



Late Quaternary environmental changes in southernmost South America reflected in marine calcareous macro-and-microfossils



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ABSTRACT

Late Quaternary environmental changes, especially sea-level fluctuations and glacial advances and retreats, affected the distribution of the benthic marine fauna which inhabited the Beagle Channel in southernmost South America. To evaluate these changes, calcareous macro-and-microfossils obtained from Holocene marine sediments along a sector of the western side of the Beagle Channel have been used for a multi-proxy approach. In total, 119 species were recovered: 65 mollusks (24 bivalves, 35 gastropods and 6 chitons), 33 foraminifera and 21 ostracods. Other preserved calcareous groups, which appeared in minor proportions, were brachiopods and cirripeds. The calcareous fossil assemblages from the early Holocene represent an ecosystem transition which started with vacant niches first occupied by opportunistic species, and/or eurytopic taxa. These were then replaced by more diverse fauna assemblages, associated with the proliferation of habitats which occurred under truly marine conditions during the Mid Holocene. When Holocene calcareous fauna is compared with its Pleistocene counterparts from the same region, some differences in the proportion of taxonomic groups and taxa composition are noted. These partly follow the heterogeneity of habitats in the Beagle Channel and water masses of different origin which have either greater or less influence throughout the Late Quaternary, but they can also be interpreted in association with environmental changes after the Last Glacial Maximum. In conclusion, the data provide insights into both spatial and temporal changes, and show evidence of a gradual transformation from a brackish to a marine environment caused by the Holocene sea transgression. It also documents Late Quaternary faunistic changes associated with topographic and oceanographic local conditions in this microbasin.

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1. Introduction

During the Late Quaternary, the Beagle Channel, located in Tierra del Fuego, in southernmost South America, suffered significant changes. During the last glaciation (Marine Isotope Stages – MIS-4 to 2) this depression was fully covered and filled by the Beagle Glacier, which emerged from the Cordillera Darwin mountain ice sheet. At the Last Glacial Maximum (LGM; approximately 20–18 ka BP, MIS 2; Rabassa, 2008), global sea level was located

between –120 and –140 m below present sea level. Taking into account that during the LGM the eastern boundary of the Patagonian continental area extended approximately 450 km farther east from its present location (Ponce et al., 2011), it appears that during this period the Isla Grande de Tierra del Fuego, Cape Horn and the Wollaston Archipelago were connected to South America, when the coastline was located approximately 140 km east and 240 km south. This stage lasted for a long period, at least up to the end of the Pleistocene, when the surrounding oceanic waters gradually flooded the present Beagle Channel.

In addition to glaciations, neotectonics also played a role in the development of local conditions. The Beagle Channel is located within a tectonic valley, and uplift is related to the motion between the South American, Antarctic and Scotia plates

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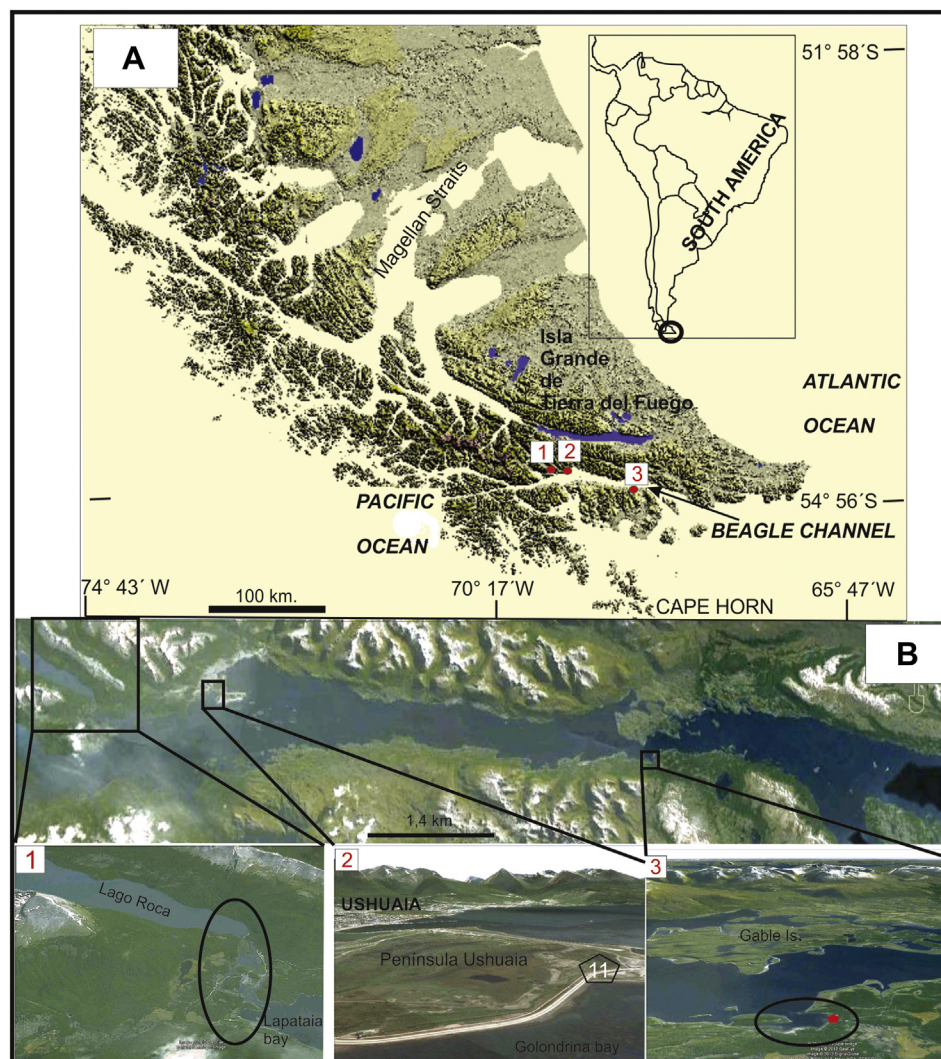


Fig. 1. Location map of the Beagle Channel region, southernmost South America. A: Tierra del Fuego Island and sampling sites location along the Beagle Channel; 1: Lago Roca – Lapataia area; 2: Ushuaia Peninsula (site 11); 3: Corrales Viejos area (sampled site in red). B: Beagle Channel and detailed 3-D views of the sampling sites (images from Google Earth). See the large-scale map for more detailed Beagle Channel views. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Menichetti et al., 2008). There is also evidence that the Beagle Channel coastline is under differential rates of tectonic uplift, which diminishes eastwards (Rabassa et al., 2004, 2009; Gordillo et al., 2010), resulting in a dephasing between the global eustatic curve and the sea level in this region (Rabassa et al., 2009). These changes must have affected the distribution of the benthic marine fauna which inhabited the region during the Late Quaternary.

The aim of this paper is to assess whether micro-and-macro calcareous fossil assemblages reflect the main paleoenvironmental changes from the beginning of the Holocene. To do this, depositional paleoenvironments of different ages during the Holocene were characterized using mollusks, ostracods and foraminifera. Shelly marine mollusks occupy a great range of ecological niches from intertidal to deeper waters, and thus adopt different modes of life; ostracods colonize most aquatic environments, encompassing a wide range of salinity and temperature conditions, including ephemeral lakes and ponds; meanwhile, foraminifera are invaluable tools in Quaternary stratigraphic, paleoceanographic and paleoclimatic reconstruction (Lowe and Walker, 1997). In this case, a multi-proxy approach will provide

stronger evidence than a single-proxy alone. Previous studies in the area which focused on environmental changes after deglaciation (Borromei et al., 1997; Candell et al., 2009; Rabassa et al., 2009) used vegetation and pollen in conjunction with mollusk shells, and were thus able to show a much more powerful picture of environmental interpretation.

In addition, this study compared the macro-and-micro-calcareous fauna over the Pleistocene–Holocene, using data previously obtained for the Beagle Channel (Gordillo et al., 2010) to help in the interpretation of environmental changes in this area prior to the Last Glacial Maximum.

2. Regional setting

The Beagle Channel (55°S; Fig. 1A, B) is a glacial trough carved out by ice, meltwater streams and marine transgression in several periods during the Quaternary. It develops along a dominant W–E regional fault system (Coronato and Rabassa, 2011) between the Isla Grande de Tierra del Fuego (northward) and Hoste and Navarino islands (southward), as part of an Upper Paleozoic–Cretaceous, low grade metamorphic rock environment. It extends almost

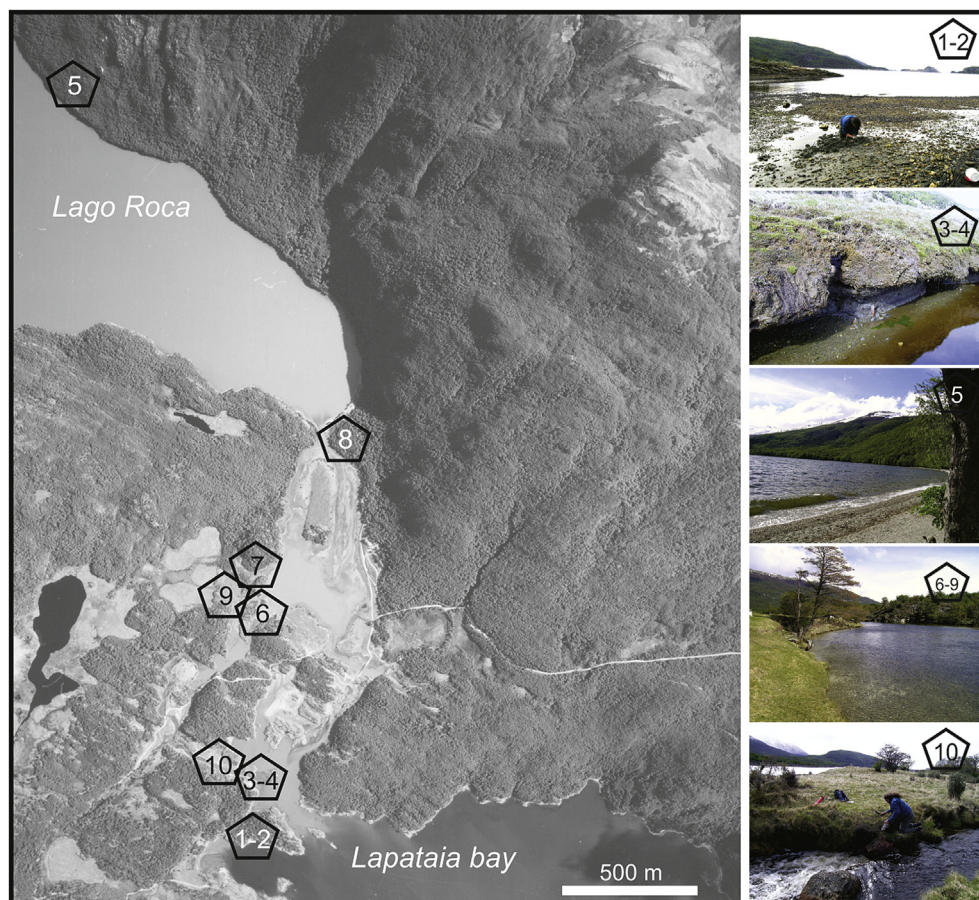


Fig. 2. Lago Roca–Lapataia bay sampling sites. 1–2: Arroyo Baliza; 3–4 Aserradero; 5: Lago Roca; 6–9: Cormoranes Archipelago; 10: Los Castores.

200 km, connecting the Pacific and Atlantic waters further north of the Antarctic Circumpolar Current and the Oceanic Convergence. This landscape feature is the longest of the Fuegian Archipelago channels.

