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REVIEW

First Steps in Addressing the Submerged Archaeological Evidence in the Patagonian Continental Shelf, Argentina

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Abstract
Noting the minimal research in South America related to cultural remains which could have become submerged due to sea-level rise at different stages in the past since the Pleistocene–Holocene transition, we take a systematic approach in this article towards making a positive contribution regarding inundated sites and landscapes in Eastern Patagonia and Tierra del Fuego, Argentina. This is a region with a vast continental shelf and high potential for addressing significant archaeological topics such as human migration routes, characteristics of peopling processes, and the use of space and natural resources in the Southernmost part of the American continent. In the context of the latter, the study of submerged landscapes can shed light on past use of the marine environment and its resources. We begin by presenting a regional overview of the archaeological record which can be chronologically and geographically relevant for the topics considered. The characteristics of such record, combined with a general evaluation of coastal and underwater geomorphology as well as other environmental variables, is used to infer some possible targets or "hotspots" with higher potential for past human use as well as preservation of cultural remains. This article provides a basis for further model-developing and ground-truthing surveys.

Keywords Prehistoric archaeology · Underwater archaeology · Submerged landscapes · Patagonia · Tierra del Fuego, Argentina

Introduction

For decades archaeologists agreed that the New World was colonized sometime in the very Late Pleistocene by land-based hunter-gatherers who moved across Beringia and down the fabled ice-free corridor into the heartland of America, gradually spreading south. More recently the alternative route along the Pacific coasts of North America was added (Fladmark 1979; Erlandson 2001; Dixon 2013; among others). The abundant biological, osteological, and archaeological evidence gathered during the past two decades fuelled debates related with the specific adaptations of the first colonizers (Madsen 2004; Graf et al. 2013;

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Borrero 2016). It is now well accepted that both coastal and inland terrestrial routes are valid ones for human dispersal into America that need not be exclusive (e.g., Braje et al. 2018; Erlandson 2013; Erlandson and Fitzpatrick 2007; Potter et al 2017). A dispersal route across the Atlantic, connecting the Iberian Peninsula and North America was recently added to the discussion (Stanford and Bradley 2012).

In this article we synthesize and critically examine existing information concerning early sites in the hinterland, provide details about later coastal sites from parts of the Atlantic coast of Patagonia, and discuss their implications for the use of locations which are now on the continental platform. Information concerning the platform will also be presented, all of it aiming at constructing a search model for archaeological manifestations.

Hypotheses no longer need to be exclusively focused on chronology, which should only be another variable. Instead, the challenge is to explain the processes of exploration and colonization of the southern land mass. In Patagonia and Tierra del Fuego the Pleistocene–Holocene Transition was the critical time for the dispersal of hunter-gatherers. As a step in the direction of developing more complex models and theories about the peopling of the New World we need to consider the dramatic climatic and environmental fluctuations, as well as the variety of climates and environments during such a transition (Anderson et al. 2013). These fluctuations profoundly affected the biotic and abiotic structures of the different regions (Borrero 1989-90, 1999, 2004; Borrero and Martin 2021; Franco et al. 2019; Miotti 2003; Miotti and Salemme 2004; Miotti et al. 2014; Salemme and Miotti 2008; Salemme and Santiago 2017; among others). Studies based on pollen records indicate that the presence of humans in Southern Patagonia would have been influenced not only by major but also possibly by distinct short-term climate shifts during the Pleistocene–Holocene transition. Water availability, as well as temperature, would have played significant roles in such impact (Brook et al. 2013a, b). This is the scenario within which the first explorers and settlers integrated into local ecosystems. These conditions presented risks associated with exploring unknown landscapes. Marine environments would have offered ways to minimize some of these risks, by providing a relatively greater variety of resources, including those from the sea and from freshwater rivers, as well as good access to terrestrial resources.

Regardless of the route through which human populations entered North America -either coastal or inland- by the time they reached South America they probably were moving on both coastal and inland areas (Fiedel 2007). Accordingly, they possessed a working basis to deal with a diversity of environments and resources. The incorporation of the continental shelf into archaeological investigations becomes crucial when we try to understand the role and importance of the former Atlantic coast of Patagonia for those first populations. The gentle slope of the continental platform (with a gradient of less than 5°) also implies that large portions of land were exposed during periods when sea levels were lower (Ponce et al 2011), and that can be a favourable condition in terms of survival potential (Flemming et al. 2017).

To date there is very little information available on submerged pre-contact remains from this submerged region, and the evidence for the Atlantic coast of South America in general is extremely scarce (Bayón and Politis 2014; Blasi et al. 2013; Calippo 2004, 2006, 2008; Carabias et al. 2014; Cartajena et al. 2013; Flores-Aueveque et al. 2021; Sturt et al 2018). A recent article by Zangrando et al (2022) provides a thorough and most welcome academic report on the first record of underwater archaeological evidence found by chance in Tierra del Fuego, Argentina. This is an important development as the discipline begins to capture the attention of the archaeological research community in Argentina and the wider region. However, a single find is only the

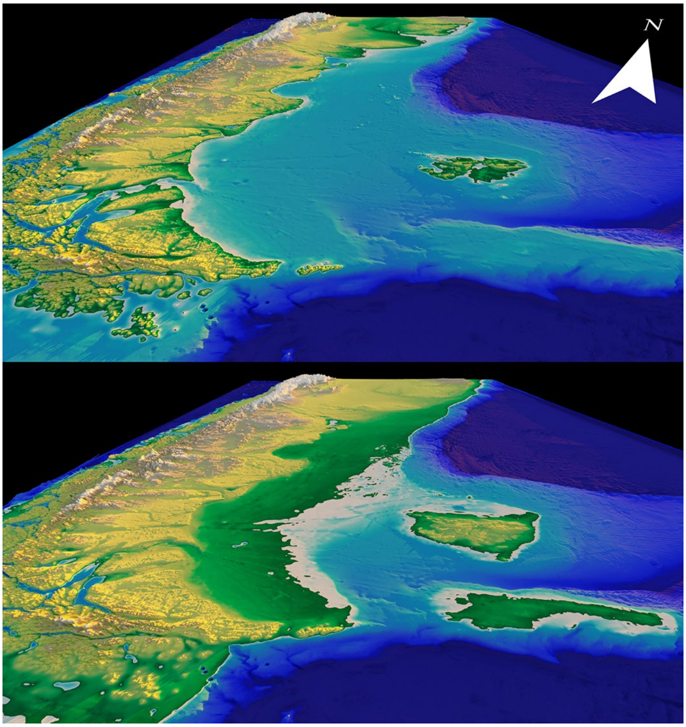

Fig. 1 Image of the area under study depicting current sea level (top) and − 130 m sea level (bottom) during the LGM. Aside from the large exposed continental shelf in the latter, note the significant increase in size for the Malvinas archipelago -unified as a single island in the North- and the exposed bank known as Namuncurá or Burdwood, currently a completely submerged plateau

