



# Subsistence variations and landscape use among maritime hunter-gatherers. A zooarchaeological analysis from the Beagle Channel (Tierra del Fuego, Argentina)

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## ABSTRACT

Changes in the exploitation of resources among prehistoric hunter-gatherer-fishers of the Beagle Channel (Southern South America) are examined in this paper. Archaeological investigations show the prevalence of maritime hunter-gatherer organization throughout the occupation of the region (ca. 6400 BP – 19th century). Notwithstanding, variations in the exploitation of different kind of animal resources have been detected, and a concomitant reorientation in the landscape use is then inferred. Zooarchaeological evidence from five shellmiddens is analyzed here: evenness measures and relative abundance prey types are used to evaluate such adjustments. Results indicate the major utilization of coastal and terrestrial ecozones and the predominance in the exploitation of mammals (pinnipeds and guanacos) in ancient occupations. While, during the Late Holocene an expansion in ranges of maritime mobility for subsistence is detected, which was associated with an increase in the representation of birds and fish in the zooarchaeological record.

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## 1. Introduction

The archipelago of Tierra del Fuego extends from the south coast of the Magellan Strait to Cape Horn, between nearly 52° and 56° South latitude. It includes the Isla Grande de Tierra del Fuego, the islands Hoste, Santa Inés, Navarino, Dawson, Clarence, Desolation, Staten Island and other smaller ones. In the north area of the Isla Grande de Tierra del Fuego it extends an area of steppe landscape, while the south and west is dominated by a mountainous terrain with *Nothofagus* forests and a strong oceanic influence.

The Beagle Channel is located on the southern coast of the Isla Grande de Tierra del Fuego (Fig. 1). It was inhabited by maritime hunter-gatherers from 6400 radiocarbon years BP until their nearly total extinction in the late nineteenth century. Faunal analyses from sites across this region have characterized a broad-spectrum subsistence by the procurement of marine mammals, guanacos, birds, fish, and mussels (Orquera and Piana, 1999). Although this maritime hunter-gatherer strategy remained stable throughout the occupational sequence, recent zooarchaeological researches have noticed variations in human–animal relationships during the Late Holocene (Tivoli, 2010a,b; Zangrando, 2009a,b). These variations consider arguments regarding offshore-going practices and the growth in ranges of maritime mobility for subsistence activities.

It is well known that subsistence activities of hunter-gatherers generally involved movements linking resource zones into an annual round or at longer intervals. Ethnographic information is abundant on this subject (Binford, 1980; Kelly, 1995; Politis, 1996; among others). Therefore, the landscape so encompassed is a fundamental notion to understand the subsistence patterns of hunter-gatherers (Bailey, 1983). The zooarchaeological record can contribute significantly to evaluate how the use of space and its resources might have varied throughout the occupational sequence of a region.

This paper focuses on understanding the changes in the kinds of resources exploited in order to assess variations in landscape use by hunter-gatherers of the Beagle Channel. First, we present the methods used in this study, which involved analytical tools to evaluate archaeofaunal record as indicator of ecological niche use. Second, we analyze the zooarchaeological samples taking into account potential taphonomic and sampling problems. Finally, we present the results of archaeofaunal analysis, and discuss variations in landscape use for foraging activities by hunter-gatherers of the Beagle Channel.

## 2. Methods

### 2.1. Evenness measures

The study of niche breadth in the archaeological record has become a well established procedure to identify and interpret human subsistence variations. Evenness analysis is being increasingly used by archaeologists operating within an optimal foraging theory

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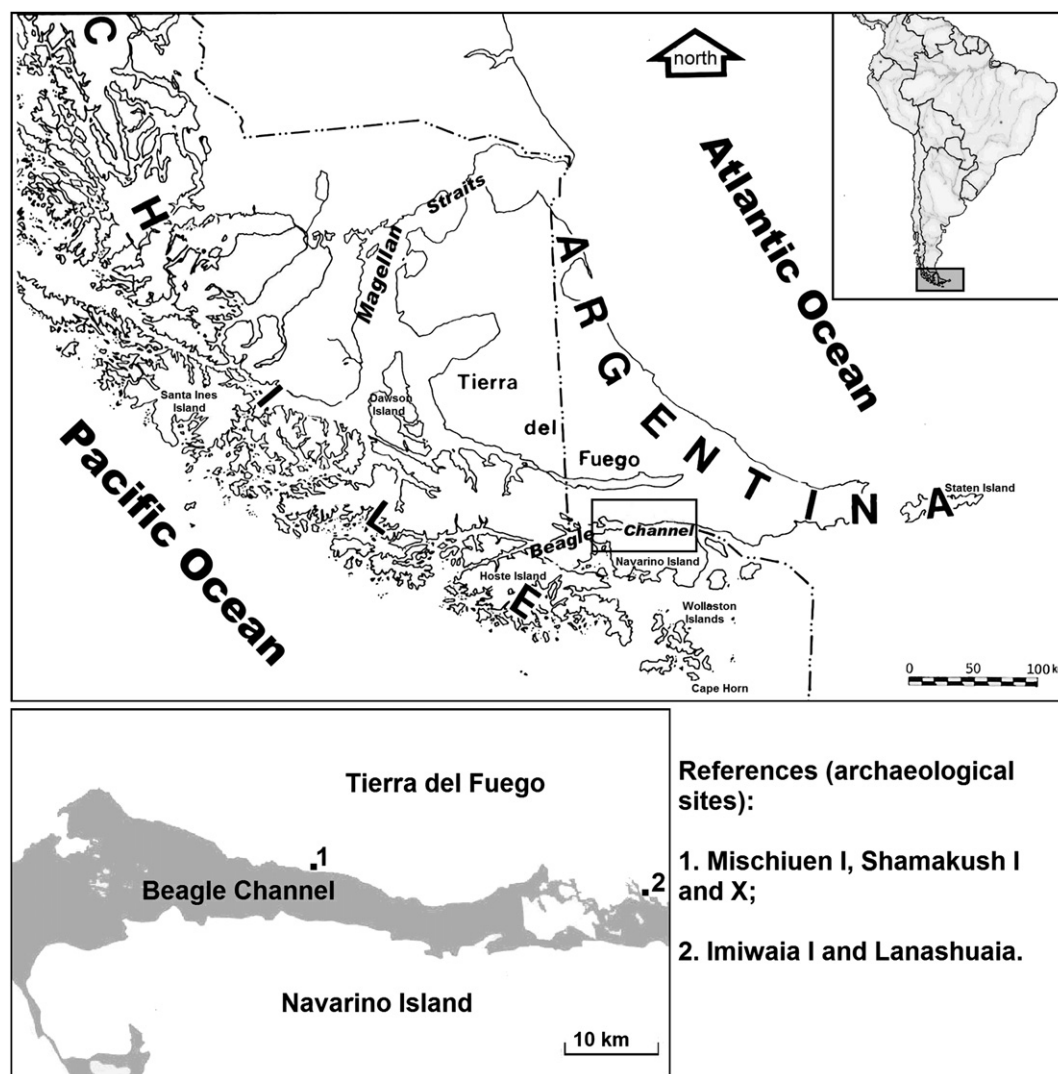


