

# **Fishing activities of hunter-gatherers in Cambaceres bay co-varied with palaeogeographical changes along the Holocene**

## **Abstract**

## **Keywords**

## **Introduction**

Since 1920s, the Cambaceres bay area (Beagle Channel, Tierra del Fuego, Argentina) has been the focus of archaeological studies, including extensive field surveys (Lothrop 1928: 182-184; Bjerck 2014) and excavations (Piana et al. 2000, 2012; Orquera and Piana 1999, 2000a; Briz et al. 2009; Zangrando 2009a; Alvarez et al. 2013). As a result, the distribution of archaeological sites is well known in that place and the excavations allowed developing temporal analyses of the settlement system and subsistence of hunter-gatherer populations from 8000 BP until historic times. One of these studies focused on subsistence activities of hunter-gatherers at the Imiwaia I site (located in the Cambaceres Interior Bay) during middle and late Holocene (Zangrando 2003, 2009a).

The Cambaceres Bay area is located within a drumlin field assigned to the Last Maximum Glacial (Rabassa et al. 1990). After removal of the ice, the Beagle channel was occupied by a proglacial lake since 9400 BP (Rabassa et al. 1986) and the irregular relief generated by the drumlin field would have led to the formation of lagoon environments and peatlands in depressed areas (inter-drumlins areas). Prior to 7900 BP, the marine environment in the vicinity of Beagle Channel (Rabassa et al. 1986) was fully installed with a sea level located at least 30 m below the present sea level, taking into account the bathymetric thresholds located in Mackinlay and Murray Channels (Bujalesky 2011). The current coastal configuration was acquired at around 7000 cal BP (Borromei et al. 2013). At present, Cambaceres Interior bay has a semi-enclosed configuration and the subtidal substrate is muddy; the *Macrocystis pyrifera* ecosystem is absent inside the bay. The water salinity is lower (~26‰ Vanella 2013, personal communication) than in open waters of the Beagle Channel (~32‰). The euryhaline conditions in the interior of the bay lead to a different composition of the fish fauna to

that observed in open waters and characterized by a greater abundance of Patagonian blenny (*Eleginops maclovinus*) and silversides (*Odontesthes* sp.).

The exploitation of marine resources by hunter-gatherers is evidenced through the archaeological sequence of the Beagle Channel region, starting approximately 6400 BP. The zooarchaeological assemblages include bone remains of pinnipeds, terrestrial mammals (principally guanaco), birds and fish. From 1500 BP, fish became one of the most represented resources in the archaeological record until the last hunter-gatherer occupations of the region. Fishing intensification is evidenced in the Late Holocene both by a significant increase in the representation of coastal taxa as an increase in the diversity of pelagic fishing (Zangrando 2009a; 2009b).

Zooarchaeological evidence from the Imiwaia I site shows a different pattern to this regional trend in terms of temporal variation in the exploitation of coastal fish. While in later occupations of that site pelagic fishing was clearly important, few remains of coastal fish were recovered. In order to explain the fishing pattern in this particular area, special attention was given to the possibility that changes in coastal geomorphology along the Holocene might have impacted on the subsistence activities of hunter-gatherers. In this paper we present an analysis based on an interdisciplinary research carried out in the area, mainly focusing on the geomorphological and ichthyoarchaeological studies.

## **Environment and fish resources**

The Beagle Channel region is located at the southern tip of South America. It constitutes a route between the Atlantic and Pacific oceans. The north coast is formed by the Isla Grande de Tierra del Fuego and the southern islands by Hoste, Navarino and other Chilean islands (54° 50' S and between 66° 30' and 70° W). The information that we are going to present comes from an archaeological locality situated in the north coast of the channel. The Beagle Channel is approximately 180 km long and between 4 and 7 km wide. It presents a large bathymetric variation with waters over 100 meters deep, low salinity level (32‰) and a mean annual temperature of 6.5°C.