beginning, and significant work over the coming decades by interdisciplinary teams will be required for the resource and potential to be understood properly. Clearly then, and especially for Argentina where the only underwater evidence of hunter-gatherer groups resulted from accidental finds, the potential for a systematic survey on the subject is enormous and it has seldom been duly recognized (Zangrando 2018, 2022). The comparison between exposed territories with current sea level and with the one at the LGM is quite striking (Fig. 1).

During the Last Glacial Maximum, approximately 24,000 calibrated (cal) years BP, the sea level became established between 120 and 140 meters (m) below present. After a gradual rise since then, by 12,500 cal cal Years Before Present (YBP) it was at − 60 m, by 11,800 cal YBP at − 50 m, by 7800 cal YBP at − 10 m, and by 6000 Cal YBP at − 8 m (Ponce et al 2011). Current bathymetric data for the region has a variable degree of resolution, with some quadrants covered in more detail as can be seen in the on-line Geoportal of the Argentine Hydrographic Service (Servicio de Hidrografía Naval 2022). It is evident, however, that several bays, inlets and coastal sectors along the Patagonian coast would currently have maximum depths of 18 m (see, for example, Servicio Hidrográfico del Ministerio de Marina 1926), thus representing exposed territory prior to 7800 cal YBP.

Systematic Approaches to Submerged Archaeological Remains

For the past decade, investigations have been carried out around the world which explore the role of past coastal environments, reconstructing coastal paleoenvironments and demonstrating the archaeological potential of the continental shelf (Bailey et al. 2020a, b; Benjamin et al. 2020; Evans et al. 2014; Flemming et al. 2017; Mackie et al. 2018; among others). However, systematic investigation of underwater archaeological sites is challenging. Constraints include the ephemeral or not so obvious nature of hunter-gatherer material culture and subsequent archaeological signatures, limited knowledge of the taphonomic conditions under which sites can be preserved, site visibility and accessibility to discover or encounter an archaeological signature, and uncertainties about what can remain sufficiently intact to make a useful and decisive contribution to new knowledge (Benjamin et al. 2020: 2). It is not only a matter of the survival of archaeological material, but sites, particularly when they are not covered by sediment and their long-term equilibrium is disturbed, can be rapidly lost, be it through natural or cultural processes (Erlandson and Fitzpatrick 2007).

Considering the numerous natural and cultural considerations determining archaeological potential of submerged remains, no universal methodology exists. However, there are fundamental aspects that can be evaluated in order to consider its appropriateness for an in-depth assessment for potential cultural resources on submerged territories (Benjamin 2010). This assessment refers to the combination of different sources of information to generate a site search and discovery model (Faught and Smith 2021; McLaren et al. 2020; Sturt et al. 2018; Veth et al. 2020; Wiseman et al. 2021). This requires data for the defined study area, including sea-level changes over time, bathymetry, topography, as well as isostatic and eustatic processes usually related to ice sheets. The use of remote sensing techniques is of great interest as they provide a complementary source of information (e.g., Wiseman et al. 2021). However, although geophysical techniques have been used to encounter larger features of submerged landscapes (e.g., Astrup et al. 2020; O'Shea et al. 2014), marine geophysics alone are not yet able to identify small artefacts.[1] Instead searches rely on scientific divers, drop cameras or Remotely Operated or Autonomous Vehicles (ROVs and AUVs) to confirm the presence of cultural material, particularly in the form of stone tools and other ephemeral material. Remote sensing by means of multibeam echosounder or sub-bottom profiler is mainly used to search for sedimentary deposits or other geomorphological features that could have archaeological potential and preserved such record (Faught 2014). Combining this paleoenvironmental and geomorphological information with the available archaeological data obtained from on-land research, patterns of prehistoric people's use of space can be predicted and it may be possible to anticipate where sites might be located on the now-submerged landscape (Faught and Smith 2021, Fischer 1995; Galili 2019; Mackie et al. 2018; Wiseman et al. 2021).

Additionally, preservation and taphonomic factors must be considered at both a regional and a local scale. The regional scale provides coarse guidelines on what can be expected, while local factors produce pockets characterized by site-specific preservation properties. So, to determine an area with archaeological potential, geographic and physical factors should be assessed followed by detailed information gathering and assessment of

[1] Seismic surveys using Chirp high resolution technology have allowed to detect experimental submerged and buried flint-knapping debris, indicated by acoustic disturbances in the water column resembling haystacks (Grøn et al. 2018). However, the expectation to achieve similar results in actual archaeological sites still seems limited.

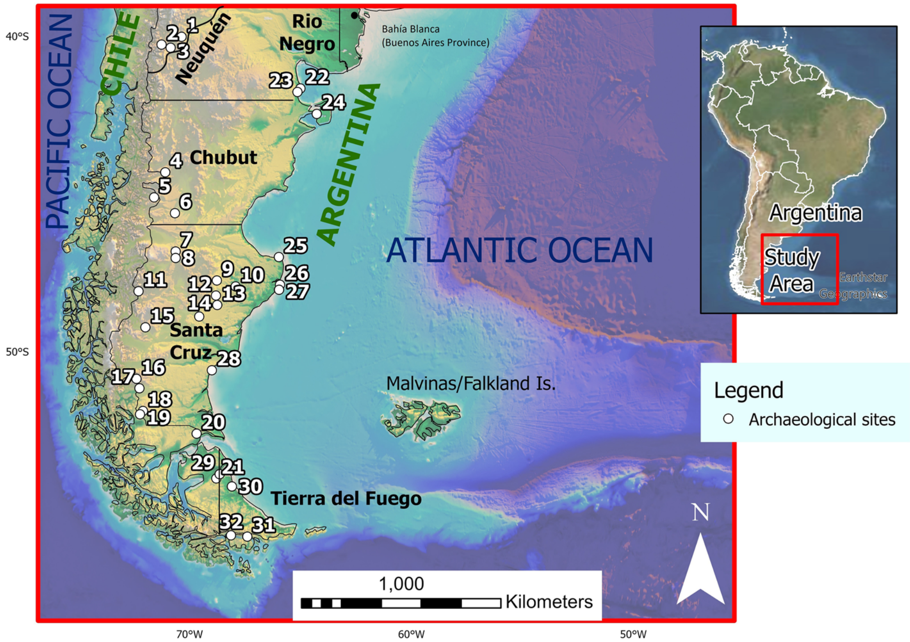

Fig. 2 Patagonia and Tierra del Fuego archaeological sites distribution (see Table 1 for references)

