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Human use of birds and fish in marine settings of southern Patagonia and Tierra del Fuego in the Holocene: A first macro-regional approach

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ABSTRACT

This paper presents a review of the zooarchaeological representations of birds and fish in coastal archaeological sites of southern Patagonia and Tierra del Fuego (47°–55°S). The spatial and temporal variations of this faunal record are assessed in order to understand their contribution in human subsistence in different geographic and cultural settings between 6500 and 100 BP. Spatially, the importance of birds and fish in human subsistence was similar between the Pacific and Atlantic coasts along the Holocene, although differences in taxonomic compositions of bird bone assemblages are observed among regions. Temporally, the analysis suggests an increase in bird hunting in the considered area in the last 3000 years, while an intensification of fishing activities can be proposed for the archipelagic area for that time period.

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1. Introduction

In the southernmost part of America, a diverse and continuous use of bird and fish resources by hunter–gatherer–fishers took place during the Holocene. These resources performed key roles in subsistence (e.g. Lefèvre, 1989a, 1989b, 1992, 1993–1994, 1997a, 1997b; Legoupil, 1997, 2000; Orquera and Piana, 1999a, 2009; Zangrando, 2003, 2009a, 2009b; Torres, 2009; Tivoli, 2010a, 2010b, 2014), as well as providing various raw materials for technology (e.g. Orquera and Piana, 1986–1987; Legoupil, 1997, 2000; Scheinsohn, 1997, 2010; Tivoli, 2013). However, the variability in the use of these resources in broad spatial scales and in long-term is poorly known, and previous analyses were limited to certain sectors (Tivoli and Zangrando, 2011; Santiago and Vázquez, 2012). In this paper, a review of the zooarchaeological representations of birds and fish in coastal archaeological sites of southern Patagonia and Tierra del Fuego is presented (Fig. 1). The spatial and temporal variability of bird and fish bone remains is analysed between 47° and 55° S, and 6500 and 100 BP. Relative abundance and taxonomic

compositions of these resources are assessed in order to understand their contribution in human subsistence in different geographic and cultural settings in the coasts of southern Patagonia and Tierra del Fuego.

2. Current distribution and abundance of seabirds and fish in southern Patagonia and Tierra del Fuego

The coasts of southern Patagonia and Tierra del Fuego are included in two marine ecological zones: the Patagonian cold estuarine zone and the Patagonian tidal zone (Fig. 1; Acha et al., 2004). These zones are characterized by high primary and secondary production, which allows important food availability (e.g. fish) transferring the energy to higher trophic levels (seabirds, marine mammals). The Patagonian cold estuarine zone extends along the South Pacific and Atlantic coasts, encompassing the southern tip of South America from Chiloé to south of San Jorge Gulf. The Patagonian tidal zone includes the Patagonian coasts from Peninsula Valdés to Peninsula Mitre (Tierra del Fuego). Both zones are part of the biogeographic Magellanic Province. Breeding colonies of seabirds and pinnipeds need high quantities of food and this condition is presented in those zones. Acha et al. (2004) have suggested that a good visual correlation exists between bird colonies and marine fronts.

The Pacific coast and the tip of South America are characterized by strong winds and heavy precipitation (approximately 2500 mm

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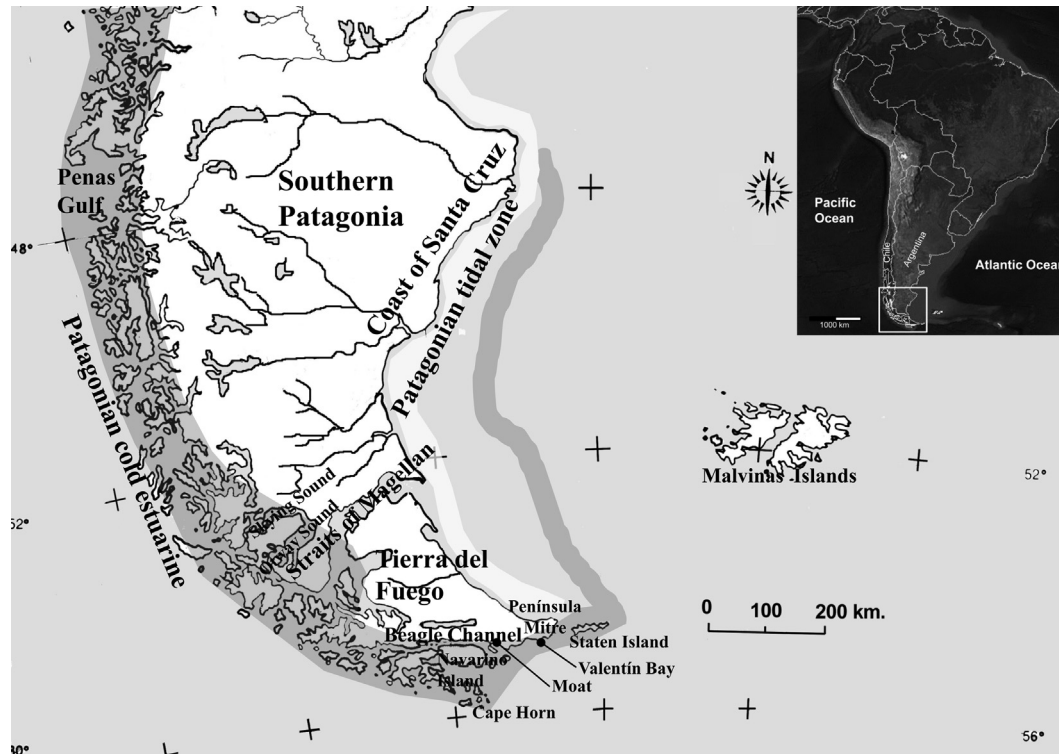


Fig. 1. Map of Southern Patagonia and Tierra del Fuego showing the geographical features and locations mentioned in the text.

per year). The continental runoff is important. The estuarine waters in fjords and channels are relatively poor in alimentary resources, while the oceanic subantarctic waters are the main source of nutrients (Silva and Neshiba, 1979). These conditions significantly affect the composition and spatial distribution of some pelagic fish, such as the Fuegian sprat (*Sprattus fuegensis*). A decrease in the richness, abundance and diversity of species is observed with the decreasing of temperature and salinity and the increasing of sedimentation in inland fjords (Hüne and Ojeda, 2012). The Patagonian blennie (*Eleginops maclovinus*) is the species with the largest biomass and distribution in the fjords and channels system (Lloris and Rucabado, 1991), and this species is normally associated with low salinity estuarine areas (Pequeño, 1979). The ichthyofauna of the Archipelago of Tierra del Fuego is characterized by the taxonomic dominance of the Nototheniidae families (mainly belonging to the genus *Patagonotothenia*) and Zoarcidae (Lloris and Rucabado, 1991; Sielfeld and Vargas, 1999).

Colonies of cormorants are present mainly in fjords and channels (Fig. 2; Garay et al., 2008; Kush and Marín, 2013). Kush and Marín (2013) calculated a population of 5300 of breeding pairs for imperial shags (*Phalacrocorax atriceps*) over 20 colonies, although these authors estimate that the population could be higher. Most breeding sites were detected between Beagle Channel and Nassau Bay, in Cook Bay, and in the NW coast of Dawson Island and Barbara Channel. Four colonies of Magellanic penguins (*Spheniscus magellanicus*) are established in Martillo Island (Beagle Channel), Franklin Bay (Staten Island), Observatorio Island and Goffré Island. Observatorio Island has the higher population with 105,500 breeding pairs, while the other colonies were much smaller (Schiavini et al., 2005). Breeding colonies of Southern Rockhopper penguins (*Eudyptes chrysocome*) were also recorded in Franklin Bay, Diego Ramirez Archipelago, Ildefonso Island and Noir Island (Kirkwood, 2007; Falabella et al., 2009); the colony of Franklin Bay has 166,700 breeding pairs (Schiavini et al., 2005). Breeding colonies of

albatrosses and petrels have been reported in offshore and oceanic islands (e.g. Diego Ramirez Archipelago, Ildefonso Island, Diego de Almagro Island). Approximately 20% of the world population (approximately 100,000 breeding pairs) of black-browed albatross (*Thalassarche melanophrys*) inhabited those islands (Robertson et al., 2008). These seabirds use to forage far away from the coasts both in the Atlantic and the Pacific oceans. Although black-browed albatross from colonies of Diego Ramirez and Ildefonso islands may spread over fjords and channels, the areas with higher densities are in outer localities such as Cape Horn and Staten Island (Falabella et al., 2009). Geese (e.g. *Chloephaga picta*) are also abundant in wetlands and forests of southern Patagonia and Tierra del Fuego (Humphrey et al., 1970; Schlatter et al., 2002; Ibarra et al., 2010).

