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The human occupation of northwestern Patagonia (Argentina): Paleoecological and chronological trends

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ABSTRACT

Archaeological radiocarbon databases are being increasingly used as a proxy of past demographic trends. In this paper we compile and analyze an extensive database of paleoecological information and ^{14}C dates from archaeological sites in northwestern Patagonia (Argentina, South America). On this basis, we assess the regional distribution of human populations since the late Pleistocene, and their relation with the evolution of Patagonian climate and landscapes. We explore the spatial and temporal distribution of evidence and discuss sampling biases affecting the record in different ecological contexts. The analysis is set in the frame of three main ecological regions that have implications for human subsistence: Andean forest, grass steppe, and shrub steppe. The intensity of the archaeological signal differs among these regions through time, being stronger and more homogeneous in the grass steppe. In the Andean forest and the shrub steppe the signal is weaker and even absent during short periods of the middle Holocene. We suggest likely sampling biases contributing to these tendencies, since these three regions present variable research cover and intensity. On the other hand, we also suggest that these differences may reflect variations in the intensity of human occupation, in favor of more attractive environments for hunting (i.e., areas where guanaco are generally more abundant). This macro-regional synthesis of the paleoecology and archaeology of northwestern Patagonia provides a platform for developing future oriented research.

1. Introduction

Starting with the seminal 'Dates as data' paper of Rick (1978), and after two decades of development, radiocarbon series are now increasingly used as a proxy of the intensity of the archaeological signal and, hence, of human demography (e.g., Gamble et al., 2004; Shennan and Edinborough, 2007; Williams, 2012; Martínez et al., 2013; Prates et al., 2013; Williams et al., 2013). Recent developments include the use of taphonomic corrections accounting for the time-dependent preservation of the archaeological record (Surovell et al., 2009), methodological discussions on the analytical steps required to process the data (Steele, 2010; Buchanan et al., 2011), and the proposition of equations translating frequencies of dates in terms of numeric population reconstructions (Williams, 2013), among others. In this paper we assemble radiocarbon data available for northwestern Patagonia (Argentina, Fig. 1), a region with very discontinuous field sampling and dating. The long-term goal is to assess the regional distribution of human populations since the late Pleistocene, and their relation with the evolution of the Patagonian climate and landscapes, as well as studying the economic and social context for demographic change and/or stability. We consider this work as a first step focused in assembling the database, characterizing its structure and critically assessing its quality and main limitations.

2. Present environmental context (35–41°S)

Northwestern Patagonia is located on the east side of the Andes and the adjacent volcanic fields and plateaus between 35° and 41°S (Fig. 1). Climate regime is characterized by winter precipitation and summer droughts, although seasonality disappears to the east (San Martín de Los Andes vs. Neuquén climograms; Fig. 2). During the

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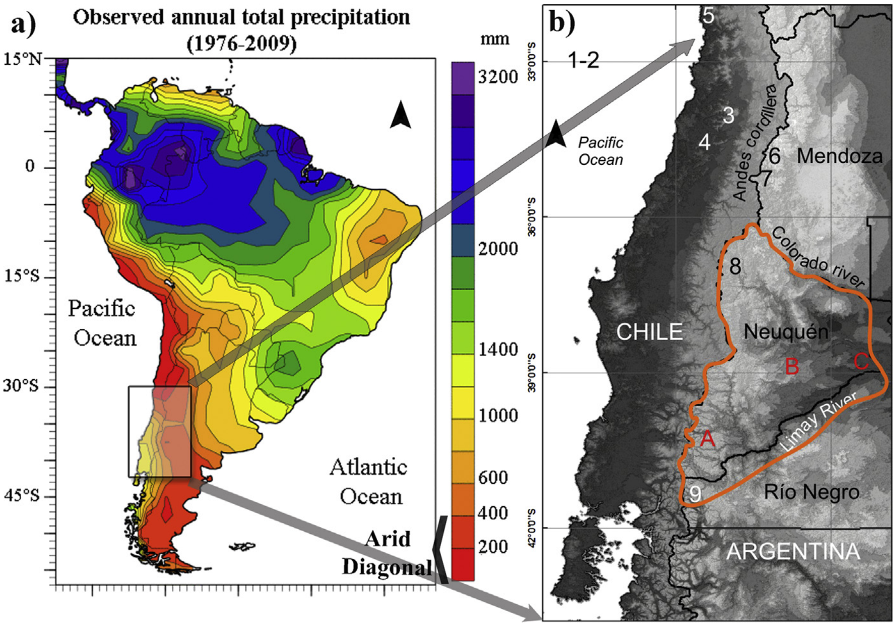

Fig. 1. a) South America: observed total annual precipitation between 1976 and 2009 (source: Liebmann and Allured, 2005). b) Location of study area (orange outline); climograms location (A) San Martín de Los Andes, (B) Zapala, (C) Neuquén City; and palaeorecords mentioned in the text (1–10; see Table 1).

austral winter, the Southern Westerly Wind Belt (westerlies, herein) migrates northwards affecting regions up to about 30°S (Garreaud et al., 2008). Precipitation occurs through frontal systems associated with migratory surface cyclones that tend to migrate eastward along rather narrow latitudinal bands known as "storm tracks" (Garreaud et al., 2008). As a consequence of the rain shadow effect produced by the forced subsidence of the surface winds over the Andes, precipitations present a strong west-east decreasing gradient. Thus, annual precipitation varies from 1065 mm close to the Chile–Argentina border (San Martín de los Andes; Fig. 2a), to 205 mm in Zapala (Fig. 2b) and 172 mm (Neuquén; Fig. 2c) in the Patagonia plateau to the east.

Vegetation distribution follows the decreasing west-east precipitation gradient, from the forest to the grass steppe and then to shrub steppe communities. Forest [Subantartic province (Roig, 1998)] distribution is almost confined to the Andean slopes and former glacial valleys. Forest communities in Neuquén and northern Río Negro provinces are diverse including the *Araucaria araucana* forest, the *Nothofagus* sp. forest and the *Austrocedrus* forest (Roig, 1998). *A. araucana* usually associates with *Nothofagus dombeyi* and *Nothofagus pumilio* forming mixed forests whereas pure *Nothofagus obliqua*, *Nothofagus alpina and Nothofagus antarctica* forest develop in the area.

The *Festuca pallescens* grass steppe [Subantartic province (Roig, 1998)] is a narrow and discontinuous band between 71° and 71°30′W. It is characterized by a high cover of grasses (>60%) accompanied by few shrubs, except for deteriorated areas where shrubs become abundant (Roig, 1998).

The shrub steppe comprises plant communities belonging to the Patagonic and Monte provinces (Payenia, Monte–Patagonia transition and Monte) as well as the transitional vegetation between them (Roig, 1998). The most frequent community distributed on volcanic landscapes from northern Neuquén (Payenia district, Patagonic province) is the shrub steppe dominated by *Ephedra ochreata* together to *Lycium chilense*, *Senecio filaginoides*, *Grindelia chiloensis* and *Mulinum spinosum*, among others (León et al., 1998). The shrub-grass steppe (Occidental district, Patagonic province) is a transitional community between the grass and the shrub steppes. It is a 60–80 cm tall plant community dominated by *Stipa speciosa*, *Stipa humilis*, *Adesmia campestris*, *Berberis heterophylla* and *Poa lanuginose* (León et al., 1998).

3. Materials and methods

The ^{14}C dates included in this paper were obtained through exhaustive review of published information, supplemented by a few unpublished dates, from northwestern Patagonian archaeological sites. The radiocarbon evidence is organized according to the three main plant communities described in Section 2. The chronological database presented here integrates the results produced by different research teams since the beginning of investigations in northwestern Patagonia. The results are spatially heterogeneous, with some regions largely devoid of systematic research. As defined here, this spatial unit includes Neuquén province, bounded by the Colorado river to the north and the Limay river to the south, plus the southern margin of the Limay river in Río Negro province (Fig. 1). The database is organized with single radiocarbon dates as the basic unit of analysis. The ages were obtained from diverse materials (charcoal, faunal and human bone, macro-botanical remains) related to human activity. It is not our goal to address each site in detail, but to identify the main trends emerging from the analysis.

The calibration of ^{14}C ages and the multi sample Probability Plots were done using Calib Rev. 7.0.1 (Reimer et al., 2013). Ages are expressed at two-sigma confidence level and in calendar years BP. As radiocarbon ages of contemporaneous samples from the opposite hemispheres are different (McCormac et al., 2004; Hogg et al., 2011), we used the southern hemisphere calibration curve (SHCal13, Hogg et al., 2013).

4. Results

The results synthesized in this review are presented in two main sections: paleoecological trends and archaeo-chronological data.

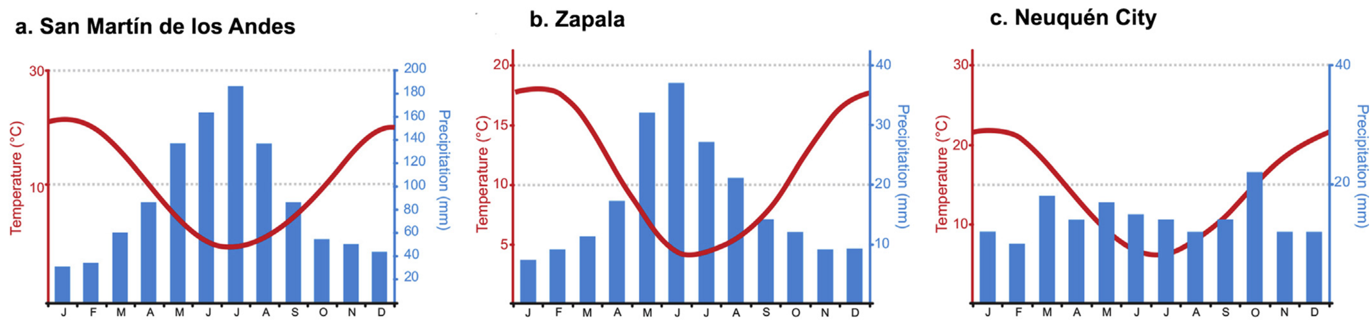

Fig. 2. Climograms from selected northern Patagonian regions.

