Chapter

Quaternary Marine Mollusk Associations of the Last Interglacials in North Patagonia (Argentina): Paleoecology and Paleoclimates

M.P. Charó

Abstract

Deposits of different Quaternary marine transgressions are largely exposed in the Argentine north Patagonian littoral (39°15′S–41°02′S), south of the Buenos Aires and north of Río Negro provinces. The malacological associations of 84 sites were studied. Among them, 31 belong to Pleistocene deposits of the interglacials ≥ MIS 9, MIS 7, MIS 5e, 29 to Holocene deposits of the interglacial MIS 1, and 24 sites of modern beaches. These sites yielded 7385 fossils among valves and shells, of 78 species (42 bivalves and 36 gastropods), including 11 micromolluskan species. The record of the bivalves *Crassostrea rhizophorae* in the south of the Buenos Aires Province, and *Anomalocardia brasiliana* (both currently inhabiting lower latitudes), and very likely the gastropod *Tegula atra* (inhabiting today the Pacific Ocean) in the north of Río Negro Province, suggests that interglacials MIS 7, MIS 5e and MIS 1 were warmer than today. However, the associations determined for the studied interglacials have not changed in their composition, but in abundance of species, except for the latitudinal shifts of the three mentioned species, and the presence of cold to temperate water taxa since the MIS 1 in the ecotonal area of the north of Río Negro Province. Changes in the associations of northern Patagonia during the Quaternary derived from global changes (sea surface temperature, salinity, etc.), and the existence of habitat heterogeneity in each of the areas, that enabled the co-existence of different bivalve and gastropod species of the local benthic marine malacofauna.

Keywords: quaternary, mollusks, paleoenvironments, paleoecology, north Patagonia

1. Introduction

1.1 Quaternary in the world

The Quaternary is characterized worldwide by important climate oscillations, with extremes represented by glacial and interglacial periods resulting from temperature variations that caused marked changes in sea level (e.g., [1]). In coastal areas, transgressive-regressive events have generated a sequence of erosion forms (coastal terraces and paleocliffs) and beach deposits that, for different reasons, have been protected from degradation processes and are therefore an important testimony of climate changes that have occurred in most recent geologic time [2].

1.2 Glacial and interglacial cycles

In 1941, Milankovitch developed a planetary theory that attributes Quaternary glacial and interglacial cycles to modifications of orbital parameters such as eccentricity (100 Ka), obliquity (41Ka), and precession of the equinoxes (19 Ka).

Since the beginning of the Pleistocene, climatic oscillations would have followed periodic cycles of about 40 Ky that seem to conform the variation cycle of the earth axis. The amplitude of the cycles tended to increase 1.5 My ago, and from 600 Ka the glacial cycles have occurred at intervals of between 80 and 120 Ky (e.g., [3, 4]). This duration of the recent cycles is similar to the period of variation of the eccentricity of the earth orbit, of 100 Ky.

1.3 Marine isotopic stages (MIS)

The different glacial and interglacial events occurred during the Quaternary were differentiated through the marine isotope stages (MIS). These MIS represent alternate cold and warm periods established on the basis of δ180 of benthic foraminifers, obtained from cores of the sea bottom [5]. Emialiani [6] divided the last million years in successive isotopic stages on the basis of the δ180/δ160 relationship. Each isotopic stage represents a glacial period (designated with an odd number) or interglacial (designated with an even number), and reveal the advance and retreat of the ice during the last glaciations.

1.3.1 Interglacials in the world

Globally, the MIS 11 encompasses from 424 to 374 ka. It was a long warm period that reached a global mean sea level of 6 to 13 m above the present one between 410 and 400 ka [2]. Some authors (e.g., [7–9]) consider the MIS 11 as an analogous of the Holocene both in climatic conditions and orbital forcing. According to Ashton et al. [10] the climatic conditions in marine isotopic and ice sheet records include at least two large warm episodes with an intermediate cooling phase. The warm conditions of this interglacial were reflected in different marine and terrestrial communities (e.g., [9, 11, 12]).

MIS 9 encompasses from ca. 330 up to 310 ka and sea level was 3 ± 3 m below the present one [13]. In the Northern Hemisphere, at Henderson Island (24°22'S/128°20'W), the highest sea level recorded in MIS 9 is between 334 ± 4 and 324 ± 3 ka in agreement with the maximum sun insulation of 333 ka [14]. In the western Mediterranean (Spain) the sea surface temperature (SST) and the salinity recorded in this interglacial were similar to those of MIS 7 and MIS 5e [15], whereas other authors (e.g., [16]) suggested that according to paleontological evidence, this interglacial was warmer than MIS 7 and the Holocene, and similar to MIS 5e.

MIS 7 encompasses from ca. 245 up to 190 ka [17] with three temperature maximums [18]. Isotopic data of some deep sea cores suggest that the sea level would not have reached the level of the present cero [19, 20], although other authors suggest values around −18 m [17]. SST of this interglacial was higher than the present one [21–23]. In the European coasts, the marine deposits of MIS 7 record the appearance of the "Senegalese" marine fauna from the African coast, confirming this stage as warm in the Northern Hemisphere (e.g., [24–26]). Similar conditions are observed in the Southern Hemisphere: the SST of the southern Argentine Patagonia (42°–43°S) is proposed to be similar or slightly warmer than today on the basis of the record of warm water mollusks (e.g., [27, 28]).

MIS 5 in the substage e, is one of the most studied episodes, and best represented worldwide. It encompasses from ca. 130 ± 2 to 119 ± 2 ka [29] and the SST was approximately 2°C higher than the present one (e.g., [30, 31]). Comparing with other interglacials, MIS 5e has the best records of SST [18]. Evidence of warm water benthic mollusks, and changes in their geographic distribution was found in MIS 5e (e.g., [5, 26, 27, 32–48]).

MIS 1 encompasses the last 11.7 ka [49], when the last glaciation is considered to be ended [50]. There is an increase of the SST and humidity worldwide (e.g., [4, 51–56]) with some records in the Southern Hemisphere (e.g., [37, 49, 50, 57–59]). This phenomenon is reflected worldwide in the biotic communities with changes in composition, abundance, diversity and distribution (e.g., [60–62]).

In the Argentine Patagonian region, the stages MIS 11 to MIS 1 are represented, as well as ingressions older then MIS 11, but with poor records and fossil content [32].

2. Area of study

2.1 Quaternary marine deposits from the northern argentine Patagonia

Along the Argentine coast, broad extensions of the littoral of the Buenos Aires Province (BAP) and north Patagonia were affected by accumulation and erosion processes produced by sea level oscillations during Quaternary transgressions (e.g., [63, 64]).

Northern Patagonia has been divided into two regions according to their province. The first groups three areas of the south of the BAP (A-C) and record the presence of the interglacials ≥ MIS 9, MIS 5e and MIS 1 [5, 65, 66], and the other one belongs to region D, and records the presence of the interglacials ≥ MIS 9, MIS 7, MIS 5e, and MIS 1 (**Figure 1**).

In region A, from Peninsula Verde to Otero Island, the transgressive deposits have been assigned to the Sangamon (? Late Pleistocene), which are represented in the area of the Colorado River delta by paleocliffs associated with coast lines up to 10 m height [67]. These marine deposits are assigned to the oldest interglacials because of their geomorphological, altimetric and cementation similarity [68]. Among them, there are scarce, thin, and isolated deposits on the continent which are assigned to ≥ MIS 9 [68, 69].

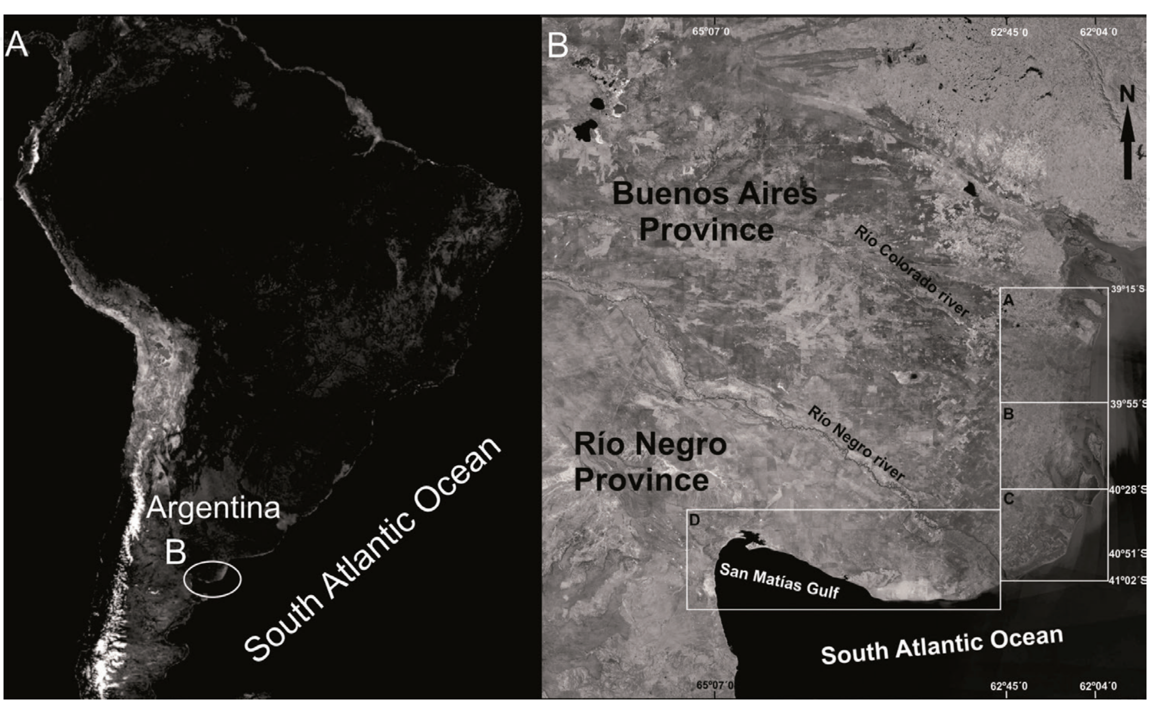

Figure 1.
(A) Map of study, and (B) four areas in the northern Patagonia in Argentina.

The terminal area of the delta is formed by the marine deposits of the MIS 1 ingression, which are beach ridges or intertidal environments [68].

In region B, which extends from the Otero Island to near the Jabalí Island, Weiler [70] correlated the Pleistocene and Holocene marine deposits of the central area with three transgressive events of the Late Pleistocene and Holocene, and related them to environments of barriers and coastal lagoons of the transgression of the Sangamon interglacial (with a minimum age of 43 Ka), the interstadial transgression of the middle Wisconsin (38.5 to 25 Ka), and the postglacial transgression of the MIS 1 (middle Holocene, between 5 and 5.2 Ka). More recently, Schnack et al. [71] related the oldest deposits of the area described by Weiler [43] with the Interglacial MIS 5e, considering the radiocarbon datings as minimum ages.

In region C, from the Jabalí Island up to Villa 7 de Marzo, Fucks et al. [68] reinterpreted the stratigraphic sequences, assigning a minimum of four transgressive cycles. Beach ridges, as well as beach strand plains and tidal plains, with maximum altitudes of 6 m a.s.l. and very clear morphologies are present from the coast to the present day continent, particularly in Isla Jabalí. Above them, at altitudes of 8 to 10 m a.s.l. that increase gradually to over 30 m a.s.l., clear ridges could be probably related to MIS 5e. These could have been originated in two ≥ 9 transgressive events.