During the Last Glacial Maximum (20–25 cal. ka BP) a paleo-glacial discharge, fed by the Darwin Cordillera mountain ice sheet (69°34'W) and several tributary alpine glaciers, flowed as far as the Moat area (66°42'W), where terminal moraines from this period developed (Rabassa et al., 1990a). The easternmost part of the trough was free of ice in around 14.7 ^{14}C ka BP (Heusser and Rabassa, 1987; Rabassa et al., 1990b), and cold steppe and peat bogs started to form in the Harberton area (67°23'W, Heusser, 1990). Undated recessional latero-frontal moraines are located westwards, at Punta Segunda (67°58'W). These are considered to be the result of an ice stabilization phase during a later Pleistocene cold period (ca. 16–14 ka BP; Coronato et al., 2004). No evidence of receding moraines exists along the Beagle coast west of the city of Ushuaia (68°20'W); instead, erosional glacial features are abundant.

Radiocarbon ages of basal peat located in the Ushuaia Peninsula and Lapataia Bay (68°34'W) show that the ice would have disappeared entirely in this part of the trough in ca. 10 ka BP. Subantarctic open forest then started to grow, following the general Holocene climate warming. Lakes, shallow ponds and several melt-water streams developed along the deglaciated valley (Gordillo et al., 1993; Isla et al., 1999). Glacioeustasy and local tectonics forced marine waters to fill the trough during the Early Holocene, probably from the south (along the Murray Channel, 68°23'W) and

from the east, once the shallow, narrow McKinley channel (67°29'W) was flooded (Bujalesky, 2007). The marine localities 1 to 10 studied here (Fig. 2) are found within a glacially eroded valley landscape which was temporarily flooded by the sea, whereas locality 11 (Fig. 1B) corresponds to non-functional marine beaches attached to sub-glacial moraines which form the Ushuaia Peninsula.

The post-glacial marine transgression is represented by several discontinuous raised terraces along the northern Beagle Channel coast, informally called the Beagle Formation (Gordillo, 1993). Low-energy marine and estuarine environments have also been recognized in the study area (Rabassa et al., 2009).

According to Bujalesky et al. (2004), Holocene littoral deposits and landforms are distributed along the northern coast of the Beagle Channel, and are controlled by three major tectonic blocks, each bordered by faults. These blocks are named as A, B and C from west to east. The westernmost block (sector A), where most of the studied localities (1–10) are located, has marine deposits which developed up to 8 m above the present sea level (m a.s.l.). Subtidal low energy deposits which yielded Early Holocene ages (see Table 1 for ^{14}C and calibrated ages for each locality) are located between 0.5 and 3 m a.s.l., while Mid Holocene deposits are distributed between 1 and 8 m a.s.l.; Late Holocene deposits are located at 2–3 m a.s.l. Recent findings at Arroyo Baliza (locality 1 in Fig. 2) provide evidence of a recessional phase which occurred during the Late Holocene, although the faunal evidence is found –1.50 m below present sea level (Rabassa et al., 2009).

Table 1

Localities studied and chronological control performed by different authors. See sampling sites in Fig. 1 (site 11) and Fig. 2 (sites 1–10).

Samples	Site, locality	Radiocarbon age (laboratory number)	Mean corrected age (min:max values)	Source
1, 2	Baliza, Lapataia Bay	2844 ± 34 (AA74046) ^a	2298 (2145:2451)	Rabassa et al. 2009
3	Aserradero II, Lapataia Bay	8167 ± 43 (AA74048) ^a	8421 (8300:8541)	Rabassa et al. 2009
4	Aserradero I, Lapataia Bay	8094 ± 43 (AA74074) ^a	8319 (8187:8451)	Rabassa et al. 2009
5	Lago Roca	7518 ± 58 (NZ-7730)	7769 (7622:7915)	Gordillo et al., 1993
6, 7, 8, 9	Cormoranes Archipelago	4425 ± 55 (SI-6735)	4286 (4092:4480)	Rabassa et al., 1986
10	Arroyo Los Castores, Lapataia Bay	5800 ± 65 (SI-6739)	5981 (5787:6177)	Rabassa et al., 1986
11	Ba. Golondrina, Peninsula Ushuaia	6276 ± 41 (AA 62801) ^a	6482 (6337:6626)	Gordillo et al., 2008

AA: NSF-Arizona AMS Laboratory (University of Arizona); NZ: DSIR, Institute of Nuclear Sciences, New Zealand; SI: Smithsonian Environmental Research Center (USA).

^a AMS analysis.

The area where most of the studied sites are located (i.e., sites 1–10) was interpreted as a paleofjord by Gordillo et al. (1993), who described the Holocene marine transgression–recession history from Lapataia Bay to the meltwater-filled Lago Roca, located 7 km inland. Site 11 is located in the middle faulted block (sector B, after Bujalesky et al., 2004), which comprises the longest portion of coast and has the widest record of marine deposits which correspond to high-energy marine environments and varied Mid to Late Holocene ages.

Rabassa et al. (2009) calculated a 2–2.5 mm/y continental uprising rate during the last 9 ka B.P., based on the elevation/age relationship of marine deposits, which is a very high rate compared with the planetary eustatic rising curve proposed by Fleming et al. (1998). This suggested that there was a continuous global sea level rise from –24 to –3 m a.s.l. (0.0084 m/y) during the Early Holocene, whereas marine deposits from that period were found in this region at higher positions, between 0.50 and 1.5 m a.s.l.

These locally high rising rates could indicate a strong influence of neotectonics within the faulted landscape of the active Scotia Plate on which it developed. However, it is possible that glacio-isostatic rebound could have forced high rising rates during the first millennium of the Holocene in this region. More detailed studies are needed to understand how the combined or single effect of both processes forced early Holocene continental rise along the Beagle Channel.

Pleistocene marine raised beaches along the Beagle Channel have not been well preserved due to the intense erosive effect of the LGM (Rabassa et al., 2000). However, remnants of a Sangamon marine terrace, rich in fossils and located in Navarino island, on the southern coast of the Beagle Channel (see Rabassa et al., 2008; Gordillo et al., 2010), indicates that seawater flooded this glacial environment at least once before the present interglacial.

3. Paleontological background

3.1. Mollusks

An early mention of southern South American fossil mollusks was given by Charles Darwin in 1833 during his visit to the region on board the *HMS Beagle*. However, the first report of Quaternary fossil mollusks from Tierra del Fuego was made by R. Hägg (in Halle, 1910), who provided a short list of taxa collected from Isla Gable, in the Beagle Channel. Later on, Feruglio (1950) listed taxa from Río Grande, on the Atlantic coast. Other mentions of fossil mollusks from the Beagle Channel appeared in Porter et al. (1984) and Rabassa et al. (1986).

Later, several studies of Quaternary paleoenvironments from Tierra del Fuego included information on species composition (e.g. Gordillo et al., 1992, 2005; Gordillo, 1993; Rabassa et al., 2009; Gordillo et al., 2010, among others), and a few other papers focused

on taxonomy (Gordillo and Schwabe, 2009; Zelaya and Gordillo, 2011; Gordillo and Nielsen, in press).

3.2. Foraminifera and ostracods

The study of foraminifera and ostracod fauna along the Patagonian coast and the Malvinas–Falkland Islands started in the early 19th century with an investigation by d'Orbigny (1839). During the oceanographic voyage of the *H.M.S. Challenger* (1873–1887), research into foraminifera and ostracods was carried out by the Brady brothers; G. S. Brady (1880) analyzed the ostracods, while H. B. Brady (1884) studied the foraminifera. This led to the description of several new species from the Sub-Antarctic region (Cusminsky and Whatley, 2008).

Müller (1908) and Skogsberg (1928) studied the ostracods in the southern south Atlantic and Sub-Antarctic regions, and identified many new species in this area. The ostracod analysis continued through a series of studies of the beaches and continental shelf of South America, from the Antarctic region to the Río de la Plata area (Whatley and Mokuilevsky, 1975; Whatley et al., 1987, 1988, 1995, 1996a,b, 1997a,b, 1998; McKenzie et al., 1995; Hartmann, 1997; Wood et al., 1999).

Herb (1971) and Boltovskoy (1976) described foraminifera from the Drake Passage. The foraminifera from the Straits of Magellan were studied by Zapata and Alarcón (1988), Hromic and Águila (1993), Hromic (1996, 1999, 2002, 2009) and Hromic et al. (2006). Cusminsky (1992) described the distribution of foraminifera from the Burdwood Bank, in the South Atlantic Ocean. Hromic and Zúñiga-Rival (2003, 2005), and Figueroa et al. (2005) determined the association present in southern Chile. The foraminifera from Tierra del Fuego were analyzed by Boltovskoy and Watanabe (1980), Boltovskoy et al. (1980), Zúñiga-Rival (2006), Cusminsky and Whatley (2008) and Gordillo et al. (2010).

4. Material and methods

4.1. Sites

Eleven samples were collected in order to analyze the presence of calcareous fauna in this area (Figs. 1 and 2). Ten samples (Fig. 1) were taken from sites located within the Tierra del Fuego National Park (Lapataia Bay, Lago Roca and Cormoranes Archipelago), and one sample was obtained from the Ushuaia Peninsula, further east (Fig. 2). The macrofauna of mollusks from this last location was described by Gordillo et al. (2008), but not the microfauna. Unfortunately, this site was later destroyed during road construction. In this study, the Holocene and Pleistocene fauna were compared using fauna recovered from the Corrales Viejos site, on Navarino island (Fig. 1-1; see taxa in Gordillo et al., 2010; Gordillo and Nielsen, in press).

4.2. Sampling and data treatment

For the analysis of microfossils, samples were washed with tap water through a 63- μm -sieve screen (Tyler Screen System N° 230). Five grams of dry sediment were chosen for the identification of ostracods and foraminifera. The foraminifera fauna was identified by genera according to Loeblich and Tappan (1988, 1992), and by specific level using Boltovskoy (1954a,b), Boltovskoy et al. (1980), Kahn and Watanabe (1980), Cusuminsky (1992), Hromic (1996, 2002), Hromic and Águila (1993), Figueroa et al. (2005) and Hromic et al. (2006), among others. The generic level of the ostracods was determined using Moore and Pitrat (1961) and van Morkhoven (1963). The species level was identified using Whatley and Mokuilevsky (1975), Whatley et al. (1987, 1988, 1995, 1996a,b, 1997a,b, 1998) and Whatley and Cusuminsky (2002).

In the case of mollusks, large specimens were separated from the sediment matrix (0.05 m³) in the field. The smaller specimens (<10 mm) were sorted in the laboratory from a bulk sediment subsample, under stereoscopic microscopy. Identification and taxonomic position of mollusk taxa is based on the work of several authors, including Ramorino (1968), Dell (1971, 1990), Ponder and Worsfold (1994), Linse (1997, 1999, 2002), Reid and Osorio (2000), Zelaya and Ituarte (2004), Cárdenas et al. (2008), Gordillo and Schwabe (2009) and Zelaya and Gordillo (2011), among others.

The number of specimens (A) was quantified for each sample. In order to document diversity, the species richness (S) was also determined for mollusks, foraminifera and ostracods. The Shannon–Weaver index (H) was also calculated for foraminifera and mollusks.

To compare faunal variations on a longer time scale (i.e. Holocene versus Pleistocene) calcareous fauna was sorted by age. Although species richness was considered, in order to capture higher level diversity (i.e. families) efficiently, a diversity index was calculated, taking into account the number of species as well the number of families. A DSF index (diversity of species per family) measures the richness of species within families and was performed using the PAST (Hammer et al., 2005). A diversity profile which uses Renyi entropy (Tóthmérész, 1995) was also generated to graphically compare the diversity index collected from the Beagle Channel over time.

