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Fish and plants: The "hidden" resources in the archaeological record of the North–central Patagonian coast (Argentina)

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ABSTRACT

Archaeological research conducted from 1990 on the North–central Patagonian coast showed certain discrepancies between the archaeofaunal and the human stable isotopic record. In general, zooarchaeological studies indicated that most faunal remains consisted of guanacos and mollusks, followed by pinnipeds, and small mammals, birds, and fish in very low proportions. Unexpectedly, stable isotopes (^{13}C and ^{15}N) from human skeletal samples indicated that all individuals' diet included not only sea resources of high trophic level in variable proportions, but also terrestrial plants. Therefore, the need arose to investigate these differences, especially in regards to the less documented resources in the archaeological record: fish and plants. In this paper, we present the results of diverse methodological approaches used to inquire into the role these resources would have played among the native populations of the area through time. The methods include archaeofaunal and isotope analyses, gas chromatography in ceramic sherds, oral health in human samples, a distributional record of fishing and plant processing technology, and actualistic studies that explore the impact of post-depositional processes on the fish record.

The results indicate that these resources were more important in the subsistence of the native populations of the study area than what was estimated a decade ago. However, plants seem to have been exploited in a higher systematic manner than fish due to the fact its presence was determined in most samples analyzed with stable isotopes and gas chromatography. For its part, fish remains were found only in some zooarchaeological assemblages and in fifty percent of the organic residues in pottery samples. The integrity of the ichthyoarchaeological record may have been altered by post-depositional processes and as well by cultural practices such as milling and processing in ceramic containers.

1. Introduction

Before 1980, the limited archaeological record for the arid Atlantic coast of Patagonia indicated that this region was first occupied from 3000 BP by hunters who usually lived on the inland plateaus, and occasionally or in certain seasons visited the littoral habitat (Orquera and Gómez Otero, 2007). At that time it was accepted that these populations fed preferably on guanacos and other terrestrial prey but took little advantage of the vegetable resources and the food provided by the sea, especially fish.

This record coincides with the ethnographic image built by travelers and chroniclers from the XVI century, who reported that guanacos, rheas, and also horses during equestrian times (after XVII century), were the main prey of the Patagones or Tehuelches (Casamiquela, 1983; Martinic, 1995). Concerning fish exploitation, not only is there no mention of fishing on the Patagonian coast, but several travelers emphasized that natives were not interested in these resources and as well ignorant of how to obtain them. There are more references about plant foods, but in general they show that their consumption was not frequent and regular, but rather occasional or seasonal. For the pre-equestrian period, Pigafetta (1970 [1520] and Vehedor (1866 [1535]) reported the intake of wild herbs, sweet roots or tubercles; some of them toasted and/or minced to obtain flour. Pigafetta (1970: 23) also observed the presence of a "white powder" inside a ceramic container in San Julián Bay. For the equestrian period, the reports of several travelers, colonial officials and naturalists improved the list of wild plants profited by the Patagonian natives (synthesis in Williams, 1979): roots, tubercles, thistles, water-cress, celeries, green

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vegetables, berries, seeds, the husks of diverse *algarrobos* (carob trees), and mushrooms. Moreover, at this time the Tehuelches' diet also included processed carbohydrates obtained by trade with the colonial settlers or with the European navigators that occasionally landed at the Atlantic shore. Yerba mate, tobacco, sugar, rice, beans, flour, cookies, and alcoholic drinks, were the foods most frequently requested by natives (Palermo, 1991; Martinic, 1995).

The advance of archaeological investigations along the coast of Argentina gave new knowledge which challenged that widespread vision (Cruz and Caracotche, 2006; Orquera and Gómez Otero, 2007): this environment had been used since the Middle Holocene and the marine resources, particularly mollusks and pinnipeds, were exploited with variable intensity according to the different coastal areas. In the case of the North–central coast (Gómez Otero, 2006), the radiocarbon record determined that human occupations began at least by 7400 BP, occurring in all seasons and in different manners. A diversity of sites were registered which included different functions and duration (*sensu* Binford, 1980), such as residential and temporary camps, locations and human burials. The first archaeofaunal studies indicated that the majority of the fauna consisted of guanacos and mollusks, followed by pinnipeds, and then small mammals, birds and fish in lower proportions. Subsequently, an analysis of stable isotopes (^{13}C and ^{15}N) from nine human skeletal samples of the Late Holocene (Gómez Otero et al., 2000) showed unexpected results: most of the individuals' diet included not only plants and marine resources, but more substantially in some individuals, the percentage of marine fauna of high trophic level exceeded 50% (Gómez Otero, 2007). With respect to the technological record, the presence of fishing weights, milling artifacts and ceramics in several sites suggested that there were exploitation and processing of fish and/or carbohydrates (Gómez Otero, 2006; Schuster, 2012). Due to these facts, the need arose to investigate these discrepancies between the archaeofaunal, isotopic and technological data, especially in regards to the less documented resources: fish and plants. The main goal of the present work was to evaluate the role accomplished by fish and plants in the subsistence of the native populations of the study area through time. This would allow a more complete assessment of subsistence and spatial organization.

In order to assist in answering and discussing this objective the search was focused, on one side, to recognize direct and indirect evidence of exploitation of these resources, and to evaluate the impact of post-depositional processes on the fish record. Therefore, diverse analyses were carried out: new archaeofaunistic studies; carbon and nitrogen isotopes analyses and gas chromatography of organic residues in ceramics potsherds (Schuster, 2012; Gómez Otero et al., 2014); distributional studies of technology related to the fish and plants obtaining and processing; oral health analyses to determine the presence of caries in human remains, and finally, actualistic taphonomy on experimental fish assemblages (Svoboda and Moreno, 2014).