In region D, north of San Matías Gulf from near the El Cóndor beach up to Las Grutas beach, there are records of the interglacials MIS 7, MIS 5e and MIS 1 plus a fourth one, 60 m height, that probably corresponds to an interglacial ≥ MIS 9. According to Fucks et al. [72] the deposits of interglacials MIS 7 and MIS 5e correspond to Baliza San Matias and San Antonio formations, respectively, and those of Holocene age have no designation.

The main geomorphological features are littoral ridges formed by high energy conditions, although, deposits corresponding to intertidal environments, coastal lagoons, spit sand cliffs forms have been described mainly for the Holocene transgressive event as well (e.g.,[5, 68, 72–75]).

All these deposits contain marine mollusks, particularly gastropods and bivalves (**Figure 2**) (**Table 1**) [5, 35–37, 65, 82].

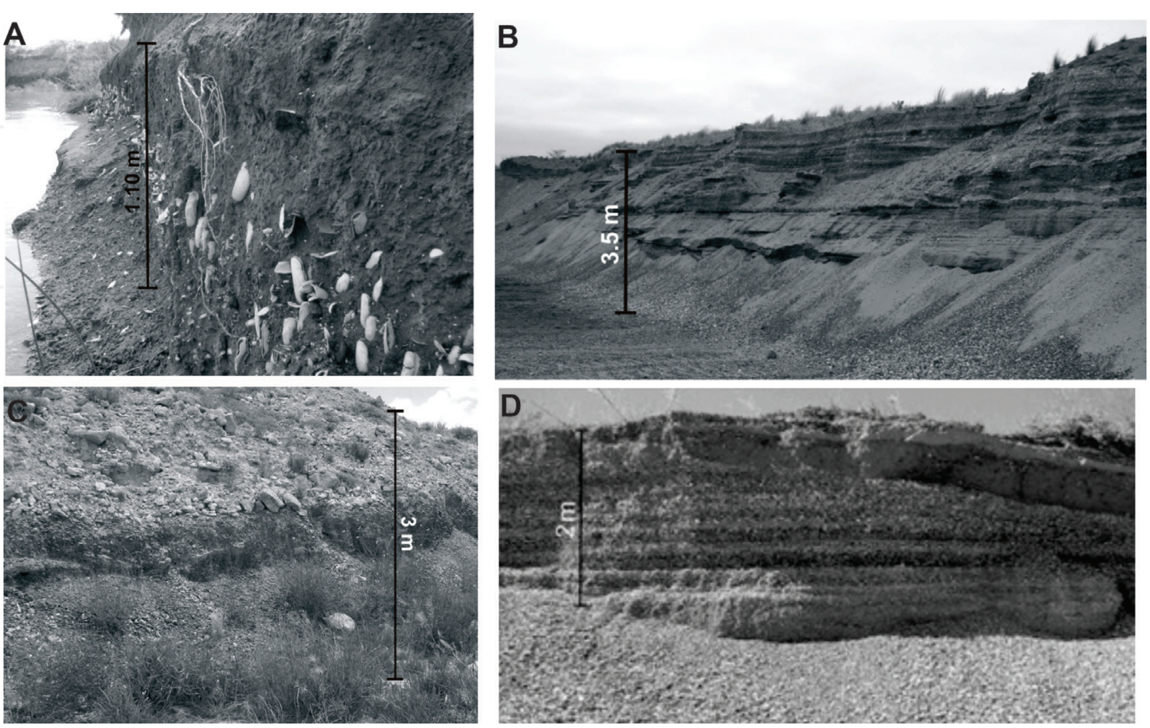

Figure 2.
(A) Profile of Holocene deposit with Tagelus plebeius *in life position (region a, MIS 1); (B) Holocene littoral ridge in canal Villalonga (region B, MIS 1); (C) Pleistocene outcrops near Cardenal Cagliero locality (region C, MIS 9) and (D) Holocene cliff near San Antonio Este Harbor (region D, MIS 1).*

DOI: http://dx.doi.org/10.5772/intechopen.99221

Province	Área	Coordinates (Lat-long)	Sites	Ages (14C and ESR)	Altitude (m.a.m.s.l)	Cites
South of Buenos Aires	Delta del río Colorado	39°20′S;62°04′W–39°55′S;62°08′W	P. Verde (39°21′S;62°5.9′W)	2170 ± 86 ka	5–2.5	[76]
			Pta Laberinto – rio Colorado Viejo (39°30′S–39°50′S)	6.63 ± 0.12 ka–0.409 ± 0.10 ka	10–7.5 7.5 and 2	[74]
			Sur del río Colorado viejo (39°53′S; 62°10′W)	9.46 ± 0.12 ka–0.407 ± 0.10 ka	5–2.5	[74]
	Bahía Anegada	39°55′S;62°08′W–40°28′S;62°11′W	Pleistocene deposits (40°03′S–40°26′S)	43 ka, 38.55 ka, 25 ka	40–25	[70, 77]
				43 ka, 38.8 ka, 31 ka	10–7	[75]
			Canal Villalonga (40°1′S; 62°19′W)	5.98 ± 0.10 ka–3.69 ± 0.10 ka	4–2.5	
			Los Pocitos (42°25′S; 62°25′W)	4.4 ± 0.08 and 4.5 ± 0.09 ka	3	[72, 74, 78]
	Isla Jabalí – Villa 7 de marzo	40°36′S;62°11′W–41°1′S;62°45′W	Oeste de isla Jabalí (40°40′S;62°30′W)	30.78 ± 1.65 ka–28.4 ± 0.80 ka	3–9.5	[75, 79]
			Isla Jabalí (40°34′S;62°13′W)	5. 37 ± 0.11 ka-2.17 ± 0.11	4–5	[37]
			Faro Segunda Barranca (40°46′S;62°16′W)	102–108 ka 94.5, 79 and 72.7 ka 28 a 40 ka	8–10	[80, 81]
Northern of Rio Negro	Norte del golfo San Matías	40°51′S;65°7′W–41°02′S; 62°49′W	Caleta Falsa correlation with localities: south of Piedras Coloradas	≥230 and ≥169 ka	8–12	[80, 81]
			Baliza San Matias (40°42′S; 64°51′W)	97.3–83 ka	8	[73]
			La Rinconada (40°41′S;65°9′W)	107–91 ka	10	
			Las Grutas (40°48′S;65°4′W)	70.3–66.8 ka	10	
			La Conchilla (40°49'S/64°52'O)	2.43 ± 0.60 ka	1.50	[5]

Table 1.
Absolute dating available from the study área.

3. Materials and methods

3.1 Methodology for marine mollusks associated with littoral deposits

A total of 84 localities were studied in two areas, 31 Pleistocene, 29 Holocene, and 24 modern ones. In these localities 7385 valves and shells of mollusks were collected. Each coastal deposit to be studied is identified on topographic maps. At each level of the site, a volumetric sample of 1 dm^3. In contrast, at modern beach sites the sample is taken in a quadrant 1 m x 1 m along transects perpendicular to the coast line.

Each fraction of biogenic content recovered from the sieves (2.80, 1.40 and 0.080 mm) was identified, measured with digital caliper, and labeled. Species were identified through catalogs and specific literature.

Valves and shells found in the marine deposits are considered as assemblages representing the accumulation of non-contemporary individuals in a single set, and occurs because the time of generation of these individuals is faster than the burial rates. In this context, it has to be taken into account the changes produced during the transition of the animal remains from the biosphere to the lithospere, which is studied through a discipline called taphonomy (etymologically derived from the Greek taphos, tomb, and nom, law). Taphonomy was defined by Efremov [83] as the science that studies the laws of burial, and accepted that taphonomic processes lead to the loss of information and are the cause of gaps in the fossil record. Currently this concept has been reversed since numerous studies (e.g., [84–87]) support the idea that the faunal associations of both current and fossil valves provide relevant information on living communities, or paleocommunities, being able in both cases to reconstruct the environments or paleoenvironments from the analysis of the faunal associations and thus interpret environmental and climatic changes.

The studied mollusks form transported faunal associations, which, according to different authors, preserve compositional fidelity concerning taxonomy and relative abundance of the communities that inhabited each environment within the considered period, and represent the accumulations of non-contemporary individuals as a whole.

4. Results

4.1 Marine malacology of northern Patagonia

The four areas identified in northern Patagonian according to their geomorphology (A-D), in which 84 sites were studied, yielded 78 species (42 bivalves and 36 gastropods). Eleven of them are micromollusks: *Heleobia australis*, *Olivella tehuelcha*, *Parvanachis isabellei*, *Turbonilla argentina*, *Turbonilla paralaminata*, *Chrysallida multituberculata* (gastropods) and *Nucula nucleus*, *Ennucula grayi*, *Carditamera plata*, *Corbula patagonica*, and *Corbula lyoni* (bivalves) (**Tables 2** and **3**).

4.2 Malacological analysis

Seventy species were identified in areas A-C (37 bivalves and 33 gastropods), and 45 species in region D (19 bivalves and 24 gastropods), with a similarity of 51.3% in bivalve species and 48.5% in gastropods.

In areas A-C, all the studied sites assigned to the interglacial ≥ MIS 9, are paleobeaches and littoral ridges; i.e., high energy environments in which the marine fauna is euryhaline (salinity > 30–35 gr/l) and of sandy substrate. Warm water species prevailed in bivalve associations (50–67%) compared to the other interglacials recorded in the area. However, no bivalve or gastropod of warm lineage that constitutes itself a paleoindicator was found.

Bivalves	Salinity	Life habit	Depth (m)	Substrate	Trophic type	Distribution area
Nucula (N.) nucleus [88]	E	I	0–200	S	D	23°S–53.5°S
Ennucula grayi (d'Orbigny, 1846)[1]	E	I	5–1850	S	D	22.93°S–55.5°S
Adrana electa [89]	E	I	20–75	S	D	22.93°S–39°S*
Glycymeris (G.) longior [90]	E	I	10–75	S	Sf	10°S–42°S
Mytilus edulis platensis (d'Orbigny, 1846)[1]	P–E	Ep	0–50	H	Sf	68°N–55.5°S
Brachidontes (B.) rodriguezii (d'Orbigny, 1846)[1]	P–E	Ep	0–25	H	Sf	34°S–42°S
Aulacomya atra [91]	E	Ep	0–30	H	Sf	34°S–55.5°S
Aequipecten tehuelchus (d'Orbigny, 1842)[1]	E	Ep	10–120	M	Sf	21°S–42.58°S
Atrina seminuda [92]	P–E	Ce	0–3	H	Sf	35°N–35°S*
Plicatula gibbosa [93]	E	Ce	0–120	H	Sf	35.3°N–34°S*
Ostreola equestris [94]	P–E	Ce	0–80	H	C	37°N–42°S
Ostrea puelchana (d'Orbigny, 1841)[1]	P–E	Ce	0–70	H	C	22°S–42°S
Crassostrea rhizophorae [95]	P–E	Ce	0–50	H	C	21.4°S–35°S
Crassostrea gigas [96]	E	Ce	0–40	H	Sf	Cosmopolitan
Diplodonta (D.) patagonica (d'Orbigny, 1842)[1]	E	I	36–102	S	Sf	21°S–42.58°S
Diplodonta (F.) vilardeboana (d'Orbigny, 1846)[1]	E	I	25–77	S	Sf	21°S–42°S
Carditamera plata [97]	E	I	17–70	S	Sf	23°S–39°S*
Trachycardium muricatum [88]	E	I	0–11	S	Sf	35°N–42°S
Mactra guidoi [98]	P–E	I	0–25	S	Sf	34°S–42°S
Mactra isabelleana (d'Orbigny, 1846)[1]	P–E	I	0–25	S	Sf	23°S–42°S
Raeta (R.) plicatella [99]	P–E	I	0–11	S	Sf	39°N–41°S
Mesodesma mactroides [100]	E	I	0–20	S	Sf	23°S–41°S
Solen tehuelchus [101]	E	I	10–18	S	Sf	23°S–39°S*
Macoma (P.) uruguayensis [102]	E	I	18–70	S	D	29°S–39°S*
Angulus gibber [97]	E	I	13–55	S	D	23°S–43°S
Abra (A.) aequalis [94][1]	E	I	0–50	S	D	35°N–23°S*
Tagelus (T.) plebeius [103]	P	I	0–10	S	Sf	42°N–54°S
Tivela isabelleana (d'Orbigny, 1846)[1]	E	I	0–55	S	Sf	21°S–42°S
Anomalocardia brasiliana [104]	P–E	I	0.3–5	S	Sf	18°N–39°S*
Pitar (P.) rostratus (Philippi, 1844)[1]	E	I	10–100	S	Sf	22°S–38.7°S*
Amiantis purpurata (Dillwyn, 1817)[1]	E	I	0–20	S	Sf	19°S–43°S
Retrotapes exalbidus [105]	E	I	50–70	S	Sf	34°S–55.5°S

