



Exploitation of faunal resources by marine hunter–gatherer groups during the Middle Holocene at the Copaca 1 site, Atacama Desert coast



L. Olguín^{a,*}, V. Castro^b, P. Castro^c, I. Peña-Villalobos^d, J. Ruz^c, B. Santander^{e, f, g}

^a Instituto de Investigaciones Arqueológicas y Museo R.P. Gustavo Le Paige, Universidad Católica del Norte, Antonio Varas, 60 Dept., 413 Providencia Santiago, Chile

^b Departamento de Antropología, Universidad Alberto Hurtado University, Cienfuegos 41, Santiago, Chile

^c Departamento de Antropología, Facultad de Ciencias Sociales, Universidad de Chile, Ignacio Carrera Pinto 1045, Ñuñoa, Santiago, Chile

^d Departamento de Ciencias Ecológicas, Universidad de Chile, Las Palmeras 3425, Box 635 Ñuñoa, Santiago, Chile

^e Universitat Rovira i Virgili, Av. Catalunya 35, 43002 Tarragona, Spain

^f IPHES, Institut Català de Paleoecologia Humana i Evolució Social, Spain

^g GQP-CG, (uid 73 – FCT), Portugal

ARTICLE INFO

Article history:

Available online 21 March 2015

Keywords:

Pacific coast
Marine hunter–gatherers
Middle Holocene
Atacama Desert

ABSTRACT

The article presents the results of a study conducted on an assemblage of archeofaunal remains from the Copaca 1 archaeological site, located on the arid coast of Northern Chile. The site corresponds to an extensive shell midden that was used generally as an occupational site and specifically as a funerary one by specialized marine hunter–gatherers exclusively during the Archaic period.

The analysis of the faunal remains enabled a general description of the use of local fauna throughout the site's cultural sequence, which range from 7866 to 5040 cal. BP. According to the results obtained, marine and terrestrial fauna, including marine and terrestrial mammals, sea birds, pelagic and oceanic fish, mollusks, crustaceans and equinoderms, were used as a source of both food and technological implements during the Middle Holocene. This implies that the human groups that inhabited Copaca 1 accessed most of the ecoanthropic spheres of the Southern Cone of the Southwestern Pacific coast from early times onward, an adaptation dated since 12,000 BP in the south-western coast from southern Peru and northern Chile.

© 2015 Elsevier Ltd and INQUA. All rights reserved.

1. Introduction

Archeological investigations conducted in recent years offer a wealth of data on the coastal societies that inhabited the hyper-arid, extreme desert coast of northern Chile (from the Loa River in the north to the Salado River in the south) throughout the Holocene. Using the marine hunter–gatherer contexts identified, we have systematically studied the use of the rocky shore system along this stretch of coast between 24 and 27°S, which holds an extremely productive ecosystem that contains a wide range of resources including fish, shellfish, seaweed, and marine mammals. Abundance and predictability of these resources has allowed the development of a human history of 12,000 years, both in what is now Peruvian and Chilean territory (Llagostera, 1979, 1989, 2005;

Sandweiss et al., 1998; Llagostera et al., 2000; Sandweiss, 2008). Despite this, human populations in dry coasts have had to cope with a complex and extreme environment. This area is one of the driest in the world due to low rainfall and the absence of permanent freshwater springs reaching the sea (Bittmann, 1986; Llagostera, 1989), which strongly contrasts with the rich marine ecosystem. Water resources are only available in small springs along the coastal terrace and/or the coastal mountain range (Nunez and Varela, 1967–1968), or from the coastal low fog that allows the development of hill ecosystems (e.g. Marquet et al., 1998).

These environmental conditions have allowed a continuity and conservatism in the economy and social organization of human groups that inhabited the region from ca. 12,000 BP until the nineteenth century, except for some technological innovations (Llagostera, 1979, 1982, 1989, 2005). However, such continuity and resilience in Holocene coastal lifestyle is a relevant research question, given that resources and environmental conditions are important variables to understand the decisions made by human

* Corresponding author.

E-mail address: olguinlaura.o@gmail.com (L. Olguín).

groups in marginal or extreme environments as the interfluvial coast of northern Chile (Avery, 1995).

Thus, to approximate the variables of change and continuity in the archaeological context registered in the archaeological site of Copaca 1, is necessary, in the first place, to identify strategies for resource exploitation and subsistence of the inhabitants from Copaca used during Middle Holocene, studying the faunal component recovered in the excavations of the site. This will allow us to identify the high variability and technological expertise that these human groups developed since early times in such complex and extreme environmental conditions.

2. The Atacama Desert coast environment

The Pacific coast of the Atacama–Sechín desert stretches for approximately 3000 km from Northern Peru (5°S) to Northern Chile (27°S). The southernmost “absolute desert” section (24–27°S) is known as Atacama Sur and is presently one of the driest zones on the planet. Hyper-arid conditions remain constant throughout the year and rainfall is extremely low (3–4 mm annual average) (Vargas et al., 2000). While arid ecological systems are characterized by low productivity and species richness (Noy-Meir, 1973) along with high spatial heterogeneity (Kelt et al., 1996; Tongway et al., 2004) in our study area, the coastal fog (locally known as “Camanchaca”) generates an environment sufficiently humid to sustain relatively abundant and diverse communities of perennial and endemic plants, such as lichens, annual herbaceous, shrubs and cactus (e.g. Follman, 1967; Rundel et al., 1991; Pliscoff and Luebert, 2008), which have been used by humans as food, fuel and medicine, among others.

In contrast to the inhospitably arid coastal desert and the limited resources available there, the coastal waters of Atacama Sur represent one of the most productive ecosystems on the globe thanks to the cold waters of the Humboldt Current, which rise to the surface from the seabed, generating a nutrient-rich environment that attracts a wide variety of marine species, most notably neritic–benthonic, neritic–pelagic, and oceanic–epipelagic species. The zone furthest from the shoreline plays host to a wide variety of migratory species including swordfish and tuna, among others (Mann, 1954; Fonseca and Farías, 1987; Santibáñez et al., 2005; Fariña et al., 2008).

Nevertheless, the productivity of the Atacama Desert coastal waters is frequently altered by the El Niño Southern Oscillation (ENSO), defined as a change in the oceanic–atmospheric system that causes significant alterations in climatic behavior along the South American coast. ENSO affects different areas differently, depending on its magnitude, duration and coverage (Wyrki et al., 1976), and one of its key indicators is ocean surface temperature, which can rise by 1–4 °C during an ENSO event, altering environmental conditions and marine ecosystems and having a consequent effect on fishing activity (Santibáñez et al., 2005).

The origin, strength, and frequency of ENSO events in the past has been the subject of extensive discussions, especially during the Early and Middle Holocene (Rollins et al., 1986; DeVries and Wells, 1990; Sandweiss et al., 1996; DeVries et al., 1997; Carré et al., 2011). Various proxies have been used to propose that this phenomenon was initially established between 9000 and 7900 BP with short and intense events that altered the characteristics of the cold upwelling system conditions of the southern coast of Peru (Carré et al., 2005). From ~5000 to 2000 BP, the occurrence of ENSO would have been intensified and more variable, both in coastal Peru and Chile (Veit, 1996; Marchant et al., 1999; Sandweiss et al., 2001). It is possible that these changes have affected coastal adaptations during the Middle Holocene not only in South American, but also in other parts of the Pacific, as has been noted in the arid coast of Australia

(Williams et al., 2008). In any case, the occurrence of ENSO events significantly affected the development and reproduction of efficient marine adaptation in the coastal Atacama Desert. In this context, the dynamic interaction between ENSO, the freshwater springs in the area and the dense fog that typically blankets the coast in this zone have produced a unique environment (Follman and Weisser, 1966) that has enabled human groups to subsist here uninterruptedly since the Early Holocene by making use of the rocky coastal system’s abundant variety of fish, mollusks, seaweed and marine mammals and by hunting terrestrial mammals in the coastal mountains.

3. Archaeological context of Copaca 1 site

Copaca 1 is located at 22° S on the hyper arid, arid desert coast of Chile (Fig. 1), and corresponds to a shell midden 5000 m² in area situated at 22 m a.s.l. upon an ancient terrace formed by marine erosion (Fig. 2). The site is easily accessed from the present-day shoreline. The settlement has been defined as a residential camp that was occupied semi-permanently, primarily to take advantage of marine resources (Castro et al., 2012, 2014; Olguín et al., 2013).

This sequence includes at least eight occupational events dated between 7966 and 5040 cal BP (C¹⁴ date) (Table 1 and Fig. 3). The occupations show that the site’s inhabitants made extensive use of faunal resources, primarily eared seals, dolphins, cetaceans, mollusks, and fish and, to a lesser extent, terrestrial fauna such as camelids and birds. The instruments they used to catch and process these resources included, among others, projectile points, harpoon barbs, fishing weights and hooks, scrapers and knives (Santander, 2010; Varela et al., 2010; García-Albarido, 2012; Olguín et al., 2013). Notably, during the V and VI occupational events, the site was used as a funerary repository associated with stone architecture (Fig. 4) (Castro, pers. comm. 2013; Olguín et al., 2013).

The occupation at Copaca was preceded by small groups of people that colonized the coast of Taltal by camping inside little caves, dated 10,290–10,040 B.P. These groups originated cultural processes that allowed people to cope with the ecological instability, which later in the Archaic made it possible to establish little hamlets with stone masonry structures along the coast. Like other coastal groups along the littoral of northern Chile, the Copaca people based their economy and diet on marine resources, which is reflected in the wide variety of artifacts, linked to fish, shellfish,

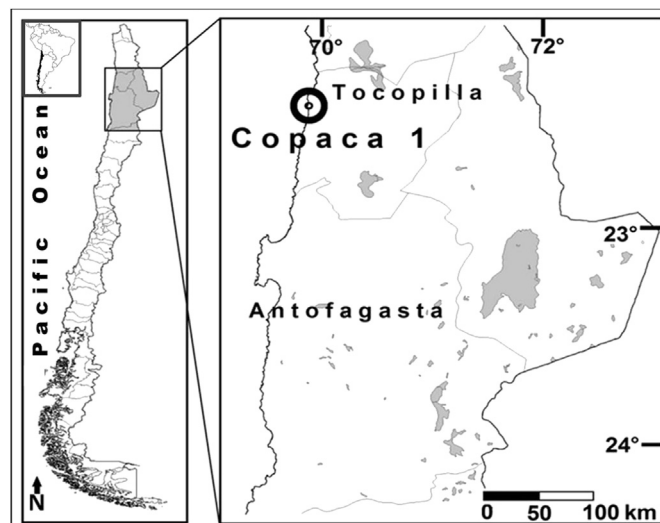


Fig. 1. Location of the area of study.