The Beagle Channel is inhabited by approximately 56 fish species, grouped in 23 families and 9 orders (Lloris and Rucabado 1991, López et al. 1996). Moreno and Jara (1984) analyzed the distribution of species in shallow waters in two types of marine bottoms. Rocky substrates allow the consolidation of *Macrocystis pyrifera* kelp. These

kelps may form extensive "forests" located below the lower limit of the intertidal zone to 30 m deep. These forests of *Macrocystis pyrifera* are one of the most highly productive components of cold-water marine coasts (Vanella et al. 2007). They are inhabited by many species invertebrates and fishes and generate a space for trophic interactions among those, with seabirds and marine mammals (Moreno and Jara 1984; Schiavini et al. 1997; Raya Rey and Schiavini 2000; Vanella et al. 2007), and also with humans in the past (Zangrando 2009a). On the contrary, sandy bottoms are more homogeneous substrates and do not permit the colonization of this kelp. From their observations, Moreno and Jara (1984) inferred that where the density of kelps is larger, greater is the abundance of fishes in shallow waters (particularly *Paranotothenia magellanica* and some species of the genus *Patagonotothen*). The ecosystem of kelps has two conditions that positively influence the adaptive adjustment of the Nototheniid fish (Moreno and Jara 1984; Rae 1991; Vanella et al. 2007): 1. Food availability (their diet is basically the consumption of amphipods and isopods associated with *M. pyrifera*), and 2. Refuge from predators. Studies conducted in 1987 and 1988 by Lopez et al. (1996) and Vanella et al. (2007) are consistent with these observations.

Fish taxa that not inhabit in the kelp belt were also important for human subsistence. *Eleginops maclovinus* is perhaps the most representative species of the Beagle Channel by distribution and abundance (Lloris and Rucabado 1991, López et al. 1996; Figure 3). This species runs along the shoreline at shallow depth and usually enters in the rivers. *Sprattus fueguensis* is a pelagic species with some tolerance to low salinities. Large shoals of this species can beach in bays with some frequency (Lloris and Rucabado 1991). Species of the Zoarcidae family can be found frequently in the intertidal zone.

*Macruronus magellanicus* commonly inhabits depths between 30 and 500 meters, although youth individuals may frequent coastal waters (Leible et al. 1981). In the Beagle Channel, this species can be captured abundantly from the coast at depths less than 1 meter to 110 meters of deep, regardless of their size and maturity (Lloris and Rucabado 1991). Its presence in the Beagle Channel is recorded usually between January and April (Lopez et al. 1996). Although less common, two species of the genus *Merluccius* (*Merluccius australis* and *Merluccius hubbsi*) can also be captured in depths more than 30 meters. Other species inhabit deep waters all year round; among the most characteristic species are *Salilota australis*, *Genypterus blacodes*, *Dissotichus eleginoides* and several species of *Chondrichthyes* (Lloris and Rucabado 1991).

*Thyrsites atun* is recorded in archaeological sites, although specimens of this species are not currently captured in the Beagle Channel.

### **Geomorphology of Cambaceres Bay**

Cambaceres bay (coordenadas) is located in a coastal area of a drumlin field in a confluence of Lasifashaj valley and Beagle Channel. This drumlin field covers an area of 100 km<sup>2</sup> and presents a maximum W-E length of 20 km. The drumlins on Cambaceres bay area have a NW-SE main direction. The maximum height of these landforms varies between 30 and 60 m and its maximum length is 1.2 km.

Northward, the drumlin field limits with rounded hills lower than 500 m, southward, these landforms disappear on the present coastal lineforming cliffs and depth bays on the interdrumlin areas. Probably, part of the drumlin field is submerged or eroded by the sea.

The coastal studied area presents many landforms like marine terraces and coastal ridge. The distribution of these landforms and the associated marine deposits is controlled by the drumlin field morphology. On this sector, the drumlin field has a NW-SE direction and the marine outgoing (salientes marinas) is developed as rounded marines promontories associated with the drumlins axis (Figure 1). Between these promontories areas there are pocket beaches associated with the axis inter-drumlin depressions.