4.1. Review of past environmental and climatic dynamics

Major climatic changes seem to be related to the shifts of the westerlies and their associated precipitation changes. Therefore, information from sites sensitive-to-precipitation from both sides of the Andes (between 32 and 40°S) and from climate proxies of marine cores (Table 1; Fig. 3) was integrated to perform a paleoclimatic synthesis and provide an environmental context to the archaeological record analyzed in the present paper.

Past environmental and climatic history from northwestern Patagonia (35°–40°S; Argentina) since the Last Glacial Maximum (LGM) termination [23–18 cal ka BP] was quite dynamic. Despite the scarce evidence from the northernmost regions (35°–39°S; Espizúa, 2005; Markgraf et al., 2009; Navarro et al., 2012), the southern area ~40°S shows a clear picture of past environmental and climatic scenarios as well as potential forcings (e.g. Markgraf, 1984; Whitlock et al., 2006; Bianchi and Ariztegui, 2012; Iglesias et al., 2012).

4.1.1. Lateglacial (17–12 ka)

The pollen record from Laguna Tagua Tagua shows the presence of *Nothofagus* and *Pumnopytis andina* forests which indicate cooler and wetter conditions than present (Fig. 3; Heusser, 1990; Valero-Garcés et al., 2005). Precipitation and temperature proxies from marine cores along the Pacific coast at 33°S agree with these inferences and suggest that temperature would have been 3°–7 °C below present, and precipitation about 1200 mm above modern values (Fig. 3; Lamy et al., 1999; Kim et al., 2002). This environmental and climatic scenario would be most likely consequence of a northward position or a strengthening of the Southern Westerlies Wind Belt (SWWB) after its “extreme glacial position” (centered on 41°S) during the LGM (e.g., Heusser, 1990, 2003; Valero-Garcés et al., 2005). After this, the SWWB would have migrated southwards towards its modern position (45–50°S) or weakened, but either case would have brought more precipitation to Central Chile (Heusser, 1990, 2003; Valero-Garcés et al., 2005).

On the east side of the Andes, the presence of scrub steppes around Mallín Vaca Lauquen and *Nothofagus-Prumnopitys andina* woodland on mountains slopes between 17 and 14.8 ka (Markgraf et al., 2009; Fig. 3), and the dominance of Poaceae accompanied by shrubs and herbs around Laguna El Trébol (40°S) between 17 and 15 ka (Fig. 3; Whitlock et al., 2006), suggest cooler and drier conditions than present. Markgraf et al. (2009) suggest that cooler conditions in Mallín Vaca Lauquen area are consistent with the lower sea surface temperatures recorded in the Pacific coast (Lamy et al., 1999; Kim et al., 2002), whereas drier conditions would be consequence of weakened westerlies produced by a strengthening of the Southeastern Pacific High pressure system during the late Glacial. A more diverse steppe and a high proportion of herbs after 14.8 ka at Mallín Vaca Lauquen (Fig. 3; Markgraf et al., 2009) and the development of open *Nothofagus* woodlands (reflected by a greater abundance of forest taxa) around Laguna El Trebol from 15 to 11.4 ka (Fig. 3), implies warmer and moister conditions, but less than present (Whitlock et al., 2006).

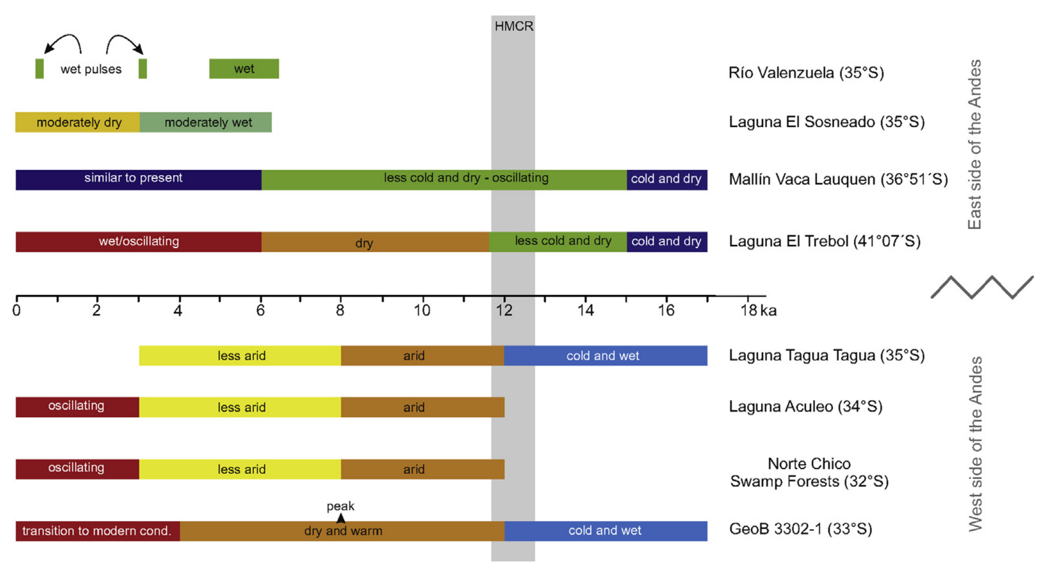

Fig. 3. Synthesis of paleoclimatic conditions at northwestern Patagonia and selected westward Andes records since 17ka. (HMCR, Huelmo Mascardi Cold Reversal).

Table 1
Paleoecological archives for northwestern Patagonia.

Site	Latitude/Side of the Andes	Depositional environment/proxy	References
1. GeoB 3302-1	33°S/West	Marine core/geochemical and sedimentary data	Lamy et al., 1999; Kim et al., 2002
2. GIK 17748-2	33°S/West	Marine core/geochemical and sedimentary data	Kim et al., 2002
3. Laguna Aculeo	33°50′S/West	Lake/Multiproxy	Jenny et al., 2002, 2003; Villa-Martínez et al., 2003
4. Laguna Tagua Tagua	34°30′S/West	Lake/Multiproxy	Heusser, 1990; Valero-Garcés et al., 2005
5. Norte Chico Swamp Forests	32°S/West	Swamp forests/pollen	Maldonado and Villagrán, 2006; Maldonado et al., 2010
6. Río Valenzuela	35°S/East	Valley/moraines	Espizúa, 2005; Espizúa and Pitte, 2009
7. Laguna El Sosneado	35°S/East	Lake/Pollen and macroscopic charcoal	Navarro et al., 2012
8. Mallín Vaca Lauquen	36°51′S/East	Meadow/Pollen and macroscopic charcoal	Markgraf, 1987; Markgraf et al., 2009
9. Laguna El Trébol	41°07′S/East	Lake/Pollen and macroscopic charcoal	Whitlock et al., 2006

Around 41°S, a cold reversal episode called Huelmo/Mascardi (HMCR) was recorded between 13.3 and 11.7 ka either on the western side of the Andes (Chilean Lake District; Hajdas et al., 2003; Moreno and León, 2003) or the eastern side (Lago Mascardi; Ariztegui et al., 1997; Bianchi and Ariztegui, 2012). Pollen and charcoal records located east of the Andes between 40° and 42°S (e.g. Laguna El Trébol, Whitlock et al., 2006; Lago Mosquito – Laguna Cóndor, Iglesias et al., 2012) do not reflect a regional cooling but lower chlorophyll and organic content at Laguna El Trébol around 13.4 ka was interpreted as evidence of localized temperature decline (Tatur et al., 2002). Whitlock et al. (2006) interpret high Charcoal Accumulation Rates (CHAR) values at Laguna El Trébol between 13.3–13.0 ka and 12.5–11.4 ka as synchronous with the HMCR.

4.1.2. *Early Holocene (~12–8 ka)*

On the west side of the Andes, pollen records from Norte Chico (Quereo and Santa Julia; Villagrán and Varela, 1990; Maldonado et al., 2010), Laguna Tagua Tagua (Heusser, 1990; Valero-Garcés et al., 2005) and Laguna Aculeo (Jenny et al., 2003; Villa-Martínez et al., 2003) show arid conditions, as indicated by increased percentages of Chenopodiaceae (Fig. 3). Marine records are consistent with terrestrial data and indicate the gradual establishment of dry and warm conditions peaking after 8 ka (Fig. 3; Lamy et al., 1999; Kim et al., 2002). These widespread arid conditions along the west side of the Andes (32–35°S) would be the result of a stronger Southeastern Pacific High Pressure system and weakened and/or deflected southward westerlies (Lamy et al., 1999; Valero-Garcés et al., 2005).

Pollen records from Mallín Vaca Lauquen demonstrate no vegetation changes regarding the latter period, but the diverse steppe development would be related to increased precipitation and temperatures (but less than present day). Markgraf et al. (2009) hypothesized that the existence of opposite precipitation patterns west and east of the Andes (dipole) during the early Holocene would have been the result of an anomalous component of upper level flow. However, the development of open *N. dombeyi* forest supporting substantial amounts of steppe and shrubland elements (Fig. 3) associated with low CHAR in Laguna El Trébol between 11.4 and 6 ka was interpreted as a signal of drier conditions than present (Whitlock et al., 2006). As such, Laguna El Trébol record supports the early Holocene aridity conditions recorded in those sites on the west side of the Andes and does not support the climatic inferences (precipitation dipole) proposed by Markgraf et al. (2009).