Bivalves	Salinity	Life habit	Depth (m)	Substrate	Trophic type	Distribution area
Ameghinomya antiqua [106]	E	I	5–50	S	Sf	34°S–54°S
Panopea abbreviata (Valenciennes, 1839)[1]	E	I	25–75	S	Sf	23°S–48°S
Corbula (C.) patagonica (d'Orbigny, 1846)[1]	E	I	15–90	S	Sf	23°S–43°S
Corbula (C.) lyoni [107]	E	I	11–67	S	Sf	19°S–43°S
Cyrtopleura (S.) lanceolata (d'Orbigny, 1846)[1]	E	I	10–27	S	Sf	6°S–42°S
Barnea lamellosa (d'Orbigny, 1846)[1]	E	I	15–150	R	Sf	34°S–43°S
Lyonsia (L.) alvarezii (d'Orbigny, 1846)[1]	E	I	50–86	S	Sf	38.3°S–41°S
Periploma ovatum (d'Orbigny, 1846)[1]	E	I	?	S	Sf	35°S–40.5°S
Thracia similis [108]	E	I	50–86	S	Sf	22°S–42.58°S

Ep, epifaunal; I, infaunal; Ce, cemented; H, hard; S, soft; C, carnivorous; D, detritivorous; He, herbivore; Sf, suspension feeder; O, oligohaline (3–8‰); M, mesohaline (8–18‰); P, polyhaline (18–30‰); E, euhaline (>30–35‰).
[*]Taxa found in the studied area.
[1]The references of species are found on MolluscanBase eds(2021).

Table 2.
Ecological requeriments and distribution of bivalves.

Interglacial MIS 5e is represented in all the studied sites mostly by littoral ridges in which most associations are euryhaline, of sandy substrate and subordinate rocky substrate. Most species are epifaunal except in region A, prevailing filter feeders and carnivores. The proportion of warm water species in this interglacial is lower than in the previous one (44–50%) being outstanding the record of the warm lineage bivalve *Crassostrea rhizophorae*, excellent paleoindicator. In region D, this proportion is only 27% of the bivalves.

Interglacial MIS 1 was recorded in the whole study area, with two types of deposits in areas A-C: littoral ridges (high energy environments) and tidal plains (low energy environments). In the first ones, the malacofaunal associations are mostly euryhaline, of sandy substrates. In the second ones instead, the associations vary in salinity from oligohaline to mesohaline-polyhaline (salinity between 3 and 30 gr/l), of fine sand substrate, mostly epifaunal and filter feeders prevailing infaunal and carnivores in region A. This latter would be related to the modern geomorphological features of low energy environments (wide tidal plains, tidal channels and non-functional fluvial courses), that resulted in the formation of islands which can be seen in all the southern coast of the Buenos Aires Province. This interglacial MIS 1 is recognized in area D in littoral ridges, being the malacofaunal associations mostly euryhaline, of sandy substrate with rocky subordinate. In the associations of MIS 1 there is 45 to 50% of warm water species in areas A-C, unlike areas D in which this proportion is only 18% of the total bivalves.

In modern beaches of the south of BAP, but not in the northern sector of Bahía Anegada there are sandy beaches together with mud-sandy ones, and malacofaunal associations correspond to marine parameters of high energy, euryhaline of sandy substrate with scattered rocky substrate, mainly in area C. Instead, the modern

Gastropods	Salinity	Life habit	Depth (m)	Substrate	Trophic type	Distribution area
Nacella (P.) magallanica [104]	E	Ep	0–200	H	He	38.5°S–55.5°S
Diodora (D.) patagonica (d'Orbigny, 1841)[1]	E	Ep	0–15	H	He	11°N–45°S
Fissurella radiosa radiosa (Lesson, 1831)[1]	E	Ep	0	H	He	48°S–55°S
Lucapinella henseli [109]	E	Ep	0–55	H	He	23°S–
Calliostoma carcellesi (Clench and Aguacho, 1940)[1]	E	Ep	0–60	S	He	40.37°S–41.67°S
Calliostoma coppingeri [110]	E	Ep	13–86	S	He	30°S–44.21°S
Tegula (A.) patagonica (d'Orbigny, 1835)[1]	E	Ep	0–57	H	He	23°S–54°S
Tegula atra (Lesson, 1830)[1]	E	Ep	0–9	H	He	38°S–55°S
Bostrycapulus odites [111]	E	Ep	0–46	H	Sf	25°S–45.8°S
Crepidula argentina [112]	E	Ep	30–50	H	Sf	38°S–41.03°S
Crepidula dilatata [113]	E	Ep	0–66	H	Sf	35°S–55.8°S
Notocochlis isabelleana (d'Orbigny, 1840)[1]	E	I	0–113	S	C	22.4°S–42.58°S
Heleobia australis (d'Orbigny, 1835)[1]	O, P, M	Ep	0–60	M	He	24°S–41°S
Epitonium (E.) georgettinum (Kiener, 1838)[1]	E	Ep	0–101	M	He	23.37°S–44.27°S
Epitenium striatellum (Nyst, 1871)[1]	E	Ep	30	M	He	23°S–41°S
Trophon patagonicus (d'Orbigny, 1839)[1]	E	Ep	0–50	H	C	32°S–40°S
Trophon geversianus [114]	E	Ep	0–58	H	C	36.42°S–54.98°S
Urosalpinx cala [107]	E	Ep	28–28	H	C	32°S–41°S
Zidona dufresnei [115]	E	Ep	10–90	S	C	23°S–42°S
Adelomelon (P.) brasiliana [116]	E	Ep	0–250	S	C	23°S–52°S
Adelomelon beckii [117]	E	Ep	40–75	S	C	20° S–52°S
Odontocymbiola magallanica [104]	E	Ep	10–200	M	C	35°S–55.2°S
Marginela martini (Petit, 1853)[1]	E	Ep	10–80	S	C	22.93°S–42°S
Olivella (O.) tehuelcha [118]	E	Ep	15–57	S	C	23.69°S–43°S
Olivancillaria urceus (Röding, 1798)[1]	E	Ep	5–50	S	C	19°S–42°S
Olivancillaria carcellesi [119]	E	Ep	0–22	S	C	23°S–42.5°S
Olivancillaria uretai [119]	E	Ep	0–30	S	C	23°S–40.6°S
Buccinanops monilifer [120]	E	Ep	0–50	S	C	35°N–42°S

Gastropods	Salinity	Life habit	Depth (m)	Substrate	Trophic type	Distribution area
Buccinanops cochlidium [105]	E	Ep	5–66	S	C	23°S–42.58°S
Buccinanops globulosus [120]	E	Ep	0–6	S	C	35°S–46°S
Buccinanops uruguayensis [107]	E	Ep	15–45	S	C	24°S–42°S
Parvanachis isabellei (d'Orbigny, 1839)[1]	E	Ep	10–65	S	C	30°S–54°S
Costoanachis sertulariarum (d'Orbigny, 1839)[1]	E	Ec	0–20	S	C	35°N–54°S
Turbonilla argentina [121]	E	Ec	18–57	S	C	35°S–41°S
Turbonilla paralaminata [122]	E	Ec	30–65	S	C	39°S–41°S
Chrysallida multituberculata [122]	E	Ec	30–65	S	C	40°S–46°S
Siphonaria lessoni [123]	E	Ep	0	H	He	32°S–55.22°S

Ep, epifaunal; I, infaunal; Ce, cemented; Ec, ectoparasite; H, hard; S, soft; M, mixed; C, carnivorous; D, detritivorous; He, herbivore; Sf, suspension feeder; O, oligohaline (3–8‰); M, mesohaline (8–18‰); P, polyhaline (18–30‰); E, euhaline (>30–35‰).
[1]*The references of species are found on MolluscanBase eds(2021).*

Table 3.
Ecological requeriments and distribution of gastropods.

beaches of area D are larger often exceeding hundreds of meters wide. There are two types of beaches regarding the granulometry: a low intertidal sector of fine to medium sand with high distal sectors of gravels, organogenic in composition, and a low intertidal sector and high distal one of fine-medium sand. Both are associated with high energy environments where the malacological associations are mostly euryhaline, of sandy substrate, with less proportion of fauna of scattered rocky substrate. There is one exception, the modern beach of Villa 7 de Marzo which has a particular feature, fine sand substrate with abundance of two bivalves *Plicatula gibbosa* and *Ostrea puelchana*, and the gastropod *Crepidula*, which could be due to the influence of the Negro River. This is also observed in the southern area of this river, in El Cóndor Beach, which has a similar environment and the same mollusks. The modern malacofaunal associations bear 33 to 50% of warm water species in regions A-C, and 31% in area D.

In area D, all the analyzed sites of MIS 7 correspond to paleobeaches. They are currently represented by coastal platforms, of high energy, with mostly euryhaline malacofaunal associations of sandy substrate and subordinated rocky substrate. Respect to the indicators of sea water temperature, these associations are formed only by 20% of warm water bivalves, although it is recorded the gastropod *Tegula atra*, probably indicator of warm water.

In MIS 5e there is a slightly higher proportion of associations of warm waters (27%) with respect to the previous interglacial, being conspicuous the presence of *Anomalocardia brasiliana* and *Tegula atra*, the first one an excellent paleoindicator, and quite probably also the second one.

In MIS 1 the associations of warm water are in lesser proportion than those of MIS 5e (18%), being outstanding the record of *Mesodesma mactroides*. The bivalves *Aulacomya atra*, *Retrotapes exalbidus*, *Ameghinomya antique* and the gastropods *Fisurella radiosa radiosa* and *Crepidula dilatata* are recorded in the beaches of Río

Negro Province. These species have not been described in the modern marine malacofauna of areas A-C (**Figures 3–6**).