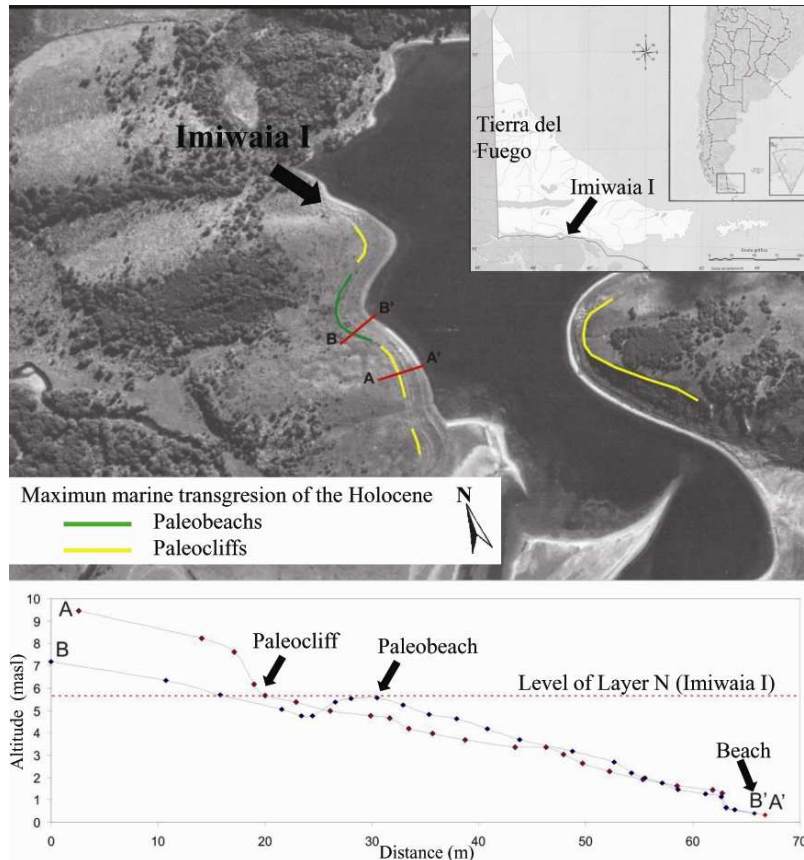


Figure 1.

Two topographic profiles were built to characterize the marine landforms close to Imiwaia I archaeological site (Figure 1). On the profile A-A' which is lined with a drumlin's axis, was identified a paleocliff of 2.1 m high and its base at 5.5 m a.s.l. On the profile B-B', located in an inter-drumin area, a marine ridge was identified with 70 cm high and a maximum elevation of 5.5 m a.s.l.

The analysis of satellite images and aerial photographs allowed to observe the lateral continuity of these landforms along 500 m on the NW coast of Cambaceres bay. This feature was observed in other sectors of this bay.

### Paleogeographic reconstruction

During the times of marine coastal landforms formation, Cambaceres bay would have presented a different paleogeographic configuration. Taking into account an altitude of 5.5 m above the present sea level of the marine landforms, the bay would

have presented a more open coastal environment features than current time. This would have taken place when part of the tombolo that connect the drumlin located in the central part of the bay with the rest of the island and part of the Varela river mouth was submerged. At that moment, Cambaceres bay presented two direct connections to the sea, one of this to the east, with 200 m wide and 5 m depth, and another to the west, with 300 m wide and 10-15 m maximum depth, taken into account actual bathymetric dates. In this way, the Cambaceres paleo-bay had a higher circulation due the present of these two connections to the sea, allowing more wave and marine currents influence and better water oxygenation than the present.

