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Palaeoenvironmental conditions during the Middle Holocene at Isla de los Estados (Staaten Island, Tierra del Fuego, 54° S, Argentina) and their influence on the possibilities for human exploration

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ABSTRACT

The Middle Holocene is a particular time period in which there are uneven environmental dynamics all along the southern portion of the continent. Whereas in the Puna, extreme aridity and high temperatures (the so-called "Hypsithermal" period) have been recorded, a more humid and rainy phase dominated southern Tierra del Fuego. The present paper explores the palaeoenvironmental situation of Isla de los Estados (Staaten Island, 54°38′–54°55′ S; 63°48′–64°46′ W) and its relationship with the archaeological record left behind by ancient canoeing people. The considered period is characterized by exceptionally windy conditions. The palaeoenvironmental information could be used as an explanation for the absence of cultural remains and also for the scarce archaeological record for Península Mitre. At the beginning of the Middle Holocene, the diatom record shows a large amount of *Aulacoseira* sp that could indicate either windy conditions or higher water levels at the site core. The more distinctive changes in the diatom assemblages occurred at ca. 5000 cal B.P., suggesting a shallower water level and more acidic conditions. By 3000 cal B.P., the diatom species are strongly linked to peat and swampy environments. However, during the late Holocene, milder conditions might have favored seasonal travelling to the outer islands of the Fuegian Archipelago, though no definitive or permanent settlements have been found.

1. Introduction

Environmental conditions, inferred from the palaeoenvironmental studies and their relationship with past human groups play a remarkable role for a better understanding of the processes which form, directly or indirectly, the archaeological record. At the large scale, this is due to the fact that natural environments constitute a very strong influential factor for human behavior (Dearing, 2006). The period which includes the Middle Holocene (ca. 8000–3000 ^{14}C BP) was characterized by important climate changes, which undoubtedly forced remarkable cultural adaptations (Sandweiss et al., 1999). There is general agreement that the first occupation of the Fuegian Archipelago by hunter-gatherer groups with littoral adaptation took place around 6200 ^{14}C BP (Orquera and Piana, 1999). The process of human colonization was not homogeneous, and therefore the outermost islands of the archipelago might have been occupied later. The outer area of the archipelago is formed by Península Mitre (the easternmost portion of Isla Grande de Tierra del Fuego), Isla de los Estados (Staaten Island) and the Chilean islands Nueva, Picton and Lennox, located at the eastern end of the Beagle Channel, together with other islands around Cape Horn (Fig. 1). Several research projects are presently being carried out, having as an objective the understanding of the peopling dynamics that took place in this area of the Fuegian Archipelago.

Isla de los Estados is situated between 54°38′ and 54°55′ S, and 63°48′ and 64°46′ W, not far from the southeastern end of the Isla Grande de Tierra del Fuego. This subantarctic island is the easternmost one of the Fuegian Archipelago, and it is a highly environmentally-sensitive area as the Circumpolar Antarctic Current (CAC) goes quite close from its southern coast, bringing moisture and precipitation from the neighboring Antarctic Peninsula. Even though the current moves along the Drake Passage, its direct influence makes this strait one of the worst for sail

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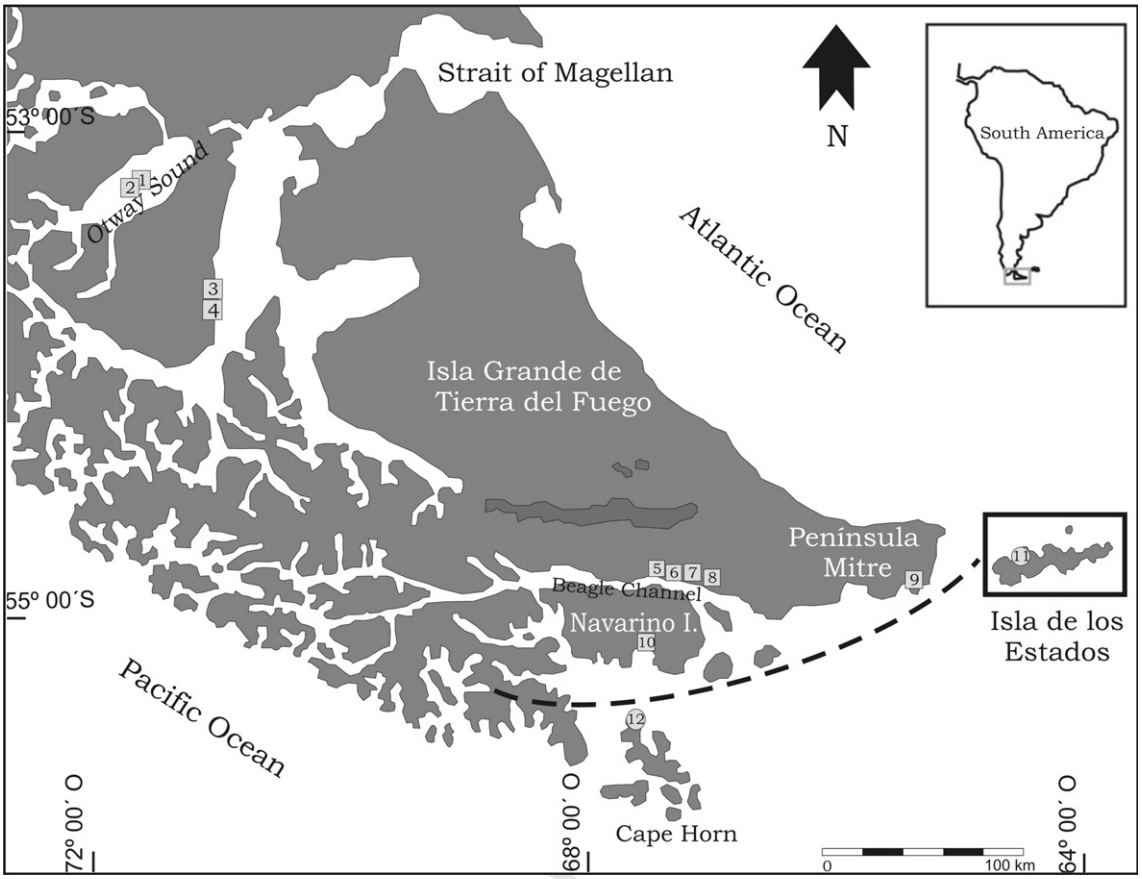

Fig. 1. Fueguian Archipelago. The study area is depicted in the box. Main archaeological sites during the Middle Holocene are indicated. The dotted line points the boundary between some of the most important occupations in the area whose archaeological remains dated from the Late Holocene. 1. Englefield I (6100 ± 110 ^{14}C B.P.) (Legoupil, 1988); 2. Bahía Colorada (5900 ± 65 ^{14}C BP) (Legoupil, 1997); 3. Bahía Buena (5895 ± 65 ^{14}C BP) (Ortiz-Troncoso, 1975); 4. Punta Santa Ana (6810 ± 70 ^{14}C BP) (Legoupil and Fontugne, 1997); 5. Lancha Packewaia (4980 ± 70 ^{14}C BP) (Orquera and Piana, 1999); 6. Túnel I (6980 ± 110 ^{14}C BP); 7. Mischiuen I (4890 ± 210 ^{14}C BP) (Piana et al., 2004); 8. Imiwaia I (7840 ± 50 B.P. ^{14}C BP) (Orquera and Piana, 2009); 9. Bahía Valentín (5900 ± 80 ^{14}C BP) (Vidal, 1988); 10. Grandi I (6120 ± 80 ^{14}C BP) (Legoupil, 1993–94); 11. BC I (2730 ± 90 ^{14}C BP) (Horwitz, 1993); 12. Bayly I (1410 ± 50 ^{14}C BP) (Legoupil, 1993–94).

navigation in the world (Payró, 1898) due to the strong action of the southwestern winds drift, the "westerlies".

Within this ample context, the aims of this paper are to analyze why there is no evidence of human occupation at Isla de los Estados during the Middle Holocene, and to discuss if this could be related to certain palaeoenvironmental conditions acting in this area and the adjacent seas. In order to make a palaeoenvironmental reconstruction, diatom analysis from a core taken at Isla de los Estados has been done, and the data compared with the pollen record, and other "proxies" and lines of evidence.

