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Ichthyoarchaeology on a site located in the border of the alluvial plain of the Paraná River: Familia Primón case (Santa Fe, Argentina)

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Abstract

The present study aims at presenting and discussing the variability of ichthyoarchaeological remains recovered from the Familia Primón (FP) site, located at a border sector of the alluvial plain of the Paraná River (Santa Fe, Argentina). To this end, the assemblage was analyzed through its anatomical-taxonomic identification and quantification, and the different taphonomic agents that might have influenced their origin and preservation were evaluated. Also, habitability characteristics for fish and ethnographic data were used to expand the knowledge about certain human behaviors and to generate hypotheses that can be subsequently tested and discussed through the analysis of the ichthyoarchaeological record. In order to establish a micro-regional pattern of exploitation, a comparison with other fish assemblages recovered in archaeological sites situated at the middle stretch and the Paraná River Delta was made. The results suggest that fish constituted a central resource for the subsistence of the human groups that inhabited the region during the final period of the Late Holocene.

Keywords Ichthyoarchaeology · Paraná River basin · Late Holocene · Hunter · Gatherers and fishers

Introduction

Archaeological research carried out in the Alluvial Plain of the Middle Parana River (APPR) indicates that the area was inhabited by hunters, gatherers, and fishers, at least from the final period of the Late Holocene (Pérez Jimeno 2007; Bonomo et al. 2010; Barboza and Píccoli 2013; Ottalagano 2013; Sartori 2013, among others). The archaeological sites are located in different geomorphological units of the plain, and also in the continental border, with both areas affected by the periodical flooding cycles that take place in this huge plain

river. In the region, fish seem to have had a central role in the subsistence of the human groups (Musali et al. 2013; Sartori 2013; Barboza 2016; Sartori et al. 2017, among others).

The Familia Primón (FP) site is located at a border sector of the Paraná River fluvial system and, in that sense, differs from most of the sites of the area that are located within the alluvial plain. The spatial configuration of the landscape allows access to the different landscape units, both of the interior—which are typical of the Espinal ecoregion—and of the insular sector. The occupation of both areas provides an optimal use of the rich fauna, composed by a variety of species adapted to the

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river environment (e.g., Actinopterygii, *Myocastor coypus*, *Blastocerus dichotomus*) and other species characteristic of the Espinal ecoregion (e.g., *Ozotoceros bezoarticus*, dasypodids).

The archaeological evidence for the area claims that around 1000 years BP, and until the first contact between Europeans and indigenous people, there was a recurrence in the occupation of insular areas and border sectors of the alluvial plain of the Paraná River (Sartori 2013). The latter—as is the case of FP—would have been located on higher ground, at sites with good visibility and close to water courses, but protected from flooding. This would have allowed the supply of critical resources, such as water, fuelwood, and vegetal and animal products (Sartori 2008, 2013; Balducci 2014). Considering that a previous regional study has proposed that fauna exploitation goes hand-in-hand supply (Sartori et al. 2017), it is interesting to evaluate the variations in the prevalence of fish in two related environments within the alluvial plain of the Paraná River, i.e., continental vs. insular areas.

The specific identification of fish allows inferring the places and fishing methods of the hunters-gatherers-fishers who inhabited the area in the past. Also, the evaluation of the variability of fish items in terms of their specific representation allows addressing whether a more intense exploitation of a given taxon occurred and establishing macro and micro-regional patterns of utilization of that specific resource. In that sense and considering that the deposits located outside the APPR counting with a specific determination are scarce, the aim of this study is to present and discuss the results obtained from the analyses of ichthyoarchaeological remains recovered from the Familia Primón site. Also, data were compared with other assemblages of the area, in order to established micro-regional exploitation patterns.

Environment

The Paraná River is one of the major rivers of the world. Its alluvial plain has an area of around 20.000 km^2 and an average width of 30 km and is located at the middle stretch of the river (Bosisio and Ramonell 2014). This middle stretch is characterized by the presence of big lagoons whose area reaches several tens of km^2 (e.g., Coronda, Setúbal), characterized by their scarce depth (2 to 3 m in mid-water) and great elasticity. As a product of its fluvial dynamics, low flooded islands develop in the landscape, which are delimited by the lateral branches and main river channels (Marchetti et al. 2013). For the fish communities, alluvial plains are critical ecosystems because they represent excellent environments for the breeding and growth of migratory and forage species. These species greatly benefit from the substrate, which is full of microorganisms and insect larvae that develop in association to the great abundance of aquatic macrophytes (Burkart et al. 1999).

From a biogeographic perspective, the area where the FP is located presents a transitional character that allows the presence of tropical-subtropical fauna reaching high latitudes through the Paraná River, which mix with species from other regions, such as the Chaco and Pampas (Burkart et al. 1999; Bérnils et al. 2007; Arzamendia and Giraudo 2009). The ichthyofauna of the Paraná River corridor belongs to the subtropical potamic axis ecoregion and presents the highest biodiversity of Argentina (López et al. 2002). Several authors mention the existence of 188–236 species for the medium and low Paraná—from the confluence of the Paraguay and Paraná Rivers to Villa Constitución (Santa Fe)—among which the most representative correspond to the Orders Characiformes (31%) and Siluriformes (25%) (López et al. 2002; Drago et al. 2003; López et al. 2008). It is worth remarking that in this sector, there are endemic fish, such as the granulated cat fish (*Pterodoras granulosus*), *Hypostomus sp.*, and the armored cat fish (*Hyphessobrycon wajat*) (López et al. 2002; Liotta 2005).