The Atlantic sector has a high production of zooplankton resulting in a significant assemblage of fish and squids (Acha et al., 2004). The fish community of the Southern Patagonia and Tierra del Fuego shelves is mainly composed of pelagic and demersal species such as: *Micromesistius australis*, *Macruronus magellanicus*, *Sprattus fuegensis*, *Genypterus blacodes*, *Merluccius australis*, *Dissostichus eleginoides*, *Salilota australis*, Macrouridae and *Notothenia* spp (Bezzi et al., 1995). There are, however, few large-scale studies concerning the fish productivity of the area. In the Patagonian tidal zone, the Fuegian sprat (*Sprattus fuegensis*) and hakes (*Merluccius hubbsi* and *Merluccius australis*) are key species of the system: they are the most abundant fish resources providing food to large populations of seabirds and marine mammals (Acha et al., 2004; Alemany et al., 2009). Spawning areas of the Fuegian sprat have been recorded near the Tierra del Fuego coasts (Sánchez et al., 1995). In coastal areas, the Patagonian blennie is the most abundant and most widely distributed species. Diverse species of the Nototheniidae family are also presented in the intertidal and neritic zones (Lloris and Rucabado, 1991).

Cormorant and penguin colonies are particularly abundant on the Atlantic coast (Fig. 2). Three main species of cormorants are

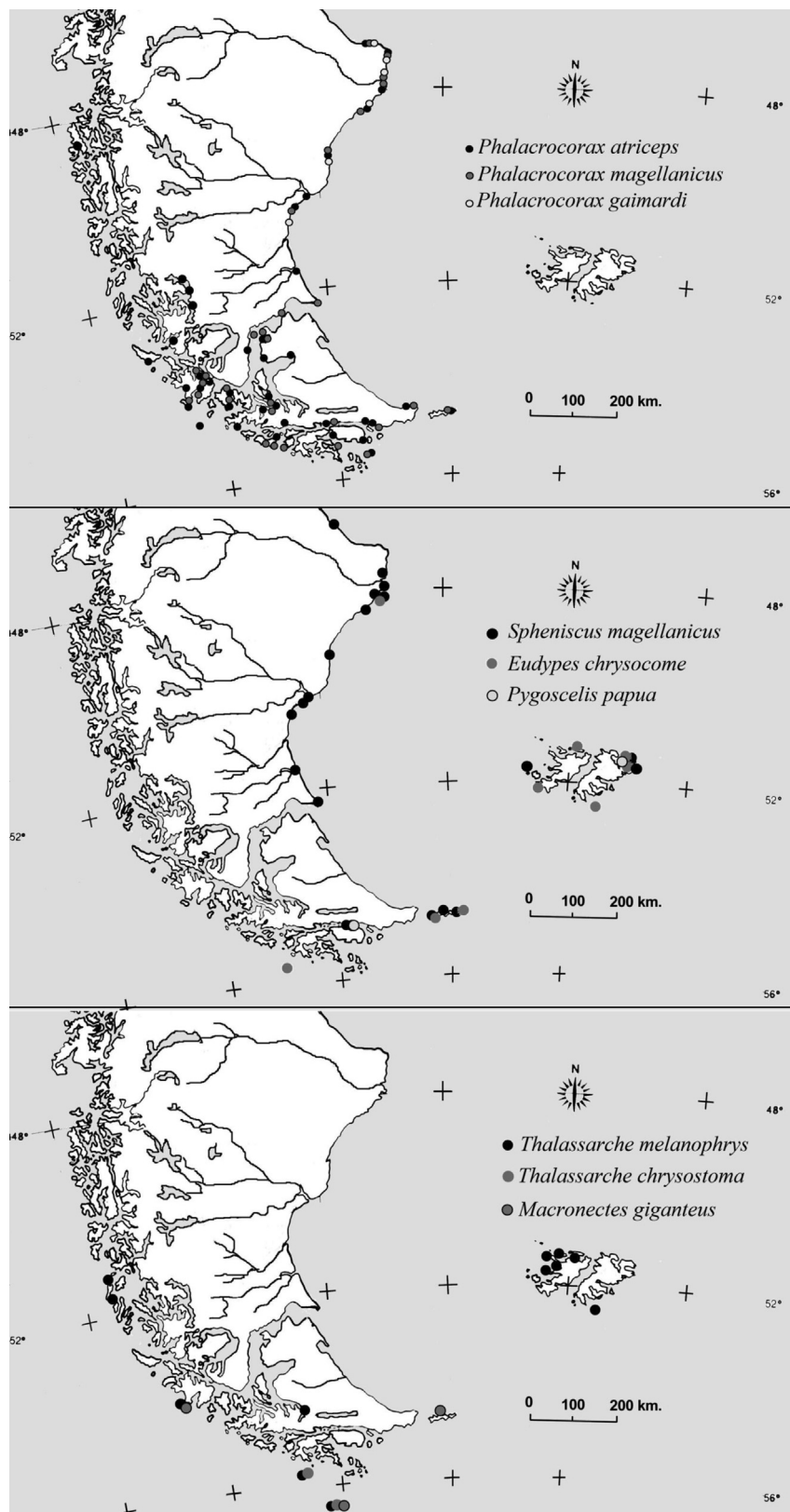


Fig. 2. Locations of seabird colonies in Southern Patagonia and Tierra del Fuego. Additional information about the composition of seabird colonies can be found in the [Supplementary data file](#).

distributed in 228 colonies along the coast of Santa Cruz and Tierra del Fuego (Argentina), totalling approximately 63,000 breeding pairs (Frere et al., 2005); the species most abundant is the imperial shag (*P. atriceps*). At the present time, a total of 63 colonies of Magellanic Penguin (*S. magellanicus*) are established along the Atlantic coast, with a minimum of 827,000 breeding pairs (Schiavini et al., 2005), from Isote Redondo to Cabo Vírgenes. The major part of the population of black-browed albatross (*Thalassarche melanophrys*) nests in Islas Malvinas, 66% of the world population (approximately 330,000 breeding pairs) but this species occasionally reaches the coast of southern Patagonia (Falabella et al., 2009). Medium sized and small petrels may feed close to or in association with the Patagonian tidal front.

3. Cultural geography

The coasts and islands of southern Patagonia and Tierra del Fuego were inhabited by human populations with two distinct subsistence and mobility patterns. In general, the Patagonian archipelago was mainly occupied by hunter–gatherer–fishers with aquatic mobility and heavily reliant upon marine resources for production of technology and for the majority of subsistence needs (Orquera et al., 2011). The Atlantic coast was inhabited by pedestrian hunter–gatherers who made fluent use of coastal and marine resources as a part, sometimes very significant, of their subsistence patterns. These coastal populations include the possibility of considerable use of ungulates in inland areas (Barberena et al., 2004; Zubimendi et al., 2005; Caracotche et al., 2006).

In the archipelagic area, human occupations are reported from 7800 BP (Zangrando, 2009a; Piana et al., 2012), but reliable evidence of maritime adapted people is present from circa 6400 BP in different locations, as in Otway Sound (Legoupil, 1997; San Román, 2013), in Beagle Channel (Orquera and Piana, 1999a, 2009), in the Valentín Bay (Zangrando et al., 2009; Vázquez et al., 2011) and in Navarino Island (Legoupil, 1993–1994). Legoupil and Fontugne (1997) have suggested that the distribution of occupations and the use of the archipelago of Tierra del Fuego were not spatially constant over the past 6400 BP. They note: 1. an initial occupation of interior channels and islands (Beagle Channel and Navarino Island), where the hunting of terrestrial and marine resources was equally possible, and 2. a subsequent dispersal and use of offshore islands, indicated by occupations with radiocarbon ages post-2000 BP (e.g. Wollaston Islands, Staten Island). Recent zooarchaeological research has noticed variations in the proportions of those resources throughout the Holocene (Zangrando, 2009a; Tivoli, 2010a,

2010b). These variations consider arguments regarding offshore-going practices and the growth in ranges of maritime mobility for subsistence activities (Zangrando, 2009b; Tivoli and Zangrando, 2011). It has also been postulated that Cape Horn islands and Staten Island were visited for seasonal exploitations of bird colonies (Horwitz, 1993; Legoupil, 1993–1994; Lefèvre, 1993–1994).