local coastal topography, oceanographic and coastal data such as currents, tides, and wave refraction and diffraction, and geomorphological data such as sedimentary type and rate of contribution, and any data related to changes in coastline such as erosion, or prograding or retrograding coastlines for any particular area (Bailey 2014; Flemming et al. 2017). Relevant information on some of those aspects is already available for the study area, such as on marine transgressions in northern Patagonia (Cavallotto and Violante 2003) or on sedimentology of the Argentinean continental shelf (Servicio de Hidrografía Naval 1974), but despite the usefulness of such background studies the generation of new data at the appropriate resolution for the purposes of this study will be necessary. Once those steps have been carried out, and the landscape, the existing and the potential archaeological records are well understood and integrated, it is necessary to then test these theoretical predictive models through field survey.

Archaeological Evidence for the Study Area

The study area chosen for this research is focused on the Atlantic coast of Patagonia and Tierra del Fuego, defined as the space delimited from Bahía Blanca—39° 04′ S—(Buenos Aires) to the Beagle Channel—55° 04′ S—(Tierra del Fuego) and which extends for more than 3700 km. Additionally, an archaeological criteria was applied to the study area, including inland locations with the earliest archaeological evidence available, since they might be relevant for identifying patterns in the use of space during the process or peopling of the region (Fig. 2).

As can be seen in Fig. 2, archaeological evidence for the initial human dispersal and settlement is not uniform, given that archaeological surveys are only partial. It is more than possible that this discontinuity is a result of sampling bias, but it also may result from taphonomic processes. Alternatively, the geographical discontinuity could be indicating small and scattered populations, which would make sense while exploring new lands and result from adaptation challenges (Borrero 1999, 2004; Miotti and Salemme 2004; Salemme and Miotti 2008). The presence of at least five sites with dates older than 10,000 ^{14}C BP at the Deseado Massif (DM) makes this region the most important known reservoir of Late Pleistocene human occupations (Miotti 1996, 1998; Miotti et al. 2022; Paunero 2000, 2003b; Steele and Politis 2009; Franco et al. 2019). The DM clearly was a staging area (sensu Anderson et al. 2013), that is, a place selected for long-term occupation by the Patagonian pioneer populations. Colonization of the Pali Aike Volcanic Field (PAVF), another important occupational node south of DM, was probably also connected with the DM (Borrero and Martin 2021). The DM probably acted as a node from which logistical forays to neighbouring areas were initiated. Sites like La Gruta or cueva Maripé can be used to discuss these movements. Corridors and Least Cost Paths discussed by Franco et al. (2019) display some of the potential routes within the DM nodes. Holocene evidence at most of the sites suggests that the DM was probably instrumental during the Late Holocene exploration of the western steppes and the peri-Andean zone in general. Late Holocene occupations of the coast can also be related with the DM, with the minimal evidence of Pampa del Asador obsidian on the coast as a link. At any rate, there is very little evidence relating the occupations recorded at the DM with the Atlantic coast. It is difficult to think that there was complementary use of the coast by the inhabitants of the DM node. The situation during Transition times, when the coast was even farther away remains unknown, but any potential connection with the coast was dismissed by Miotti et al. (2022). Other nodes beyond those that we know were probably used during the initial human excursions into Patagonia (see below), and perhaps some of them are located in the continental platform, but this remains speculation.

Middle Holocene sites offer the oldest evidences for systematic interaction with the Atlantic coast, and some of these sites are located near the current coast. Lithic raw materials from the interior are present at coastal sites, always in proportion to the distance from the source. Thus, the well-known black obsidian from the Pampa del Asador is present in minimal frequencies. Moreover, it is not really known if these few coastal findings made all the travel from Pampa del Asador or if they were sourced at secondary deposits like 17 de Marzo, discovered in the DM (Franco et al. 2017). Consumption of both terrestrial and maritime resources is indicated at the coastal sites. Then, the available evidence tells a story of Mid-Holocene complementary use of the ocean resources, that only during the Late Holocene display some hints toward localized maritime adaptations.

Ultima Esperanza, the PAVF or Tres Arroyos (TA) in Tierra del Fuego must be only some of many nodes occupied by early foragers in South Patagonia at the end of the Pleistocene. We can envision a metapopulation within which variable degrees of connectivity existed. These connections need not be regular, just possible. Very little evidence supports the proposition that early settlers come from the far eastern plains, which are today under the oceanic waters. Beyond the potential existence of early settlement, the reality is that we do not know of any settlement under the water at all, early or late. On the other hand, no maritime items are found at the early sites, except for very limited Early Holocene isolated findings (v.gr. Pinturas Basin), which cannot be associated with any systematic relationship with the sea. Nothing to support anything near what Sandra Bowdler calls a partial sustain in her coastal colonisation hypothesis for Sahul- “transliterated coastal economy” (Bowdler

1977). What we have at the DM, the PAVF, Última Esperanza or Tres Arroyos 1 represents full terrestrial adaptations.

Elsewhere, the continental ice sheets of the Andes would have limited the movement flow of both the fauna and the first settlers during the Pleistocene–Holocene transition. Periglacial lakes and valleys in the area are not considered to have been explored and exploited until the early Holocene, when temperatures increased, and their access became feasible (Borrero 2004). It is important to highlight that the technology and skills required to exploit these environments were already in place when the first humans arrived in Patagonia (Borrero 2001); and, also, the areas where the earliest sites have been found were already available before their arrival (Borrero 2004; Girault et al. 2022; Martin et al. 2015; Miotti et al. 2022). Lastly, the archaeological evidence for the northern and central Patagonia area consists mainly of cave-sites from this initial peopling process of the early Holocene (Aguerre et al. 2017; Barberena 2015; Ceballos 1982; Crivelli et al. 1993, 1996; Méndez et al. 2018). Although most of the archaeological sites in the eastern foothills of the Andes date from the mid-Holocene, there are sites with early evidence (see Table 1).