The system presents a high fish species richness, with several life strategies linked to a variety of habitats and environmental mosaics. In turn, the strong flood and low water spatiotemporal dynamics generate connectivity and isolation gradients between the aquatic habitats of the alluvial plain and those of the main channel (Drago et al. 2003; Liotta 2005; Rossi et al. 2007). Broadly, three habitat units are considered: the main channel, the plain lotic environments, and the lentic environments, where a reduced number of species inhabits only one of them, while several species inhabit two or more. The most abundant species in the three habitats are the streaked prochilod (*Prochilodus lineatus*), and the tetras (e.g., *Astyanax f. fasciatus*), while frequent but not as abundant species are the golden dorado (*Salminus brasiliensis*), the white catfish (*Pimelodus albicans*), the yellow catfish (*P. maculatus*), and *Ageneiosus valenciennesi*. In lotic environments, medium- and big-sized catfish are frequent, such as the surubí, *Pseudoplatystoma corruscans* and *P. reticulatum*, the duckbill catfish (*Sorubim lima*), and the pati (*Luciopimelodus pati*). Finally, in lentic environments, frequent species are the wolf fish (*Hoplias malabaricus*), the piranhas (*Serrasalmus* sp. and *Pygocentrus* sp.), and cichlids (*Gymnogeophagus* sp. and *Cichlasoma* sp.) (Rossi et al. 2007).

Sample provenance and recover

The archaeological site FP is located in a semi-urban area, towards the south of Coronda City (San Jerónimo Department, Santa Fe, Argentina), at the right margin of the Coronda River—secondary channel of the Paraná River— (Fig. 1a). The site is ca. 20 m from the Coronda river, but it is not flooded even in the extraordinary grow of the Paraná
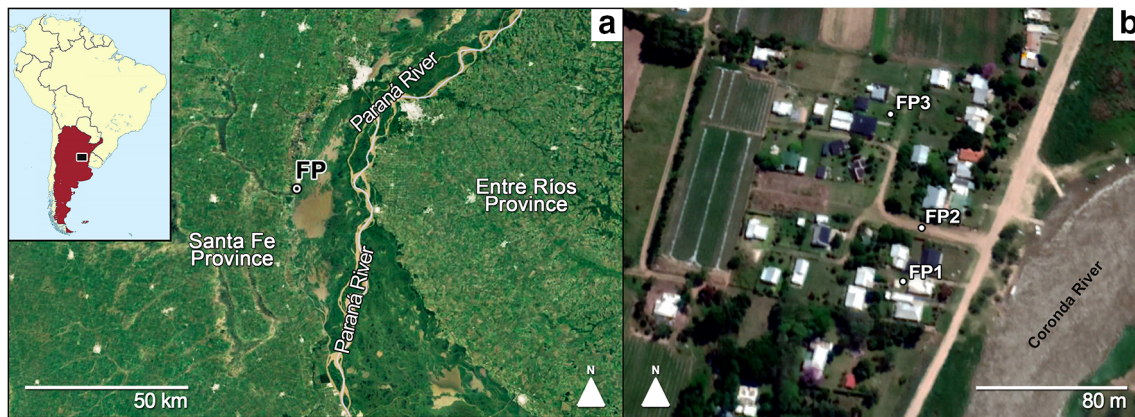
Fig. 1 **a** Location of the Familia Primón site. **b** Identifications of the three sectors (FP1, FP2, and FP3)

River. This situation was observed in field and also corroborated with the hydraulic information provided by the Centro de Investigaciones Meteorológicas of the Facultad de Ingeniería y Ciencias Hídricas (Universidad Nacional del Litoral).

The site was systematically and successively excavated in the years 2004, 2013, and 2014, resulting in the identification of a burial area (FP1), and two sectors with abundant archaeofaunistic and ceramic materials (FP2 and FP3) (Fig. 1b). These three sectors are located at a maximum distance of approximately 80 m among each other.

The first excavation (FP1) took place at the backyard of a private household of the neighborhood. The materials were recovered through the layout of eight 2×2 m grids, which were systematically excavated in 5 cm artificial levels, down to a depth of 1 m. Human bone remains ($n = 260$), faunistic remains ($n = 171$), ceramic fragments ($n = 608$), and lithic items ($n = 5$) were found (Feuillet Terzaghi 2009; Sartori 2010).

In 2013, the second excavation took place a few meters away of the formerly excavated area. In that occasion, a great number of archaeological materials were exposed after the opening of a street. For their safeguard and recovery, two 2×2-m and 30-cm depth grids were plotted, in addition to superficial collections in a 6-m^2 area, and two 1×1 m surveys. The archaeological materials recovered in this sector, named FP2, correspond to ceramic fragments ($n = 1610$), faunistic remains ($n = 1319$), and lithic elements ($n = 10$). These materials were almost completely obtained from the plotted grids and the superficial collections. The archaeofaunistic remains are 94% from stratigraphy, associated to ceramic remains, and present an overall good state of preservation (Fig. 2).

In 2014, before the construction of a household, ca. 60 m from FP2, a last archaeological intervention (FP3) was carried out. In that occasion, three 2×1-m grids were excavated in 5-cm artificial levels, covering an approximate 5.50 m^2 area, and reaching a depth of 80 cm (Fig. 1b). A large amount of ceramic ($n = 2864$) and faunistic ($n = 2560$) remains were recovered,

as well as scarce lithic artifacts ($n = 7$) and vegetal macroremains ($n = 2$). It is worth remarking that compared to the two other sectors, FP3 presented the lowest current anthropic disturbance, which derived in a better preservation of its archaeological record. In that sense, scales and pieces of mollusks which are generally very affected by fragmentation were found (Sartori 2013) (Table 1).