The earliest coastal occupations (6300–5800 BP) on the Atlantic coast of Southern Patagonia have been reported at the Punta Medana and Isla Lobos localities (Zubimendi et al., 2005). Occupations of the Mid-Holocene have also been recorded in the Atlantic coast of Tierra del Fuego (e.g. Rio Chico 1; Santiago, 2013). Nevertheless, the majority of the coastal occupations known for the Atlantic coast are in the last 2000 years. Different lines of archaeological inquiry suggest an important role for marine foods in subsistence of hunter–gatherer–fishers (Lanata, 1995; Borrero and Barberena, 2006; Moreno, 2008; Santiago, 2013). Home ranges deduced from the distribution of human remains with stable isotopic data are not represented by long distances from the Atlantic coast in Southern Patagonia (Borrero and Barberena, 2006; Barberena, 2008). The Atlantic coast of Tierra del Fuego shows variability in the isotopic information corresponding to human remains, with a greater reliance on marine resources recorded southward (Yesner et al., 1991; Borrero et al., 2001; Guichón et al., 2001; Zangrando et al., 2004).

4. Data sources and methodology

The geographic scope of this review corresponds to the coastal and island zones between 47° and 55° S. We use information from bibliographic sources published until 2013. Faunal representations were taken from archaeological sites located in coastal environments at a distance of no major than 5 km from the present coast. The sites considered represent a time period between approximately 6500 to 100 BP.

Table 1 presents information about the bird and fish assemblages from archaeological sites of southern Patagonia and Tierra del Fuego. The analysed database corresponds to 149 assemblages from 126 archaeological sites; 46 sites were reviewed for the Atlantic coast and 80 for the Patagonian archipelago. Some sites are comprised by multiple stratigraphic components representing long chronological sequences; in these cases, we considered the faunal information from layers with different ages separately. On both coasts, archaeological sites cover similarly the temporal line between 6500 and 100 BP, although assemblages of the Mid-Holocene are more abundant in the archipelago.

Table 1
Bird and fish assemblages from archaeological sites of Southern Patagonia and Tierra del Fuego.

Area	Site	Layer/Level	¹⁴ C BP	Latitud	Bird NISP	Fish NISP	Σ NISP	References
Archipelago of Cape Horn	Herschel 1		680 ± 60	55°–56°	807	12	889	Legoupil, 1993–1994; Lefèvre, 1993–1994
	Herschel 3		No data	55°–56°	366	14	481	Legoupil, 1993–1994; Lefèvre, 1993–1994
	Herschel 4		No data	55°–56°	585	8	717	Legoupil, 1993–1994; Lefèvre, 1993–1994
	Wollaston 7		No data	55°–56°	841	0	940	Legoupil, 1993–1994; Lefèvre, 1993–1994
	Wollaston 8		No data	55°–56°	283	13	319	Legoupil, 1993–1994; Lefèvre, 1993–1994
	Bayly 1		1410 ± 50	55°–56°	557	20	742	Legoupil, 1993–1994; Lefèvre, 1993–1994
Navarino Island	Grandi 1		6120 ± 80	55°–56°	52	182	391	Legoupil, 1993–1994; Lefèvre, 1993–1994
Staten Island	Bahía Crossley 1	I	No data	54°–55°	1068	5	1135	Horwitz and Weisell, 2011
		II	2000 ± 70	54°–55°	4870	136	5258	Horwitz and Weisell, 2011
		III	No data	54°–55°	1496	20	1692	Horwitz and Weisell, 2011
		IV	2480 ± 60	54°–55°	2154	7	2586	Horwitz and Weisell, 2011
		V	No data	54°–55°	358	20	544	Horwitz and Weisell, 2011
		VI	2730 ± 90	54°–55°	3563	16	3912	Horwitz and Weisell, 2011
		VII	No data	54°–55°	2574	16	2688	Horwitz and Weisell, 2011
Valentín Bay	BVS11	Early Component (Layers P–X)	5085 ± 39;	54°–55°	589	22	1851	Vázquez et al., 2011
			4939 ± 43					

Table 1 (continued)

Area	Site	Layer/Level	¹⁴ C BP	Latitud	Bird NISP	Fish NISP	Σ NISP	References
		Medium Component (layers M–N)	No data	54°–55°	5	3	52	Vázquez et al., 2011
		Late Component (layers B–K)	1590 ± 34; 1400 ± 34	54°–55°	351	11	1074	Vázquez et al., 2011
	BVS42		984 ± 36	54°–55°	166	7	3108	Vázquez et al., 2011
	BVS7		No data	54°–55°	121	4	229	Vázquez et al., 2011
	BVS1		335 ± 85	54°–55°	523	13	647	Vázquez et al., 2011
	BVS13		370 ± 120	54°–55°	44	0	179	Vázquez et al., 2011
Beagle Channel	Túnel I (layer D)	Phase I	6470 ± 100	54°–55°	630	39	3148	Zangrando, 2009a; Orquera pers. comm., 2012
		Phase II	6410 ± 150	54°–55°	1779	463	9299	Zangrando, 2009a; Orquera pers. comm., 2012
		Phase III	5950 ± 170	54°–55°	1221	484	5013	Zangrando, 2009a; Orquera pers. comm., 2012
		Phase IV	No data	54°–55°	5313	194	18,129	Zangrando, 2009a; Orquera pers. comm., 2012
		Phase V	5840 ± 185	54°–55°	2160	859	8703	Zangrando, 2009a; Orquera pers. comm., 2012
		Phase VI	4590 ± 130	54°–55°	2797	387	8353	Zangrando, 2009a; Orquera pers. comm., 2012
		Phase VII	No data	54°–55°	3286	1028	9603	Zangrando, 2009a; Orquera pers. comm., 2012
		Phase VIII	No data	54°–55°	3239	404	7265	Zangrando, 2009a; Orquera pers. comm., 2012
	Túnel I (Third Component)		4300 ± 80	54°–55°	800	107	2652	Zangrando, 2009a
	Túnel I (Fourth Component)		2690 ± 80	54°–55°	960	44	3328	Zangrando, 2009a
	Túnel I (Fifth Component)		1920 ± 80	54°–55°	64	19	1109	Zangrando, 2009a
	Shamakush I		1020 ± 100	54°–55°	568	2605	4366	Zangrando, 2009a; Orquera and Piana, 1999a; Tivoli, 2010a
	Túnel I (Sixth Component)		670 ± 80	54°–55°	32	233	389	Zangrando, 2009a
	Shamakush X		500 ± 100	54°–55°	198	352	568	Zangrando, 2009a; Tivoli, 2010a
	Imiwaia I (layer B)		1500 ± 70	54°–55°	2156	2366	4841	Zangrando, 2009a
Moat	Isla El Salmon		1560 ± 90	54°–55°	12	0	64	Figuerero Torres and Mengoni, 1986
	Heshkaia 28		678 ± 38	54°–55°	80	22	121	Zangrando, 2010
	Heshkaia 39		no data	54°–55°	6	0	48	Zangrando, 2010
	Heshkaia 35		656 ± 35	54°–55°	105	26	335	Zangrando, 2010
	Heshkaia 30		263 ± 35	54°–55°	444	677	1197	Zangrando, 2010
	Heshkaia 34		981 ± 36	54°–55°	78	58	933	Zangrando, 2010
Skyring Sound	Escarpada 2		No data	52°–53°	1	0	4	Legoupil, 2000
	Escarpada 3		1290 ± 100	52°–53°	2492	0	2596	Lefèvre, 1997a; Legoupil, 2000
	Escarpada 4		No data	52°–53°	28	0	29	Legoupil, 2000
	Escarpada 5		No data	52°–53°	6	0	56	Legoupil, 2000
	Escarpada 6		No data	52°–53°	44	0	46	Lefèvre, 1997a; Legoupil, 2000
	Escarpada 8		No data	52°–53°	8	0	14	Legoupil, 2000
	Escarpada 9		No data	52°–53°	0	0	7	Legoupil, 2000
	Escarpada 10		No data	52°–53°	12	0	16	Legoupil, 2000
	Escarpada 20		No data	52°–53°	2	0	16	Legoupil, 2000
	Senoret 11, 12		1760 ± 80	52°–53°	87	0	104	Legoupil, 2000
	Senoret 13		No data	52°–53°	17	0	28	Legoupil, 2000
	Senoret 14		1215 ± 70	52°–53°	471	6	653	Legoupil, 2000
	Senoret 15		No data	52°–53°	0	0	25	Legoupil, 2000
	Agua Cal. 16		No data	52°–53°	75	8	129	Lefèvre, 1997a; Legoupil, 2000
	Agua Cal. 18		No data	52°–53°	4	0	7	Legoupil, 2000
	Agua Cal. 23		No data	52°–53°	1	0	3	Legoupil, 2000
	Centro Norte 25		No data	52°–53°	73	1	80	Lefèvre, 1997a; Legoupil, 2000
	Centro Norte 26		3970 ± 60	52°–53°	64	40	128	Lefèvre, 1997a; Legoupil, 2000
	Centro Norte 27		No data	52°–53°	10	5	18	Legoupil, 2000
	Centro Norte 28		No data	52°–53°	1	4	20	Legoupil, 2000
	Centro Norte 29		4660 ± 70	52°–53°	48	0	131	Lefèvre, 1997a; Legoupil, 2000
	Centro Norte 31		No data	52°–53°	6	0	28	Legoupil, 2000
	Centro Norte 32		No data	52°–53°	0	0	34	Legoupil, 2000
	Centro Norte 33		No data	52°–53°	17	76	101	Lefèvre, 1997a; Legoupil, 2000
	Centro Norte 34		No data	52°–53°	10	1	64	Legoupil, 2000
	Centro Norte 35		No data	52°–53°	0	0	7	Legoupil, 2000
	Centro Norte 41		No data	52°–53°	3	0	12	Legoupil, 2000
	Centro Norte 42		No data	52°–53°	2	0	6	Legoupil, 2000
	Centro sur 24		No data	52°–53°	87	0	212	Lefèvre, 1997a; Legoupil, 2000
	Centro sur 44		1970 ± 70	52°–53°	0	0	22	Legoupil, 2000
	Centro sur 49b		No data	52°–53°	4	0	301	Legoupil, 2000
	Centro sur 49a		1040 ± 50	52°–53°	33	0	133	Lefèvre, 1997a; Legoupil, 2000
Otway Sound	Bahía Tilly		No data	53°–54°	39	40	90	San Román et al., 2002
	Río Batchelor 1		220 ± 60	53°–54°	21	1	48	San Román et al., 2002
	Alero Los Chilcos		1100 ± 60	53°–54°	15	1	21	San Román et al., 2002
	Puesto La Sal		No data	53°–54°	0	0	1	San Román et al., 2002
	Ba. Bending		No data	53°–54°	19	3	32	San Román et al., 2002