The archaeological sites recorded in Isla de los Estados are BC I and BC II (Chapman, 1987), in Crossley Bay, Flinder III (Chapman, 1987) and Colnett Beach (Horwitz, 1985) (Fig. 2). The first site of this list has the earliest available radiocarbon dates, comprising a sequence that extends from 2700 to 1500 ^{14}C BP (Horwitz, 1993). This author interpreted that this site was the result of occasional, seasonal occupation by canoe-travelling people around Península Mitre. But, what happened before this occupation? Between 6000 and 4000 cal B.P., Península Mitre was already inhabited if the published dates are considered (Vidal, 1988; Zangrando et al., 2009). Moreover, Zangrando et al. (2009) noted that the following period between 4000 and 2000 B.P. lacks information in Península Mitre, probably due to abandonment processes or a population replacement. In addition, the population density around that time could have been low in the Fuegian Archipelago. Thus, a sampling bias could not be discarded because of a better preservation of earlier archaeological sites (Vázquez et al., 2007).

1.1. Peopling of the Beagle Channel and neighboring islands

The early peopling of the southern Fuegian Archipelago has been under study since the beginning of the XXth century or even before (Ortiz-Troncoso, 1972; Legoupil, 1993–1994; Legoupil and Fontugne, 1997; Orquera and Piana, 1999, 2006; Ocampo and Rivas, 2000; Orquera, 2005). Legoupil and Fontugne (1997) observed that the geographical distribution of the occupation in the area had been discontinuous during the last 6400 years. They considered two phases or stages in the peopling of this southern region: first, the adaptation to littoral environments in certain spaces called "*núcleos de base*" (base nuclei) and possible sites of transition where groups adapted to both terrestrial and marine environments inhabited; second, a later expansion in a progressive and concentric movement towards the outer edge islands or "*offshore islands*". The aforementioned authors believed that the Magellan Strait-Otway Sound area and the Beagle Channel could have been these "*núcleos de base*" places, mostly because of the earliest sites with adaptation to the littoral way of life located there. Nevertheless, they considered that a process of adaptation like that could have started further north and later expanded southwards by highly mobile small canoeing groups (Legoupil and Fontugne, 1997, p. 85).

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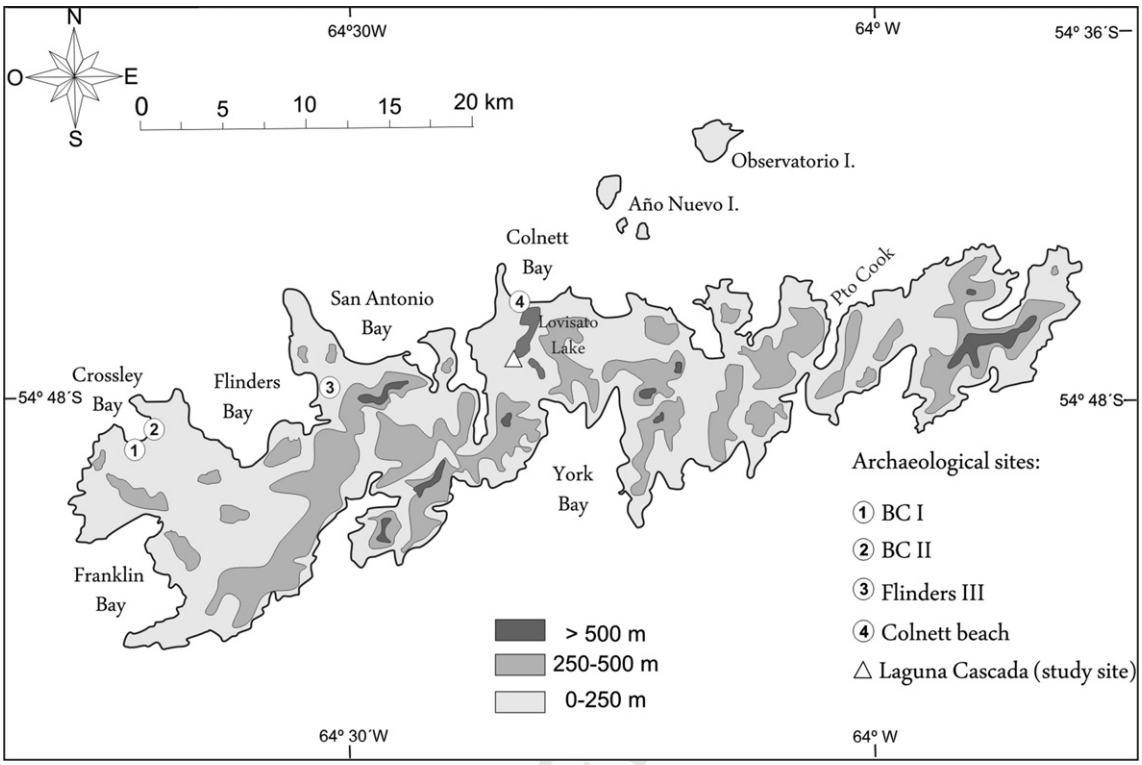

Fig. 2. Isla de los Estados (Staaten Island) with the location of the main archaeological sites and the core location. Modified after Horwitz, 1990.

However, according to Orquera and Piana (1999, 2009), the Beagle Channel would have been a less likely alternative space for the origin of a process of adaptation to littoral environments. Orquera and Piana (2005, 2006) believed that there are other regions which would have been more appropriate for the starting of this specialized littoral life, for example, the island of Chiloé (42°36′ S; 73°57′ W) or the Otway Sound-western portion of the Strait of Magellan, both in Chile. They have analyzed the cultural material evidence from these places and those from central and southern Patagonia.

Several radiocarbon dates from archaeological sites all along the coast of the Chilean fjords and the Beagle Channel indicate occupation of that area during the Middle Holocene. In the Beagle Channel, the earliest known radiocarbon date comes from the Imiwaia I site (7840 ± 50 B.P.; Orquera and Piana, 2009). Together with the earliest assemblage from Túnel I site (6680 ± 210 B.P.; Orquera and Piana, 1999), toolkits remind those of the inland hunters (Orquera and Piana, 2009). From there, the adaptive strategy seems to have expanded gradually to the offshore islands looking for good places to settle. But around 6500 cal B.P., the Beagle Channel region was already inhabited by people who were exploiting marine resources such as in the "Second Component" of Túnel I (TISC) and the "Lower Component" of the Imiwaia I site (LCII) (Orquera and Piana, 1999, 2009) (Fig. 1). A characteristic of the local toolkit is the occurrence of two distinct harpoon points; one is detachable from the hafts which have a cross-shaped base, whereas the other has a long non-detachable base and multiple barbs (Orquera and Piana, 1999, 2009). The first inhabitants of the archipelago seem to have developed a special technology (harpoons with detachable points) to be used in these littoral environments. They also could have reached the surrounding islands of the Fuegian seas using canoes. Following this idea, arriving at Isla Navarino (at least at 6120 ± 80 ^{14}C B.P.; Legoupil, 1993–94), Isla de los Estados and other islands situated near Cape Horn, would have been possible using canoes and/or rafts. According to the available environmental information for ca. 8000 ^{14}C B.P., the Beagle Channel, an ancient glacial valley, was flooded by raising marine waters around this time (Rabassa et al., 1986; Gordillo et al., 2005). Therefore, the possibility for these people to become maritime-specialized was established. The most important favorable factors were abundant marine fauna, sea waters protected from both huge and fast Antarctic waves and furious winds, and availability of forested areas where raw materials to make canoes and harpoons hafts were available (Orquera and Piana, 1988). The increase of some significant resources for human subsistence as wood and tree bark might have positively influenced the availability of other resources (Zangrando, 2009). Mobility was an important strategy to exploit other lesser-used patches, rather than to intensify the exploitation of only one.

There were other tool innovations, especially during the Middle Holocene, such as large lanceolate and standardized spear points, triangulated middle-sized points (4–8 cm) and arrow heads (Orquera and Piana, 2009, p. 71). How can these slight differences in technology be linked with palaeoenvironmental conditions? Is there any kind of relationship? Orquera and Piana (2009, in Piana, 2010) suggested that these points can be seen as a diffusion of a technological innovation which did not entail ethnic replacements or basic cultural changes. Q1

The canoeing people used most of their time traveling between resource sites as well as looking for higher quality materials. Bettinger (2001) called this the "traveler and time minimizing" foraging strategy. The abundant and homogeneously distributed resources made possible a higher mobility in hunter-gatherer societies, which was precisely what was recorded in this area of the southern cone of the Americas (Orquera and Piana, 2006). There might then be a relationship between native people, navigation conditions, coastal landscape, resource availability and unpredictable weather. Due to these factors, it seems of high importance to explore the prevailing palaeoenvironmental conditions during the Middle Holocene.