The site counts with three radiocarbon dates that come from each sector (Table 2). The data were grouped through the calculation of a weighted mean (Ward and Wilson 1978), since they are statistically undistinguishable (g.l. = 3; T = 3.35; X2 = 7.81; $p > 0.05$). As a consequence, the expression of the weighted value (Mp) and the standard deviation of the analyzed samples is of 384 ± 12 years ^{14}C cal BP. The calibration of the dates was performed through the SHCal-14 curve (Hogg et al. 2013), using the Calib Rev. 7.0.2 software (Stuiver et al. 2005).

Considering the radiocarbon data (Table 2), the characteristics of the pottery sherds (Balducci et al. 2019), the homogeneity of the faunal record (Sartori 2013; Sartori and Balducci 2015), and the short distance between FP1, FP2, and FP3, is that Familia Primón is considered as a single site

Fig. 2 Bony elements and Characid scales attached to the sediment of the ceramic container remains from FP2

Table 1 NISP and %NISP of the three sectors of FP site

Taxa	FP1 NISP	FP1 %NISP	FP2 NISP	FP2 %NISP	FP3 NISP	FP3 %NISP
Actinopterygii	55	32.16	838	63.53	652	25.47
Mammalia large	0	0	47	3.56	373	14.57
Mammalia medium	0	0	27	2.05	739	28.87
Mammalia small	0	0	106	8.04	186	7.27
Mammalia indet.	64	37.43	78	5.91	211	8.24
Dasypodidae	9	5.26	57	4.32	41	1.60
Cervidae	0	0	7	0.53	10	0.39
Blastocerus dichotomus	0	0	3	0.23	5	0.20
Ozotoceros bezoarticus	1	0.58	4	0.30	3	0.12
Equus caballus-Bos taurus	0	0	5	0.38	174	6.80
Myocastor coypus	37	21.64	142	10.77	152	5.94
Hydrochoerus hydrochaeris	0	0	1	0.08	1	0.04
Cricetidae	5	2.92	2	0.15	0	0
Birds	0	0	1	0.08	0	0
Undetermined	0	0	1	0.08	0	0
TOTAL	171	100.00	1319	100.00	2560	100.00

with different sectors within an occupation area (Feuillet Terzaghi 2009; Sartori and Balducci 2015).

Materials and methods

The elements were referred to taxonomic categories of different hierarchy, according to the level of identification reached (Order, Family, Genus, Species). Then, they were assigned to one of the following anatomical sections: axial, appendicular, and neurocranial-branchicranial skeleton. For the specific identification, a listing of anatomical units was used, as in the case of other studies (see Wheeler and Jones 1989; Colley 1990; Musali 2010). In order to recover small elements, a fine mesh—0.1 cm—was used and the sieving was made on the water in all cases.

The taphonomic agents relieved with the purpose of knowing the integrity and the origin of the sample were presence-absence of roots, rodents, manganese, cut marks, and thermal alterations (Stiner et al. 1995; Butler and Schroeder 1998;

Gifford-González et al. 1999; González 2005; Willis et al. 2008). Regarding the anthropic modifications, the general criteria established by Buc (2005, 2010) were applied.

To establish the relative abundance of the represented taxa and their skeletal parts, the NISP, MNI, and MNE abundance measures were applied (Lyman 1994). The MNI of Siluriformes fish was obtained mainly through the quantification of pectoral bones, taking into account their laterality, while for the rest of the identified species, the above-mentioned elements were used.

In contrast to more robust elements, the vertebrae of the different specimens are commonly affected by fragmentation processes (Musali 2010). For that reason, only vertebrae with more than 50% of the body were considered complete (Falabella et al. 1994; Gifford-González et al. 1999; Musali 2005). This issue is relevant, since these elements are usually easily fragmented during their recovery-transport, which significantly increases the NISP. To calculate sample fragmentation, the inverse of the NISP/MNE ratio, i.e., the MNE/NISP, was calculated. Such index is between 0 and 1, reaching 0 as

Table 2 Radiocarbonic dates available for the Familia Primón site

Laboratory code	Depth	Sector	Material	^{14}C years BP	cal. Years BP (2 sigma)	Reference
UGAMS 02471	70 cm	FP1	Human tooth	370 ± 30	315–485	Sartori (2008)
LP 3037	27–44 cm	FP2	Organic material in sediment	470 ± 50	327–544	Balducci (2014)
D-AMS 030252	35 cm	FP3	*Blastoceros dichotomus* ulna	374 ± 24	318–485	This paper

fragmentation increases. The advantage of this index is that it allows the comparison among assemblages (Mondini 2003; Musali 2010). Considering that a proportional relation between the vertebrae diameter with the fish size exists and in order to evaluate the presence of different dimensions' taxa, the vertebrae bones were measure establishing the following criteria: large (> 11 mm), medium (between 10 and 0.7 mm), and small (< 0.6 mm). In the region of the LLAP, a study with *Prochilodus lineatus* demonstrates a linear progression between the vertebrae diameter and the fish size (Occhi 1973). Although, as has been pointed out, measurements of the vertebrae can be used to predict standard length, though with only limited accuracy (Plug 2008). In this sense, the aim of making this discrimination in the sample of FP is to obtain a general range size of the fish represented, but not to estimate the standard length at the species level. Only were measured the vertebrae that were complete and not broken.