(continued on next page)

Table 1 (continued)

Area	Site	Layer/Level	¹⁴ C BP	Latitud	Bird NISP	Fish NISP	Σ NISP	References
	Camden 2		3030 ± 80	53°–54°	163	495	1120	San Román et al., 2002
	Camden 4		No data	53°–54°	0	1	3	San Román et al., 2002
	Río Caleta 2		110 ± 40	53°–54°	1	0	36	San Román et al., 2002
	Pta. Pichintún 1		No data	53°–54°	0	1	2	San Román et al., 2002
	Martín Pescador 2		No data	53°–54°	35	39	110	San Román et al., 2002
	Cta. Eros 2		No data	53°–54°	0	0	24	San Román et al., 2002
	Los Noruegos		5585 ± 65	53°–54°	182	22	437	San Román et al., 2002
	Pta. Eugenia 2		No data	53°–54°	2	43	65	San Román et al., 2002
	Fitz-Roy 1		405 ± 70	53°–54°	67	76	184	San Román et al., 2002
	Río Verde 1		280 ± 60	53°–54°	24	0	638	San Román et al., 2002
	Bahía Colorada		5000 ± 70	53°–54°	1716	855	6922	Legoupil 1997; Lefèvre 1997b; San Román 2010
	Ponsonby	B	4100–4300	52°–53°	45	0	1154	Legoupil, 2003
		C	4600–5400	52°–53°	99	1	2828	Legoupil, 2003
		D	6690–7450	52°–53°	35	0	417	Legoupil, 2003
	Punta Baja		280 ± 70	53°–54°	3545	166	11,954	Legoupil, 1989; Lefèvre, 1989a, 1989b
	Pizzulic 2		5945 ± 45; 6200 ± 40	53°–54°	2798	2682	6475	San Román, 2013; Torres and Ruz, 2011
Magellan Straits	Marazzi 2 90N/1E		2745 ± 40	53°–54°	227	21	1590	Calás and Lucero, 2009
	Marazzi 2 25N/35E		1965 ± 40	53°–54°	157	8	897	Calás and Lucero, 2009
	Marazzi 2 3C		910 ± 70	53°–54°	53	0	147	Calás and Lucero, 2009
	Bahía Buena		5210–5895	53°–54°	4823	381	9718	Ortiz-Troncoso, 1975; Lefèvre, 1989a; San Román, 2007
	Punta Santa Ana 1		6330 ± 50	53°–54°	612	1234	3999	Lefèvre, 1989a; San Román, 2010; Torres and Ruz, 2011
Penas Gulf	Stuven 1		2225 ± 45	47°–48°	1439	4472	5546	Legoupil et al., 2007
Tierra del Fuego - Norte	Punta Catalina 3		2380 ± 40	52°–53°	31	3072	3144	Massone and Torres, 2004
	Punta Baxa 7		1820 ± 40; 1210 ± 40	52°–53°	283	93	1132	Calás, 2009
	Espíritu Santo 1		960 ± 80	52°–53°	12	8	151	Horwitz, 1996–1998; Horwitz, 2004
	San Genaro 1		1070 ± 80	53°–54°	35	464	599	Horwitz, 1995
	San Genaro 2		380 ± 70	53°–54°	4	44	113	Horwitz, 1995
	Río Chico 1		4476 ± 43	53°–54°	412	9919	10,776	Santiago, 2013
	Avilés 1		1609 ± 38	53°–54°	6	0	104	Santiago, 2013
	La Arcillosa 2		4440 ± 60	53°–54°	248	98	985	Santiago, 2013; Salemme et al., 2014; Tivoli and Salemme, 2014
	Punta María 2		300 ± 100	53°–54°	1732	309	3007	Lefèvre, 1989a; Borrero, 1985
	San Pablo 1		No data	54°–55°	41	917	1164	Borrero, 1985
	San Pablo 7		No data	54°–55°	0	0	60	Borrero, 1985
Península Mitre	María Luisa A3		1020 ± 80	54°–55°	1032	38	2629	Lanata, 1995
	Marí Luisa 5		360 ± 50	54°–55°	339	23	1027	Lanata, 1995
	María Luisa B5		1110 ± 60	54°–55°	162	4	384	Lanata, 1995
	María Luisa 7		690 ± 50	54°–55°	368	68	595	Lanata, 1995
	Aleph 1		No data	54°–55°	191	10	402	Lanata, 1995
	Aleph 2		330 ± 50	54°–55°	71	1	165	Lanata, 1995
	Aleph 3		450 ± 60	54°–55°	266	39	513	Lanata, 1995
	Close to the Site 2		230 ± 50	54°–55°	196	85	429	Lanata, 1995
	Rancho Donata 7		1500 ± 50	54°–55°	445	523	1938	Lanata, 1995
	Rancho Donata A		No data	54°–55°	196	274	680	Lanata, 1995
	Cerro Mesa		No data	54°–55°	220	55	511	Lanata, 1995
Santa Cruz	San Gregorio 2		2830 ± 150	52°–53°	7	0	7	Barberena et al., 2004
	San Gregorio 5		1530	52°–53°	3	0	30	Barberena et al., 2004
	Posesión 3		1640 ± 170	52°–53°	29	1	51	Barberena et al., 2004
	Dungeness 2		1590 ± 110	52°–53°	0	0	120	Barberena et al., 2004
	Cabo Vírgenes 1		1380 ± 70	52°–53°	37	1	86	Barberena et al., 2004
	Cabo Vírgenes 2		1050 ± 50	52°–53°	5	0	26	Barberena et al., 2004
	Cabo Vírgenes 6		1200	52°–53°	805	0	1159	L'Heureux and Franco, 2002; Barberena et al., 2004
	Punta Bustamante		3200 ± 80	51°–52°	5	0	460	Mansur, 2006; Mansur et al., 2004
	Monte León		1380 ± 50	50°–51°	50	2	259	Caracotche et al., 2006
	Sitio Moreno (Comp. 1)		2720 ± 50	47°–48°	10	2950	2960	Moreno, 2008
	Cabo Blanco 1		1700 ± 30	47°–48°	1367	37	1646	Moreno et al., 1998; Moreno, 2008
	Cabo Blanco 2 (Comp. Inf. y Sup.)		960 ± 60	47°–48°	56	0	188	Moreno, 2008
	Médanos del Salitral		No data	47°–48°	2	0	60	Moreno, 2008
	Isla Lobos		No data	47°–48°	1	0	33	Moreno, 2008
	Punta Medanosa 1		2390 ± 90	47°–48°	0	0	92	Moreno, 2008
	Punta Medanosa 2		No data	47°–48°	56	0	213	Moreno, 2008
	Punta Medanosa 3		2240 ± 80	47°–48°	23	0	361	Moreno, 2008
	Punta Medanosa 4		No data	47°–48°	3	0	101	Moreno, 2008
	El Piche		1850 ± 90	47°–48°	2725	71	2863	Trola et al., 2007; Zubimendi, 2012
	Laguna Del Telégrafo		2357 ± 40	47°–48°	415	6	516	Trola et al., 2007
	Palo alto		690 ± 90	47°–48°	33	102	568	Zubimendi et al., 2010
	Los Albatros		ca. 1000	47°–48°	116	49	234	Bogan et al., 2007; Zubimendi pers. Comm.