4.3. Chronology

Chronology of the sites is based on the published results of radiocarbon dating of mollusk shells carried out in different laboratories. These were then calibrated using the Radiocarbon Calibration Program (Stuiver and Reimer, 1993). To accommodate local regional effects, a marine calibration dataset (Reimer and Reimer, 2000), which incorporates a time-dependent global ocean reservoir correction of about 400 years and a difference ΔR of 221 ± 40 in reservoir age, was used in conjunction with this program for calibrating these samples. Radiocarbon ages and calibrated values are summarized in Table 1.

5. Results

5.1. Abundance and taxa composition

A total of 33 species of foraminifera were identified from six (5, 6, 7, 8, 10 and 11) of the 11 samples examined; two of them correspond to nomenclature aperta. These species were distributed among 17 genera and included individuals belonging to Rotaliina (99%), Lagenina (0.6%) and Miliolina (0.4%). Taxonomic composition is listed in Table A.1.

Twenty-one species of ostracods were recognized in four of 11 samples (6, 7, 8 and 11). These are made up of 18 genera belonging to one superfamily and 8 families. Their abundance in all samples is very low, while diversity is quite high, especially in samples 6, 7 and 8. These are listed in Table A.2.

A total of 65 mollusks belonging to 3 classes were identified: bivalves (24 species), gastropods (35 species) and chitons (6 species). These are listed in Table A.3. Other preserved calcareous groups appearing in minor proportions are brachiopods and cirripeds.

Fig. 3 shows the distribution of total abundance and diversity in the different samples and localities. The distribution of the main species per group, separately per localities, is plotted in Figs. 4–6.

5.2. Variations in faunal composition from the Early to the Late Holocene

5.2.1. ca. 8500–8300 BP

In samples 3 and 4 (Aserradero Lapataia LP-3 and LP-4), the Early Holocene mollusk assemblages are characterized by eurytopic taxa able to tolerate the sharp salinity gradients within this area and large fluctuations of suspended particulate matter caused by the action of tides. This pioneer group is formed of two plastic taxa (*Mulinia edulis* and *Mytilus chilensis*) recovered in the oldest sediments, plus a few other species (*Aulacomya atra*, *Yoldia woodwardi*, *Pachysiphonaria lessoni*). *M. chilensis* lives bysally attached to hard bottoms, forming clusters associated with other species (e.g. *A. atra*). Other epifaunal elements are the pulmonate gastropods (e.g. *P. lessoni*). In contrast, *M. edulis* and *Y. woodwardi* are infaunal burrower elements, thus suggesting areas with soft substrates suitable for burrower clams that alternate with the epifauna.

Foraminifera and ostracods were not found in these sediments. However, given the poor preservation of mollusks, it is possible that microfossils were not preserved and that their absence could be due to the acidity of this environment (taphonomic reasons).

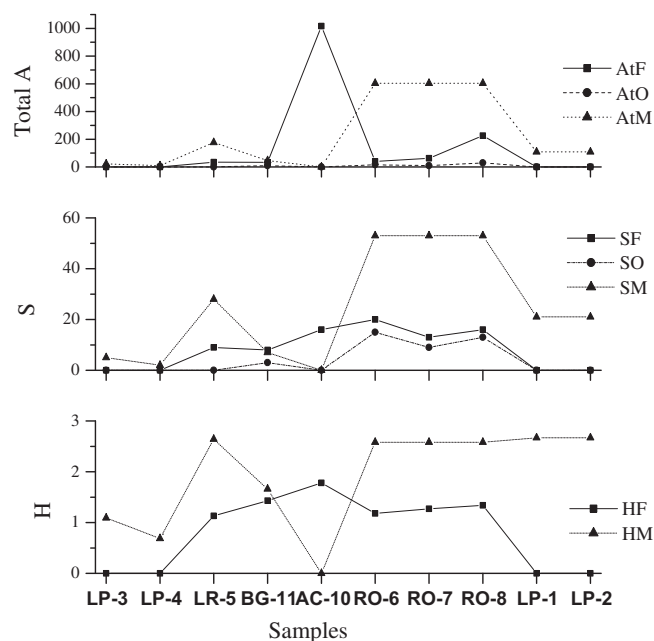


Fig. 3. Total abundance (At), Species richness (S) and Shannon–Weaver diversity index (H), M: molluscs, O: ostracods, F: foraminifera. Localities arranged from the oldest (left) to the youngest (right).

Foraminifera	LR-5	BG-11	AC-10	RO-6	RO-7	RO-8
<i>Cibicides dispart</i>						
<i>Buccella peruviana</i>						
<i>Cibicides aknerianus</i>						
<i>Globocassidulina subglobosa</i>						
<i>Melonis affine</i>						
<i>Elphidium articulatum</i>						
<i>Elphidium macellum</i>						
<i>Elphidium lessonii</i>						
<i>Elphidium alvarezanum</i>						
<i>Buliminella elegantissima</i>						
<i>Elphidium</i> sp.						
<i>Nonion</i> sp.						
<i>Cibicides variabilis</i>						
<i>Discorbis isabellianus</i>						

Fig. 4. Foraminifera with 1% or more of relative abundance, discriminated for each site/sample.

Ostracods	BG-11	RO-6	RO-7	RO-8
<i>Procythereis torquata</i>				
<i>Austroaurila theeli</i>				
<i>Ameghinocythere reticulata</i>				
<i>Semicytherura clavata</i>				
<i>Heterocythereis pokorny</i>				
<i>Pectocythere magellanensis</i>				
<i>Meridionalicythere mesodiscus</i>				
<i>Aurila radiata</i>				
<i>Oculocytheropteron burdwoodbankensis</i>				
<i>Austroaurila impluta</i>				
<i>Australicythere devexa</i>				
<i>Heterocythereis chilensis</i>				
<i>Ambostracon bertelsae</i>				
<i>Hemingwayella pumilio</i>				
<i>Hemicytherura splendifera</i>				
<i>Hemicythere robusta</i>				
<i>Xestoleberis setigera</i>				
<i>Ambocythere? dentata</i>				
<i>Austroaurila recurvirostrata</i>				
<i>Australicytheridea dispersopunctata</i>				
<i>Leptocythere mosleyi</i>				

Fig. 5. Ostracods with 1% or more of relative abundance, discriminated for each site/sample.

Mollusks	LP-3	LP-4	LR-5	BG-11	RO-6to8	LP-1to2
<i>Nucula falklandica</i>						
<i>Yoldia woodwardi</i>						
<i>Aulacomya atra</i>						
<i>Mytilus chilensis</i>						
<i>Limatula pygmaea</i>						
<i>Zygochlamys patagonica</i>						
<i>Carditella naviformis</i>						
<i>Rocheffortia rochebrunei</i>						
<i>Neolepton concentricum</i>						
<i>Venus antiqua</i>						
<i>Retrotapes exalbidus</i>						
<i>Tawera gayi</i>						
<i>Mulinia edulis</i>						
<i>Ensis macha</i>						
<i>Hiatella solida</i>						
<i>Iothia coppingeri</i>						
<i>Margarella expansa</i>						
<i>Margarella violacea</i>						
<i>Eatoniella denticula</i>						
<i>Trochita pileolus</i>						
<i>Trophon geversianus</i>						
<i>Xymenopsis muriciformis</i>						
<i>Glypteuthria meridionalis</i>						
<i>Lachesis? euthrioides</i>						
<i>Pareuthria plumbea</i>						
<i>Odostomia</i> sp.						
<i>Mathilda magellanica</i>						
<i>Kerguelenella lateralis</i>						
<i>Siphonaria lessoni</i>						
<i>Toncia calbucensis</i>						
<i>Toncia lebruni</i>						
<i>Plaxiphora aurata</i>						

Fig. 6. Mollusks with 1% or more of relative abundance, discriminated for each site/sample.

5.2.2. ca. 7700 BP

In sample 5 (Lago Roca, LR-5), ca. 7700 BP, mollusks are more diversified than in older sediments. The mollusk assemblage, previously described by Gordillo (1999), includes macro-and-micromollusks. The most common macromollusks are two bivalves, *Zygochlamys patagonica* (9.5%) and *Hiatella solida* (8.4%), while the most common micromollusks are *Margarella violacea* (20.7%), *Rocheffortia rochebrunei* (16%), *Lachesis? euthrioides* (9.5%), and several other taxa in minor proportions.

In these sediments, foraminifera ($N = 35$) make their first appearance, but ostracods are still missing. The species best represented is *Cibicides disspars* (70%), followed by *Elphidium macellum* (9%) and *Cibicides aknerianus* (8%). The other species are present in proportions lower than 5%. This fauna is poorly developed, with broken and reworked individuals.

The presence of *Z. patagonica* and *C. disspars* indicates the existence of firm ground or hard substratum, as these species need to be fixed (Murray, 1991).

5.2.3. ca. 6400 BP

Sample 11 (Golondrina Bay, BG-11) is dominated ($N = 34$) by the foraminifera *C. disspars* (49%), followed by *Buccella peruviana* (20%), *Elphidium macellum* (14%), *C. aknerianus* (7%) and *Elphidium lessonii* (5%). The other species are present in proportions lower than 5%. The ostracod fauna in this sample was very poor, with only 9 individuals and 3 species, and evidence of reworking. The highest percentage corresponds to *Leptocythere mosleyi* (55.5%), whereas two other species (*Austroaurila theeli* and *Australocytheridea disspersopunctata*) represented 22%.

The mollusk assemblage (macrofauna) from this site was found in life position and has already been described by Gordillo et al. (2008). This assemblage represents a local infralittoral community developed within a high energy environment. It is dominated by two suspension feeder infaunal bivalves (*Ensis macha* and *Venus antiqua*), but micromollusks such as *Neolepton concentricum*, *Nucula falklandica* and *Rocheffortia rochebrunei* were also collected. As the foraminifera *C. disspars* needs sediments to be fixed, it is probable that this species reworked from adjacent, deeper sediments.

5.2.4. ca. 6000 BP

Sample 10 (Arroyo Los Castores, Lapataia Bay, AC-10) is characterized by *C. disspars* (28%), *B. peruviana* (31%), *C. aknerianus* (15%), *Globocassidulina subglobosa* (13.6%) and *Melonis affine* (7%). The other species are present in proportions lower than 5%. This sample has the highest abundance ($N = 1016$) and diversity ($S = 16$) of foraminifera, with numerous small and broken specimens, although it should be noted that there were no ostracods or mollusks. Gravelly sediments dominate, with a small amount of mud particles. It is very probable that the microfauna recovered in this sample were reworked from the surrounding environments (see Discussion).

5.2.5. ca. 4300 BP

Sample 6 (Archipelago Cormoranes, RO-6) is dominated ($N = 40$) by the foraminifera *C. disspars* (59%) and *C. aknerianus* (30%). The other species are present in proportions lower than 5%. The ostracods were represented by 16 individuals and 15 species.

These were comprised of two specimens of *Procythereis torquata* (11%), one specimen of the each of the following: *A. theeli*, *Ameghinocythere reticulata*, *Semicytherura clavata*, *Heterocythereis pokorny* and *Aurila radiata*, and 10 species present in proportions of no more than 5%.

