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Maize (*Zea mays*) consumption in the southern andes (30°–31° S. Lat): Stable isotope evidence (2000 BCE–1540 CE)

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Abstract

Objectives: The timing and dietary role of maize agriculture is central to archaeological discussions in the Andean region. In the semi-arid region of northern Chile (SARNC), archaeological models propose that maize was adopted during the Early Ceramic period in tandem with pottery and sedentism. Through stable isotope (SI) analyses, of bone collagen and apatite, this study assesses the timing of maize introduction, diachronic changes (2,000 BCE to 1,540 CE.), and synchronic dietary variability in the prehistoric SARNC.

Materials and Methods: Fifty-two prehistoric individuals from SARNC were analyzed for $\delta^{13}C_{ap}$, $\delta^{13}C_{col,}$ and $\delta^{15}N$. Descriptive statistics were used to characterize the results by period and location (inland and coast). Between-periods (ANOVA or Kruskal-Wallis tests), and synchronic comparisons (inland vs. coast; Student's t-tests), were conducted. A SIAR model was run to further evaluate dietary changes. Dietary interpretations are based on food web data.

Results: Coastal groups show significant changes in the diet during the Middle (900-1,000CE; enrichment in $\delta^{13}C$), and Late Intermediate periods (100-1450CE; when the $\Delta^{13}C_{ap-col}$ is above 5.2‰). In the inland, significant changes in SI occurred in the Late Intermediate period ($\delta^{13}C$ enrichment). In the Late period, the inland diet became enriched for $\delta^{15}N$. Synchronic comparisons showed coastal individuals to have higher $\delta^{15}N$.

Discussion: The popularization of maize in the SARNC was not associated with the appearance of pottery and/or sedentism, and its role as a dietary staple was a late phenomenon (c.a. 1,000CE). The results obtained in this study show that the adoption and consumption of maize varied dramatically in the Southern Andes.

KEYWORDS
Maize (*Zea mays*), stable isotopes, semi-arid Northern Chile, prehistory

1 | INTRODUCTION

Maize (*Zea mays*) is one of the most important staple cultigens in pre-Columbian America (Athens et al., 2016; Falabella et al., 2008; Staller, 2006). Early in the history of Andean archaeology, Willey and Phillips (1958) suggested the adoption of maize agriculture took place during the Formative period, a time related to sedentary life and the use of ceramics. Although somewhat dated, this model established the

framework under which prehistoric processes in the Andes (including the Southern Andean region) were organized, understood, and interpreted. In particular, the appearance of pottery in the regional stratigraphic sequences was interpreted as an indicator of the adoption of maize and sedentary life (Lumbreras, 1981; Núñez, 1974). And, it was assumed that after its adoption, maize became a central staple in the diet of prehistoric communities (Núñez, 1974; Willey & Phillips, 1958).
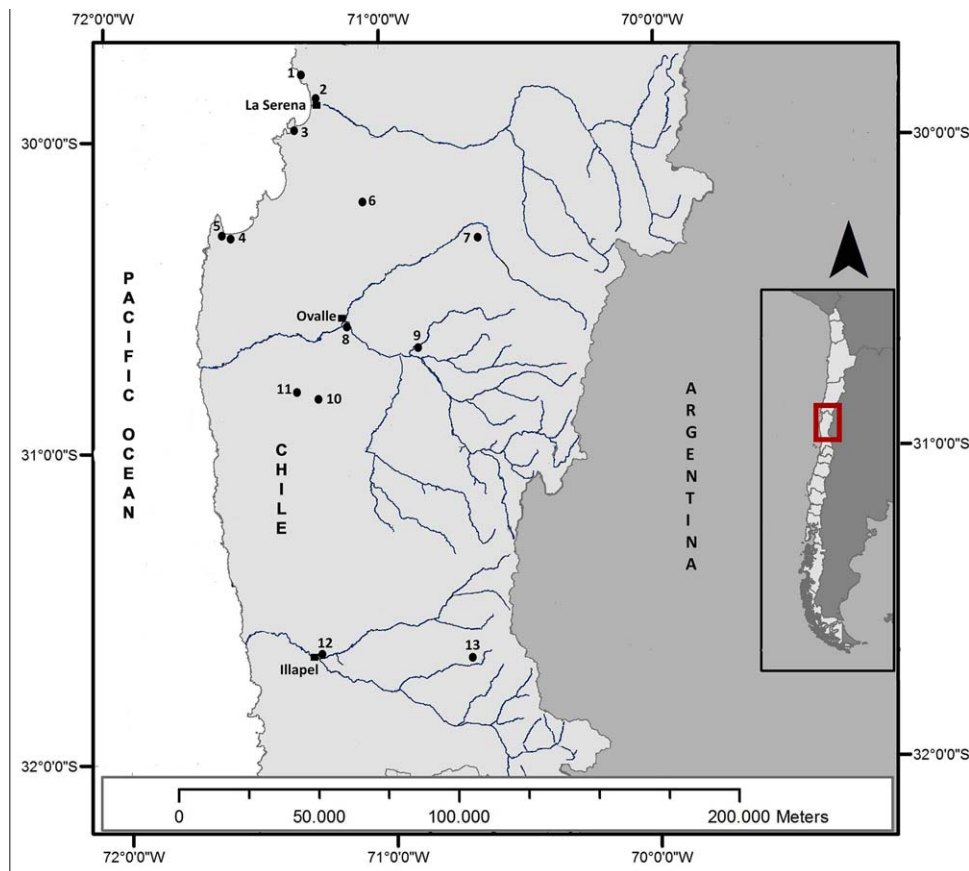
FIGURE 1 Map of the semi-arid region of Northern Chile showing the archaeological sites from where the samples were recovered: 1. Punta Teatinos; 2. Plaza La Serena; 3. La Herradura; 4. Los Pozos; 5. Puerto Aldea; 6.Churque4; 7. La Turquia; 8. Pisco Control; 9. Mirador; 10. Viña Bernarda Morin; 11.-Agricola Punitaqui; 12.EstadioIllapel; 13.Loma El Arenal

More recently, some authors have discussed these ideas using bio-archaeological, archaeological, contextual, and isotopic data from different regions of the Andes (Athens et al., 2016; Falabella et al., 2008; Gil, 2003, 2011; Lantos et al., 2015; Lumbreras, 2006; Pearsall, 2008; Pestle et al., 2015; Shady, 2006; Staller, 2006). These studies reveal the absence of a necessary relationship between the incorporation of pottery, maize agriculture, and sedentary life. Results from these studies indicate that the history of the adoption and use of maize is more diverse and complex than previously assumed. In fact, the history of maize in the Andes cannot be fully explained with a general model (Staller, 2006). Thus, more studies that address the particular historical trajectories, regarding the impact of maize agriculture in the regional sequences of the Andes, are needed.

As in many other areas of the Americas, Willey and Phillips's model (Willey and Phillips, 1955) was adopted in early archaeological studies in the semi-arid region of Northern Chile (SARNC) (29°–32° S Latitude) (Ampuero and Hidalgo, 1975; Figure 1). This area, located in the Southernmost boundary of the Andean region, is especially relevant to maize studies given its proximity to the southern border of maize's expansion during prehistoric times (Gil et al., 2006a). Previous archaeological studies in the SARNC posit that the Early Ceramic Period (0–900 ACE) was a pivotal time, when the development of ceramic technology and the consolidation of agricultural economies, were characterized by the

incorporation of maize and other cultigens—such as beans and squash—in the diet (Ampuero and Hidalgo, 1975; Ampuero and Rivera, 1972; Munizaga, 1972). The changes observed during the Early Ceramic period, would have emerged from economic transformations that were initiated during the Late Archaic (2000 BCE to 0) (Schiappacasse, 1986; Schiappacasse and Niemeyer, 1965). In time, maize consumption increased, bolstering perceptions of a successful adaptive process, which would have reached its peak with the Inka (Late period; Ampuero and Hidalgo, 1975; Ampuero and Rivera, 1972).