4.1.3. *Mid Holocene (8–3 ka)*

On the west side of the Andes, pollen records still suggest dry conditions but show a general trend towards increasing humidity based on a dramatic decrease of Chenopodiaceae percentages (e.g., Laguna Acuelo, Villa-Martínez et al., 2003; Laguna Tagua Tagua, Valero-Garcés et al., 2005; Fig. 3) and a rise of local moisture taxa indicators, such as Myrtaceae, *Gunnera* and *Escallonia* in swamp forests (32°S; Maldonado and Villagrán, 2002, 2006). Marine cores indicate a gradual decrease of temperature and increase of precipitation up to modern values (Fig. 3; Lamy et al., 1999; Kim et al., 2002).

On the east side of the Andes, Laguna El Sosneado record (Fig. 3) demonstrates wet conditions from 6.4 ka based on: (1) the presence of Patagonian shrub communities that develop today 100–500 m up slope from the lake and (2) maximum fire frequency and magnitude between 6.4–5 ka suggesting high fuel availability and, therefore, high water availability during this period (Navarro et al., 2012). At the Río Valenzuela basin (35°S; Fig. 3), the first of three Neoglacial advances occurred between 6.4 and 4.8 ka (Espizúa, 2005). According to Espizúa and Pitte (2009), glacier fluctuations in the Central Andes of Argentina are strongly affected by precipitation variations, so advances would indicate increased rainfall. Therefore, both records located at 35°S suggest wetter conditions between 6.4–5 ka. Conversely, local shoreline fluctuations and the development of a Cyperaceae wetland in the shallow basin at Mallín Vaca Lauquen indicate variable precipitation under warmer conditions until 5.3 ka, when similar-to-present conditions established (Fig. 3; Markgraf et al., 2009). Pollen and charcoal record from Laguna El Trébol show the expansion of *Austrocedrus* (Fig. 3), at most sites located at 40°S on the east side of the Andes (e.g., Whitlock et al., 2006; Bianchi and Ariztegui, 2012; Iglesias et al., 2012). This change was preceded by a change in the fire regime from crown fires towards more frequent and smaller surface fires. The expansion of *Austrocedrus* together with fire-regime changes would reflect increased spring and early summer precipitation from a strengthening of the Southern Westerlies after 6 ka and increasing short-term climate variability [e.g., El Niño Southern Oscillation, (ENSO); Whitlock et al., 2006].

4.1.4. *Late Holocene (3 ka-present)*

Records from the west of the Andes (Laguna Aculeo; swamp forests records from Norte Chico, Chile) indicate alternating dry-wet phases up to 2 ka when a gradual trend to increased precipitation similar-to-modern values was reached (Fig. 3). Most records and proxies indicate that the late Holocene was characterized by a high climatic variability (Jenny et al., 2002; Villa-Martínez et al., 2003; Maldonado and Villagrán, 2006) related to an increased frequency in El Niño events during the last 2 ka (Moy et al., 2002; Rein et al., 2005).

On the east side of the Andes, Mallín Vaca Lauquen pollen record indicates modern vegetation (Fig. 3) and similar-to present climatic conditions (winter rain and summer droughts), but with high climatic variability based on limnological changes and increased fire activity (Markgraf et al., 2009). At 35°S, Laguna El Sosneado records a trend towards drier conditions to the present (Navarro et al., 2012; Fig. 3) although, two late Holocene glacier advances at 2.6–2.5 ka and 0.6ka (Little Ice Age; Fig. 3) at Río Valenzuela, also suggest high rainfall variability (Espizúa, 2005). After 2 ka, Laguna El Trébol also shows variable values of *Nothofagus* and *Austrocedrus* (Fig. 3) along with maximum CHAR values and high fire frequency. As in the Mid Holocene, these vegetation patterns and fire-regimes would respond to seasonal, interannual and interdecadal droughts as a result of precipitation variability at short time-scales associated with ENSO (Whitlock et al., 2006).

4.1.5. Late Holocene (3 ka-present)

Records from the leeward of the Andes (Laguna Aculeo; swamp forests records from Norte Chico, Chile) indicate alternating dry-wet phases up to 2 ka when a gradual trend to increased precipitation similar-to-modern values was reached (Fig. 3). Most records and proxies indicate that the late Holocene was characterized by a high climatic variability (Jenny et al., 2002; Villa-Martínez et al., 2003; Maldonado and Villagrán, 2006) related to an increased frequency in El Niño events during the last 2 ka (Moy et al., 2002; Rein et al., 2005).

On the lee side of the Andes, Mallín Vaca Lauquen pollen record indicates modern vegetation (Fig. 3) and similar-to present climatic conditions (winter rain and summer droughts), but with high climatic variability based on limnological changes and increased fire activity (Markgraf et al., 2009). At 35°S, Laguna El Sosneado records a trend towards drier conditions to the present (Navarro et al., 2012; Fig. 3), although two late Holocene glacier advances at 2.6–2.5ka and 0.6ka (Little Ice Age; Fig. 3) at Río Valenzuela, also suggest high rainfall variability (Espizúa, 2005). After 2 ka, Laguna El Trébol also shows variable values of *Nothofagus* and *Austrocedrus* (Fig. 3) along with maximum CHAR values and high fire frequency. As in the mid Holocene, these vegetation patterns and fire-regimes would respond to seasonal, interannual and interdecadal droughts as a result of precipitation variability at short time-scales associated with ENSO (Whitlock et al., 2006).

4.2. Archaeological database

The archaeo-chronological database per ecological region is presented in Tables 2 (Andean forest), 3 (grass steppe), and 4 (shrub steppe). The structure of these samples is synthesized in Table 5 and the location of the sites is presented in Fig. 4.

There is a total of 252 radiocarbon samples from 64 archaeological sites from Neuquén province and the southern margin of the Limay river, in Río Negro province. Of these sites, 44 (68.75%) correspond to sheltered sites (caves and rockshelters), and 20 (31.25%) to open air sites, indicating a bias towards archaeological deposits from shelters. This bias is strong in the Andean forest and in the grass steppe where shelters account for 76.9% and 78.1% of all sites respectively. Interestingly, in the shrub steppes the representation of open air vs. shelter sites is homogeneous with only 47.4% of sites from shelters (Table 2). In this eco-region, many of the open-air records correspond to burial sites.

The overall number of dates from open-air sites in the three landscape units is only 35 (13.9%), while 217 dates (86.1%) come from shelters. Taphonomic loss and differential visibility probably generated these differences at some level, particularly in the Andean forest, with low archaeological visibility and poor conditions for preservation of organic materials (Borrero and Muñoz, 1999; Fernández, 2010). In the cases of the grass and shrub steppe, sampling bias towards stratified sequences from sheltered contexts may be a more important cause, since research efforts tend to be focused on this landscape features.

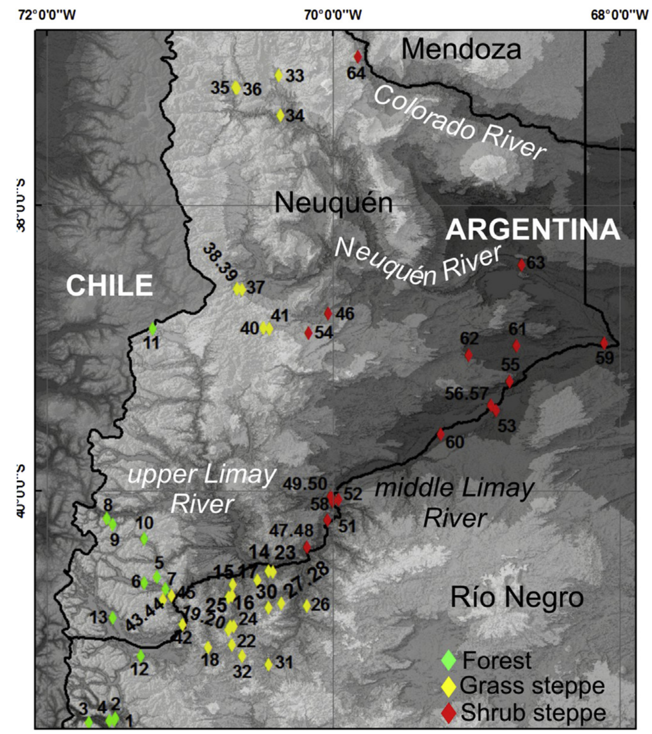

Fig. 4. Location of the archaeological sites represented in the database (see Supplementary kmz file).

4.2.1. Distribution of radiocarbon dates in the landscape units

Table 5 synthesizes the number of sites and radiocarbon dates from the three ecological units defined in Section 2: Andean forest, grass steppe, and shrub steppe. These units are used as operational definitions for an initial description and analysis of spatial-temporal tendencies.

The database for the Andean forests of Neuquén and Río Negro provinces is composed of 63 dates that come from 13 archaeological sites. This record shows a highly discontinuous pattern until the late Holocene (Fig. 5). Importantly, the only dates older than the late Holocene come from a single site, El Trébol rockshelter, located in the Nahuel Huapi Lake basin (Hajduk et al., 2006). There is a persistent radiocarbon signal after 4000 cal years BP, which is particularly intense in the last 1000 years. It is also relevant to indicate that earlier occupations at El Trébol occurred when the site was not in a dense forest, as it is today, but probably in a grass open forest within the steppe/forest ecotone (Whitlock et al., 2006).

The temporal record from the grass steppes is composed of 127 samples from 35 sites (Table 2). It shows a remarkable continuity of dates since the first human presence in the early Holocene (9000 cal years) and up to recent times (Fig. 6).