Sample 7 (CRO3, Cabecera Río Ovando, RO-7) is dominated ($N = 63$) by the foraminifera *C. dispers* (46%) and *C. aknerianus* (40%). The other species are present in proportions lower than 5%. The ostracods were represented by 9 individuals belonging to different species, for example *P. torquata*, *A. theeli*, *Ameghinocythere reticulata*, *H. pokorny* and *Aurila radiata*.

Sample 8 (Archipiélago Cormoranes, RO-8) is dominated ($N = 226$) by *C. aknerianus* (52%) and *C. dispers* (32%), although specimens were broken. The other species are present in proportions lower than 5%. The greatest S value was obtained for this sample.

The ostracods ($N = 29$) were represented by 13 species, of which five are in proportions higher than 5% – *P. torquata* (17%), *A. theeli* (17%), *A. reticulata* (13.7%), *Australicythere devexa* (13.7%) and *Heterocythereis chilensis* (10.3%).

This mollusk outcrop is very rich in fossil remains and contains a large proportion of whole, well-preserved shells. The sculpture of most specimens is unaltered, and many also retain their original color. Bivalves normally occur as whole, joined valves, oriented in life position or horizontally, randomly oriented within the bed. A minor proportion of shells have an abraded surface and damaged margins, thus indicating that they were transported some distance. Bivalves contribute most of the biomass, although gastropods exhibit the highest richness. Chitons are also present in low numbers.

Some of the profiles located in the Cormoranes area have been described previously (i.e. the Laguna Verde and Río Ovando sites, Gordillo, 1999).

Macromollusks are dominated by the clams *Tawera gayi* and *V. antiqua*, although another common species is the bivalve *H. solida*. Among gastropods, the most common taxa are two muricids (*Trophon geversianus*, *Xymenopsis muriciformis*) and one buccinid (*Pareuthria plumbea*). Within the small sized mollusks, a great number of taxa (such as the bivalves *Rochefortia rochefortia* and *N. concentricum*, and the gastropod *Eatoniella denticula*, among others) are characteristic. These assemblages are dominated by filter-feeding shallow infaunal/semi-infaunal burrowers (*T. gayi*, *V. antiqua* and *H. solida*), and vagrant epifaunal elements, which prey upon bivalves (i.e., the predators *Trophon geversianus* and *X. muriciformis*), or feed on carrion (i.e., *Pareuthria plumbea*).

5.2.6. ca. 2800 BP

Samples 1 and 2 (Arroyo Baliza LP-1 and LP-2) are clayey silts containing several mollusks, including the gastropods *Trophon geversianus*, *X. muriciformis* and *P. plumbea*, and the bivalves *V. antiqua*, *A. atra*, *M. chilensis*, *M. edulis*, *Yoldia* sp. and *Malletia* sp. The mollusks in this assemblage are well preserved, with slight taphonomic alterations. These species suggest marginal marine environments, with low to moderate salinity and high nutrient concentration in the surface waters. The fragmentation of shells is low, and bivalves have articulated valves. The only exceptions are mytilids, which are generally broken. Foraminifera and ostracods were absent in these sediments. However, other groups, such as acritarchs and remnants of copepods, have been described for this site (Rabassa et al., 2009).

It is probable that the absence of calcareous microfauna is due to the preservation degradation of these groups in sulfuric sediments. In this site, a large amount of decaying organic matter, probably macroalgae, was observed. In Yendegaia, a bay west of Lapataia, Zúñiga-Rival (2006) also noticed a large amount of decaying

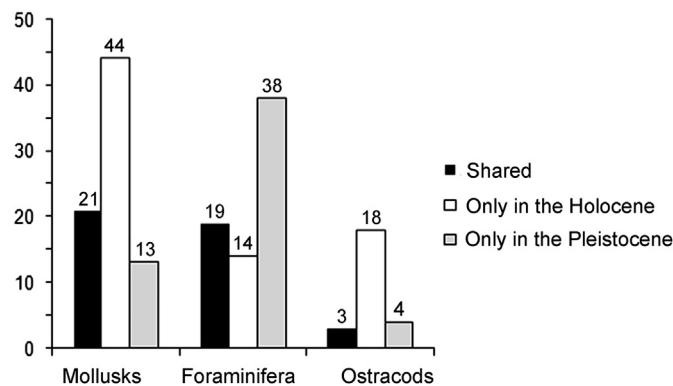


Fig. 7. Number of shared and non-shared calcareous taxa.

macroalgae, as indicated by the smell of sulfur and blackened sediments.

5.3. Holocene versus Pleistocene macro-and-micro fauna from the Beagle Channel

The Holocene calcareous fauna from the Beagle Channel accounts for at least 119 species, which is slightly more than the 98 species registered for the Pleistocene Corrales Viejos site. However, important qualitative differences exist between the three studied groups (Table 2, Fig. 7). Mollusks and ostracods had their highest species richness during the Holocene, but foraminifera reached their highest value during the Pleistocene. Additionally, from a total of 174 taxa, 55 species (31.6%) are only found in Pleistocene sediments, 76 (43.7%) species are only present in Holocene sediments, and 43 (24.7%) species are common to both periods.

Table 2

Taxonomic diversity of the Holocene fauna from the Beagle Channel in comparison with the Pleistocene site previously studied by Gordillo et al. (2010).

Calcareous fauna sorted by age	Taxonomic richness			DSF	Not shared	Shared
	Spp.	Gen.	Fam.			
Holocene						
Mollusks	65	56	37	3.45	44	21
Foraminifera	33	17	12	2.32	14	19
Ostracods	21	18	8	1.62	18	3
M + F + O	119	91	57	3.80	76	43
Pleistocene						
Mollusks	34	26	19	2.73	13	21
Foraminifera	57	28	18	2.65	38	19
Ostracods	7	6	5	1.48	4	3
M + F + O	98	60	42	3.47	55	43

DSF: diversity of species per family. M: mollusks. F: foraminifera. O: ostracods.

The number of species per family (DSF; Table 2) was highest for mollusks (3.45) during the Holocene, and lowest (1.48) for ostracods during the Pleistocene. Foraminifera have intermediate values which are higher during the Pleistocene (2.65) compared to the Holocene (2.32).

With respect to diversity profiles (Fig. 8), for mollusks the Holocene curve lies above the Pleistocene curve over the entire range, thus indicating a higher taxonomic diversity for the younger period. In contrast, for foraminifera, the Pleistocene curve is always above the Holocene curve, thus showing higher taxonomic diversity for the Pleistocene. For the Atlantic coast of Tierra del Fuego,

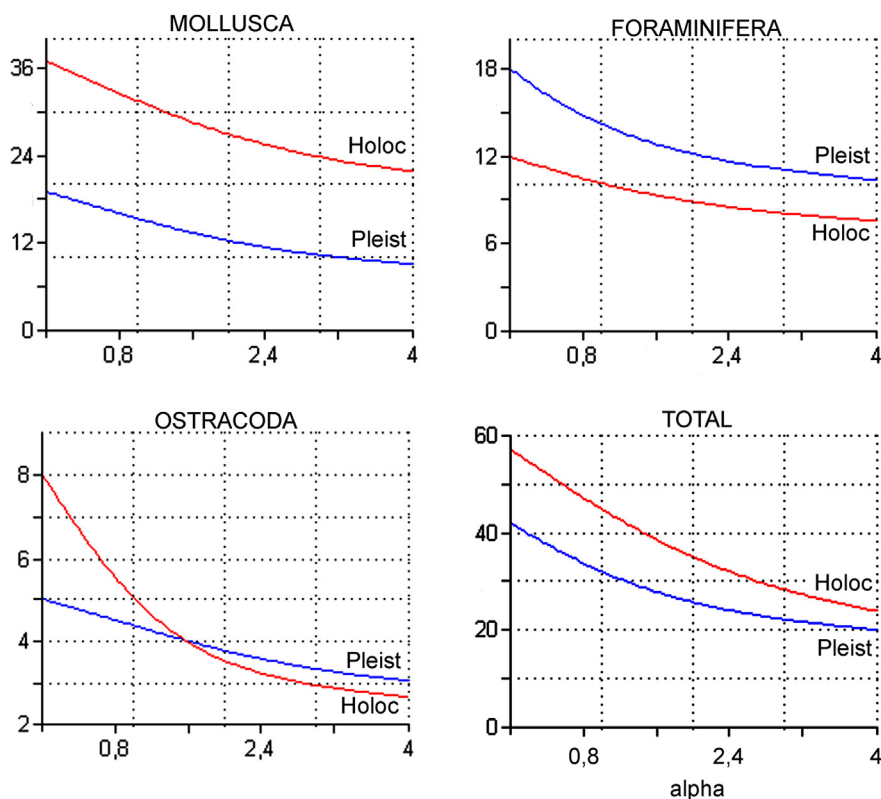


Fig. 8. Diversity profiles for Holocene and Pleistocene calcareous fauna from the Beagle Channel.

Gordillo and Isla (2011) obtained similar results (i.e. Holocene mollusk assemblages were more diverse than Pleistocene assemblages). In contrast, as the ostracod curves intersect, particularly when $1 \leq \alpha \leq 2$, this indicates that they are not comparable, and shows that one of the profiles (the Holocene) is more diverse in species per family for only one family, while the other profile (the Pleistocene) is almost equally diverse in species per family. Having said this, the Holocene faunal assemblage, as a whole, is more diverse than the Pleistocene assemblage.

6. Discussion

6.1. Life assemblages, allochthonous elements and biases in preservation

According to previous studies in the Beagle Channel (e.g. Gordillo et al., 1993; Gordillo, 1999), most bivalves recovered from these sites were found in life position (a vertical position). If they were found in a horizontal position, their valves were either together or were found with the same proportion of opposite (right and left) valves. Therefore, these mollusk assemblages are the preserved part of shallow local benthic communities that developed during the Holocene within these inlets and bays located along the northern side of the Beagle Channel. Gastropod or bivalve shells and chiton plates from nearly all sampled sites also show no signs of abrasion or high transport, and the lack of external ornamentation, when it occurs, is due to the dissolution of external layers, and not as a result of transport. On the other hand, ostracods and foraminifera do not always reflect life assemblages, as seen by the presence of broken specimens and signs of reworking by transport. The presence of dead ostracods (coming from the surrounding marine environment rather than

from far away) also shows that they represent a mixture of autochthonous and allochthonous elements. This is further reinforced by records of the depths in which many of these species live within the study region.

The Beagle Channel is a very interesting environment. It is partially closed by sills, and contains water masses of different origins either surrounding the channel or entering it from the south via the Murray Channel (see more details below). In the shallow depths of exposed coasts, mollusk shells are normally transported, but in this environment of low to moderate energy, only small carapaces (i.e. foraminifera and ostracods) are susceptible to being transported by currents from slightly deeper water to shallower environments where they are deposited and finally buried. In addition to calcareous species of foraminifera, there are also non-calcareous (agglutinated or arenaceous) forms, which do not have the same potential for preservation, and which may represent a significant portion of the foraminifera. For example, 27% of the foraminifera collected by Lena (1966) in Ushuaia Bay are non-calcareous forms. In the Beagle Channel, another study carried out at Yendegaia, a bay located to the west of the study area, showed that the proportion of calcareous and non-calcareous forms was 3:2 (Zúñiga-Rival, 2006), while in southern Chile (43°–46°S), on the Pacific (Hromic, 2007), this relationship was 9:1. Differential preservation between calcareous and non-calcareous forms is therefore another taphonomic bias to be considered.

6.2. The Beagle Channel as “a mosaic”: habitat heterogeneity promoting local benthic communities

Variations in faunal composition not only reflect changes over time, but also local circumstances which determine the distribution

of the different species within the Beagle Channel microbasin; this presents geomorphological and oceanographic features of relative complexity.