4.3 Warm water bivalves and gastropods

4.3.1 Interglacials ≥ MIS 9 and MIS 7

These two interglacials recorded in area D were not recorded in the northeast of BAP. In areas A-C, a total of nine species of mollusks were recorded in the

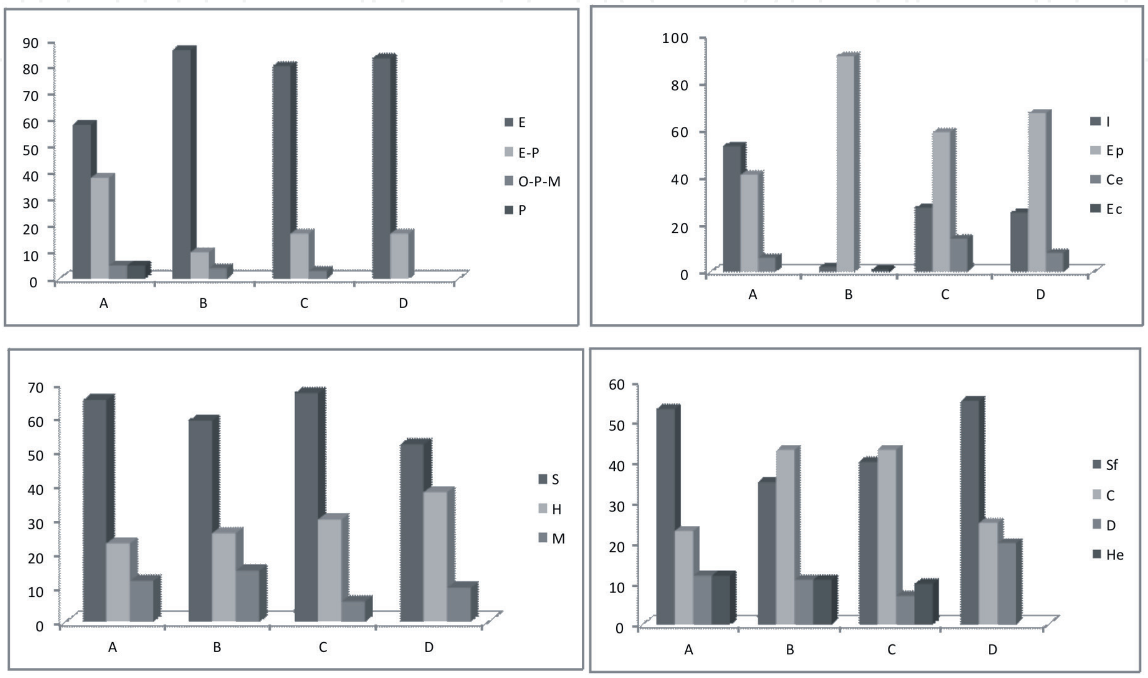

Figure 3.
Paleoecological features of all regions (A–D) in interglacial MIS 5e.

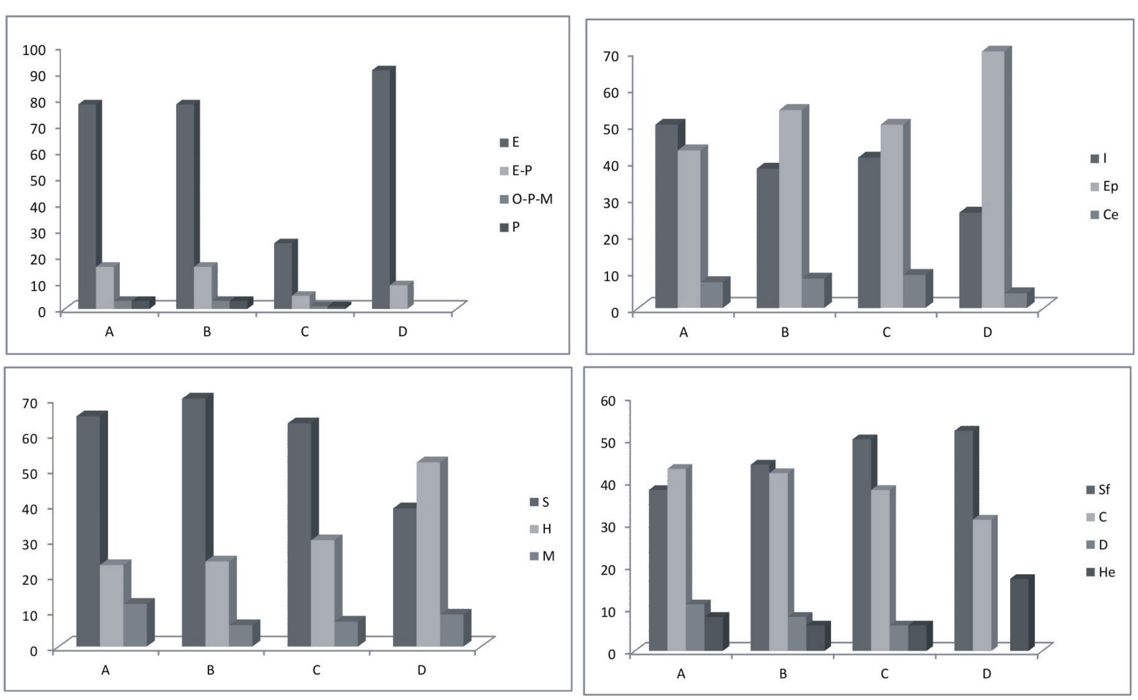

Figure 4.
Paleoecological features of all regions (A–D) in interglacial MIS 1.

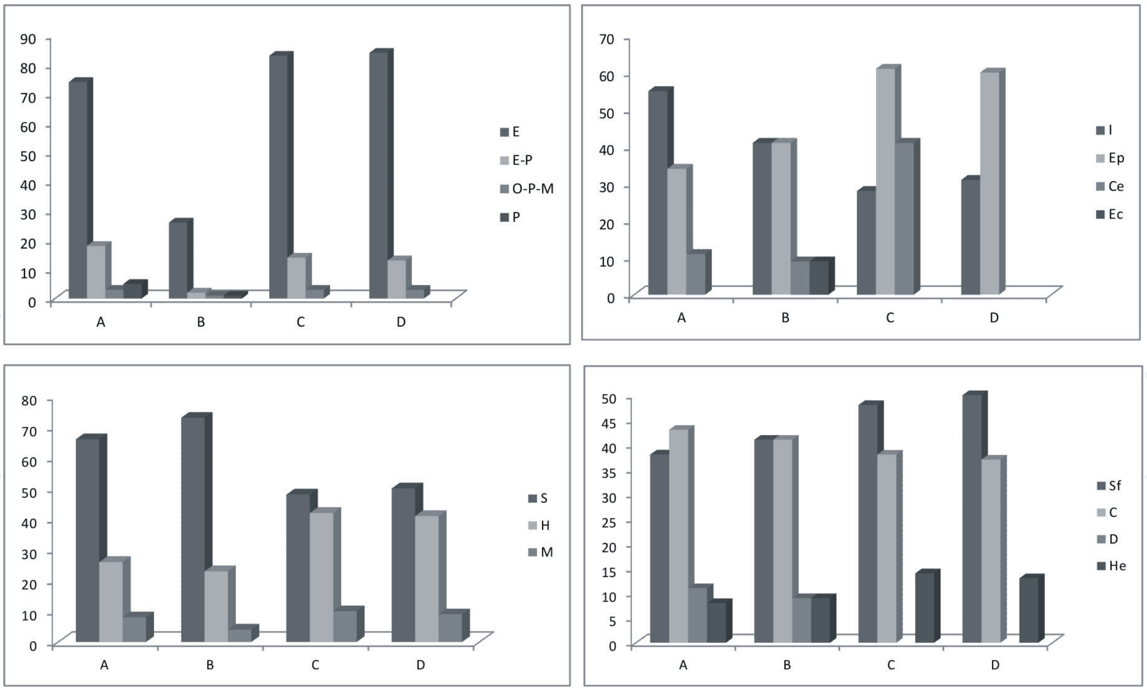

Figure 5.
Paleoecological features of all regions (A–D) in modern beaches.

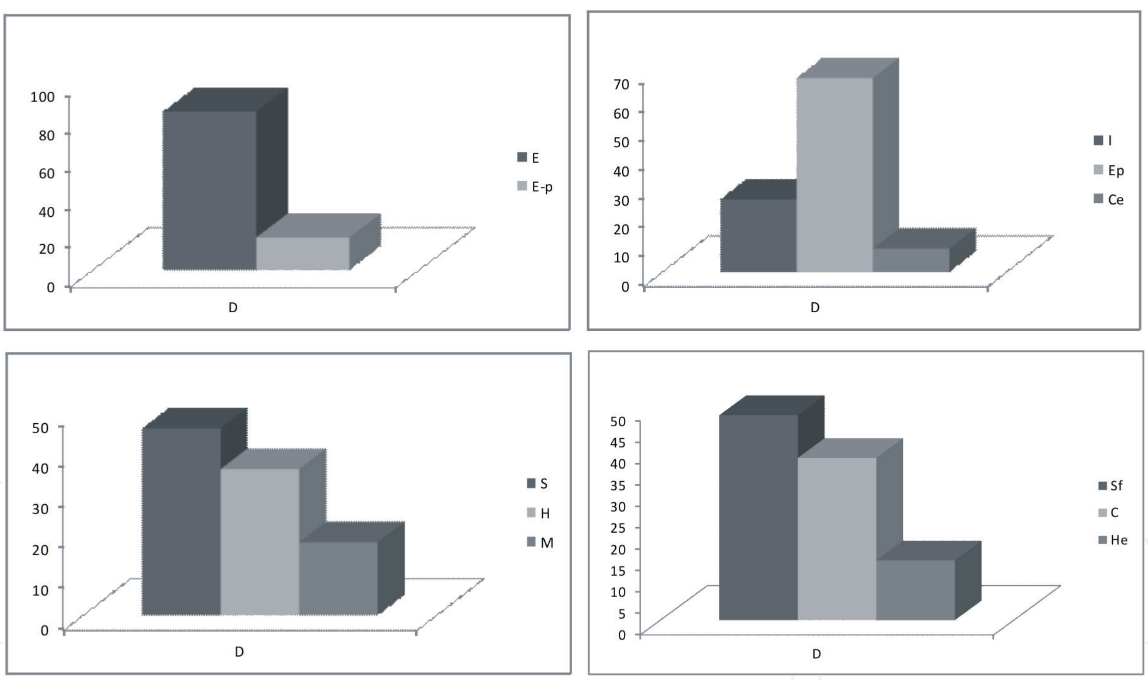

Figure 6.
Paleoecological features of region D in interglacial MIS 7.

Interglacial ≥ MIS 9, and among them, there is 50–67% of warm water species of bivalves, being this the oldest record of marine mollusks for the BAP. In MIS 7 analyzed in area D, a total of 11 species was recorded with 20% of warm water bivalves. Most recorded species in both interglacials still inhabit the modern coasts of Argentina, except for the gastropod *Tegula atra*, absent since the MIS 1.

Both interglacials (≥MIS 9 and MIS 7) revealed the presence of warm water mollusks which are not recorded in the marine deposits of the northeast of BAP where these deposits have not been preserved [124]. The record of these interglacials in the BAP is a novelty in the analysis of gastropods and bivalves. Whereas Aguirre et al. [27, 28] reported that in the coasts of southern Patagonia, in areas such as Bahía Vera-Camarones (44.2° to 45°S) and Bahía Bustamente-Caleta Olivia (44.9°–45.3°S, Chubut Province, Argentina), the environmental conditions (substrate, depth, and energy conditions) during the late Pleistocene (MIS 7 and MIS 5e) suggest SST similar to those of the modern littoral and even slightly higher than present, recording faunas of warm to temperate waters.