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2. Regional setting

Isla de los Estados is situated southeast of the main island of Tierra del Fuego. It is separated from it by the Le Maire Strait, 30 km wide. The mountains follow a range that has a west-east direction, being the outermost extension of the Andean cordillera, covering a total of 68 km. Both the relief and the coastal geography are the result of the erosion effect of glaciers that covered the island in the past. Many fjords (Ponce et al., 2009; Möller et al., 2010) shaped the coast line giving origin to many bays and cliffs (mainly in the southern coast). The main bays are the following: Crossley, Flinders, San Antonio and Colnett, which are located in the northern shoreline (Fig. 2). The landscape of the islands shows a strong glacial abrasion to an altitude of ~450 m a.s.l. (Möller et al., 2010). Most of the glacial topography and glacial sequences were products of local glaciations in northern Isla de los Estados, where local ice caps were more or less interconnected and sent outlet glaciers towards the north, terminating on a dry shelf (Ponce, 2009; Möller et al., 2010). The most representative vegetation is the *Nothofagus betuloides* ("guindo") forest which dominates from the coast to about 500 m a.s.l. where Alpine tundra begins (Dudley and Crow, 1983). The *Drymis winteri* evergreen forest and dense shrub also make up the typical island vegetation. The island is dotted with numerous bogs and reed fields of *Marsippospermum grandiflorum*. Higher up (400 m a.s.l.), a *Nothofagus antarctica* forest occurs, which is extremely dense, with squat and curved trunks. The three *Nothofagus* species (including *Nothofagus pumilio*, though rarer) may be found also together with *Empetrum rubrum*. The main climatic characteristics are the numerous and rapid daily variations of meteorological conditions, creating unstable conditions as in the entire Fuegian Archipelago. The instability is caused by low pressure centers (Kühnemann, 1976). The climate is colder, windier and more humid than the main island of Tierra del Fuego, with the exception of the western channel areas. Strong winds from the south, southwest and west dominate all year around (Kühnemann, 1976). This island has one of the most oceanic climates in the world (Tuhkanen, 1992). Summer temperature is colder than in the rest of the archipelago and winter temperatures are less severe. Average summer temperature at sea level ranges from 7 to 10 °C and the mean winter temperature is about 2 °C. In the island, terrestrial resources are scarce or almost null.

3. Archaeological sites at Isla de los Estados

The first archaeological survey was conducted by Anne Chapman in 1982. Later on, studies continued in 1985 by A. Chapman and Victoria Horwitz (Chapman, 1987) and by Horwitz (1986, 1990) in the following geographical areas: Crossley, Colnett, Flinders, San Antonio, Puerto Presidente Roca, Basil Hall, Puerto Parry, Cánepa and Franklin bays (Horwitz, 1993) (Fig. 2).

After the evaluation of the presence of sites and non-sites in terms of their location, Horwitz (1993) suggested that there are multiple factors that determined the human peopling of Isla de los Estados. For example, food resources availability, habitable space and distance to the nearest landmass are considered to be equally significant determinant factors.

The archaeological remains in Isla de los Estados include three scatters and one stratified site located at Zaratiegui Bay. The sites defined as scatters are: Palet Beach (Crossley Bay), Flinder III (Flinder Bay) and another site in Colnett Bay (Horwitz, 1990).

3.1. Flinder III

Chapman collected some lithic artifacts lying on the surface at the base of a sand-dune, but no test pits were excavated (Horwitz, 1990). The cultural remains include three cores, two flakes, two picks and two flaked pebbles, all made from pyroclastic devitrified rocks. Also, some birds bones scattered were observed on the surface. No charcoal for dating purposes was found (Horwitz, 1990).

3.2. Colnett Beach

The cultural remains in this scatter are doubtful and consist of a few cobbles flaked or fractured and three partially weathered long bones (Horwitz, 1990). Some test pits were dug, but no evidence of archaeological remains was found. The lithic remains are made all in coarse-grained igneous rocks, and include three cobbles, fractured in a vertical plane, one cobble with marginal flaking around the entire perimeter and two large primary flakes. No carbon remains for dating were obtained (Horwitz, 1990).

3.3. BC I (Crossley Bay)

This site is located on the southwestern section of Playa Zaratiegui, a beach in Crossley Bay. It is a stratified shell-midden which lies on a sandy beach (Horwitz, 1990). A. Chapman located the site in 1982. It appeared as a surface scatter of bones, lithic artifacts and faunal remains. BC I is one large site which was covered in part by a 4 m high sand-dune. Part of this dune is bounding the site at the south. The northern boundary is closer to the sea, and the western and eastern limits were determined by archaeological criteria. Playa Zaratiegui is protected from cold, southern and northern winds but it is exposed to the western winds (Horwitz, 1990, p. 181). In the non-eroded part of the site, there are three different overlapping shell-middens. These shell-midden levels are separated by gray sand horizons (levels) that also include archaeological remains but in a much lesser quantity (Horwitz and Scheinsohn, 1996). These levels were radiocarbon dated by Horwitz (1990), as follows: Level II: 2180 ± 130 B.P.; Level IV: 2480 ± 60 B.P.; Level VI: 2730 ± 90 B.P. However, a younger date for Level II is available: 1527 ± 58 B.P. (Chapman, 1987, p. 67).

The portion of BC I on the 2.5 m high terrace is a surface scatter of lithic debris, including two side-scrapers, three end-scrapers, two knives, one small oval-shaped stone with a groove around half of its circumference and flakes of pyroclastic devitrified rock. Some seal bones in a very poor preservation condition were also obtained (Horwitz, 1990). The eroded portion covered most of the site which was not originally buried under the dune. This is an area with scatter lithic flakes and weathered faunal remains (Horwitz, 1990). All the lithic artifacts of BC I and BC II were manufactured mainly from marine pebbles found along the coast. The choppers, side-scrapers, grooved oval cobbles and the picked oval pebble of BC I were made of local raw material found in Crossley Bay (Horwitz, 1990).

3.4. BC II (Crossley Bay)

This site was found in an 8 m-high beach terrace. The cultural remains are continually eroded by wind action. The BC II site is located about 30 m above present sea level, on the sand dunes behind Playa Palet (Horwitz, 1990). Over the years different materials were found: one flaked pebble and one end-scraper (Chapman, 1987, p. 64); two end-scrapers, six flakes; two end-scrapers, one percussion stone and a few flakes (Horwitz, 1990). According to Horwitz (1990), the characteristics of such occupation remained unknown. Also, no organic material was found for dating.

The site located at Playa Palet is well protected from the northern and western winds. This site would have been used as a shelter, or just in those moments in which the western winds were too strong in BC I. It is located quite far away from the current cormorant and penguin colonies (Horwitz, 1990, p. 181).

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3.5. Faunal assemblages from BC I and BC II sites

The low quantity of tools or artifacts found in these sites is linked with feeding activities as the catch of fish and terrestrial animals. Mainly, three explanations about the lower found artifact density were given. The assemblage is essentially composed of marine faunal remains. The main taxa represented were penguins, cormorants, pinnipeds, albatrosses, wild-geese, cetaceans and molluscs. Likely, pinnipeds were the main food resource consumed in BC I. Penguins are represented in all levels of BC I. Many penguin species live and breed even today in Isla de los Estados (Horwitz, 1990; Schiavini, 2000; Liljesthröm et al., 2008). A small rockhopper colony is located about a 1 h and a half walk from the BC I site (on Franklin Bay) (Chapman, 1987; Horwitz, 1990). Albatross is the largest bird in the area. Currently, this bird lives and breeds in the island. Furthermore, cormorants have a colony in a southeasterly direction from the BC I site. Four species of wild geese are found in the island today. According with the observations made by J.L. Lanata (in Horwitz, 1990), the faunal assemblage was badly preserved due to the action of wind and rain and the aggressive sandy environment. He observed that the marine faunal assemblages were increasing eastwards.

The quality of archaeological sites is linked with the dominant geomorphological processes involved in site formation. Wind action is one of the most important factors acting upon the stratified archaeological sites at Isla de los Estados. In the area of Bahía Franklin (southwest of the island), there is a dune field. Between these dunes, peat has developed with a basal ^{14}C date of 10,679 ± 62 B.P. (AA62509; Ponce, 2009). The present wind action not only erodes, but also sand spits are born on the beach, and they advance and bury grasslands and surrounding peatlands (Ponce, 2009). The wind direction is coincident with the principal axis of the dunes, which is evidence that the wind direction (coming from the west-southwest) might have remained constant during the entire period from the beginning of the Holocene (Ponce, 2009).

At the BC I site, the dune continued growing and then partially covered the southern end of the site (Horwitz, 1990, p. 165). Following this, it is hard to establish the date of the site as a whole. Probably, an earlier level with archaeological remains might be buried under the sand. The mentioned age of 2700 ^{14}C B.P. should be considered as a minimum age (L. Borrero, personal communication). However, the published radiocarbon date is helpful to the purpose of building up a new model.