One significant difference between the two more represented orders in the area are that Characiformes—that had an ample representation in terms of fish biomass (Ringuelet 1961)—are rarely represented in the APPR samples. Considering that their bones are less robust, they tend to be susceptible to fragmentation process until non-identifiable (Musali 2005). For these reasons, the taxonomic determination was also held through the use of radiographies for the vertebral bodies, following the methodological criteria initially proposed by Colley (1990). Such methodology—employed in bone assemblages of the lower basin of the Paraná River—showed that vertebrae, which have low diagnosis value, mask a high specific diversity if they are analyzed with traditional methods (Musali 2005, 2010). For the identification of the obtained images, the references established in current samples, performed by Loponte and collaborators (2009), were used. The results show that in five Characiformes species (frequent in archaeological records of the region), the ossification pattern follows a star-like scheme. In contrast, the patterns of the Siluriformes show higher interspecific variability, although they essentially follow an annular ossification pattern (Loponte et al. 2009). For this analysis, it only could use those vertebrae that were complete and had a medium-big size, considering that those attributes directly affect the possibility of their determination in taxonomic terms. When a precise identification was not possible, either due to the resolution of the radiography or to a different pattern than the reference patterns, the vertebrae were assigned to Actinopterygii.

Elements which are infrequent in the archaeological records of the area were also identified, specifically scales and lepidotrichia. The former contributes to a higher taxonomic determination, while the latter, although very abundant per specimen, allows inferring discard locations and consumption practices (see point 6, "Discussion").

The analysis will be focused on FP2 and FP3 samples considering that in FP1 we could not arrive to specific determination. In that case, the skeletal elements of fish ($n = 55$)—corresponding to vertebrate and undetermined cranium—were only assigned to Actinopterygii level (Sartori 2013). The sample will be presented separately considering that they correspond to two different sectors from the same site. Finally, to establish the regional comparison, different assemblages were considered. Accordingly, only published data that count with the specific determination of fish and that it came from the APPR were included. Also, it was considered the previous archaeofaunistic synthesis works in the area, like Musali et al. (2013), Sartori et al. (2014), and Sartori et al. (2017).

Results

Taphonomic considerations

The sample of FP2 and FP3 shows a good preservation state, considering that attributes as surface corrosion and microfissures or cracks (sensu Galligani et al. 2019) were absent (Zangrando 2009; Svoboda and Moreno 2014). The depositions agents relieved show that manganese affected in similar intensity: 46 specimens (15.1%) in FP2 while in FP3 38 (13.7%). Rodents are absent in FP2 and present in two elements in FP3. Elements with rodent marks were found in pectoral spines of *Rhamdia quelen* and Pimelodidae. Roots etching were present in 14 FP2 (4.6%) and 17 in FP3 (6.1%), with a dendritic pattern and slightly changing the color of the cortical surface of the bones.

Cut marks were registered in one pectoral spine of *Pterodoras granulosus* and in a spine of *Pimelodus albicans* in FP3. The marks presented a transversal and semitransversal pattern as well as variations in the intensity of the incisions. Also, one vertebra in FP2 showed signs of scraping (Fig. 3a). Different intensities of thermo-alterations mostly in cranial, vertebrae, and lepidotrichia fragments were identified: 30 burnt (pectoral of *Pimelodus* sp., cranium of Doradidae, predorsal spine of *Prochilodus lineatus*, cranium of Loricariidae, vertebrae, lepidotrichia, tooth of *Salminus* sp., and indeterminate cranium) and nine calcined elements in FP2 (cranium Doradidae, vertebrae, and lepidotrichia) and 28 burnt (pectoral and cranium of Doradidae, dorsal of *Hypostomus* sp., pectoral of *Pimelodus* sp., vertebrae, cranium and lepidotrichia) and 13 calcined elements in FP3 (cranium and pectoral Doradidae, pectoral of *Pimelodus* sp. and lepidotrichia). Among the anthropic modifications, the presence of a smoother made of a pectoral spine of *Pterodoras granulosus* was corroborated (Fig. 3b). This instrument is defined as all the spines of fishes that present modifications that can be observed in one or both faces by the naked eye (sensu Buc 2005). These artifacts are usually made on the pectoral and dorsal spines of Silurids by following the natural structure

Fig. 3 **a** Scraping marks in vertebrate from FP2 and cut marks in pectoral spines of *Pterodoras granulosus* and *Pimelodus albicans* in FP3. **b** Smoother made of a pectoral spine of *Pterodoras granulosus* from FP3. Archaeological instrument (upper) and modern sample without anthropic modifications (lower)
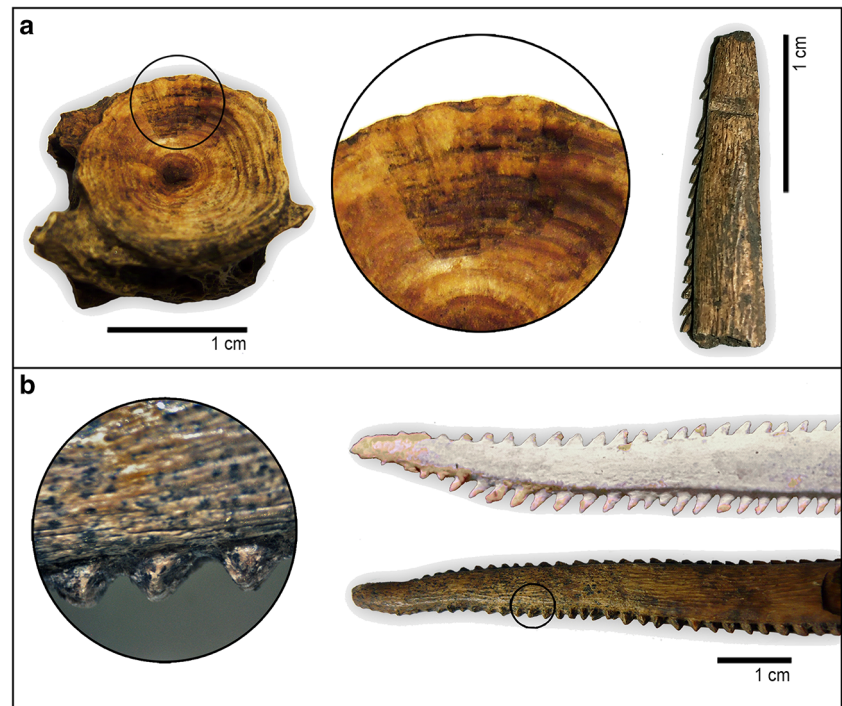
of the bone and not present manufactured signs (Pérez Jimeno and Buc 2010). The FP smoother represents the first tool made from fish found in the zone, is characterized by a length of 6.8 mm, apical ends rounded, symmetric contours, and biconvex section, while their base is broken.