This model is now questioned. Studies in the SARNC reveal that the adoption of ceramics did not radically transform the lifeways of local communities. In fact, archeobotanical analyses show that maize became a stable resource in the Late Intermediate period (1,000–1450 CE), a millennia after the adoption of ceramics. So far, however, the discussion regarding prehistoric maize consumption during the Late Holocene in the SARNC has been based on indirect evidence, due to the paucity of diachronic and regional-level isotopic studies (Belmar & Quiroz, 2003, 2004; Troncoso & Pavlovic, 2013). North to the SARNC, in both the arid and hyper-arid regions, maize appears during the Formative period. But, studies consistently show that coastal resources played a role in the diet of both coastal and inland groups throughout the prehistory of these areas (Pestle et al., 2015; Roberts et al., 2013; Santana-Sagredo et al., 2015; Torres-Rouff et al., 2012). This is not

surprising given the importance of marine resources in the prehistory of the Andean region (Moseley, 1974). However, in the neighboring areas of Central Chile and South-Central Argentina, maize consumption deviates from the traditional propositions for the Southern Andean region since, notably, maize becomes a dietary staple later than expected (ca. 800—1,000 CE) and its intake decreased during Inka times in some areas (Falabella et al., 2008; Gil, 2003; Gil, et al., 2006a, 2006b; Sanhueza & Falabella, 2010). These results, however, cannot be extrapolated into other areas of the Southern Andean region, due to the unique socio-political processes that took place in each one of them. Additionally, during the Late (Inka) period, local economic strategies were influenced by differing Inka policies that altered the access to trade networks and crop production. The Inka also implemented new taxation systems that consequently modified local economies and diets (D'Altroy, 2003; D'Altroy & Stein, 2005; Malpass & Alconini, 2010a, 2010b; Murra, 1978).

Thus, the goal of this study is to examine the timing and relevance of maize in the diet of prehistoric SARNC groups, and to evaluate it in light of new isotopic evidence, which to date has not been done in the SARNC. This study discusses the results for $\delta^{13}C_{ap}$, $\delta^{13}C_{col}$, and $\delta^{15}N$, from 52 prehispanic individuals from the SARNC. The goals of this study are to: (a) assess the timing of maize introduction to the local diets, (b) evaluate the diachronic changes in the diet of prehistoric groups in the SARNC during the Late Holocene (2,000 BCE to 1,540 CE.), and (c) estimate the synchronic dietary variability between inland and coastal prehistoric individuals from SARNC. We interpret and discuss these results in relation to the general trends recognized for maize in the Southern Andes, the southern-most frontier of maize expansion.

1.1 | Paleoenvironment and prehistory of the semiarid region of Northern Chile

The SARNC (29–32°S) marks the transition between the Atacama Desert, the hyper-arid region of Northern Chile, and the mediterranean conditions of Central Chile. Today, SARNC is characterized by its aridity and marked interannual precipitation oscillation. Paleoenvironmental studies suggest that the Middle Holocene (ca. 6,000 - 2,000 BCE) was arid, and that it was followed by environmental conditions that became stable and similar to the ones currently observed at the beginning of the Late Holocene (Jenny et al., 2002; Maldonado & Villagrán, 2002, 2006; Veit, 1996).

SARNC has a long prehispanic occupational sequence that extends from the late Pleistocene until Inka times. The prehistory of SARNC has traditionally been interpreted through a cultural-history and cultural-evolution lens that depicts ever increasing social complexity accompanied by progressively efficient environmental adaptations (Ampuero & Hidalgo, 1975; Ampuero & Rivera, 1972; Llagostera, 1989; Méndez & Jackson, 2008; Méndez et al., 2009; Méndez et al., 2009; Méndez & Jackson, 2004; Pavlovic, 2004). The accepted model for this region is as follows: Hunter-gatherer groups characterize the Archaic period (8,000 BCE - 0). Towards the Late Archaic (ca. 2000 BCE - 0) local groups experienced a demographic expansion that led to a reduction in mobility and an intensification in the exploitation of

vegetable resources (as evinced by the increased presence of grinding stones in the archaeological record; Schiappacasse & Niemeyer, 1965; Schiappacasse, 1986). The first experimentations with cultigens followed, so that by the Early Ceramic period (0–900 CE) agricultural practices were already established (Ampuero & Rivera, 1964; Castillo, 1986; Kuzmanic & Castillo, n.d.; Llagostera, 1989; Niemeyer et al., 1989). In accordance with the assumptions of Willey and Phillips (1958), the Formative period triad of pottery, sedentism, and agriculture would have appeared during the Early Ceramic in the SARNC. Through the Middle period (Animas complex; 900–1000 CE) the economic orientation of these communities was principally maritime, but their diet was complemented with cultigens (e.g. maize and quinoa) and resources obtained from pastoralism. Afterwards, during the Late Intermediate period (Diaguita culture; 1,000–1,450 CE), agriculture was the principal economic activity, which would have led to the formation of hierarchical societies that were the precursors for the type of social organization found during Inka times. Once the region was incorporated to the Inka empire (1,450 - 1,540 CE), maize production and consumption increased because of the state's labor taxation and the popularity of this staple among the Inkas (Ampuero & Hidalgo, 1975).

In the last decade, assumptions regarding the impact and timing of pottery, sedentism and agriculture among SARNC prehistoric groups have been widely questioned. Studies of settlement patterns and lithic assemblages reveal that the introduction of pottery did not substantially alter the lifeways of the local SARNC communities, as their reliance on hunting and gathering and a mobile life style continued (Méndez & Jackson, 2008; Méndez et al., 2009; Pavlovic, 2004). Moreover, beans found at the San Pedro Viejo de Pichasca site, originally thought to be from the Late Archaic, have been radiocarbon dated to the end of the Early Ceramic (Rivera, 1975). Furthermore, flotation and microfossil analyses have shown that maize was not a staple resource in the region. In fact, maize only becomes visible in the archaeological record of the SARNC during the Late Intermediate period, increasing its presence in Inka times (Belmar & Quiroz, 2004; Troncoso, 2004; Troncoso et al., 2009). The data contradicts the traditional cultural-history-evolutionary model, and is at odds with the previously proposed timing and trends for maize consumption in the SARNC. However, the data is limited, given that it only provides an indirect assessment of maize consumption in the SARNC.

2 | MATERIALS AND METHODS

A total of 52 individuals, from archaeological sites from SARNC, specifically the Choapa and Limarí river-valleys, were sampled (Figure 1). Radiocarbon dates, and contextual information, indicate these individuals come from sites dated between 2,000 BCE—1,540 CE, broadly corresponding to five archaeological periods (Table 1). All samples were analyzed for carbon-13 in apatite ($^{13}C_{ap}$) and collagen ($^{13}C_{col}$), as well as nitrogen-15 (^{15}N). Of these 52 samples, 18 were processed at the Center for Applied Isotope Studies at the University of Georgia. A detailed description of the methods used at that laboratory can be found at: http://siel.uga.edu/laboratory-capabilities/animal-analysis.