2. Environmental setting

The study area extends between 42° S and 43° 15′ S – 63° 35′ and 65° 03′ W (Fig. 1). The coastal landscape is comprised of a series of Cenozoic plateaus that do not rise above 110 m a.s.l. In terms of bathymetry, the area is wide and with a smooth relief; during

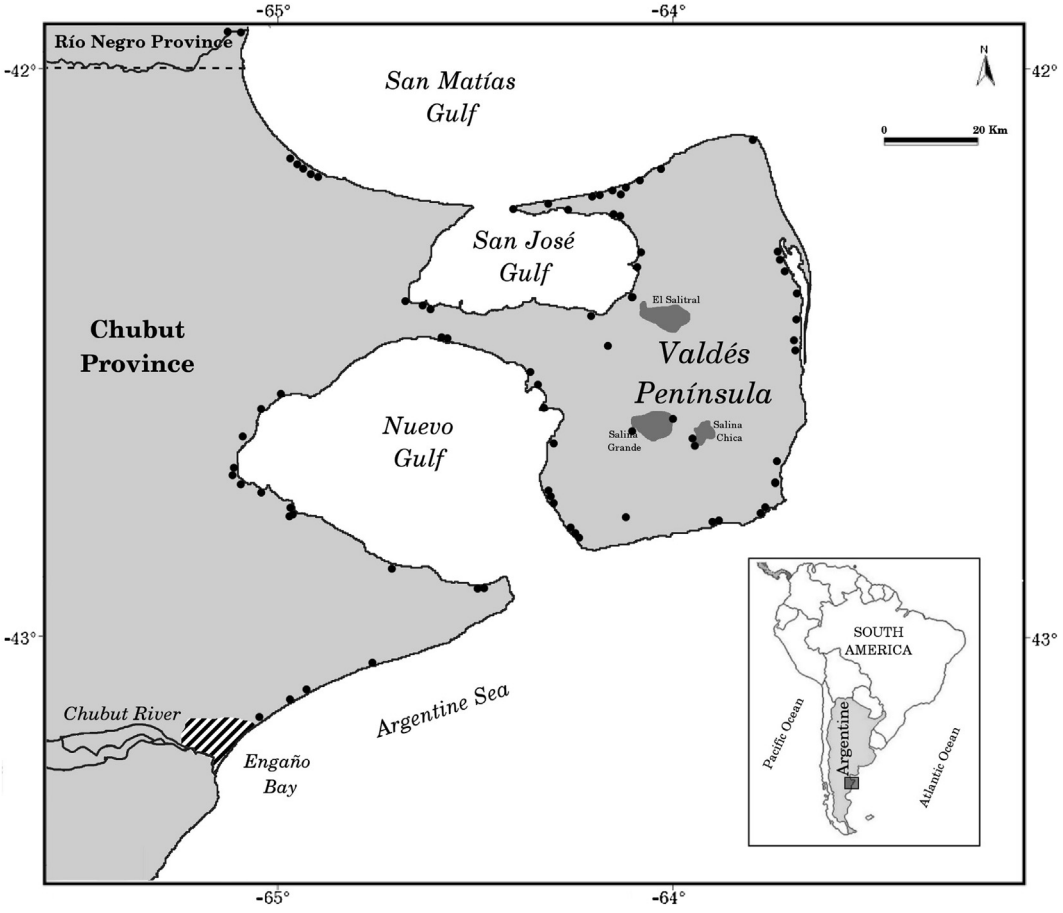

Fig. 1. Study area indicating locations of the archaeological sites.

normal low tides, large intertidal areas remain exposed, allowing mollusks and other invertebrates to be collected. The climate is temperate arid, with an annual mean temperature of 13 °C, average mean annual precipitation around 200 mm and strong winds (Beeskow et al., 1987). The only permanent fresh-water sources are the Chubut River and the springs from the three large salinas in the center of the Valdés peninsula.

The predominant plant formation is the steppe shrub, the main carbohydrate source provided by *Arjona tuberosa* (macachín), *Condalia microphilla* (piquillín), cacti of genus *Opuntia* and two species of *Prosopis* (alpataco and algarrobillo). In regards to terrestrial animals, the most important ones in terms of body size and food quality are *Lama guanicoe* (guanaco) and *Pterocnemia pennata* (choique), the lesser Patagonian rhea. Felids, canids, the Patagonian hare, two species of armadillos and diverse small rodents are also available in the area.

The marine fauna offers a variety of invertebrates (mollusks, crustaceans) and vertebrates (fish, birds, mammals). Mollusks are represented by diverse gastropods and bivalves as *Aulacomya atra* (Magellan mussel), *Mytilus edulis* (blue mussel), *Venus antiqua* (clam), and *Chlamys tehuelcha* (scallop). Among vertebrates, the regional marine fish correspond to the transitional zone of both Magallanic and Argentinean biogeographic provinces. The most relevant littoral species are *Eleginops maclovinus* (Patagonian blenny), *Odonthestes* spp. (silver side), *Seriolella porosa* (silver warehou), *Percophis brasiliensis* (Brazilian flathead), *Callorhynchus callorhynchus* (elephant fish), and diverse species of Rajidae (skate) and Trikidae (shark). On the rocky shores it is possible to capture reef fish such as *Acanthistius patachonicus* (Argentine sea bass), *Sebastes oculatus* (Patagonian redfish), *Patagonotothen* spp. (nototenias) *Polyprion anemericanus* (wreckfish) and *Pinguipes brasilianus*, *Pomatomus saltatrix*, *Pseudopercis semifasciata* (all of them sandperch). The principal marine birds are *Spheniscus* spp. (penguins) and *Phalacrocorax* spp. (cormorants), while the sea mammals include pinnipeds (*Otaria flavescens*, *Mirounga leonina*) and cetaceans (*Eubalaena australis*, *Orcinus orca*). The Chubut River mouth provides *Percichthys* spp. (perches), ducks, swans, and also *Myocastor coypus* (coipo), a large rodent that lives in colonies associated with rivers, creeks, lakes, and sloughs.

The preservation and visibility of the archaeological record in the littoral of Atlantic Patagonia in general is often irregular because of the highly dynamic environment which has occurred since the Pleistocene–Holocene transition (Kokot, 2004). Firstly, the earliest coastal sites might have been submerged or destroyed due to the Holocene sea level variations. Secondly, most sites are currently on the surface of sandy environments and show clear evidence of intense aeolian and hydric erosion as well as other post-depositional processes, which include human activities (Fig. 2). In these sites all remains are widespread and mingled, forming palimpsests. Also established is the presence of thin and isolated, stratified, shellfish layers in dunes and alluvial silts. However, no shell mounds have yet been found.