In its adult stage, the studied fauna is part of the benthos, and thus lives on the sea bed, and during its ontogenetic development it depends on currents for dispersal. This condition is a primary distribution factor. In the study area, the restricted and patchy distribution of a great number of Magellan species is therefore influenced by the local topographic and oceanographic conditions within this channel. In general, the water masses in the fjord and channel system of the Magellan region comprise (1) Pacific Subantarctic water, (2) Atlantic Subantarctic water, (3) freshwater and a mixture of the latter two types, (4) estuarine water (21 and 31 psu) and (5) modified subantarctic water (31 and 33 psu) (Sievers and Silva, 2008). The circulation of water is affected by constriction-sills (e.g. submarine topography, emerged Navarino and Hoste islands) which represent obstacles that interfere with the free movement of the different waters. This means that horizontal communication is limited to shallower depths, and the renewal of water is slow, with differences in salinity and oxygen between the sea bed and the surface.

This scenario presents habitat heterogeneity and therefore leads to the development of different local benthic communities, as mentioned for mollusks in previous studies (Gordillo, 1999; Gordillo et al., 2005). The relative abundance of a species also varies greatly between sites, thus showing that they are patchy, rather than regular, in distribution.

6.3. Ecological aspects associated with the taxa

The calcareous fossils recovered are typical species of the cold-temperate or cold waters of the Magellan region. However, there is very little information concerning the autecology of many of these species, since their distribution is restricted within the region. Despite this, some taxa are more ubiquitous, and their environmental preferences are better understood, thus helping with paleoenvironmental interpretations.

Regarding mollusks, during the early Holocene new local communities developed in newly formed or recently vacated habitats through immigration of taxa from surrounding waters. After deglaciation, the first mollusks to arrive were eurytopic species as *M. edulis*, *M. chilensis*, *A. atra* and *Y. woodwardi*, and then towards the Mid Holocene the number of species increased and different local communities arose, depending on the physical characteristics that prevailed in each area. These taxa are typical of tidal flats or areas more exposed to highly unstable conditions with longer episodes of exposure. In southern Chile, Velasco and Navarro (2003) demonstrated that *M. chilensis* and *M. edulis* exhibit a high degree of physiological plasticity. Reid and Osorio (2000) also mentioned a group of euryhaline taxa (including *M. chilensis*, *A. atra* and *M. edulis*) from a fjord system in southern Chile which tolerate sharp salinity gradients.

Foraminifera fauna is characterized by species typical of the Malvinas current (Boltovskoy et al., 1980; Violanti et al., 2000). The association described here resembles the estuarine environments of the Chilean channels and fjords; these are favorable for settlement of calcareous foraminifera, and are dominated by calcareous forms. In these environments, high correlation between species distribution and substrate, water circulation patterns and depth were mentioned by Hromic and Zúñiga-Rival (2005) and Hromic (2011). Violanti et al. (2000) suggested that the species distribution is related to the area's bathymetry, while Hromic (2002, 2011) described the region as a complex scenario with numerous geographical accidents that lead to patchy distribution. The main species of foraminifera coincide with the main species found in the

Chilean channels (i.e. *C. dispers*, *B. peruviana*, *E. macellum*), except for the absence of *Ammonia beccarii* and non-calcareous forms. The presence of these species, with the predominance of rotalid individuals and the absence of non-calcareous forms, reflects high energy and well oxygenated conditions, thus suggesting marine water intrusions. The absence of *A. beccarii* is probably due to its inability to live in the cold temperatures of this region, since this species is normally found further north (Hromic, 2011). Although non-calcareous forms have been mentioned for other places in this region (see Herb, 1971; Violanti et al., 2000; Zúñiga-Rival, 2006), their absence in the study area could be due to local parameters which impeded their development. It is also very possible that the non-calcareous species have not been preserved due to the acidity of the environment.

The ostracod assemblages are represented by both adults and later instars, thus corroborating the presence of high energy environments (Boomer et al., 2003). The lower species diversity could be associated with environmental conditions such as lower temperature and lower salinity, which are common in the southern part of the Magellan strait (Whatley et al., 1997b). On the other hand, species distribution in the shelf environment is also regulated by the depth (Whatley et al., 1997b). In this respect, shallow shelf species were found, such as *L. mosleyi* and *A. dispersopunctata*, as well as other shelf species from up to depths of 500 m e.g., *A. reticulata*, *Meridionalicythere mesodiscus*, *Australocythere devexa* and *Hemigwaella pumilio* (Whatley et al., 1997b).

6.4. Is the Holocene fauna the same as that which inhabited the channel before the Last Glacial Maximum?

In the Fuegian region, Quaternary glaciations, and especially the Last Glacial Maximum (LGM), are surely one of the main precursors of the distribution patterns of living fauna in the region. Glacial bodies such as the Beagle Glacier, as well as topographic and oceanographic local conditions of this microbasin, together with physical barriers that restricted water masses and circulation, would be responsible for the changes detected in the entire fauna that inhabited the channel before the LGM, as well as the fauna that reoccupied the channel after the LGM.

Information on Pleistocene species that inhabited the Beagle Channel before the LGM, as seen above, comes from a paleontological site, Corrales Viejos, on Navarino Island, as described by Gordillo et al. (2010). This outcrop is situated near Gable Island, which acts as a constriction-sill, dividing the channel into two microbasins: one to the east, characterized by the predominance of a westward propagating tide, and one to the west, marked by a second, eastward propagating tide. Both come from the main tide, which originates in the Pacific, and their encounter in the area is reflected by a high-energy environment.

The Corrales Viejos site therefore has a number of features which make it unique, and which show that it is a different sub-environment from the Holocene sub-environments. The main differences between the fauna of the two ages include changes in species richness and taxonomic composition.

Within the calcareous taxonomic groups of this Pleistocene marine deposit, foraminifera were slightly more diverse than in Holocene sediments, while ostracods and mollusks were less diverse. Pleistocene foraminifera assemblages are characterized by *E. macellum* and *Elphidium alvarezianum*, representing shallow waters, while the Holocene sequences are dominated by *C. dispers*, *B. peruviana* and *C. aknerianus*, suggesting high energy and good oxygen conditions (Hromic, 2002, 2006, 2009 and 2011). Among mollusks, several size and taxonomic composition characteristics have been noted which differentiate between the two periods.

The Pleistocene site is characterized by the dominance of small specimens of the bivalve *Hiatella* and several small muricid gastropods, but also by the presence of cirripeds, which provide food and refuge to mollusks. A new muricid species (*Lepsiella ukika*; Gordillo and Nielsen, in press) was recently identified at this site. In the Pleistocene, some families are more diversified, particularly Muricidae and Buccinulidae, while in the Holocene, diversity occurs in other families such as Carditidae, Patellidae and Fissurellidae.

It is interesting to compare the fauna recovered from Corrales Viejos with the fauna living in the area today, as there are notable differences. As mentioned above, the Pleistocene macrofauna is dominated by cirripeds, small nesting bivalves *Hiatella*, and small muricid gastropods, but the fauna that lives on the adjacent beach has a different living local community, dominated by huge suspension feeder bivalves (mytilids and cirripeds). This suggests that the Beagle Channel is not only a “mosaic” (with spatial differences from place to place), but would also have acted as a “dynamic mosaic” (changes in one site over time) affecting the development of local benthic communities during the Late Quaternary, and reflecting changes related to ecology and local physical variations (i.e. substrate, availability of food and currents) after the LGM.

The main differences between Pleistocene and Holocene sequences are therefore at least partly related to the fact that in the fossil record different marine sub-environments are represented. These also differ from each other in the nature of their water bodies and are not therefore entirely equivalent. However, they are also interpreted in association with environmental changes after the LGM which resulted in the reoccupation of vacant niches by retreating glaciers and reestablishment of the marine conditions within the Beagle Channel. It would be interesting to investigate whether these changes in communities drive changes in the Earth's biota over time.

7. Summary and conclusions

The diversity of habitats in the Beagle Channel results in a great diversity of local communities. This, in conjunction with the poor preservation of Pleistocene sites, means that the Holocene and Pleistocene sequences are not entirely equivalent. However, it can be concluded that faunistic changes during the Late Quaternary partly reflect changes over time, and partly reflect local circumstances. Discerning how much of each is still difficult. Despite this, on a local and regional scale, the multi-proxy evidence used in this study provides a consistent picture of spatial and temporal environmental changes.

On one hand, variations in abundance, richness and dominance are part of a complex environment characterized by an intricate topography which results in both exposed and protected shallow and deep sub-environments with different circulation and seasonal changes of water masses. This set of features not only attracted the presence of opportunistic species (the most abundant taxa), it also favored the development of endemic taxa, which appeared in minor proportions.

However, on the other hand, during the Holocene there was an increase in the number of taxa from older marine layers (Early Holocene) to younger ones (Middle to Late Holocene). During the Early Holocene, an initial phase of marine conditions with marine water flooding via constricted waterways (e.g. the Murray Passage) connected the area to the open sea. Until that time, the study area was a freshwater estuarine environment, but the input of marine waters resulted in the arrival of the first taxa able to tolerate high salinity fluctuations or estuarine-saline waters. In the Early Holocene (ca. 8000 BP), mollusks make their first appearance after

deglaciation with only two eurytopic species (*M. edulis* and *M. chilensis*), followed immediately by the addition of a few other species (*A. atra* and *Y. woodwardi*).

During the Mid Holocene, mollusks diversified hugely, with brackish-water fauna replaced by marine species. In this period, mollusks were dominated by *T. gayi* and *H. solida*, and the most common micromollusks (<1 cm) were the bivalves *Rochefortia rochefortia* and *N. concentricum*, and the gastropod *E. denticula*. Foraminifera make their appearance during the Early-Mid Holocene, with *C. dispers* best represented. By around 6000 years BP, *B. peruviana* is better represented than *C. dispers*, but towards the 4000 year mark it is replaced by *C. dispers* and *C. aknerianus*. Finally, ostracods are poorly represented compared with foraminifera and mollusks, and appeared at ca. 6000 BP with 3 species (*L. mosleyi*, *A. theeli* and *A. dispersopunctata*). They later diversified towards the Mid Holocene, with several more species (e.g. *P. torquata*, *A. theeli*, *A. reticulata*, *M. mesodiscus*), although in low quantities. Thus, during the Mid-Holocene there was a phase of major faunal expansion, with further diversification of taxa and higher salinities, indicating an evolution towards Modern conditions.

Finally, in the Beagle Channel the Holocene fossil record is more complete than the Pleistocene record because different local Holocene communities were preserved, while the record for the Pleistocene is reduced to a single site in Navarino Island. This should be taken into account when comparing the Holocene and the Late Pleistocene. Differences between Pleistocene and Holocene fauna at least partly follow the heterogeneity of habitats in the Beagle Channel, but they are also interpreted in association with environmental changes as local physical variations after the LGM and water masses of different origin which have varying influence throughout the Late Quaternary.