TABLE 1 Stable isotope results for all samples organized by archaeological period

Period	Site	Location	Code	Cultural group	Date (BP)	Chronological range	$\delta^{13}C_{ap}$	$\delta^{13}C_{col}$	$\delta^{13}C_{ap} - {}^{13}C_{col}$	$\delta^{15}N$	C/N
Late Archaic	Churque 4	Inland	26CHI3[b]	Late Archaic	2510 ± 20	1000 BCE-0	−10.69	−17.64	6.95	10.09	3.07
	Churque 4	Inland	27CHI7[b]	Late Archaic	2130 ± 20	1000 BCE-0	−11.76	−19.5	7.74	6.46	3.01
	Churque 4[a]	Inland	UGAMS 11896	Late Archaic	2440 ± 25	1000 BCE-0	−11.60	−18.8	7.20	10.50	n/a
	Punta Teatinos	Coast	72[b]	Late Archaic	2440 ± 25	1000 BCE-0	−10.44	−13.77	3.33	17.37	3.27
	Punta Teatinos	Coast	99[b]	Late Archaic	2440 ± 25	1000 BCE-0	−10.75	−13.71	2.96	18.63	3.19
	Punta Teatinos	Coast	101[b]	Late Archaic	2440 ± 25	1000 BCE-0	−11.48	−15.82	4.35	13.71	3.17
	Punta Teatinos	Coast	104[b]	Late Archaic	2440 ± 25	1000 BCE-0	−10.26	−13.34	3.08	16.90	3.31
	La Herradura	Coast	27[b]	Late Archaic	2440 ± 25	1000 BCE-0	−8.25	−11.61	3.35	21.29	3.24
	La Herradura	Coast	30[b]	Late Archaic	2440 ± 25	1000 BCE-0	−9.88	−16.19	6.31	8.21	3.16
	La Herradura	Coast	34[b]	Late Archaic	2440 ± 25	1000 BCE-0	−9.63	−12.02	2.39	20.55	3.24
Early Ceramic	Churque 4[a]	Inland	UGAMS 11894	Molle	1240 ± 20	0 - 1000 CE	−11.80	−16.20	4.40	9.40	n/a
	Churque 4[a]	Inland	UGAMS 11895	Molle	1890 ± 25	0 - 1000 CE	−13.80	−19.60	5.80	9.80	n/a
	Mirador	Inland	07M[b]	Molle	No Direct dating	0 - 1000 CE	−8.40	−13.51	5.11	11.07	3.23
	Agricola Punitaqui	Inland	18APE1[b]	Molle	No Direct dating	0 - 1000 CE	−9.73	−14.95	5.22	6.39	2.97
	Agricola Punitaqui	Inland	24APE2[b]	Molle	No Direct dating	0 - 1000 CE	−10.16	−16.03	5.87	6.81	3.08
	ViñaBernardaMorin	Inland	25VBM	Molle	No Direct dating	0 - 1000 CE	−7.77	−15.37	7.60	6.67	3.48
	La Turquia	Inland	UGAMS 9637	Molle	1220 ± 20	0 - 1000 CE	−10.30	−16.00	5.70	6.50	3.26
Middle Period	Plaza La Serena	Coast	UGAMS 9377	Animas	900 ± 25	1000–1450 CE	−5.00	−8.30	3.30	12.20	3.20
	Plaza La Serena	Coast	UGAMS 9378	Animas	870 ± 20	1000–1450 CE	−5.50	−8.10	2.60	11.90	3.20
	Plaza La Serena	Coast	UGAMS 9379	Animas	970 ± 20	1000–1450 CE	−3.50	−8.70	5.20	14.00	3.31
	Plaza La Serena	Coast	UGAMS 9380	Animas	890 ± 20	1000–1450 CE	−4.50	−7.60	3.10	12.80	3.25
	Plaza La Serena	Coast	UGAMS 9381	Animas	1000 ± 20	1000–1450 CE	−7.90	−11.30	3.40	8.60	3.26
Late Intermediate	Loma El Arenal	Inland	UGAMS 8316	Diaguita	560 ± 25	1000–1450 CE	n/a	−10.60	n/a	7.30	3.66
	Loma El Arenal	Inland	UGAMS 8317	Diaguita	460 ± 25	1000–1450 CE	n/a	−16.50	n/a	8.80	3.51
	Loma El Arenal	Inland	UGAMS 8318	Diaguita	490 ± 25	1000–1450 CE	n/a	−12.10	n/a	8.00	3.66
	Loma El Arenal	Inland	UGAMS 8319	Diaguita	620 ± 25	1000–1450 CE	n/a	−12.20	n/a	6.70	3.26
	Loma El Arenal	Inland	21LEAE28[b]	Diaguita	No Direct dating	1000–1450 CE	−7.72	−13.37	5.65	5.57	2.87
	Loma El Arenal	Inland	22LEAE11[b]	Diaguita	No Direct dating	1000–1450 CE	−7.75	−12.84	5.09	5.83	2.88

(Continues)

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TABLE 1 (Continued)

Period	Site	Location	Code	Cultural group	Date (BP)	Chronological range	$\delta^{13}C_{ap}$	$\delta^{13}C_{col}$	$\delta^{13}C_{ap} - {}^{13}C_{col}$	$\delta^{15}N$	C/N
	Loma El Arenal	Inland	23LEAE26[b]	Diaguita	No Direct dating	1000–1450 CE	−6.31	−11.45	5.14	8.47	3.07
	Loma El Arenal	Inland	LEAE25	Diaguita	500+-30	1000–1450 CE	n/a	−11.60	n/a	6.50	n/a
	Plaza La Serena	Coast	UGAMS 9376	Diaguita	670+-20	1000–1450 CE	−7	−12.47	5.47	10.80	3.22
	Puerto Aldea	Coast	UGAMS 9639	Diaguita	800+-20	1000–1450 CE	−0.30	−10.20	9.90	18.30	3.28
	Puerto Aldea	Coast	11PA5[b]	Diaguita	No Direct dating	1000–1450 CE	−12.11	−15.57	3.46	15.79	2.88
	Puerto Aldea	Coast	17PACDM[b]	Diaguita	No Direct dating	1000–1450 CE	−6.03	−9.73	3.70	16.77	2.78
	Los Pozos	Coast	UGAMS 9638	Diaguita	780+-20	1000–1450 CE	−5.30	--0.20	4.90	19.40	3.31
Late Period	Estadiollapel	Inland	UGAMS 8315	Diaguita	410+-25	1450–1540 CE	n/a	−7.90	n/a	9.10	3.41
	Pisco Control	Inland	01PCS12[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−6.30	−11.68	n/a	8.17	2.82
	Pisco Control	Inland	02PCsS9[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.30	−13.57	6.27	6.99	3.21
	Pisco Control	Inland	03PCS15[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−6.40	−12.21	5.81	9.29	3.03
	Pisco Control	Inland	04PCS14[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.09	−12.65	5.56	9.81	3.08
	Pisco Control	Inland	05PCS8[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−8.50	−14.14	5.64	9.72	3.11
	Pisco Control	Inland	06PCS11[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.60	−12.45	4.85	9.97	2.85
	Pisco Control	Inland	09PSC10[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.56	−13.92	6.36	9.61	3.01
	Pisco Control	Inland	10PCS13[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.46	−13.32	5.86	8.43	3.08
	Pisco Control	Inland	08PSC1l1[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.09	−12.25	5.16	9.80	2.92
	Pisco Control	Inland	12PCS3[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−5.80	−12.45	6.65	9.61	3.06
	Pisco Control	Inland	13PCS4[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−6.95	−12.06	5.11	8.38	2.89
	Pisco Control	Inland	14PCS6[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.26	−12.46	5.20	8.86	2.91
	Pisco Control	Inland	15PCS15[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−6.35	−15.15	8.80	8.39	3.56
	Pisco Control	Inland	16PCS7[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−6.58	−12.45	5.87	9.66	3.08
	Pisco Control	Inland	20PCS2[b]	Diaguita Inca	No Direct dating	1450–1540 CE	−7.87	−13.70	5.83	9.30	2.90
	La Turquia	Inland	UGAMS 9636	Molle	410+-20	1450–1540 CE	−4.00	−12.20	8.20	10.90	3.39

[a]Results previously published in Vergara et al. 2012.
[b]Samples analyzed at the Alaska Stable Isotope Facility. All other samples were analyzed at the Center for Applied Isotope studies at the University of Georgia.