Summarizing, this distribution of sites within the archaeological record could suggest that during the Pleistocene–Holocene transition in southern South America, exploration and eventual colonization (sensu Borrero 1994–5) could have been linked to a selective and hierarchical process of human dispersal of the different environments, and, also, at different times. This process could have been the result of environmental stress and/or geographical filters or permeable barriers, such as the Andes Mountain range, the extensive basaltic plateaus, and the Strait of Magellan (Miotti and Salemme 2004; Borrero 2018). As already mentioned, variable degrees of connectivity existed between those areas (Borrero and Martin 2021). Faunal evidence of the first archaeological sites points towards a generalised subsistence, making it difficult to maintain the notion that the first inhabitants of Patagonia were specialized hunters of extinct fauna. Even when large Pleistocene mammals were exploited, either by hunting or scavenging, it is argued that they were not a primary or critical source of protein (Borrero 1999; Miotti et al. 2022; Paunero et al. 2017).

Models

Seeking to explain the scarce and fractional archaeological evidence in Patagonia and Tierra del Fuego, different peopling models have been proposed (see Borrero 1990; Miotti 2006; Salemme and Miotti 2008; Franco et al. 2019). Nevertheless, it is necessary to note there is a considerable research bias for the interpretation of the archaeological record and modelling of the southernmost peopling in South America since, as stated already, there is a large submerged unexplored area that has not been considered. Models for submerged site prediction have been discussed in the literature (Benjamin 2010; Fischer 1993; Galili 2019; Veth et al 2020; Wiseman et al. 2021), though we take note that models have limitations and indeed some have suggested that using them for site prediction can be counterproductive (see Grøn 2018).

Several archaeologists have focused their terrestrial archaeological work on the Atlantic coast (Favier Dubois 2001, 2013; Favier Dubois et al. 2016; Gómez Otero 2007; Vázquez et al. 2011, 2017; Zubimendi 2010; among others) and the archaeological record found there dates from the middle Holocene (ca. 8500–4200 BP) and, to a greater extent, the Late Holocene (ca. 4200 BP—historic times), when the current sea level had already been established. The lack of archaeological data for earlier periods

Table 1 Archaeological sites references from Fig. 1. Those in italics are located in what is now Chilean territory

	Site	14c years BP	References
1	Cueva Epullán Grande	9970 ± 100–7060 ± 90	Crivelli et al. (1996) and Cordero (2009)
2	Cueva Traful	9430 ± 230–9285 ± 105	Crivelli et al. (1993)
3	Cuyín Manzano	9920 ± 85	Ceballos (1982)
4	El Chueco 1	10.010 ± 60–8830 ± 30	Méndez et al. (2011)
5	*Cueva de la Vieja*	10.269 ± 43–8413 ± 50	Méndez et al. (2018)
	Baño Nuevo 1	8695 ± 25–8530 ± 160	Mena et al. (2000)
6	Alero Dásovich	10.600 ± 160–10.170 ± 130	Aguerre et al. (2017)
7	Arroyo Feo	9330 ± 80–8610 ± 70	Alonso et al. (1984-1985) and Gradín and Aguerre (1994)
8	Cueva de las Manos	9320 ± 90–9300 ± 90	Gradín et al. (1979) and Gradín and Aguerre (1994)
9	Cueva Maripe	9177 ± 56–7153 ± 50	Miotti et al. (2014)
10	Piedra Museo AEP-1	11.000 ± 65–9350 ± 130	Miotti (1996) and Miotti et al. (2022)
11	Cerro Casa de Piedra 7	9730 ± 100–8920 ± 200	Aschero (1996) and Civalero and Franco (2003)
12	Cerro Tres Tetas	11.145 ± 60–10.915 ± 65	Paunero (2003a) and Paunero et al. 2017
13	Casa del Minero	10.999 ± 55–10,250 ± 110	Paunero (2003b) and Paunero et al. (2017)
	Cueva Túnel	10.510 ± 100–10.400 ± 100	Paunero et al. (2017)
14	La Gruta	10.840 ± 62–10.477 ± 56	Franco et al. (2019)
15	Bloque 1 Oquedad	9760 ± 60	Belardi et al. (2010)
16	Chorrillo Malo 2	9740 ± 750–6170 ± 750	Franco and Borrero (2003)
17	Cerro León 3	8856 ± 84–4370 ± 50	Borrero and Borrazzo (2011) and L'Heureux and Borrazzo (2013)
18	*Cueva Lago Sofía*	10.780 ± 60–10.140 ± 120	Prieto (1991), Massone and Prieto (2004) and Steele and Politis (2009)
19	*Cueva del Medio*	10.860 ± 110–10.410 ± 50	Nami (1987) and Martin et al. (2015)
20	*Cueva Fell*	10.835 ± 50–10.080 ± 160	Bird (1988), Waters et al. (2015) and Martin (2022)
21	*Tres Arroyos*	10.685 ± 70–9960 ± 50	Massone and Prieto (2004) and Steele and Politis (2009) and Martin et al. (2009)
22	Arroyo Verde 1	7420 ± 90	Gómez Otero (2007)
23	Alero 2	6624 ± 31 / 3680 ± 90	Carranza and Cardillo (2019)
24	Punta Pardelas	5580 ± 90	Gómez Otero (2007)
25	Cabo Tres Puntas	6300 ± 90	Castro et al. (2003, 2006) and Zubimendi (2010)

Table 1 (continued)

	Site	14c years BP	References
26	Alero El Oriental	6930 ± 100–5810 ± 110	Ambrústolo et al. (2011)
	Médano Alto	5790 ± 79	Castro et al. (2001, 2007) and Zubimendi (2010)
	Cueva Marsicano	6853 ± 48–6684 ± 48	Paunero et al. (2019)
27	Médano 1	6300 ± 90	Castro et al. (2001, 2007), Zubimendi (2010) and Zubimendi et al. (2005)
28	Yegua Quemada 3	5570 ± 120	Caracotche et al. (2017)
29	Cerro Las Bandurrias	5700 ± 180	Favier Dubois and Borrero (2005
30	Río Chico 1	5956 ± 44–5856 ± 44	Santiago et al. (2007a, b)
	La Arcillosa 2	5508 ± 48–3690 ± 70	Salemme and Bujalesky (2000) and Salemme et al. (2007)
31	Binushmuka 1	7486 ± 64–7310 ± 40	Zangrando et al. (2018)
	Imiwaia 1	6490 ± 120–5872 ± 147	Zangrando (2009) and Piana et al. (2012)
32	Tunel 1	6680 ± 210–4500 ± 90	Orquera et al. (2011) and Orquera and Piana (1999)

could be due to several reasons, such as a late colonization of the coastal area, only when the sea level stabilized (after ca. 6900 BP), or to visibility problems related to sea level variations.