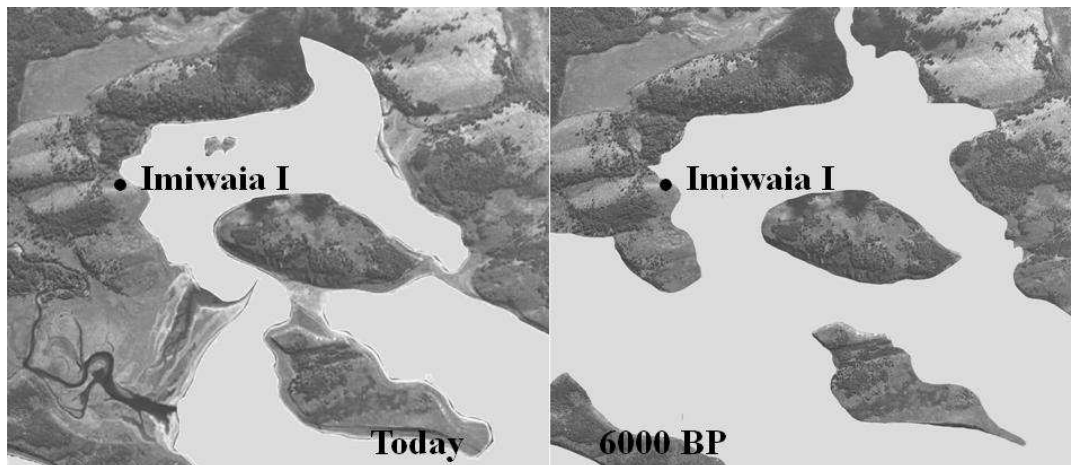


Figure 2.

### **Imiwaia I site**

#### *Chronology and stratigraphy*

The chronological and stratigraphical information of the Imiwaia I site allow discriminating the occupations in the site into five time periods: layer B (1500 BP), layer D (3000 BP) and a unit composed by layers K, L and M (5900-5700 BP), level R (6400 BP) and layer S (7800 BP). Except for this last unit, all deposits are shellmiddens in which 59 m<sup>2</sup> were excavated in total on the sides of a central pit (Figure 3). The level R has no continuity in the stratigraphy and appears as small spots on the surface of layer

S. Layers C and J are paleosoils between shellmiddens. Layer N covers the level R and layer S and is characterized by being composed of a large quantity of gravel.

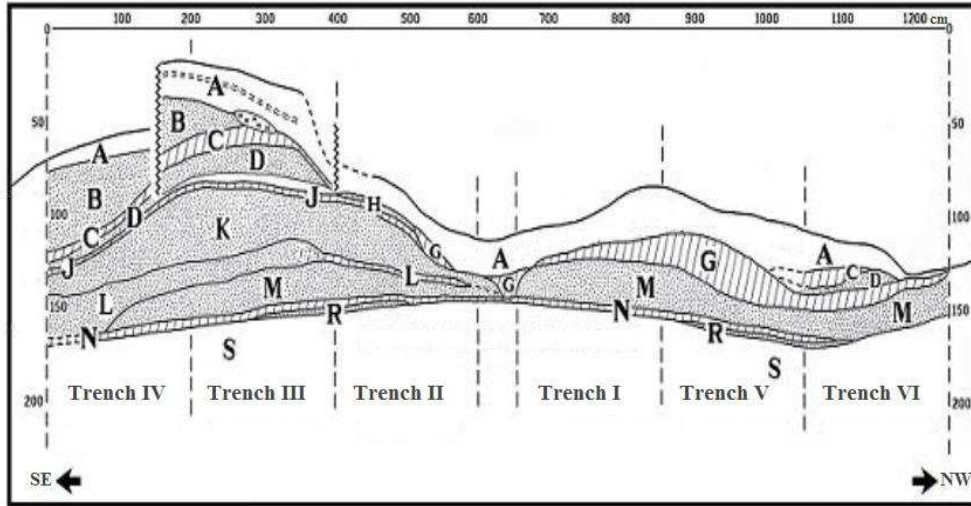


Figure 3.

### *Sedimentological analysis*

Imiwaia I archaeological site is located about 5.5 m above sea level. The paleogeographic reconstruction shows that the early occupations of the site may have had a direct spatial relationship with the marine landforms described above. To characterize the depositional environment of low stratigraphic levels, textural analysis were made of sand, silt and clay fractions from layers N and S and beach ridge present in the area (Figure 1: B-B'). The sedimentological analyses from those archaeological levels and the surrounding areas permitted to assess the spatial relation between the site and the marine landforms, and to narrow the time limits of that event in this sector of the Beagle Channel.

The layer N presents a textural composition dominated by fine and coarse sand, with low percentage of silt and clay (Figure 4). On the other hand, the layer S, located immediately bellow layer N, shows a dominance of silt fraction and absence of sand fraction. The dominance of silt and clay fraction in the matrix is characteristic of till deposits. Finally, the sample corresponding to the top and base ridges shows a

dominance of sand fraction, with low percentages of silt and clay. The ridge base shows a higher abundance of fine sand, whereas the top ridge shows the dominance of coarse sand. Comparing the textural composition of the different samples is possible to see that the composition of layer N is similar to the ridge base sample.