3. Materials and methods

3.1. Ichthyoarchaeological record and the actualistic studies

Seventy eight faunal assemblages were analyzed (Gómez Otero, 2006). Fish bones were recovered in stratified small samples, using a 1.3 mm screen mesh. The sample size was 0.50 m or 1 m each side,

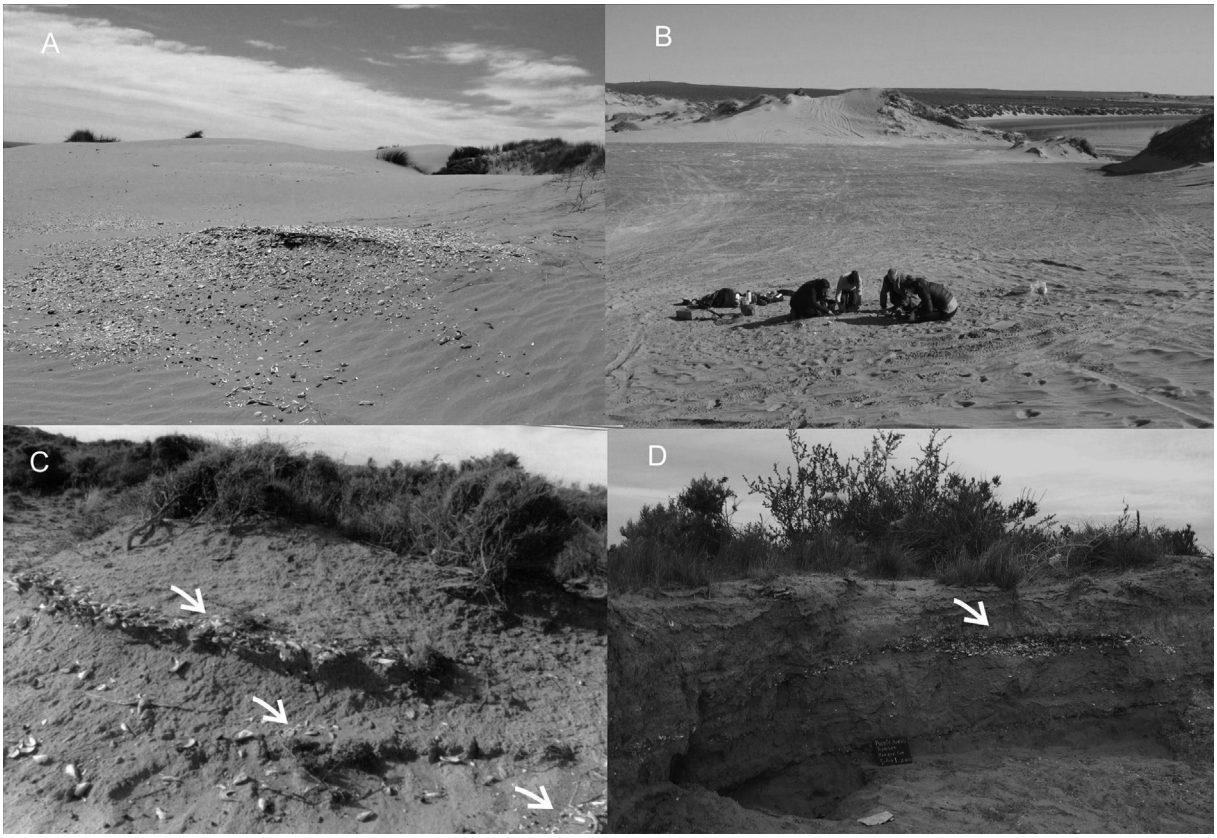

Fig. 2. Archaeological contexts general view: A) a shellmidden from San Roman site; B) excavation in Médano Grande; C) three shellfish stratified layers in San Roman site; D) shellfish stratified layers in Puente Nuevo site.

by the cultural deposit height, which never exceeded 0.15 m. Taxonomic identification was performed with the collaboration of Dr. Atilio Francisco Zangrando, using comparative collections at the Centro Nacional Patagónico (Puerto Madryn, Chubut Province, Argentina) and the Asociación de Investigaciones Antropológicas (Buenos Aires, Argentina). Remains were identified to the most specific possible taxonomic level and abundance was determined using NISP and MNI units (Wheeler and Jones, 1989).

Actualistic studies (Gifford Gonzalez, 1991) were carried out in order to understand how natural formation processes impacted on fish remains at the study area. Taking into account that it is virtually impossible to determine the origin, range and extent of all post-depositional processes affecting a bone assemblage (Nicholson, 1992), research efforts were oriented towards identifying taphonomic biases (preservation and dispersal) through two experiments. One aimed to evaluate the rate of weathering and the duration of this process (Svoboda and Moreno, 2014). It consisted of the sub-aerial exposure of four perch carcasses (*Percichthys trucha*) and long bones of one sheep (*Ovis aries*) over six years old. The other experiment evaluated how post-depositional processes affect the spatial distribution of fish remains in erosive and sedimentary coastal environments (Svoboda and Moreno, 2014). Five fish bone samples were placed along a 1 m line on different landforms (active dunes, beach ridges, shallows, and littoral terraces) and substratum (sand, pelitic sediment and desert pavement) during a period of 15 months.

3.2. Stable carbon and nitrogen isotope analyses of human skeletal remains

Carbon (^{13}C) and nitrogen (^{15}N) isotope ratios in human bone (collagen and apatite) and enamel may be used to reconstruct prehistoric diet because of differential fractionation during photosynthesis and nitrogen uptake in plants, and the isotopic enrichment in relation to each trophic level. Bone collage and bone apatite of 23 human skeletons of different age and sex were studied in order to differentiate between the consumption of C_3 and C_4 plants and between terrestrial and marine diets (Gómez Otero et al., 2000; Gómez Otero, 2007). The analyses were done by Dr. Robert H. Tykot and Dr. Scott Grammer (Department of Anthropology, University of South Florida, Tampa) using well-established laboratory procedures (Tykot et al., 1996). Fifteen individuals were dated: one at 6000 BP, and the others spanning a temporal range from 2600 BP to 200 BP. In the case of undated individuals or sites, relative chronology was assigned considering other individuals' age, and/or the presence of cultural items with well-known chronology, such as microlithic arrowpoints, ceramics and European materials, as well as others.

3.3. Oral health in human remains: presence of caries

Caries are holes in the teeth formed by mouth bacterial reaction when particles of foods containing carbohydrates are not removed; therefore, they can be considered as indirect evidence of carbohydrate consumption. Indicators of oral health were assessed through the observance of caries, abscesses, wear, pulp cavity exposure, and *ante mortem* loss presence (Gómez Otero and Novellino, 2011). Dental caries were macroscopically evaluated in 563 permanent molars and premolars of 45 individuals: 34 adults (10 females, 19 males, 5 undetermined), 11 juveniles (3 females, 2 males, 6 undetermined). In this study, caries are considered as distinct cavities formed by demineralization, in contrast with pulp cavities which do not feature demineralization (Hillson, 2001). It was also taken into account that this variable is affected by other factors apart from diet, such as age groups and tooth types (Jackes and Lubell, 1996). With the aim of exploring temporal trends, the samples were separated into three series: “Before 1000 BP”, “1000–500 BP”, and “Post-contact” (after 400 BP).