Fig. 1. Beagle Channel and location of studied sites.

framework (v.g. Grayson and Delpech, 1998; Jones, 2004; Nagaoka, 2001), and from another perspectives (v.g. Betts and Friesen, 2004; Zangrando, 2009b).

The evenness index used in this analysis is (Reitz and Wing, 1999: 235):

$$V = H / \ln S$$

where  $S$  is the number of non-overlapping taxa identified in an assemblage, and  $H$  is defined as

$$H = - \sum (P_i) (\ln P_i)$$

where  $P_i$  is the relative abundance of specimens for each taxon in the archaeofaunal assemblage.

While the evenness indices are advantageous as they allow comparison of many contexts, attempts to describe the complex of an archaeofaunal assemblage by one single attribute could be problematical because so much valuable information is lost. Evenness values do not take into account the positions of preys in a rank-ordered distribution, and this could be a difficulty if our purpose is to evaluate variations in the use of different ecozones for foraging activities. To determine if diet is changing in relation with variations in the use of different ecozones, evenness must be tested

jointly with relative abundance of prey types. A complete picture of the distribution of species abundances for a single assemblage can be obtained from a rank-abundance diagram, which makes use of the full array of abundance values by plotting them against rank (Grayson, 1984: 96). Even though, species abundance distributions were originally developed in ecological studies to assess the taxonomic organization of assemblages (Tokeshi, 1990), they can also be used by archaeologists to evaluate the organization of foraging activities by sort of resources. For the latter, we must consider the kinds of taxa that could be included in diet, and build parameters that refer to the order in which a number of species is related to landscape use.

## 2.2. Ecozones of Beagle Channel

In the Beagle Channel three distinct ecological zones can be distinguished, both based on its biological features and the opportunities and constraints that provide for human subsistence: terrestrial, coastal and offshore areas.

In the terrestrial environment, a significant part of biotic energy is absorbed by the woody structure formation. The supply of carbohydrates and proteins of plant origin is very small (Tuhkanen, 1992), therefore there is little animal life in forests. Indeed, few species of

mammals and birds inhabit terrestrial domain. Among first are guanacos (*Lama guanicoe*), Fuegian foxes (*Dusicyon culpaeus lycoides*) and small rodents. Concerning birds, forests abound with several raptor species: the most common are chimangos (*Milvago chimango*) and Southern crested-caracara (*Polyborus plancus*), but also there are small eagles and hawks. Among the scavengers, it is necessary to mention the turkey vultures (*Cathartes aura*) and condors (*Vultur gryphus*). The biodiversity of birds is complete with austral parakeet (*Enicognathus ferrugineus*), woodpeckers (*Campephilus magellanicus*), and several species of passerines. The conditions of abundance and diversity of native freshwater fish have been extremely poor during Middle and Late Holocene.

The coastal ecozone divides the marine and terrestrial systems. Coastal margins provide the most biomass resources for human subsistence, and present the most favorable conditions in terms of accessibility and predictability for obtaining resources. In this ecozone two species of pinnipeds are presented: sea lions (*Otaria flavescens*) and fur seals (*Arctocephalus australis*). In the coastal areas there is also important bird biodiversity: penguins (*Spheniscus magellanicus*), three species of cormorants (*Phalacrocorax magellanicus*, *Phalacrocorax atriceps* and *Phalacrocorax olivaceus*), Anatidae (*Chloephaga* sp., *Tachyeres* sp., *Lophonetta specularioides*, etc.), gulls (*Larus dominicanus*, *Larus scoresbii*, etc.), among many other types of birds. Several of these species are gregarious: the *P. atriceps* (imperial cormorants) form large colonies on flat surfaces of blocks, sometimes associated with sea lions (Schiavini and Yorio, 1995). There are numerous fish species represented in the shallow waters. Most of them fall within the Nototheniidae family, in which there is a predominance of small-sized species.