The temporal record from the shrub steppes of eastern Neuquén and Río Negro includes 62 samples from 19 sites. It shows an early first human presence in the Pleistocene–Holocene transition that is recorded in spatially separate places at a similar time, such as Cueva Huenul 1 in northern Neuquén, and Cueva Epullán Grande in southern Neuquén (Fig. 4). This record is highly discontinuous during the Mid-Holocene, particularly between 8000 and 6000 cal BP. Radiocarbon dates resume ~6000 BP and are particularly abundant in the last 2000 BP.

5. Discussion and conclusions

A comparison of the distribution of radiocarbon dates for the three ecology-based spatial units shows interesting trends since

Table 2
Radiocarbon information for the Andean forest.

Site#	Site	Lat °	Lat '	Lat "	Lon °	Lon '	Lon "	Lab code	Method	Dated material	^{14}C ys BP	Sigma	Cal ys BP	Site type	Reference
1	Población Anticura	41	36	33	71	31	9	LP-2376	Conv.	Charcoal	3350	100	3379/3838	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2274	Conv.	Charcoal	2530	60	2426/2755	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2375	Conv.	Bone (*H. sapiens*)	710	70	545/761	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2402	Conv.	Charcoal	550	50	509/651	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	UGA-7119	AMS	Charcoal	2960	25	3057/3210	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2266	Conv.	Charcoal	2660	80	2493/2961	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2257	Conv.	Charcoal	2270	80	2044/2490	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	UGA-4825	AMS	Bone (*H. sapiens*)	3180	30	3357/3455	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2390	Conv.	Charcoal	530	50	502/648	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	UGA-3553	AMS	Bone (*H. sapiens*)	1550	30	1377/1527	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2264	Conv.	Charcoal	1420	70	1184/1520	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2398	Conv.	Charcoal	690	60	550/709	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2102	Conv.	Charcoal	1150	60	935/1184	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2429	Conv.	Charcoal	590	50	529/659	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2100	Conv.	Charcoal	810	50	666/799	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2421	Conv.	Charcoal	660	50	549/680	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2084	Conv.	Charcoal	700	60	552/731	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2079	Conv.	Charcoal	400	70	307/532	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2064	Conv.	Charcoal	480	70	319/648	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2266	Conv.	Charcoal	480	70	319/648	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2419	Conv.	Charcoal	300	50	284/488	rs	Fernández et al., 2013
	Población Anticura	41	36	33	71	31	9	LP-2413	Conv.	Charcoal	280	40	153/465	rs	Fernández et al., 2013
2	Paredón Lanfré	41	36	18	71	32	38	LP-1610	Conv.	Charcoal	1570	60	1336/1570	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1429	Conv.	Charcoal	1500	60		rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1444	Conv.	Charcoal	1450	70	1273/1523	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1436	Conv.	Charcoal	1480	70	1289/1527	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1594	Conv.	Charcoal	1030	70	781/1087	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-2566	Conv.	Charcoal	930	66	726/958	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1607	Conv.	Charcoal	790	60	652/902	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1642	Conv.	Charcoal	490	60	332/649	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1625	Conv.	Charcoal	470	70	317/644	rs	Fernández et al., 2013
	Paredón Lanfré	41	36	18	71	32	38	LP-1587	Conv.	Charcoal	330	50	302/495	rs	Fernández et al., 2013
3	Peumayén 1	41	36	47	71	42	54	LP-2161	Conv.	Charcoal	210	60	1/429	Shelter	Fernández et al., 2013
	Peumayén 1	41	36	47	71	42	54	LP-2266	Conv.	Charcoal	480	70	319/648	Shelter	Fernández et al., 2013
4	Campamento Argentino	41	36	15	71	33	46	LP-2136	Conv.	Charcoal	560	60	511/655	rs	Fernández et al., 2013
	Campamento Argentino	41	36	15	71	33	46	LP-2134	Conv.	Charcoal	230	70	1/462	rs	Fernández et al., 2013
5	Alero Lariviere	40	36		71	13		Beta-57836	Conv.	Charcoal	2760	80	2747/3064	rs	Silveira, 1999a
	Alero Lariviere	40	36		71	13		Beta-57837	Conv.	Charcoal	780	50	657/791	rs	Silveira, 1999a
6	Alero Los Cipreses	40	39	47	71	19	5	LP-159	Conv.	Charcoal	3490	80	3573/3972	rs	Silveira, 1996
	Alero Los Cipreses	40	39	47	71	19	5	Ingeis 2814/936	Conv.	Charcoal	2890	100	2785/3254	rs	Silveira, 1996
	Alero Los Cipreses	40	39	47	71	19	5	Ingeis 2813/954	Conv.	Charcoal	840	90	655/932	rs	Silveira et al., 2010
	Alero Los Cipreses	40	39	47	71	19	5	LP-145	Conv.	Charcoal	1510	90	1280/1572	rs	Silveira et al., 2010
7	Alero Cicuta	40	41		71	1			Conv.	Charcoal	1370	55	1181/1377	rs	Silveira, 1999b
	Alero Cicuta	40	41		71	1			Conv.	Charcoal	1080	50	918/1089	rs	Silveira, 1999b
8	Cueva Parque Diana	40	11		71	34		LP-1704	Conv.	Charcoal	2370	70	2306/2712	Cave	Pérez and Smith, 2008
	Cueva Parque Diana	40	11		71	34		LP-1720	Conv.	Charcoal	990	60	764/1002	Cave	Pérez and Smith, 2008
	Cueva Parque Diana	40	11		71	34		LP-1713	Conv.	Charcoal	900	60	722/927	Cave	Pérez and Smith, 2008
	Cueva Parque Diana	40	11		71	34		LP-1697	Conv.	Charcoal	760	60	561/796	Cave	Pérez and Smith, 2008
	Cueva Parque Diana	40	11		71	34		LP-1695	Conv.	Charcoal	580	60	518/660	Cave	Pérez and Smith, 2008
9	Las Cachañas							LP-1727	Conv.	Charcoal	1090	60	919/1176	oa	Pérez and Smith, 2008
10	Lago Meliquina (F. M.)	40	20	3	71	19	8	LP-1721	Conv.	Charcoal	920	60	725/935	oa	Pérez and Smith, 2008
	Lago Meliquina (F. S.)	40	20	3	71	19	8	LP-1569	Conv.	Charcoal	750	60	561/790	oa	Pérez and Smith, 2008
	Lago Meliquina (F. S.)	40	20	3	71	19	8	LP-1559	Conv.	Charcoal	730	80	541/796	oa	Pérez and Smith, 2008
11	Montículo Angostura	38	51		71	15		n/d	Conv.	n/d	900	75	686/934	Oa	Hajduk, 1986
12	Cueva El Trébol	41	8	20	71	20	30	AA-65707	AMS	Mylodon bone/cutmark	10570	130	12093/12720	Cave	Hajduk et al., 2006; Lezcano et al., 2010
	Cueva El Trébol	41	8	20	71	20	30	AA-75678	AMS	Fox bone/ cutmark	10600	100	12234/12724	Cave	Hajduk et al., 2006; Lezcano et al., 2010
	Cueva El Trébol	41	8	20	71	20	30	AA-75679	AMS	Mylodon bone/ cutmark	10640	120	12,228/12,746	Cave	Hajduk et al., 2006; Lezcano et al., 2010
	Cueva El Trébol	41	8	20	71	20	30	AA-65712	AMS		5863	83	6480/6887	Cave	Hajduk et al., 2006; Lezcano et al., 2010
	Cueva El Trébol	41	8	20	71	20	30	AA-65708	AMS		5731	70	6394/6677	Cave	Hajduk et al., 2006; Lezcano et al., 2010
	Cueva El Trébol	41	8	20	71	20	30	LP-1525	Conv.		5620	80	6283/6568	Cave	Hajduk et al., 2006; Lezcano et al., 2010
13	Puerto Tranquilo I	40	53		71	32		n/d	Conv.?	n/d	1980	60	1816/2114	rs	Hajduk, 1989–1990

Table 2 (*continued*)

Site#	Site	Lat °	Lat '	Lat "	Lon °	Lon '	Lon "	Lab code	Method	Dated material	^{14}C ys BP	Sigma	Cal ys BP	Site type	Reference
	Puerto Tranquilo I	40	53		71	32		n/d	Conv.?	n/d	640	60	538/678	rs	Hajduk, 1989–1990
	Puerto Tranquilo I	40	53		71	32		n/d	Conv.?	n/d	1890	80	1618/1998	rs	Hajduk, 1989–1990

References: site type: rs, rockshelter; oa, open air.

the late Pleistocene. Globally, there are important sample size differences between these regions, with the grass steppe almost exactly doubling the size of the forest and the shrub steppe respectively. Although the shrub steppe region covers a significantly larger area (~43,300 km^2) than the other two (Andean Forest: ~13,000 km^2; grass steppe: ~27,000 km^2), it does not have as many archaeological sites as could be expected in terms of its size. This contrast is not necessarily due to varying patterns of human presence through time and may also reflect systematic factors affecting the visibility and level of preservation of the archaeological record, besides biased sampling and dating efforts. For instance, the Cueva Haichol site, in central-western Neuquén (Fig. 4), certainly modifies the relative sample sizes, as it provides 44 samples for the grass steppe, many of them with a mid-Holocene chronology.

5.1. *Early human peopling during the late Pleistocene*

We have reviewed large changes in climate and ecology recorded for the Pleistocene–Holocene transition. This hampers the applicability of the ecological zoning used here. For instance, as mentioned above, the early data from El Trébol site, currently located in the forest, could be associated to the presence of open spaces around the site (Whitlock et al., 2006), so it does not indicate human occupation of the forest (Hajduk et al., 2006).