3.4. Technological record of fish and plant foods exploitation

In order to evaluate fish and plant procurement and processing, two methodological approaches were applied. One examined the distribution and frequency of fish harvesting tools (fishhooks and stone weights) as well as grinding and pottery artifacts, which could have been used for processing and cooking plants in addition to all types of faunal resources, with fish being one of them. In regards to stone weights, their presence in Patagonian archaeological sites is considered as indirect evidence of fishing activities (Massone and Torres, 2004; Gómez Otero, 2006; Mansur, 2007; Favier Dubois and Scartascini, 2012; amongst others). The technological samples include: 58 stone weights and a wooden hook, 31 grinding stones, 1528 potsherds and an entire vessel. The other methodological approach consisted of ceramic technology studies (Schuster, 2012). The purpose was to assess its features, identify the different sourcing strategies, the manufacturing, the use and discard, and the roles that ceramics would have played amongst the hunter-gatherers of the area (Schuster, 2012). They were carried out with macroscopic and microscopic (thin section petrography) analysis, X-ray diffraction (XRD), diagnostic imaging (x-rays), stable carbon and nitrogen isotopes studies and gas chromatography of organic residues adhered and/or absorbed by the ceramic matrix.

3.5. Organic residues in pottery samples

In certain circumstances, organic residues can survive in ceramic artifacts. The most common forms are the undetected absorbed residues into pores within the pot walls, and the visible encrustations of charred foods on the internal or external surface of potsherds. Absorbed organic residues are much more frequent (approximately half of all vessels chosen for analysis) than visible adhered residues (Reber and Evershed, 2004). Both, absorbed and encrusted residues can be extracted, separated and identified using different methods: isotopic analyses, gas chromatography (GC) (Skibo, 1992), and also a combination of gas chromatography and combustion-isotope ratio mass spectrometry (GC-C-IRMS). In this investigation, and for the first time in Patagonian archaeology, gas chromatography and carbon and nitrogen isotopes studies were applied to identify organic residues in pottery samples.

Six body vessel potsherds of respective vessels were studied using GC. Lipids extraction, fatty methyl esters preparation, and fatty acid determination were performed by Dr. Diana Constenla of the Planta Piloto de Ingeniería Química-CONICET-UNS (Bahía Blanca, Buenos Aires Province, Argentina), following well established procedures (see Gómez Otero et al., 2014). For comparison with reference standards, the work of Skibo (1992), Malainey et al. (1999) and Evershed et al. (2008), was used for flora and fauna at the global level, and Frère et al. (2010) for the guanaco and for freshwater resources from the pampa region such as catfish (*Rhandia toad*), vizcacha (*Lagostomus maximus*) and coipo (*M. coypus*).

Carbon stable isotope analysis was applied to seven charred residue samples; one was also examined for nitrogen isotopic values (Gómez Otero, 2007; Schuster, 2012; Gómez Otero et al., 2014). One sample was studied by Dr. Robert H. Tykot and the remainder by Lic. Susana Valencio and Lic. Estela Ducos at the Instituto de Geocronología y Geología Isotópica-CONICET-UBA (Argentina). The obtained values were compared to isotopic values of modern flora, terrestrial and marine faunal samples (current and

archaeological) from the central Patagonian coast (Forero et al., 2004; Gómez Otero, 2007; Ciancio et al., 2008).

4. Results

Fish bone remains, currently associated with charcoal, shell, birds and mammalian bones, and/or lithic artifacts, were recorded in 25 (32%) of all the faunal assemblages analyzed (Table 1) (Gómez Otero, 2006; Gómez Otero et al., 2009, 2013). The antiquity of these samples extends from 7400 BP to 440 BP (Gómez Otero et al., 2013) (Table 1). The total NISP was 2446; six assemblages had more than 160 specimens, and the rest less than 70 specimens. With respect to temporal variations, the lesser NISP was observed among the Late Holocene contexts (Post 1500 BP). The total MNI was 94 individuals (MNI average: 3.7 individuals per assemblage), though there was one with 14 individuals and another with 24. The density per sample varied from 0.01/dm^3 to 74.0/dm^3 (mean = 12.7/dm^3; SD 5.3), however, fifty percent of the cases ranges between 0.04/dm^3 and 2.0/dm^3 (mean = 0.6/dm^3; SD 0.1). The higher values were determined for pre-ceramic contexts: 41.5/dm^3 in Bahía Cracker 4 (5390 ^{14}C BP), located in the Nuevo Gulf (Gómez Otero et al., 2013); and 27/dm^3 to 105/dm^3 in Los Cangrejales Sur-Sector 4 (2290 ^{14}C BP-1980 ^{14}C BP), near the Chubut river mouth (Gómez Otero et al., 2009). The prevailing taxa correspond to Argentine sea bass, sandperch, Patagonian blenny, and silver side (Table 1). With regard to anthropic modifications, burning damage was detected in a few vertebrae and ribs.

Considering the results of the actualistic studies, though weathering stages have not yet been defined, a faster weathering rate was observed in fish bones than in sheep bones. In addition, significant cracking and fragmentation were determined in some elements (*i.e.* vomer, postemporal, opercular, cleithrum, pterygiophore, among others) after 20–30 months (Svoboda and Moreno, 2014). On the other hand, preliminary results from experimental fish samples placed on different landforms suggest a substantial post-depositional alteration in a short time, probably due to wind action (Svoboda and Moreno, 2014). During the observation period, wind gusts ranged from 69 to 106 km/h (Centro Nacional Patagónico Metheorological Station, 2013–2014). Two experimental sets placed in sedimentary environments showed the faster alterations (within the first 15 days): in the active sand-dunes the bones were completely buried, and in the lagoon all remains disappeared. At the beach ridge and the edge of the lagoon the modifications occurred more slowly, as 65%–90% of the fish bones were preserved for 15 months, but in the lagoon edge they were transported between 1.30 m and 2 m. In the erosive littoral terrace environment 75% of the bones were lost and the rest transported 1.6 m and 3 m.