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Appendix A

Table A. 1.
List of FORAMINIFERA

Class FORAMINIFERIDA Eichwald, 1830
Family HAUERININAE Schwager, 1876
<i>Quinqueloculina patagonica</i> d'Orbigny, 1839
<i>Quinqueloculina seminulum</i> (Linné), 1767
<i>Quinqueloculina milletti</i> (Wiesner), 1898
<i>Pyrgo nasuta</i> Cushman, 1935
<i>Pyrgo peruviana</i> d'Orbigny, 1839
Family STILOSTOMELLIDAE Finlay, 1947
<i>Lenticulina limbosa</i> Reuss, 1863.
Family LAGENIDAE Reuss, 1812
<i>Lagena lyellii</i> (Seguenza), 1963

(continued on next page)

Table A. 1. (continued)

<i>Lagena striata</i> (d' Orbigny), 1839
Family ELLIPSOLAGENIDAE Silvestri, 1923
<i>Fissurina earlandi</i> Parr, 1950
<i>Fissurina quadricostulata</i> (Reuss), 1870
Family CASSIDULINIDAE d'Orbigny, 1839
<i>Globocassidulina subglobosa</i> (Brady), 1881
<i>Cassidulinoides parkerianus</i> (Brady), 1881
Family BULIMINIDAE Jones, 1875
<i>Bulimina marginata</i> d' Orbigny, 1826
<i>Bulimina gibba</i> Fornasini, 1902
<i>Globoulimina affinis</i> d'Orbigny, 1839
Family BULIMINELLIDAE Hofker, 1951
<i>Buliminella elegantissima</i> (d'Orbigny), 1839
Family DISCORBIDAE Ehrenberg, 1838
<i>Discorbis williamsoni</i> (Chapman and Parr), 1858
<i>Discorbis isabelleanus</i> (d'Orbigny), 1893
Family CIBICIDIDAE Cushman, 1927
<i>Cibicides aknerianus</i> (d' Orbigny), 1846
<i>Cibicides dispers</i> (d' Orbigny), 1839
<i>Cibicides variabilis</i> (d' Orbigny), 1826
Family NONIONIDAE Schultze, 1854
<i>Nonion pauperatum</i> Balkwill and Wright, 1885
<i>Nonion</i> sp.
<i>Melonis affine</i> (Reuss), 1851
<i>Pullenia bulloides</i> (d'Orbigny) 1826
<i>Pullenia subcarinata</i> (d' Orbigny, 1839) <i>subcarinata</i>
Family TRICHOHYALIDAE Saidova, 1981
<i>Buccella peruviana</i> (d'Orbigny), 1839
Family ELPHIDIIDAE Galloway, 1933
<i>Elphidium alvarezanum</i> (d'Orbigny), 1839
<i>Elphidium articulatum</i> (d'Orbigny), 1839
<i>Elphidium excavatum</i> (Terquem), 1876
<i>Elphidium lessonii</i> (d' Orbigny) 1839
<i>Elphidium macellum</i> (Fitchel and Moll) 1798
<i>Elphidium</i> sp.

Table A. 2.

List of OSTRACODA

Phylum CRUSTACEA Pennant, 1777
Class OSTRACODA Latreille, 1806
Order PODOCOPIDA Müller, 1894
Superfamily CYTHEROIDEA Bair, 1850
Family CYTHERIDEIDAE Sars, 1925
<i>Australicytheridea dispersopunctata</i> Whatley et al., 1987
Family CYTHERURIDAE Müller, 1894
<i>Hemicytherura splendida</i> Whatley et al., 1988
<i>Semicytherura clavata</i> (Brady, 1880)
<i>Hemingwayella pumilio</i> (Brady, 1880)
<i>Oculocytheropteron burdwoodbankensis</i> Whatley and Cusminsky, 2002
Family HEMICYTHERIDAE Puri, 1953
<i>Ambostracon bertelsae</i> (Sanguinetti et al., 1991)
<i>Australicythere devexa</i> (Müller, 1908),
<i>Meridionalicythere mesodiscus</i> (Skogsberg, 1928)
<i>Aurila radiata</i> (Skogsberg, 1928)
<i>Austroaurila impluta</i> (Brady, 1880)
<i>Austroaurila recurvirostrata</i> (Skogsberg, 1928)
<i>Austroaurila theeli</i> (Skogsberg, 1928)
<i>Hemicythere robusta</i> (Skogsberg, 1928)
<i>Heterocythereis chilensis</i> (Hartman, 1962)
<i>Heterocythereis pokorny</i> (Hartmann, 1962)
Family LEPTOCYTHERIDAE Hanai, 1957
<i>Leptocythere mosleyi</i> (Brady, 1880)
Family PECTOCYTHERIDAE Hanai, 1957
<i>Pectocythere magellanensis</i> Whatley et al., 1996b.
<i>Ameghinocythere reticulata</i> Whatley, Toy, Chadwick y Ramos, 1997
Family THAEROCYTHERIDAE Hazel 1987
<i>Procythereis torquata</i> Skogsberg, 1928
Family TRACHYLEBERIDIDAE Silvester-Bradley, 1948
<i>Ambocythere? dentata</i> Hartmann, 1962
Family XESTOLEBERIDIDAE Sars, 1928
<i>Xestoleberis setigera</i> Brady, 1880

Table A. 3.

List of MOLLUSCA

Phylum MOLLUSCA Linnaeus, 1758
Class BIVALVIA Linnaeus, 1758
Family NUCULIDAE Gray, 1824
<i>Nucula falklandica</i> Preston, 1912
Family NUCULANIDAE Adams H. and A. Adams, 1858
<i>Tindariopsis sulculata</i> (Gould (Couthouy MS), 1852)
<i>Yoldia woodwardi</i> Hanley, 1860
Family MALLETIIDAE Adams H. and A. Adams, 1858
<i>Malletia cumingii</i> (Hanley, 1860)
Family LIMOPSIDAE Dall, 1895
<i>Lissarca miliaris</i> (Philippi, 1845)
Family PHILOBRYIDAE Bernard, 1897
<i>Philobrya</i> sp.
Family MYTILIDAE Rafinesque, 1815
<i>Aulacomya atra</i> (Molina, 1782)
<i>Mytilus chilensis</i> Hupé in Gay, 1854
<i>Brachidontes purpuratus</i> (Lamarck, 1819)
<i>Crenella magellanica</i> Linse, 2002
Family LIMIDAE Rafinesque, 1815
<i>Limatula pygmaea</i> (Philippi, 1845)
Family PECTINIDAE Rafinesque, 1815
<i>Zygochlamys patagonica</i> (King and Broderip, 1832)
Family CARDITIDAE Fleming, 1828
<i>Carditella naviformis</i> (Reeve, 1843)
<i>Carditella pallida</i> Smith, 1881
<i>Cyclocardia compressa</i> Reeve, 1843
Family LASAEIDAE Gray, 1842
<i>Lasaea</i> sp.
<i>Rocheortia rochebrunei</i> Dall, 1908
Family NEOLEPTONIDAE Thiele, 1934
<i>Neolepton concentricum</i> (Preston, 1912)
Family VENERIDAE Rafinesque, 1815
<i>Venus antiqua</i> (King and Broderip, 1832)
<i>Retrotapes exalbidus</i> (Dillwyn, 1817)
<i>Tawera gayi</i> (Hupé in Gay, 1854)
Family MACTRIDAE Lamarck, 1809
<i>Mulinia edulis</i> (King and Broderip, 1832)
Family PHARIDAE Adams H. and A. Adams, 1858
<i>Ensis macha</i> Molina, 1782
Family HIATELLIDAE Gray, 1824
<i>Hiatella solida</i> (Sowerby, 1834)
Class GASTROPODA Cuvier, 1797
Family PATELLIDAE Rafinesque, 1815
<i>Nacella deaurata</i> (Gmelin, 1791)
Family LEPETIDAE Gray, 1850
<i>Lothia coppingeri</i> (Smith, 1881)
Family FISSURELLIDAE Fleming, 1822
<i>Fissurella picta</i> (Gmelin, 1791)
<i>Fissurellidea patagonica</i> (Strebel, 1907)
Family SCISSURELLIDAE Gray, 1847
<i>Scissurella clathrata</i> Strebel, 1908
Family CALLIOSTOMATIDAE Thiele, 1924
<i>Calliostoma dozei</i> Mabilie & Rochebrune in Rochebrune & Mabilie, 1889
Family TROCHIDAE Rafinesque, 1815
<i>Ganesa</i> sp.
<i>Margarella expansa</i> (Sowerby, 1838)
<i>Margarella violacea</i> (King, 1832)
Family CYCLOSTREMATIDAE Fischer, 1885
<i>Cyclostrema crassicostatum</i> Strebel, 1908
Family EATONIELLIDAE Ponder, 1965
<i>Eatoniella denticula</i> Ponder and Worsfold, 1994
Family RISSOIDAE Gray, 1847
<i>Onoba schythei</i> (Philippi, 1868)
Family LITTORINIDAE Children, 1834
<i>Laevilitorina caliginosa</i> (Gould, 1848)
<i>Laevilitorina</i> sp.
Family CALYPTRAEIDAE Lamarck, 1809
<i>Crepidula dilatata</i> Lamarck, 1822
<i>Trochita pileolus</i> (d'Orbigny, 1841)
Family CERITHIOPSIDAE (s.l.) Adams H. & A. Adams, 1853
<i>Cerithiella</i> sp. 1
<i>Cerithiella</i> sp. 2
<i>Eumetula michaelsoni</i> (Strebel, 1905)
Family MURICIDAE Rafinesque, 1815
<i>Fuegotrophon pallidus</i> (Broderip in Broderip & Sowerby, 1833)
<i>Trophon geversianus</i> (Pallas, 1774)

Table A.3. (continued)

<i>Xymenopsis muriciformis</i> (King, 1832)
Family NATICIDAE Guilding, 1834
<i>Falsilunatia soluta</i> (Gould, 1847)
Family BUCCINULIDAE Finlay, 1928
<i>Glypteuthria meridionalis</i> (Smith, 1881)
<i>Lachesis? euthrioides</i> Melville & Standen, 1898
<i>Pareuthria plumbea</i> (Philippi, 1844)
<i>Pareuthria powelli</i> (Cernohorsky, 1977)
<i>Savatieria meridionalis</i> (Smith, 1881)
Family TURRIDAE Adams H. & A. Adams, 1853
<i>Belalora thielei</i> Powell, 1951
Family PYRAMIDELLIDAE Gray, 1840
<i>Odostomia</i> sp. 1
<i>Odostomia</i> sp. 2
<i>Turbonilla smithi</i> Strebel (Pfeffer, MS), 1905
Family MATHILDIDAE Dall, 1889
<i>Mathilda magellanica</i> Fischer in De Folin & Périer, 1870
Family SIPHONARIIDAE Gray, 1827
<i>Kerguelenella lateralis</i> Gould (Couthoy, MS), 1846
<i>Siphonaria lessonii</i> Blainville, 1827
Class POLYPLACOPHORA Gray, 1821
Family CALLOCHITONIDAE Plate, 1901
<i>Callochiton puniceus</i> (Couthouy MS, Gould, 1846)
Family CHITONIDAE Rafinesque, 1815
<i>Tonicia atrata</i> (Sowerby, 1840)
<i>Tonicia calbucensis</i> Plate, 1897
<i>Tonicia chilensis</i> (Frembly, 1827)
<i>Tonicia lebruni</i> de Rochebrune, 1884
Family MOPALIIDAE Dall, 1889
<i>Plaxiphora aurata</i> (Spalowsky, 1795)

Appendix B. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.quaint.2012.11.016>.