The faunal assemblage shows that the most important food resource during the earliest occupation was composed of pinnipeds, penguins, cetaceans, cormorants, wild geese and smaller birds. Along the entire occupation (about 2000 years) penguins became a much more important food resource relative to the pinnipeds, and the consumption of mollusks also increased (Horwitz, 1990). Up to now, it is not possible to confirm if the difference between bird and pinniped assemblages is due to the availability of the resource and its variability through time, or to seasonal fluctuations of migratory birds, or to cultural decisions (Horwitz, 1990).

It is not possible to say that hunter-gatherers lived permanently at Isla de los Estados. This is linked with Borrero's (2001) hypothesis about the difficulty in affirming the colonization of the island. It is possible to think this island as just a place where people arrived, stopped, and exploited the natural resources for their subsistence, but which was never colonized definitively.

4. Materials and methods

Field work was carried out by an Argentine-Swedish expedition to the island on the summer of 2005 (see Pianzola, 2006). A core was retrieved from a mire on the northeastern portion of Laguna Cascada (54°45′51.3″ S; 64°20′20.7″ W). Coring was performed with a Russian chamber corer with diameters of 5 and 7.5 cm, and a chamber length of 1 m. Overlap between the cores was at least 20 cm. All the sediments cores were packed in PVC plastic tubes and transported by ship to Sweden, where they were kept in a cooling room until sub-sampling.

Samples for diatom analysis were taken from the core every 3 cm. All samples were treated with 10% HCl, washed and treated with 30% H_2O_2, prior to heat at 80–90 °C for 2–3 h until all the organic matter were removed. Afterwards, the samples were put it in a 100 ml beaker with distilled water for 2 h and then decanted. This process was repeated until the water was transparent. Clay samples were washed repeatedly by suspending and dispersing the material in distilled water. The supernatant was discarded after 2 h. Permanent slides were mounted on Naphrax® resin. Diatom identification was made in a light microscope at 1000× magnification. A minimum of 400 valves were counted in every slide, although in some cases (sedimentation rate and/or valves preservation) this amount was not possible to be reached. Many floras were consulted for taxa identification: Patrick and Reimer (1966–1977), Krammer and Lange-Bertalot (1986, 1988, 1991a,b), Rumbrich et al. (2000), and many others papers that helped in diatom identification. All the data were plotted using Tilia and TG view (Grimm, 1991). The diatom graph shows the species occurring in more than 3% relative abundance in one sample (Fig. 3). Geochemical analysis and magnetic susceptibility results have already been published by Unkel et al. (2010). This paper will use those outcomes that help in understanding what happened in the units comprised in the Middle Holocene (see Table 1). Radiocarbon dating (see Table 2) was done at the Lund Quaternary Department Laboratory and was calibrated using the SHCal04 calibration curve (McCormac et al., 2004), published by Unkel et al. (2010).

5. Results

Diatom results for the Middle Holocene (Fig. 3) are expressed in a Tilia graph.

5.1. Zone A

5.1.1. Subzone A1: 376–360 cm (8029–7404 cal B.P.)

The subzone is characterized by the dominance of several planktonic, *Aulacoseira* species (including *A. alpigena*, *A. distans*, *A. laevissima*, *A. ambigua*, *A. subartica* and *A. tethera* Haworth) (Figs. 4–6). Those species need turbulent waters and/or high water levels to remain suspended in the water column (Köster and Pienitz, 2006). There were also present but less abundant, *Frustulia rhomboides* (Ehr.) De Toni, *Eunotia minor* (Kützing) Grunow, *Eunotia paludosa* Grunow, *Eunotia* sp. and *Pinnularia interrupta* W. Smith. Most of these taxa are acidobiontic mainly occurring on water bodies, wet and moist places (Van Dam et al., 1994).

5.1.2. Subzone A2: 360–320 cm (7404–6365 cal B.P.)

A decrease in the content of *Aulacoseira* sp. is evident, but still this genus is dominant. The assemblage also contains *E. paludosa*, *Eunotia* sp., *Stauroforma exiguiformis* (Lange-Bertalot), *Staurosirella leptostauron* (Ehrenberg) Williams and Round, *F. rhomboides*, *P. interrupta*, *Pinnularia rupestris* Hantzsch, *Pinnularia viridis* (Nitzsch) and *Pinnularia* sp. Ehrenberg (mainly at the end of the subzone). Oligotrophic–dystrophic environments are indicated by the benthic representatives of *Eunotia* and *Pinnularia*.

The constant sedimentation curve becomes stable until 345 cm, when it is sharply interrupted by an unconformity that could be an erosive discordance. Diamictic sediment of unit 14 continues at 325 cm. Some samples in unit 14 have no diatom valves.

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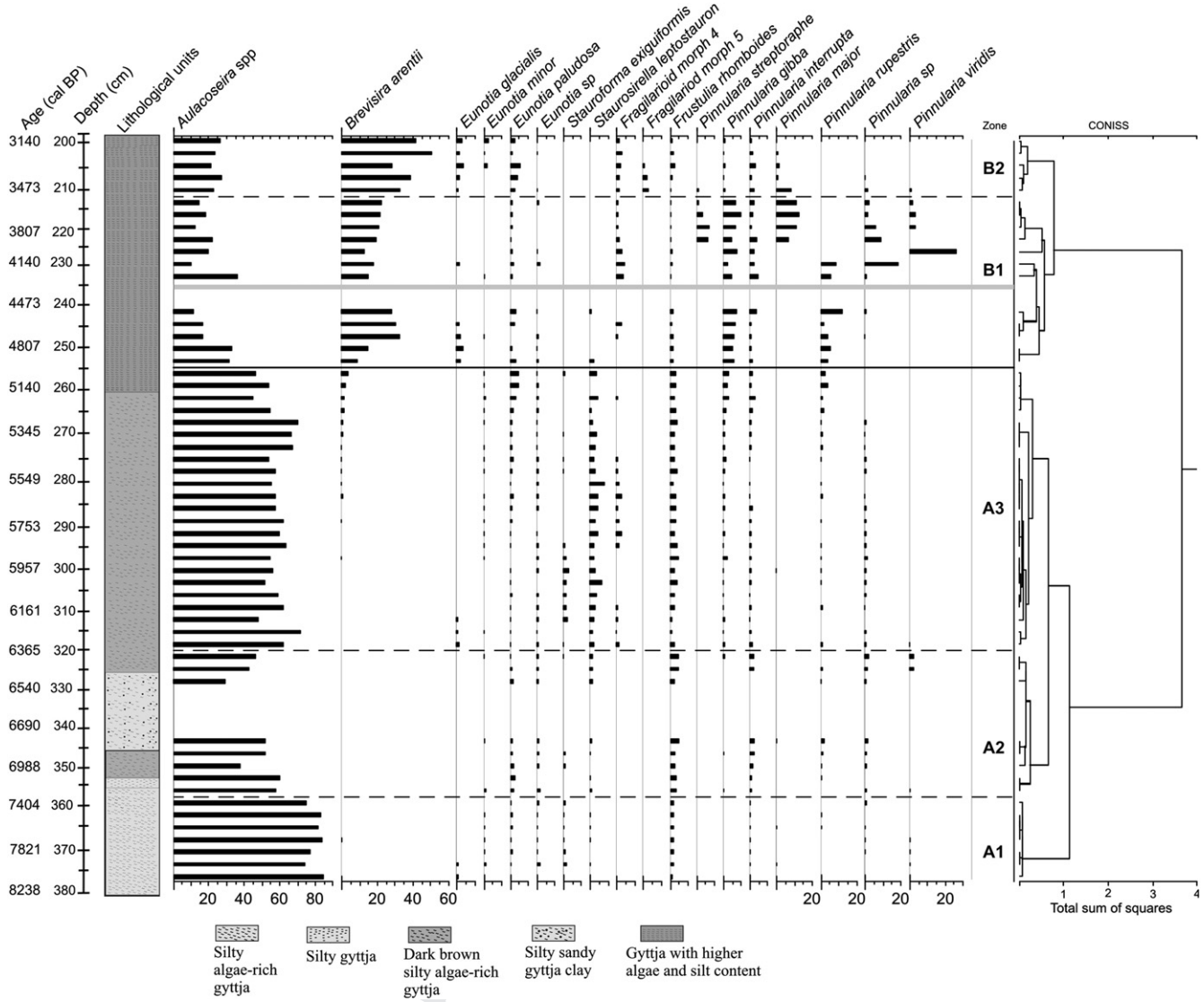

Fig. 3. Relative abundance of the main diatom species (>3%) at Laguna Cascada sediment record during the Middle Holocene. The grey line in subzone B1 represents a tephra layer, probably the Mt. Burney 2nd Eruption.

Table 1
Units and lithological description of the sections of Laguna Cascada core that correspond to the Middle Holocene. The lithostratigraphy of the core was described previously by Unkel et al. (2008, 2010).