Table 1
Samples, fish relative abundances, Minimal number of individual and Number of identified specimens per taxon of fish by temporal ranges, after Gómez Otero (2006), Gómez Otero et al. (2009, 2013). References: x (presence).

	^{14}C years BP		
	7000–4800	3200–1500	1500–400
N sample	4	14	7
NISP	939	1158	349
MNI	32	37	25
Taxa			
A. patachonicus	x	x	x
P. brasilianus	x	–	x
S. oculatus	x	–	–
P. saltatrix	x	x	x
P. semifasciata	–	x	x
Nototheniidae	–	x	–
E. maclovinus	–	x	x
Odontesthes sp.	–	x	x
N. barbas	–	x	x
Rajidae	–	–	x

With respect to isotope analyses of human skeletal remains, of 23 individuals examined, 13 indicated a diet where high trophic level marine resources comprised up to one third of their intake. Six showed these items represented more than 50%, and in the rest this percentage was very low (Fig. 3). Regarding the proportion of proteins, fats and carbohydrates, the difference between the δ^{13}C values of collagen (protein diet) and apatite (total diet) showed that 65% of the individuals would have consumed mostly C_3 proteins and CAM carbohydrates, although this enrichment might also be due to the consumption of marine lipids. In the remaining individuals, marine fats and proteins and C_3 plants were important. Therefore, all individuals (including the 6000 BP one) regularly consumed carbohydrates. No sexual trend was determined in the sample. With respect to changes through time, some trends were detected: high intra-site variability in the terrestrial-marine resource ratio between 2600 BP and 1000 BP, an increase in high trophic level marine resources and CAM carbohydrates intake between 1000 and 400 BP, and a predominant intake of C_3 carbohydrates and proteins after the European contact and the equestrian period. To summarize, in all cases plant consumption was shown.

In regards to the oral health in 45 individuals of the late Holocene separated into three temporal series, the study does not indicate significant differences between sexes, but shows some trends through time (Gómez Otero and Novellino, 2011). The series after 1000 BP period, contemporary with ceramic technology, showed a progressive increase in caries percentage and a decrease in abscesses, dental wear and *ante mortem* losses frequency. Caries reached the highest degree during the Post-contact times. However, statistical tests did not show significant differences in caries proportion amongst the three series. On the other hand, grinding and cooking in ceramic containers would have led to a softer diet, hence less dental wear and the greater the possibilities for registering cavities.

Concerning the technological record, the fifty eight stone weights were recovered in 29 (20%) of 143 archaeological sites, seven of which (24%) also contained fish bone remains. All corresponded to surface contexts, and only one to a stratified hearth dated in 590 ± 70 BP (Gómez Otero et al., 2009). Most of them were isolated findings, except for a few cases where they were clustered in a small area (Gómez Otero, 2006). The majority are flat marine pebbles with a sub-circular or oval shape and two or more notches at opposite sides (Fig. 4). The maximum length ranges from 3.8 cm to 8.7 cm, while the mass varies between 12 g and 236 g (x = 103.3 ± SD 7 g). The fishhook that was found in an intertidal pool in the San Jose Gulf (Valdés Peninsula) is the only discovery of this type in Patagonia (Gómez Otero, 1996). The sample is made of wood, 52 mm long, and it is different from common hooks because the (point) is longer than the rod shank (Fig. 4). It was inferred that it was used as a hook to capture rocky fish from the edge of reefs (Gómez Otero, 1996). The fishhook would have formed part of a fishing rod made up of a stick, with a line tied to a sinker (Fig. 4).

With respect to grinding and pottery artifacts, within 143 registered sites, 21 (15%) had grinding stones, 46 (32%) pottery remains, 18 (13%) included both technologies and 12 (8%) of the last also contained lithic weights. All the evidence was found in surface sites located in dune settlements, most of them interpreted as residential camps. The grinding tools are represented by mortars (*N* = 5), *conanas* (*N* = 12) and manos (*N* = 14) (Gómez Otero, 2006). Mortars are made of allochthonous rocks such as granites and ignimbrites, which suggest a search for high quality raw materials for grinding. Up to now, it is not possible to understand the kind of processing resources through these artifacts, as specific studies (for example, pollen and phytolith identification, fatty acids

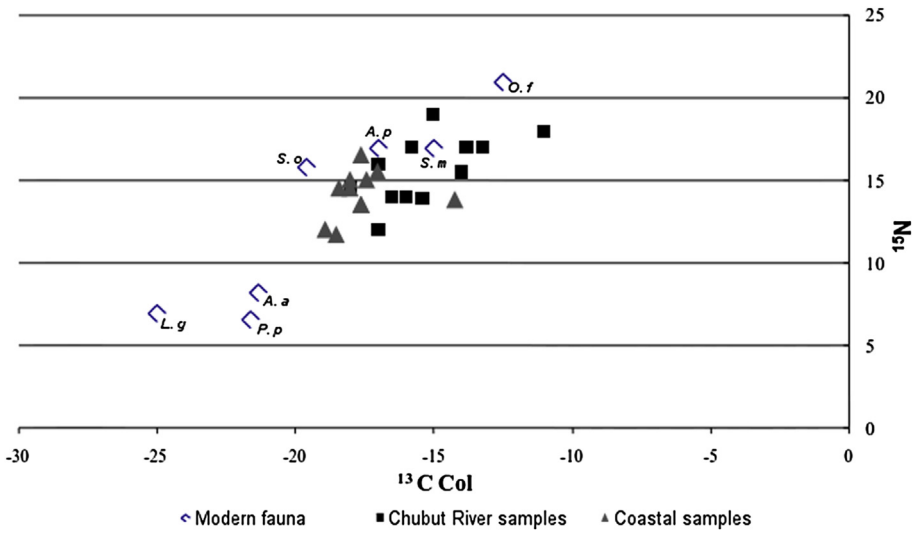

Fig. 3. Isotopic values of modern fauna and human samples of the Low Basin of the Chubut River and the Northern coast of Chubut province. O.f = *Otaria flavescens*.; A.p = *Acanthistius patachonicus*; S.m = *Spheniscus magellanicus*; S.o = *Sebastes oculatus*; A.a = *Aulacomya ater*; P.p = *Pterocnemia pennata*; L.g = *Lama guanicoe*.