Fig. 2. Stratigraphic profile and occupational events of the Copaca 1 site.* *Uncalibrated dates expressed as year before the present (BP) uncorrected for reservoir effect. All samples are charcoal (AMS). CAIS – University of Georgia.

Table 1

¹⁴C dates for the Copaca 1 site, calibrated to two sigmas and using the ShCAL13 curve with Program Oxcal 4.2 (Bronk Ramsey, 2013). All dates are expressed in calendar years before the present (BP). Dating was performed by Center for Applied Isotope Studies, University of Georgia, USA.

Lab. Code	Unit	Layer	Data (years BP)	2nd C ¹⁴ Data Cal. (years BP)	2nd C ¹⁴ Data Cal. (years BC)	Sample
UGAMS 8342	C2	2	4540 ± 25	5301–5040	3364–3105	Charcoal
UGAMS 8343	C4	3	5170 ± 25	5940–5749	3650–3527	Charcoal
UGAMS 8344	C5	4	5130 ± 25	5913–5746	3984–3807	Charcoal
UGAMS 8345	C2	5	4810 ± 25	5590–5462	3650–3527	Charcoal
UGAMS 8346	C2	6	5060 ± 25	5892–5657	3949–3795	Charcoal
UGAMS 8347	C2	7	5240 ± 25	6004–5901	4225–3973	Charcoal
UGAMS 8348	C2	8	5710 ± 25	6542–6395	4649–4644	Charcoal
UGAMS 9145	C2	9	7010 ± 25	7866–7699	5983–5841	Charcoal

birds and sea mammals extractive, processing and consumption tasks.

4. Methods

The site's faunal material comes from a large 96 m² area divided into eight adjacent quadrants, within which it was possible to distinguish eight separate occupational layers (Fig. 3). The recovery of cultural material (artifacts and ecofacts) during the excavation was performed using a 3 mm mesh sieve. Control columns were also performed after the excavation was completed, one for archeofauna (0.5 × 0.5 m) and another for archeobotanics (0.2 × 0.2 m), adjacent to Unit C-2, for laboratory processing with a 1 mm mesh screen in the former case and flotation in the latter case. This control method enabled the recovery of remains within a given size that were representative of each occupational event and mitigated to some degree the arbitrary nature of field sieving, especially for deposits with extremely dense organic material such as Copaca 1 (Zohar and Belmaker, 2005; Olguín, 2011).

The analysis considered all marine mammal, bird, fish and invertebrate remains, which consisted primarily of fragments and only rarely of complete anatomical parts. Taxonomic and anatomical identification was performed using comparative osteological

collections and an array of manuals on animal osteology (Pacheco Torres et al., 1986; Siegel-Causey, 1988; Van Tets and Meredith, 1988; Falabella et al., 1995; Guzmán and Saa, 1996; Guzmán et al., 1998; Zuñiga, 2002; Navarro, 2007), and the anatomical and taxonomical abundance of the set was calculated in terms of NISP, MNI, MNE and MAU (MAU%) (Binford, 1984; Grayson, 1984; Lyman, 1994).

Together with the study of the skeletal parts, taphonomic analysis involved the study of those natural and anthropogenic variables that affected the assemblage in order to clarify the formation processes of the archaeological record and its degree of integrity (differential preservation), as well as to reconstruct patterns of wildlife management (processing and consumption). Among the taphonomic variables for bones of mammals, birds and fish, stages of weathering (Behrensmeier, 1978) were estimated; including the action of carnivores, rodents, birds and rootlets; fragmentation index; thermal alteration; and man-made cut marks and scraping. For mollusk shells and other marine invertebrates, grades of abrasion, fragmentation and peeling were recorded; natural marks and barnacle epibionts; and anthropogenic combustion traces, drilling and scraping.

5. Hunting, fishing and gathering at Copaca 1: faunal data

According to the anatomical and taxonomical identification of the 25,755 remains analyzed (Table 2), 53.81% corresponded to fish, 26.67% to marine invertebrates, 16.71% to mammals and 2.65% to birds (Table 3). Fish and marine invertebrates together made up the largest segment, accounting for 80% of the sample studied. However, when the calories contributed are measured instead of the quantity of remains, fishing and gathering become considerably less important than hunting of large marine mammals such as pinnipeds (sea lions) and cetaceans (dolphins). While the presence of sea birds in general and terrestrial mammals such as camelids remains constant throughout virtually all Copaca 1 occupational events, these kinds of remains are much less abundant than those of other taxa.

Overall, the whole zooarchaeological record does not register major changes due to taphonomic processes. Low degree of

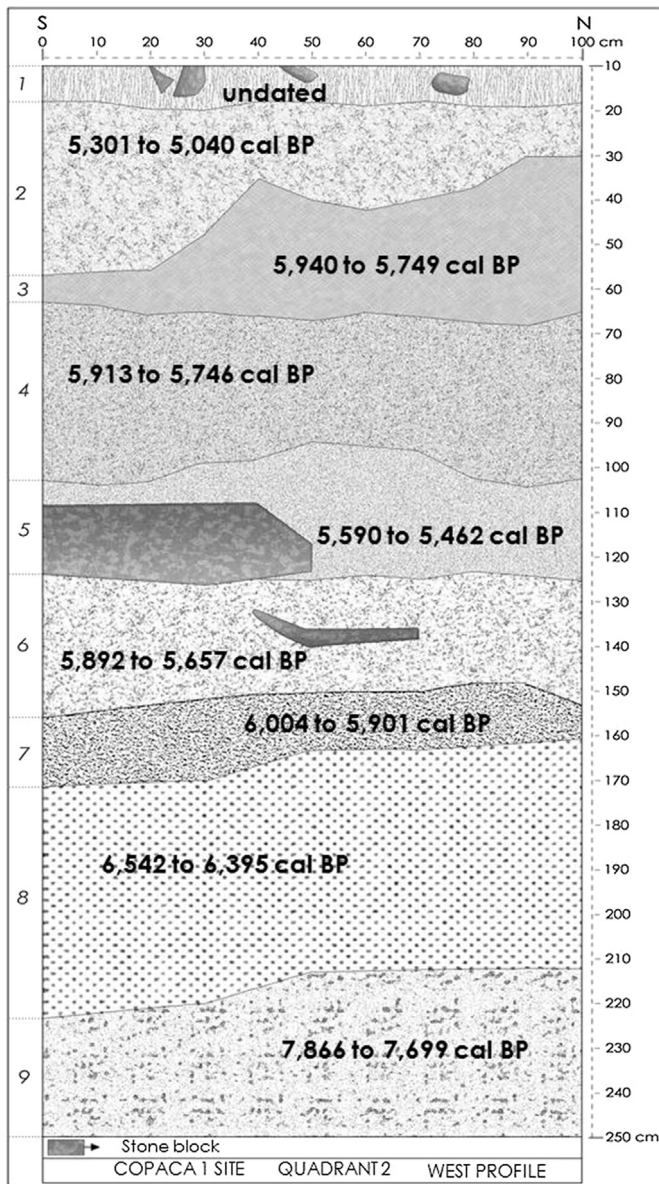


Fig. 3. Copaca 1 site.

weathering and fragmentation were identified on the different faunal remains, reflecting the integrity of the zooarchaeological sample. Furthermore, no natural marks due to the action of carnivores, rodents, and birds regurgitation were recorded. Only scant remains of fish with deformities as the result of pressure from the sediment matrix of teleost greater plasticity (Ruz, 2013) were identified. However, the presence of almost all skeletal parts of marine mammal (Otariidae, Delphinidae and Camelidae) show that individuals were included, processed and completely discarded in the same place (Olguín et al., 2012). Consequently, there is the possibility that the deformed fish remains found in the archaeological context became part of it as stomach content of marine mammals. Nevertheless, deformed remains are proportional scarce in relation to the intensive use of marine mammals throughout the occupational sequence of the site.

The scarce anthropogenic traces are mostly related to cut marks generated by butchering (Olguín et al., 2012; Peña-Villalobos et al., 2013; Ruz, 2013). As mollusk shells, they presented little

fragmentation and are low erosion, further strengthening the integrity of the analyzed archaeological context (Castro, 2013b).

5.1. Marine hunting

Judging by their great caloric contribution, the huge quantity of their remains and the large number of individuals they represent (Table 3), marine mammals, particularly dolphins and pinnipeds, are considered to have been the most important prey during the entire occupational sequence of the site (Olguín et al., 2012). Anatomical identification of the remains indicated an abundance of cetaceans, particularly dolphins corresponding to the large Delphinoidea family. Work is still in progress on more specific taxonomic identification, but the diagnostic presence of the tympano-periotic complex makes it very likely that the remains correspond to the genera *Cephalorhynchus* and/or *Tursiops*. Moreover, these remains are concentrated in the upper layers of the site, primarily within the 3 and 4 occupational layers (Table 4).

Anatomical identification also pointed to the less abundant presence of larger cetaceans, including baleen and/or sperm whales, though the absence of diagnostic morphological features prevented us from identifying individual species. As with the dolphins, these remains are more concentrated in later occupations, specifically in layers 2 and 3, and are also associated with the burial context of occupational layer 5, and therefore the presence of these particular bones may not indicate that these animals were consumed but perhaps that they were grave goods and/or raw materials for tool making (Table 4).