Unit	Depth (cm)	Lithological description
16	260–161.5	Brown-dark brown gyttja. Algae-rich content between 240 and 210 cm. At 235 there is a layer of possible tephra.
15	325–260	Dark brown silty algae-rich gyttja with a 1 mm thin sand layer at 317.5 cm. At 279.5 cm a light grey 0.5 cm medium sand layer occurs followed by 4 cm of brownish-grey clayey, sandy silt gyttja ending with a thin grey layer at 275 cm.
14	345–325	Silty-sandy gyttja clay, "diamictic", with gravel clast and organic lenses.
13	352.5–345	Dark brown silty algae-rich gyttja with one light layer at 349 cm.
12	354.5–352.5	Light grayish-brown silty gyttja, which starts and ends with distintly light layers (tephras?).
11	388–354.5	Dark brown silty algae-rich gyttja, thickly laminated with more coarse detritus above 378 cm. At 360 cm a 0.5 cm light layer occurs.

5.1.3. Subzone A3: 320–255 cm (6365–4873 cal B.P.)

The content of planktonic *Aulacoseira* sp. increased up to 70%. The great abundance of these species implies higher lake levels, possibly as a result of more humid conditions. Other species also occurring in water bodies that are present in this subzone, but in modest frequency, are *S. exiguiformis*, *S. leptostauron*, circumneutral and alkaliphilus, respectively, they occur also in water bodies (Van Dam et al., 1994); *fragilarioid morph 4* (Fig. 8), from which there is

Table 2
List of radiocarbon samples and calibrated ages obtained at Laguna Cascada (CAS) core. All samples were calibrated with OxCal 4 (modified from Unkel et al., 2010).

Depth (cm)	Sample no.	Analysis no.	Sample material	^{14}C age BP	1σ error	SHCal0$_4$
189	CAS/189	LuS 6930	Gyttja	2600	50	2746–2502
235	CAS/235	LuS 6931	Gyttja	4115	50	4785–4438
281	CAS/281	LuS 6932	Gyttja	5000	50	5720–5609
324	CAS/324	LuS 6933	Gyttja	5675	50	6445–6318
346	CAS/346	LuS 6934	Gyttja	5920	50	6775–6571
387	CAS/397	LuS 6935	Gyttja	7715	60	8537–8400

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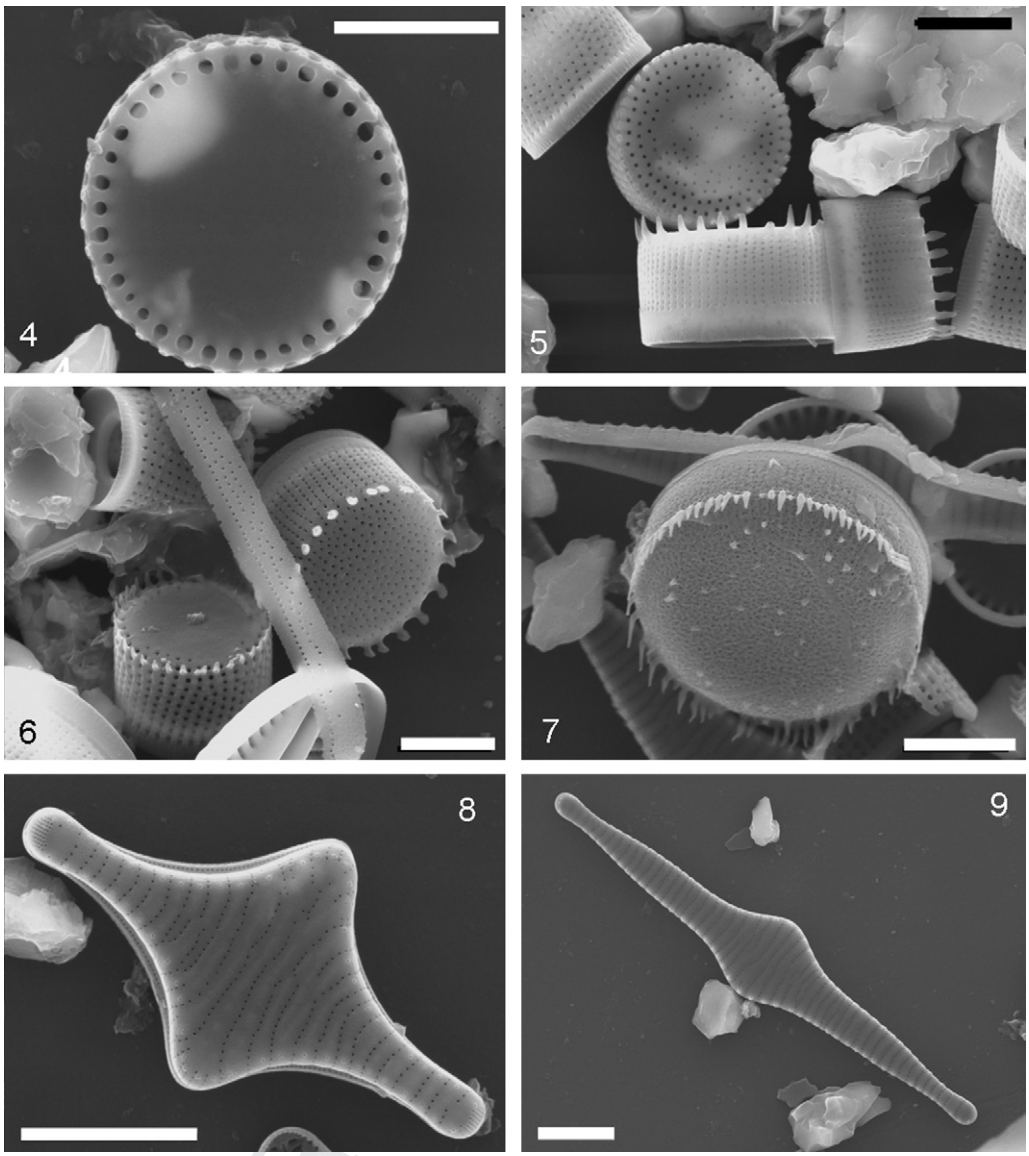

Figs. 4–9. SEM photographs.4: *Aulacoseira perglabra*, valve view; 5–6: *Aulacoseira alpigena* (5: girdle view; 6: valve view); 7: *Brevisira arentii*, valve view; 8–9: unidentified fragilarioids (8– Morph 4; 9: Morph 5). Scale bar: 5 μm.

not available ecological information, *E. paludosa*, *Eunotia* sp., *F. rhomboides*, *Pinnularia gibba* Ehr., *P. interrupta*, *P. rupestris* Hantzsch and *Pinnularia* sp. The *Pinnularia* group contains benthic species which commonly occur in acidic environments, such as damp surfaces and peat bogs (Sterken et al., 2008). At the end of the subzone, *Brevisira arentii* (Fig. 7) appears but in a rather low frequency. It is a common species in acid and dystrophic to mesotrophic lakes (Krammer and Lange-Bertalot, 1991a). Also, its presence is associated with high concentrations of dissolved organic carbon (DOC) in the water column (Köster and Pienitz, 2006).

5.2. Zone B

5.2.1. Subzone B1: 255–213 cm (4873–3573 cal B.P.)

There is a decrease of *Aulacoseira* sp. and an increase of *B. arentii*. However, the former reached high values immediately after the assumed Mt. Burney MB_2 eruption and tephra deposition at 235 cm. Others peat and damp species as *Eunotia glacialis*, *E. paludosa*, *Pinnularia streptoraphe*, *P. gibba*, *P. interrupta*, *Pinnularia major* (Kützing) Rabenhorst, *P. rupestris*, *P. viridis* (Nitzsch) Ehrenberg and *Pinnularia* sp. are present. All these species indicate more acidic conditions around the lake, a decrease in water level and development of surrounding vegetation.

5.2.2. Subzone B2: 213–200 cm (3573–3140 cal B.P.)

There is a co-dominance of *B. arentii* and *Aulacoseira* sp. The number of species associated with peat environments increases upwards and they become dominant at the end of the zone. The most abundant are *E. glacialis*, *E. minor*, *E. paludosa*, *F. rhomboides*, *P. interrupta* and *P. major*, and two fragilarioid diatoms named here "*fragilarioids morph 4* and *5*" (Figs. 8 and 9), respectively, both without any available ecological information.

5.3. Diatom interpretation and comparison with geochemical and pollen results

The large amount of *Aulacoseira* sp. at 8000 cal B.P. could indicate either windy conditions or higher water levels in the lake, or

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both. The diatom assemblages from 7000 to 6000 cal B.P. could suggest a greater range of precipitation, probably due to the southward displacement of the westerlies and the influence of the Circumpolar Antarctic Current. Lamy et al. (2002) have documented through marine sediment cores at the coast of Chile (41° S), a poleward position of the westerlies wind belt between 7700 and 4000 cal B.P. Also, between 7300 and 6300 cal B.P. the geochemical parameters (Haberzettl et al., 2007) from Laguna Potrok Aike (in southern continental Patagonia) show an overall lake level increase with distinct fluctuations, thus supporting a southern position of the westerlies.