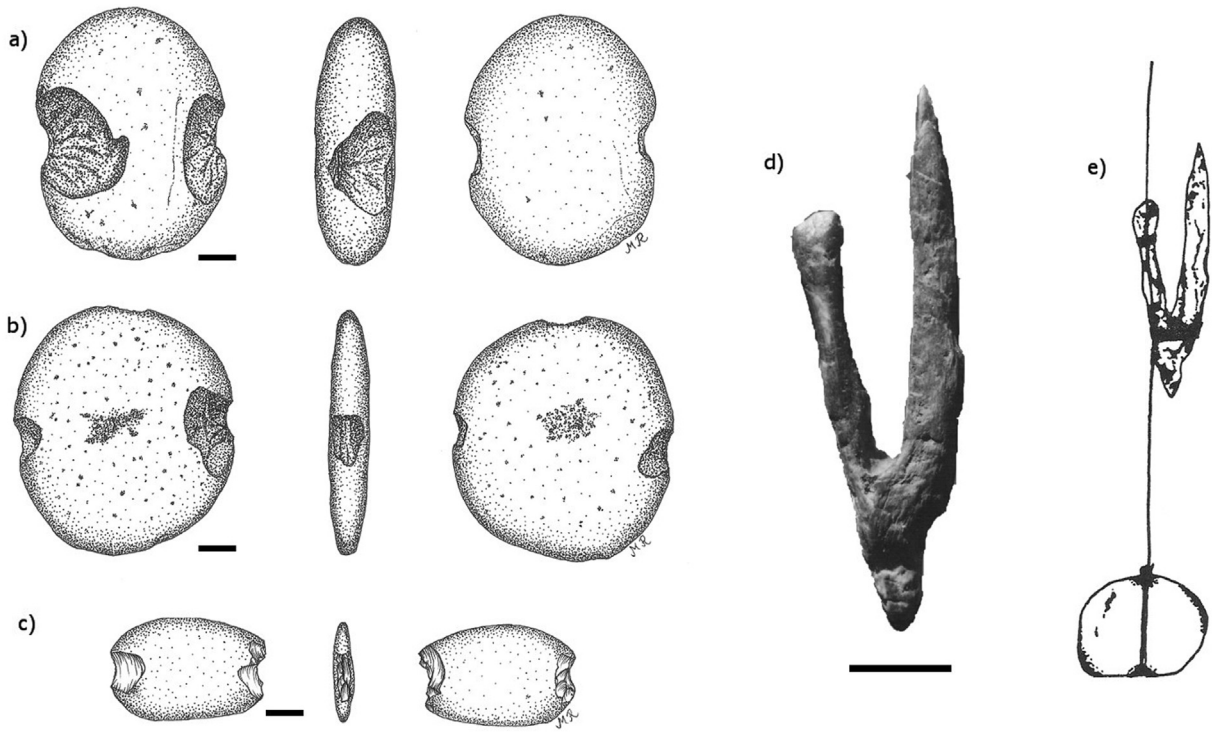

Fig. 4. Fish harvesting technologies from the study area. Stone weights from: a) Las Ollas; b) Los Abanicos 2; and c) Los Abanicos 3; d) a fishhook of wood recovered in San José Gulf (Gómez Otero, 1996); e) reconstruction of a fishing line (Gómez Otero, 1996). Scales bar denotes 1 cm (Drawing: Mariano Reyes).

determination and functional analyses) have still not been applied. An EVE (Estimated Vessel Equivalent) of 51 vessels was determined (Schuster, 2012). The majority is made of local clays, and exhibits ovaloid or spheric restricted shapes, simple contours, concave bases and an orifice diameter which in general do not exceed 16 cm (Schuster, 2012) (Fig. 5). These vessels would have been used in multiple functions: cooking (by boiling, frying and stewing), and storage (Schuster, 2012). Three radiocarbon dates indicate that pottery technology was adopted after 1500 BP (Gómez Otero et al., 2014) and endured at least until 440 BP (Gómez Otero et al., 2013).

The analysis of gas chromatography indicated the presence of vegetable lipids in all samples ($N = 6$), mixed with fats from terrestrial fauna ($N = 3$) and marine fauna ($N = 3$) in varying proportions (Table 2). If Marchbanks (1989), Malainey et al. (1999) and Buonasera's (2005) criteria are considered for some of the relations of certain AG, five of the ceramic pieces analyzed could have been used to cook fish. However, this data must be taken with caution, as these authors worked with resources from the Northern Hemisphere. The studies of stable isotopes showed the following situations (Gómez Otero et al., 2014): (a) mixture of C_3 plants and land animals, and probably also a low proportion of marine lipids that may be fish lipids ($N = 2$); (b) dominance of C_3 plants and/or lipid and protein C_3 database ($N = 3$); and (c) mixture of C_3 plants, land animals, and marine resources ($N = 2$) (Table 3). The sample of Bajo de los Huesos site suggests the presence of freshwater protein (fish and coipo). None of the values obtained shows more ^{13}C