To be able to narrow this vast area into approachable areas for underwater archaeological survey, an exhaustive compilation of information related to the Argentinean Atlantic coast and its continental shelf is summarized. Firstly, geomorphological characteristics are described, along with sea level fluctuations and isostatic movements of the earth's crust through time. Secondly, since there is no archaeological data dating from the Pleistocene–Holocene transition on the current coasts nor near them, the focus is on the mid-Holocene, pre and post marine transgression.

Geomorphological Setting

The Fuego-Patagonian Atlantic coast is characterized by erosive coastlines, with active cliffs of great height and extension, and some forms of marine accumulation such as gravel and occasionally sandy beaches. In addition, its configuration is partly created by erosion, constituting a system of bays and spits (Codignotto et al. 1992; Codignotto 1997; Kokot 1999). Regarding the tidal regimes, meso-tides (2–4 m) and macro-tides (+4 m) predominate with a semi-diurnal regime that increases from south to north with a high-energy swell (Kokot 1999; Ponce et al. 2011).

Regarding eustatic sea level variation, during the LMG, sea level was approximately between 120 and 140 m below the present one, thus exposing the continental shelf in the form of a huge coastal plain. From the present mouth of the Río de la Plata estuary to its southernmost end at Isla de los Estados (Staten Island), this plain was approximately 590,000 km^2, with a varying width between 100 and 490 km (Ponce et al. 2011). Around 11,000–10,000 BP, Pleistocene–Holocene transition, the sea level would have risen considerably, but still maintaining negative levels of 20–0 m below current sea level (Weiler 1998). At this time, the coastline of what are now the provinces of Santa Cruz and Tierra del Fuego were located less than 25 km and about 15 km to the East, respectively (Ponce et al. 2011: 372–373).

With regard to elevations in the earth's crust (tectonism and isostasy), certain variations have been recorded in the height of the terraces ranging from + 5 to + 6.5 m (littoral terraces) and from 8.5 to 9.5 masl (littoral ridges) (Bujalesky and Isla 2006; Schellmann and Radtke 2010). Based on these differences, a differential tectonic rise has been estimated between the Pleistocene beaches of Tierra del Fuego and those of the south-central Patagonia (Chubut and north of Santa Cruz), the latter being the ones that show greater levels than that of the first ones (Bujalesky and Isla 2006). Despite these differences, the general height of the Holocene terraces along the entire Atlantic coast is between 6 and 10 MASL and taking into account that the coasts with higher elevations within that range are those of Chubut and those of northern Santa Cruz, the generalized vision of a stronger glacio-isostatic coastal uplift closer to the centres of the glaciations by authors such as Rabassa et al (2000) would not hold (Schellmann and Radtke 2010). Consequently, the sea level during the period under study would not have been affected by these phenomena. A detailed discussion and map of sample locations relevant to isostatic variation across the Atlantic coast is available in Schellmann and Radtke (2010).

Archaeological Record

Background

The Eastern coasts of Fuego-Patagonia have been the object of study since the 1950s, but it was not until the late 1990s when an interest in obtaining chronological data was also included. For the provinces of Rio Negro and Chubut, although several archaeological sites showing exploitation of marine resources have been identified, they date from mid to late Holocene and therefore, do not fall within the chronological scope of this paper.

For the timeframe under consideration, in the province of Santa Cruz, most of the archaeological surveys have been concentrated on the northern coast, such as the one by Zubimendi (2010), who focused on the relationship between different landscape units (high plateaus, plateau flanks, canyons, interior lagoons and the coast), showing complementarity between them. The archaeological record spans from ca. 7000 BP to the recent historic period, and shows that, for mid-Holocene, specific activities would have been done in every landscape unit. The coast presented a great availability of food resources in a safe and highly predictable way, and included mollusks, pinnipeds, and other seasonal resources, such as seabirds (Zubimendi 2010). Other archaeological sites in this province, including some with clear evidence of marine resource exploitation, have yielded later dates (Castro et al. 2006; Zilio et al. 2013).

Finally, Tierra del Fuego has been studied in depth, given its interest and particularities: together with other remote or insular locations and can be considered one of the last parts of the world to be populated by humans and has clear evidence of hunter-gatherers settling there by ca. 10,000 BP (Tres Arroyos site; Massone 2004) when it was still part of the continent (ca. 8200 BP Magellan Strait flooded, and Tierra del Fuego became an island (McCulloch and Morello 2009). This site is located on the Western sector of Tierra del Fuego, but it is closer to the Atlantic than to the Pacific Ocean. Also, on the Beagle Channel's northern coasts, the archaeological record shows marine adaptation by the mid-Holocene, with the development of a specific toolkit that includes harpoons and canoes used to exploit marine fauna. This makes it the only area within the study area with these characteristics (Orquera and Piana 1999, 2006; Zangrando 2009, 2018), though the chronological timeframe is outside the scope of this study.

As shown, in the last 30 years the archaeological information of the Patagonian and Fuegian Atlantic coast has increased considerably, and, despite still being areas to be investigated, the currently available corpus of information is abundant. However, this record is temporally biased toward the Late Holocene. The location marine items in the interior of Patagonia for this period and their distance to the coast were analyzed by Zubimendi and Ambrústolo (2011), and they found that these artefacts or ecofacts–usually isolated or few in number- can be regularly recovered at sites up to 150 km from the current coast and they would not represent food processing or consumption activities. Objects found up to > 300 km from the coast are usually mollusk beads from necklaces recovered at burials (Zubimendi and Ambrústolo 2011).