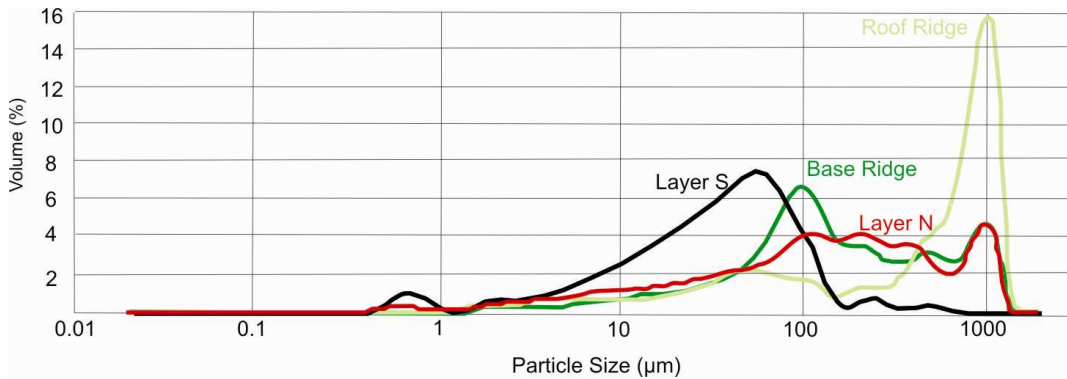


Figure 4.

#### *Archaeological assemblages*

The layers B and D have provided few artifacts; only one instrument related to fishing activities (stone weight) was found in the first layer. A total of 4901 faunal remains were recovered in layer B, among which 48% were identified as fish, 44% as birds, 6% as pinnipeds, and 2% as guanacos. In the D layer, 7293 faunal remains were recovered: 89% corresponds to fish, 5% to birds, 3% to guanacos and 2% to pinnipeds.

In the early stratigraphic component (layers K, L and M), the artefact assemblages were numerous and diverse, in part due to the increased of the excavated volume in these units. Fishing gear is represented by numerous multi-barbed harpoon points and stone weights in that component. Fish remains are also dominant in the zooarchaeological assemblages, since these comprise 59% of a total of 34686 identified remains. The identified specimens is also integrated by 17% of pinnipeds, 15% of birds, 9% of guanacos and 1% of cetacean bones.

The representations of invertebrates in the shellmidden deposits have already been presented in detail in Orquera and Piana (2000b, 2001). Over 90% of shells is represented by mussels, 6% by limpets (*Patinigera*) and the remaining 4% by other taxa (Orquera and Piana 2000b).



## Ichthyoarchaeological analysis

### *Materials and methods*

The archaeological matrix from the sites was sieved through 2.5 mm meshes. Bone remains are well-preserved, and almost all bone elements of the different species are represented. The analysis of fish bones followed the techniques described in Zangrando (2009a). Identifications were made to the lowest taxonomic level possible. A total of 29192 fish bones from Imiwaia I site were able to be identified to taxon. The comparisons among the relative abundance of fish taxa were made by NISP and MNI categories.

### *Early component (layers K, L and M)*

A total of 20366 fish remains could be identified taxonomically (Table 1 and 2). Pelagic taxa comprise 66% of the total NISP, among which hakes (*Macruronus magellanicus*, *Merluccius* sp., Merlucciidae) are the most abundant with 55%. Sardines (*Sprattus fueguensis*) are represented by 8% and snoeks (*Thyrsites atun*) and Channel bull blenny (*Salilota australis*) are found in 2% and 1% respectively. Pelagic taxa comprise 60% of the total MNI in the assemblage and show a similar distribution of proportions among species than NISP values: hakes (47%), sardines (9%), and snoeks and Channel bull blenny (2%).

Coastal fish comprise the 34% of the total NISP of the assemblage; the species with higher representation is *Paranotothenia magellanica* with 18%. Other coastal fish have lower values: Patagonian blenny (*Eleginops maclovinus*) are represented by 7%, *Cottoperca gobio* by 4%, and *Austrolycus* sp., *Patagonotothen* sp. and other taxa of Nototheniidae family are represented by values less than 2%. MNI values show similar proportions among coastal taxa.