In regard to purely pelagic mammals, various species of cetaceans can enter the Beagle Channel discontinuously: a variety of dolphins and baleen whales, two species of porpoises (*Phocoena spinipinnis* and *Australophocoena dioptrica*), and sporadically sperm whales (*Physeter catodon*). Occasionally these resources are run aground on the shores of the Beagle Channel. Among offshore birds, there are different species of petrels (*Macronectes giganteus*, *Procellaria* sp., *Daption capense*, etc.), shearwaters (*Puffinus* sp.), fulmars (*Fulmarus glacialis*), and albatrosses (*Diomedea exulans*, *Diomedea melanophrys*, *Diomedea crhyssostoma*, etc.). All these birds usually inhabit coastal and outer islands of the Fuegian archipelago, although some of these species enter the channel, flying near the shore. In deep waters, fish community has characteristics markedly different from the coastal cluster. First, the variability in the sizes of the fish is more marked, and there are species from large sizes (Merlucciidae) to very small (Clupeidae). Some taxa that inhabit pelagic waters occasionally approach the coasts. A common scenario is what happens with the sardines, which can produce extensive stranding. The same happens with hakes (*Macruronus magellanicus*, *Merluccius hubbsi* and *Merluccius australis*), when they prey on shoals of sardines. However, there are fish species that only have offshore habits in the Beagle Channel, among which we can find the barracouta (*Thyrstites atun*) and the pink cusk-eel (*Genypterus blacodes*).

### 2.3. Taxonomic groups

The development of taxonomic groups constitutes a methodological resource needed in the discussion of this paper for at least two reasons. First, the use of general categories minimizes the effects generated by the variability of methods and the degree of specificity in taxonomic identification (Stiner et al., 2000). Second, taxonomic groups provide a means of testing expectations of changes in faunal assemblages due to economic and social factors. Although specific taxonomic identifications constitute a necessary basis for the formation of the broad categories, this study is not

concerned strictly with taxonomic diversity, but with changes in the use of space for foraging activities by hunter-gatherers of the Beagle Channel. In this sense, more general categories that include multiple animal species are advantageous, since they focus on the variable of interest (landscape use) rather than on Linnaean categorization (Dean, 2007).

Previous information shows that faunal diversity potentially represented in zooarchaeological assemblages of Beagle Channel could reflect the use of different ecozones by hunter-gatherers. Thus, it is possible to join traditional taxonomic categorizations to include the manner in which animals are distributed in the environment. For example, it appears that catches of mammals could be obtained from terrestrial to coastal zones. Bird catches could have been obtained from terrestrial to offshore sectors, and so on. Based on this information the taxonomic groups used in this study are: marine mammals, terrestrial mammals, near-shore fish (terrestrial or coastal marine), near-shore birds (terrestrial and sea birds regularly found on shore), offshore fish, and offshore birds (offshore implying going some distance to sea or to offshore islands to procure). Coincidentally with Pickard and Bonsall (2004), in this article we use the term “offshore” for hunting and fishing practices conducted in sight of land. Table 1 shows a distributional matrix of faunal resources for the Beagle Channel region for these categories.

### 3. Zooarchaeological assemblages

The zooarchaeological samples discussed in this paper come from five shellmiddens excavated at two different archaeological localities of the Beagle Channel.

One location is situated at Cambaceres Bay, and includes archaeofaunal samples from two stratigraphic components of Imiwaia I (layers K, L and M – 6000 years BP – and layer B – 1500 years BP) and samples from Lanashuaia I site (19th century). The samples from Imiwaia I site included here were analyzed by Tivoli (2010a,b) and Zangrando (2008, 2009a). The Lanashuaia I site (19th Century) was excavated by J. Estévez Escalera, E. Piana and A. Vila Mitja, and data discussed here was published by Piana et al. (2000). The other group of sites is located at Estancia Remolino, and includes assemblages from Shamakush I site (1000 years BP), Shamakush X site (500 years BP) and Mischiuen I site (layer F – 4000 years BP). The analyses of faunal remains from these assemblages have been reported in Tivoli (2010a) and Zangrando (2008).

An important consideration of this faunal data is that there are not significant differences concerning excavation methods and bone preservation between sites. Excavations of these sets were made following the same procedures (Orquera and Piana, 1992), and the materials were recovered by screening the excavated sediments through 5 and 2 mm mesh screens in all cases. Bone preservation in archaeological deposits of the Beagle Channel is generally excellent: 1. formation processes of these deposits imply high sedimentation rates, there being relatively small lapses of exposure of bone material at the surface (Orquera and Piana, 1992), and 2. sediments are stable in pH and humidity conditions (Orquera and Piana, 2000, 2001; Linse, 1992).

Our purpose here is not to develop a comprehensive overview on the various taphonomic aspects of the analyzed zooarchaeological assemblages, as this has been presented in previous studies (Mameli and Estévez Escalera, 2004; Tivoli, 2010a; Zangrando, 2007, 2008, 2009a). Nevertheless, three general trends can be noticed: a. high integrity measured on birds and fish bone indicated by WMI % rates (Zohar et al., 2001) that fall within a range between 47% and 85% (Tivoli, 2010a; Zangrando, 2007, 2009a). b. the results published so far indicate that the marks caused by animal agents do not exceed 7% in any of the zooarchaeological assemblages (Tivoli, 2010a; Zangrando, 2009a) and c. weathering stages (Behrensmeyer,

**Table 1**

Distribution of animal resources in the terrestrial and marine ecozones.