The earliest events of human presence are synchronously recorded for widely separated localities at ~12000 cal BP (Cueva Huenul 1, El Trébol, Cuyín Manzano, Arroyo Corral 2, Cueva Traful I, Epullán Grande). This is compatible with a scenario of human dispersal to marginal regions, such as the northwestern Patagonian deserts, from occupational nodes that were colonised before. Unlike the record from sites located west of the Andes Mountains, in currently Chilean territory, most of these cases do not present evidence of coexistence between humans and megafauna (Barberena, 2014). This favours an ecological explanation for the retraction of some taxa, such as the ground sloth *Mylodon*, from large parts of their range (Borrero, 2009; Barnosky and Lindsey, 2010).

5.2. *Human biogeography during the mid and late Holocene*

The Andean forest presents the most discontinuous temporal sequence with a relatively continuous signal starting only after 4000 cal BP (Fig. 5). Independent of sampling or taphonomic biases, which cannot be dismissed at this stage, we suggest that this indicates the chronology of the first instance of effective human occupation (sensu Borrero, 1994–1995 see also Fernández, 2010) of the closed forest environments of northwestern Patagonia. The integration of the forest to human home ranges could have been either by societies demographically based on the eastern steppes (Borrero, 2004; Hajduk et al., 2011; Scheinsohn, 2011), or showing adaptations to the forest ecosystem and its resources (Pérez and Batres, 2008; Pérez and Smith, 2008). In light of the record of intense human occupation of the grass steppe to the east, we favor the first scenario. Similar suggestions have been defended for southern areas of the Patagonian forest (Borrero, 2004; Méndez et al., 2014). In any case, due to the marked contrast in the distribution of radiocarbon samples, it seems likely that important geographical changes occurred in the late Holocene, when the forest began occupying a more important role than ever before. Since the Andean forests connect people at the western and eastern sides of the mountain range, this temporal pattern can also suggest that regional social interaction across the Andes intensified at this time (Hajduk et al., 2011; Berón, 2015). This is clearly expressed in east-west corridor areas (e.g., río Manso valley), where the archaeological signal is particularly strong since this time (Fernández et al., 2013).

The grass steppe landscape unit displays the most continuous chronological record in northwestern Patagonia since 9000 cal BP, without any significant temporal gaps (Fig. 6). In previous research, we have explored the current spatial variations in herbivore carrying capacity (Mendía, 2006), indicating that the grass steppe has the highest values in northwestern Patagonia, offering the greatest protein resources for prehistoric people (Barberena, 2013). The shrub steppe and Andean forest have lower values of herbivore carrying capacity (Mendía, 2006).

The low frequency of archaeological sites in parts of the shrub steppe, such as the middle-lower Limay basin, likely demonstrates a demographic trend, since there has been relatively intensive archaeological research for decades (Sanguinetti de Bórmida, 1981; Crivelli Montero et al., 1996; Borrero, 2005). Besides, we consider that in this dry ecologic context there are few systematic factors likely to bias archaeological visibility and produce this record. In particular, this region shows a discontinuous temporal record (Fig. 7) during the 8000–6000 cal years BP period.

The low herbivore carrying capacity in the shrub steppes would have implied a lower density of guanacos (Puig et al., 1997), which are the largest herbivore with the most predictable territorial behavior, and arguably the top ranked terrestrial resource in Patagonia (Borrero, 1990; Mengoni Goñalons, 1999). Differences in the abundance of this top-ranked species would have influenced human dietary breadth and demography. Interestingly, in large regions of the shrub steppes, such as the lower Limay river basin, hunter-gatherers show a broad subsistence, including not only guanaco but also several lower-ranked medium and small sized animals (Prates, 2008). As Crivelli Montero has mentioned (2010), this is consistent with historic observations made by Basilio Villarino (1972[1782-83]) during his trip up the Limay river, who described all this shrub steppe area as desolate with little evidence of guanacos and hunter-gatherers.

The low frequency of permanent water sources, as well as the unpredictability of temporary ones, could have contributed to the low-density archaeological record in large tracts of the shrub steppe, such as northeastern and central Neuquén province and the Lower Limay river. Similar suggestions have been suggested for the deserts in the Payunia volcanic field east of northern Neuquén (Gil, 2006). These regions have good visibility of archaeological materials. At some of them, sampling biases cannot be dismissed due to the unsystematic character of research; in others, such as the lower Limay basin, which has been subject to intense research, low human intensity of occupation is therefore likely to be the main explanation (Crivelli Montero, 2010). Broad diets including several animal –terrestrial and fluvial- and plant resources appear as the usual pattern in many of these contexts (Borrero, 1981; Caviglia and Borrero, 1981; Barberena et al., 2002; Cordero, 2010). An economy

Table 3
Radiocarbon information for the grass steppe.

Site#	Site	Lat °	Lat '	Lat ''	Lon °	Lon '	Lon ''	Lab code	Method	Dated material	^{14}C ys BP	Sigma	Cal ys BP	Site type	Reference
14	Locus Torres (S1)	40	33		70	26		n/d	n/d	n/d	3380	60	3442/3720	rs	Sanguinetti and Curzio, 2005
	Locus Torres (S16,3)	40	33		70	26		n/d	n/d	n/d	1360	90	1051/1376	rs	Sanguinetti and Curzio, 2005
	Locus Torres (S16,2)	40	33		70	26		n/d	n/d	n/d	1310	80	982/1308	rs	Sanguinetti and Curzio, 2005
	Locus Torres (S16,1)	40	33		70	26		n/d	n/d	n/d	1040	70	749/1055	rs	Sanguinetti and Curzio, 2005
	Locus Torres (S6)	40	33		70	26		n/d	n/d	n/d	540	60	450/637	rs	Sanguinetti and Curzio, 2005
15	El Manantial 1/88	40	39	3.1	70	41	14.35	Beta-81304	Conv.	Charcoal	3380	60	3442/3270	oa	Sanguinetti et al., 1999
	El Manantial 1/88	40	39	3.1	70	41	14.35	Beta-92642	Conv.	Charcoal	1360	90	1051/1376	oa	Sanguinetti et al., 1999
	El Manantial 1/88	40	39	3.1	70	41	14.35	Beta-92640	Conv.	Charcoal	1040	70	749/1055	oa	Sanguinetti et al., 1999
	El Manantial	40	46	41.96	70	29	59.86	LP-590	Conv.	Bone (*Homo sapiens*)	540	60	450/637	oa	Sanguinetti et al., 1999
	El Manantial	40	39		70	41		LP-wn	Conv.	Bone (*Homo sapiens*)	200	?		oa	Sanguinetti, 2005
16	Casa de Piedra de Ortega	40	43	49	70	42	21	LP-146	Conv.	Charcoal	2840	80	2755/3080	Cave	Fernández, 2001
	Casa de Piedra de Ortega	40	43	49	70	42	21	AC-951	Conv.	Bone (*Homo sapiens*)	2710	100	2462/3037	Cave	Fernández, 2001
	Casa de Piedra de Ortega	40	43	49	70	42	21	LP-168	Conv.	Charcoal	2000	90	1706/2148	Cave	Fernández, 2001
	Casa de Piedra de Ortega	40	43	49	70	42	21	LP-1320	Conv.	Tephra	1490	70	1267/1522	Cave	Fernández, 2001
	Casa de Piedra de Ortega	40	43	49	70	42	21	AC-936	Conv.	Charcoal	1440	80	1170/1484	Cave	Fernández, 2001
	Casa de Piedra de Ortega	40	43	49	70	42	21	LP-191	Conv.	Charcoal	280	50	142/457	Cave	Fernández, 2001
17	Alero Carriqueo	40	37	27	70	31	42	n/d	n/d	Charcoal	2620	110	2353/2875	rs	Crivelli M. et al., 2007
	Alero Carriqueo	40	37	27	70	31	42	LP-1829	Conv.	n/d	610	50	511/650	rs	Crivelli M. et al., 2007
18	Visconti	41	4		70	52		LP-85	Conv.	Charcoal	2526	93	2485/2718	Cave	Ceballos and Peronja, 1984
19	Sarita 1	40	56	30	70	43	9	AC-378	Conv.	n/d	2720	120	2420/3076	Cave	Boschín, 2009
	Sarita 1	40	56	30	70	43	9	AC-377	Conv.	n/d	2180	120	1822/2376	Cave	Boschín, 2009
	Sarita 1	40	56	30	70	43	9	AC-376	Conv.	n/d	1980	105	1691/2151	Cave	Boschín, 2009
20	Sarita 2	40	56	30	70	43	9	AC-1082	Conv.	n/d	1480	80	1185/1524	Cave	Boschín, 2009
	Sarita 2	40	56	30	70	43	9	AC-1079	Conv.	n/d	1380	100	1048/1423	Cave	Boschín, 2009
	Sarita 2	40	56	30	70	43	9	AC-1080	Conv.	n/d	1200	90	919/1275	Cave	Boschín, 2009
	Sarita 2	40	56	30	70	43	9	AC-1078	Conv.	n/d	1010	90	811/922	Cave	Boschín, 2009
	Sarita 2	40	56	30	70	43	9	AC-1077	Conv.	n/d	410	100	148/557	Cave	Boschín, 2009
21	Sarita 4	40	56	30	70	43	9	LP-199	Conv.	n/d	2300	50	2151/2354	Cave	Boschín, 2009
22	Abrigo de Pilcaniyeu	41	5		70	42		GAK-8845	Conv.	n/d	2540	180	2142/2979	rs	Boschín, 2009
23	Pampa de los Guanacos	40	33		70	26		n/d	n/d	n/d	2440	50	2338/2703	rs	Sanguinetti, 1981
	Pampa de los Guanacos	40	33		70	26		n/d	n/d	n/d	2600AC?	n/d		rs	Sanguinetti, 2005
24	Alonso 2	40	58	3	70	43	37	LP-222	Conv.	n/d	2240	50	2085/2340	Cave	Boschín, 2009
	Alonso 2	40	58	3	70	43	37	LP-212	Conv.	n/d	740	60	557/725	Cave	Boschín, 2009
25	Nestares	40	43		70	42		AC 1673	Conv.	Charcoal	2760	130	2459/3181	rs	Silveira and Cordero, 2010
	Nestares	40	43		70	42		LP-1775	Conv.	n/d	2080	70	1830/2159	Rs	Silveira and Cordero, 2010
	Nestares	40	43		70	42		LP-1157	Conv.	Charcoal	1550	50	1311/1488	Rs	Silveira and Cordero, 2010
26	Loncomán	40	47	33	70	10	51	LP-1130	Conv.	n/d	1960	40	1745/1993	Cave	Boschín, 2009
27	Bichara 1	40	47		70	21		n/d	n/d	n/d	1900	70	1609/1933	Cave	Sanguinetti and Curzio, 2005
	Bichara 1	40	47		70	21		n/d	n/d	n/d	360	n/d		Cave	Sanguinetti and Curzio, 2005
28	Bichara 2	40	47		70	21		LP- sn	Conv.	n/d	290	90	58/493	rs	Sanguinetti and Curzio, 2005
29	La Marcelina	40	56	30	70	43	9	LP-1040	Conv.	n/d	1770	50	1531/1746	rs	Sanguinetti et al., 2000
	La Marcelina	40	56	30	70	43	9	LP-1030	Conv.	n/d	1720	70	1407/1741	rs	Sanguinetti et al., 2000
30	Alero Álvarez 4	40	48	38.8	70	27	12.9	LP-1967	Conv.	Charcoal	210	90	1/440	rs	Crivelli and Palacios, 2010
	Alero Álvarez 4	40	48	38.8	70	27	12.9	LP-1968	Conv.	Charcoal	330	70	148/500	rs	Crivelli and Palacios, 2010
	Alero Álvarez 4	40	48	38.8	70	27	12.9	LP-1969	Conv.	Charcoal	580	70	486/661	rs	Crivelli and Palacios, 2010