The frequency of different dolphin skeletal remains (MNE and MAU) was determined, and shows a high occurrence of anatomical parts of the axial skeleton, namely fragments of vertebrae, the cranium, the tympanic–periotic complex, sternum, and mandible (Table 5). Less frequently occurring remains corresponded to the appendicular skeleton and included the scapula, humerus, radius, ulna, carpals, metacarpals, and phalanges. Regardless of their relative frequency, the presence of all parts of the dolphin skeleton indicates that the carcasses were brought to the site, which means that the site served as the primary and secondary slaughtering area for this prey, a typical feature of semi-permanent residential camps of Coastal Archaic groups in Northern Chile.

Another faunal resource that was extremely important in the settlement was the pinniped. The present-day existence of a sea lion colony on the coast adjacent to Copaca 1 likely explains the high frequency of these animals in the archaeological context, above all during occupational layers 8 and 6 (Table 4).

Two pinniped species were identified at the site: *Otaria flavescens* (South American sea lion) and *Arctocephalus australis* (South American fur seal), both belonging the Otariidae family. This taxonomic differentiation was established thanks to the discovery of mandibular remains, specifically of the ascendant process, which allowed morphological measurements to be taken according to the guidelines proposed by Legoupil (1989–1990). *O. flavescens* individuals are not only larger than *A. australis* but also exhibit a much more pronounced male–female sexual dimorphism, with the male *A. australis* having a mass similar to the female *O. flavescens* (Maxwell, 1967; Aguayo and Maturana, 1973; Vaz Ferreira, 1981; King, 1983; Guerra and Torres, 1984, 1987; Bonner, 1994; Quintana et al., 2000). With no osteometric controls to determine which anatomical parts belonged to which species, therefore, identification was established solely at the level of the family—Otariidae (Table 4).

In regard to axial and appendicular skeletal remains of the most important marine mammals – dolphins and pinnipeds – the frequency and fragmented condition of both types of bones, coupled with the fact that most parts of the skeleton are represented,



Fig. 4. (a) human inhumation at Copaca with intentional interventions, including the deposition of an infant between his legs (badly preserved), placed over a prepared clay floor, (b) detailed of the neck enlarged with sea urchins shells, (c) inhumation placed inside a masonry stone structure used also for domestic purposes.

Table 2
Number of remains (NISP) analyzed from the faunal assemblage of the Copaca 1 site.

Taxon	NISP identified	NISP unidentified	Total NISP
Mammals	4131	189	4320
Birds	124	561	685
Marine invertebrates	6870	0	6870
Fish	10,849	3012	13,861
Total	18,613	3187	25,755

indicates that the individual animals, after being killed, were brought to the site whole, where they were completely processed and the unusable parts (Table 5).

In regard to other marine mammals, one unique piece in particular stands out: a segment of spinal column, connected anatomically, corresponding to a marine otter (*Lontra felina*) in the stratum corresponding to occupational layer 7 (Table 4). It is likely that these groups only rarely hunted otters, given that records of this species in Middle Holocene archeological contexts on the arctic coast are rare, with isolated individuals discovered only occasionally at some sites.

5.2. Terrestrial hunting

Today, the stock of terrestrial mammals on the coast near Copaca 1 is much lower than the number of marine mammals there, and the situation was not much different in the past, a fact that is reflected in the consistently low frequency of camelids (only 120 remains were identified in all) throughout the site's entire occupational sequence. In contrast, however, a significant number of tools made from the bones of these mammals have been found, including harpoon points and shafts, awls and fish hooks, among other items. Nevertheless, the presence of these artifacts is consistent with the high frequency of camelid appendicular remains (extremities), as these bones were the hardest yet most elastic, making them suitable raw material for tools and weapons (Table 5).

There are two possible explanations, at least, for the low frequency of camelid remains at Copaca 1. The first is that, unlike the practice with pinnipeds and dolphins, only certain camelid anatomical parts were brought to the site throughout the occupational sequence. In other words, the camelids were slaughtered

elsewhere, away from Copaca 1, their appendages were carried to the site, and only the extremities (feet) were disposed of at the camp itself. The second, more likely explanation is that the long bones were transported separately from inland ravines to the settlement and then were made into the bone tools recorded there (Olguín et al., 2012).

The presence of a single anatomical piece (femur) of a small rodent of the Simodontinae family could indicate the natural intrusion of this species at Copaca 1, especially considering the tiny amount of meat this species could provide in comparison to other mammals, as well as its infrequent presence at other arctic coast sites with a context and chronology similar to this one.

5.3. Seabirds

Although their caloric contribution is low, avian resources are well represented in the entire occupational sequence of Copaca 1, where they account for 2.65% of all faunal remains recovered (Table 3). However, the quantity of remains increases gradually deeper in the deposit, meaning that bird remains were more prevalent during earlier occupations of the settlement.

Some of the main bird families identified at Copaca 1 – Procellariidae, Sulidae, Phalacrocoracidae and Spheniscidae (Peña-Villalobos et al., 2013) – coincide with the current distribution of these life forms on the northern coast of Chile, according to articles on faunal recognition (Carhart, 1969; Brown, 1971; Estades, 1992), identification guides (Harrison, 1983; Jaramillo, 2003) and censuses of dead seabirds (Fibla et al., 2010). The taxa identified include only strictly coastal seabird species (except *Phalacrocorax brasilianus*, which has been known to fly inland), which would indicate that these groups hunted and consumed seabirds exclusively, in contrast to the situation observed in other coastal archeological contexts (Simeone and Navarro, 2002; DeFrance and Umire, 2004). The most predominant seabird species identified among the remains are *Puffinus* sp., *Pelecanus thagus*, and *Phalacrocorax* sp., which are most plentiful during the intermediate occupational layers (7, 6, 5 and 4) of the deposit (Table 6).

Taking into account the nesting behavior of the most frequently represented bird species, we deduced that these resources must have been obtained using a variety of traditional hunting techniques, from direct manual capture from their nesting colonies, to

Table 3
Faunal NISP for the entire occupational sequence of the Copaca 1 site.

				Occupational Layers											
Taxa				1	2	3	4	5	6	7	8	9	TOTAL	% TOTAL	
MAMMALS	Marine	Pinnipeds	Otariidae	3	15	38	45	17	80	133	81	13	425	16,7	
		Dolphins	Delphinoidea	58	137	966	530	140	90	26	29	19	1995		
		Whales	Cetacea		1	24	49	14	2				90		
	Terrestrial	Otters	Mustelidae								18				18
		Guanaco	Camelidae	1	4	21	9	8	15	10	43	9	120		
		Rodents	Sigmdontinae			1									1
Indeterminate mammals			21	11	245	256	299	327	137	235	126	1657			
		Subtotal		83	169	1294	889	478	514	324	388	167	4306		
SEABIRDS	Cormorants	Phalacrocoracidae		1	1	4	4	7	3	2	3	4	29	2,6	
	Cormorants/ Boobies	Phalac./Sulidae				1	1	7		1			10		
	Boobies	Sulidae			1	3	3	1	1				8		
	Penguins	Spheniscidae						1					1		
	Pelicans	Pelicanidae				2	1	10	3	5			21		
	Petrels, shearwaters and fulmars	Procellariidae		1	8	9	4	5	6	4	3		40		
	Gulls	Laridae				1			1		5	7	14		
Indeterminate birds			9	1	31	33	90	147	61	138	51	561			
		Subtotal		10	4	45	53	112	167	74	155	65	685		
FISH	Marine near-shore	Rocky intertidal				1	1	1	1		13	4	20	53,8	
		Rocky seabed		1	2	13	26	30	162	64	87	5	390		
		Rocky/sandy seabed			13	15	25	63	26	48	94		284		
	Marine off-shore	Benthonic				3	25	30	34	12	21		125		
		Neritic pelagic		9	80	617	949	476	2103	1599	2637	190	8660		
		Benthopelagic		2	6	36	53	41	55	5	104	18	320		
	Oceanic		4	56	112	103	51	251	169	271	33	1050			
Indeterminate fish		15	76	412	401	509	631	295	639	34	3012				
		Subtotal		31	233	1208	1583	1201	3263	2192	3866	284	13861		
MARINE INVERTEBRATE	Mollusk	Gastropods	Abalone	Muricidae	26	24	63	46	74	80	36	116	34	499	26,6
			Limpets	Fissurellidae	178	188	291	72	344	265	143	394	42	1917	
			Sea snail	Trochidae	49	14	94	108	246	424	161	347	22	1465	
		Sea cradles	Chitonidae	53	44	153	86	217	72	30	95	17	767		
		Others snails		69	40	111	86	220	94	36	306	11	973		
		Clams	Veneridae	2	4	9	9	17	21	10	45	11	128		
	Bivalves	Mussels	Mytilidae	2	4	3	20	3	9	4	30	4	79		
		Other bivalves		1		4	1	1	5	2	4	8	26		
		Urchins	<i>Loxechinus albus</i>	76	48	177	83	203	34	10	141	13	785		
	Crustaceans	Crabs		6	13	32	26	37	41	26	43		224		
		Barnacles		1	1	1	1	1			1	1	7		
		Subtotal		463	380	938	538	1363	1045	458	1522	163	6870		
		TOTAL		587	786	3485	3063	3154	4989	3048	5931	679	25722	100	

Table 4
MNI for marine and terrestrial mammals in occupational events recorded at Copaca 1.

Occupational layers														
Taxa			1	2	3	4	5	6	7	8	9	8	Total	%Total
Otariidae	<i>Otaria flavescens</i>		1	1	2	3	1	1	8	6	1	6	24	43
	<i>Arctocephalus australis</i>				1				6				7	
Cetacea	Delphinoidea		1	6	6	4	2	2	1	1	1	1	24	40.2
	Cetacea indet.			1	1	1	1	1					5	
Mustelidae	<i>Lontra felina</i>								1				1	1.3
Camelidae	<i>Lama guanicoe</i>		1	1	2	1	1	1	1	1	1	1	10	13.8
Sigmdontinae				1									1	1.3
Total			3	10	12	9	5	5	17	8	3	8	72	100

the use of projectiles (slingshots or lances), though the use of nets and lassos has not been ruled out either (Gusinde, 1951). The presence of all anatomical elements (feet, beaks, craniums, and wings) throughout the entire occupational sequence suggests that the birds were brought to the camp intact, meaning that Copaca 1 was a primary and secondary processing area where the birds were butchered and the unused parts discarded in the same place (Fig. 6).