	Mammals	Birds	Fish
Terrestrial	Guanacos (Camelidae: <i>Lama guanicoe</i> ) Fuegian foxes (Canidae: <i>Dusicyon culpaeus lycoides</i> )	Falcons and Caracaras (Falconidae: <i>Milvago chimango</i> , <i>Polyborus plancus</i> , etc.) Scavengers (Cathartidae: <i>Cathartes aura</i> , <i>Vultur gryphus</i> ) Eagles, hawks (Accipitridae) Hérons (Ardeidae: <i>Nycticorax nycticorax</i> ) Woodpeckers (Picidae: <i>Campephilus magellanicus</i> ) Parakeet (Psittacidae: <i>Enicognathus ferrugineus</i> ) Passerines (Emberizidae, Furnariidae, etc.)	
Marine (near-shore)	Pinnipeds (Otariidae: <i>Arctocephalus australis</i> , <i>Otaria flavescens</i> ) Otters (Mustelidae: <i>Lutra felina</i> , <i>Lutra provocax</i> ) Cetaceans (beachings). Odontoceti: Dolphins (Delphinidae: <i>Orcinus orca</i> , <i>Globicephala melaena</i> , <i>Lagenorhynchus obscurus</i> , etc.) Whales (Ziphiidae: <i>Tasmacetus shepherdi</i> , <i>Berardius arnuxii</i> , <i>Mesoplodon hectori</i> and occasionally <i>Physeteridae: Physeter catodon</i> ). Porpoises (Phocoenidae: <i>Phocoena spinipinnis</i> , <i>Australophocoena dioptrica</i> ) Mysticeti: Baleen whales ( <i>Megaptera novaeangliae</i> , <i>Balaenoptera musculus</i> , <i>Caperea marginata</i> , <i>Eubalaena australis</i> , etc)	Penguins (Spheniscidae: <i>Spheniscus magellanicus</i> , <i>Eudyptes chrysocome</i> ) Cormorants (Phalacrocoracidae: <i>Phalacrocorax</i> sp.) Ducks, geese, swans (Anatidae: <i>Tachyeres</i> sp., <i>Chloephaga</i> sp., <i>Lophonetta specularioides</i> , etc.) Gulls (Laridae: <i>Larus</i> sp.) Skuas (Stercorariidae: <i>Catharacta</i> sp.) Petrels, shearwaters and fulmars (Procellariidae: <i>Macronectes giganteus</i> , <i>Procellaria</i> sp., <i>Daption capense</i> , <i>Puffinus</i> sp., <i>Fulmarus glacialis</i> ) Albatrosses (Diomedidae: <i>Diomedea</i> sp.)	Nototheniids (Nototheniidae: <i>Eleginops maclovinus</i> , <i>Patagonotothen</i> sp., etc.) Eelpouts (Zoarcidae: <i>Austrolycus</i> sp.) Channel Bull Blenny (Bovichthyidae: <i>Cottoperca gobio</i> ) Puyen (Galaxiidae: <i>Galaxia maculatus</i> ) Patagonian grenadier (beachings) (Merlucciidae: <i>Macruronus magellanicus</i> ) Sardines (Clupeidae: <i>Sprattus fuegiensis</i> )
Marine (offshore)		Petrels, shearwaters and fulmars (Procellariidae: <i>Macronectes giganteus</i> , <i>Procellaria</i> sp., <i>Daption capense</i> , <i>Puffinus</i> sp., <i>Fulmarus glacialis</i> ) Albatrosses (Diomedidae: <i>Diomedea</i> sp.)	Barracouta (Gempylidae: <i>Thyrstites atun</i> ) Hakes (Merlucciidae: <i>Macruronus magellanicus</i> ) Tadpole codling (Moridae: <i>Salilota australis</i> ) Pink cusk-eel (Ophidiidae: <i>Genypterus blacodes</i> )

1978) are low in all fish bone assemblages analyzed (Zangrando, 2009a).

Only the vertebrate exploitable taxa are included in the analysis of this paper. Some taxa are excluded from our analysis for failing to present clear evidence of consumption. Among mammals, we excluded remains of foxes and rodents, since they do not show evidences of processing (v.g. cut marks) and their inclusion in the archaeological record might have been due to natural mechanisms. Cetacean bones are also problematic because their presence in the archaeological record can be explained as raw materials or bone debris for instrumental production rather than as food resource (Borella, 2004; Orquera and Piana, 1999; Smith and Kinahan, 1984). Moreover, the specimens that can be attributed to cetaceans usually appear with low frequencies. The skeletal remains of Stercorariidae family and passerines are not considered in our analysis because they have very low frequencies, and do not have evidence of processing; hence their inclusion in the archaeological record could be a result of taphonomic factors.

The archaeofaunal database discussed in this study is large and taxonomically diverse, containing over 20,000 identified specimens (Table 2). All assemblages are large enough to be representative of the whole extensions of the sites from which they were excavated. In the lower layers of Imiwaia I, bone remains of pinnipeds and guanacos (*L. guanicoe*) predominate over a diverse range of bird and fish specimens, nesting cormorants (Phalacrocoracidae), hakes

(Merlucciidae) and sardines (Clupeidae) from high to low representations. In the F layer of Mischiuen I, a predominance of mammals is also observed, although in this case guanacos have a higher representation than pinnipeds. Penguins (Spheniscidae) and hakes have also relatively high NISP values in this assemblage. Layer B of Imiwaia I shows a completely different situation to that observed in the two previous assemblages, since it shows a clear predominance of fish and birds resources, particularly *T. atun*, and Diomedidae and Procellariidae families. Shamakush I site is dominated by guanacos and some fish species (*Patagonotothen* sp. and *Paranotothenia magellanica*). In Shamakush X fish and bird remains predominate. Among the first, *P. magellanica* has the highest NISP value, followed by *M. magellanicus*. Remains of penguins (Spheniscidae) are also numerous. Both pinnipeds and guanacos have very scarce representations. Finally, Lanashuaia I site is dominated by bone remains of fish and birds. Among fish, *T. atun* is the most represented resource, while gulls (*Larus* sp.) and tailed hakes (*M. magellanicus*) have high moderate values of NISP.

Studies done by Orquera and Piana (2001) on the composition of the shellmiddens indicate that no significant changes have been occurred in the types of shellfish consumed over time, with a largely predominance of mytilids over other mollusks.