Taxa	M				L				K			
	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%
<i>Thyrstites atun</i>	205	2,5	4	1,9	50	1,6	1	2,0	135	1,5	4	2,4
<i>Macruronus magellanicus</i>	2087	25,0	66	31,4	410	13,4	15	15,9	1494	16,6	18	10,8
<i>Merluccius</i> sp.	92	1,1	2	0,9	130	4,2	3	3,2	658	7,3	10	6
Merlucciidae	2906	34,9	53	25,2	411	13,4	16	17,0	2969	33	39	23,5
<i>Salilota australis</i>	114	1,4	3	1,4	87	2,8	3	3,2	48	0,5	2	1,2
<i>Sprattus fueguensis</i>	26	0,3	1	0,5	1	0,0	1	1,0	1631	18,2	42	25,3
<i>Austrolycus</i> sp.	63	0,7	5	2,4	127	4,1	7	7,4	130	1,4	6	3,6
<i>Cottoperca gobio</i>	244	2,9	9	4,3	400	13,1	11	11,7	262	3	7	4,2
<i>Eleginops maclovinus</i>	427	5,1	14	6,7	196	6,4	8	9,0	803	8,9	16	9,7
Nototheniidae	246	2,9	8	3,8	2	0,1	1	1,0	131	1,4	6	3,6
<i>Paranotothenia magellanica</i>	1874	22,5	42	20	1234	40,4	26	27,6	545	6	12	7,2
<i>Patagotothen</i> sp.	47	0,6	3	1,4	6	0,5	1	1,0	175	1,9	4	2,5
Totals	8331	100	210	100	3054	100	93	100	8981	100	166	100

Table 1.

Taxa	NISP	NISP%	MNI	MNI%
<i>Thyrstites atun</i>	390	1,9	9	1,9
<i>Macruronus magellanicus</i>	3991	19,6	99	21,1
<i>Merluccius</i> sp.	880	4,3	15	3,2
Merlucciidae	6286	30,9	108	23,0
<i>Salilota australis</i>	249	1,2	8	1,7
<i>Sprattus fueguensis</i>	1658	8,1	44	9,4
<i>Austrolycus</i> sp.	320	1,6	18	3,8
<i>Cottoperca gobio</i>	906	4,4	27	5,8
<i>Eleginops maclovinus</i>	1426	7,0	38	8,1
Nototheniidae	379	1,9	15	3,2
<i>Paranotothenia magellanica</i>	3653	17,9	80	17,1
<i>Patagotothen</i> sp.	228	1,1	8	1,7
Totals	20366	100	469	100

Table 2.

#### Layer D

The number of remains taxonomically identified is 6497 (Table 3). The major part of the sample (75%) comprises specimens of hakes and represents 188 individuals. Only 4% is comprised by other pelagic taxa (*Sprattus fueguensis*, *Thyrsites atun*, and *Salilota australis*). Coastal taxa only comprise 1% of the whole identified assemblage. Coincidentally, MNI values show a small representation of these fish.

Taxa	NISP	NISP%	MNI	MNI%
<i>Thyrsites atun</i>	77	1,2	3	1,5
<i>Macruronus magellanicus</i>	280	4,3	14	7
<i>Merluccius</i> sp.	4974	76,5	141	70,5
Merlucidae	944	14,5	33	16,5
<i>Salilota australis</i>	12	0,2	1	0,5
<i>Sprattus fueguensis</i>	141	2,2	3	1,5
<i>Austrolycus</i> sp.	9	0,1	1	0,5
<i>Cottoperca gobio</i>	3	0,1	1	0,5
<i>Eleginops maclovinus</i>	22	0,3	1	0,5
<i>Paranotothenia magellanica</i>	19	0,3	1	0,5
<i>Patagonotothen</i> sp.	16	0,3	1	0,5
Totals	6497	100	200	100

Table 3.

#### Layer B

A total of 2329 fish remains could be identified taxonomically (Table 4). An important dominance of snoeks is observed with 85% in the total NISP. Hakes and sardines add a representation of 7%. Coastal fish represent a value of 8%, among which *Paranotothenia magellanica* dominates with 6%. MNI values confirm the dominance of snoeks.