The size of the bones and the presence of cultural traces on them suggest that these hunter–gatherer groups systematically targeted adult birds, though this does not rule out the possibility that other food items (eggs, chicks) were obtained during nesting periods. If

raiding nesting sites was one of the strategies used, then we would expect to find the bone remains of chicks and juveniles in the record; however, such remains have not been found at Copaca 1, probably owing to taphonomic causes (decay and fragmentation), which would have interfered with the preservation of the osteological record (Mameli and Estévez, 2004).

The exclusive presence of remains of the Laridae family (birds with less usable mass than other families such as Phalacrocoracidae, Procellariidae and Pelecanidae, according to Smith, 2011) in the earliest occupational events of Copaca 1 may be explained as the result of an opportunistic hunting strategy, or may be because

Table 5
MNE, MAU and MAU% for Camelidae, Otariidae and Delphinoidea at Copaca 1.^a

Anatomical unit	Camelidae			Otariidae			Delphinoidea		
	MNE	MAU	MAU%	MNE	MAU	MAU%	MNE	MAU	MAU%
Cranium				1	1	10.5	5	5	25
Cranium: Intermaxillary				3	3	31.5			
Cranium: Tympano/periotic				2	1	10.5	39	19.5	97.5
Mandible				19	9.5	1	23	11.5	57.5
Atlas				1	1	10.5	20	20	1
Axis	1	1	50	5	5	52.6			
Cervical vertebra				15	0.7	7.3	39	6.5	32.5
Thoracic vertebra				25	1.6	16.8	171	11.75	58.7
Lumbar vertebra				7	1	10.5	437	14.5	72.5
Hyoid				5	0.7	7.3			
Rib	9	0.75	37.5	21	1.4	14.7	56	4.3	21.5
Sternum				2	1	10.5	6	6	30
Sternebrae				8	1	10.5			
Scapula				7	3.5	36.8	3	1.5	7.5
Humerus				7	3.5	36.8	4	2	10
Humerus px				5	2.5	26.3	3	1.5	7.5
Humerus ds	2	1	50	1	0.5	5.2			
Radius				3	1.5	15.7	19	8.5	42.5
Radius px				3	1.5	15.7	1	0.5	2.5
Radius ds				3	1.5	15.7			
Ulna				4	2	21.05	1	0.5	2.5
Ulna px				4	2	21.05			
Ulna ds				2	1	10.5	1	0.5	2.5
Metapodial	1	0.25	12.5	4	2	21.05			
Metapodial px				6	3	31.5			
Metapodial ds	3	0.75	37.5	9	4.5	47.3			
Sacrum				4	4	42.1			
Hip bone				12	6	63.1			
Femur				4	2	21.05			
Femur px				4	2	21.05			
Femur ds	4	2	100	1	0.5	5.2			
Tibia	1			1	0.5	5.2			
Tibia px				2	1	10.5			
Tibia ds									
Fibula				1	0.5	5.2			
Fibula px				2	1	10.5			
Fibula ds				1	0.5	5.2			
Calcaneus	1	0.5	25	4	2	21.05			
Talus	1	0.5	25	1	0.5	5.2			
1st Phalanx	2	0.5	25	5	2.5	26.31			
1st Phalanx px	1	0.25	12.5	1	0.5	5.2			
1st Phalanx ds	2	0.5	25						
2nd Phalanx	2	0.5	25						
2nd Phalanx px	1	0.25	12.5						
3rd Phalanx	2	0.5	25						
3rd Phalanx px	1	0.25	12.5						
Phalanx	1	0.25	12.5	10			25	0.6	3
Phalanx px	1	0.25	12.5	21					
Phalanx ds	5	1.25	62.5	15					

^a Excludes teeth, caudal vertebrae, sesamoid bones, carpals, tarsals and patelas.

this kind of bird was sought after in specific contexts (e.g. in the absence of other prey, or when other resources were difficult to obtain). Lastly, the very low frequency of remains from the Humboldt penguin and birds in the Procellariiformes order (unidentifiable at the level of genus) may be due to the fact that these animals were used for specific purposes, were hunted opportunistically and/or were available only occasionally in specific contexts (Peña-Villalobos et al., 2013).

5.4. From shore fishing to deep-sea fishing

The fish remains found at Copaca 1 are extremely diverse, with a total of 25 taxa that inhabit a range of marine environments represented (Ruz, 2013). In particular, there is a marked abundance of fish from pelagic and oceanic environments, especially during occupational events II and VII (Table 3). The most frequently represented species among the remains is *Trachurus symmetricus*

(mackerel), followed by *Sardinops sagax* (sardine) and *Sarda chilensis* (bonito) (Table 7).

In addition to being the most abundant, *T. symmetricus* is the best represented in terms of anatomical units. All parts of the body are present, especially in events at the center of the stratigraphic profile and deeper down. This increase is coherent with the rise in this species NISP, while among the total estimates for MAU and MAU%, we can observe that the cranial and appendicular remains are the most frequent. This could mean that the fish were processed on site and the axial skeleton taken to another part of the settlement, or outside of it (Ruz, 2013).

It is likely that the coincident presence and abundance of mackerel and sardines in the archeological context is related to the ethology of those species. Sardines are coastal fish that live in great shoals and are the preferred food of fish such as *T. symmetricus* and *S. chilensis*, so it is common to find them together, especially in summer (Vargas et al., 1989, 1993).

Table 6
MNI of seabird species in the occupational events of Copaca 1.

Occupational layers			1	2	3	4	5	6	7	8	9	Total MNI	Total MNI%
Taxa													
Cormorants	Phalacrocoracidae	<i>Phalacrocorax bougainvillii</i>			1	2	2		1			6	25.3
		<i>Phalacrocorax. Brasilianus</i>				1	1			1		3	
		<i>Phalacrocorax sp.</i>	1	1	1	1	1	2	1	1	1	10	
Cormorants/Boobies	Phalacrocoracidae/Sulidae	<i>Phalacrocorax/Sula</i>		1	1	4			1			7	9.3
Boobies	Sulidae	<i>Sula sp.</i>		1		1		2	1			5	6.6
Penguins	Spheniscidae	<i>Spheniscus humboldti</i>				1						1	1.3
Pelicans	Pelecanidae	<i>Pelecanus tagus</i>			1	1	1	3	1	2		8	10.6
Petrels, shearwaters and fulmars	Procellariidae	<i>Puffinus sp.</i>		1	3	3	2	1	1	2	1	14	32
		<i>Macronectes sp.</i>			1	2	2		2	1		8	
		Procellariiforme indet.				1	1					2	
		<i>Leucophaeus sp.</i>			1						1	2	
Gulls	Laridae	<i>Leucophaeus modestus</i>								1	2	3	14.6
		<i>Leucophaeus pipixcan</i>									1	1	
		<i>Leucophaeus/Larus</i>								1		1	
		Laridae indet.									1	1	
		<i>Larus sp.</i>								2		2	
		<i>Rynchops niger</i>						1				1	
Total			1	4	8	14	15	8	8	11	7	75	100

Table 7
MNI of fish species in the occupational events of Copaca 1.

Occupational layers			1	2	3	4	5	6	7	8	9	Total NMI	Total NMI%
Taxa													
Rocky intertidal		<i>Sicyases sanguineus</i>				1		1	1			3	0.3
Rocky seabed		<i>Graus nigra</i>						1		1		2	6.4
		<i>Aplodactylus punctatus</i>			1		1			1		4	
		<i>Cheilodactylus variegatus</i>			2	4	4	6	2	5	1	24	
		<i>Pinguipes chilensis</i>			1			1				2	
		<i>Prolatilus jugularis</i>				1				1		2	
		<i>Semicossyphus maculatus</i>		1	2	1		1	1			6	
		<i>Auchenionchus microcirrhis</i>			1	2	2	3	2	1		11	
		<i>Doydixodon laevisfrons</i>						1		1		2	
Rocky/sandy seabed		<i>Paralichthys microps</i>			1	1	1	1	1			5	6.1
		<i>Cilus gilberti</i>	3	7	5	5	2	3	2	6	1	34	
		<i>Sciaena deliciosa</i>		2	1	3				1		6	
		<i>Mustelus mento</i>		1	1	1		1	1			6	
Benthic		<i>Sebastes capensis</i>			1	1		2	1			5	1.2
		<i>Genypterus sp.</i>			1	1	1	1	1			5	
Neritic pelagic		<i>Trachurus symmetricus</i>	6	15	111	145	35	168	51	53	6	590	79.1
		<i>Sardinops sagax música</i>	1	1	3	4	1	7	1	17	1	36	
		<i>Ethmidium maculatum</i>			1	2	2	2		3	1	11	
		<i>Thyrstites atun</i>		1	2	2	2	7	3			17	
Bentopelagic		<i>Isacia conceptionis</i>	1	1	2	3	1	3		3	1	15	1.8
Oceanic pelagic		<i>Sarda chilensis</i>		1	2	2	3	7	3	5	1	24	4.8
		<i>Serirolella violácea</i>		1	1	4	1	1	1			9	
		<i>Xiphias gladius</i>			1	1		1	1			4	
		<i>Tetrapturus audax</i>			1	1						2	
		<i>Isurus oxyrinchus</i>								1		1	
Total			11	31	141	185	56	219	72	99	12	826	100

In addition to these fish, our study yielded others from a variety of habitats that occur less frequently but are distributed evenly throughout the Copaca 1 occupational sequence. The most prevalent of these are *Isacia conceptionis* (cabinza grunt), which circulates through the entire water column from 1 to 50 m depth as well as over rocky and sandy benthopelagic seabeds; *Cheilodactylus variegatus* (bilagay), a fish prevalent in coastal waters, inhabiting the kelp forests of rocky seabeds; and *Cilus gilberti* (corvina), a usual inhabitant of sandy and rocky seabeds (Reyes and Hüene, 2012).