In sum, this information reveals that the subsistence of hunter-gatherers of the Beagle Channel was based on a significant diversity of resources and on the use of different ecological zones. Taking into



**Table 2**  
NISP values of the studied assemblages.

Taxa				Taxonomic groups	Imiwaia I (layers K, L, M)	Mischuien I (layer F)	Imiwaia I (layer B)	Shamakush I	Shamakush X	Lanashuaia I
Mammals	Carnivora	Otariidae	<i>Arctocephalus australis</i> / <i>Otaria flavescens</i>	MM	5112 (49.8%)	544 (19.3%)	79 (6.8%)	302 (6.5%)	9 (2.0%)	69 (8.1%)
	Artiodactyla	Camelidae	<i>Lama guanicoe</i>	TM	2590 (25.2%)	1130 (40.0%)	23 (2.0%)	1702 (36.6%)	9 (2.0%)	23 (2.7%)
Birds	Sphenisciformes	Spheniscidae	<i>Spheniscus magellanicus</i> , <i>Eudyptes chrysocome</i>	NB	103 (1.0%)	505 (17.9%)		122 (2.6%)	61 (13.4%)	5 (0.6%)
	Pelecaniformes	Phalacrocoracidae	<i>Phalacrocorax</i> sp.	NB	450 (4.4%)	164 (5.8%)	43 (3.7%)	86 (1.8%)		18 (2.1%)
	Procellariiformes	Diomedidae/ Procellariidae	<i>Diomedea</i> sp., <i>Macronectes giganteus</i>	OB	119 (1.1%)	40 (1.4%)	325 (27.8%)	114 (2.4%)	18 (3.9%)	29 (3.4%)
		Procellariidae	<i>Procellaria</i> sp., <i>Daption capense</i> , <i>Puffinus</i> sp., <i>Fulmarus glacialis</i> oides, etc.	OB	17 (0.2%)		2 (0.2%)	2 (0%)	1 (0.2%)	5 (0.6%)
	Anseriformes	Anatidae	<i>Chloephaga</i> sp./ <i>Tachyeres</i> sp.	NB	185 (1.8%)	8 (0.3%)	4 (0.3%)	11 (0.2%)	20 (4.4%)	6 (0.7%)
		Anatidae	(Small ducks: <i>Lophonetta specularioides</i> , etc.)	NB	61 (0.6%)	1 (0%)		1 (0%)	5 (1.1%)	
	Ardeiformes	Ardeidae	<i>Nycticorax nycticorax</i> , etc.	NB	3 (0%)	1 (0%)			1 (0.2%)	
	Falconiformes	Accipitridae		NB		1 (0%)		2 (0%)		
		Falconidae	<i>Milvago chimango</i>	NB	3 (0%)			4 (0.1%)	1 (0.2%)	3 (0.3%)
	Charadriiformes	Laridae	<i>Larus</i> sp.	NB	6 (0%)	2 (0.1%)	1 (0.1%)	2 (0%)	1 (0.2%)	153 (18%)
Fish	Gadiformes	Zoarcidae	<i>Austrolycus</i> sp.	NF		3 (0.1%)		19 (0.4%)	29 (6.4%)	
		Merlucciidae	<i>Macruronus magellanicus</i>	NF	520 (5.1%)	418 (14.8%)	3 (0.2%)	381 (8.2%)	87 (19.1%)	95 (11.2%)
			<i>Merluccius</i> sp.	NF	236 (2.3%)	2 (0.1%)	25 (2.1%)			
	Perciformes	Moridae	<i>Salilota australis</i>	OF	1 (0%)					
		Bovichthyidae	<i>Cottoperca gobio</i>	NF		5 (0.2%)		3 (0.1%)	11 (2.4%)	
		Nototheniidae	<i>Eleginops maclovinus</i>	NF	171 (1.7%)			1 (0%)		1 (0.1%)
			<i>Patagonotothen</i> sp.	NF	18 (0.2%)		17 (1.4%)	603 (13.0%)	11 (2.4%)	4 (0.5%)
			<i>Paranotothenia magellanica</i>	NF	204 (2.0%)		58 (5.0%)	1022 (22.0%)	191 (42.0%)	32 (3.8%)
			<i>Thyrstites atun</i>	OF	17 (0.2%)		551 (47.2%)	212 (4.6%)		378 (44.5%)
		Gempylidae		NF						
Clupeiformes	Clupeidae	<i>Sprattus fueguensis</i>	NF	445 (4.3%)		37 (3.2%)	54 (1.2%)		29 (3.4%)	
Total					10,261	2824	1168	4643	455	850

References: Marine mammals (MM); Terrestrial mammal (TM); Near-shore birds (NB); Offshore birds (OB); Near-shore fish (NF); Offshore fish (OF).

account that the overall objective of this study is to assess to what extent the use of these areas may have varied through time, then we discuss the information on the different zooarchaeological assemblages with the purpose to assess possible changes in landscape use for foraging activities.

#### 4. Foraging activities and landscape use

Fig. 2 shows the distribution of evenness values for the archaeological sequence on the basis of the samples previously described in this paper, where the assemblages are arranged chronologically from early (left) to later (right) occupations. The graph shows a moderate increase in the levels of evenness throughout the sequence, with values which vary from 0.55 to 0.68 (Table 3).

Evenness values close to zero describe assemblages dominated by a single species and values near 1 show a fair representation among the various resources represented. Fig. 2 describes an intermediate trend: no assemblage is dominated by a particular species, and there is no case where all species contribute equally. This distribution represents, in a broad sense, a diverse economic strategy that was maintained throughout the sequence. However, evenness increases significantly over time ( $r = 0.84$ ,  $p < 0.05$ ) (Fig. 3). Consequently, this moderate increase could be an indicator of changes in subsistence patterns throughout the archaeological sequence.