Table 1 (continued)

Area	Site	Layer/Level	¹⁴ C BP	Latitud	Bird NISP	Fish NISP	Σ NISP	References
	Alero El Oriental inferior		5860 ± 90	47°–48°	3	0	16	Ambrústolo et al., 2011
	Alero El Oriental medio		5150 ± 80	47°–48°	11	0	43	Ambrústolo et al., 2011
	Alero El Oriental superior		1530 ± 60	47°–48°	1	0	18	Ambrústolo et al., 2011
	Cueva Del Negro		1340 ± 60	47°–48°	2438	385	11,681	Beretta et al., 2011; Zubimendi et al., 2011

In this study, the spatial and temporal variability of bird and fish representations in archaeological sites is analyzed taking into account NISP values. Although the difficulties of deriving interpretations for human subsistence directly from this category are widely known, it is the measure of taxonomic abundance available for the majority of the archaeological assemblages and the calculation is uniform among analysts (Grayson, 1984; Lyman, 2003; among others). Therefore, we consider that it is an appropriate unit for the comparative purposes of this paper. The relative abundance of these resources is examined against representations of marine and terrestrial mammals through the following index: $NISP_i/\Sigma NISP$ (Grayson, 1984). Rodents are not considered, as their remains can be introduced in archaeological contexts etho-ecologically. As the coasts of southern Patagonia and Tierra del Fuego have a North-South orientation, the spatial variability of bird and fish representations are analyzed by latitudinal fringes.

5. Results and discussion

Fig. 3 shows that information concerning bird and fish bone remains is mainly concentrated between 52° and 54° S. This latitudinal distribution of the data mainly reflects the differential intensities of research in different parts of southern Patagonia and

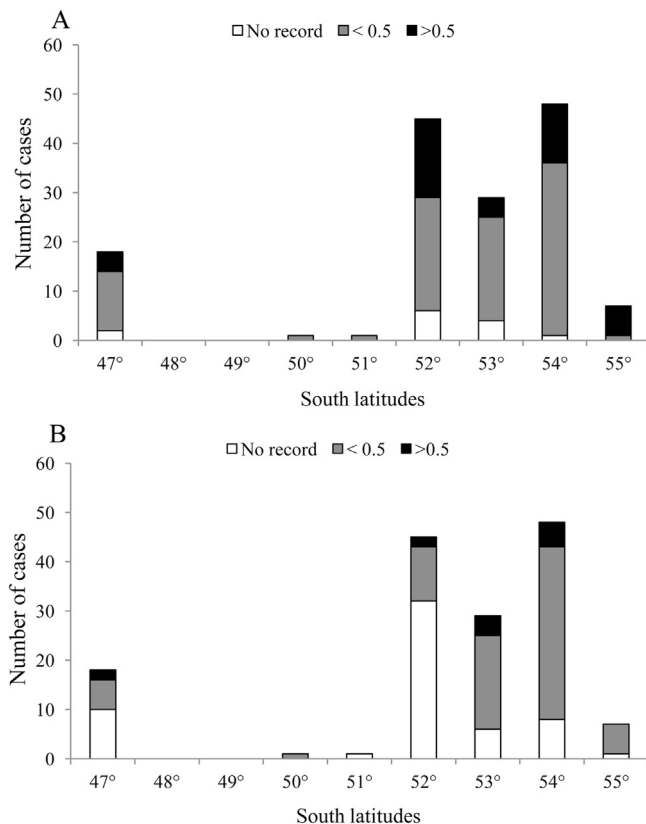


Fig. 3. Representations of bird (A) and fish (B) remains in coastal archaeological sites of southern Patagonia and Tierra del Fuego.

Tierra del Fuego and not the real distribution of the archaeological evidence. Of the total of analyzed assemblages ($N = 149$), 7% did not record bird remains. Among the deposits with representation of birds, 63% have $NISP_i/\Sigma NISP$ values below 0.5 and 28% above. The latitudinal distribution of indices seems to indicate an increase in the representation of bird remains in higher latitudes, but could be also a bias of the limited information available between 47° and 51° S. Fish remains were recorded in 61% of the assemblages, among which 52% have indices below 0.5. High and low indices are represented at different latitudes. The few cases recorded between 47° and 51° S do not allow recognition of trends. Using $NISP_i/\Sigma NISP$ values, no statistical differences in the relative abundance are reported in bird ($t = -1.84$; $p = 0.07$) and fish ($t = 0.81$; $p = 0.41$) remains between the archaeological records of Atlantic and Pacific areas. Bird remains are represented by an average index (\pm SD) 0.41 ± 0.30 ($n = 92$) in the Patagonian archipelago and 0.31 ± 0.27 ($n = 44$) in the Atlantic coast. Regarding fish remains, the average is 0.18 ± 0.19 ($N = 61$) for archaeological assemblages of the archipelago and 0.23 ± 0.27 ($N = 30$) for sites of the Atlantic coast.

Although this analysis shows that avian and fish resources have a similar importance in the subsistence of hunter–gatherer–fishers which inhabited both Pacific and Atlantic coasts, taxonomic variability is noted among the composition of the zooarchaeological assemblages of different regions. Fig. 4 shows proportions based on NISP values in bird bone assemblages for the Atlantic coast. The zooarchaeological record on the Atlantic coastline is widely dominated by penguins and cormorants. In the Atlantic coast of Tierra del Fuego, the representations of anatids and gulls increase with moderate proportions. Zooarchaeological record of the Patagonian archipelago also shows latitudinal variability in the taxonomic composition of bird remains (Fig. 5). In Skying and Otway sounds, cormorants and anatids predominate in the assemblages, while in Tierra del Fuego, the representations of anatids decrease significantly versus the increase of penguin, petrel, and albatross proportions. This geographic variability seems to be well-correlated with the spatial distribution of bird colonies, which suggests that the use of avifauna would have relied mainly on the environmental offering. Comparing Figs. 2 and 6, bone assemblages of cormorants have uniform and high representation in the entire area, which is consistent with the wide distribution of the colonies of this bird in both the Atlantic coast and in the archipelagic area. In contrast, zooarchaeological assemblages of penguins have higher representations on the Atlantic side, where colonies are located at the present time. Procellariiformes has higher representations in the southern tip of South America (Beagle Channel and Cap Horn Archipelago) nearby the colonies of Ildefonso and Diego Ramírez Islands. However, there is also an exception to this observation: the Albatros site in the north of the Santa Cruz Coast Province, where a high proportion of Black-browed Albatrosses (*T. melanophrys*) was recorded in the absence of nearby colonies (Bogan et al. 2007).