The remains of Chondrichthyes (including sharks) are rare, with only vertebrae represented in the site's earliest occupational events. Notable among those remains are *Mustelus mento* (hound shark), a coastal shark that could have been caught relatively easily, and *Isurus oxyrinchus* (mako shark), identified by a single tooth found within occupational event II. Mako sharks are generally large,

measuring 3.5–4 m in length and up to 700–750 kg. Juveniles of the species can be found relatively close to shore, within 10 km of the coast, making it possible to fish for them on the water, though not from the shore.

Last are the large, oceanic billfish species such as *Tetrapturus audax* (marlin) and *Xiphias gladius* (swordfish), which, though relatively scarce in terms of remains, are important in terms of their ethology and habitat. These species are concentrated primarily between occupational layers 7 and 3 in the context of abundant other fish remains (Table 7). The study of vertebrae was crucial for taxonomic identification of specimens of *X. gladius*, as these have identifiable features that differentiate them from other species of the Istiophoridae family (Gregory and Conrad, 1937; Nakamura, 1985). The size of the vertebrae of *X. gladius* and Istiophoridae (Fig. 5), which exceed 50 mm in length, indicate that these

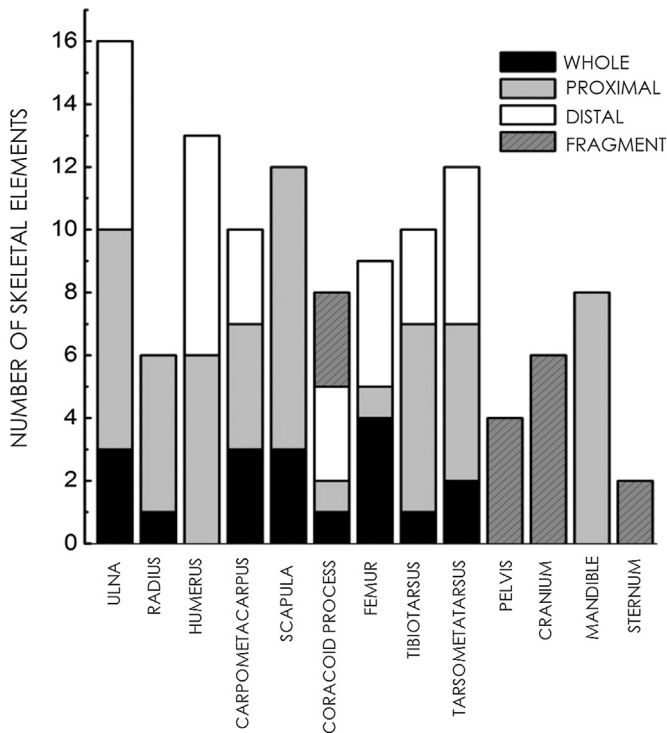


Fig. 5. NISP distribution by taxon.

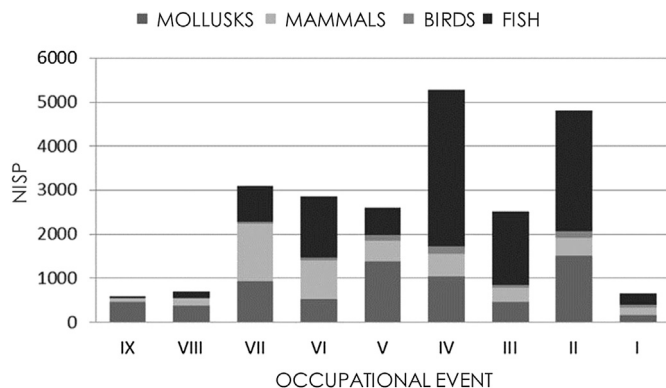


Fig. 6. MNE and state of fragmentation of seabird bones.

specimens were quite large, maybe more than 3 m long. Sexual dimorphism is a prominent feature of these large fish, with the females being larger than the males, reaching up to 4 m length and between 400 and 700 kg, particularly in the case of the swordfish (Nakamura, 1985; Froese and Pauly, 2005).

These fish inhabit waters up to 500 km offshore, though they tend to come close to shore during temperature alterations associated with ENSO events, which would make them easier to catch (Yáñez et al., 2008). However, they do not come near enough to be caught directly from the shore, and so would still have to have been caught on the open ocean, or opportunistically after washing up on the beach. The latter is unlikely, however, as the present-day behavior of these species indicates that beaching is rare. This was confirmed unanimously in interviews we conducted with the small-scale fishermen of Tocopilla, Taltal and Papos, some of whom said that they had never seen a single case of beaching among these fish. This information suggests that these species came to be present at both Copaca 1 and other archeological sites

on the absolute desert coast (Agua Dulce, Caleta Bandurrias and Zapatero, near Taltal) after being caught by skilled fishermen using some kind of oceangoing vessel (Olguín et al., 2014).

5.5. Gathering marine invertebrates

From the total of 58 taxa distributed among 20 families, it is apparent that the largest grouping consists of five species that were gathered for consumption, based on their high food value and biomass: *Concholepas concholepas* (abalone), *Fissurella* sp. (limpets); *Tegula atra* (black sea snail); *Acanthopleura echinata* (chitons); and *Loxechinus albus* (sea urchins). This wide variety of species is typical of the rocky intertidal system, the richest and most productive zone on the arctic coast (Castro, 2013b).

The Fissurellidae family is the most abundantly represented, showing extremely high concentrations throughout the occupational sequence, except for layers 9 and 6, where their frequency decreases notably. Specimens of the families Trochidae (*T. atra*), Muricidae (*C. concholepas*), and Chitonidae are also distributed evenly throughout all Holocene occupations, with no significant variation (Table 3).

Other variations in marine invertebrate distribution over the occupational sequence include a much higher concentration of sea urchins during occupational layers 5 and 3 than in either earlier or later Middle Holocene sequences, with the exception of occupation of the layer 8 (Table 3). Almost the opposite occurs with bivalves, particularly the taxa *Protothaca theca* and *Choromytilus chorus*, which display a slight but notable rise in concentration during occupational layer 8.

The frequency of crustaceans, specifically crabs, was also low during the site's occupational events, never exceeding 224 individuals, all of them dactylopodites. This low frequency is likely due to poor preservation, as the organic matter that comprises the bulk of the decapod exoskeleton tends to be very fragile, and thus only the hardest anatomical parts with the highest calcium content tend to be conserved.

Overall, gastropods represented 26.67% of the total NISP recorded (Table 3). The majority of these were probably selected for consumption, and only a few taxa are represented, including *T. atra*, *Fissurella maxima*, *Fissurella cumingii*, *Fissurella crassa*, *Fissurella limbata*, *C. concholepas* and *A. echinata*. The remaining percentage corresponds to small snails such as *Turritella cingulata*, *Scurria parasitica*, *Diloma nigerrima*, and *Nasarius gayi*, among others, which apparently became part of the archeological context unintentionally during gathering and processing of other species.

6. Discussion

Although the information available is still incomplete, the data obtained from Copaca 1 suggest that as of 8000 cal. BP groups of marine hunter–gatherers inhabiting the site were using specialized technology to fish and to hunt marine mammals, gradually colonizing the different ecoanthropic spheres of the arctic coast, developing economic practices and forms of mobility that centered around exploiting resources with a high rate of return and low processing cost.

This adaptive strategy was successful because these groups adopted technologies such as circular fish hooks, composite fish hooks, harpoons (long and short), shellfish openers, weights, darts and others, which they manufactured from a variety of raw materials including sea shells, wood, bone and stone (Castro et al., 2014). They also developed a high degree of residential mobility, moving among different base camps, some of which they may have occupied semi-permanently. Indeed, the Copaca 1 site was probably part of a settlement system similar to the one recorded 300 km

further south on the arctic coast, given that it displays a similarly dense stratigraphic context and a chronology comparable to the large middens located in that zone, namely Zapatero, Agua Dulce, Morro Colorado, Las Conchas and Punta Grande (Capdeville, 1921; Bird, 1943; Silva and Bahamondes, 1969; Durán, 1981; Andrade and Salazar, 2011; Olguín et al., 2014).

The Copaca 1 faunal record displays a significant abundance of marine resources, some of which were more economically profitable than others, including marine mammals (pinnipeds and dolphins), fish (mackerel), and mollusks (gastropods). Given the ready supply of food from resources with greater biomass and food value (higher in calories), marine invertebrates (crustaceans and equinoderms), terrestrial mammals (camelids) and birds were used much less intensively, occupying a marginal role among the array of subsistence resources throughout the Middle Holocene. This trend is reiterated at other Middle Holocene archeological sites located along the arid coast of northern Chile (such as Agua Dulce and Zapatero, in the locality of Taltal) (Olguín, 2011).

Given the wide variety of species of different sizes inhabiting a broad range of environments, we suggest that the inhabitants of Copaca 1 employed a diverse array of specialized strategies to take advantage of the resources available to them. For these activities, they used a variety of instruments tailor-made for the resources they wished to extract (selective hunting and gathering). Our observations of their technologies indicate that these groups probably used bone and stone instruments for hunting marine and terrestrial mammals and birds. Archaic occupations closely associated with stone points that have no observable microtraces of cutting, indicating that these instruments were probably not used to process prey (García-Albarido, 2012). Bone harpoon barbs and shafts were also found (Santander, 2010; Varela et al., 2010).