Around 5000 cal B.P., distinct diatom assemblage changes took place suggesting a gradual development of shallower and more acid conditions. For this time, lower rate of precipitation, weaker winds and an expansion of the vegetation are interpreted. At 4000 cal B.P., the deposition of the MB_2 (Mount Burney 2nd Eruption) tephra might have had influence on the lake chemistry composition (Unkel et al., 2010). Björck et al. (1996), in the eastern Antarctic Peninsula, documented a climatic optimum, warmer and more humid between 4500 and 3300 cal B.P. The abrupt climatic warming could be explained by a more southerly position of the westerlies wind belt as suggested by Bentley et al. (2009). By 3000 cal B.P., the diatom assemblage is strongly linked to peat and swampy environments, mainly acidic places, in agreement with some of the geochemical results (Unkel et al., 2010). At the beginning of the Middle Holocene (8000 cal B.P.), there are two peaks of Br suggesting windier conditions (Unkel et al., 2010). There is also a higher level of this element at 6000 cal B.P. There is a sedimentary gravity flow due to superficial runoff in more humid moments (Unkel et al., 2010). The available values of C/N suggest a strong terrestrial component which extended throughout the whole sequence (Unkel et al., 2010). This information is coincident with the diatom record.

Pollen analyses at Bahía Franklin (Ponce, 2009; Ponce et al., 2011) show gradual vegetation changes in the area. Between 8300 and 6700 cal B.P., the assemblage was dominated by *Nothofagus antarctica*, *Empetrum*/Ericacea, Asteroidae and *Gunnera*. Ponce (2009) suggested that this could be interpreted as an open forest with communities associated to an increase in effective moisture in agreement with the results. At 6700–5500 cal B.P., there is a decrease in *Empetrum*/Ericaceae, and an increase of *N. betuloides*, *Gunnera*, Asteroideae, Caltha and *D. winteri*. This represents the transition between the Evergreen Subantarctic Forest and the Magellanic Moorland (Moore, 1983). At the end of this period, the acidophilous diatom *B. arentii* reappeared in the record. The development of the Subantarctic Close Forest, by 5500–1000 cal B.P., suggests greater effective moisture, which was probably related to lower temperatures (Ponce et al., 2011). This is coincident with the composition of the diatom assemblages in the upper part of the studied section of the core.

6. Archaeology and palaeoenvironmental scenarios in the southern tip of Tierra del Fuego

In general, according with diatom results and the available knowledge from geochemical and pollen studies, the environmental scenarios at Isla de los Estados present the following features:

1. Windier conditions, increase in precipitation rates and surface runoff between 8500 and 4500 cal B.P. A southward shift of the Southern Westerlies and the ACC during the Middle Holocene might have been additionally related to reduce seasonal insolation differences during this time span, resulting in less northward movement of the westerlies during winter (Markgraf et al., 1992). High-resolution pollen studies from a much northern latitude (41°08′ S) have recorded a cooler and wetter climate interval between 7600 and 4100 cal B.P. (Moreno, 2004).
2. Variations in the position (poleward location) of the southwestern winds (SHW) (Unkel et al., 2010).
3. Sea ice extension around the Antarctic Peninsula. During the Middle Holocene, a complex pattern of temperature is documented. Antarctic ice core data from the Ross Sea sector show a temperature maximum between 7000 and 5000 cal B.P. (Masson et al., 2000), coinciding with maximum paleotemperature and paleosalinity in the southern Peru–Chile Current (PCC, in Lamy et al., 2002). At the site of Palmer Deep in the Antarctic Peninsula, studies likewise indicate higher temperatures and decreased sea ice.
4. According to marine sediment core studies, a shift of the Antarctic Circumpolar Current to the south (ACC) would have taken place between 7800 and 5500 cal B.P. (Lamy et al., 2002). A compilation of ice core records from the Ross Sea sector shows a general decreasing temperature trend after ~7000 cal B.P. (Masson et al., 2000).

The interaction between human culture and environment has been an important topic in anthropological literature concerned with understanding human behavioral patterns and cultural change. For this reason, the comparison of the different available proxies is a good approach in order to reconstruct the palaeoenvironmental history of Isla de los Estados.

It is curious and interesting to evaluate why, during the Middle Holocene, a special time period when many environmental and landscape modifications took place around the southern end of South America (Salemme and Miotti, 2008), the offshore islands of the Fuegian Archipelago displayed a very restricted or almost absent archaeological evidence for the time considered. Was there an environmental barrier to limit the accessibility to the outer edge groups of islands as, for example, Isla de los Estados or Bayly Island (located near Cape Horn)? Why is there evidence of human activity in southern Navarino Island as early as 6120 ± 80 ^{14}C B.P. (Grandi I site, Legoupil, 1993–94) but it is absent at Isla de los Estados? Should cultural decisions be considered? The geomorphology of the island is important to evaluate its occupation. Were there optimal places to be settled? Considering the archaeological data and taking into consideration the observations made by Chapman (1987) and Horwitz (1986, 1990, 1993), it is interesting to explore the dominant environments that might have affected or limited the settlement of the human groups. Isla de los Estados has some sheltered places to settle but, considering the archaeological record, they are mainly scattered sites. Sheltered places might have been the first sites to be occupied in stable conditions, delaying effective peopling of remote areas (Orquera and Piana, 2006). Isla de los Estados may have been used as a place for random or seasonal (Ortiz-Troncoso, 1972) visits in which canoeing people might have reached the island to exploit the resources found in penguin and pinniped colonies.

The paleoenvironmental conditions inferred from the diatom analyses together with the geochemical (Unkel et al., 2010) and pollen studies (Ponce, 2009; Ponce et al., 2011) demonstrate that the Middle Holocene was a windy period, with higher precipitation rates and variable temperature. Within this context, it is interesting to consider the evaluation of Horwitz (1993) about the regional maritime pattern, between isolated islands of the Fuegian Archipelago, "Nomadic maritime hunter-gatherers would likely have exploited any potential resource available while navigating from one island to another" (Horwitz, 1993, p. 149). The strong wind drifts or the westerlies might have dominated the climatic scenario of the Middle Holocene; hence the navigation conditions would have been almost impossible. However, it has been said (Horwitz,

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1990) that weather conditions might have been well known by the prehistoric groups, and probably they based their "traveling" on a general climatic trend of particular weather situations (moon cycles, windows of good-navigable conditions?). Isla de los Estados was an attractive spot to get to, mainly because of its abundant marine resources. Seasonal expeditions were done to Isla de los Estados and the Cape Horn islands looking for certain resources as penguins and other birds. According to Fitzhugh (1997), the outer places showed a higher instability with a clear period of abandonment and re-occupation in some areas. This is most likely the kind of archaeological evidence found at the island.

Following these results, the palaeoenvironmental scenarios to reach the offshore islands were difficult and even risky. Probably, environmental carrying capacity should be considered. Was there a large population density, causing venturing to the unknown and risky places located in the outer edge zone of the Archipelago? Probably the resources around the Beagle Channel were abundant or rich enough for the main population groups during the Middle Holocene. Therefore, there was no crucial reason to go further searching for food or even some other special location for mammals, stranded whales, pinnipeds or penguins (as currently happens in Isla de los Estados).

Perhaps, after 2700 ^{14}C B.P. (the earliest human occupation found in Isla de los Estados), the environmental conditions were much better to sail and cross the rough waters of the Le Maire Strait, with a stronger seasonality in weather prediction, allowing evaluation of the trend in climatic conditions for sailing around the outer margin of Isla Grande de Tierra del Fuego. Previously, the intensity of the southern westerlies had limited the accessibility via sea-navigation mode (Fig. 1).

How can other reasons which may explain why the prehistoric groups could not settle occasionally in the island during the Middle Holocene be evaluated? Could there be a symbolic explanation or a cultural belief about not exploring the island? There is ethnographic knowledge that the selk'nam and yamana (who named it as *Chuanisin*: land of plenty) groups knew that the island was a special and abundant land with plenty of resources such as penguin and pinniped colonies (Chapman, 1987, p. 7). The main *Arctocephalus australis* colonies were located on the outer arc of islands and Isla de los Estados. Most of the adult animals concentrate on these islands during the summer. When summer ends, females and offsprings remain close by, but the geographical range of males is greater, as they go farther away, for instance to the Beagle Channel. The pinniped hunting could last with time because humans did not exploit the place of breeding located in the external part of their camp sites. The Beagle Channel, together with Cape Horn, was one of the common places for males to feed (Piana, 2010). The archaeological sites located in Isla de los Estados and Península Mitre share a higher quantity of artifacts made of bones instead of lithics, and also a more intense exploitation of penguins and marine mammals than of terrestrial fauna (Horwitz, 1990).