References

- Boltovskoy, E., Watanabe, S., 1980. Foraminíferos de los sedimentos cuaternarios entre Tierra del Fuego e islas Georgias del Sur. *Revista Instituto Nacional de Investigaciones Naturales y Museo de Ciencias Naturales Bernardino Rivadavia, Hidrobiología* 8, 96–124. Buenos Aires.
- Boltovskoy, E., Giussani, G., Watanabe, S., Wright, R., 1980. Atlas of Benthic Shelf Foraminifera of the Southwest Atlantic. W. Junk. Publishers, The Hague, 147 pp.
- Boltovskoy, E., 1954a. Foraminíferos del Golfo San Jorge. *Revista Instituto Nacional de Investigaciones Naturales y Museo Argentino Bernardino Rivadavia, Ciencias Geológicas* 3, 79–228.
- Boltovskoy, E., 1954b. Foraminíferos de la Bahía San Blas. *Revista del Instituto Nacional de Investigaciones de Ciencias Naturales y Museo Argentina Bernardino Rivadavia* 3, 247–300.
- Boltovskoy, E., 1976. Distribution of recent foraminifera of the South American Region. *Foraminifera* 2, 171–236.
- Boomer, I., Horne, D.J., Slipper, I.J., 2003. The use of ostracods in palaeoenvironmental studies, or what can you do with an ostracod shell? *Paleontological Society Papers* 9, 153–179.
- Borromei, A., Quattrocchio, M., Rabassa, J., 1997. Estudio palinológico de sedimentos marinos holocénicos en bahía Lapataia, Tierra del Fuego, Argentina, 6° Congreso de la Asociación Brasileira para Estudios Cuaternarios (ABEQUA), Curitiba, Abstracts, pp. 317–321.
- Brady, G.S., 1880. Report on the Ostracoda dredged by HMS Challenger during the years 1873–1876. Report of the Voyage of the Challenger. *Zoology* 1, 1–184.
- Brady, H.B., 1884. Report on the Foraminifera dredged by HMS Challenger during the years 1873–1876. Report of the Voyage of the Challenger. *Zoology* 9, 1–814.
- Bujalesky, G., Coronato, A., Roig, C., Rabassa, J., 2004. Holocene Differential Tectonic Movements Along the Argentine Sector of the Beagle Channel (Tierra del Fuego) Inferred from Marine Palaeoenvironments. *Geosur 2004 International Symposium on the Geology and Geophysics of the Southernmost Andes, the Scotia Arc and the Antarctic Peninsula. Bollettino di Geofisica Teorica ed applicata*, 45, pp. 235–238.
- Bujalesky, G., 2007. Coastal geomorphology and evolution of Tierra del Fuego (Southern Argentina). *Geológica Acta* 5, 337–362.
- Candel, M.S., Borromei, A.M., Martínez, M.A., Gordillo, S., Quattrocchio, M., Rabassa, J., 2009. Middle-Late Holocene palynology and marine mollusks from Archipiélago Cormoranes area, Beagle Channel, southern Tierra del Fuego, Argentina. *Palaeogeography, Palaeoclimatology, Palaeoecology* 273, 111–122.
- Cárdenas, J., Aldea, C., Valdovinos, C., 2008. Chilean marine Mollusca of the northern Patagonia collected during the CIMAR-10 Fjords cruise. *Gayana* 72, 31–67.
- Coronato, A., Rabassa, J., 2011. Pleistocene glaciations in Southern Patagonia and Tierra del Fuego (Chapter 51). In: Ehlers, J., Gibbard, P. (Eds.), *Quaternary Glaciations – Extent and Chronology, Part IV – a Closer Look. Developments in Quaternary Science*, vol. 15, pp. 715–727.
- Coronato, A., Meglioli, A., Rabassa, J., 2004. Glaciations in the Magellan Straits and Tierra del Fuego, Southernmost South America. In: Ehlers, J., Gibbard, P. (Eds.), *Quaternary Glaciations – Extent and Chronology. Part III. Quaternary Book Series*, pp. 45–48.
- Cusminsky, G., Whitley, R., 2008. Calcareous Microfossils (Foraminifera and Ostracoda) of the Late Cenozoic from Patagonia and Tierra del Fuego: a Review. In: Rabassa, J. (Ed.), *Late Cenozoic of Patagonia and Tierra del Fuego. Developments in Quaternary Science*, vol. 11, pp. 327–341.
- Cusminsky, G., 1992. Foraminíferos bentónicos provenientes de testigos del Océano Atlántico Sudoccidental austral. *Revista Española de Micropaleontología* 24, 5–32 (Madrid).
- d'Orbigny, A.D., 1839. Voyage dans l'Amérique méridionale, Foraminifères, vol. 5. P. Bertrand, Strasbourg, pp. 1–86.
- Dell, R.K., 1971. The marine Mollusca of the Royal Society Expedition to Southern Chile, 1958–1959. *Records of the Dominion Museum* 7, 155–233.
- Dell, R.K., 1990. Antarctic Mollusca with special reference to the fauna of the Ross Sea. *Bulletin of the Royal Society of New Zealand* 27, 1–311.
- Feruglio, E., 1950. Descripción geológica de la Patagonia, vol. 3. Dirección General de Y.P.F. Buenos Aires, 431 pp.
- Figueroa, S., Marchant, M., Giglio, S., Ramírez, M., 2005. Foraminíferos Bentónicos Rotalinidos del Centro Sur de Chile (36°S–44°S). *Gayana* 69, 329–363.
- Fleming, K., Johnston, P., Zwart, D., Yokoyama, Y., Lambeck, K., Chappell, J., 1998. Refining the eustatic sea level curve since the Last Glacial Maximum using far- and intermediate field sites. *Earth and Planetary Science Letters* 163, 327–342.
- Gordillo, S., Isla, F., 2011. Faunistic changes between the Middle/Late Pleistocene and the Holocene on the Atlantic coast of Tierra del Fuego: molluscan evidence. *Quaternary International* 233, 101–112.
- Gordillo, S., Nielsen, S. The Australasian muricid gastropod *Lepsiella* as Pleistocene visitor to southernmost South America. *Acta Palaeontologica Polonica*, in press.
- Gordillo, S., Schwabe, E., 2009. First fossil Quaternary record of Polyplacophorans from southern South America. *Geobios* 42, 265–271.
- Gordillo, S., Bujalesky, G.G., Pirazzoli, P.A., Rabassa, J.O., Saliege, J.F., 1992. Holocene raised beaches along northern coast of the Beagle Channel, Tierra del Fuego, Argentina. *Palaeogeography, Palaeoclimatology, Palaeoecology* 99, 41–54.
- Gordillo, S., Coronato, A., Rabassa, J., 1993. Late Quaternary evolution of a subantarctic paleofjord, Tierra del Fuego. *Quaternary Science Reviews* 12, 889–897.
- 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.
- Gordillo, S., Rabassa, J., Coronato, A., 2008. Paleoeecology and paleobiogeographic patterns of Mid-Holocene mollusks from the Beagle Channel (southern Tierra del Fuego, Argentina). *Revista Geológica de Chile* 35, 1–13.
- Gordillo, S., Cusminsky, G., Bernasconi, E., Ponce, F., Rabassa, J.O., Pino, M., 2010. Pleistocene marine calcareous macro- and microfossils of Navarino Island (Chile) as environmental proxies during the last interglacial in southern South America. *Quaternary International* 221, 159–174.
- Gordillo, S., 1993. Las terrazas marinas holocenas de la Región del Beagle (Tierra del Fuego) y su fauna asociada. In: Abstracts XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos, Mendoza, 4, pp. 34–39.
- Gordillo, S., 1999. Holocene molluscan assemblages in the Magellan region. *Scientia Marina* 63 (Suppl. 1), 15–22.
- Halle, T.G., 1910. On Quaternary deposits and changes of sea level in Patagonia and Tierra del Fuego. *Bulletin of the Geological Institution of the University of Upsala* 9, 93–117.
- Hammer, O., Harper, D.A.T., Ryan, P.D., 2005. PAST-Palaeontological Statistics, ver. 1.35. <http://folk.uio.no/ohammer/past>.
- Hartmann, G., 1997. Antarktische und subantarktische Podocopa (Ostracoda). In: Wägele, W., Sioeg, J. (Eds.), *Synopses of the Antarctic benthos*, 7. Koeltz Scientific Books, Koenigstein, p. 355.
- Herb, R., 1971. Distribution of recent benthonic foraminifera in the Drake Passage. *Biology of the Antarctic Sea. Antarctic Research Series* 4 (17), 251–300.
- Heusser, C.J., Rabassa, J., 1987. Cold climate episode of Younger Dryas age in Tierra del Fuego. *Nature* 32, 609–611.
- Heusser, C.J., 1990. Late Glacial and Holocene vegetation and climate of subantarctic South America. *Review of Palaeobotany and Palynology* 65, 9–15.
- Hromic, T., Águila, H., 1993. Asociación de Foraminíferos epibiontes, Bahía Zenteno, estrecho de Magallanes, Chile. *Anales Instituto Patagonia, Serie Ciencias Naturales* 22, 51–61.
- Hromic, T., Zúñiga-Rival, M., 2003. Foraminíferos (Protozoa: Foraminiferida) de la Superfamilia Buliminacea Jones 1875, en canales y fiordos patagónicos, Chile. *Anales Instituto Patagonia, Serie Ciencias Naturales* 31, 55–74.
- Hromic, T., Zúñiga-Rival, M., 2005. Foraminíferos bentónicos de ambientes someros extraídos durante la expedición CIMAR 7 fiordos, canales patagónicos (42° S–47° S). *Boletín de la Sociedad Biológica de Concepción* 76, 25–38. Concepción, Chile.
- Hromic, T., Ishman, S., Silva, N., 2006. Benthic foraminiferal distributions in Chilean fjords: 47° S to 54° S. *Marine Micropaleontology* 59, 115–134.