The many different faunal resources found at Copaca 1 derive primarily from the hunting of marine mammals such as dolphins and pinnipeds, which contributed the highest caloric value to the diet of the site's Middle Holocene inhabitants. In regard to the transportation, processing, and consumption of these animals, based on the wide variety of skeletal parts found, we propose that the prey were brought into the camp whole and then processed, consumed and disposed of *in situ*. As for hunting frequency, pinniped hunting would have been a predictable, reliable activity requiring a low outlay of energy and little mobility, as there was a breeding rookery on the coast just next to the site - an important fact, given the reproductive philopatry of sea lions, especially the species *O. flavescens*, which allows us to suppose that these rookeries have remained in the same location for thousands of years (Grandi et al., 2008; San Román, 2011). In this regard, a Middle Holocene pinniped hunting strategy would not have required extensive mobility, as most of the residential camps associated with this period were located on the coast, sometimes near a breeding rookery, as in the case of Copaca 1.

Regarding the patterns of production, hunting seals is especially prominent in the earliest occupational layers. This was predictable, as it is a safe activity, with low cost in mobility to locate breeding colonies located nearby.

Although there are known cases of large cetacean washed ashore on the southern coast of Chile (Massone and Prieto, 2005), the surprising high frequency of dolphins in most occupational layers of Copaca 1, especially in the upper levels of the deposit is not considered as the effect of these type of events. Dolphins are large and powerful fast swimming mammals, which implies a completely different challenge to the systematic hunting of, for example, pinnipeds. Nets or harpoons and some kind of watercraft were probably used to catch dolphins (Meighan, 1959; Raab, 2009), as might occur with fishing for swordfish.

In regard to the consumption of terrestrial mammals, our study showed a notable use of camelid skeletal parts (probably *Lama guanicoe*) to fabricate artifacts, with an evident link between the consumption of terrestrial fauna and the development of technologies useful for obtaining the marine resources (hunting, fishing and gathering) that were the foundation of the groups' diet. Though the skeletal parts of terrestrial fauna are scant in the record, it is reasonable to assume that the groups used dispersed remains to manufacture fish hooks, jigs, foreshafts, awls, and other items (Santander, 2010). Recovering extremities abandoned by other predators could still have presented a nutritional opportunity, given the exceptional preservation of the bone marrow in the extremities of these hoofed animals, above all in the lower segments (metapodials and first phalange), which are rich in fat and oleic acid (Munro and Bar-Oz, 2005; Santander, 2009).

As for marine birds, the data suggests that these groups systematically hunted adult individuals, though it is impossible to state whether or not they also took advantage of other avian food resources (eggs, chicks, etc.) during the nesting season. If they did catch the birds at their nesting sites, we would expect to find the bone remains of chicks and young birds in the record, but this is not the case at Copaca 1, probably owing to taphonomic causes (loss and fragmentation) that would have affected the preservation of such remains. The few species that are represented, such as the Humboldt penguin, allow us to infer that the groups may have captured solitary birds opportunistically and/or targeted others that were available only occasionally in certain places (Peña-Villalobos et al., 2013).

Although we have partially ruled out that meat processing was a regular practice throughout the chronological sequence of Copaca 1, we can affirm that the degree of fragmentation of the bird bones and the cut marks found on them indicate that they were dismembered using cutting instruments. Moreover, proximal fragments of these animals are more numerous than distal ones, indicating that in processing the bird, the more distal portions of their motor appendages (i.e. ulna, tibiotarsus) were discarded prior to the carcass being brought on site.

In the case of fishing, the fish hooks used by these Middle Holocene groups were designed to suit the particular fish's habitat, size and type of mouth (to ensure the hook would be swallowed), while the fish's body size would have determined the kind of nets used, if any. We also do not know whether or not these people used harpoons to spear fish found in tidal pools when the tide went out. Today, free divers on this coast catch *Sicyases sanguineus* (clingfish) using a harpoon or fishing spear (Reyes and Hüne, 2012).

While no remains of netting have been found at the site, the ichthyological evidence could support their use, as two pelagic fish found at the site - *S. sagax* (sardine) and *S. chilensis* (bonito) - could have been a bycatch of fishing mackerel (*T. symmetricus*), which the Middle Holocene groups evidently favored. Added to this is that the sardines are too small to have swallowed a seashell fish hook. Nevertheless, the sardines found at the site may also have arrived as part of the stomach contents of larger fish or marine mammals (dolphins and/or pinnipeds) that feed off this species. Evidence of large shoals of mixed fish species would support the former idea, or at least both possibilities. Moreover, nets could have been deployed more efficiently from the side of a vessel, especially since the coast in the zone of study is predominantly rocky, making the handling of nets difficult from the shore.

The presence of large oceanic fish such as *T. audax* (marlin), *X. gladius* (swordfish) and *I. oxyrinchus* (mako shark) at the site allows us to suggest that, at least during the Middle Holocene, groups with fishing technology that specialized in coastal resources also navigated on the open ocean, probably more than 2 km offshore, in some kind of vessel that would have enabled them to catch these

large fish. The variety of oceanic taxa recorded at other sites on the arctic coast including Agua Dulce, Caleta Bandurrias, Cachinales and Zapatero (Olguín, 2011; Olguín et al., 2014), reinforces the idea that these groups not only navigated on the open ocean but hunted pelagic species there as early as 7000 cal. BP in the area of Taltal, as the bone remains of those deepwater species appear in all occupational events for that period, albeit in small numbers.

Above and beyond variations in the frequency of certain taxa across the occupational sequence, the wide variety of marine invertebrates found in the settlement allows us to infer that mollusks were a regular source of calories for these Middle Holocene coastal groups, providing significant economic stability thanks to their predictability, abundance, and ease of gathering and processing. This high-biomass food source can be gathered at low tide or between high and low tide in the intertidal zone without the need for specialized skills or technologies. Simple implements were all that was needed, making this a task that could be performed by people of all ages, notably women and children, as the energy outlay required to extract them was low.

Thus, marine invertebrates were a staple in the diet of these coastal peoples as well as a potential stabilizer of the hunter–gatherer economy. This does not imply that these groups relied exclusively on mollusks as a food source, but rather that they used them to complement their main diet of sea lions, dolphins, and fish.

To summarize, based on the malacological composition studied we can affirm that there are no significant differences observed in the presence and distribution of marine invertebrates over the entire occupational sequence. This allows us to contend that both the economic role of mollusks and the cultural strategies and approaches employed to obtain them remained the same throughout the different periods represented by the layers identified in each site. Nevertheless, one notable difference we recorded in the malacological set analyzed is the low frequency of the bivalve *C. chorus*. Pre-Hispanic coastal populations extracted this species and used the shells to make both functional and ornamental items, and the valves served as raw material for tools throughout the Middle Holocene. In the Copaca 1 deposits, five straight-shafted fish hooks were recovered made of the seashell *C. chorus*, associated with layers 3, 4 and 5 (Varela et al., 2010), along with some expedient cutting instruments made from the same species of seashell, and some necklace beads (Castro P., 2013a, 2013b). We also recorded, though very infrequently, traces of tool use on *C. concholepas* valves and on different types of *Fissurella* spp., suggesting that these mollusks were extracted and opened using a bone opener or possibly another shell. Hopefully, more advanced techniques and new studies of the arctic coast will provide more clues about the daily lives of these Holocene groups that lived on the arid coast of Northern Chile.

Acknowledgements

This investigation was made possible through FONDECYT Grant 1100951. We especially wish to thank the entire research team, especially Pedro Andrade and Felipe Rubio and all those who participated in the excavation of Copaca 1.

References

Aguayo, A., Maturana, R., 1973. Presencia del lobo marino común *Otaria flavescens*, en el litoral chileno. Arica (18°27'S.) a Punta Maiquillahue (39°27'W.). *Biología Pesquera*, Chile 6, 45–75.

Andrade, P., Salazar, D., 2011. Revisando Morro Colorado: comparaciones y propuestas preliminares en torno a un conchal arcaico en las costas de Taltal. *Taltalia* 4, 63–83.

Avery, D., 1995. Physical environment and site choice in South Africa. *Journal of Archaeological Science* 22, 343–353.

Behrensmeyer, A.K., 1978. Taphonomic and ecological information from bone weathering. *Paleobiology* 4, 150–162.

Binford, L.R., 1984. *Faunal Remains from Klasies River Mouth*. Academic Press, Orlando.

Bird, J., 1943. Excavation in Northern Chile. In: *New York: Anthropological Papers of the American Museum of Natural History*, 38 (4). American Museum of Natural History.

Bittman, B., 1986. Los Pescadores, cazadores y recolectores de la costa árida chilena: un modelo arqueológico. *Chungara, Revista de Antropología* 16–17, 59–65.

Bonner, N., 1994. *Seals and Sea Lions of the World*. Blandford, UK.

Brown, A., 1971. Lista de las aves de Antofagasta. *Boletín Chileno de Ornitología* 3, 3–5.

Capdeville, A., 1921. Notas Acerca de la Arqueología de Taltal. Introducción. *Boletín de la Academia Nacional de Historia II*, N° 3–4.

Carhart, E., 1969. *Birds of Robinson Crusoe Island, Antofagasta, Calama and Angol*. *Boletín Chileno de Ornitología* 1, 5–6.

Carré, M., Azzoug, M., Benteleb, I., Chase, B.M., Fontugne, M., Jackson, D., Ledru, M.P., Maldonado, A., Sachs, J.P., Schauer, A.J., 2011. Mid-Holocene mean climate in the south eastern Pacific and its influence on South America. *Quaternary International* 256, 55–66.

Carré, M., Benteleb, I., Fontugneand, M., Lavallée, D., 2005. Strong El Niño events during the early Holocene: stable isotope evidence from Peruvian sea shells. *The Holocene* 15 (1), 42–47.

Castro, P., 2013a. Informe de Procedimiento de Laboratorio Manufactura de Cuentas. Fondecyt Project # 1100951 “Del Período Formativo al Tardío en la Costa de Antofagasta. Cronología e Interrelaciones con las Tierras Altas”. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.