No comparable information exists for the Middle Holocene and, at this stage, it is not possible to establish the precise distances between archaeological coastal sites and the position of the coast during those times, but it is generally accepted that regular anthropic deposition of marine mammal bones, mollusks and other marine resources occurs within a 5 km band from the coast (Bonomo 2005; Zubimendi and Ambrústolo 2011). Since most of the Middle Holocene sites mentioned in this article are located within a 1–2 km littoral band, beyond which marine items rapidly decay in number, the coast line should not have been too far away.

Characteristics of the Archaeological Record

In general, the archaeological record is distributed discontinuously along the coast in response to its heterogeneity, concentrating on those areas that combine multiple resources such as coastal inlets (topographic lowlands), or areas covered with dunes that favoured its preservation (see details in Cruz and Caracotche 2006). Archaeological materials are usually found scattered on the surface and are characterized by shell midden sites in the form of relatively thin lenses and sometimes as large mounds. The vast majority are located on topographic lowlands or low marine terraces (3–10 MASL—Holocene) and to a lesser extent, elevated (15–30 masl—Pleistocene), and no more than 1 or 2 km from the current coastline. For the time frame considered here, some of the exceptions to such contexts would be sites located in hard rock formations such as Alero 2 (ca. 6500 BP; Carranza and Cardillo 2019), Alero el Oriental (ca. 7000 BP; Ambrustolo et al. 2011) and Médano Alto (ca. 5800 BP; Castro et al. 2001, 2006; Zubimendi 2010). It is worth noting that these shelters have some of the earliest dates for the whole study area.

However, with the exception of the Beagle Channel, given the limited extension of the sites, the low concentration of both artefacts and faunal remains, and long temporal archaeological gaps, it can be suggested that, at least for the mid-Holocene, the coast would have been used briefly with rare reoccupations of the same site, by small highly mobile groups with mixed diets, as a complementary space within wide ranges of action of hunter-gatherers with their organizational nodes located in the interior (Barberena 2008; Borrero and Barberena 2006; Salemme and Bujalesky 2000). Bone artifacts, within the Patagonian coast, consist mainly of bone points, harpoons, hollow awls, and some beads (Vázquez et al. 2011; Zangrando et al. 2009; Zubimendi et al. 2011). However, at the Beagle Channel the abundance and variety of bone artifacts and their exceptional preservation condition stands out. In comparison, the lithic inventory is extremely limited. It includes detachable harpoon points (cruciform and simple shouldered) and other fixed ones. Harpoon points lengths rarely exceed 20–22 cm, though at Túnel I one multidentate point reaches 48 cm (Orquera and Piana 2006). The archaeological record for the Beagle Channel shows the opposite situation from the Patagonian Atlantic coast as sites are the result of multiple occupations by maritime foragers, and all of them quite near the current coastline (no more than 300 m; Orquera and Piana 1999).

Target Areas

Having defined the potential regional scale, it is possible to begin to narrow it down to target areas where intertidal and subtidal archaeological surveys could be done. In this sense, two issues must be considered (Veth et al. 2020):

(1) The location of topographic features likely to have been attractive to past hunter-gatherers and prone to the accumulation of cultural material.
(2) The identification of locations where the archaeological material could have survived the potentially destructive effects of marine erosion during the early stages of inundation by sea-level rise, and are potentially discoverable by visual inspection, remote

sensing, coring, or erosion of overlying marine-sediment cover (Bailey et al. 2020a, b; Flemming et al. 2017).

This is in essence the same for all archaeological sites, terrestrial or marine. However, the variables for site taphonomy, preservation of observable archaeological signature, and methods for survey and investigation are considerably different. In the Fuego-Patagonian Atlantic coast there is no archaeological record dating from the Pleistocene–Holocene transition related to, nor near the coast (the closest are those in the Deseado Massif, in Santa Cruz–Cueva Maripe, Piedra Museo AEP-1, Cerro Tres Tetas, Cueva Minero, and others—that are located circa (ca.) 200 km from the current coastline). Since the sites are concentrated on the western part of the study area, it is difficult to project and hypothesize on if and how this now-submerged landscape was used during that particular period. Pinpoint areas of interest for archaeological surveys are thus difficult to project without original fieldwork and coastal and marine survey data. They are also too far away from the coast to expect that people living there regularly interacted with it. Nevertheless, it can be expected that areas that are currently submerged, and where different resources would have been concentrated, were somehow used by hunter-gatherers -either related to the inland occupations or not- Such resources could have included a concentration of marine mammals (pinnipeds, cetaceans), mollusks, and birds and, maybe, good quality rocky raw materials or quarries.

Regarding the second issue, Veth et al. (2020) state that different natural preservation factors should be considered, not only to rule out certain areas but also to strengthen others that would excel the finding possibilities. According to Flemming et al. (2017), in order to survive marine inundation, archaeological materials must have undergone certain natural protective processes that would have weakened the wave action striking them directly in an erosive manner. One of these circumstances would be the archaeological material being already buried in several meters of soil, sand, peat, or rock-fall before the sea rises over it, and the cover is sufficiently thick that the wave action does not erode down to the archaeological deposit. This certainly can happen, but then it would be unlikely for the archaeological material to be discovered until either the overburden is eroded away, or excavation brings it to light (Flemming et al. 2017). On the other hand, a relatively rapid rise of sea level may not protect sites by sufficiently reducing the time exposed to breaking waves, but it may result in rapid burial, which promotes survival in the longer term. Rapid vertical rise of sea level cannot by itself significantly increase the chance of a site surviving inundation. However, if it is combined with a low gradient, rapid horizontal transgression of the surf zone, protective topography, and is followed by a prolonged period of shallow-water coastal processes, it does enhance survival (Flemming et al. 2017).

Also, areas with active cliffs (see Fig. 3) which are affected by prolonged exposure to high energy waves would not be considered either, since they would be in a regression process that would likely cloud the possibility of finding archaeological material, though some exceptions could occur in low-lying depressions or other specific conditions suitable to preservation of submerged archaeological signatures. High-energy collision coasts and cliffs, however, are not generally considered high probability for site preservation and discovery. Thus, it is essential to consider the specifics of any local environment, especially at the area or site-scale.