	Alero Álvarez 4	40	48	38.8	70	27	12.9	LP-1921	Conv.	Charcoal	1100	70	795/1094	rs	Crivelli and Palacios, 2010
31	Comallo 1	41	12	38.2	70	27	1.9	LP- 2322	Conv.	Charcoal	1060	70	772/1061	Cave	Arrigoni et al., 2010
32	La Figura 1	41	9	17	70	38	13	Teledyne ?	Conv.?	n/d	2670	90	2432/2951	rs	Nacuzzi, 1991
	La Figura 1	41	9	17	70	38	13	Teledyne ?	Conv.?	n/d	1050	80	743/1063	rs	Nacuzzi, 1991
	La Figura 1	41	9	17	70	38	13	AC-0950	Conv.	n/d	1510	190	965/1748	rs	Nacuzzi, 1991
33	Aquihueco 1	37	5	35	70	22	31	LP-1418	Conv.	Bone (*Homo sapiens*)	3650	70	3703/4093	oa	Della Negra and Novellino, 2005
	Aquihueco 1 (Indiv. 23)	37	5	35	70	22	31	AA-78839	AMS	Bone (*Homo sapiens*)	4172	55	4518/4832	oa	Della Negra and Novellino, 2005
	Aquihueco 1 (Indiv. 22)	37	5	35	70	22	31	AA-78840	AMS	Bone (*Homo sapiens*)	4050	61	4286/4806	oa	Della Negra and Novellino, 2005
	Aquihueco 1 (Indiv. 16)	37	5	35	70	22	31	AA-78841	AMS	Bone (*Homo sapiens*)	3817	59	3976/4356	oa	Della Negra and Novellino, 2005
	Aquihueco 1	37	5	35	70	22	31	X10892A	n/d	Charcoal	8153	50?	8863/9264	oa	Della Negra et al., 2009
34	Hermanos Lazcano							LP-1440	Conv.	Bone (*Homo sapiens*)	3780	50	3915/4247	oa	Hajduk et al., 2007
35	Gubevi	37	10	35	70	40	5.5	n/d	n/d	Bone (*Homo sapiens*)	1878	43	1699/1883	oa	Della Negra, 2008
36	Truquico	37	27	33	70	17	55	AC-0002	Conv.	Botanical (wood)	630	80	499/674	Cave	Fernández, 1981–1982
	Truquico	37	27	33	70	17	55	AC-0004	Conv.	Botanical (wood)	585	75	485/664	Cave	Fernández, 1981–1982
	Truquico	37	27	33	70	17	55	AC-0005	Conv.	Shell	350	70	178/503	Cave	Fernández, 1981–1982
37	Haichol, cranium 1	38	35		70	40		TO-8524	AMS	Bone (*Homo sapiens*)	890	70	670/912	Cave	Fernández and Panarello, 2001
	Haichol, cranium 2	38	35		70	40		TO-8525	AMS	Bone (*Homo sapiens*)	2170	70	1992/2319	Cave	Fernández and Panarello, 2001
	Haichol, cranium 3	38	35		70	40		TO-8526	AMS	Bone (*Homo sapiens*)	5410	130	5891/6414	Cave	Fernández and Panarello, 2001
	Haichol, cranium 4	38	35		70	40		TO-8527	AMS	Bone (*Homo sapiens*)	2920	100	2776/3252	Cave	Fernández and Panarello, 2001
	Haichol, cranium 5	38	35		70	40		TO-8528	AMS	Bone (*Homo sapiens*)	5410	110	5915/6324	Cave	Fernández and Panarello, 2001
	Haichol, cranium 6	38	35		70	40		TO-8529	AMS	Bone (*Homo sapiens*)	3930	70	4091/4518	Cave	Fernández and Panarello, 2001
	Haichol, 7 occipital 58	38	35		70	40		TO-8989	AMS	Bone (*Homo sapiens*)	5470	60	6002/6318	Cave	Fernández and Panarello, 2001
	Haichol, 8 frontal 35	38	35		70	40		TO-8990	AMS	Bone (*Homo sapiens*)	5650	70	6278/6564	Cave	Fernández and Panarello, 2001
	Haichol	38	35		70	40		AC-069	Conv.	Charcoal	7020	120	7593/8008	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		A-2363	Conv.	Charcoal	6775	75	7456/7702	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-021b	Conv.	Charcoal	6140	130	6661/7270	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-021	Conv.	Charcoal	6000	115	6499/7069	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-232	Conv.	Charcoal	5525	110	5991/6494	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-231	Conv.	Charcoal	5050	100	5583/5945	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-222	Conv.	Charcoal	4870	100	5316/5750	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-012	Conv.	Charcoal	4500	120	4828/5464	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-016	Conv.	Charcoal	4360	115	4576/5291	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		A-2364	Conv.	Charcoal	4264	86	4518/4974	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-221	Conv.	Charcoal	3690	95	3693/4246	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-230	Conv.	Charcoal	3590	100	3577/4093	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-901	Conv.	Charcoal	2440	100	2301/2744	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-229	Conv.	Charcoal	2420	100	2177/2737	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-013	Conv.	Charcoal	2380	100	2148/2721	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-896	Conv.	Charcoal	2350	150	2006/2740	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-899	Conv.	Charcoal	2290	120	1934/2700	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-018	Conv.	Charcoal	2260	100	1992/2473	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-217	Conv.	Charcoal	2230	100	1918/2379	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-080	Conv.	Charcoal	2150	90	1899/2325	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-900	Conv.	Charcoal	2130	110	1832/2335	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-077	Conv.	Charcoal	1830	85	1529/1917	Cave	Fernández, 1988–1990

(*continued on next page*)

Table 3 (*continued*)

Site#	Site	Lat °	Lat '	Lat "	Lon °	Lon '	Lon "	Lab code	Method	Dated material	^{14}C ys BP	Sigma	Cal ys BP	Site type	Reference
	Haichol	38	35		70	40		AC-898	Conv.	Charcoal	1440	90	1158/1511	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-011	Conv.	Charcoal	1390	100	1050/1432	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-075	Conv.	Charcoal	1290	70	984/1297	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-897	Conv.	Charcoal	1290	110	934/1321	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-015	Conv.	Charcoal	1250	80	962/1275	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		A-4877	Conv.	Organic textile	980	130	649/1094	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AA-3480		PS 652	695	70	532/689	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AA-3479		PS 555	610	70	502/660	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AA-3093		PS 503	490	50	329/554	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-550	Conv.	Egg-shell	470	110	281/652	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AC-551	Conv.	Egg-shell	420	110	145/631	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AA-3092	AMS	PS 638	365	45	307/488	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AA-3094	AMS	Botanical (*Zea mayz*)	350	120	58/535	Cave	Fernández, 1988–1990
	Haichol	38	35		70	40		AA-3095	AMS	Botanical (*Lagenaria* sp.)	225	85	1/442	Cave	Fernández, 1988–1990
38	Alamo de Haichol	38	35		70	40		AC-0635	Conv.	Charcoal	Modern	–	–	oa	Goñi, 1983–1985
39	Alamo de la Mina	38	35		70	40		AC-0637	Conv.	Charcoal	Modern	–	–	oa	Goñi, 1983–1985
	Alamo de la Mina	38	35		70	40		AC-0635	Conv.	Charcoal	Modern	–	–	oa	Goñi, 1983–1985
40	Mallín del Tromen IV	38	51		70	26		GX-	Conv. ?	Charcoal	1060	120	717/1181	rs	Perrotta and Pereda, 1987
	Mallín del Tromen IV	38	51		70	26		GX-	Conv. ?	Charcoal	135	145	1/446	rs	Perrotta and Pereda, 1987
	Mallín del Tromen IV	38	51		70	26		n/d	Conv. ?	n/d	890	120	622/965	rs	Perrotta and Pereda, 1987
	Mallín del Tromen IV	38	51		70	26		n/d	Conv. ?	n/d	3560	70	3607/3982	rs	Perrotta and Pereda, 1987
	Mallín del Tromen IV	38	51		70	26		n/d	Conv. ?	n/d	4400	130	4574/5317	rs	Perrotta and Pereda, 1987
41	Laguna Montículo 1	38	51		70	28		n/d	Conv. ?	Charcoal?	1040	140	667/1185	oa	Goñi, 1991
	Laguna Montículo 1	38	51		70	28		n/d	Conv. ?	Charcoal?	1740	80	1414/1752	oa	Goñi, 1991
42	Arroyo Corral II	40	55	47	71	3	2	AA-75677	AMS	Bone (*Lama guanicoe*)	10020	96	11,210/11,825	Cave	Arias et al., 2012
43	Cueva Traful	40	43		71	7		Ingeis-2676	Conv.	Charcoal	9430	230	10,133/11,252	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		GX-1711	AMS	Charcoal	9285	105	10,225/10,689	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		LP-6213	Conv.	Charcoal	9285	313	9591/11,224	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		LJ-5133		Charcoal	7850	70	8417/8786	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		LP-8113	Conv.	Charcoal	7308	285	7561/7538	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		I-12153		Charcoal	6870	250	7249/8180	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		LJ-5132		Charcoal	6240	60	6945/7257	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		I-11304		Charcoal	6030	115	6555/7162	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		LJ-5131		Charcoal	2720	40	2742/2864	Cave	Crivelli M. et al., 1993
	Cueva Traful	40	43		71	7		LJ-5130		Charcoal	2230	40	2091/2326	Cave	Crivelli M. et al., 1993
44	Traful III	40	43		71	7		n/d	n/d	n/d	4120	80	4411/4835	Cave	Crivelli M., 2010
45	Cuyin Manzano	40	45	38	71	11	13	KN-1432	Conv.	Charcoal	9320	240	9886/11,200	Cave	Ceballos, 1982