Overall, the palaeoenvironmental information presented here could be an explanation of the absence of archaeological evidence for the Middle Holocene in Isla de los Estados and also, the weaker cultural signal in a closer area such as Península Mitre. During the Late Holocene, the environmental conditions might have been milder, allowing seasonal displacements by canoe to the outer islands of the Archipelago but not their definitive colonization.

According to Borrero (2001), human dispersal might have been slow all along Patagonia. The expansion is the result of a normal pattern of mobility to the long extension of a large amount of generations. Colonization might be found in places where accessibility was simple, with large amount of resources and easy to exploit (considering time and energy consumption) and where settling a camp was easy.

7. Conclusions

The evaluation of the archaeological record considering the models on palaeoenvironmental reconstruction in this area is important for a better understanding of the Middle Holocene population dynamics as well as the regional peopling process. Good environmental information was obtained through studying the diatom assemblages of the Laguna Cascada core; these results were crossed with other proxies, such as pollen and geochemical analyses, to shed further light into the past ecological scenarios at Isla de los Estados. In general, the palaeoenvironments during the Middle Holocene had been developed mainly under very windy conditions, higher precipitation rates and variable temperature. Considering these data, the accessibility under navigation by canoeing people through the surrounding seas should have been difficult or even impossible. Only occasional or seasonal trips could be interpreted from the archaeological remains dated for the Late Holocene. Thus, to improve the comprehension of landscape evolution, palaeoclimate and palaeoenvironment scenarios, dominating ancient times when people challenged very harsh conditions to settle, are strongly needed.

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References

Bentley, M.J., Hodgson, D.A., Smith, J.A., Cofaigh, C.O., Domack, E.W., Larter, R.D., Roberts, S.J., Brachfeld, S., Leventer, A., Hjort, C., Hillenbrand, C.D., Evans, J., 2009. Mechanisms of Holocene palaeoenvironmental change in the Antarctic Peninsula region. The Holocene 19, 51–69.

Bettinger, R.L., 2001. From traveler to processor (regional trajectories of hunter-gatherer sedentarism in the Inyo-Mono region, California). In: Billman, B.R., Feinman, G.M. (Eds.), Stettlement Pattern (Studies in the Americas: Fifty Years Since Virú). Smithsonian Institution Press, Washington, DC, pp. 39–55.

Björck, S.S., Olsson, S., Ellis-Evans, C., Håkansson, H., Humlum, O., de Lirio, J.M., 1996. Late Holocene palaeoclimatic records from lake sediments on James Ross Island, Antarctica. Palaeogeography, Palaeoclimatology, Palaeoecology 121, 195–220.

Borrero, L.A., 2001. El poblamiento de la Patagonia, Toldos, Milodones y Volcanes. Editorial Emecé, Buenos Aires.

Chapman, A., 1987. La Isla de los Estados en la Prehistoria. Primeros datos arqueológicos. Colección Temas. Editorial. Universitaria de Buenos Aires (Eudeba), Buenos Aires.

Dearing, J.A., 2006. Climate-human-environment interactions: resolving our past. Climate of the Past 2, 187–203.

Dudley, T.R., Crow, G.E., 1983. A contribution to the flora and vegetation of Isla de los Estados (Staaten Island), Tierra del Fuego, Argentina. In: Antarctic Research Series, vol. 37. American Geophysical Union, Washington, DC, pp. 1–26.

Fitzhugh, W., 1997. Biogeographical archaeology in the eastern north American Arctic. Human Ecology 25 (3), 385–418.

Gordillo, S., Coronato, A., Rabassa, J., 2005. Quaternary molluscan faunas from the island of Tierra del Fuego after the Last Glacial Maximum. Scientia Marina 69, 337–348.

Grimm, E., 1991. Tilia software. Illinois State Museum. Research & Collection Center, Springfield, Illinois.

Haberzettl, T., Corbella, H., Fey, M., Janssen, S., Lücke, A., Mayr, C., Ohlendorf, C., Schäbitz, F., Schleser, G.H., Wille, M., Wulf, S., Zolitschka, B., 2007. Lateglacial and Holocene wet-dry cycles in southern Patagonia: chronology, sedimentology and geochemistry of a lacustrine record from Laguna Potrok Aike, Argentina. The Holocene 17, 297–310.

Horwitz, V.D., 1985. Informe arqueológico de la campaña a las Bahías Colnett, Basill Hall y Puerto Presidente Roca. On file at the Museo Territorial, Ushuaia, unpublished. Q2