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The remaining 34 samples were analyzed at the Alaska Stable Isotope Facility (Table 1). In these samples, collagen was extracted as follows (modified from Misarti et al., 2009): Slices of cortical bone (0.1–1.0g) were cleaned in a sonicator and treated with an ethanol rinse. Lipids were then removed from all samples using a 2:1 chloroform: methanol solution. Bones were demineralized in 3N HCl and ultrapure water. Remaining material was rinsed to neutral, soaked in 5% KOH (8 hours) to eliminate contamination from surrounding humic soils, and rinsed to neutral again. Samples were gelatinized by adding 0.05 ml of 3N HCl to 5 ml of ultra pure water and heated to 65°C. The samples were filtered and then placed in a dry-freeze at −75°C for 48 hours. Collagen was analyzed by Costech Elemental Analyzer (ESC 4010) combined with a ThermoDeltaV using a Conflo III interface. Apatite was prepared per Koch et al. (1997) and Garvie-Lok et al. (2004). Ten (10) mg of powdered bone were weighed out and 2% sodium hypochlorite was added for 72 hours. Samples were rinsed five times until neutral. One (1.0) M buffered acetic acid was added for four hours and samples were rinsed again until neutral, and then freeze-dried. Phospheric acid (100%) was added to 3 mg of prepared sample to release CO_2. Samples were analyzed on a Thermo Electron Gas Bench II carbonate analyzer coupled to a Finnegan DeltaPlusXP.

All stable isotope ratios are expressed relative to Vienna Pee Dee Belemnite (VPDB) and atmospheric N_2 (air) respectively. Carbon to nitrogen ratios are available for 48 of the 52 samples considered (Table 1). Ratios for all samples fall within the acceptable range (2.9–3.6) indicating good preservation (Hedges et al, 2005; Koch et al., 1994; Tuross et al., 1988). The four cases for which no C/N ratio information was available were included in the study given that their stable isotope results are within the range observed for other samples from the same periods.

Although a previous study raised issues regarding interlaboratory variability, differences in $\delta^{13}C$ and $\delta^{15}N$ in collagen were found to be minimal, and do not affect analyses (Pestle et al., 2014). While interlaboratory differences in $\delta^{13}C_{ap}$ were greater, results obtained in the current study show regional and temporal differences that surpass those resulting from interlaboratory variability (Pestle et al., 2014; see below). Thus, although the samples were analyzed in two laboratories, the results obtained are comparable.

Individual samples were assigned to the respective periods based on cultural affiliation (archaeological context) and radio-carbon dating when available (see Table 1). Furthermore, each sample was ascribed as coastal or inland based on the location of the archaeological site at which the remains were found. Information regarding the geographic location of the sites and the temporal and cultural ascription of the individual samples can be found in Figure 1 and Table 1 respectively.

Statistical analyses were conducted in SPSS 21.0 (IBM Corp., 2012). Descriptive statistics were used to characterize the mean, median, and range of $\delta^{13}C_{ap}$, $\delta^{13}C_{col}$, and $\delta^{15}N$ by period and location (inland or coast). Individuals included in this study derive from two geographical areas, inland and coast, with access to different resources. Thus, between-periods comparisons were conducted for inland and coastal individuals separately. These comparisons were carried out

with ANOVA, followed by post-hoc Tukey tests to identify differences between the periods when the assumption of equality of variance was not violated. Comparisons for $\delta^{13}C_{ap}$, $\delta^{13}C_{col}$ and $\delta^{15}N$ among coastal individuals were conducted with ANOVA. In the inland, while comparisons for $\delta^{13}C_{ap}$ and $\delta^{13}C_{col}$ were conducted with ANOVA, the disparity in the variances of $\delta^{15}N$ between periods required the use of Kruskal-Wallis tests, followed by the Mann-Withney post-hoc tests. Synchronic comparisons for $\delta^{13}C_{ap}$, $\delta^{13}C_{col}$, and $\delta^{15}N$ were conducted with Student's t-tests between inland and coastal individuals from the Late Archaic and the Late Intermediate periods. Proportional probabilities of food resources were derived from the SIAR mixing model package in R (Parnell et al., 2010). The source data included in the model was divided into 5 groups: marine fish, marine mollusks, coastal camelids, inland camelids, maize, and quinoa. The trophic enrichment factor was 3.4‰ for $\delta^{15}N$ and 1.0‰ for $\delta^{13}C$.

Dietary interpretations by period and location are based on food web data obtained in this study, and supplemented with data from published analyses conducted in nearby regions (Figure 2, Table 2; Sanhueza & Falabella, 2010; Szpak et al., 2013). Isotopic variation of $\delta^{13}C$ and $\delta^{15}N$ among organisms results from differences in the organisms that constitute the base of particular food webs, the specific ways in which organisms fractionate stable isotopes, spatial variability in environmental conditions, and fluctuations in primary productivity, which are linked to climate shifts (Dehn et al., 2006; DeNiro & Epstein, 1981; Hobson et al., 1996, 1997; Misarti et al., 2009; Newsome et al., 2010; Schell, 2000; Schoeninger & DeNiro, 1984). $\delta^{15}N$ values increase in marine and terrestrial food webs by ∼3–3.4‰ per trophic level while $\delta^{13}C$ increases by ∼2‰ from primary to secondary producers and from between ∼0.5 and 1‰ in higher trophic levels (Post, 2002; Schoeninger & DeNiro, 1984). The $\delta^{15}N$ in marine animals is greater than that found in terrestrial animals (the average in bone is ∼9.0‰ per Schoeninger & DeNiro 1984), and therefore consumers of marine versus terrestrial diets can be differentiated based on their $\delta^{15}N$.

Apatite differs from collagen in that it reflects the "whole diet", including plants, while collagen reflects the protein base of the diet (to
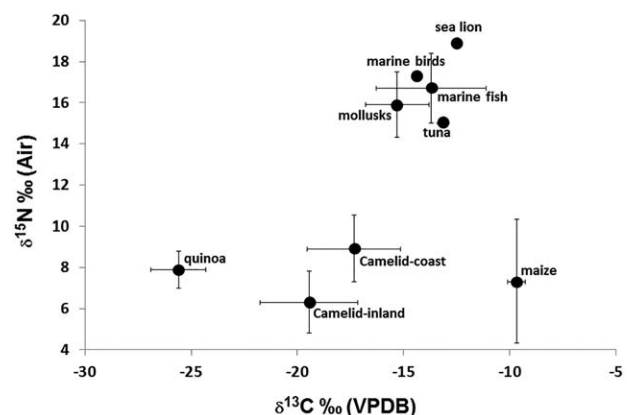
FIGURE 2 Stable isotope data for known food resources. Data are compiled from this study, Sanhueza & Falabella 2010; Gil et al. 2011; and Szpak et al. 2013 (Error bars represent ± 1SD from the mean)

TABLE 2 Average stable isotopes results for food resources in the SARNC and neighboring regions[a]