The taxonomic determinations of fish remains to family and species levels were conducted in a few sectors and mainly in archaeological sites of the Magellan Strait, Atlantic coast of Tierra del Fuego, and the Beagle Channel. Important differences between the taxonomic compositions are observed (Fig. 7). Archaeological assemblages of the Beagle Channel are dominated by

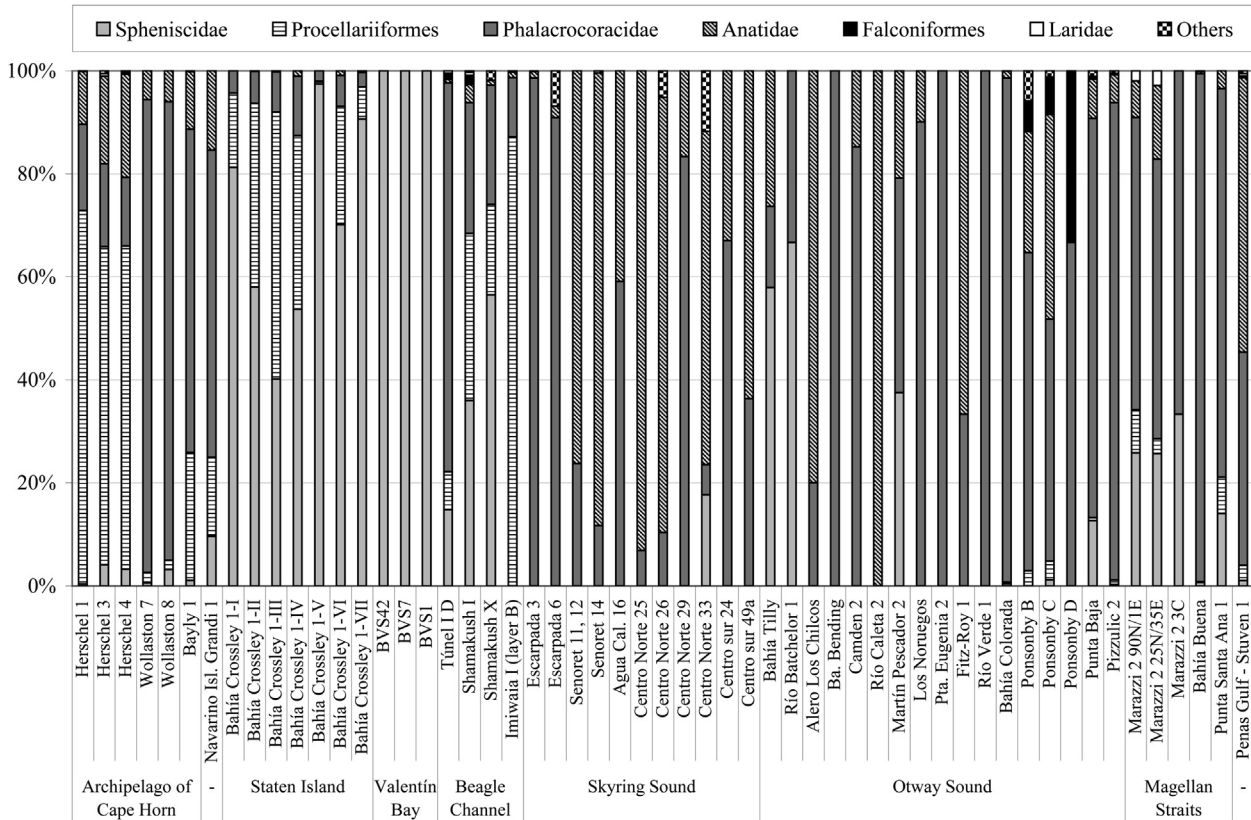


Fig. 4. Taxonomic compositions of bird bone assemblages (NISP%) in the Atlantic coast of southern Patagonia and Tierra del Fuego.

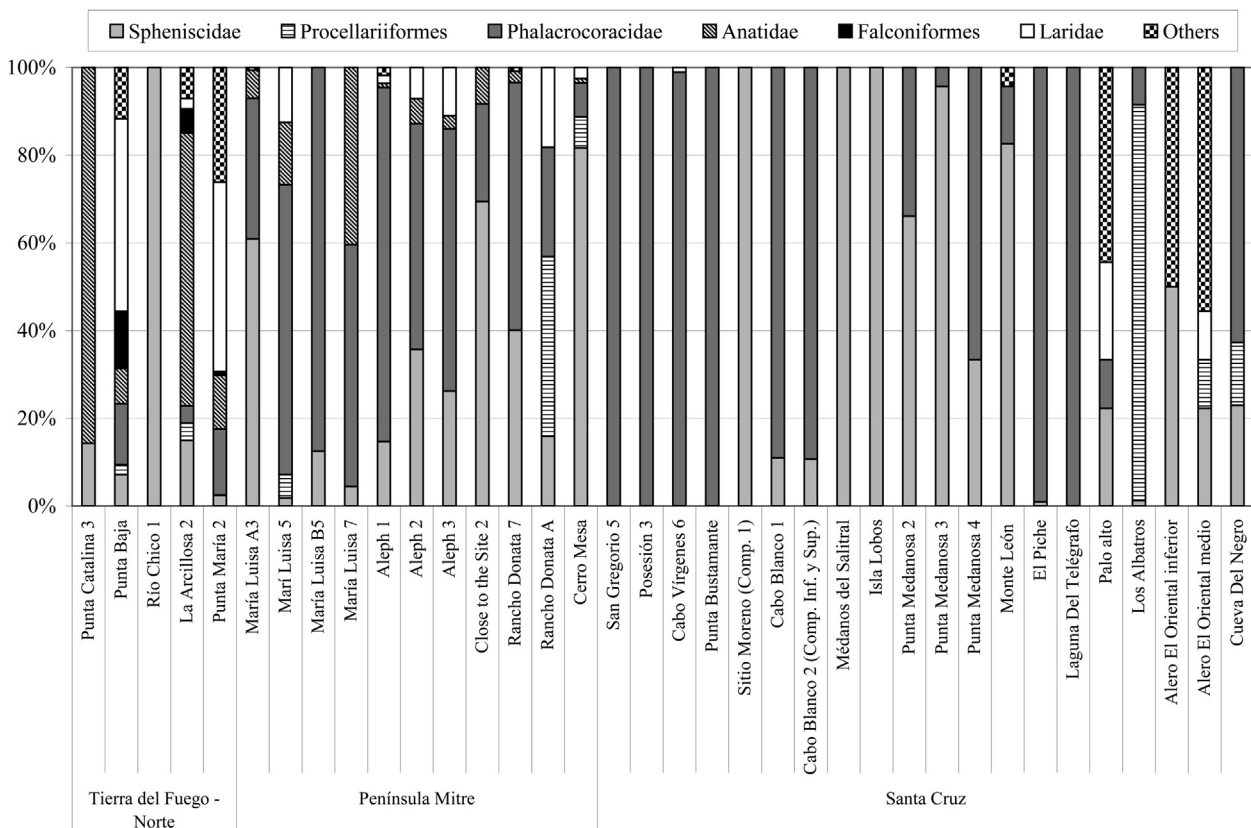


Fig. 5. Taxonomic compositions of bird bone assemblages (NISP%) in the Magellan and Fuegian archipelago.