References: site type: rs, rockshelter; oa, open air.

Table 4
Radiocarbon information for the shrub steppe.

Site#	Site	Lat°	Lat'	Lat''	Lon°	Lon '	Lon ''	Lab code	Method	Dated material	^{14}C ys BP	Sigma	Cal ys BP	Site type	Reference
46	Llamuco 1	38	45		70	18		Beta-38180	Conv.	Charcoal	1140	80	802/1184	oa	Goñi et al., 1996
	Llamuco 1	38	45		70	18		Beta-38181	Conv.	Charcoal	1010	140	658/1181	oa	Goñi et al., 1996
47	Epullán Grande	40	23		70	11		LP-213	Conv.	Charcoal	9970	100	11,178/11,772	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-44412	Conv.	Charcoal	7900	70	8516/8982	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-47401	Conv.		7550	50	8199/8402	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-41622	Conv.	Charcoal	7060	90	7675/8000	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-61147	Conv.	Charcoal	5140	70	5659/5952	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-44411	Conv.		3080	40	3139/3362	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-61146	Conv.		2740	50	2742/2893	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-47402	Conv.		2360	50	2158/2490	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-62499	Conv.	Charcoal	2190	60	2006/2315	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-54770	Conv.		2180	50	2008/2307	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-61145	Conv.		1720	50	1468/1708	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-68178	Conv.	Charcoal	1080	50	804/1058	Cave	Crivelli M. et al., 1996
	Epullán Grande	40	23		70	11		Beta-54769	Conv.	Charcoal	320	60	152/491	Cave	Crivelli M. et al., 1996
48	Epullán Chica	40	23		70	11		Beta-54772	Conv.		2220	50	2051/2329	Cave	Crivelli M. et al., 1996
	Epullán Chica	40	23		70	11		Beta-54771	Conv.		2200	60	2011/2317	Cave	Crivelli M. et al., 1996
49	Piedra del Águila 11	40	2		70	0		Beta-50679	Conv.		4880	130	5307/5898	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		Beta-50678	Conv.		4800	130	5050/5749	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		Beta-50676	Conv.		4710	210	4840/5765	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		Beta-50677	Conv.		4590	70	4968/5464	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		Beta-39945	Conv.		4040	41	4349/4582	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		LP-387	Conv.		3760	130	3711/4422	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		LP-361	Conv.		3390	90	3393/3828	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		LP-190	Conv.		3020	60	2963/3343	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0			Conv.		2750	100	2494/3078	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		Beta-41619	Conv.		1830	60	1566/1838	Cave	Sanguinetti and Curzio, 1996
	Piedra del Águila 11	40	2		70	0		Beta-54773	Conv.		910	50	683/906	Cave	Sanguinetti and Curzio, 1996
50	Piedra del Águila 15	40	2		70	0		Beta-50674	Conv.		860	50	663/804	Cave	Sanguinetti and Curzio, 1996
51	Rincón Chico 2	40	12		70	2		Beta-47403	Conv.	Charcoal	710	60	546/688	rs	Crivelli M., 2009
	Rincón Chico 2	40	12		70	2		LP-855	Conv.	Charcoal	680	65	527/680	rs	Crivelli M., 2009
52	Alero Arias	40	3		69	57		Beta-41621	Conv.	Charcoal	3230	60	3246/3565	rs	Sanguinetti and Curzio, 1996
	Alero Arias	40	3		69	57		Beta-47400	Conv.	Charcoal	1370	60	1074/1320	rs	Borrero et al., 1996
53	Bajada del Salitral 2	39	26	12	68	51	35	n/d	n/d	n/d	2440	50	2338/2703	rs	Sanguinetti, 1981
	Bajada del Salitral 2	39	26	12	68	51	35	Teledyne	Conv.	Charcoal	1975	50	1747/2001	rs	Sanguinetti, 1973
54	Michacheo	38	53	38	70	1	17.8	n/d	n/d	Bone (*Homo sapiens*)	1860	40	1612/1870	oa	Lema et al., 2012
55	Alero de los Sauces	39	14		68	46		CSIC-134	Conv.	n/d	4490	60	4875/5289	rs	Borrero, 1981
	Alero de los Sauces	39	14		68	46		CSIC-374	Conv.	n/d	750	40	563/722	rs	Borrero, 1981
56	Médanos del Gigante	39	24		68	54		CSIC-136	Conv.	n/d	930	50	721/920	oa	Borrero, 1981
57	Planicie del Gigante	39	24		68	54		n/d	Conv.?	n/d	2530	60	2376/2737	oa	Saguinetti, 1981
58	Cueva del Choique	40	5	27.4	69	59	97.2	Beta-134081	Conv.	Charcoal	1250	50	981/1268	Cave	Barberena et al., 2002

(continued on next page)

Table 4 (*continued*)

Site#	Site	Lat°	Lat'	Lat''	Lon°	Lon '	Lon ''	Lab code	Method	Dated material	^{14}C ys BP	Sigma	Cal ys BP	Site type	Reference
	Cueva del Choique	40	5	27.4	69	59	97.2	Beta-134079	Conv.	Charcoal	410	50	319/503	Cave	Barberena et al., 2002
	Cueva del Choique	40	5	27.4	69	59	97.2	Beta-134078	Conv.	Charcoal	530	50	459/562	Cave	Barberena et al., 2002
59	Collón Chico	39	1		68	4		AC-0309	Conv.	Charcoal	2490	90	2344/2742	oa	Alberó and Angiolini, 1985
60	Sitio Grande	39	55		69	15		UGA-9209	AMS	Bone (*Homo sapiens*)	670	40	551/659	oa	Della Negra and Novellino, 2005
61	Retamal 1	38	59		68	43		LP-1689	Conv.	Bone (*Homo sapiens*)	190	60	1/292	oa	Pérez et al., 2009
62	Chacra Bustamante	39	3		69	3		UGA-9208	AMS	Bone (*Homo sapiens*)	450	40	327/525	oa	Pérez et al., 2009
63	Loma de la Lata	38	25		68	41		UGA-11669	AMS	Bone (*Homo sapiens*)	600	60	504/651	oa	Pérez et al., 2009
	Loma de la Lata	38	25		68	41		UGA-12318	AMS	Bone (*Homo sapiens*)	740	40	560/720	oa	Pérez et al., 2009
64	Cueva Huenul 1 (#10)	36	57	31	69	49	25.3	AA99106	AMS	Bone (*Lama guanicoe*)	10155	98	11,306/12,032	Cave	Barberena, 2014
	Cueva Huenul 1 (#1)	36	57	31	69	49	25.3	AA85718	AMS	Charcoal	9531	39	10,588/10,868	Cave	Barberena et al., 2010
	Cueva Huenul 1 (#15)	36	57	31	69	49	25.3	AA102574	AMS	Botanical (*Prosopis* sp.)	9402	60	10,389/10,747	Cave	Barberena, 2014
	Cueva Huenul 1 (#8)	36	57	31	69	49	25.3	AA99104	AMS	bone (*Lama guanicoe*)	9375	91	10,249/10,763	Cave	Barberena, 2014
	Cueva Huenul 1 (#9)	36	57	31	69	49	25.3	AA99105	AMS	Bone (*Lama guanicoe*)	9295	90	10,236/10,609	Cave	Barberena, 2014
	Cueva Huenul 1 (#11)	36	57	31	69	49	25.3	AA99107	AMS	Botanical (*R. pat.*)	9261	66	10,242/10,557	Cave	Barberena, 2014
	Cueva Huenul 1 (#16)	36	57	31	69	49	25.3	AA102575	AMS	botanical (*Senna aphylla*)	4786	46	5324/5588	Cave	Barberena, 2014
	Cueva Huenul 1(#13)	36	57	31	69	49	25.3	AA99110	AMS	Bone (*Lama guanicoe*)	1753	47	1528/1727	Cave	Barberena, 2014
	Cueva Huenul 1 (#7)	36	57	31	69	49	25.3	AA99103	AMS	bone (*Lama guanicoe*)	1590	46	1347/1537	Cave	Barberena, 2014
	Cueva Huenul 1 (#4)	36	57	31	69	49	25.3	AA85721	AMS	Botanical (grass bed)	1416	37	1185/1354	Cave	Barberena et al., 2010
	Cueva Huenul 1 (#12)	36	57	31	69	49	25.3	AA99109	AMS	bone (*Lama guanicoe*)	1269	46	1056/1271	Cave	Barberena, 2014
	Cueva Huenul 1 (#14)	36	57	31	69	49	25.3	AA102573	AMS	Botanical (*Lagenaria* sp.)	541	42	491/560	Cave	Barberena, 2014
	Cueva Huenul 1(#6)	36	57	31	69	49	25.3	AA99102	AMS	Bone (*Lama guanicoe*)	373	43	312/489	Cave	Barberena, 2014

References: site type: rs, rockshelter; oa, open air.

