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Evaluating fish processing patterns in the lower stream of the Colorado River (eastern Pampa-Patagonian transition, Argentina): An experimental work

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ABSTRACT

Fish processing and consumption became an increasing part of the subsistence patterns in the lower stream of the Colorado River (Buenos Aires province, Eastern Pampa-Patagonian transition, Argentina) during the Middle and Late Holocene (ca. 6000–250 years BP). Freshwater and marine fish specimens recovered from the zooarchaeological assemblages of these periods exhibit processing cutmarks. Since cutmarks are unusual traits in this type of prey and actualistic research related to fish processing are not abundant, an experimental study was performed. The objective was to determine whether the activities related to fish butchering generate cutmarks and, in that case, if a pattern in the distribution of the marks is found in specific anatomic units. Results indicate that independently from the kind (Perciformes or Siluriformes) and size of fish, as well as the type of lithic raw materials used in the butchering process, cutmarks were consistently found on vertebrae. Despite two different methods of butchering employed for Perciformes and Siluriformes, the filleting stage produced the highest frequency of cutmarks. Nevertheless, results obtained in the experimental work show differences when comparing with archaeological assemblages. A combination of factors related to variations in butchering processes, the butchery skill, the employment of specific methods of cooking, and taphonomic factors, could be the causes of the differences.

1. Introduction

Experimental animal butchery has made an important contribution to the development of zooarchaeological studies, particularly those concerning large mammals (Binford, 1981; Buikstra and Swegle, 1989; Miotti, 1990–1992; Blumenschine, 1995; Lupo and Schmitt, 1997; Lupo, 1998; De Nigris, 2001; Mengoni Goñalons, 2001; Egeland, 2003). However, there have been few such studies on smaller vertebrates (Speth, 2000; Laroulandie, 2001; Lloveras et al., 2009; Escosteguy and Vigna, 2010; Medina et al., 2012) and fewer still concerning fish (Wheeler et al., 1989; Colley, 1990; Morin, 2004; Steffen and Mackie, 2005; Willis et al., 2008; Willis and Boehm, 2014, 2015; Archer and Braun, 2013; Svoboda and Moreno, 2014; Nurminen, 2015; Corbat et al., 2017).

Some ethnographic work on fish processing techniques has been undertaken (Stewart, 1991, 1994; Stewart and Gifford-Gonzalez, 1994; Zohar and Cooke, 1997; Gifford-Gonzalez et al., 1999) but less attention has been given to zooarchaeological evidence for fish processing. This is largely because cutmarks and other indicators of processing are rarely observed on archaeological fish remains, presumably because their small size means that they can usually be consumed either whole or without intensive processing (Wheeler et al., 1989; Colley, 1990; Juan-Muns i Plans et al., 1991; Willis et al., 2008; Zohar et al., 2018). Nevertheless, in different archaeological sites from the Pampas and Northern Patagonia several fish species with evidence of consumption have been observed (Quintana and Mazzanti, 2001; Martínez and Gutiérrez, 2004; Gonzalez, 2005; Prates, 2008; Musali, 2010; Bayon et al., 2012; Favier Dubois and Scartascini, 2012; Corbat, 2016; among others). Also, in the Eastern Pampa-Patagonian transition (the lower stream of the Colorado River), sizeable fish bone assemblages containing a variety of species have been recovered (e.g., sea catfish "*Genidens barbus*"; white croaker "*Micropogonias furnieri*"; perch "*Percichthys trucha*"; striped weakfish "*Cynoscion guatucupa*"). Within these assemblages there are specimens that exhibit evidence of processing and consumption (e.g., cutmarks and thermal alteration; Martínez et al., 2010; Stoessel, 2010, 2012a, 2012b, 2015). This situation and the lack of ethnographic or ethnohistorical evidence for these regions about fish procurement and processing techniques deserve the generation of frames of reference (Binford, 2001). Results can help interpret the mechanisms by which fish became incorporated into the archaeological

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record, as well as to understand patterns of fish processing, cooking and consumption. This paper represents a first step towards achieving this baseline dataset. To this end the aims of this paper are: a) to develop an experimental work[1] to observe if the activities related to fish butchering generates material correlates that can later be detected on bone surfaces; b) to determine which stages of the butchering sequence - from procurement to discarding-produce cutmarks, and to identify on which anatomical elements they occur; c) to compare these results to those from other experimental studies, and d) to compare the results obtained from the experimental work with the evidence provided by the ichthyoarchaeological record of the study area.