	Taxa	n	Geographic area	Provenience	Archaeological Site	Dates	$\delta 1^3 C_{ap}$	$\delta 1^3 C_{col}$	$\delta 1^5 N$	Source
Marine Fauna	Species:Xiphidae sp.	1	Coast	Archaeological	Punta Teatinos (Chile)	3320+-70 BP	2.18	−13.29	14.98	This study
	Class: Pisces	5	Coast	Archaeological	San Antonio (Chile)	Modern		−13.7 (1.7)	16.7 (2.6)	Falabella et al., 2007; Sanhueza & Falabella, 2010
	Class: Aves	1	Coast	Archaeological	Punta Teatinos (Chile)	3320+-70 BP	−7.16	−14.42	17.29	This study
	Class: Gastropoda	4	Coast	Archaeological	Maintencillo (Chile)	Modern		−15.30 (1.6)	15.90 (1.5)	Falabella et al., 2007; Sanhueza & Falabella, 2010
Terrestrial Fauna	Family: Camelidae	3	Coast	Archaeological	La Herradura, Punta Teatinos (Chile)	3940+-30 BP	−8.36	−17.34 (2.24)	8.91 (1.66)	This study
	Family: Camelidae	8	Valley	Archaeological	La Fundición, San Pedro Viejo Pichasca (Chile)	9130+40 BP	−10.36 (1.47)	−19.46 (2.39)	6.31 (1.50)	This study
Terrestrial Cultigens	Species: Zea mays	5	Lowlands	Archaeological	Iglesia, Callingasta, Cueva Zanjon del Buitre, Gruta del Indio (Argentina)	645+-40 BP		−9.69 (0.43)	7.32(3.37)	Gil et al., 2011, 2015
	Species: Quinoa sp.	3	Inland	Modern				−25.6 (0.9)	7.9 (1.3)	Szpak et al., 2013

[a]Standard deviation in parenthesis.

TABLE 3 Descriptive statistics by period for carbon13 in apatite ($\delta^{13}C_{ap}$), collagen ($\delta^{13}C_{col}$), carbon 13 apatite-collagen ($\delta^{13}C_{ap}$- $\delta^{13}C_{col}$‰), and nitrogen15 ($\delta^{15}N$) with Inland and Coastal individuals grouped.

Period	$\delta^{13}C_{ap}$‰ Min[a]	Max[b]	Mean	Median	SD[c]	$\delta^{13}C_{col}$‰ Min	Max	Mean	Median	SD	$\delta^{13}C_{ap}$-$\delta^{13}C_{col}$‰ Mean	$\delta^{15}N$‰ Min	Max	Mean	Median	SD
Coastal Late Archaic	−11.48	−8.25	−10.10	−10.26	1.01	−16.19	−11.61	−13.78	−13.71	1.73	3.68	8.21	21.29	16.67	17.37	4.49
Inland Late Archaic	−11.76	−10.69	−11.35	−11.60	0.58	−19.50	−17.64	−18.65	−18.80	0.94	7.30	6.46	10.50	9.02	10.09	2.22
Inland Early Ceramic	−13.80	−7.77	−10.28	−10.16	2.04	−19.60	−13.51	−15.95	−16.00	1.86	5.67	6.39	11.07	8.09	6.81	1.94
Coastal Middle	−7.90	−3.50	−5.28	−5.00	1.64	−11.30	−7.60	−8.80	−8.30	1.45	3.52	8.60	14.00	11.90	12.20	2.01
Coastal Late Intermediate	−12.11	−0.30	−6.15	−6.03	4.22	−15.57	−9.73	−11.63	−10.20	2.45	5.49	10.80	19.40	16.21	16.77	3.33
Inland Late Intermediate	−7.75	−6.31	−7.26	−7.72	0.82	−16.50	−10.60	−12.58	−12.50	1.80	5.29	5.57	8.80	7.15	7.00	1.20
Inland Late	−8.50	−4.00	−6.92	−7.09	1.05	−15.15	−7.90	−12.62	−12.45	1.52	6.08	6.99	10.90	9.18	9.30	0.90

[a]Min: Minimum; [b]Max: Maximum; [c] SD: Standard deviation.

which plants only contribute about 10%; Hedges & van Klinken, 2000). Differences in $\delta^{13}C$apatite- $\delta^{13}C$collagen ($\Delta^{13}C_{ap-co}$) are often used to differentiate herbivores, omnivores, terrestrial and marine carnivores from each other (Ambrose, 1993; Ambrose & Krigbaum, 2003; Ambrose & Norr, 1993). Overall, studies show that in herbivores the $\Delta^{13}C_{ap-co}$ is approximately +6.8‰ while in omnivores it is approximately +5.2‰ (Hedges, 2003). In contrast terrestrial carnivores have an approximate $\Delta^{13}C_{ap-co}$ of +4.4‰ while in marine omnivores/carnivores the difference is closer to 2.5 to 3.0‰ (Lee-Thorp & van der Merwe, 1989). Thus, as trophic level increases the $\Delta^{13}C_{ap-co}$ decreases. In general, if the $\Delta^{13}C_{ap-co}$ is greater than 5.2‰ in an omnivore then the carbohydrates are more enriched than the proteins (e.g. maize is incorporated into a terrestrial diet that includes meat; Lee-Thorp, 2008). If the $\Delta^{13}C_{ap-co}$ is smaller than 5.2‰ then the dietary protein is more enriched than the whole diet (e.g. marine consumers with some C3 plants incorporated into the diet). As this difference decreases then the protein in collagen is equal to the protein in the whole diet (e.g. consumers of an all marine diet; Clementz et al., 2009).

3 | RESULTS

Stable isotope results by individual sample are presented in Table 1 and summary descriptive statistics by period and location (inland or coast), can be found in Table 3. Diachronic comparisons among coastal individuals revealed statistically significant differences in $\delta^{13}C_{ap}$ (Anova $F(2,14)=6.434$, $p = 0.010$). The differences correspond to comparisons between the Late Archaic and the Middle ($p = 0.014$) and Late Intermediate periods ($p = 0.044$; Table 4). No statistically significant difference was identified between the Middle and the Late Intermediate period ($p > 0.05$). Between period comparisons for $\delta^{13}C_{col}$ were also significant in the coast (Anova $F(2,14)=10.059$, $p = 0.002$). Post-hoc comparisons indicate the difference occurs between the Late Archaic and the Middle period only ($p = 0.001$; Table 4), where the later shows enriched levels (Table 3). This difference is corroborated by the SIAR mixing model which outlines a change from marine resources to maize between the Late Archaic and the Middle Period (Figure 3). However the Late Intermediate has almost identical proportions of resources as the Late Archaic (Figure 3a,c). Comparisons for $\delta^{15}N$ however, were not significant (Anova $F(2,14)=2.874$, $p > 0.05$; Table 4). Between period comparisons of mean $\Delta13Cap-col$ showed no significant changes in the coast (Anova $F(2,14)=2.115$, $p > 0.05$).