4.3.2 Interglacial MIS 5e

In the marine deposits of this interglacial in area D, 44 molluskan species (25 bivalves and 19 gastropods) were recorded. These deposits are represented by littoral ridges and tidal plains along the south of the BAP coast, and by littoral ridges along area D, with scarce content of calcium carbonate, favoring the record of mollusks. In area C the associations of MIS 5e and MIS 1 have respectively 34 and 33 species. This similarity was also found in area D, in which 22 species were recognized for MIS 5e and 23 for MIS 1. Unlike area D, the mollusks of MIS 5e of the northeast of the BAP are characterized by less abundance and diversity of species related to those of the Holocene MIS 1 [32]. This could be due to a less representation of the Interglacial MIS 5e, and because most valves and shells of Pleistocene deposits are dissolved and/or crystallized, preventing the species identification.

Between 50 and 44% of warm water species of bivalves recorded in the Interglacial MIS 5e of area D, are represented in areas A-C, whereas this relationship is only 27% of the species from area D. Warm water mollusks were recognized in the study area, among the most prominent species of this interglacial, in areas A-C, is the bivalve *Crassostrea rhizophorae* (**Figure 7A**). This is a warm lineage species that inhabits currently the Caribbean, Venezuela, Surinam, and Brazil up to Uruguay, but is not recorded in the present Argentine coast. However, it is recorded as fossil in the northeast and south of the BAP in the MIS 5e (e.g., [33, 125]).

Another warm lineage species found in area D, is the bivalve *Anomalocardia brasiliana*, recorded in the area north of the Negro River (**Figure 7B**). This is the most austral record of the species in the Argentine coast. This species is distributed currently from the French Antilles (18°N) up to the coasts of Brazil (33°S), being an infaunal surface species able to support wide salinity ranges (e.g., [126, 127]).

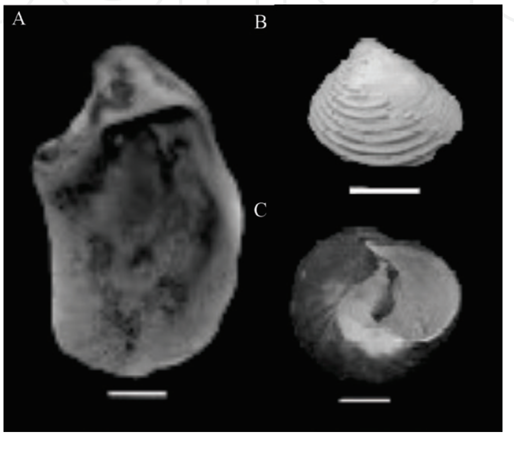

Figure 7.
The warm species of Pleistocene. (A) Crassostrea rhizophorae *(Guilding) (MLP: 34.012, MIS 5e, region B), (B)* Anomalocardia brasiliana *(Gmelin) (CEGH-UNC: 25.609. MIS 5e, region D) and (C) Tegula atra (lesson) (CEGH-UNC: 25.615, MIS 5e, region D).*

As fossil, it was found in Uruguay, both in the MIS 5e of the Nueva Palmira Formation [43] and in the Holocene of the Villa Soriano Formation [128]. In Argentina, this species is reported for marine deposits within the Pampiano Formation of Lomas de Zamora (34°46′S, northeast of BAP; [129]), as well as in the localities of Magdalena, Punta Piedras (BAP) and south of Entre Ríos Province [124]. This species was found in the Pleistocene deposits of Bahía Blanca (south of BAP) together with *Crassostrea rhizophorae* [33].

Tegula atra is distributed in intertidal and subtidal shallow rocky substrates, up to 6 m depth (**Figure 7C**) [130]. It is among the most abundant species of the Pleistocene of area D, and is well preserved in deposits of MIS 7 and MIS 5e [5] but it is not recorded in deposits of MIS 1. Whereas in the Pacific coast, *Tegula atra* is recorded in the late Pleistocene and Holocene deposits of the northern and southern coast of Peru (e.g., [131, 132]). In Chile, it is recorded in late Pleistocene deposits of Caleta Coloso (23°45′S/70°28′W), north and south of Antofagasta (23°37’ S) [45], as well as in archeological sites such as the late Pleistocene-middle Holocene of Quebrada de Lazareto (south of Chile) [133], middle and late Holocene of the IV Region, Los Vilos (e.g., [134]) and Holocene deposits of the Magellan Straight [135]. *Tegula atra* is currently distributed in the Pacific coasts from Pacasmayo (7°24′S, Peru) up to the Magellan Straight (53°S) [136], but there is no evidence of living specimens in the south Atlantic coasts.

4.3.3 Interglacial MIS 1

A total of 58 species (31 bivalves and 27 gastropods) was recorded in the marine malacofauna of the Interglacial MIS 1 of northern Patagonia (areas A-D), which differs from the northeast of BAP where Aguirre [89] reported a total of 62 species (25 bivalves and 37 gastropods). Concerning the molluscan composition, in the northeast of BAP, gastropods are more abundant than bivalves both in number of species and of individuals. As a comparison, among the regions studied, area A recorded 51 species (29 bivalves and 22 gastropods), and area B 49 species (25 bivalves and 24 gastropods), being in both regions, bivalves more numerous than gastropods. Whereas in area C, 34 species (17 bivalves and 17 gastropods) were recorded, unlike area D where 42 species (20 bivalves and 22 gastropods) were recorded, being in this latter the number of gastropods slightly higher than bivalves.

The marine deposits of MIS 1 in areas A-C are formed by tidal plains and littoral ridges. Tidal plains yielded mainly *Tagelus plebeius* among bivalves and *Heleobia australis* among gastropods. These species support variable salinity, being recorded in oligohaline–mesohaline–polyhaline associations (salinity between 3 and 30 gr/l), typical of low energy environments, most of them with low diversity indexes. In the littoral ridges, the diversity indexes are mostly higher than those of tidal plains. They yielded among bivalves *Pitar rostratus*, *Amiantis purpurata*, *Ostreola equestris*, and among gastropods *Buccinanops cochlidium* and *Heleobia australis*, typical of high energy environments.

The marine deposits and their malacofauna in the northeast and south (areas A-C) of the BAP are similar in the two types of deposits of the Interglacial MIS 1. The tidal plains are represented in regions A-C and are related to the development of the Colorado River and Bahía Anegada. The most common species are *Heleobia australis*, *Tagelus plebeius* (in life position) and *Corbula patagonica*, being similar to the marine malacofauna of the northeast of the BAP of the Canal 18 Member of the Las Escobas Formation (Holocene, MIS 1) and the estuarine facies of the Mar Chiquita Formation (**Figure 8**).

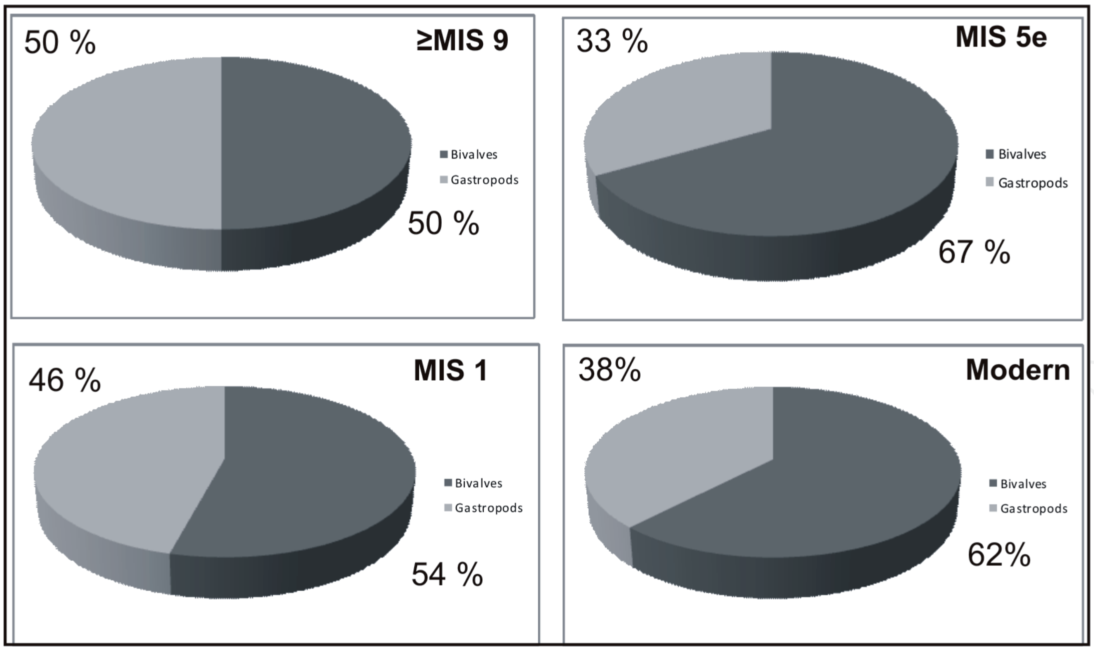

Figure 8.
Warm water vs. cold water during the quaternary in all regions (A–D).

5. Final comments

In the last 400.000 years there were variations in the molluskan paleocommunities of north Patagonia (southern BAP and north of Río Negro Province). The marine malacofauna of this area is composed by two associations, the first one is formed by Holocene sites with abundance of *Heleobia australis* and *Corbula patagonica*, and the other, mainly by Pleistocene sites and modern beaches with *Amiantis purpurata* as the most abundant, together with *Buccinanops globulosus*, *Bostrycapulus odites* and *Tegula patagonica*. The record of *Crassostrea rhizophorae*, *Anomalocardia brasiliana* and *Tegula atra*, in north Patagonia suggests that the interglacials MIS 7, MIS 5e and MIS 1 were slightly warmer than today. These latter species, except for *Tegula atra* live today in lower latitudes. However, the associations determined for the analyzed interglacials did not change concerning the faunal composition as a whole, and, except for the latitudinal changes of the three species mentioned above, and the record of temperate to cold water associations since the Interglacial MIS 1 in north Río Negro Province (ecotone), the composition remained similar, showing only changes in abundance of species.

Author details

M.P. Charó[1,2]

1 Servicio de Hidrografía Naval (CONICET), Caba, Argentina

2 Instituto Superior de Correlación Geológica (INSUGEO/CONICET-UNT), San Miguel de Tucumán, Argentina

*Address all correspondence to: charomelisa@gmail.com

References

[1] Rutherford, S. and D'Hondt, S., 2000. Early onset and tropical forcing of 100.000-year Pleistocene glacial cycles. Nature, 408, 72-75.

[2] Reyes, A. V.; Carlson, A. E., Beard, B. L., Hatfield, R. G., Stoner, J. S., Winsor, K., Elke, B. and Ullman, D. J. 2014. South Greenland ice-sheet collapse during Marine Isotope Stage 11. Nature, 510: 525-528.

[3] Raymo, M. E., Lisiecki, L. E., Nisancioglu, K. H. 2006. Plio-Pleistocene ice volume, Antarctic Climate, and the global d018 record. Science, 313, 492-495.

[4] Salvigsen, O.; Elgersma, A. and Landvik, J.Y. 1991. Radiocarbon dated raised beaches in northwestern Wedel Jarlsberg L and, Spitsbergen, Svalbard. Wyprawy Geograficzne na Spitsbergen, Lublin, Poland, 9-16.