- Hromic, T., 1996. Foraminíferos bentónicos (Protozoa: Foraminiferida) de aguas profundas del estrecho de Magallanes, Chile. *Anales Instituto Patagonia, Serie Ciencias Naturales* 24, 65–86.
- Hromic, T., 1999. Foraminíferos bentónicos de canales australes: canal Kirke, golfo Almirante Mont y seno Última Esperanza, XII Región, Magallanes y Antártica Chilena. *Anales del Instituto de la Patagonia, Serie Ciencias Naturales* 27, 91–104.
- Hromic, T., 2002. Foraminíferos bentónicos de Bahía Nassau, cabo de Hornos, Chile. Comparación con foraminíferos del Cono sur de América, Antártica e islas Malvinas. *Anales Instituto Patagonia, Serie Ciencias Naturales* 30, 95–108.
- Hromic, T., 2006. Distribution latitudinal de foraminíferos bentónicos (Protozoa: Foraminiferida) a nivel de subórdenes y familias, en canales y fiordos patagónicos chilenos. *Investigaciones Marinas* 34, 71–81.
- Hromic, T., 2007. Biodiversidad y ecología del microbentos (Foraminifera: Protozoa), entre la boca del Guafo y Golfo de Penas (43°–46°S), Chile. *Red de Revistas Científicas de América Latina y el Caribe, España y Portugal, Ciencia y Tecnología del Mar* 30, 1–21.
- Hromic, T., 2009. Distribución batimétrica de foraminíferos bentónicos (Protozoa: Foraminiferida) al sur del estrecho de Magallanes (52°–56°S), Chile. *Anales Instituto Patagonia, Serie Ciencias Naturales* 37, 23–38.
- Hromic, T., 2011. Foraminíferos bentónicos recientes del Estrecho de Magallanes, y canales australes chilenos Cimar 3 Fiordos (52°–56°S). *Anales Instituto Patagonia* 39, 17–32.
- Isla, F., Bujalesky, G., Coronato, A., 1999. Procesos estuarinos en el Canal Beagle, Tierra del Fuego. *Revista de la Asociación Geológica Argentina* 54, 307–318.
- Kahn, G., Watanabe, S., 1980. Foraminíferos bentónicos como indicadores de la corriente de Malvinas. *Revista Española de Micropaleontología* 12 (2), 169–177.
- Lena, H., 1966. Foraminíferos Recientes de Ushuaia (Tierra del Fuego, Argentina). *Ameghiniana* 4, 311–336.
- Linse, K., 1997. Distribution of epibenthic Mollusca from the Chilean Beagle Channel. *Berichte zur Polarforschung* 228, 1–131.
- Linse, K., 1999. Mollusca of the Magellan region. A checklist of the species and their distribution. *Scientia Marina* 63 (Suppl. 1), 399–407.
- Linse, K., 2002. The Shelled Magellanic Mollusca: with Special Reference to Biogeographic Relations in the Southern Ocean. *theses Zoologicae*, vol. 74. Ganter Verlag KG, Ruggell, Liechtenstein.
- Loeblich, A., Tappan, H., 1988. Foraminiferal Genera and their Classification, vol. 2. Van Nostrand Reinhold, New York, 969 pp.
- Loeblich, A.R., Tappan, H., 1992. Present status of foraminiferal classification. In: Takayanagi, Y., Saito, T. (Eds.), *Studies in Benthic Foraminifera. Proceedings of the Fourth International Symposium on Benthic Foraminifera, Sendai, 1990 (Benthos '90)*. Tokai University Press, Tokyo, Japan, pp. 93–102.
- Lowe, J.J., Walker, M.J.C., 1997. *Reconstructing Quaternary Environments*. Longmans, London, 446 pp.
- McKenzie, K.G., Benassil, G., Ferrari, I., 1995. Morphologies of some Cytheracean from Magellan Straits. In: Riha, J. (Ed.), *Ostracoda and Biostratigraphy*. A.A. Balkema Publishers, Rotterdam, pp. 365–375.
- Menichetti, M., Lodolo, E., Tassone, A., 2008. Structural geology of the Fuegian Andes and Magallanes fold-and-thrust belt in Tierra del Fuego Island. *Geologica Acta* 6, 19–42.
- Moore, R., Pirat, W., 1961. In: *Treatise on Invertebrate Palaeontology*. Part Q, Arthropoda 3. Crustacea, Ostracoda. Geological Society of America and University of Kansas Press, Lawrence, 442 pp.
- Müller, G.V., 1908. Die Ostracoden der Deutschen Südpolar-Expedition 1901–1903. *Deutsche Südpolar Expedition*, 10. Zoologische 2, 51–181.
- Murray, W., 1991. *Ecology and Paleocology of Benthic Foraminifera*. Longman, Wiley, Harlow/Essex, New York, 397 pp.
- Ponce, F., Rabassa, J., Coronato, A., Borromei, A., 2011. Paleogeographic evolution of the Atlantic coast of Pampa and Patagonia since the Last Glacial Maximum to the middle Holocene. *Biological Journal of the Linnean Society* 103, 363–379.
- Ponder, W.F., Worsfold, T.M., 1994. A review of the rissiform gastropods of southwestern South America (Mollusca, Gastropoda). In: *Contributions in Science*, vol. 445. Natural History Museum of Los Angeles County, pp. 1–63.
- Porter, S., Heusser, C.J., Stuiver, C., 1984. Holocene sea-level change along the Strait of Magellan and Beagle Channel, southernmost America. *Quaternary Research* 22, 59–67.
- Rabassa, J., Heusser, C.J., Stuckenrath, R., 1986. New data on Holocene sea transgression in the Beagle Channel: Tierra del Fuego, Argentina. *Quaternary of South America and Antarctic Peninsula* 4, 291–309.
- Rabassa, J., Serrat, D., Heusser, C., Martí, C., Coronato, A., 1990b. The Termination of the Pleistocene in the Beagle Channel, Southernmost America. IGCP 253. The Termination of the Pleistocene, Field Conference. Norway Sweden and Finland, May 1990. Extended Abstracts.
- Rabassa, J., Serrat, D., Martí Bono, C., Coronato, A.M., 1990a. Internal structure of drumlins in Gable Island, Beagle Channel, Tierra del Fuego, Argentina. *LUND-QUA Report* 32, 3–6. Lund, Suecia.
- Rabassa, J., Coronato, A., Bujalesky, G., Salemme, M., Roig, C., Meglioli, A., Heusser, C., Gordillo, S., Roig, F., Borromei, A., Quattrocchio, M., 2000. Quaternary of Tierra del Fuego, southernmost South America: an updated review. *Quaternary International* 68–71, 217–240.
- Rabassa, J., Coronato, A., Roig, C., Martínez, O., Serrat, D., 2004. In: Blanco Chao, R., López Bedoya, J., Pérez Alberti, A. (Eds.), *Un bosque sumergido en Bahía Sloggett, Tierra del Fuego, Argentina: evidencias de comportamiento tectónico diferencial en el Holoceno tardío. Procesos geomorfológicos y evolución costera*. Universidad de Santiago de Compostela, 2° Reunión de Geomorfología Litoral, Actas 333–346. Santiago de Compostela.
- Rabassa, J., Gordillo, S., Ocampo, C., Rivas Hurtado, P., 2008. The southernmost evidence for an interglacial transgression (Sangamon?) in South America. First record of upraised Pleistocene marine deposits in Isla Navarino (Beagle Channel, Southern Chile). *Geológica Acta* 6, 251–258.
- Rabassa, J., Coronato, A., Gordillo, S., Candel, M., Martínez, M., 2009. Paleoambientes litorales durante la trasgresión marina Holocena en Bahía Lapataia, Canal Beagle, Parque Nacional Tierra del Fuego, Argentina. *Revista de la Asociación Geológica Argentina* 65, 648–659.
- Rabassa, J., 2008. Late Cenozoic glaciations in Patagonia and Tierra del Fuego. In: Rabassa, J. (Ed.), *The Late Cenozoic of Patagonia and Tierra del Fuego*. *Developments in Quaternary Science*, vol. 11, pp. 151–204. Amsterdam.
- Ramolino, L., 1968. Pelecypoda del fondo de la Bahía Valparaíso. *Revista de Biología Marina* 13, 175–285.
- Reid, D.G., Osorio, C., 2000. The shallow-water marine Mollusca of the Estero Elefantes and Laguna San Rafael, southern Chile. *Bulletin of the Natural History Museum, London (Zoology)* 66, 109–146.
- Reimer, P., Reimer, R., 2000. Marine Reservoir Correction Database. <http://calib.org/marine>.
- Sievers, H., Silva, H., 2008. Waters masses and circulation in austral Chilean channels and fiords. In: Silva, N., Palma, S. (Eds.), *Progress in the Oceanographic Knowledge of Chilean Inner Waters, from Puerto Montt to Cape Horn*. Comité Oceanográfico Nacional - Pontificia Universidad Católica de Valparaíso, Valparaíso, pp. 53–58.
- Skogsberg, T., 1928. *Studies on Marine Ostracods. External Morphology of the Genus Cythereis with Descriptions of Twenty-one New Species. Part II*. San Francisco, Occasional Papers of the California Academy of Sciences. 154 pp.
- Stuiver, M., Reimer, P.J., 1993. Extended ¹⁴C database and revised Calib radiocarbon calibration program. *Radiocarbon* 35, 215–230.
- Tóthmérész, B., 1995. Comparison of different methods for diversity ordering. *Journal of Vegetation Science* 6, 283–290.
- van Morkhoven, F.P.C.M., 1963. *Post-paleozoic Ostracoda, their Morphology, Taxonomy and Economic Use*, vol. 1. Elsevier, Amsterdam, 204 pp.
- Velasco, L.A., Navarro, J.M., 2003. Energetic balance of infaunal (*Mulinia edulis* King, 1831) and epifaunal (*Mytilus chilensis* Hupé, 1854) bivalve in response to wide variations in concentration and quality seston. *Journal of Experimental Marine Biology and Ecology* 296, 79–92.
- Violanti, D., Loi, B., Melis, R., 2000. Distributio of Recent Foraminifera from the Strait of Magellan. First quantitative data. *Bollettino del Museo Regionale di Scienze Naturali Torino* 17, 511–539.
- Whitley, R.C., Cusiminsky, G.C., 2002. Upper Pliocene ostracoda from the Burdwood Bank, SW Atlantic. *Revista Española de Micropaleontología* 34, 53–80.
- Whitley, R.C., Moguilevsky, A., 1975. The family Leptocytheridae in Argentine waters. *Biology and Paleobiology of Ostracoda. Bulletins of American Paleontology* 65, 501–527.
- Whitley, R.C., Chadwick, J., Coxill, D., Toy, N., 1987. New genera and species of Cytheracean Ostracoda from the SW Atlantic. *Journal of Micropaleontology* 6, 1–12.
- Whitley, R.C., Chadwick, J., Coxill, D., Toy, N., 1988. The Ostracod family Cytheruridae from the Antarctic and South-West Atlantic. *Revista Española de Micropaleontología* 20, 171–203.
- Whitley, R.C., Toy, N., Moguilevsky, A., Coxill, D., 1995. Ostracoda from the South West Atlantic Part I, the Falklands Islands. *Revista Española de Micropaleontología* 27, 17–38.
- Whitley, R.C., Ramos, M.I., Moguilevsky, A., Chadwick, J., 1996a. The provincial distribution of recent littoral and shelf ostracoda in the SW Atlantic. In: Crasquin-Soleau, S., Braccini, E., Lethiers, F. (Eds.), *What about ostracoda? 3er European Ostracodologist Meeting Paris Bierville (Francia)*, pp. 8–12.
- Whitley, R.C., Staunton, M., Kaesler, R., Moguilevsky, A., 1996b. The taxonomy of recent Ostracoda from the southern part of the Magellan Straits. *Revista Española de Micropaleontología* 28, 51–76.
- Whitley, R.C., Moguilevsky, A., Toy, N., 1997a. Ostracoda from the South west Atlantic. Part II. The littoral fauna from between Tierra del Fuego and the Río de La Plata. *Revista Española de Micropaleontología* 29, 5–83.
- Whitley, R.C., Staunton, M., Kaesler, R., 1997b. The depth distribution of recent marine Ostracoda from the southern Strait of Magellan. *Journal of Micropaleontology* 16, 121–130.
- Whitley, R.C., Moguilevsky, A., Chadwick, J., 1998. Ostracoda from the South West Atlantic, Part. III, the Argentinian, Uruguayan and Southern Brazilian continental shelf. *Revista Española de Micropaleontología* 30, 89–116.
- Wood, A.M., Ramos, M.I., Whitley, R.C., 1999. The paleozoogeography of Oligocene to Recent marine Ostracoda from the Neotropics (mid and South America) and Antarctica. *Marine Micropaleontology* 37, 345–364.
- Zapata, J.A., Alarcón, B., 1988. Foraminíferos Bentónicos del Estrecho de Magallanes (52° 33' S; 69° 54' W), Chile. *Biota* 4, 17–29.
- Zelaya, D., Gordillo, S., 2011. Fossil gastropods from raised marine deposits along the Beagle Channel, Southern Argentina: the ancestors of the living fauna. *Marine Biodiversity Records* 4. <http://dx.doi.org/10.1017/S1755267210001235>.
- Zelaya, D.G., Ituarte, C., 2004. The genus *Neolepton* Monterosato, 1875 in Southern South America (Bivalvia: Neoleptonidae). *Journal of Molluscan Studies* 70, 123–137.
- Zúñiga-Rival, M., 2006. Estudio preliminar de los foraminíferos bentónicos (Protozoa: Foraminiferida) de Bahía Yendegaya, Tierra del Fuego, Chile. *Anales Instituto Patagonia, Serie Ciencias Naturales* 34, 33–39.