodología de excavación y análisis de concheros: experiencias acumuladas después de 20 años de estudios etnoarqueológicos en la costa norte del Canal Beagle (Tierra del Fuego, Argentina). Férvedes 6:25–30
Vigie B, Courtin J (1986) Les outils sur coquilles marines dans le Neolithique du midi de la France. Mesogée Bull Muséum Hist Nat Marseille 46:51–61
Vigie B, Courtin J (1987) Le probleme des coquillages a bord dentele dans la prehistoire du midi de la France. Mesogee Bull Muséum Hist Nat Marseille 47:93–98
Whelchel DL (2005) Ozette archaeological project research reports, vol III, Ethnobotany and Wood Technology. Northwest Regional Office, WSU Department of Anthropology Reports of Research, 68. National Park Service, Seattle
White R (2007) Systems of personal ornamentation in the Early Upper Palaeolithic: methodological challenges and new observations. In: Mellars P, Boyle K, Bar-Yosef O, Stringer C (eds) Rethinking the human revolution. New behavioural and biological perspectives on the origin and dispersal of modern humans. McDonald Institute for Archaeological Research, Cambridge, pp 287–302
Zangrando AF (2009) Historia evolutiva y subsistencia de cazadores-recolectores marítimos de Tierra del Fuego. Sociedad Argentina de Antropología, Buenos Aires
Zubimendi MA (2010) Malacological artifacts in Argentine Patagonia. Munibe-Supl 31:262–270

Zurro D (2011) Ni carne ni pescado (consumo de recursos vegetales en la Prehistoria): Análisis de la variabilidad de los conjuntos fitolitológicos en contextos cazadores-recolectores. Dissertation, Universitat Autònoma de Barcelona

Support for the residue analysis program was provided by the Canada Foundation for Innovation (CFI) New Opportunities and CFI-Canada Research Chair Infrastructure funds as well as the Canada Research Chair program, the Social Sciences and Humanities Research Council and the Brandon University Research Council.