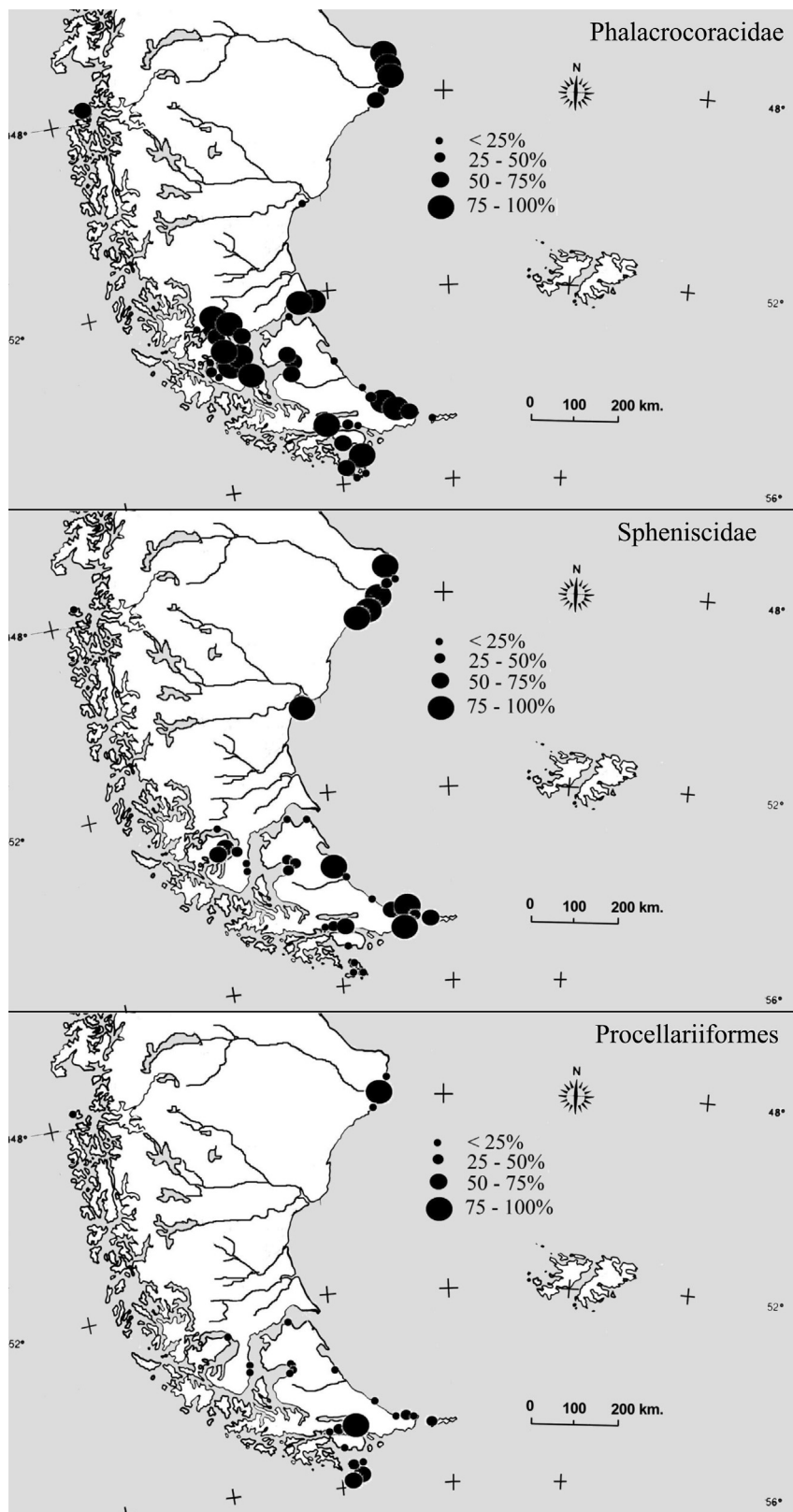


Fig. 6. Relative importance of main seabird taxa in the archaeological record of Southern Patagonia and Tierra del Fuego.

Nototheniidae (especially *Paranotothenia magellanica* and *Patagonotothen* sp.), hakes (Merlucciidae), sardines (Clupeidae) and baracoutas (Gempylidae), while in the Magellan Strait the taxa more represented are Patagonian blennies (*Eleginops maclovinus*),

Tadpole codlings (*Salilota australis*) and silversides (Atherinopsidae). On the Atlantic side, both in Santa Cruz and Tierra del Fuego, hakes and Patagonian blennies are the most important fish resources. It is not simple to explain these differences. As

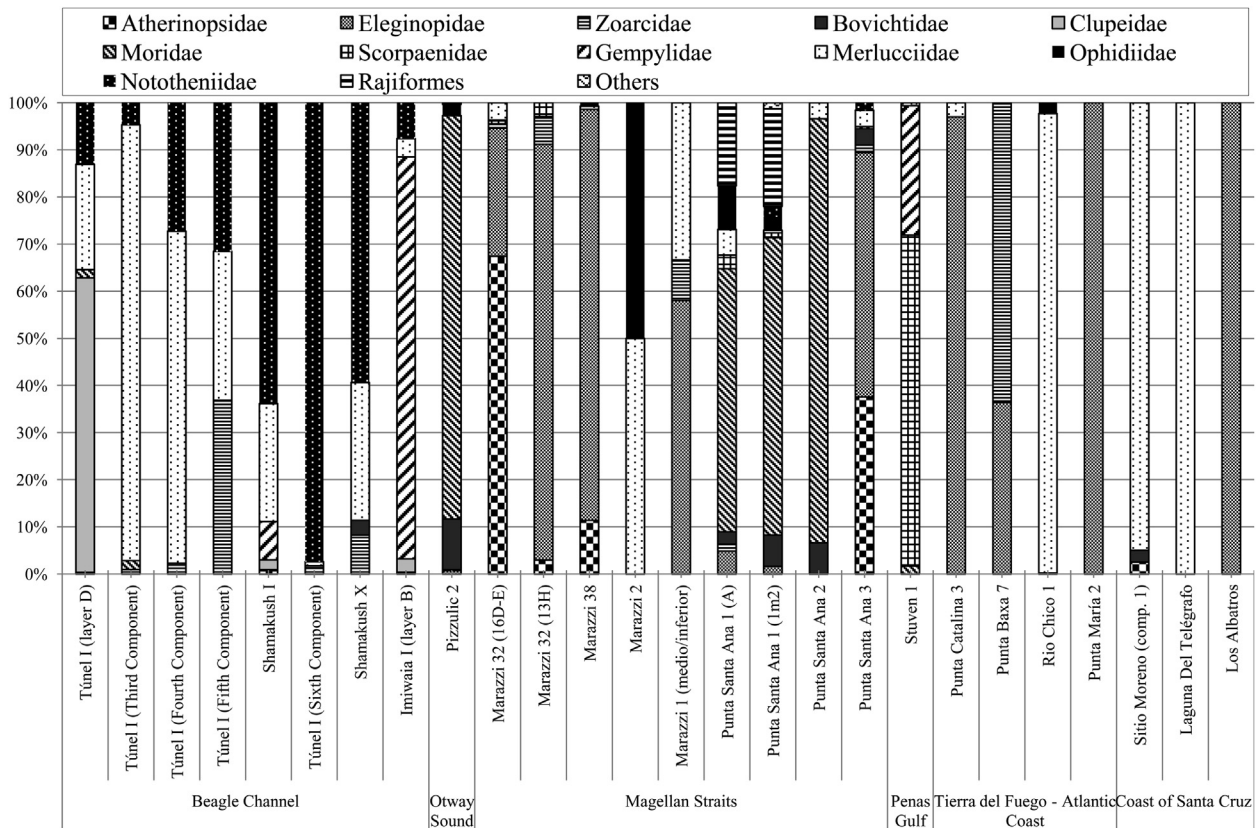


Fig. 7. Taxonomic compositions of fish bone assemblages (NISP%) in Southern Patagonia and Tierra del Fuego.

was previously noted by Torres and Ruz (2011), there are not significant variations in the fishing gear use between the hunter–gatherer–fishers societies which inhabited those sectors; they mainly consisted of fishing lines and harpoons in the archipelago, though the use of fish nets was recorded in the Atlantic coasts of southern Patagonia (Mansur, 2007) and Tierra del Fuego (Torres, 2009). The spawning areas of the Fuegian sprat (*Sprattus fueguensis*) nearby the Beagle Channel could explain the higher representation of this resource in the Second Component of Túnel I site, while the estuarine conditions in inner parts of the archipelago (e.g. Otway sound) could affect the income of this pelagic fish, as well as other fish taxa that forage on sardines (e.g. hakes and baracoutas). Although they are some differences in the current ichthyofaunal distribution between those areas, the environmental distinctiveness seems to be not so significant to explain other taxonomic disparities observed in the archaeological record. For example, since the Patagonian blenny is the most important fish resource in the archipelago sector, both by biomass and distribution, the extremely low representations of this species in archaeological sites of the Beagle Channel is striking. This factor was analysed contrasting the zooarchaeological evidence with the artistic representations of this species in ethnographic moments and suggests avoidance of this resource due to social and/or ideological factors (Fiore and Zangrando, 2006; Fiore et al., 2013).

Concerning temporal variability, $NISP_i / \sum NISP$ values show a significant increase of bird remains in archaeological assemblages towards the late Holocene (Fig. 8). Between 7000 and 3000 BP, all indices are below 0.5, which means that bird bones remains have representations of less than 50% for that time period. After 3000 BP, several assemblages clearly show higher indices for bird remains. Considering the Patagonian archipelago and the Atlantic coast

separately, the same trend is recorded in both sectors, although the Atlantic coast has few cases for the middle Holocene.

Fish remains present a similar temporal trend towards the late Holocene (Fig. 8). With the exception of the Rio Chico site I (north coast of Tierra del Fuego; Santiago, 2013), the values remain below 0.5 during the middle Holocene and then increase significantly in the late Holocene in coastal archaeological sites of Southern Patagonia and Tierra del Fuego. However, when fish indices are plot separately between the Pacific and Atlantic coasts, the trend dissipates in the archaeological record of the Atlantic coast; this could reflect the limited number of cases recorded for the middle Holocene in that sector.