2. Biogeography of the Colorado River and the subsistence model

The lower stream of the Colorado River (38°–41° S; 62°–64° W), is located in the Pampa-Patagonian transition, within the so-called "Diagonal Árida", in southern South America (Abraham de Vázquez et al., 2000). The study area covers part of Villarino and Patagones districts, in the southern tip of the Buenos Aires province (Fig. 1). This area presents ecotonal characteristics from a faunal and floral point of view (Morello, 1958; Páez et al., 2001; Villamil and Scoffield, 2003). Given the purpose of this paper, ichthyofaunal aspects of the area are described in depth below.

Regarding fresh water fish species, the study area is located in the Andean Cuyan province (López et al., 2008), whose representative species include patagonian catfish (*Hatcheria macraei*), otuno (*Olivaichthys cuyanus*), perch (*Percichthys trucha*) and uruguay tetra (*Cheirodon interruptus*). This province shares species with the Aymaran, Patagonic and Great Rivers provinces (López et al., 2008). Almirón et al. (1997) pointed out that between the mouths of Colorado and Negro Rivers there are also species of the Austral and Brasílica subregions. The marine species are more abundant and present a larger diversity than the fresh water fish species. The marine sector, where the Colorado River delta is located, is included in the Rio Negro District, belonging to the Argentine province (Balech and Ehrlich, 2008). This province has significant fish heterogeneity due to the mixture of subtropical and subantarctic species. Some of these belong to families such as Sciaenidae (*Micropogonias furnieri*, *Cynoscion guatucupa*, *Macrodon ancylodon*, *Umbrina canosai*), Sparidae (*Pagrus pagrus*) and Cheilodactylidae (*Nemadactylus bergi*) (Balech and Ehrlich, 2008). Besides the Teleostei already mentioned, there are also Chondrichthyes species such as *Mustelus schmitti*, *Galeorhinus galeus*, Rajidae, Myliobatidae and Dasyatidae families (Cousseau and Perrotta, 2000). The largest richness of fish species is related to the Colorado River estuary, in which several euryhaline marine species such as white croaker (*Micropogonias furnieri*), black drum (*Pogonias cromis*), striped weakfish (*Cynoscion guatucupa*) and sea catfish (*Genidens barbus*) are present (Cousseau and Perrotta, 1998; Carozza et al., 2000; Macchi et al., 2002).

The knowledge generated about the subsistence of the hunter-gatherer groups that occupied the study area comes from the isotopic and zooarchaeological analyzes. On the one hand, information obtained from isotopic analysis ($\delta^{13}C$ and $\delta^{15}N$) of human remains from several sites (e.g., La Modesta, Paso Alsina 1, La Petrona and La Primavera; see Fig. 1) indicate that during the Middle Holocene diet was diverse, including marine, terrestrial, and fluvial resources. Towards the Late Holocene diet was relatively homogeneous and continental, characterized by the consumption of terrestrial herbivores and freshwater fish (Martínez et al., 2009; Flensborg et al., 2018). On the other hand, zooarchaeological analyses in Middle Holocene (ca. 6000–4100 years BP) inland sites indicate the exploitation of ungulates (specifically guanaco, *Lama guanicoe*) and smaller species such as large-sized rodents (nutria, *Myocastor coypus*), and possibly birds and armadillos (Alcaráz, 2017). In addition to these species, the presence of freshwater fish (*Percichthys* sp.) with evidence of consumption (cutmarks) is noteworthy (Stoessel, 2015). During the Late Holocene (3000–250 years BP) a diet based on the exploitation of large size species (guanaco, pampas deer-*Ozotoceros bezoarticus*, ñandú-*Rhea americana*), smaller-sized terrestrial species (e.g., rodents, armadillos), and inland fresh water prey species (e.g., anatids) was recorded. The simultaneous exploitation of fluvial and marine fish (e.g., sea catfish, white croaker, indeterminate sciaenidae) was recorded towards the Final Late Holocene (1000–250 years BP).