Castro, P., 2013b. Progress Report on Undergraduate Thesis. Uso de invertebrados marinos a través del tiempo: Continuidad y cambio en la secuencia ocupacional de la costa arcaica, Norte Grande. Fondecyt Project # 1100951 “Del Período Formativo al Tardío en la Costa de Antofagasta. Cronología e Interrelaciones con las Tierras Altas”. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.

Castro, V., Aldunate, C., Varela, V., 2012. Paisajes Culturales de Cobija, Costa de Antofagasta, Chile. *Chungara, Revista de Antropología Chilena* 26, 97–128.

Castro, V., Aldunate, C., Varela, V., Andrade, P., Olguín, L., García-albarido, F., Rubio, F., Castro, P., Ruz, I.J., 2014. Nuevos aportes al arcaico en la costa arcaica de Antofagasta, Norte de Chile. *Chungara, Revista de Antropología Chilena* (submitted for publication).

DeFrance, S., Umire, A., 2004. Quebrada de Tacahuay: un sitio marítimo del pleistoceno tardío en la costa sur del Perú. *Chungará, Revista de Antropología Chilena* (Chile) 36, 257–278.

De Vries, T.J., Wells, L.E., 1990. Thermally anomalous Holocene molluscan assemblages from coastal Peru: evidence for paleogeographic, not climatic change. *Palaeogeography, Palaeoclimatology, Palaeoecology* 81, 11–32.

De Vries, T.J., Ortlieb, L., Díaz, A., Wells, L., Hillaire-Marcel, C., Wells, C., Noller, L.E., Sandweiss, D.H., Richardson III, J.B., Reitz, E.J., Rollins, H.B., Maasch, K.A., 1997. Determining the early history of El Niño. *Science* 276, 965–967.

Durán, A., 1981. Investigación Arqueológica en Punta Grande. Memoria para optar al Título de Arqueólogo. Universidad del Norte, Antofagasta, Chile.

Estades, C., 1992. Avifauna de la Segunda Región de Antofagasta. *Boletín Chileno de Ornitología* (Chile) 14, 12–18.

Falabella, F., Meléndez, R., Vargas, M.L., 1995. Claves Osteológicas para Peces de Chile Central. Un Enfoque Arqueológico. Editorial Artegrama, Santiago, Chile.

Fariña, J., Ossa, P., Castilla, J.C., 2008. Ecosistemas marinos. In: CONAMA (Ed.), *Biodiversidad de Chile: Patrimonio y desafíos*. Editorial Ocho Libros, Santiago, pp. 96–105.

Fibla, P., Sallaberry-Pincheira, N., Sallaberry, M., 2010. Cuento de aves marinas muertas en la playa La Rinconada, Antofagasta y comentarios acerca de la distribución de *Macronecteshalli*. *Boletín Chileno de Ornitología* (Chile) 16, 37–41.

Follman, G., 1967. Die Flechtenflora de nordchilenischenNebeloase Cerro Moreno. *Nova Hedwigia* 14, 215–281.

Follmann, G., Weisser, P., 1966. Oasis de neblina en el norte de Chile. *Boletín de la Universidad de Chile* 67, 34–38.

Fonseca, T., Fariás, M., 1987. Estudio del proceso de surgencia en la costa chilena utilizando percepción remota. *Revista de Investigación Pesquera* 34, 33–46.

García-Albarido, F., 2012. Estrategias de subsistencia en Cobija durante el Período Intermedio Tardío y el Tawantinsuyu. Aproximación desde la funcionalidad de los instrumentos líticos. Undergraduate paper to obtain the professional title of archaeologist. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.

Grandi, M.F., Dans, S.L., Crespo, E.A., 2008. Social composition and spatial distribution of colonies in an expanding population of South American Sea Lions. *Journal of Mammalogy* 89 (5), 1218–1228.

Grayson, D.K., 1984. *Quantitative Zooarchaeology. Topics in the Analysis of Archaeological Faunas*. Academic Press Inc., Orlando.

Gregory, W., Conrad, M., 1937. The comparative osteology of the swordfish (*Xiphias*) and the sailfish (*Istiophorus*). *American Museum Novitates* 952, 1–28.

Guerra, C., Torres, D., 1984. The presence of the South American fur seal, *Arctocepalus australis* (Zimm., 1783) in Northern Chile. In: *International Symposium and Workshop on the Biology of Fur Seals*, Cambridge.

Guerra, C., Torres, D., 1987. Presence of the South American fur seal, *Arctocepalus australis*, in Northern Chile. In: Croxall, J.P., Gentry, R.L. (Eds.), *Status, Biology and Ecology of Fur Seals*, Proceedings of an International Symposium and Workshop, Cambridge, England, 23–27 April, 1984, 51, pp. 169–175. NOAA Technical Report NMFS.