[5] Charo, M. P., 2014. Caracterización paleoambiental y paleodiversidad malacológica en los depósitos marinos cuaternarios del norte patagonico (sur de Buenos Aires y Norte de Rio Negro). Facultad de Ciencias Naturales y Museo, La Plata, Argentina, 306.

[6] Emialiani, C., 1955. Pleistocene temperatures. Journal of Geology, 63, 538-578.

[7] De Abreu, L., Abrantes, F. F., Shackleton, N. J., Tzedakis, P. C., McManus, J. F., Oppo, D. W. and Hall, M. A., 2005. Ocean climate variability in the eastern North Atlantic during interglacial marine isotope stage 11: A partial analogue to the Holocene? Paleoceanography, 20. DOI:10.1029/2004PA001091.

[8] Loutre, M. F. and Berger, A., 2003. Marine isotope Stage 11 as an anologue for the present interglacial. Global Planet Change, 36: 209-217.

[9] Wu, N.; Chen, X., Rousseau, D. D., Li, F., Pei, Y. and Wu, B. 2007. Climatic conditions recorded by terrestrial mollusc assemblages in the Chinese Loess Plateau during marine Oxygen Isotope Stages 12-10. Quaternary Science Reviews, 26:1884-1896

[10] Ashton, N., Lewis, S. G., Parfitt, S. A., Penkman, K. E. M., Russel Coope, G. 2008. New evidence for complex climate Change in MIS 11 from Haxne, Suffolk, UK. Quaternary Science Reviews, 27: 652-668.

[11] Ortlieb L.; Guzman, N. and Marquardt, C. 2003. A Longer-Lasting and Warmer Interglacial Episode During Isotopic Stage 11: Marine Terrace Evidence in Tropical Western Americas. Earth's Climate and Orbital Eccentricity The Marine Isotope Stage 11 Question Geophysical Monograph, 137. DOI:10.1029/137GM12.

[12] Preece, R. C.; Parfitt, S. A., Bridgland, D. R., Lewis, S. G., Rowe, P. J., Atkinson, T. C., Candy, I., Debenham, N. C., Penkman, K. E. H., Rhodes, E. J., Schwenninger, J. L., Griffiths, H. I., Whittaker, J. E. and Gleed-Owen, C. 2007. Terrestrial environments during MIS 11: evidence from the Palaeolithic site at West Stow, Suffolk, UK. Quaternary Sciences review, 26 (9-10): 1236-1300. DOI:10.1016/j.quascirev.2006.11.016.

[13] Pedoja, K.; Regard, V., Husson, L., Martinod, J., Guillaume, B., Fucks, E., Iglesias, M. and Weill, P. 2011. Uplift of Quaternary shorelines in eastern Patagonia: Darwin revisited. Geomorphology, 127:121-142.

[14] Stirling, C. H.; Esat, T. M., Lambeck, K., Mc Culloch, M. T., Blake, S. G., Lee, D. C. and Halliday, A. N. 2001. Orbital Forcing of the Marine Isotope Stage 9 Interglacial. Science, 291 (5502): 290-293. DOI:10.1126/ Science.291.5502.290.

[15] Zazo, C.; Goy, J.L., Dabrio, C.J., Bardají, T., Hillaire-Marcel, C., Ghaleb, B., González-Delgado, J.A. and Soler, V. 2003a. Pleistocene raised marine terraces of the Spanish Mediterranean and Atlantic coasts: records of coastal uplift, sea-level highstands and climate changes. Marine Geology, 194: 103-133.

[16] Green, C. P., Branch, N. P., Coope, G. R., Field, M. N., Keen, D. H., Wells, J. M., Schwenniger, J. L., Preece, R. C., Schereve, C. D., Canti, M. G. and Gleed-Owen, C. D., 2006. Marine Isotope Stage 9 environments of fluvial deposits al Hackney, north London, UK. Quaternary Science Reviews, 25 (1-2): 89-113.

[17] Dutton, A., Bard, E., Antonioli, F., Esat, T. M., Lambeck, K. and McCulloch, M. T. 2009. Phasing and amplitude of sea-level and climate change during the penultimate interglacial. Nature Geoscience, 2: 355-359. DOI:10.1038/ngeo470.

[18] Lang, N. and Wolff, E. W. 2011. Interglacial and glacial variability from the last 800 ka in marine, ice and terrestrial archives. Climate of the Past, 7: 361-380.

[19] Ortlieb, L. 1987. Neotectonic and Quaternary sea level variations in the gulf of California region. Bulletin of the Inqua Neotectonic Commission, 10: 28-31.

[20] Shackleton, N. J. 1987. Oxyigen isotopes, ice volume and sea level: Quaternary Science Review, 6: 183-190.

[21] Desprat, S., Sanchez Groñi, M. F., Turon, J-L., Duprat, J., Malaizé, B. and Peypouquet, J. -P. 2006. Climatic variability of marine isotope stage 7: direct land-sea-ice correlation from a multiproxy analysis of a north-western Iberian margin deep-sea core. Quaternary Science Reviews, 25 (9-10): 1010-1026.

[22] Isla, F. I. and Bujalevsky, G. 2008. Coastal Geology and morphology of Patagonia and Fueguian Archipelago. In: Rabassa, J. R. (ed) The Late Cenozoic of Patagonia and Tierra del Fuego., Elsevier Sciences Publication of Chile, 10: 227-240.

[23] Shackleton, N. J.; Berger, A. and Peltier, W. R. 1990. An alternative astronomical calibration of the lower Pleistocene timescale based on ODP Site 677. Earth and Environmental Science Transactions of the Royal Society of Edinburgh, 81 (4): 251-261.

[24] Hillaire-Marcel, C., Carro, C., Causse, O., Goy, J. L. and Zazo, C. 1986. Th/U dating of *Strombus bubonius*-bearing marine terraces in southeastern Spain. Geology, 14: 613-329.

[25] Zazo, C. and Goy, J. L. 1989. Sea level changes in the Iberian Peninsula during Last 200.000 years. Late Quaternary Sea-Level correlation and applications (D. B. Scott, P. A. Pirazolli and A. Honing, eds), NATO ASI Series C, 256, Blackwell Publication, 27-39.

[26] Zazo, C.; Goy, J. L., Hillaire-Marcel, C., Dabrio, C. J., Gonzalez Delgado, J. A., Cabero, A., Bardají, T., Ghaleb, B. and Soler, V. 2010. Sea level changes during the last and present interglacial in SalIsland (Cape Verde archipelago). Global and Planetary Changes. DOI: 10.1016/j.gloplacha.2010.01.006.

[27] Aguirre, M. L., Negro Sirch, Y. and Richiano, S. 2005. Late Quaternary molluscan assemblages from the coastal area of Bahía Bustamante (Patagonia, Argentina): Paleoecology and paleoenviroments. Journal of South Earth Sciences, 20: 13-32.

[28] Aguirre, M. L., Richiano, S. and Negro Sirch, Y. 2007. Moluscos de terrazas marinas cuaternarias del área de Camarones, Patagonia. Bolletín de la Societat d'Història Natural de las Balears, 14: 81-120.

[29] Hearty, P. J., Hollin, J. T., Neumann, A. C., O'Leary, M. J. and McCulloc, M. 2007.

Global sea-level fluctuation during the last Interglaciation (MIS5e). Quaternary Science Reviews, 26: 2090-2112.

[30] Murray-Wallace, C. V.; Beu, A. G., Kendric, G. W., Brown, L. J., Belperio, A. P. and Sherwood, J. E. 2000. Palaeoclimatic implication of the occurrence of the arcoid bivalve *Anadara trapezia* (Deshayes) in the Quaternary of Australasia. Quaternary Science Review, 19: 559-590.

[31] Rohling, E. J.; Grant, K., Hemleben, C. H., Siddall, M., Hoogakker, B. A. A., Bolshow, M., and Kucera, M. 2008. High rates of sea-level rise during the last interglacial period. Nature Geoscience, 1: 38-42.

[32] Aguirre, M. L., Donato, M., Richiano, S. and Farinati, E. A. 2011. Pleistocene and Holocene interglacial molluscan assemblages from Patagonian and Bonaerensian littoral (Argentina, SW Atlantic): Palaeobiodiversity and palaeobiogeography. Palaeogeography, Palaeoclimatology, Palaeoecology, 308: 277-292.

[33] Chaar, E. and Farinati, E. 1988. Evidencias paleontológicas y sedimentológicas de un nivel marino pleistocénico en Bahía Blanca, provincia de Buenos Aires, Argentina. Segundas Jornadas Geológicas Bonaerenses, Bahía Blanca, Argentina. Acta, 1: 47-54.

[34] Cohen, A. L., Parkington, J. E., Brundrit, G. B. and Van der Merwe, N. J. 1992. A Holocene marine climate record in mollusc shells from the Southwest African coast. Quaternary Research, 38 (3): 379-385.

[35] Charó, M. P., Fucks, E. E. and Gordillo, S. 2013b. Moluscos bentónicos marinos del Cuaternario de Bahía Anegada (Sur de Buenos Aires, Argentina): variaciones faunísticas en el Pleistoceno Tardío y Holoceno. Revista Mexicana de Ciencias Geológicas, V (30): 404-416.

[36] Charó, M. P., Gordillo, S., Fucks E. E. and Giaconi, L. M. 2014. Late Quaternary molluscs from the Northern San Matías Gulf (Northern Patagonia, Argentina), Southwestern Atlantic: Faunistic changes paleoenvironmental interpretation. Quaternary International. DOI:10.1016/j.quaint.2013.12.044

[37] Charó, M. P., Gordillo, S. and Fucks, E. E., 2013a. Paleoecology significance of Late Quaternary molluscan faunas of the Bahia San Blas area, Argentina. Quaternary International, 301: 135-149.

[38] Codignotto, J.O. and Aguirre, M. L. 1993. Coastal evolution in sea level and molluscan Fauna in northeastern Argentina during the Late Quaternary. Marine Geology, 110: 163-175.

[39] Cuerda, J., Vicens, D. and Gracia, F. 1991. Malacofauna y estratigrafía del Pleistoceno Superior marino de San Real (Santa Margalida, Mallorca). Bolletín de la Societat d'Història Natural de las Balears, 34; 99-108.

[40] Gowan, E. J., Rovere, A., Ryan, D. D., Richiano, S., Montes, A., Pappalardo, M., and Aguirre, M. L. (2021). Last interglacial (MIS 5e) sea-level proxies in southeastern South America (Earth Syst. Sci. Data, 13, 171-197.

[41] Kidwell, S. M. 2001. Preservation of species abundance in marine death assemblages. Science, 294: 1091-1094.

[42] Lario, J., Zazo, C., Goy, J. L., Somoza, L., Hoyos, M., Silva, P. G. and Hernández-Molina, F. J. 1993. Los episodios marinos cuaternarios de la costa de Málaga (España). Revista Sociedad Geológica de España, 6: 42-46.

[43] Martínez, S.; Ubilla, M., Verde, M., Perea, D., Rojas, A., Guéréquiz, R. and Piñeiro G. 2001. Paleoecology and Geochronology of Uruguayan Coastal Marine Pleistocene Deposits. Quaternary Research, 55: 246-254.