Table 5
Synthesis of ^{14}C information for northwestern Patagonia.

Andean forest	
Sites	
Shelter sites	10 (76.9%)
Open air sites	3 (23.1%)
Total N of sites	13 (20.3% of total)
Dates	
Shelter dates	58 (92.1%)
Open air dates	5 (7.9%)
Total N of ^{14}C samples	63 (25% of total)
Grass steppe	
Sites	
Shelter sites	25 (78.1%)
Open air sites	7 (21.9%)
Total N of sites	32 (50% of total)
Dates	
Shelter dates	110 (86.6%)
Open air dates	17 (13.4%)
Total N of ^{14}C samples	127 (50.4% of total)
Shrub steppe	
Sites	
Shelter sites	9 (47.4%)
Open air sites	10 (52.6%)
Total N of sites	19 (29.7% of total)
Dates	
Shelter dates	49 (79%)
Open air dates	13 (21%)
Total N of ^{14}C samples	62 (24.6% of total)
Total results	
Sites	
Total N of shelter sites	44 (68.75%)
Total N of open air sites	20 (31.25%)
Total N of sites	64 (100%)
Dates	
Total N of ^{14}C dates from shelters	217 (86.1%)
Total N of ^{14}C dates from open-air	35 (13.9%)
Total N of ^{14}C dates	252 (100%)

more focused on guanaco may have prevailed in mesic and grassy neighboring environments, such as the middle portion of the Limay river (Crivelli Montero, 2010).

Differences in intensity of human occupation are expected to occur in areas with variations in predictability and availability of resources and, as suggested for several South American deserts (Grosjean et al., 2007; Neme and Gil, 2009; Yacobaccio, 2013; Méndez et al., 2015), this effect would have been enhanced during arid periods, such as parts of the mid-Holocene (ca. 8000–6000 cal ys BP). We suggest that the differential temporal distribution of radiocarbon dates between the grass steppe, which is relatively continuous, and that from the shrub steppe, that is highly discontinuous, represents 'refugia – temporary barrier' demographic dynamics (sensu Veth, 1993). In this scenario, the more humid western regions would experience more intense human use through arid periods in detriment of the eastern deserts.

5.3. Conclusions

We have assembled an exhaustive database of paleoecological and chronological data for northwestern Patagonia (Argentina). This is the first comprehensive work attempted at this scale, and provides a starting point that will be built upon through time and is made available to other researchers. The changes identified in this paper are considered as preliminary. The demographic inferences presented here are best considered as working hypotheses that will be evaluated in the future in the light of increasing information.

The need for local and regional palaeoclimatic and environmental data from northwestern Patagonia since the late Pleistocene is fundamental for understanding human demographic patterns. Major challenges regarding these issues include: (1) did the

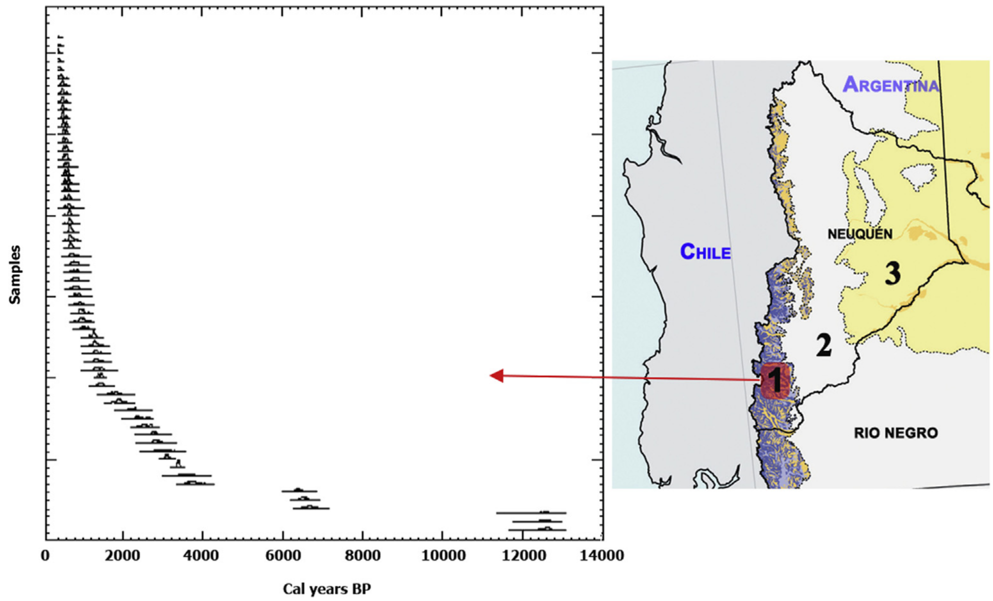

Fig. 5. Calibrated age ranges from the Andean forest.

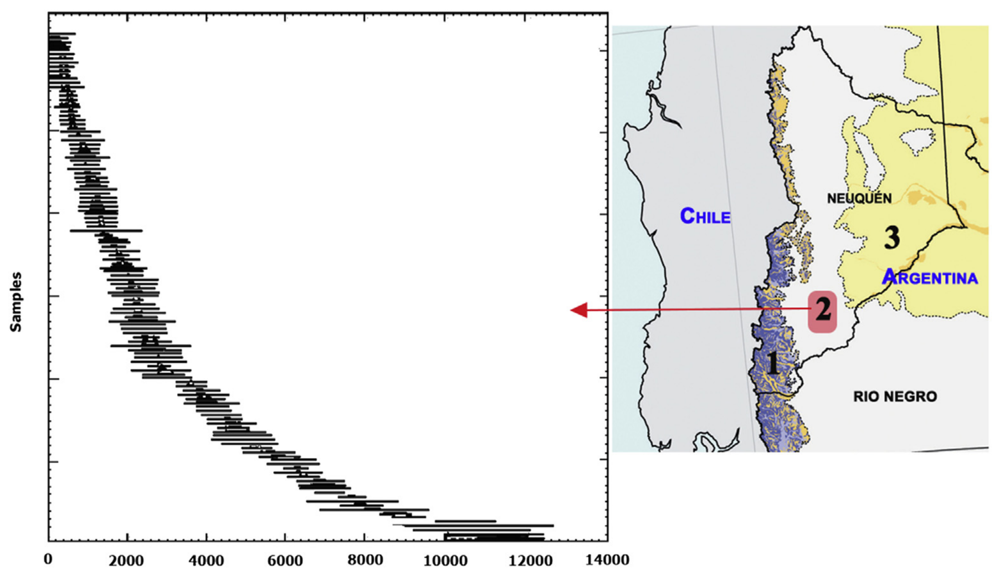

Fig. 6. Calibrated age ranges from the grass steppe.

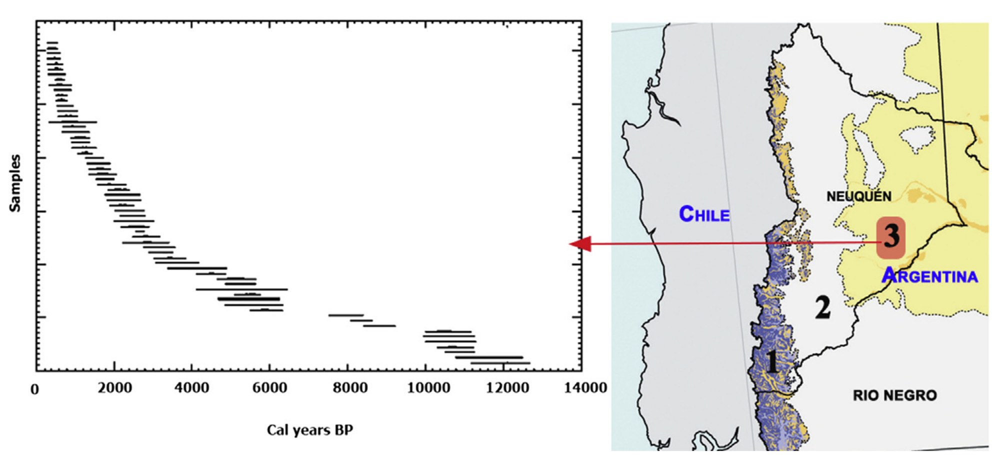

Fig. 7. Calibrated age ranges from the shrub steppe.

different environments from northern Patagonia respond in the same way to the different climate forcings in the past? (2) Was the early Holocene actually wetter than the late Pleistocene on the lee side of the Andes (dipole hypothesis)? (3) What is the local character of arid periods recorded for the mid-Holocene in South American deserts? (4) To what extent do northern Patagonia environments actually respond to increased precipitation due to El Niño events during the late Holocene?

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quaint.2014.09.055.

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