Taxa	NISP	NISP%	MNI	MNI%
<i>Thyrsites atun</i>	1982	85	27	61
<i>Macruronus magellanicus</i>	27	1,2	1	2
<i>Merluccius</i> sp.	48	2	4	10
Merlucciidae	17	0,7	1	2
<i>Sprattus fueguensis</i>	65	2,8	2	5
<i>Austrolycus</i> sp.	8	0,4	1	2
<i>Austrotherina nigricans</i>	1	0,1	1	2
<i>Eleginops maclovinus</i>	1	0,1	1	2
Nototheniidae	6	0,2	1	2
<i>Paranotothenia magellanica</i>	149	6,4	4	10
<i>Patagotothen</i> sp.	25	1,1	1	2
Totals	2329	100	44	100

Table 4.

## Discussion

Paleogeographic reconstructions are an important tool in the study of human-environment relationship in coastal areas. Raised beaches of the Holocene have been recognized on the northern coast of the Beagle Channel, but only in central and western sectors (Rabassa et al. 1986; Gordillo et al.,1992; Isla y Bujalesky, 2008). Older raised beaches present an age of around 6000 BP and their altitudes vary from a maximum of 8-10 m in the West: Acigami Lake –Roca–,Golondrina Bay, Playa Larga (Rabassa et al., 1986; Rabassa, 1987; Gordillo et al.,1992, 1993; Bujalesky, 1998; Bujalesky, 2007), decreasing to the East with altitudes around 5.5 m in Cambaceres bay. Marine deposits dated at 6240 years AP have been described below the high tide level at -1.26 m in the Rio Varela locality (Grill et al., 2002). Raised beaches of the Holocene have not been described in easternmost sectors than Cambaceres bay.

The coastal landforms in the Cambaceres bay perimeter indicate higher levels during the Holocene than the current sea level. The levels of these landforms match in 5.5 m a.s.l. approximately. Furthermore, the similarity in the textural compositions between the layer N of Imiwaia I and the deposits corresponding to the base and roof

ridges indicate a marine origin for layer N, in a similar environment of formation than the deposits at the base ridge. The altitude of layer N coincides with the levels of marine landforms. Therefore, it is possible to correlate the datings of layer N with the formation of coastal landform of Cambaceres bay; the presence of organic remains associated with human activity, below and above layer N allowed to limit the time of its formation between 6400 BP and 5900 BP (Zangrando 2009a). Thus, it is possible to associate the formation of marine landforms and the sea level present in the site Imiwaia I (layer N) to the time of the Maximum Transgression of the Holocene (es correcto este término en ingles para la maxima transgresión del Holoceno?) in this area of Canal Beagle (Gordillo *et al.* 1993).

This information suggests that the occupations of the layers M, L and K have developed under different marine conditions that currently dominate in the bay. About 6000 years ago, the Paleo-bay Cambaceres had an open configuration that would have allowed greater influence of waves and currents, and better oxygenation of the waters than current time. In turn, this would have generated different conditions for the composition of the fish fauna of the place.

Ethnographic information indicates that the Yamana groups developed coastal fishing on kelp belts near the settlements (Orquera and Piana 1999:156). If this activity was organized by a similar strategy during the last 6000 years, then we would expect to find variability in the ichthyo-archaeological record along the sequence of Imiwaia I.

Figure 5 compares the ichthyofaunal evidence from various layers of Imiwaia I site. A greater representation of coastal species is observed in the layers K, L and M (Figure 5a): while these resources are represented with percentages between 23 and 65% in those early shellmiddens, in layers D and B the values are only 1 and 8% respectively. Figure 5b shows that species of Nototheniidae family dominate in the taxonomic composition of coastal fish resources, among which *Paranotothenia magellanica* significantly prevails. No differences in taxonomic composition between assemblages of middle and late Holocene are observed. While we have expected a greater representation of *Eleginops maclovinus* in layers D and B, with presumably similar environmental conditions which currently present the bay, Figure 5c shows that this species presents moderate to low representations in all layers. In sum, coastal fishing was developed more intensively in the *Macrocystis pyrifera* ecosystem, which is not currently present in Cambaceres bay. Late Holocene occupations (layers D and B) show that fishing activities were mainly developed on pelagic areas, being very low the

representations of coastal fish taxa. The abundance and taxonomic diversity recorded in the lower layers of Imiwaia I coincide with the expectations arising from paleogeographic reconstructions presented in this paper.