[44] Martínez, S., del Río, J. and Rojas, A. A. 2016. A Pleistocene (MIS 5e) mollusk Assemblages from Ezeiza (Buenos Aires Province, Argentina). Journal of South doi: 10.1016/j.jsames.2016.05.008

[45] Ortlieb, L.; Guzmán, N. and Candia, M. 1994. Moluscos litorales del Pleistoceno superior en el área de Antofagasta, Chile: Primeras determinaciones e indicaciones paleoceanográficas. Estudios Oceanológicos, 13: 57-63.

[46] Rojas, A. and Urteaga, D. 2011. Late Pleistocene and Holocene chitons (Mollusca, Polyplacophora) from Uruguay. Palaeobiogeography and palaeoenvironmental reconstruction in mid latitudes of the southwestern Atlantic. Geobios, 44: 377-386.

[47] Valentin, J. 1987. Noticia sobre un yacimiento de conchillas en el cementerio de Lomas de Zamora. Anales del Museo Nacional de Buenos Aires, 5: 227-231.

[48] Zazo, C., Goy, J. L., Hillaire-Marcel, C., González Delgado, J. A., Soler, V., Ghaleb, B, Dabrio, C., 2003b. Registros de los cambios del nivel del mar durante el Cuaternario en las Islas Canarias Occidentales (Tenerife y La Palma). Estudis geológicos, 59, 133-144.

[49] Cohen, K. M., Finney, S. and Gibbard, P. L. 2013. International Chronostratigraphic Chart. International Commission of Stratigraphy.

[50] Lutaenko, K. A. 1993. Climatic optimum during the Holocene and the distribution of warm-water mollusks in the Sea of Japan. Palaeogeography, Palaeoclimatology, Palaeoecology, 102: 273-281.

[51] Duplessy, E. -C., Ivanova, E., Murdmaa, E., Paterne, M. and Labeyrie, L. 2008. Holocene paleoceanography of the northern Barents Sea and variations of the northward heat transport by the Atlantic Ocean. Boreas, 30: 2-16. DOI:10.1111/j.1502-3885.2001.tb00984.x

[52] Funder, S. and Weidick, A. 1991. Holocene boreal mollusk in Greenland: palaeoceaonographic implications. Palaeogeography, Palaeoclimatology, Palaeoecology, 85 (1-2): 123-135.

[53] Hjort, C., Mangerud, J., Adrielsson, L., Bondevik S., Landvik, J. and Salvigsen, O. 1995. Radiocarbon dated common mussels *Mytilus edulis* from eastern Svalbard and the Holocene marine climatic optimum. Polar Research, 14 (2): 239-24

[54] Rohling, E. J. and De Rijk, S. 1999. The Holocene Climate Optimum and Last Glacial Maximum in the Mediterranean: the marine oxygen isotope record. Marine Geology, 153: 57-75.

[55] Salvigsen, O.; Forman, S. L. and Miller, G. H. 1992. Thennophilous molluscs on Svalbard during the Holocene and their paleoclimatic implications. Polar Research, 11(1): 1-10.

[56] Yuan, L.X.; Sun, L. G., Wei, G., Long, N., Xie, Z. and Yuhong, W. 2011. 9.400 yr B. P.: the mortality of mollusk shell (*Mya truncata*) at high Artic is associated with a sudden cooling event. Environmental Earth Sciences, 63: 1385-1393.

[57] Aguirre, M. L. 1990. Holocene Macrobenthic Molluscan Associations from North-eastern Buenos Aires Province, Argentina. Quaternary of South America and Antarctic Peninsula, 7: 161-195.

[58] Aguirre, M. L. 1993. Palaeobiogeography of the Holocene molluscan fauna from Northeastern Buenos Aires Province, Argentina: its relation to coastal evolution and sea

level changes. Palaeogeography, Palaeoclimatology, Palaeoecology, 102: 1-26.

[59] Aguirre, M. L. 2002. Óptimo climático en el Holoceno marino de la Argentina: evidencias Malacológicas. Actas XV Congreso Geológico Argentino, Calafate, Santa Cruz, Argentina. Tomo I, p. 548-553.

[60] Gaillard, M. J. and Lemdahl, G. 1994. Early-Holocene coastal environments and climate in southeast Sweden: a reconstruction based on macrofossils from submarine deposits. The Holocene, 4 (1): 53-68.

[61] Macsotay, O. and Cáceres, Hernández, R. C. 2005. Palaeoclimatology of the Pleistocene-Holocene using marine molluscs and hermatypic corals from northern Venezuela. Caribbean Journal of Earth Science, 39: 93-104.

[62] Parmesan, C. 2006. Ecological and Evolutionary Responses to Recent Climate Change. Annual Review of Ecology, Evolution and Systematic, 37: 637-674.

[63] Isla, F., Rutter, N., Schnack, E. and Zárate, M. 2000. La trasgresión Belgranense en Buenos Aires. Una revisión a cien años de su definición. Cuaternario y Ciencias Ambientales, 1: 3-14.

[64] Rostami, K., Peltier, W., Mangini, A. 2000. Quaternary marine terraces, sea – level changes and uplift history of Patagonia, Argentina: comparison with predictions of the ICE-4G (VM2) model of the global process of glacial Isostatic adjustment. Quaternary Science Reviews, 19: 1495-1525.

[65] Charó, M. P., Fucks, E. E., and Gordillo, S., 2015. Late Pleistocene-Recent marine malacological assemblages of the Colorado River delta (south of Buenos Aires Province): paleoecology and paleoclimatology. Quaternary International, 377: 52-71.

[66] Charó, M. P., Aceñolaza, G., Cavallotto, J.L. 2020. Ostrea stentina Payraudeau, 1826 found in a marine Deposit of Middle Late Pleistocene in the south of Buenos Aires Province, Argentina. I virtual Meeting of Systemtics, Biogeography δ Evolution (SBE). A joint Effort the Coronavirtual.

[67] Gonzalez, M. A., Weiler, N. E., Guida, N. C., 1986. Late Pleistocene transgresive deposits from 33°to 44°S, Argentine Republic. Journal of Coastal Research. Special Issues, N°1, 39’48.

[68] Fucks, E. E., Charó, M. and Pisano, F., 2012a. Aspectos estratigráficos y geomorfológicos del sector oriental patagónico bonaerense. Revista de la Sociedad Geológica de España, 25 (1-2): 29-44.

[69] Fucks, E. E. and Schnack, E. 2011. Evolución geomorfológica en el sector norte del golfo San Matías. XVIII Congreso Geológico Argentino, Neuquén, Argentina. Actas: 273-274.

[70] Weiler, N. E. 1988. Depósitos litorales del Pleistoceno tardío y Holoceno en Bahía Anegada, Provincia de Buenos Aires: Segunda Reunión Argentino de Sedimentología, Buenos Aires, Argentina. Actas, p. 245-249.

[71] Schnack, E. J.; Isla, F. I., De Francesco, F. O. and Fucks, E. E. 2005. Estratigrafía del Cuaternario Marino Tardío en la Provincia de Buenos Aires. Geología y Recursos Minerales de la Provincia de Buenos Aires. Relatorio del XVI Congreso Geológico Argentino, La Plata, Argentina. Capítulo X, p. 159-182.

[72] Fucks, E. E., Schnack, E. J. and Charó, M. P., 2012b. Aspectos geológicos y geomorfológicos del sector N del Golfo San Matías, Río Negro, Argentina. Revista de la Sociedad Geológica de España, 25 (1-2): 95-105.

[73] Angulo, R., Fidalgo, F., Gómez Peral, M. A. and Schnack, E. J. 1981. Geología y geomorfología del bajo de San Antonio y alrededores, provincia de Río Negro. Centro de Investigaciones científicas, Secretaria de planeamiento. Estudios y documentos, 8.

[74] Weiler, N. E. 1984. Rasgos geomorfológicos evolutivos del sector costero comprendido entre bahía Verde e isla Gaviota, provincia de Buenos Aires. Asociación Geológica Argentina, Revista XXXVIII (3-4): 392-404.

[75] Weiler, N. E. 2000. Evolución de los depósitos litorales en Bahía Anegada, Provincia de Buenos Aires, durante el Cuaternario tardío. Tesis Doctoral, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, 184 p.

[76] Alberó, M. C., Angioloni, F. B, Codignotto, J.L., Linares, E., Weiler, N. E. 1980. Primeras edades Carbono-14 de afloramientos de conchillas de la Republica Argentina. Asociación Geológica Argentina. Revista XXXV(3): 363-374.

[77] Weiler, N.E. 1993. Niveles marinos del Pleistoceno tardío y Holoceno en Bahía Anegada, Provincia de Buenos Aires. Geocronología y correlación. Revista de la Asociación Geológica Argentina, 48 (3-4): 207-216.

[78] González, M.A. and Weiler, N. E. 1983. Ciclicidad de niveles marinos holocénicos en Bahía Blanca y en el delta del río Colorado. Simposio Oscilaciones de niveles del mar durante el Último Hemiciclo Deglacial en la Argentina. Revista de la Asociación Geológica, Mar del Plata, Actas 69-90.

[79] Trebino, L. 1987. Geomorfología y Evolución de las costas en los alrededores del pueblo de San Blas, Provincia de Buenos Aires. Revista de la Asociación Geológica Argentina, 42 (1-2): 9-22.

[80] Rutter, N., Schnack, E., Del Río, J., Fasano, J., Isla, F., Radkte, U. 1989. Quaternary litoral zones along the Patagonian coast, Argentina. Quaternary Science Reviews, 8: 213-234.

[81] Rutter, N., Radkte, U., Schnack, E. 1990. Comparison of ESR and amino acid data in correlating and dating quaternary shorelines along the Patagonian coast, Argentina. Journal of Coastal Research, 6 (2): 391-411.

[82] Bayer, S. and Gordillo, S., 2013. A new Pleistocene species of *Glycymeris* (Bivalvia, Glycymerididae) from northern Patagonia, Argentina. Ameghiniana, 50 (2): 265-268.

[83] Efremov, J. A. 1940. Taphonomy: new branch of paleontology. PanAmerican Geologist, 74: 81-93.

[84] Kidwell, S. M. 2002. Time-averaged molluscan death assemblages. Palimpsests of richness, snapshots of abundance. Geology, 30: 803-806.

[85] Kidwell, S. M. 2008. Ecological fidelity of open marine molluscan death assemblages: effects of post-mortem transportation, shelf health, and taphonomic inertia. Lethaia, 41: 199-217.

[86] Kidwell, S. M. 2013. Time-averaging and fidelity of modern death assemblages: building a taphonomic foundation for conversation palaeobiology. Palaeontology, 56: 487-522.

[87] Kidwell, S. M. and Tomasovych, A. 2013. Implications of Time-Averaged death assemblages for ecology and Conservation biology. Annual Review of Ecology, Evolution, and Systematics, 44: 539-563.

[88] Linné, C. 1758. Systema Naturae per regnatria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Edition decima, reformata [10th revised edition],vol. 1: 824.

[89] Adams, A. 1856. Descriptions of thirty four New species of bivalve Mollusca (Ledo, Nucula and Pythina) from the Cumingian Collection. Proceedings of the Zoological Society of London, 24: 47-53

[90] Sowerby G. B., I. 1833. Descriptions of new species of shells from the collection formed by Mr. Cuming on the western coast of South America, and among the islands of the southern Pacific Ocean. Proceedings of the Committee of Science and Correspondence of the Zoological Society of London. 2 ("1832"): 194-202.

[91] Molina, J. I., 1782. Saggio sulla storia naturale del Chile, del Signor Abate Giovanni Ignazio Molina. Bologna. i-v, 1-306.