The distributions of NISP% values of pinnipeds show a progressive decrease towards later times, while guanacos do not reflect a clear trend over time (Fig. 4). If we correlate the NISP% of pinnipeds against evenness values for different assemblages, we obtain a significant relationship ( $r = -0.83$ ,  $p < 0.05$ ) indicating that the two variables co-vary negatively: the abundance of pinnipeds decreases, while the values of evenness increase. On the other hand, the relationship between the proportions of guanacos and evenness values is not significant ( $r = -0.51$ ,  $p > 0.10$ ). Among

recent assemblages, Shamakush I is the only site that has a high representation of guanacos: even if we exclude this site, the relationship between these variables is not significant ( $r = -0.64$ ,  $p > 0.10$ ). For birds and fish distributions we use the totals of NISP values presented in Table 2. There is a clear rising trend of fish towards recent assemblages, while the percentages for birds are relatively low in all samples (Fig. 5). The correlation between NISP% of fish remains and evenness values is highly significant ( $r = 0.86$ ,  $p < 0.05$ ), indicating that fish representations increase uniformly with evenness values. On the other hand, there is not a significant relationship between the representations of birds and evenness values ( $r = 0.32$ ,  $p > 0.10$ ).

The main purpose presented in the introductory statements is to evaluate if archaeofaunal representations exhibit or not spatial and temporal patterning in the archaeological record. This patterning can

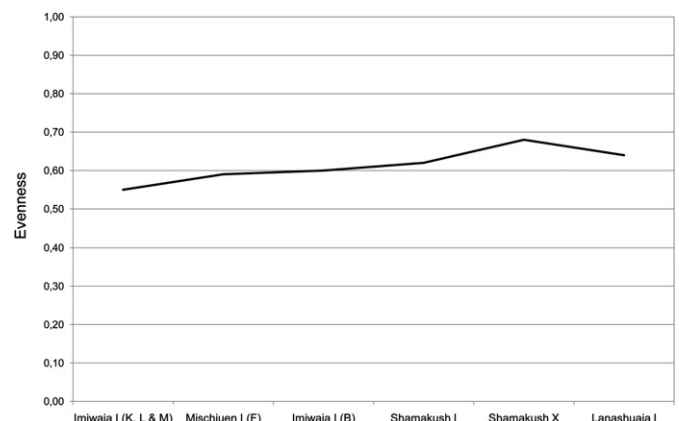


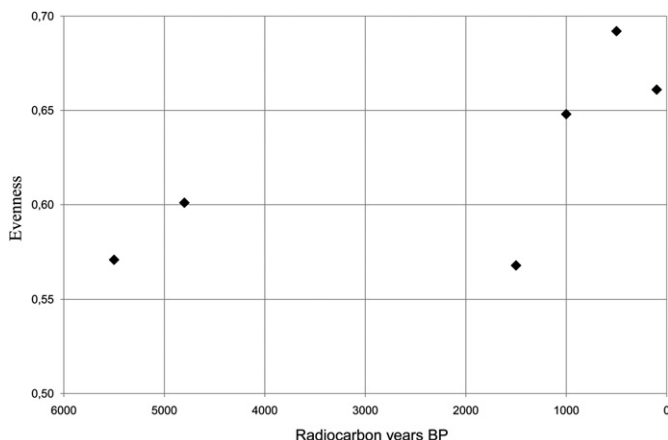
Fig. 2. Evenness values by zooarchaeological assemblages of the Beagle Channel.

**Table 3**  
Evenness values for the regional archaeological sequence.

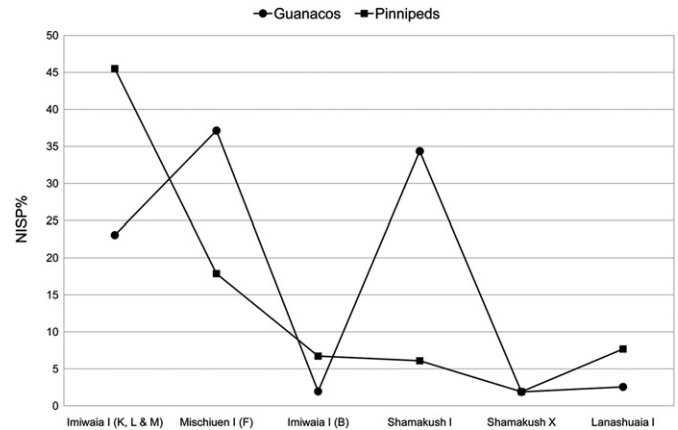
Assemblages	Radiocarbon years BP	V
Imiwaia I (layers K, L y M)	5750 ± 170	0.55
	5872 ± 147	
	5943 ± 48	
Mischien I (layer F)	4890 ± 210	0.59
Imiwaia I (layer B)	1580 ± 41	0.60
Shamakush I	940 ± 110	0.62
	1220 ± 110	
Shamakush X	500 ± 100	0.68
Lanashuaia I	19th Century	0.64

help illuminate changes in subsistence strategies related to the use of different ecozones of the Beagle Channel. To discuss if differences observed in evenness values are associated with variations in logistic organization of foraging activities, we analyze the representations of different resources through the rank-abundance diagrams for each assemblage (Table 4). Fig. 6 illustrates the NISP – converted to  $\log_{10}$  – of each functional taxonomic group, ordered by corresponding ranks. These rank-abundance distributions for the six data assemblages are similar to one another visually, which show a fairly continuous decrease in the abundance of different taxonomic groups (Fig. 6). However, there are important changes in regard to taxonomic categories. Early assemblage of Imiwaia I (layers K, L and M) shows a greater dominance of pinnipeds, followed by guanacos, fish and coastal birds in order of importance. Offshore resources – in strict sense – occupy the lowest positions in the ranges of relative importance. Fish remains are dominated by hake and sardines; although they are pelagic species in an ethologically sense, in the Beagle Channel these fish could be caught from the shore or by massive beachings. In the case of the F layer of Mischien I, ordering is a bit different: guanacos have the highest rank of importance, followed by coastal birds and coastal fish and pinnipeds. Again, offshore resources appear in lower ranks positions with visibly less relative importance compared to other resources. In sum, the range of abundance distributions recorded for both assemblages indicate that the procurement activities of resources in early moments of the regional sequence of the Beagle Channel were mainly oriented towards the exploitation of coastal and terrestrial ecozones.