Quantitative analysis

The NISP of the ichthyoarchaeological items recovered was 838 in FP2 and 652 in FP3 (Tables 3 and 4). The 93.5% and 87.9% of the remains in FP2 and FP3, respectively, were identified as Actinopterygii, since they included non-diagnostic elements (vertebrae and ribs) or fragmented elements which had lost their identifiable traits. NISP differences between both assemblages may be explained in terms of the higher material fragmentation in FP2. In this sector, the axial skeleton was represented in a 79.7%, while in FP3, it was represented in a 70.7%. In both cases, it was majorly composed by rib fragments (Tables 3 and 4). In both cases, vertebrae's sizes are similar, with a noticeable predominance of medium size (Fig. 4).

Most of the elements were assigned to different taxonomic levels, represented by the Orders Siluriformes and Characiformes and the Families Pimelodidae, Doradidae, Heptapteridae, Loricariidae, Anostomidae, Prochilodontidae, and Characidae, while nine genera and seven species were identified at more specific taxonomic levels (Tables 3 and 4).

Describing the samples using wide taxonomic categories, it can be observed that the specimens assigned to Siluriformes are present in 4.8% of the sample in FP2, and in 9.2% in FP3,

while Characiformes had a lower NISP representation in both cases (1.4% and 2.9%, respectively). The most represented families in FP2 correspond to Pimelodidae (catfish, $n = 16$) and Doradidae (armored, $n = 18$) and Loricariidae (*Hyposthomus* sp.)—with five specimens (Table 3). Specifically, the pimelodids (*Pimelodus maculatus* and *Pimelodus albicans*) reached an MNE of 6, and the granulated catfish (*Pterodoras granulosus*) had an MNE of 2 in FP2. In FP3, Doradidae has the most significant NISP with 36; Pimelodidae are represented by 10 specimens and Loricariidae with eight elements (Table 4). It is likely that many of the elements identified to the family level correspond to catfish and armored catfish identified in the assemblages. In turn, among Characiformes, the most representative in FP2 and FP3 was *Prochilodus lineatus*, with an MNE of 6 and 4 respectively. In FP2, the MNI considering all the taxa reached a total of 14, while in FP3, it was 8 (Table 5). The most abundant species in both assemblages was the streaked prochilod (MNI = 6 in FP2 and 1 in FP3), although it was not the best represented in anatomical terms, since its presence in the record consisted almost exclusively of predorsal spines (Tables 3 and 4). The utilization of fine mesh strainers allowed the recovery of predorsal bones, which were assigned to streaked prochilod (*Prochilodus lineatus*) by Dr. Pablo Scarabotti. The noteworthy aspect of this evaluation is that the skeleton of this species (as the other Characiformes) has low mineral bone density, which hinders its preservation, and usually leads to its underrepresentation in the assemblages. In that sense, the predorsal bones have a series of advantages: (1) they are a diagnostic element for species determination; (2)

Table 3 Anatomical elements represented in the ichthyoarchaeological samples of FP2

Group	Element	Siluriformes	Hypostomus sp.	Pimelodus maculatus	Pimelodus albicans	Parapimelodus valenciennis	Pterodoras granulosus	Pimelodidae	Doradidae	Loricariidae	Characiformes	Prochilodus lineatus	Megaleporinus obtusidens	Salminus brasiliensis	Actinopterygii	TOTAL	NISP%
Neurocranium	Anteorbital	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.12
	Nucal plate	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4	0.48
Branquiocranium	Articular	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.12
	Opercular	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.12
	Cleithrum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.12
Undetermined cranium		2	0	0	0	0	0	0	8	3	4	0	0	0	100	117	13.96
Appendicular skeleton	Predorsal spine	0	0	0	0	0	0	1	0	0	0	6	0	0	1	8	0.95
	Pectoral spine	0	0	3	2	1	0	7	5	1	0	0	0	0	5	24	2.86
	Dorsal spine	0	1	1	0	0	0	0	0	0	0	0	0	0	3	5	0.60
	Lepidotrichia	0	0	0	0	0	0	0	0	0	0	0	0	0	X[a]	0	0.00
Axial skeleton	Vertebrae	0	0	0	0	0	0	0	0	0	0	0	0	0	133	133	15.87
	Ribs	0	0	0	0	0	0	0	0	0	0	0	0	0	534	534	63.72
Others	Teeth	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	0.24
	Scales	0	0	0	0	0	0	0	0	0	X[a]	0	0	0	0	0	0.00
	Undet.	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	0.84
TOTAL		3	1	4	2	1	2	9	16	4	5	6	1	1	783	838	100.00

[a] "Presence"

Table 4 Anatomical elements represented in the ichthyoarchaeological samples of FP3