Taking these key factors into consideration, in addition to the archaeological record distribution on land, areas such as the west coast of the San Matías Gulf (W-SMG); Río Negro Province, and the southern part of the Deseado Estuary or *Ría* Deseado (S-RD);

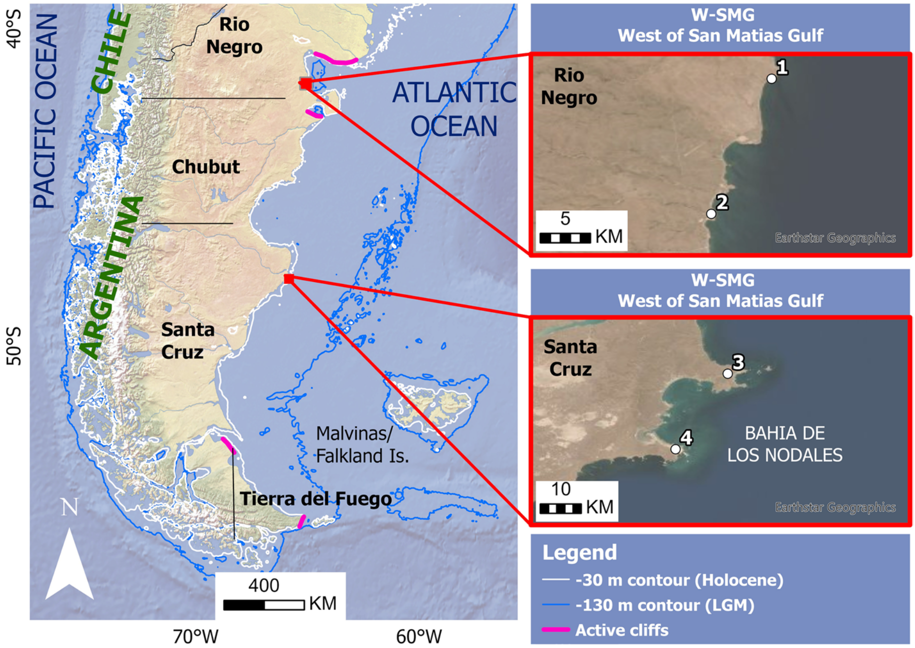

Fig. 3 Left—Archaeological record distribution on the study area, and sediment accumulation areas and active cliffs. Right—Possible areas of interest for further archaeological surveys (See Table 2 for archaeological sites references)

Santa Cruz Province, provide interesting areas for intertidal and submerged archaeological surveys. Given their geological formation of hard rocks (igneous and plutonic) these areas are characterised by a high resistance to erosion (Kokot 1999) and are also areas where fine sediments have accumulated during the early and mid-Holocene but did not cause an extensive progradation of the coasts. Additionally, in both areas the archaeological record is found in different landforms such as rock-shelters (Alero 2, W-SMG and Alero El Oriental, S-RD) and between Pleistocene and Holocene marine ridges, covered by dunes (Arroyo Verde 1, W-SMG and Médano 1, S-RD), and it would be interesting to evaluate how the landscape was being used on a narrower scale. There is evidence of local and no-local lithic materials in both of them, but in the S-RD it is worth mentioning there is a source of very good quality raw material for knapping (Punta Norte—black dot on Fig. 2), very close to the present coastline (Ambrústolo and Zubimendi 2019).

The combination of these elements makes the possibility of archaeological record to have survived inundation relatively 'high' since, if these areas were being used by people in the past, their cultural material would have been covered by fine sediments while the sea was rising during transgression, and so, be protected from the wave action by its natural geological characteristics.

Once more oceanographic, geological and paleoenvironmental data is gathered, it might be possible to analyze these two possibilities in more detail and also propose other areas worth considering for ground truthing, despite not being located within a potential mobility range covered by the humans who occupied the archaeological sites known to date. Perhaps places like the San José Gulf in Chubut Province, formed around 12,000 years BP (Ponce et al. 2011) and quite sheltered from the open ocean due to its narrow-mouthed shape, could have provided beneficial conditions for the preservation of early archaeological materials during and after the flooding process.

Potential Field Methods

In future stages of the research, the relevance and archaeological potential of the W-SMG and S-RD should be verified through fieldwork surveys, which would include different methods and techniques.

Initially, coastal, and intertidal pedestrian surveys could be done to have a closer approach to local landscape and possible finding of archaeological materials after systematic test pit excavation, if considered appropriate on the basis of the environmental characteristics.

The subtidal area could be then surveyed by means of appropriate remote sensing techniques since they have proved to be quite useful not only for better recording and understanding of the offshore bathymetry but also of underwater landscape features with archaeological potential and paleoenvironmental significance (see Bailey et al. 2020a, 2020b; Benjamin et al. 2020; McLaren et al. 2020; O'Shea 2021; Wiseman et al. 2021; among others). The archaeological information available for sites on land (Table 2) should be useful for identifying such landscape features with archaeological potential. This would narrow down the target areas to smaller ones considered appropriate for ground-truthing either by remotely operated vehicles, sediment sampling -by coring or other- and/or direct survey with divers.

Such staged research should be implemented in Argentina. As seen above there is published data on marine geological and geomorphological research that would be relevant for the topic, including assessments of sea-level fluctuations in different parts of the continental shelf since the late Pleistocene (Bujaleski et al. 2014; Isla 2011; Rabassa et al. 2009; Ponce et al. 2011; Violante et al. 2014a, b). And the find in Beagle Channel confirms the potential for such studies. Therefore, this information, combined with bathymetric charts, provides a good starting point for the area under study at different scales.

Subsequently, depending on the logistical requirements of the areas selected on the bases of their potential -and the available budget- there would be two possible approaches for conducting remote sensing surveys. One would imply the use of a fully equipped research vessel. This task could be performed by RV ARA Austral, property of the National Research Council (CONICET) and operated by the National Hydrographic Service of the Argentinean Navy. It has an autonomy of 50 days to carry out activities related to geology, geophysics, geodynamics, and seismic, physical and chemical oceanography, among others.[2] The vessel is equipped with various devices that can be used for inspection and sampling of the seabed, namely: Ocean Floor Observation System (OFOS), dredge, box corer, gravity corer (tubular), trawler, deck winch (Atlapa/Mac Gregor) with cable for optic fiber, single beam echosounders Simrad EK-80 and multibeam echosounder Kongsberg EA-640,

[2] For more information on the ARA Austral see https://www.argentina.gob.ar/armada/superficie/unidades/buque-oceanografico-ara-austral-q-21