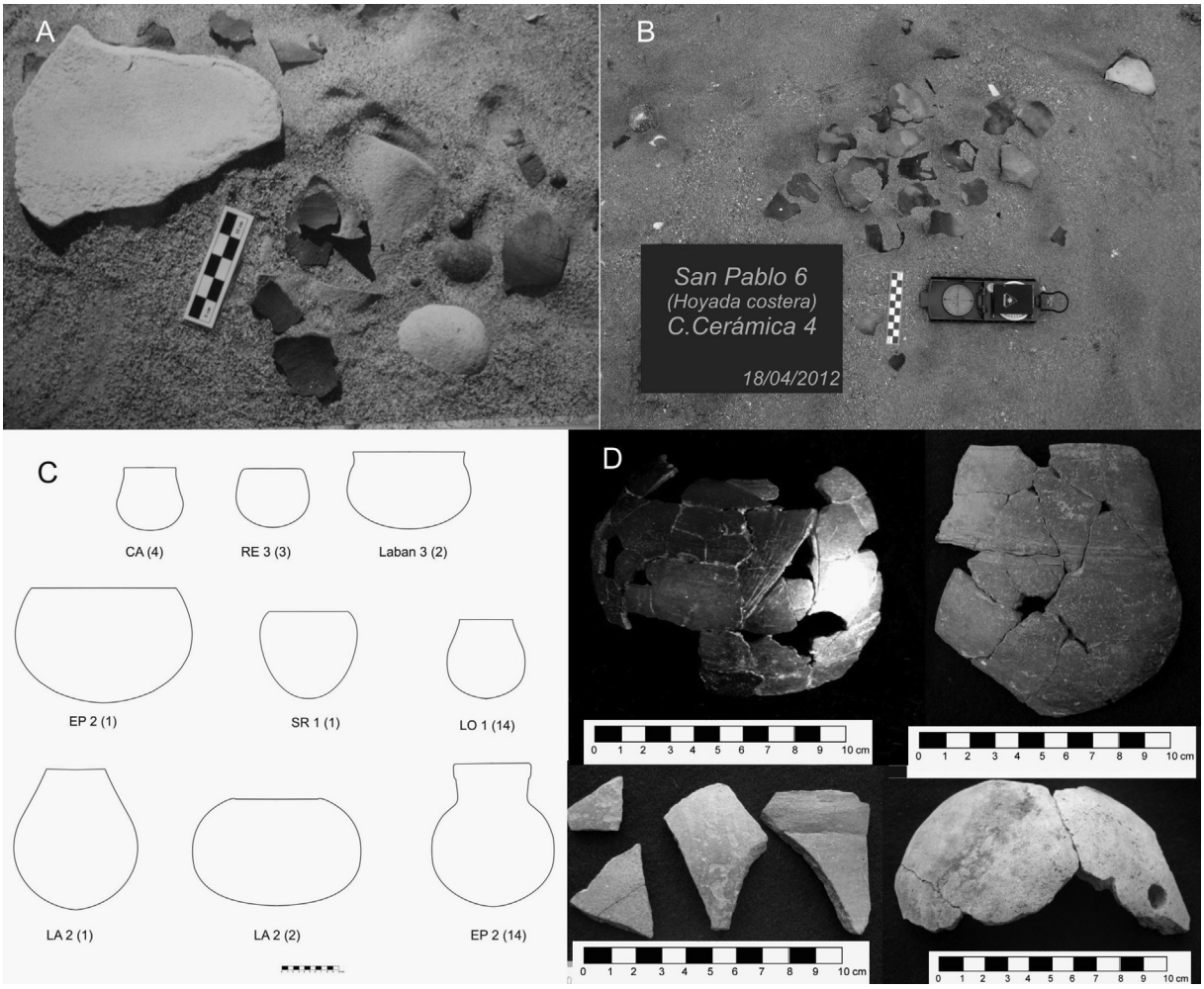

Fig. 5. Pottery collection from North–central Patagonian coast: A) pottery sherds and grinding artifacts from Las Ollas 1; B) pottery sherds from San Pablo 6 site; C) main pottery shape from the study area; D) some pottery vessel and assembled fragments.

enrichment than −19.9‰, which would indicate that the most important contribution comes from C_3 plants and/or proteins and lipids from terrestrial animals (Gómez Otero et al., 2014), probably guanaco judging by its dominant presence in the archaeofaunal contexts and its average carbon isotopic value (−21.34‰) (Gómez Otero, 2007).

5. Discussion

The low presence of fish bone remains in the faunal assemblages and the scarce fish specimen density in merely half of the samples could be attributed to exiguous fish exploitation. However, another hypothesis might be connected to post-depositional processes, as actualistic studies have demonstrated significant alterations on fish skeletal integrity due to rapid weathering rate, displacement and even bone loss. This would explain, for example, the presence of ichthyofaunal remains in only 24% of the sites with stone weights. In the case of Bahía Cracker 4 and Los Cangrejales Sur-Sector 4 sites, that show higher bone density, it is possible that fish remains have been preserved under exceptional conditions, but also due to the fact that these assemblages were the consequence of brief and frequent occupations, where harvesting activities (especially fishing) had taken place (Gómez Otero et al., 2009, 2013).

Concerning the intra and intersite variability, a general trend was recognized: each fish sample shows a correspondence

Table 2
Fatty acids composition by gas chromatography analyses in pottery samples, after Schuster (2012) and Gómez Otero et al. (2014). References: 1 (presence); 0 (absence); 1? (probable presence).

Sites/Samples	Plants fats	Terrestrial animals fats	Marine animals fats	Fish fats
R. Elizalde 3 (3)	1	1	1	1
S. Román 1 (1)	1	1?	0	1?
B. Norte 2 (1)	1?	0	0	1?
E. Progreso 2 (1)	1	1	1	0
L. Azucena 2 (2)	1	0	1	1
C. Avanzado (4)	1	1	0	1

Table 3
Stable isotope values in pottery samples, after Gómez Otero (2006) and Gómez Otero et al. (2014). References: 1 (presence); 0 (absence); 1? (probable presence).

Sites/Samples	Plants	Terrestrial lipids and proteins	Marine lipids	Riverine lipids	Fish
B. Norte 2 (1)	1	1	1	0	1?
B. Norte 2 (2)	1	1	1	0	1?
E. Progreso 2 (7)	1	1	1	0	0
L. Azucena 2 (2)	1	1?	0	0	0
L. Ollas 1 (9)	1	1	1	0	0
B. Cracker 5 (5)	1	1	0	0	0
B. de los Huesos (1)	1	1	0	1	1?

between taxonomic composition and the coastal habitats close to the study sites. For example, rocky fish prevailed in the sites near reefs, while littoral fish, such as silver side and Patagonian blenny, were more frequent in the Chubut river mouth. This suggests that fishing occurred more often in the vicinity of camp locations, and probably as an activity embedded in other food-getting tasks, such as mollusk gathering.

Different methods could have been used for fish capture, but only stone weights and the wooden hook were the fishing artifacts recovered in the study area. Noting that investigation has not yet been done as to whether these weights were parts of nets or lines, some may have been placed in lines for the capture of reef fish. These fish do not school and usually protect themselves in caves, which reduces the advantage of net use. In this sense, the discovery of the fishhook in an intertidal pool reinforces the interpretation. Nevertheless, some weights could have been part of nets used for fishing along non-rocky coastlines.

With respect to temporal variability, the lesser fish bone density observed among post-1500 BP sites hints a decline in fish exploitation at that time. However, if the fatty acid contained in just over 50% of the analyzed potsherds belong to fish, their exploitation would have continued or perhaps increased during the ceramic period, with boiling or stewing as the main cooking methods. Fish carcasses might also have been processed through grinding stones. Therefore, grinding and ceramics technologies would have allowed obtaining more fish by-products, including oil, “butter”, soups and flour. Limp and Reidhead (1979) mentioned a significant increase in the energy and protein yield of fish first cracked by hand and then cooked by boiling. However, these food processing techniques produce bone fragmentation and collagen denaturing, which dramatically reduce the bone's resistance to destruction (Nicholson, 1992). Therefore, fish bone survival might have been affected by cultural activities as well. The lesser fish NISP values were determined for contemporary sites with ceramic technology, while fish remains were only found in four (25%) of the 21 sites with grinding tools.