Category	Element	Siluriformes	Hypostomus sp.	Pimelodus albicans	Rhamdia quelen	cf. Pseudoplatystoma sp.	Pterodoras granulosus	Pimelodidae	Doradidae	Loricariidae	Characiformes	Prochilodus lineatus	Megaleporinus obtusidens	Salminus brasiliensis	Actinopterygii	TOTAL	NISP%
Neurocranium	Anteorbital	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.15
	Basioccipital	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.15
	Lateral medial plate	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.15
	Frontal	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.15
Branquiocranium	Opercular	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.15
	Cleithrum	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.15
Undetermined cranium		3	0	0	0	0	0	2	21	1	11	2	0	0	109	149	22.85
Appendicular skeleton	Predorsal spine	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0.31
	Pectoral spine	1	2	3	3	0	1	3	10	0	0	0	0	0	5	28	4.29
	Dorsal spine	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.15
	Lepidotrichia	0	0	0	0	0	0	0	0	0	0	0	0	0	X[a]	0	0.00
Axial skeleton	Vertebrae	0	0	0	0	0	0	0	0	0	0	0	0	0	86	86	13.19
	Ribs	0	0	0	0	0	0	0	0	0	0	0	0	0	376	376	57.67
Others	Teeth	0	0	0	0	0	0	0	0	0	1	0	1	1	0	3	0.46
	Scales	0	0	0	0	0	0	0	0	0	X[a]	0	0	0	0	0	0.00
	Bone plate	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.15
TOTAL		5	2	3	3	1	3	6	33	1	13	4	1	1	576	652	100.00

[a] "Presence"

Fig. 4 Vertebrae size in FP2 and FP3

Fig. 5 Archaeological (left) and present (right) predorsal bone of *Prochilodus lineatus*
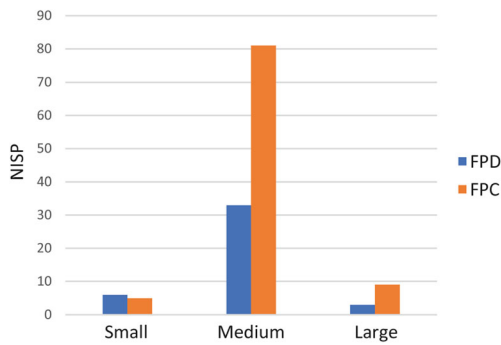
their robustness and size allow an excellent preservation and low fragmentation of the items; (3) since there is only one per individual, it allows the estimation of MNI (Fig. 5).

In order to achieve a higher taxonomic determination, and to evaluate to which extent Characiformes might have been underrepresented, 55 vertebral bodies of FP2 (41% of the total) were subjected to the radiography method. Between them, it was possible to assign 45 elements (i.e., 82% of the vertebrae) to a given Order. The data were robust, since they showed a dominance of Characiformes ($n = 37$, 67.27%) over Siluriformes ($n = 8$, 14.55%), with an 18.2% assigned to Actinopterygii ($n = 10$).

With respect to the recovered scales, although they were abundant (Tables 3 and 4), they do not allow the estimation of the number of individuals, since each specimen presents hundreds of these elements. However, they did contribute to address the presence of Characiformes in the assemblage, and to infer possible discard locations (see "Discussion"). Likewise, all the ribs and certain cranial elements were fragmented, although in many cases, it was observed that fragmentation occurred when detaching the elements from the sediment. However, the elements did not lose their diagnostic characters, which were reflected in a low fragmentation index (0.94).
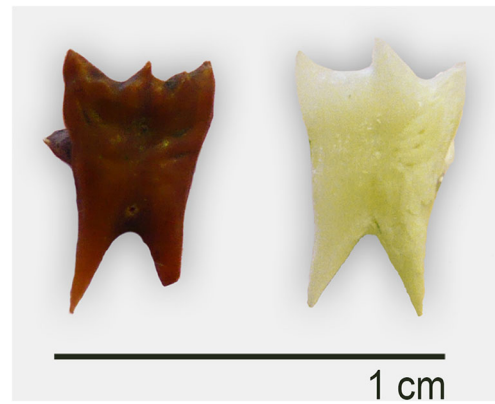
Discussion

First, taphonomic and contextual aspects about the precedence/overall status of the ichthyoarchaeological assemblage should be discussed (Zohar et al. 2001). This allows establishing the extent to which the materials were affected by post-depositional processes, as well as evaluating whether its presence in the record is due to past anthropic activity. On this latter point, several authors argue that according to the representation of skeletal parts in assemblages deposited, it could be expected the representation of complete skeletons, while in cultural assemblages, the opposite situation may be more frequent depending on several factors such as the processing technique and its objective and differential transport (Gifford-González et al.1999; Zohar et al. 2001). Also, research based on comparative studies between human and natural fish assemblages point out that fish natural deposition is generally very low (Stewart and Gifford-González 1994). A local study in the area supports this idea since the results show that natural levee without human occupation not only had

Table 5 MNE and MNI per species of FP2 and FP3

Siluriformes	Taxa	FP2		FP3		Total
		MNE	MNI	MNE	MNI	
	Pimelodus maculatus	4	2	0	0	2
	Pimelodus albicans	2	1	3	1	2
	Parapimelodus valenciennis	1	1	0	0	1
	cf. *Pseudoplastystoma* sp.	0	0	1	1	1
	Pterodoras granulosus	5	1	2	1	2
	Hypostomus sp.	2	1	2	1	2
	Rhamdia quelen	0	0	3	1	1
Characiformes	*Prochilodus lineatus*	5	5	4	1	6
	Megaleporinus obtusidens	1	1	1	1	2
	Salminus brasiliensis	1	1	1	1	2
TOTAL		29	13	14	8	21

lower faunistic elements than archaeological sites but also that fish remains are absent (Acosta et al. 2004).