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Horwitz, V.D., 1986. Final report, Isla de los Estados, Bahía Crossley, Argentina. On files at the Museo Territorial, Ushuaia, unpublished.
Horwitz, V.D., 1990. Maritime settlements patterns in southeastern Tierra del Fuego (Argentina), Unpublished Ph.D. Dissertation, University of Kentucky, Lexington, Kentucky, U.S.A.
Horwitz, V.D., 1993. Maritime settlements patterns: the case from Isla de los Estados (Staaten Island). In: Lanata, J.L. (Ed.), Explotación de Recursos Faunísticos en sistemas Adaptativos Americanos. Arqueología Contemporánea, vol. 4, pp. 149–161.
Horwitz, V., Scheinsohn, V., 1996. Los instrumentos óseos del sitio Bahía Crossley I (Isla de los Estados). Comparación con otros conjuntos de la Isla Grande de Tierra del Fuego. In: Gómez-Otero, J. (Ed.), Arqueología. Sólo Patagonia CENPAT-CONICET, Puerto Madryn, Argentina, pp. 359–368.
Krammer, K., Lange-Bertalot, H., 1986. Bacillariophyceae. 1. Teil: Navicullariaceae. In: Ettl, H., Gerloff, J., Heyning, H., Mollenhauer, D. (Eds.), Süssewasser-flora von Mitteleuropa, vol. 2(1). Gustav Fisher Verlag, Stuttgart, New York, p. 876.
Krammer, K., Lange- Bertalot, H., 1988. Bacillariophyceae. 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. In: Ettl, H., Gerloff, J., Heyning, H., Mollenhauer, D. (Eds.), Süssewasser-flora von Mitteleuropa, vol. 2(2). Gustav Fisher Verlag, Stuttgart, New York, p. 596.
Krammer, K., Lange-Bertalot, H., 1991a. Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. In: Ettl, H., Gerloff, J., Heyning, H., Mollenhauer, D. (Eds.), Süssewasser-flora von Mitteleuropa, vol. 2(3). Gustav Fisher Verlag Stuggart, New York, p. 576.
Krammer, K., Lange-Bertalot, H., 1991b. Bacillariophyceae. 4. Teil: Achnanthaceae, Kritische Ergänzungen zu Navicula (Lineolatae) un Gomphonema. In: Ettl, H., Gerloff, J., Heyning, H., Mollenhauer, D. (Eds.), Süssewasser-flora von Mitteleuropa, vol. 2(4). Gustav Fisher Verlag, Stuttgart, New York, p. 437.
Köster, D., Pienitz, R., 2006. Late-Holocene environmental history of two New England ponds: natural dynamics versus human impacts. The Holocene 16, 519–532.
Kühnemann, O., 1976. Observaciones ecológicas sobre la vegetación marina y terrestre de la Isla de los Estados (Tierra del Fuego, Argentina). Ecosur 3 (6), 121–248.
Lamy, F., Rühlemann, C., Hebbeln, D., Wefer, G., 2002. High- and low-latitude climate control on the position of the southern Peru–Chile current during the Holocene. Paleoceanography 17 (2), 1028.
Legoupil, D., 1988. Últimas consideraciones sobre las dataciones del sitio de isla Englefield (seno de Otway). Anales del Instituto de la Patagonia 18, 95–98.
Legoupil, D., 1993–94. El archipiélago del Cabo de Hornos y la costa sur de la Isla Navarino: poblamiento y los modelos económicos. Anales del Instituto de la Patagonia 22, 101–121.
Legoupil, D., 1997. Bahía Colorada Île Englefield. Recherche sur les Civilisations, Paris.
Legoupil, D., Fontugne, M., 1997. El poblamiento marítimo de los archipiélagos de Patagonia: núcleos antiguos y dispersión reciente. Anales del Instituto de la Patagonia 25, 75–87.
Liljesthröm, M., Emslie, S.D., Frierson, D., Schiavini, A., 2008. Avian predation at a southern rockhopper penguin colony on Staten Island, Argentina. Polar Biology 31 (4), 465–474.
McCormac, F.G., Hogg, A.G., Blackwell, P.G., Buck, C.E., Higham, T.F.G., Reimer, P.J., 2004. SHCal04 southern hemisphere calibration, 0–11.0 cal B.P. Radiocarbon 46, 1087–1092.
Masson, V., Vimeux, F., Jouzel, J., Morgan, V., Delmotte, M., Ciais, P., Hammer, C., Johnsen, S., Lipenkov, V. Ya, Mosley-Thompson, E., Petit, J.-R., Steig, E.J., Stievenard, M., Vaikmae, R., 2000. Holocene climate variability in Antarctica based on 11 ice-core isotopic records. Quaternary Research 54, 348–358.
Markgraf, V., Dodson, J.R., Kershaw, P.A., McGlone, M.S., Nicholls, N., 1992. Evolution of late Pleistocene and Holocene climates in the circum-South Pacific land areas. Climate. Dynamics 6, 193–211.
Moreno, P.I., 2004. Millennial-scale climate variability in northwest Patagonia over the last 15,000 yr. Journal of Quaternary Science 19 (1), 35–47.
Moore, M.D., 1983. Flora of Tierra del Fuego. Nelson, Oswestry, p. 396.
Möller, P., Hjort, C., Björck, S., Rabassa, J., Ponce, J.F., 2010. Late Quaternary glaciation history of Isla de los Estados, southeasternmost South America. Quaternary Research 73 (3), 521–534.
Ocampo, C., Rivas, P., 2000. Nuevos fechados ^{14}C de la costa Norte de la Isla Navarino, costa sur del Canal Beagle, Provincia Antártica chilena, Región de Magallanes. Anales del Instituto de la Patagonia 28, 197–214.
Orquera, L.A., 2005. Mid-Holocene littoral adaptation at the southern end of south America. Quaternary International 132, 107–115.
Orquera, L.A., Piana, E.L., 1988. Human littoral adaptation in the Beagle Channel region: maximum possible age. Quaternary of South America and Antarctic Peninsula 5, 133–165.
Orquera, L.A., Piana, E.L., 1999. Arqueología de la región del Canal Beagle (Tierra del Fuego, República Argentina). Sociedad Argentina de Antropología, Buenos Aires.
Orquera, L.A., Piana, E.L., 2005. La adaptación al litoral sudamericano sudoccidental: qué es y quiénes, cuándo y dónde se adaptaron. Relaciones de la Sociedad Argentina de Antropología XXX, 11–32.
Orquera, L.A., Piana, E.L., 2006. El poblamiento inicial del Área Litoral Sudamericana Sudoccidental. Magallania 34 (2), 21–37.
Orquera, L.A., Piana, E.L., 2009. Sea nomads of the Beagle Channel in southernmost south America: over six thousand years of coastal adaptation and stability. Journal of Island and Coastal Archaeology 4, 61–81.
Ortiz-Troncoso, O.R., 1972. Nota sobre un yacimiento arqueológico en el archipiélago del Cabo de Hornos. Anales del Instituto de la Patagonia 3 (1–2), 83–85.
Ortiz-Troncoso, O.R., 1975. Los yacimientos de Punta Santa Ana y Bahía Buena (Patagonia Austral). Excavaciones y fechados radiocarbónicos. Anales del Instituto de la Patagonia 7, 93–122.
Patrick, R., Reimer, C.W., 1966–1977. The Diatoms of the United States Exclusive of Alaska and Hawaii, vol. 1–2(13). The Academy of Natural Sciences of Philadelphia, U.S.A. 688.
Payró, R., 1898. La Australia Argentina. Excursión periodística a las costas patagónicas, Tierra del Fuego e Isla de los Estados, Buenos Aires.
Piana, E.L., Vazquez, M., Rua, N., 2004. Mischiuen I primeros resultados de una excavación de rescate en la costa norte del canal Beagle. In: Civalero, M.T., Fernández, P.M., Guráieb, A.G. (Eds.), Contra viento y marea. Arqueología de la Patagonia. Instituto Nacional de Antropología y Pensamiento Latinoamericano, Buenos Aires, pp. 815–832.
Piana, E.L., 2010. Our past and present beliefs on the History of the sea nomads of Tierra del Fuego. Concepts from the 17th to the 21th centuries. In: Del Acebo Ibáñez, E., Gunnlaugsson, H. (Eds.), La circumpolaridad como fenómeno sociocultural. Pasado, presente y futuro. Fac. de Cs. Económicas. Universidad de Buenos Aires, pp. 217–252.
Pianzola, E.L., 2006. Viaje a Isla de los Estados. Editorial Cuatro Vientos, Buenos Aires, p. 142.
Ponce, J.F., 2009. Palinología y geomorfología del Cenozoico tardío de la Isla de los Estados, Universidad del Sur. Ph.D. Thesis Universidad del Sur, Bahía Blanca, Argentina.
Ponce, J.F., Rabassa, J., Martínez, O., 2009. Morfometría y génesis de los fiordos de la Isla de los Estados. Revista de la Asociación Geológica Argentina 65 (4), 638–647.
Ponce, J.F., Borromei, A., Rabassa, J., Martínez, O., 2011. Late Quaternary environmental change in western Isla de los Estados (54°5 S; 64° W), Fuegian Archipelago. Quaternary International 233, 89–100.
Rabassa, J., Heusser, C.J., Stuckenrath, R., 1986. New data on Holocene sea transgression in the Beagle Channel (Tierra del Fuego). Quaternary of South America and Antarctic Peninsula 4, 291–309.
Rumbrich, U., Lange-Bertalot, H., Rumbrich, M., 2000. Diatomeen der Anden. Iconographia Diatomologica 9, 1–672.
Salemme, M., Miotti, L., 2008. Archaeological hunter-gatherer landscapes since the latest Pleistocene in Fuego-Patagonia. In: Rabassa, J. (Ed.), The Late Cenozoic of Patagonia and Tierra del Fuego. Developments in Quaternary Science, vol. 11. Elsevier, pp. 437–483.
Sandweiss, D., Maasch, K.A., Anderson, D.G., 1999. Transitions in the Mid-Holocene. Science 283, 499–500.
Sterken, M., Verleyen, E., Sabbe, K., Terryn, G., Charlet, F., Bertrand, S., Boës, X., Fagel, N., De Batist, M., Vyverman, W., 2008. Late Quaternary climatic changes in southern Chile, as recorded in a diatom sequence of Lago Peyehue (40°40′S). Journal of Paleolimnolog 39, 219–235.
Schiavini, A., 2000. Staaten Island, Tierra del Fuego: the largest breeding ground for southern Rockhopper Penguins? Waterbirds 23 (2), 286–291.
Tuhkanen, S., 1992. The climate of Tierra del Fuego from a vegetation geographical point of view and its ecoclimatic counterparts elsewhere. Acta Botanica Fennica 145 Helsinski.
Unkel, I., Björck, S., Wolhfarth, B., 2008. Deglacial environmental changes on Isla de los Estados (54.41°S), southeastern Tierra del Fuego. Quaternary Science Reviews 27, 1541–1554.
Unkel, I., Fernández, M., Björck, S., Ljung, K., Wohlfarth, B., 2010. Records of environmental changes during the Holocene from Isla de los Estados (54.4°S), southeastern Tierra del Fuego. Global and Planetary Change 74, 99–113.
Van Dam, H., Meriens, A., Sinkeldam, J., 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Aquatic Ecology 28, 117–133.
Vázquez, M., Zangrando, F., Tessone, A., Ceraso, A., Sosa, L., 2007. Arqueología de Bahía Valentín (Península Mitre, Tierra del Fuego): nuevos resultados y perspectivas. In: Morello, F., Martinic, M., Prieto, A., Bahamonde, G. (Eds.), Arqueología de Fuego-Patagonia. Levantando piedras, desenterrando huesos…y develando arcanos. CESQUA, Punta Arenas, pp. 755–766.
Vidal, H., 1988. Bahía Valentín: 6000 años de ocupación humanas en el oriente fueguino. IX National Congress of Argentinian Archaeology, Buenos Aires, p. 77.
Zangrando, F.A., 2009. Historia evolutiva y subsistencia de cazadores-recolectores marítimos de Tierra del Fuego. Sociedad Argentina de Antropología, Buenos Aires.
Zangrando, F., Tessone, A., Vázquez, M., 2009. El uso de espacios marginales en el archipiélago fueguino: implicancias de la evidencia arqueológica de Bahía Valentín. In: Salemme, M., Santiago, F., Alvarez, M., Piana, E., Vazquez, M., Mansur, M.E. (Eds.), Arqueología de la Patagonia, una mirada desde el último confín. Editorial Utopías, Ushuaia, pp. 47–62.

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