Among inland individuals diachronic comparisons show statistically significant differences in $\delta^{13}C_{ap}$ (Anova $F(3,24)= 16.499$, $p < 0.001$). Post hoc tests revealed the differences are significant between the Late Archaic and the Late Intermediate ($p = 0.005$) and Late ($p < 0.001$) periods. Likewise the Early ceramic period showed significant differences with the Late Intermediate ($p = 0.015$) and Late periods ($p < 0.001$). No statistically significant differences were found between the Late Intermediate and the Late periods ($p > 0.05$; Table 5). Overall, these diachronic changes in the inland result from the enrichment of $\delta^{13}C_{ap}$ in the Late Intermediate and Late periods in relation to the Late Archaic and Early Ceramic periods. Comparisons of $\delta^{13}C_{col}$ are also significant

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TABLE 4 Statistical significance of post-hoc tests (Tukey tests) for Carbon 13 in apatite ($\delta^{13}C_{ap}$), collagen ($^{13}C_{col}$), and nitrogen 15 ($\delta^{15}N$) between periods for Coastal individuals

	δ13Cap		δ13Ccol		δ15N	
	Middle	Late Intermediate	Middle	Late Intermediate	Middle	Late Intermediate
Late Archaic	0.014	0.044	0.001	0.166	0.095	0.975
Middle	—	0.85	—	0.079	—	0.177
Late Intermediate	—	—	—	—	—	—

(AnovaF(3,31)=17.421, $p < 0.001$). Post-hoc analyses show significant differences between the Late Archaic and Late Intermediate ($p < 0.001$), and Late ($p < 0.001$) periods. Likewise, the Early Ceramic showed to be significantly different from the Late Intermediate ($p = 0.002$) and the Late ($p < 0.01$) periods (Table 5). The Late Archaic and the Early ceramic were not significantly different (p>.05) and neither were the Late intermediate and the Late period (p>.05). All significant comparisons are the result of an enrichment of $\delta^{13}C_{col}$ over time. Analyses of $\delta^{15}N$ were also statistically significant (Kruskal − Wallisx^2 (3, $N=35$)= 9.481, $p = 0.02$). Post-hoc tests show that the difference was restricted to the comparison between the Late Intermediate and the Late period ($p = 0.001$) were the latter is more enriched (Tables 3 and 5). Between period comparisons of mean $\Delta^{13}C_{ap-col}$ showed no significant diachronic changes in the inland (AnovaF(3,24)=2.507, $p > 0.05$). SIAR mixing models suggest that much of the statistical difference can be attributed to the potential of a significant increase in maize in the diet from the Late Archaic to the Late Intermediate along with an increase in the proportion of the diet attributed to camelid and maize. Additionally, the role of marine resources in the diet decreased during the Late Period (Figure 4).

Comparisons between coastal and inland individuals from the Late Archaic period showed no statistically significant difference for $\delta^{13}C_{ap}$ $\left(Student's t=-1.971, df=8, p > 0.05\right)$. However, significant differences between coastal and inland individuals from the Late Archaic were observed in $\delta^{13}C_{col}$ (Student's $t=-4.489, df=8, p=0.002$), where coastal individuals showed significantly enriched levels in relation to their inland counterparts ($\bar{x}=-13.78$ vs. $\bar{x}=-18.65$, respectively). Differences in $\delta^{15}N$ were also significant $\left(Student's t=-2.74, df=8, p=0.025\right)$, and showed enriched levels in the coast compared to the inland ($\bar{x}=16.67$ vs. $\bar{x}=9.02$, respectively). SIAR models suggest that the intake of marine fish and mollusks was proportionally higher in the diets of coastal than inland people during the Late Archaic (Figures 3a and 4a).

During the Late Intermediate period, comparisons between inland vs. coastal individuals showed no statistically significant difference in $\delta^{13}C_{ap}$ $\left(Student's t=-0.438, df=6, p > 0.05\right)$ or $\delta^{13}C_{col}$ $\left(Student's t= -0.809, df=11, p > 0.05\right)$. However, $\delta^{15}N$ was significantly enriched in coastal individuals in relation to their inland counterparts $\left(Student's t=-7.152, df=11, p < 0.001; \bar{x}=16.21\right.$ vs. $\bar{x}=7.15$, respectively). Concordantly, SIAR models suggest a higher proportion of maize and a lower proportion of marine resources in the diet of inland individuals (Figures 3c and 4c).

4 | DISCUSSION

The results obtained in this study inform us about the historical trends of maize consumption in the southern-most limit of its geographic dispersion. Previous interpretations of the archaeological evidence in the SARNC, which have not been substantially changed since the early 1990s, estimated that the adoption of agriculture and its associated dietary changes took place during the Early Ceramic period. While on the coast no Early Ceramic period samples are available, significant changes in $\delta^{13}C_{ap}$, and $\delta^{13}C_{col}$ appear by the Middle Period. The $\delta^{13}C$ of individuals from the Middle period are enriched in relation to coastal individuals from the Late Archaic. These results can be interpreted in two ways: (a) the enrichment observed in $\delta^{13}C$ among Middle Period individuals results from a change in the marine diet towards lower trophic level benthic resources or (b) Middle period individuals had already incorporated maize in their diet. Although it is possible that maize was consumed by the coastal populations during the Middle period (as seen from SIAR results in Figure 3b), the $\delta^{15}N$ results obtained in this study also show that coastal individuals from the Middle period had a diet that was heavily influenced by marine resources. In fact, coastal individuals present enriched $\delta^{15}N$ for all the periods analyzed, indicating that marine resources played a central and constant role in their diet. Additionally, $\Delta^{13}C_{ap-col}$ on the coast during the Late Archaic and the Middle period are similar ($\bar{x}=3.68$ and $\bar{x}=3.52$ respectively) and suggest a marine omnivore diet. In contrast, although the differences in $\Delta^{13}C_{ap-col}$ between the Middle and Late Intermediate periods in the coast are statistically non-significant, they are biologically significant given that the $\Delta^{13}C_{ap-col}$ for the latter period is higher than 5.2 ($\bar{x}= 5.49$). This suggests that the Late Intermediate coastal individuals had an omnivore diet where the carbohydrates were more enriched than the proteins, which indicates that maize became an important component of the diet at that time.