In the analyzed case, the contextual information supports an anthropic origin of the assemblage (or at least of most of the present specimens), for several reasons. Firstly, the site does not flood, even under exceptional floodwaters, for which it is unlikely that fish enter and get naturally trapped. Secondly, the materials are associated to ceramic, with fragments in which the skeletal remains are attached to the container walls, together with sediment and carbon (see Fig. 2). Likewise, the presence of thermo-altered elements, together with anthropic modification (i.e., the instrument) and cut marks in certain specimens, corroborates an anthropic over a natural origin.

In general, the ichthyoarchaeological remains were in a good preservation state, such as the other archaeofaunistic materials from the different sectors of the FP site. This implies a rather infrequent situation for fish element recovery, as in the case of scales, which are generally not preserved in humid environments like the study site. The presence of manganese in certain materials would indicate that surface and/or underground water affected the records for long time cycles, although bearing evidence (which would indicate fluvial redeposition situations) was not observed. On the other hand, the good preservation state of the external tissue, as well as the presence of highly fragile elements, indicates relatively fast burial conditions. Signs of roots, carnivores, and rodents were recorded in low rates, which might be related to specimen size. However, the context of each sector within the site is different, since FP2's location is on the street, which possibly explains the higher fragmentation of this assemblage.

According to these considerations and the anatomical and taxonomical analysis carried out, it can be concluded that no significant difference between the FP2 and FP3 assemblages exists. In this sense, the two samples will be treated as one henceforth in order to discuss the importance of the fish for the FP inhabitants.

The fish assemblages recovered in FP show a dominance of Pimelodidae and ossified catfish—the latter representing 78% of the elements determined to specific levels—and Characiformes, among which the streaked prochilod represented 66% of the elements within the order. The latter is one of the most abundant species of the middle stretch of the Paraná River, and its estimated biomass reaches 50% of the total biomass (Tablado et al. 1988). Since its representation in records is usually low, one hypothesis is that its scarcity is influenced by the post-depositional processes. In that sense, the new diagnostic element—predorsal spine—presented in this study might improve its representation. In FP, an MNI of 7 was found, for which the taxon was the best-represented both within Characids and at the individual level. This is concordant with the result obtained of vertebrae radiography that shows the inverse relation that was expressed by the traditional method. The predominance of the Characiformes order by

the Siluriformes in vertebrae has been also pointed out for the sub-assemblages of the Delta and of the middle stretch of the Paraná River (Musali 2010; Sartori 2015).

The specific determination performed in FP is relevant due to its contribution regarding prey capture areas. The habitability characteristics for fish (both migrant and resident) in alluvial plains are mediated by water thermal-hydrologic behavior, as well as by geomorphology, presence of hydrophile vegetation, and season of the year (Welcomme 2001; Minotti et al. 2013). Wetland vegetation also provides areas that meet the requirements of the different species, such as shade and shelter from predators and currents. However, by generating environments with oxygen deficits and low pH, they can also constitute "natural" traps for fish (Minotti et al. 2013). All these particularities can affect prey offer and distribution and influence the capture strategies that human groups might have implemented in the past.

Considering the ethology of some species in the case of FP, catfish and armored catfish might have been captured in shallow, vegetated environments, while other fish, such as the surubí, might have been captured in relatively deep waters (Menni 2004). On the other hand, the characids (boga, dorado, streaked prochilod) frequently inhabit lotic environments, such as the Coronda River, which can be directly accessed from the site. In turn, both the time of the year and the species reproductive strategies determine the different habitats, meaning that the species present in a given site reflect potentially different extractive environments, from medium-sized rivers, to lagoons and wells towards the interior of the APPR. Likewise, among the identified families, Doradidae and Pimelodidae were found, whose majority of species are available throughout the annual cycle, and certain migratory species are available during the spring and summer months (Bonetto et al. 1981; Arámburu 1985). Taking into account the intrinsic hydrogeographic characteristics of the Paraná sector under study, it can be said that the fish fauna might have presented a certain degree of spatial concentration, becoming a highly predictable resource.

Although the number of cut marks was scarce ($n = 3$), they were more abundant than those registered in other sites of the APPR and the Paraná Delta (see Musali 2010; Sartori 2015). Such low frequency might be due to fish anatomy, and the small/medium size of most prey, with small bony elements which might become easily fragmented, thus likely masking the identification of signs. In that sense, the elements showing signs in FP are robust and comparatively larger, as in the case of the only recovered vertebra, with a 2-cm radius. Further, the intensity and variation of the employed techniques for processing-consumption might also be agents leading to scarce-null evidences (Lyman 1994; Willis and Boehm 2014, 2015; Zohar et al. 2016).

With respect to fish capture, cooking, and storage strategies, the available evidence in the archaeological records—as

well as in ethnographic and ethnohistoric sources—allows inferring a likely usage of different techniques. The earliest chronicles, such as those from García de Moguer (1908 [1526]), Ramírez (2007 [1528]), Fernández de Oviedo (1959 [1535]), Santa Cruz 1918 [1539], and Schmidel (1884 [1567]), mention fishing as a recurring and basic activity for the subsistence of many ethnical groups inhabiting the APPR. Among the consumed species, the first chroniclers that arrived to the South American territory mention the catfish and dorados (Lopes de Sousa 1861 [1530–1532]). On the other hand, among the Qom and Wichí, who fish in the Pilcomayo River, most of the captured species are integrated as part of the diet (Arenas 2003). However, certain restrictions or food taboos linked to the cultural configuration of each group are worth remarking, which have been registered for species such as the gilded catfish (*Zungaro zungaro*) in Qom groups (see Terán 1998).