[92] Lamarck J.B. P.A. 1819. Histoire naturelle des animaux sans vertèbres, Paris.Tome 6(1): 343 pp.

[93] Lamarck, J. B. 1801. Système des animaux sans vertèbres, ou tableau général des classes, des ordres et des genres de ces animaux; Présentant leurs caractères essentiels et leur distribution, d'apres la considération de leurs rapports naturels et de leur organisation, et suivant l'arrangement établi dans les galeries du Muséum d'Histoire Naturelle, parmi leurs dépouilles conservées; Précédé du discours d'ouverture du Cours de Zoologie, donné dans le Muséum National d'Histoire Naturelle l'an 8 de la République. Published by the author and Deterville, Paris: viii + 432 pp.

[94] Say, T., 1830-1834. American Conchology, or descriptions of the shells of North America. Illustrated by coloured figures from original drawings executed from nature. School Press, New Harmony, Part 6 (April 1834); Part 7 (1834?, published after Say's death; edited by T. A. Conrad).

[95] Guilding, I. 1828. Observations on the zoology of the Caribbean Islands. The Zoological Journal. 3: 527-544.

[96] Thunberg, C.P. 1793. Tekning och Beskrifning på en stor Ostronsort ifrån Japan. Kongliga Vetenskaps Academiens Nya Handlingar. 14(4-6): 140-142.

[97] Ihering, H.V. 1907. Les Mollusques fossiles du Tertiaire et du Cretace superieur de l'Argentine. Anales del Museo Nacional de Buenos Aires, Serie III, 1-611.

[98] Signorelli, J. and Scarabino, F. 2010. Mactra guidoi n sp. and Mactra patagonica (Bivalvia: Mactridae) two long misunderstood species from southwestern Atlantic Ocean Malacologia, 52 (1): 31-52.

[99] Lamarck, J. B. P. A. 1818. Histoire Naturelle des Animaux Sans Vértebrés. Paris Tome 5, 612 pp.

[100] Reeve, L. A. 1854. Monograph of the genus Mesodesma. In: Conchologia Iconica, or, illustrations of the shells of molluscous animals, vol. 8. L. Reeve & Co., London. Pls 1-4.

[101] Hanley S.C.T. 1842-1843. Illustrated, enlarged and English edition of Lamarck's species of shells forming the third edition of the Index Testaceologicus. London: Wood. 224+8+[3]+8 pp., 3 pls. [pp. 1-32. pl. 1-2. late 1842; pp. 11-32 [reissue]

[102] Smith, E. A. 1885. Report on the Lamellibranchiata collected by HMS Challenger during the years 1873-76. Report on the Scientific Results of the Voyage of H.M.S.Challenger during the years 1873-76, Zoology 13: 1-341, pls 1-25.

[103] Lightfoot, J. 1786. A Catalogue of the Portland Museum, lately the property of the Dutchess Dowager of Portland, deceased; which will be sold by auction by Mr. Skinner & Co. [book]. London. viii + 194 pp.

[104] Gmelin, J. F. 1791. Vermes. In: Gmelim J. F. (Ed.) Caroli a Linnaei Systema Naturae per Regna Tria

Naturae, Ed. 13. Tome 1 (6). G. E. Beer, Lipsiae [Leipzig]. pp. 3021-3910.

[105] Dillwyn, L. W. 1817. A descriptive catalogue of Recent shells, arranged according to the synonymy London: John and Arthur Arch, Vol 1: 1-158. Vol 2: 581-1092.

[106] King P.P. 1832. Description of the Cirrhipeda, Conchifera and Mollusca, in a collection formed by the officers of H.M.S. Adventure and Beagle employed between the years 1826 and 1830 in surveying the southern coasts of South America, including the Straits of Magalhaens and the coast of Tierra del Fuego. Zoological Journal, 5: 332-349.

[107] Pilsbry, H. A. 1897. New species of mollusks from Uruguay. Proceedings of the Academy of Natural Sciences of Philadelphia. 49: 290-298.

[108] Couthowy, J.P. 1839. Monograph on the family With remarks on two species of Patelloidea, and descriptions of new Species of marine shells, a species of Anculotus and one of Eolis. Boston Journal of Natural History 2 (2): 129-189.

[109] Martens, E. von. 1900. Neue Fissurella aus Südbrasilien. Nachrichtsblatt der deutschen malakozoologischen Gesellschaft. 32(11/12): 187.

[110] Smith, E. A. 1880. Descriptions of five new species of shells from Uruguay. Annals and Magazine of Natural History. ser. 5, 6 (34): 319-322.

[111] Collin, R. 2005. Development, Phylogeny and taxonomy of Bostry-Capulus (Caenogastropoda Calyphacidae), an ancient cryptic radiation. Zoological Journal of the Linnean Society, 144:75-101.

[112] Simone, L. R., Pastorino, G., Penchaszadeh, P. E. 2000. Crepidula argentina (Gastropoda: Calyptraeidae) a new species from the littoral of Argentina. The nautilus, 114 (4): 127-141.

[113] Lamarck, J.B. M. de. 1822. Histoire naturelle des animaux sans vertèbres. Tome septième. Paris: published by the Author, 711 pp.

[114] Pallas, P.S. 1774. Spicilegia Zoologica quibus novae. Imprimis et Obscurae Animalium Species. Part 10. Berolini, Lange, 267 pp.

[115] Donovan, E. E. 1823-1827. The Naturalist's repository, or monthly miscellany of exotic natural history, etc. [Book series]. In 5 volumes 1 (1823)-5 (1827).

[116] Lamarck, J.B. 1811. Suite de la détermination des espèces de Mollusques testacés. Annales du Muséum National d'Histoire Naturelle. 16: 300-328.

[117] Broderip, W.J. 1836. Description of some Species of shells apparently not hitherlo Recorded. Proceedings of the Zoological. Society of London, 4: 43-45.

[118] Duclos, P. L. 1835-1840. Histoire naturelle générale et particulière de tous les genres de coquilles univalves marines a l'état vivant et fossile publiée par monographie. Genre Olive. Paris: Institut de France. 33 plates: pls 1-12

[119] Klappenbach M.A. 1965. Consideraciones sobre el género Olivancillaria d'Orbigny 1840 (Moll. Gastr.) y descripción de dos nuevas especies de aguas Argentinas y Uruguayas. Com.Zool.Mus.His.Nat. Montevideo, 8:104.

[120] Kiener L.C. 1834-1841. Spécies général et iconographie des coquilles vivantes. Vol. 9. Famille des Purpurifères. Deuxième partie. Genres Buccin (Buccinum), Adanson, pp. 1-112 + table with duplicate page numbers 105-108, pl. 1-31 [pp. 1-64 (1834),

65-104 and 105-108 of table (1835), 105-112 of text (1841); pl. 1-24 (1834).

[121] Doello-Jurado, M. 1938. Nuevos datos sobre la fauna marina de la meseta continental de la Argentina y del Uruguay. Phys., 12: 279-292.

[122] Castellano, Z. 1982. Los Pyramidellidae de la República Argentina (Mall, Entomo taeniata). Comunicaciones del Museo Argentino de Ciencias Naturales ¨Bernardino Rivadavia¨. Hidrobiología 2(7): 61-85.

[123] Blainville, H.M. D. de 1824. Mollusques, Mollusca (Malacoz.). In: Diccionnarie des Sciences Naturelles (F. Cuvier, ed.) Vol 32: 1-392. Leuralt, Strasbourg et Paris, δ Le Normant, Paris.

[124] Aguirre, M. L. and Fucks, E. E., 2004. Moluscos y paleoambientes del Cuaternario marino en el sur de Entre Rios y litoral bonaerense. Temas de Biodiversidad del litoral fluvial argentino. Miscelánea, 12: 55-10.

[125] Tonni, E. P. and Fidalgo, F. 1978. Consideraciones sobre los cambios climáticos durante el Pleistoceno Tardío–Reciente en la provincia de Buenos Aires. Aspectos ecológicos y zoogeográficos relacionados. Revista de Asociación Paleontológica Argentina. Tomo XV (1-2): 235-253.

[126] Arruda, C. C. B., Beasley, C. R., Vallinoto, M., Marques-Silva, N. S. and Tagliaro, C. H. 2009. Significant genetic differentiation among populations of *Anomalocardia brasiliana* (Gmelin, 1791): a bivalve with planktonic larval dispersion. Genetic Molecular Biology, 32: 423-430.

[127] Oliveira, I.; Amorim, A., Lavander, H., Peixoto, S. and Gálvez, A. O. 2011. Spatial and temporal distribution of the shellfish *Anomalocardia brasiliana* (Gmelin, 1791) on Mangue Seco beach, Pernambuco, Brazil. International Journal of Acuatic Science, 2: 68-79.

[128] Martínez, S.; Rojas, A., Ubilla, M., Verde, M., Perea, D., Piñeiro, G. 2006. Molluscan assemblages from the marine Holocene of Uruguay: composition, geochronology, and paleoenvironmental signals. Ameghiniana, 43 (2): 385-397.

[129] Walker, M.; Johnsen, S., Rasmussen, S. O., Popp, T., Steffensen, J.P., Gibbard, P., Hoek, W., Lowe, J., Andrews, J., Björck, S., Cwynar, L.C., Hughen, K., Kershaw, P., Kromer, B., Litt, T., Lowe, D.J., Nakagawa, T., Newnham, R. and Schwander, J. 2009. Formal definition and dating of the GSSP (Global Stratotype Section and Point) for the base of the Holocene using the Greenland NGRIP ice core, and selected auxiliary records. Journal of Quaternary Science, 24(1): 3-17.

[130] Veliz, D. and Vásquez, J. A. 2000. La Familia Trochidae (Mollusca: Gastropoda) en el norte de Chile: consideraciones ecológicas y taxonómicas. Revista Chilena de Historia Natural, 73: 757-769.

[131] Díaz, A. and Ortlieb, L. 1993. El fenómeno del Niño y los moluscos de la costa peruana. Bulletin de Institut Francais d'Estudes Andines, 22 (1):159-177.

[132] Ortlieb, L. and Díaz, A. 1991. Distribuciones de moluscos litorales del Perú en el Pleistoceno Superior: primeras interpretaciones paleoceanográficas y paleoclimáticas. IIIa Reunión anual Proyecto PICG, 281, p. 39-56.

[133] Jackson, D. S., Méndez, M. C., López, M. P. and Sequel, R. Q. 2005. Evaluación de un asentamiento arqueológico en el semiárido de Chile: procesos de formación, fauna extinta y componentes culturales. Intersecciones en Antropología, 6: 139-151.

[134] Baez, P. R. and Jackson, D. S., 2008. Exploitation of loco, *Concholepas*

concholepas (Gastropoda: Muricidae), during the Holocene of Norte Semiárido, Chile. Early Human Impact on Megamolluscs Publishers of British Archaeological Reports, 79-94 p.

[135] Cárdenas, J. and Gordillo, S. 2009. Paleoenviromental interpretation of late Quaternary molluscan assemblages from southern South America: A taphonomic comparison between the Strait of Magellan and the Beagle Channel. Andean Geology, 36(1): 81-93

[136] Moreno, C. A. 2004. Efectos de El Niño en el reclutamiento de *Concholepas concholepas* y *Tegula atra* (Mollusca, Gastropoda) en la costa de Valdivia, Sur de Chile. En Avaria y otros Eds. El Niño-La Niña 1997-2000 Sus efectos en Chile. Comité Oceanográfico Nacional (CONA), p. 179-190.