In the inland, definite differences were identified between Late Archaic and Early Ceramic individuals with those from the Late Intermediate and Late periods in both apatite and collagen $\delta^{13}C$. These differences result from the enrichment in carbon levels over time. Thus, in the inland, dietary changes occurred around 1,000 CE (during the Late Intermediate period), which is in agreement with the results obtained in other neighboring areas (Falabella et al., 2008; Gil, 2003; Gil et al., 2006a,b; Sanhueza & Falabella, 2010). By the Late Intermediate period inland individuals seem to have incorporated maize in their diet. Once again, the Middle period sample is exclusively composed of coastal
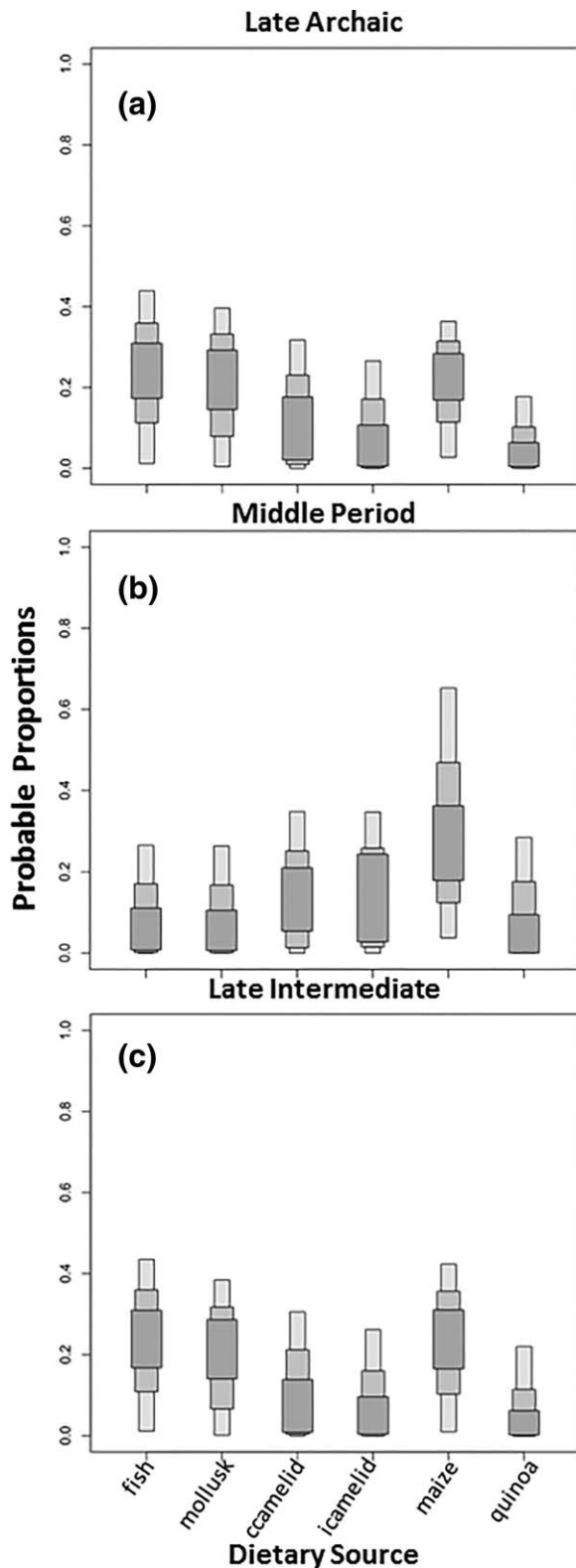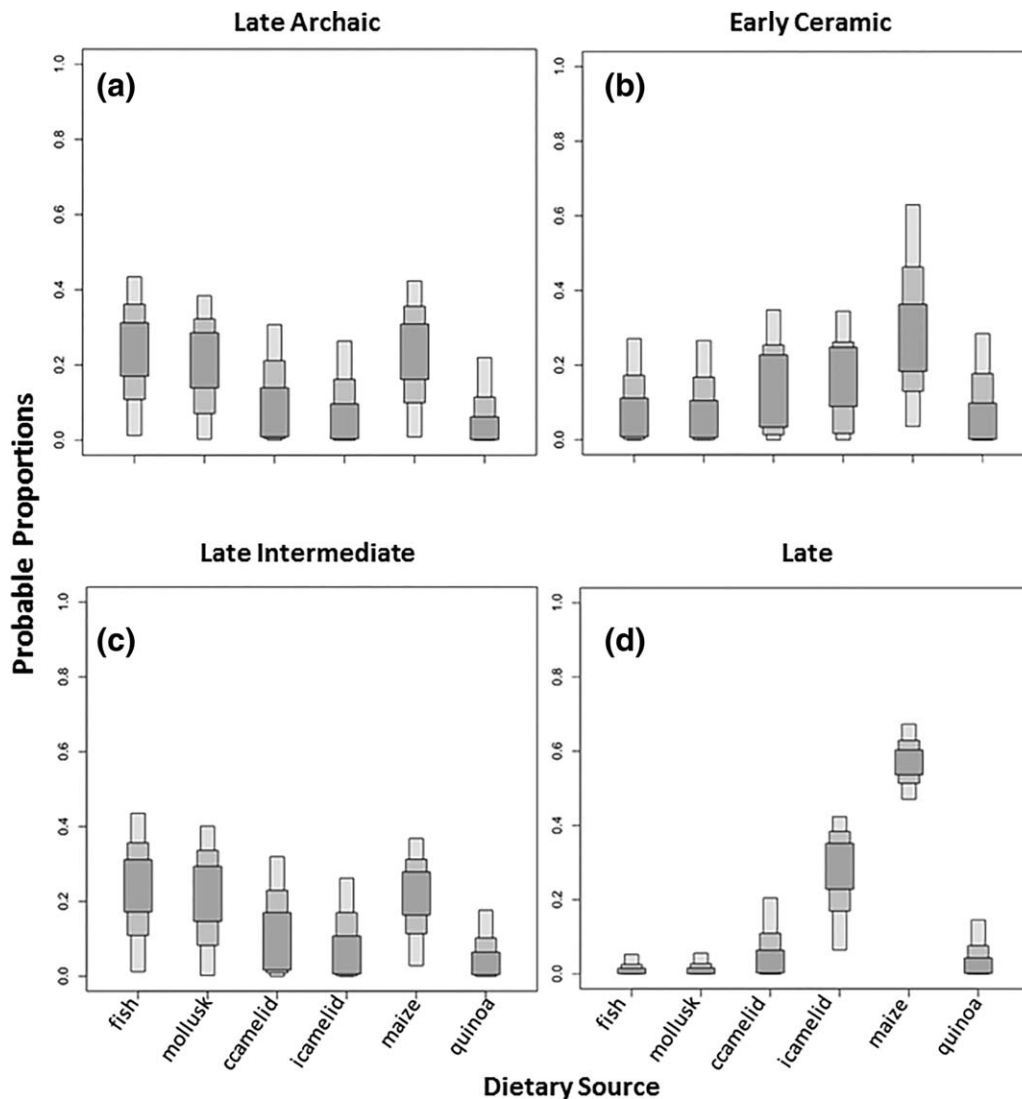
individuals and, thus, it is not possible to assess whether inland individuals from the Middle period had already experience this dietary transition. Based on the information obtained in this study, the incorporation of maize in the diet of the prehistoric peoples of the Semi-arid region of Chile was both abrupt and late. Botanical and sediment analyses in the SARNC date early maize consumption to the Late Intermediate Period with a notable increase during the Late Period (Belmar & Quiroz, 2003, 2004, 2006; Belmar et al., 2012), which supports the results of this study. But, further studies that include inland individuals from the Middle period are needed to assess this. Maize may have also been introduced in the diet in the form of chicha. To date, however, there is no clear way to differentiate maize consumed as a meal or in the form of chicha from carbon and nitrogen stable isotope data. Some preliminary analyses show enrichment in $\delta^{18}O$ as a result of the boiling involved in the preparation process of chicha (Gagnon et al., 2015). However, an absence of enrichment in $\delta^{18}O$, which is beyond the scope of this paper, does not eliminate the possibility that Maize was consumed in the form of chicha, since studies in Northern Chile and other Andean regions shows that the local production of maize chicha included beverages that were uncooked. If maize chicha consumption in this region did not involve cooking it, the isotope signature would be similar to maize consumed as food (e.g. flour; Arriaza et al., 2015; Nicholson, 1960). Further studies into this subject are needed.

Dietary changes also took place between the Late Intermediate and Late period in the inland. In particular, the enrichment in $\delta^{15}N$ may have resulted from a greater access to camelids due to the introduction of domesticates (*Lama glama*) by the Inka or the access to marine resources from the coast (Becker, 2004; Cartajena et al., 2014; López et al., 2015). SIAR models suggest the former rather than the latter (Figure 4c,d). In the inland, no significant differences in $\delta^{13}C_{ap}$ were identified between the Late Intermediate and Late periods. While in neighboring areas, central Chile and central-western Argentina, maize intake decreased during Inka times (Falabella et al, 2007; Gil et al., 2014), our results show no significant changes in maize intake between the Late Intermediate and the Late period. Moreover, the SIAR model suggest an increase in maize consumption in the SARNC at that time (Late Period). Gil et al. (2014) explained the depletion in $\delta^{13}C$ during the Late period in central-western Argentina as the result of climate change. However, the absence of changes statistically significant changes in $\delta^{13}C$ between the Late Intermediate and Late period in the SARNC signal that climate change during Inka times cannot be used as a macro-regional explanation (contra Gil et al., 2014). Thus, we emphasize that the interpretation of dietary changes must carefully consider the historical and social conditions in which they occurred.