Zooarchaeological assemblages with chronologies after 1500 years BP recorded a different status of preys in rank-ordered sets. Both in Imiwaia I (layer B) as in Lanashuaia I, offshore fish occupy the first rank of importance. Offshore birds also occupy high or intermediate locations within the distributions of these assemblages.



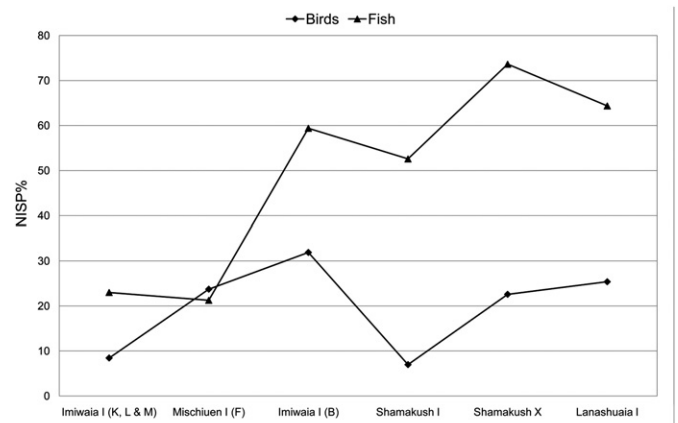
**Fig. 3.** Plot of evenness values across Beagle Channel sequence.



**Fig. 4.** Distribution of guanacos and pinnipeds NISP% for the regional archaeological sequence.

This result demonstrates a different configuration of the foraging activities with respect to early times, which clearly indicates an increase in the use of offshore spaces in logistic organization of subsistence. Also it is necessary to note that an increase in the relative importance of coastal fish; *P. magellanica* and *Patagonotothen* sp. occupy high ranks in distributions of Shamakush I and X sites, which also indicates an intensification of fishing activities in near-shore areas. In contrast to the increase in general representations of fish and offshore birds, marine and terrestrial mammals stage intermediate to low positions in rank distributions, while shorebirds maintain mean positions in later assemblages.

In sum, the analysis developed in this study indicates that significant changes in the subsistence of hunter-gatherers occurred between initial and final moments of the Beagle Channel archaeological sequence. With respect to coastal resources, there is a relative decrease in the representation of pinnipeds while the abundance of certain species of fish of the family Nototheniidae increases considerably. Coastal birds seem to show no significant variations and have intermediate positions in the abundance distributions of both early and late assemblages. The guanacos occupied important positions in relatively early and late assemblages. The high representation of *T. atun* and Procellariiformes resources only in later assemblages indicates that the offshore habitats were incorporated more actively involved in subsistence activities since at least 1500 years BP.



**Fig. 5.** Distribution of fish and birds NISP% for the regional archaeological sequence.

**Table 4**

NISP values and ranks by taxonomical groups.

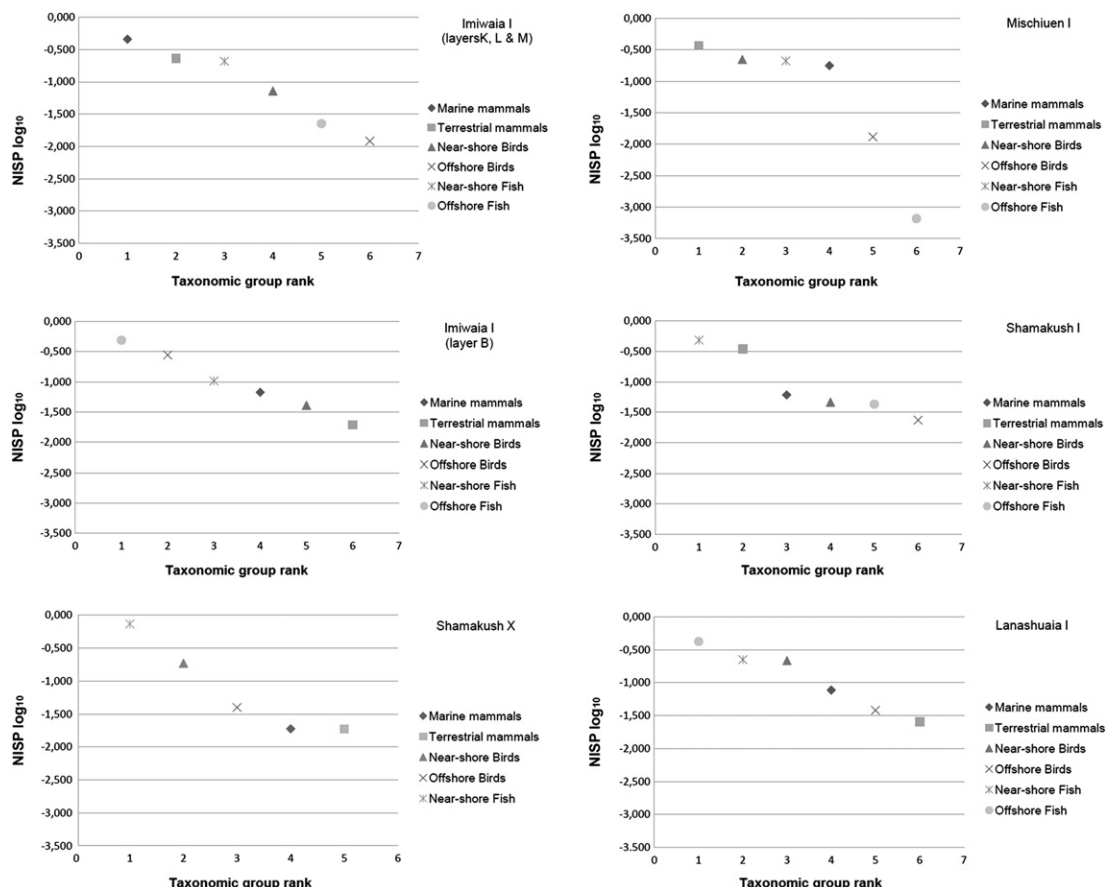
Zooarchaeological assemblages		Marine mammals	Terrestrial mammals	Near-shore birds	Offshore birds	Near-shore fish	Offshore fish
Imiwaia I (layers K, L, M)	NISP	5112	2590	811	136	1594	18
	Rank	1	2	4	5	3	6
Mischiuén I (layer F)	NISP	544	1130	682	40	428	0
	Rank	2	1	3	5	4	
Imiwaia I (layer B)	NISP	79	23	48	327	140	551
	Rank	4	6	5	2	3	1
Shamakush I	NISP	302	1702	228	116	2083	212
	Rank	3	2	4	6	1	5
Shamakush X	NISP	9	9	89	19	329	0
	Rank	5	4	2	3	1	
Lanashuaia I	NISP	69	23	185	34	161	378
	Rank	4	6	2	5	3	1