The archaeological record also demonstrates fish exploitation in other Atlantic Patagonian coasts, although in variable intensity. This was determined for San Blas (Eugenio and Aldazábal, 2004), the north of San Matías Gulf (Favier Dubois and Scartascini, 2012), San Jorge Gulf (Arrigoni et al., in Cruz and Caracotche, 2006), the north coast of Santa Cruz province (Izeta, 1999), and Punta Bustamante (Mansur, 2007). Available radiocarbon data show that fishing activities ranged from at least the Mid Holocene to European contact period. Isotopic studies of Late Holocene human skeletal remains indicate moderate consumption in the lower basin of the Colorado River (Martínez et al., 2009) and more intensive in the north of San Matías gulf, even though in the last area fish profiting would have decreased after 1500 BP (Favier Dubois et al., 2009). On the other hand, gas chromatography applied in the analysis of fatty acids in ceramic vessels of the lower Colorado River Basin, has also demonstrated the presence of fish (Stoessel et al., 2013). Finally, similar stone weights were found in San Blas (Eugenio and Aldazábal, 2004), the north coast of San Matías Gulf (Favier Dubois and Scartascini, 2012), San Jorge Gulf (Arrigoni et al. in Cruz and Caracotche, 2006), and Punta Bustamante (Mansur, 2007). All these artifacts were interpreted as probable parts of nets.

Isotopic analyses in human samples show the regular exploitation of wild-origin C_3 and/or CAM vegetable foods in all the individuals analyzed, including those from 6000 BP. According to oral health studies, the carbohydrate consumption would have progressively increased after 1000 BP, as a higher caries percentage that reached its maximum degree among the Post-contact individuals, was determined. This was correlated to a decrease in abscesses, dental wear, and *ante mortem* loss frequency. Taking into account that ceramic technology was implemented at that time, this evidence would be the consequence of a softer diet. In short, before the adoption of pottery technology, plants would have been eaten raw or processed by grinding; afterwards, by boiling and stewing. In the post-contact period the intake of processes carbohydrates diversified as diet included wheat flours, sugar, biscuits and alcoholic drinks obtained from exchanges in Hispanic colonial villages (Palermo, 1991; Martinic, 1995).

Indirect and direct and evidences of plant consumption have been registered in other parts of the Patagonian coast. Numerous grinding stones and ceramic remains were recovered in several sites between the Colorado River mouth and San Julián Bay (Gómez Otero, 1996; Eugenio and Aldazábal, 2004; Arrigoni et al., in; Cruz and Caracotche, 2006; Favier Dubois et al., in; Cruz and Caracotche, 2006; Prates et al., 2010). On the other hand, isotopic analyses in human bones suggest that carbohydrate intake was relatively high, but only in the north and central–north coast. In this sense, plants of C_3 origin were one of the principal foods in the north of San Matías Gulf between 1500 BP and 420 BP (Favier Dubois et al., 2009). In contrast, their regular consumption was not determined amongst human samples from the northern and southern coast of Santa Cruz province (Barberena, 2002; Moreno et al., 2011). One explanation could be related to the reduced availability of high energy plants in the south, which would have not promoted processing strategies (Gómez Otero, 2006, 2007; Moreno et al., 2011).

6. Conclusions

The diverse lines of evidence here analyzed suggest two aspects of the economic organization: first, that fish and plants were usual foods in the local hunter-gatherers' diet since at least the Mid Holocene; secondly, that during the Late Holocene (after 2000 BP) their consumption would have intensified with the use of grinding and ceramics. Such processing technologies increased the return rate of these and other resources by obtaining more by-products (for example, flour, bone collagen), and the applying of new methods of meal preparation and cooking. In addition, cooking by boiling would have improved the food hygiene, which impacted on the health of human groups (Gómez Otero, 2006).

In principle, this change in the foraging behavior does not seem to be linked to external factors as paleoenvironmental events or a depletion on the availability of high rank resources, such as the guanaco and pinnipeds. On the one hand, the coastal region offers a wide and abundant food supply, which is much higher than the normal requirements of low demography hunter-gatherers groups, like those of the study area. On the other hand, it is important to consider that certain climatic events such as the Holocene neoglacial advances or the Medieval Climatic Anomaly (MCA) could not have affected the availability of marine fauna. Finally, as detailed in the results, the bioarchaeological studies did not find nutrition stress or anemia evidence amongst the analyzed individuals. Therefore, it seems more likely that the incorporation of new processing technologies have been caused by internal socio-economic factors. In this sense, the archaeological record after 1500 BP shows an increase in population density, a reduction in residential mobility, an expansion of exchange networks within and outside of Patagonia, and growth in social complexity (Gómez Otero, 2006). However, in terms of the settlement system, no changes are recorded in the base residential camps location, as they continued to be placed in sand dune environments close to rocky platforms that provide fixed and predictable resources, such as mollusks and fish.

In sum, the purpose of this paper was to evaluate, based on different lines of research, the apparent discordance between the

zooarchaeological and isotopic evidences related to fish and plants exploitation. These studies indicated that these resources were more important in the subsistence of the native populations of the study area than what was estimated a decade ago. However, plants seem to have been exploited in a more systematic manner than fish because their presence was determined in most samples analyzed for stable isotopes and by gas chromatography. Fish remains were found only in some zooarchaeological assemblages and in fifty percent of the organic residues in pottery samples. The integrity of the ichthyoarchaeological record may have been altered by post-depositional processes and also by cultural practices such as milling and processing in ceramic containers.

Further research needs to more closely examine these assumptions. The agenda involves the extension of the isotope analysis (primarily nitrogen 15) and gas chromatography as well as the application of mass spectrometry to determine the origin of organic residues in ceramics. Identification of phytoliths and fatty acids recovered in the grinding tools, as well as fish taphonomy will be also performed. Finally, experimental processing of various local resources vessels and mortars will allow interpreting the results obtained from the physical-chemical studies to be applied to the ceramic and grinding archaeological tools.

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