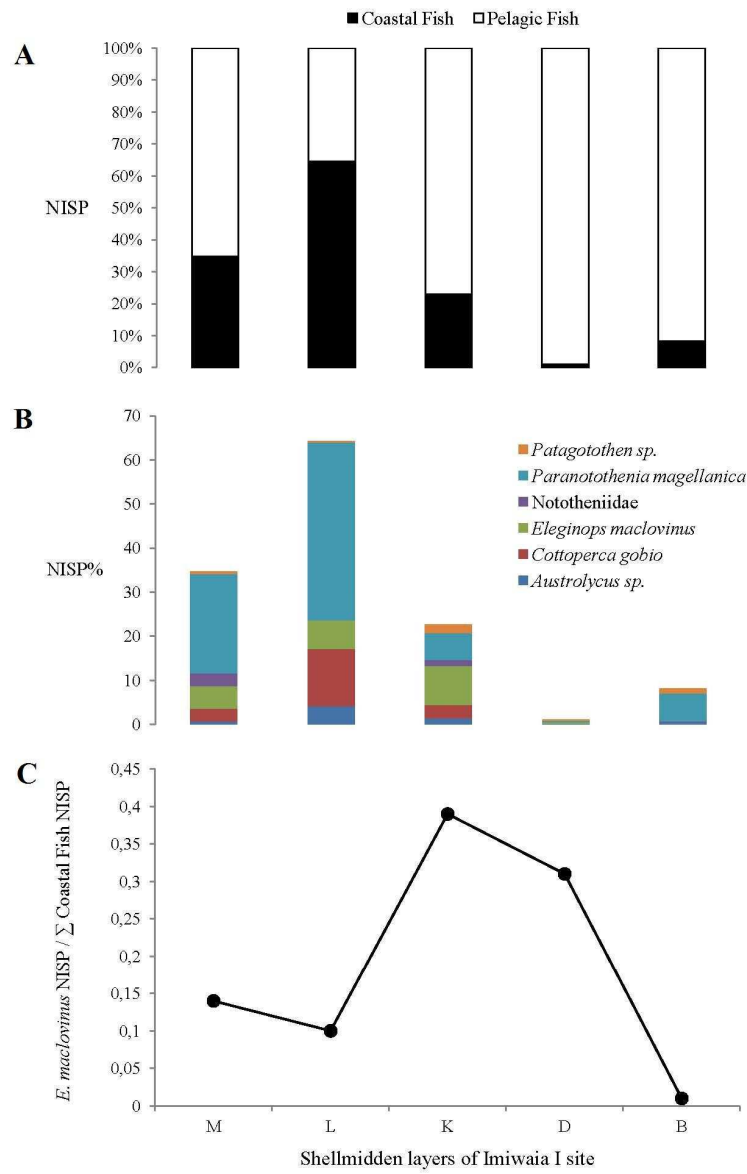


Figure 5.

Fishing activities developed during later occupations of Imiwaia I site implied ranges of mobility that clearly exceeded the microenvironmental limits of the bay. However, these movements were not utilized for the development of fisheries in the kelp belts, which rules out the interpretation proposed in Zangrando (2009a: 163). Geomorphological changes in the Cambaceres bay do not appear to have encouraged the redirection towards alternative coastal fisheries species (e.g. *Eleginops maclovinus*). The low representation of this species of great abundance and distribution in the region remains striking, and socio-cultural arguments proposed in Fiore and Zangrando (2006) continue with validity.

## **Conclusion**

The ichthyarchaeological evidence from the Imiwaia I site covaries with the interpretations developed by the paleogeographic reconstruction of the Cambaceres bay. In occupations of mid-Holocene, coastal fishing was more intensively developed on the *M. pyrifera* ecosystem and in different marine conditions that are presented in the bay at the present time. The paleogeographic information presented in this paper will be helpful for future discussions about the use of other resources and settlement patterns developed in the bay throughout the Holocene.

## **Acknowledgements**

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