It does not seem probable that changes in environmental conditions could have improved the availability from offshore resources to the Beagle Channel ecosystem in later times. These resources are present in assemblages contemporaneous both to the Medieval Climate Optimum (ca. 1000 years BP) and the Little Ice Age (ca. 200 years BP). These two episodes were recorded in the Beagle Channel and represent the extreme variations of surface sea water temperature throughout the whole archaeological sequence (Obelie et al., 1998).

The increase in offshore resources is consistent with the dynamics of population proposed by Legoupil and Fontugne (1997) for the archipelago of Tierra del Fuego, where the external islands become more important for human subsistence during the late Holocene. These authors observed that the distribution of occupations and the use of the archipelago were not spatially constant

over the past 6400 years; consequently they point out: 1. an initial occupation of interior channels and islands (v.g. 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, which is evidenced by occupations with radiocarbon ages post-2000 years BP (v.g. Wollaston Islands, Staten Island). Both Legoupil (1993–1994) and Lefèvre (1993–1994) for islands close to Cape Horn as Horwitz (1993) to Staten Island examined the archaeological evidence from a regional perspective, and postulated seasonal use of both sectors to exploit bird colonies.

While it is difficult to establish the spatial scope that fishing practices in offshore areas may have taken up, it is interesting to note that the presence of *T. atun* in the central section of the Beagle Channel is not currently documented. This raises the possibility that the ranges of mobility involved in the pursuit of this resource

**Fig. 6.** Rank-abundance diagrams by taxonomic groups.

may have crossed the Beagle Channel area, which was more feasible from locations near its eastern mouth. This could partly explain why we find the greatest representations of this species in layer B of Imiwaia I and Lanashuaia I sites.

As we have seen, a significant increase in the zooarchaeological representations of fish and bird occurred simultaneously with an important decrease in pinnipeds during the last 1500 radiocarbon years of the prehistoric human occupation of the Beagle Channel region. Different causes could be identified (Gifford-González et al., 2005; Hildebrandt and Jones, 1992; Lyman, 2003; Smith, 2005): 1. a relocation of pinnipeds breeding rookeries to marginal areas as a consequence of human predation pressure or; 2. a decrease of pinnipeds availability as a result of human overexploitation on breeding rookeries. On the first point, Vidal and Winograd (1986) had argued that the actual structure of pinniped colonies – characterized by a distribution oriented to peripheral sectors of the archipelago of Tierra del Fuego – could be the result of a process in which human intervention may have played a significant role. However, on the basis of the zooarchaeological evidence, it has been established that the captures of these resources (determined by sex, age and seasonality of death) would not have been done on breeding rookeries, but predominantly in the sea water. Hunting has been focused on males (83% of *A. australis* remains) and would have concentrated between autumn and spring (Orquera and Piana, 1999; Schiavini, 1990, 1993). This zooarchaeological information and the ecological conditions allow to suggest that human subsistence received energy originated in peripheral sea waters to the Beagle Channel through sea lions movements (Schiavini, 1990, 1993). Therefore, pinnipeds would have remained as the main nutritional source in human subsistence along the entire sequence. However, as we have seen, there were variations in the representation of these resources, which leads to support the second alternative. A recent paper suggests that demographic densities of hunter-gatherers with a specialized adaptation to marine resources remained relatively stable through time (Orquera and Piana, 2006: 27). Nevertheless, this socioeconomic system was not isolated in the Fuegian environment and coexisted with populations of terrestrial and coastal hunter-gatherers, which inhabited the main island of Tierra del Fuego (Zangrando, 2009b). It is possible that a more intensive use of the south-eastern coast of Tierra del Fuego by terrestrial hunter-gatherer groups could have resulted in an overall increase of population density in the Fuegian archipelago during the Late Holocene, raising the exploitation of terrestrial and marine mammals in coastal locations (Zangrando, 2009a,b). To conclude, the analysis developed in this paper shows a raise in spatial ranges for foraging activities and a more actively incorporation of offshore spaces for pursuit of resources, which could be a possible answer to increase the carrying capacity on a regional scale.

## 5. Conclusion

The human use of landscape and resources varied temporarily in the Beagle Channel region. The zooarchaeological record shows the existence of different forms of human–animal interaction in the archaeological sequence. Between 5200 and 4000 years BP, the archaeofaunal evidence shows a clear dominance of mammals over other resources, in addition to a greater evenness in human subsistence. Following the 1500 years BP, it was observed an increase in the representation of birds and fish, involving an extension to offshore sectors for resource procurement.

We suggest that this change in subsistence could have been caused by an increase in overall demographic density in the Isla Grande de Tierra del Fuego. This process would have led (not necessarily instantaneously) to a spatial circumscription, and to a reduction in the possibilities of obtaining food resources. In such

circumstances, a possible response from maritime hunter-gatherers could have been to broaden the spatial ranges of foraging, thereby integrating new areas of exploitation and incorporating more actively some resources in subsistence patterns.

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