As the representation of small vertebrates permits monitoring changes in foraging activities of hunter–gatherer–fishers (e.g. Broughton, 1994; Grayson and Delpech, 1998), the significant increase in bird and fish remains throughout the Holocene has interesting implications for the evolutionary history of human populations that inhabited the coasts and islands of southern Patagonia and Tierra del Fuego. A major theoretical assumption of the diet breadth model is that the relative contribution of low-rank resources to subsistence depends on the availability of high-rank resources. If procurement activities are concentrated on the latter, the rate of profit per unit time would be high (Smith, 1983). In contrast, if high-rank resources are scarce, the foraging behaviour should become more diversified by intensifying the exploitation of low-rank resources. Although not all bird and fish species of the southern tip of South America can be considered low-rank resources (Zangrando, 2009a), especially those that are available in colonies and permit mass harvests, the increase of these resources over the past 3000 years is remarkable. Similar trends have been identified for the Beagle Channel region (Zangrando, 2009a,

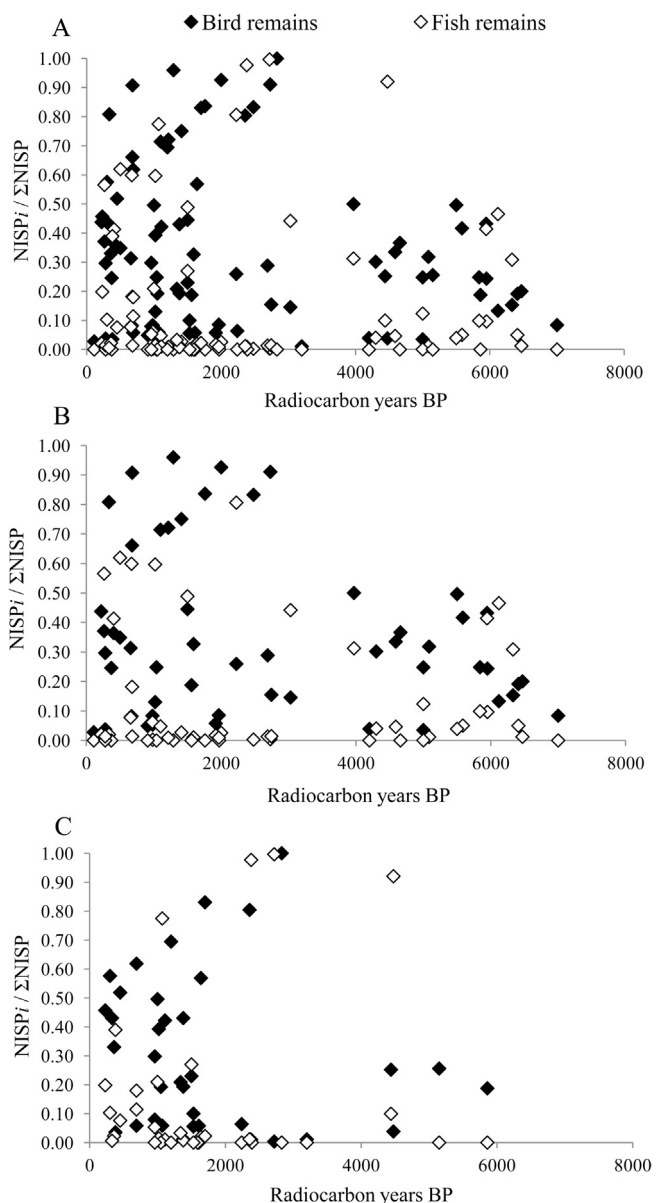


Fig. 8. Temporal distribution of bird and fish indices: A. Atlantic and Pacific fronts; B. Archipelago; C. Atlantic coast.

2009b; Tivoli, 2010a, 2010b; Tivoli and Zangrando, 2011). However, the results presented in this paper show that the diversification in subsistence patterns may have been part of a process with a wider spatial extent and including other coastal areas with different hunter–gatherer–fisher strategies. Three potential factors are normally related to this process: human population growth (e.g. Stiner et al., 1999; Stiner et al., 2000), changes in marine ecosystems (Finney et al., 2002; Misarti et al., 2009) and technological innovations (e.g. Grayson and Cannon, 1999; Lupo and Schmitt, 2005; Ugan, 2005). To develop comprehensive assessments of these three factors is beyond the possibilities of this paper, but it is interesting to explore how the identified tendencies can be related with previous investigations in the area, motivating further discussions on these topics in the future.

Human population growth has been recently proposed by many colleagues for the last two millennia in southern Patagonia and Tierra del Fuego (Barberena, 2008; Zangrando, 2009a; Tivoli and

Zangrando, 2011; Morello et al., 2012; among others). Probabilistic analyses based on chronological information from archaeological sites show an increase in the intensity of human occupations in a regional scale, including inland and coasts of Southern Patagonia (Barberena, 2008). Taking into account possible taphonomic and sampling bias, demographic variations were suggested and the strongest intensity of occupations in the Holocene was recorded between 1200 and 800 cal BP (Barberena, 2008, pp. 334). Due to population growth a reduction in the efficiency of high-rank resources (e.g. pinnipeds, guanacos, etc.) may have occurred, causing the need to intensify the use of low-rank resources. Therefore, zooarchaeological information is consistent with demographic models and it appears that potential population growths could be related with the increase of bird and fish bone remains in archaeological sites in the last 3000 years.

Plankton productivity varies spatially and temporally in the marine environment and impacts populations of animals of higher trophic levels in the food chain. In this regard, the results presented above could also be explained by an increase in the primary marine productivity that may have led to raise the populations of birds and fish, and consequently the availability for human exploitation, during the late Holocene. Southern Patagonia and Tierra del Fuego are directly linked to the West Wind Drift and by extension to the Antarctic ecosystem (Antezana, 1999). Palaeoenvironmental data from the Antarctic Peninsula glacial marine record has revealed patterns of multicentury productivity variations for the last 4000 years (Domack and Mayewski, 1999). This study demonstrates pronounced cycles of elevated palaeoproductivity (warm events) that recur every 200 years. Superimposed upon this are longer-term reductions in palaeoproductivity (cooling events) that correspond with the ‘Little Ice Age’ and an event at ~2500 BP (Domack and Mayewski, 1999). The Little Ice Age event is the strongest of the late Holocene cool periods both in its magnitude and duration, which began abruptly about 600 BP. The zooarchaeological record shows that the increase in representations of birds and fish was sustained throughout the last 3000 years. However, marine productivity has experienced significant changes during that period, especially an important reduction in the last 600 years. At first sight, archaeofaunal representations of birds and fish show no temporal correlation with these variations of marine ecosystem inferred from paleoenvironmental data for the late Holocene. Nevertheless, our knowledge about variations of the marine productivity in Southern South America along the Holocene is still scarce and further investigations are needed to evaluate properly this argument.

A final factor to be considered is whether technological innovations could have led to an increase in the capture of birds and fish. According to the technological evidence of southern Patagonia and Tierra del Fuego, fishing activities were conducted using very similar strategies in the middle and late Holocene (Orquera and Piana, 1999a, 2009; Torres, 2009). The archaeological record does not show significant changes in technology for bird hunting, excepting for the adoption of the bow and arrow in the late Holocene. Nevertheless, abundant ethnographic information suggests that the use of this technology would not have been the most used among other strategies and bird hunting was mainly conducted through ambushes using stones, sticks, or nooses (Lothrop, 1928, pp. 83–84; pp. 155–159; Savanti, 1994; Orquera and Piana, 1999b, pp. 148–152).

6. Summary

The analysis presented in this paper highlights spatial and temporal trends in the representations of birds and fish in the

coastal archaeological record of southern Patagonia and Tierra del Fuego.

Spatially, the importance of birds and fish in human subsistence was similar between the Pacific and Atlantic coasts along the Holocene; it is remarkable concerning the differences between the hunter–gatherer–fisher strategies which were developed in both marine fronts. However, taxonomic variability in bird and fish assemblages is observed among different areas. In the archipelago, avifaunal remains from Skyring and Otway sounds are primarily composed by bones of cormorants and anatids. Penguins and cormorants prevail in the archaeological sites of the Atlantic coast of southern Patagonia. South of the Magellan Strait, penguins and cormorants are abundant in the zooarchaeological assemblages but representations of petrels and albatrosses increase significantly. There is a good correlation between the taxonomic variability represented in the archaeological record and the distribution and abundance of colonies of different species of birds. This leads us to suggest that the different archaeological representations of avifaunal resources respond primarily to the environmental supply. Interesting differences were also recognised in the taxonomic composition of fish bone assemblages among different regions. The ichthyoarchaeological record of the Magellan Strait shows that fishing activities were focused on benthic fish prey, while in the Beagle Channel and in the Atlantic coasts both benthic and pelagic fish prey were used.

Temporally, the analysis showed that there was an increase in bird exploitation in the entire region in the last 3000 years. However, representations of fish bones are more ambiguous and an increase can be only proposed for the archipelagic area. These temporal trends could be linked both to anthropogenic and environmental processes, encouraging discussions on potential demographic changes in human populations and/or natural variations in marine ecosystems during the Holocene.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.quaint.2014.11.047>.

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