In fact, our results suggest that local and state-level geopolitical strategies were diverse (D'Altroy, 2003; D'Altroy & Stein, 2005; Malpass & Alconini, 2010a,b; Murra, 1978) and that in this case, as well as others such as the site of Puruchuco-Huaquerones in Peru (Williams & Murphy, 2013), the diet of local groups was improved during the Inka regime (given the higher levels of $\delta^{15}N$ for inland Late period individuals in this study and as revealed by pathological and biometric evidence at the site of Puruchuco-Huaquerones). This improvement was likely

FIGURE 3 Boxplot of the proportions of different resources of each time period for coastal humans according to the SIAR model. Boxes represent the probability densities at 25, 75, and 95% credibility intervals. Ccamelid denotes camelids in coastal ranges; icamelid denotes camelids in inland ranges

FIGURE 4 Boxplot of the proportions of different resources of each time period for inland humans according to the SIAR model. Boxes represent the probability densities at 25, 75, and 95% credibility intervals. Ccamelid denotes camelids in coastal ranges; icamelid denotes camelids in inland ranges

the result of an intensification in crop production, access to imperial trade networks, and/or the participation in redistributive economies. Thus, when studying the Late period in the Southern Andean region, isotopic evidence must be interpreted in relation to the variable state-level policies that likely affected the lives and diets of these prehistoric groups (for examples regarding earlier periods see Tung, 2013).

Some of the more striking dietary differences are observed between coastal and inland individuals regardless of the archaeological

period. Coastal individuals have significantly higher SI ratios, suggesting that regional dietary variability resulted from the geographic location of these communities (inland vs. coast). Thus, mobility and exchange between the coast and the inland was somewhat limited during prehistoric times in the SARNC. This pattern is similar to the one observed further south in Central Chile (Sanhueza & Falabella, 2010). But, it contrasts with Northern Chile where high levels of mobility and exchange between the inland and the coast helped local communities to cope

TABLE 5 Statistical significance of post-hoc tests for Carbon 13 in apatite ($\delta^{13}C_{ap}$; Tukey test), collagen ($^{13}C_{col}$; Tukey test), and Nitrogen 15 ($\delta^{15}N$; Mann-Whitney test) between periods for Inland Individuals.

	$\delta 13Cap$			$\delta 13Ccol$			$\delta 15N$		
	Early Ceramic	Late Intermediate	Late	Early Ceramic	Late Intermediate	Late	Early Ceramic	Late Intermediate	Late
Late Archaic	0.651	0.005	0.000	0.098	0.000	0.000	0.569	0.221	0.491
Early Ceramic	—	0.015	0.000	—	0.002	0.000	—	0.385	0.204
Late Intermediate	—	—	0.977	—	—	1.000	—	—	0.001

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with the extreme conditions of the Atacama Desert (Pestle et al., 2014; Santana-Sagredo et al., 2015; Torres-Rouff et al., 2012). The only exception to this trend was found in the Late Archaic coastal individual from La Herradura, sample 30**. This particular individual has $\delta^{13}C$ and $\delta^{15}N$ signatures that fall within the range observed for Late Archaic inland individuals (see Table 1). The presence of this individual in the coast is the only evidence in this study of movement between the inland and the coast prior to the Late period. Exchange patterns were likely altered by the Inka during the Late period, when enriched levels of $\delta^{15}N$ suggest that coastal resources may have been more accessible for inland groups, although the incorporation of domesticated camelids may also account for this change (Becker, 2004; Cartajena et al., 2014; López et al., 2015).

Based on the results obtained, we can state that the popularization of maize in the diet would have taken place during the Late Intermediate period in the Inland and the coast, although we cannot completely discard the possibly that maize was introduced in the coast during the Middle period (Figure 3b). The absence of inland individuals for the Middle period does not allow us to assess whether maize had been introduced in the inland during that period. However, a late introduction of maize, as suggested by this study's results, is in agreement with the scarce evidence of maize in the archaeological record previous to the Late Intermediate period in the SARNC. The only maize documented in earlier contexts correspond to the site of San Pedro Viejo Pichasca (800 CE; Rivera, 1975). This does not invalidate our results, since an isolated archaeological find does not suggest a substantial dietary role for maize. Likely, the early use of maize was varied and its consumption limited (Blake, 2006). In the archaeological record of the SARNC, maize becomes ubiquitous only after 1,000 CE. A late popularization of maize in the regional diet is in agreement with studies conducted in other regions of the Southern Andes (Falabella et al., 2007; Gil, 2003; Gil, et al., 2006a, 2006b; Sanhueza & Falabella, 2010).

Both maize and quinoa $\delta^{15}N$ and $\delta^{13}C$ are not too different from other dietary sources. Thus, these cultigens will consistently show up as a possibility within the mixing model-even if that possibility ranges from 0% on the lower probability end. The same can be said of marine resources —if they are included in the model they will show as a possible dietary proportion in the output. Therefore, despite the fact that archaeologists are fairly certain maize and quinoa were not part of the diet in the Late Archaic, SIAR models will return a probability for these resources based on the fact that they were included in the model inputs. Therefore Figures 3 and 4 can be somewhat misleading and should not be interpreted as definitive inclusion of maize in the diets of humans as far back as the Late Archaic. In fact, one should pay particular attention to the fact that maize and quinoa often have a 0% probability on the lower end.

According to mixing models the most notable dietary change occurred in the Late (Inka) Period in inland diets. The probability of marine resources occurring in the diet of inland people at this time is reduced to almost 0% while camelid and maize constituted by far the highest proportion of the diets (Figure 4d). This narrow resource base is in striking contrast to the broader diets of the preceding 2000 years

for both coastal and inland peoples. As previously mentioned, this dietary change likely resulted from socio-political transformations brought into the area by the Inka.

The results of this study are similar to findings in neighboring areas that, like the SARNC, correspond to the southern-most geographic expansion of maize. In these areas, a fully sedentary life, likely associated with an increased importance of maize in the diet, occurred during later periods. Moreover, the association between sedentism, pottery and domestication, must be reconsidered. The absence of clear evidence of maize domestication in the SARNC suggest that this cultigen was introduced from other regions, just like it has been proposed for other areas within the Central and Southern Andean regions (Falabella et al., 2007, 2008; Gil et al., 2006a; Sanhueza & Falabella, 2010; Tykot et al., 2009). And, the unique conditions of SARNC as border and marginal region for maize dispersion at the continental level (Gil, 2003), explain that these processes would have occurred at comparatively later dates. Also, consumption levels of maize during the Late Intermediate and Late period in the SARNC, are low in comparison to the ones observed in Mesoamerica and North America (Schwarcz, 2006). Although, the importance of maize in the diet of prehistoric South American groups is a matter of debate, the results obtained here concur with others (Schwarcz, 2006) that suggest that the consumption of this staple never reached the levels observed in other regions of the Americas.

5 | CONCLUSION

The timing for the adoption of maize agriculture and the popularization of maize in the diet is central to archaeological discussions and interpretations of the Andean region. This adoption, however, is a process that varies in time and space. Thus, we must carefully analyze local trajectories to understand the history of maize (Blake, 2006). The goal of this study is to assess the timing and dietary relevance of maize in the diet of the prehistoric groups of the SARNC. Based on the information obtained in this isotopic study, the popularization of maize in the diet of the SARNC prehistoric groups is a relatively late phenomenon (c.a. 1,000CE), that is not associated with the first archaeological evidence of pottery and/or sedentary life.

The adoption and consumption of maize throughout the Late Holocene shows interregional variation in the Southern Andes (Falabella et al., 2007, 2008; Gil et al., 2006a,b, 2011), including Inka times. During the Late period (Inka), it is likely that these differences respond to the diverse political strategies implemented by the Inkas and the role that maize played in Inka-state policies (Murra, 1978; Staller, 2006). The results obtained in this study uncover the need for further evaluation of the consumption of maize in the southern-most region of its geographic expansion if we are to identify its unique historical trends and, in some periods, the associated state policies.

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