- Gusinde, M., 1951. Fueguinos. Hombres primitivos en la Tierra del Fuego (de investigador a compañero de tribu). Escuela de Estudios Hispanoamericanos, Sevilla.
- Guzmán, N., Saa, S., 1996. Taxonomía, distribución y principales características ecológicas de la malacofauna de la Región de Antofagasta. In: Seminar to Obtain the Licentiate Degree in Ocean Sciences and the Professional Title of Aquaculture Engineer. Universidad de Antofagasta, Antofagasta.
- Guzmán, N., Saa, S., Ortlieb, L., 1998. Catálogo descriptivo de los moluscos litorales (Gastropoda y Pelecypoda) de la zona de Antofagasta, 23°S (Chile). *Estudios Oceanológicos* 17, 17–86.
- Harrison, P., 1983. *Seabirds, an Identification Guide*. Houghton Mifflin Company, Boston.
- Jaramillo, A., 2003. *Birds of Chile*. Princeton Field Guides. Princeton University Press, New Jersey.
- Kelt, D., Brown, J.H., Heske, E.J., Marquet, P.A., Morton, S.R., Reid, J.R., Rogovin, K.A., Shenbrot, G., 1996. Community structure of desert small mammals: comparison across four continents. *Ecology* 77, 746–761.
- King, J., 1983. *Seals of the World*. Oxford University Press, Cambridge.
- Lagostera, A., 1979. Ocupación humana en la costa norte de Chile asociada a peces local extintos y a litos geométricos: 9.680+160 a.p. In: *Actas del VII Congreso de Arqueología Chilena*. Ediciones Kultrún, Santiago, pp. 93–113.
- Lagostera, A., 1982. Tres dimensiones en la conquista prehistórica del mar: un aporte para el estudio de las formaciones pescadoras de la costa surandina. In: *Actas del VIII Congreso Nacional de Arqueología Chilena*. Ediciones Kultrún, Santiago, pp. 217–245.
- Lagostera, A., 1989. Caza y pesca marítima (9.000 a 1.000 a.C). In: Hidalgo, J. (Ed.), *Prehistoria Desde sus orígenes hasta los albores de la conquista*. Editorial Andrés Bello, Santiago, pp. 57–80.
- Lagostera, A., 2005. Culturas costeras precolombinas en el norte chileno: secuencia y subsistencia de las poblaciones arcaicas. In: Figueroa, E. (Ed.), *Biodiversidad Marina: valoración, usos, perspectivas ¿Hacia dónde va Chile?* Editorial Universitaria, Santiago, pp. 107–148.
- Lagostera, A., Weisner, R., Castillo, G., Cervellino, M., Costa-Junqueira, M., 2000. El Complejo Huentelauquén bajo una perspectiva macroespacial y multidisciplinaria. In: *Actas del XIV Congreso Nacional de Arqueología Chilena*. Tomo I, Museo Regional de Atacama, Copiapó, pp. 461–482.
- Legoupil, D., 1989–1990. Identificación de los mamíferos marinos en los sitios canoeros de Patagonia: Problema y constataciones. *Anales del Instituto de la Patagonia* 19, 101–113.
- Lyman, R.L., 1994. *Vertebrate Taphonomy*. Cambridge Manuals in Archaeology. University Press, Cambridge.
- Mameli, L., Estévez, J., 2004. Etnoarqueología de aves: El ejemplo del extremo sur Americano. *Treballs d' Etnoarqueología* 5, Madrid.
- Mann, G., 1954. La vida de los peces en aguas chilenas. Instituto de Investigaciones Veterinaria. Universidad de Chile, Santiago.
- Marchant, M., Hebbeln, D., Wefer, G., 1999. High resolution planktic foraminiferal record of the last 13 300 years from the upwelling area off Chile. *Marine Geology* 161, 115–128.
- Marquet, P., Bozinovix, F., Bradshaw, G., Cornelius, C., González, H., Gutiérrez, J., Hajek, E., Lagos, J., López-Cortés, F., Núñez, L., Rosell, E., Santoro, C., Samaniego, H., Standen, V., Torres-Mura, J.C., Jaksic, F., 1998. Los ecosistemas del desierto de Atacama y área andina adyacente en el norte de Chile. *Revista Chilena de Historia Natural* 71, 593–617.
- Massone, M., Prieto, A., 2005. Ballenas y delfines en el mundo Selk'nam: Una aproximación etnográfica. *Magallania* 33 (1), 25–35.
- Maxwell, G., 1967. *Seals of the World*. Houghton Mifflin Company, Boston.
- Meighan, C.W., 1959. The Little Harbor Site, Catalina Island: an example of ecological interpretation in archaeology. *American Antiquity* 24 (4), 383–405.
- Munro, N.D., Bar-Oz, G., 2005. Gazelle bone fat processing in the Levantine Epipalaeolithic. *Journal of Archaeological Science* 32 (2), 223–239.
- Nakamura, I., 1985. Billfishes of the world; an annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. *FAO Fisheries Synopsis* 125 (5), 1–65.
- Navarro, R., 2007. *Caracoles Marinos de Chile: Una Guía Para Observar e Identificar Caracoles*. Museo Nacional de Historia Natural, Santiago.
- Noy-Meir, I., 1973. Desert ecosystems: environment and producers. *Annual Review of Ecology and Systematics* 4, 25–51.
- Núñez, L., Varela, J., 1967–1968. Sobre los recursos de agua y el poblamiento pre-hispánico de la Costa del Norte Grande de Chile. *Estudios Arqueológicos* 3–4, 7–41.
- Olgúin, L., 2011. Historia de un conchal: procesos de formación y secuencia ocupacional del sitio Agua Dulce, costa arcaica del desierto de Atacama, comuna de Taltal, Región de Antofagasta. Undergraduate project to obtain the professional title of archeologist. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.
- Olgúin, L., Peña-Villalobos, I., Fibla, P., Sallaberry, M., 2012. Informe de Arqueofauna, Sitio Arqueológico Copaca 1, II Región de Antofagasta. Proyecto Fondecyt 1100951. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.
- Olgúin, L., Salazar, D., Jackson, D., 2014. Tempranas evidencias de Navegación y caza de especies oceánicas en la Costa Pacífica de Sudamérica (Taltal, ~7000 años cal. a.p.). *Chungara, Revista de Antropología Chilena* 46 (2), 177–192.
- Olgúin, L., Peña-Villalobos, I., Castro, V., Santander, B., Ruz, J., Castro, P., García-Albarido, F., Rubio, F., Vargas, V., 2013. Cazadores, recolectores y pescadores del Holoceno medio en el litoral árido del pacífico suroccidental: una mirada desde el contexto arqueofaunístico del sitio Copaca 1, región de Antofagasta, norte de Chile. In: XVII Congreso Nacional de Arqueología Argentina, 22–26 April, 2013, La Rioja, Argentina, p. 59.
- Pacheco Torres, V., Altamirano Enciso, A., Guerra Porras, E., 1986. The Osteology of South American Camelids. Institute of Archaeology, University of California, Los Angeles.
- Peña-Villalobos, I., Olgúin, L., Fibla, P., Castro, V., Sallaberry, M., 2013. Aprovechamiento humano de aves marinas durante el Holoceno medio en el litoral árido del norte de Chile Human use of marine birds during the middle Holocene on the arid coast of northern Chile. *Revista Chilena de Historia Natural* 86, 301–313.
- Plissock, P., Luebert, F., 2008. Los Ecosistemas Terrestres. In: Rodovira, J., Ugalde, J., Stutzin, M. (Eds.), *Biodiversidad de Chile: Patrimonio y Desafíos*. Edición Ocho Libros, Santiago, pp. 74–87.
- Quintana, V., Yáñez, J., Valdevenito, M., 2000. Orden carnívora. In: Muñoz-Pedreras, A., Yáñez, J. (Eds.), *Mamíferos de Chile*. CEA Ediciones, Santiago, pp. 155–188.
- Raab, L.M., 2009. The dolphin hunters. In: Raab, L.M., Cassidy, J., Yatsko, A., Howard, W.J. (Eds.), *California Maritime Archaeology, a San Clemente Island Perspective*. Altamira Press, UK, pp. 93–108.
- Reyes, P., Hüne, M., 2012. *Peces del Sur de Chile*. Ocho Libros Editores, Santiago.
- Rollins, H.B., Richardson III, J.B., Sandweiss, D.H., 1986. The birth of El Niño: geoarchaeological evidence and implications. *Geoarchaeology: an International Journal* 1 (1), 3–15.
- Rundel, P.W., Dillon, M.O., Palma, B., Mooney, H.A., Gulmon, S.L., Ehleringer, J.R., 1991. The phytoecology and ecology of the coastal Atacama and Peruvian deserts. *Aliso: A Journal of Systematic and Evolutionary Botany* 13, 1–49.
- Ruz, J., 2013. Informe Ictioarqueológico. Sitio Copaca 1. Proyecto Fondecyt 1100951. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.
- Sandweiss, D., 2008. Early fishing societies in western South America. In: Silverman, H., Isbell, W.H. (Eds.), *Handbook of South American Archaeology*. Springer, New York, pp. 145–156.
- Sandweiss, D.H., Richardson III, J.B., Reitz, E.J., Rollins, H.B., Maasch, K.A., 1996. Geoarchaeological evidence from Peru for a 5000 BP on set of El Niño. *Science* 273, 1531–1533.
- Sandweiss, D.H., McInnis, H., Burger, R.L., Cano, A., Ojeda, B., Paredes, R., Sandweiss, M.C., Glascock, M.D., 1998. Quebrada Jaguay: early South American maritime adaptations. *Science* 281, 1830–1832.
- Sandweiss, D.H., Maasch, K.A., Burger, R.L., Richardson III, J.B., Rollins, H.B., Clement, A., 2001. Variation in Holocene El Niño frequencies: climate records and cultural consequences in ancient Peru. *Geology* 7, 603–606.
- San Román, M., 2011. La explotación de recursos faunísticos en el sitio Punta Santa Ana 1: Estrategias de subsistencia de grupos de cazadores marinos tempranos de Patagonia Meridional. Undergraduate project to obtain the professional title of archeologist. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.
- Santander, B., 2009. Modelos Secuenciales para Tecnología Ósea durante la Transición Arcaico-Formativo en Atacama, El caso de la Quebrada Tulan. In: López, P., Cartajena, I., García, C., Mena, F. (Eds.), *Zooarqueología y Tafonomía en el Confin del Mundo*. Universidad Internacional Sek, Santiago, pp. 45–58.
- Santander, B., 2010. Informe de análisis de artefactos óseos recuperados en los sitios Cobija-1 norte y Copaca-1. Fondecyt Project # 1100951 “Del Período Formativo al Tardío en la Costa de Antofagasta. Cronología e Interrelaciones con las Tierras Altas”. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.
- Santibáñez, F., Roa, P., Santibáñez, P., 2005. El Medio Físico. Las Variaciones Climáticas el niño, La Niña y los Cambios Climáticos. In: CONAMA (Ed.), *Biodiversidad de Chile: Patrimonio y Desafíos*. Editorial Ocho Libros, Santiago, pp. 21–42.
- Siegel-Causey, D., 1988. Phylogeny of the Phalacrocoracidae. *The Cooper Ornithological Society, The Condor, USA*, pp. 885–905.
- Silva, J., Bahamondes, D., 1969. Investigaciones arqueológicas en Taltal, Informe Preliminar. In: *Actas del IV Congreso Nacional de Arqueología*. Rehue, 2, pp. 7–25.
- Simone, A., Navarro, A., 2002. Human exploitation of seabirds in coastal southern Chile during the mid-Holocene. *Revista Chilena de Historia Natural* 75, 423–431.
- Smith, I., 2011. *Meat Weight, Nutritional and Energy Yield Values for New Zealand Archaeofauna*. Anthropology Department, University of Otago, New Zealand. <http://www.otago.ac.nz/anthropology/arch/publications/OALR/OALR%20%20>.
- Tongway, D.J., Cortina, J., Maestre, F.T., 2004. Heterogeneidad espacial y gestión de medios semiáridos. *Ecosistemas* 13 (1), 2–15.
- Van Tets, G., Meredith, P., 1988. Osteological differences between *Sula* and *Morus*, and a description of an extinct new species of *Sula* from Lord Howe and Norfolk islands, Tasman Sea. 1988. *Notornis*. *Journal of the Ornithological Society of New Zealand* 35, 35–57.
- Varela, V., Letelier, J., Castro, V., 2010. Informe acerca de instrumentos y materiales formatizados del sitio Copaca 1. Costa de Antofagasta. Excavaciones año 2010. FondecytProject # 1100951 “Del Período Formativo al Tardío en la Costa de Antofagasta. Cronología e Interrelaciones con las Tierras Altas”. Facultad de Ciencias Sociales, Universidad de Chile, Santiago.
- Vargas Jr., J.M., Roberts, D., Danneberger, T.K., Otto, M., Detweiler, R., 1989. In: Leslie, A.R., Metcalf, R.L. (Eds.), *Integrated Pest Management for Turfgrass and Ornamentals*. U.S.E.P.A. Washington, D.C. pp. 121–126.
- Vargas, M.L., Falabella, F., Meléndez, R., 1993. Bases para el manejo de datos ictioarqueológicos del “jural” (Trachurusmmetricus AYRES, 1855) (PISCES: PERCIFORMES: CARANGIDAE). In: *Actas del XII Congreso Nacional de Arqueología Chilena*. Museo Regional de la Araucanía, Temuco, pp. 355–371.

- Vargas, G., Ortlieb, L., Rutllant, J., 2000. Aluviones históricos en Antofagasta y su relación con eventos El Niño/Oscilación del Sur. *Revista de Geología de Chile* 27 (2), 157–176.
- Vaz Ferreira, R., 1981. South American sea lion *Otaria flavescens* (Shaw, 1800). In: Ridgway, S., Harrison, R. (Eds.), *Handbook of Marine Mammals*. Academic Press, London, pp. 39–65.
- Veit, H., 1996. Southern Westerlies during the Holocene deduced from geomorphological and pedological studies in the Norte Chico, northern Chile (27–33°S). *Palaeoceanography, Paleoclimatology, Palaeoecology* 18, 107–119.
- Williams, A., Santoro, C., Smith, M., Latorre, C., 2008. The impact of ENSO in the Atacama Desert and Australian arid zone: exploratory time-series analysis of archaeological records. *Chungara Revista de Antropología Chilena* 40 (Número Especial), 245–259.
- Wyrтки, K., Satroup, E., Patzert, W., Williams, R., Quinn, W., 1976. Predicting and observing El Niño. *Science* 191, 343–346.
- Yáñez, E., Vega, R., Silva, C., Letelier, J., Berbieri, M.A., Espíndola, F., 2008. An integrated conceptual approach to study the swordfish (*Xiphias gladius* Linnaeus, 1758) fishery in the eastern South Pacific. *Revista de Biología Marina y Oceanografía* 43 (3), 641–652.
- Zohar, I., Belmaker, M., 2005. Size does matter: methodological comments on sieve size and species richness in fishbone assemblages. *Journal of Archaeological Science* 32, 635–641.
- Zúñiga, O., 2002. *Moluscos: Guía de Biodiversidad*, vol. 1. CREA. Universidad de Antofagasta, Antofagasta.