Table 2 Possible areas of interest for further archaeological surveys

Nr/Site	Type of Site	Emplacement	Chronology	Characteristics	References
1/Alero 2	Rockshelter	Punta Pórfido locality. Rhyolithic outcrop in a narrow canyon	6624 ± 31/3680 ± 90	Ephemeral use. Mollusks (*Aulacomya ater*), animal remains, charcoal, lithic artifacts (flakes, chips)	Carranza and Cardillo (2019)
2/Arroyo Verde 1	Open-air, shellmidden + lithic artifacts	North of the mouth of Arroyo Verde, 100 m from the sea, in high dunes parallel to the coast	7.420 ± 90	Ephemeral use. Lithic artefacts, use of local rocks + non-local rocks (hematite and obsidian—ca. 100 km). Mollusks, crabs, otoliths and other fish bone specimens, armadillo plates, few indetermined Mammalia	Borella et al. (2015), Favier Dubois and Borella (2011) and Gómez Otero (2007)
3/Alero El Oriental 4	Rockshelter	Porphyric rock outcrops of Bahía Laura Formation; 31 masl; > 1 km from the ocean	6930 ± 100–5810 ± 110	Lower component: combustion structures, very good quality local raw material + non-local rocks (obsidian), bones of marine mammals, mollusks	Ambrústolo et al. (2011)
3/Médano Alto	Shellmidden in eroded dune	Lobos Island, Bahía de los Nodales, ca. 30 masl, 4 km from the ocean	5790 ± 79	Ephemeral use. Mollusks, lithic artifacts with few tools	Castro et al. (2001, 2006) and Zubimendi (2010)
Cueva Marsicano*	Rockshelter	Porphyric rock outcrops, ca. 40 km from the ocean	6853 ± 48–6684 ± 48	Ephemeral use. Five lithic artifacts (one sidescraper), different raw materials	Paunero et al. (2019)
4/Médano 1	Shellmidden	Punta Medanosa, Bahía de los Nodales, 10 masl	6300 ± 90	Hearths, lithic tools	Castro et al. (2001, 2006), Zubimendi (2010) and Zubimendi et al. (2005)

*Not located on the coast, but it is one the oldest sites relatively close to the ocean sub bottom profiler Atlas Parasound P70, and Acoustic Doppler Current Profiler (Teledyne Ocean Surveyor 38 kHz).

Another alternative to conduct remote sensing tasks would be to use one of the locally available so called "opportunity boats", such as fishing boats, installing the necessary equipment based on the special needs of our project. There are also private companies based in Argentina which provide environmental, coastal engineering, hydrographic and oceanographic services (see www.essa.com.ar/en/) and could therefore conduct such aspects of the project.

Whenever diving is necessary or desirable, aside from the researchers and equipment of the Underwater Archaeology Program of the Instituto Nacional de Antropología y Pensamiento Latinoamericano—including diving gear, inflatable vessel and diving compressor- there are two CONICET research centers based in Patagonia which also have nautical and diving facilities and equipment: The Centro Nacional Patagónico -CENPAT- located in Puerto Madryn city, Chubut Province, and the Centro Austral de Investigaciones Científicas -CADIC- located in Ushuaia, Tierra del Fuego. If needed, scuba diving equipment can be obtained in Buenos Aires or other locations, and scientific divers could be assisted by commercial divers during the underwater work.

In the subtidal zone, surveys could be conducted with appropriate remote sensing equipment in order to obtain relevant data of the seafloor, which would allow to identify major targets areas. Sediment samples are likely to provide information related to the direct or indirect evidence of human activities (for example, by revealing the presence of certain lithic or faunal remains, or charcoal), as well as chronological data.

By combining these methods and techniques in an unexplored area, like the territorial sea and continental platform adjacent to Eastern Patagonia and Tierra del Fuego, we hope to contribute to the emerging systematized methodology for the search, discovery, and excavation of submerged early archaeological evidence. We expect submerged sites and landscape studies to contribute to the development of peopling models, or enhance those already established, as well as to the comprehension of the use and exploitation of this vast area. Any effort toward the formation and standardization of a survey methodology for submerged sites in the region would be a significant contribution to South American archaeology more broadly. Additionally, it will provide valuable information on the submerged landscape that can be useful not only for other archaeologists, but also for other disciplines researchers, such as marine and coastal biologists, geologists, and geographers, and even for the management of resources and cultural heritage in marine protected areas.

Conclusions

Research momentum is building, with many hundreds of underwater finds of early human occupations now reported mainly in Europe, North America, and Australia. The discipline of submerged landscape archaeology remains in an early phase of development, posing technological, methodological, and theoretical challenges unlike those experienced by terrestrial archaeologists. However, as Calippo notes in relation to the *sambaquis* -shell middens- in Brazil, we can ask ourselves if the belief that early submerged sites are probably lost forever is not a reflection of the archaeologists' unfamiliarity with the underwater universe rather than a question of preservation potential (Calippo 2008: 158).

This contribution has been an attempt to go beyond just noting the potential of studying territories which are currently submerged in the Argentinean territorial sea and continental shelf from an archaeological perspective in terms of the early human inhabitants of the southernmost part of the American continent. As a subsequent step and following methodological approaches which have proven successful in various cases, we have thoroughly reviewed the terrestrial archaeological evidence for the Eastern Patagonian region which can be relevant for the topic. The chronology of the sites, their setting, the type of material evidence associated to them, including that related to subsistence strategies and use of space, as well as other characteristics, were then preliminary discussed in view of patterns which can be extrapolated to areas currently under water. Some of the latter, combined with some general hydrographic data (mainly ocean past and present coastline and sea bottom topography) are the basis for predicting some potential "hotspots" which in the future can be targeted for detail field surveys and sampling in search for evidence of cultural activities. Two regions which seem to match such criteria have been identified, and could, perhaps, be the subject of actual field surveys. The possibilities of implementing such field work were evaluated, indicating optimistic expectations even with locally available human, technological and logistical resources.

The submerged find recently reported in the Beagle Channel (Zangrando et al. 2022) is significant and novel for Argentina and South American archaeology and it provides an exciting launching point for the discipline to grow in the region. Our review paper is therefore timely, as it has presented the first baseline study in Argentina for potential submerged archaeological sites associated with early hunter-gatherer groups. Hopefully, it will encourage further research which will surely shed on many relevant questions in the field which are currently unanswered.

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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