Regarding the capture strategies used, two different, non-excluding forms can be considered: (a) fishing techniques through which a single individual at time is obtained, either through the use of harpoons, bow, and arrow or lance, among other elements; (b) mass trapping systems, using nets or traps (Gragson 1992; Beckerman 1994; Arenas 2003; Pérez Jimeno 2007; Musali 2010; Sartori 2015; Scarpa 2007 among others). In FP, the predominance of small/medium-sized specimens, inferred through vertebrae size, might have implied the usage of mass trapping systems. Taking into account that net fishing is one of the most effective extractive methods, and that in FP indirect evidence of net has been found as impression in pottery sherds, this was likely one of the employed methods (Sartori 2013). Although the ethnohistoric chronicles and the ethnographic data for Chaco groups mention bow and arrow, harpoons, and lance fishing (e.g. García de Moguer 1908 [1526]; Ramírez 2007 [1528]; Paucke 2010 [1748], Arenas 2003 among others), vestiges to infer these techniques in FP have not been found to date. However, counting with more than one capture strategy turns fishing into an efficient activity (Musali 2010; Santini 2012; Sartori 2013) and allows increasing yields, even during flooding times, when fish become more dispersed.

In relation to the culinary variants, boiling (Paucke 2010 [1748]), roasting (Terán 1998), and drying (Santa Cruz 1918 [1539]) are mentioned in the chronicles, while the ethnographic observations establish that one of the most employed techniques was complete roasting, which does not leave footprints in the bony elements since it implies virtually null processing (Arenas 2003; Scarpa 2007). The recovery of calcined and burnt lepidotrichia and the scarcity of processing footprints might indicate the use of roasting, through which the fins are exposed to intense heat. Likewise, the different cooking methods are conditioned by the size of the specimen and the species to be consumed. The presence of ceramic in all the sites of the APPR suggests that boiling was likely the other

method used, since it allows high yields of both the meat and the fat present in certain species, such as Silurids (Musali 2010; Sartori 2013, 2015).

Finally, the presence of the smoother elaborated in a spine of *P. granulosus* reflects the complex resource use network in hunter-gatherer-fisher communities. These tools, elaborated in pectoral and dorsal Siluriformes spines, have been recorded in several sites of the north of the APPR and the Delta and might have been used in ceramic confection, or in leather and vegetable works (Ruggeroni 1975; Buc 2007, 2010; Pérez Jimeno 2007).

If the results obtained from this study are compared with other fish assemblages recovered in archaeological sites situated at the middle stretch and the Paraná River Delta, certain trends can be established. Firstly, fish constituted the best-represented resource in terms of NISP in all the APPR (Sartori et al. 2014; Sartori et al. 2017). In that sense, a recurrence in prey representation, such as *Pterodoras granulosus*, *Megaleporinus obtusidens*, *Pseudoplatystoma* sp., *Pimelodus maculatus*, and *Pimelodus albicans* can be observed, although differences in their abundance and representativity along the APPR are found (see Pérez Jimeno 2009; Musali et al. 2013; Sartori 2015; Musali and Pérez Jimeno 2016). On the one hand, increasingly higher representations are observed from south to north (Sartori et al. 2014), evidenced by the fact that in the Delta sector, fish widely exceed 50% of the NISP of the assemblages in all cases (Loponte 2008; Musali 2010; Musali et al. 2013). This might be linked with the "more terrestrial" environment conformed towards the north of the APPR sector—where accretion processes occur—vs. the South—where a mosaic of more aquatic environments predominates—(Marchetti et al. 2013). However, the archaeological site Cerro Aguará (towards the north of the APPR) is an exception, due to the great number of fish species found ($n = 23$) (Musali et al. 2013), while in the study area and in the Delta, 5–11 taxa are found in all the assemblages. On the other hand, *Pterodoras granulosus* is the dominating prey of all the assemblages at the lower Paraná and the Delta, unlike Pimelodidae species, which are absent or scarcely represented (Musali 2010). In the case of the mid-Paraná, catfish and other species (e.g., armored cat fish, boga) have a higher representation in the NISP% of the assemblages (Musali et al. 2013; Sartori 2015; Barboza 2016). In this context, FP presents the particularity of exhibiting a good representation of catfish (Siluriformes), especially of the families Doradidae and Loricariidae—in terms of NISP—but also of Prochilodontidae.

Final considerations

In the FP site, in addition to the great abundance of fish and other species adapted to aquatic environments—such as the coypu (*Myocastor coypus*)—species that are characteristic of the Espinal ecoregion were also found, such as dasypodids and the Pampas deer (*Ozotoceros bezoarticus*). Due to its continental characteristics, FP might be reflecting particular

conditions and different exploitation circuits than insular sites. Also, the transitional character of the area where it is located provides access to diverse faunistic resources, turning the place into a strategic point in the landscape.

The knowledge about the exploitation of ichthyofaunistic resources is relevant, both at the site level and in general. In this study, the ichthyoarchaeological assemblages of FP were specifically evaluated, which constitutes one of the few analyses carried out in the sites at the border of the APPR. In the region, specific studies about fish are scarce and should be increased since these taxa constitute one of the most relevant for the subsistence of the human groups of the area. Thus, expanding the available knowledge and information would allow generating regional comparisons, to reach wider understanding about space and resource use in the past.

Compliance with ethical standards

Conflict of interest   The authors declare that they have no conflict of interest.

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