3. Fish exploitation and the archaeological record of the lower stream of the Colorado River

The information presented here comes from Site 1 of the San Antonio Archaeological Locality and from the La Modesta site. As described below, these sites are particularly useful case studies because both contain a large amount of fish remains (Stoessel, 2015; Alcaráz, 2017).

The San Antonio archaeological locality includes six sites located on low aeolian sand dunes, at ca. 4 km from the Atlantic coast (Fig. 1). The material comes mainly from stratigraphic contexts and involved piece-plotted artifacts recovered in the excavation units and specimens recovered by dry sieving with a 2 mm mesh size. The stratigraphic sequence at San Antonio 1 site is composed of extensive aeolian strata, which overlie ancient alluvial and marine deposits. The archaeological component – including fish remains – is exclusively located in the upper part of the sequence, more specifically in a buried "A" soil horizon dated ca. 1000–800 years BP (Martínez and Martínez, 2011), and falling within the Final Late Holocene. Given the geomorphological context described previously, the presence of fish bones is clearly the result of anthropic action, which is also indicated by evidence of cutmarks and thermal alterations (Martínez et al., 2010; Stoessel, 2010; Stoessel, 2012a, 2012b). These sites are interpreted as seasonal (spring and summer) residential bases used mainly for fish procurement, processing and consumption (Martínez et al., 2010). San Antonio 1 has the most fish remains of all sites in the locality ($N = 3693$), and its assemblage includes both marine and fluvial species. The marine species are present in higher frequencies ($n = 1586$), and among them the sea catfish fully dominates the assemblage (NISP = 1412; MNI = 133; Table 1). Taphonomic analyses of these assemblages indicate that 14.62% of the specimens were affected by root etching, 2.2% presented manganese staining, and evidence of chemical deterioration occurred in 0.03% of the sample (Stoessel, 2012a).

Among the sea catfish specimens at San Antonio 1 there are both cranial elements, in higher frequencies, and post-cranial elements (Table 2). Different regions that correspond to the skull, axial and appendicular skeleton are present. However, cutmarks were found in only two of those regions, and on only four specimens: two basioccipitals and two caudal vertebrae. While 19 cutmarks were identified in the former, only 4 were registered in the latter. In both cases the cutmarks are oriented transversely to the longitudinal axis of the bone (Fig. 2).

The La Modesta site is about 60 km from the Atlantic coast. It is located on a dune and the adjacent blowout distant ca. 1 km from an ancient paleochannel (Fig. 1). The majority of the material (lithic artifacts, faunal remains, and human remains, among others) appeared mainly on the surface of the blowout. These were recovered by means of 20 transects in which all materials were collected. Radiocarbon dates from faunal and human bones indicate Middle Holocene occupations (ca. 5900–5600 years BP; Martínez, 2017; Martínez and Flensborg, 2018). The site was characterized as a base camp where funerary practices were also performed. Among the faunal assemblage, a significant number of fish remains ($N = 2748$) was recovered, but only

[1] Experimental work understood as a part of actualistic studies implies reconstruction processes where certain variables are controlled. These procedures make it possible to observe the relationship between an agent's action and the physical results produced by those actions, as well as to established specific causal relations among them (Gifford-Gonzalez, 1991; Lyman, 1994).

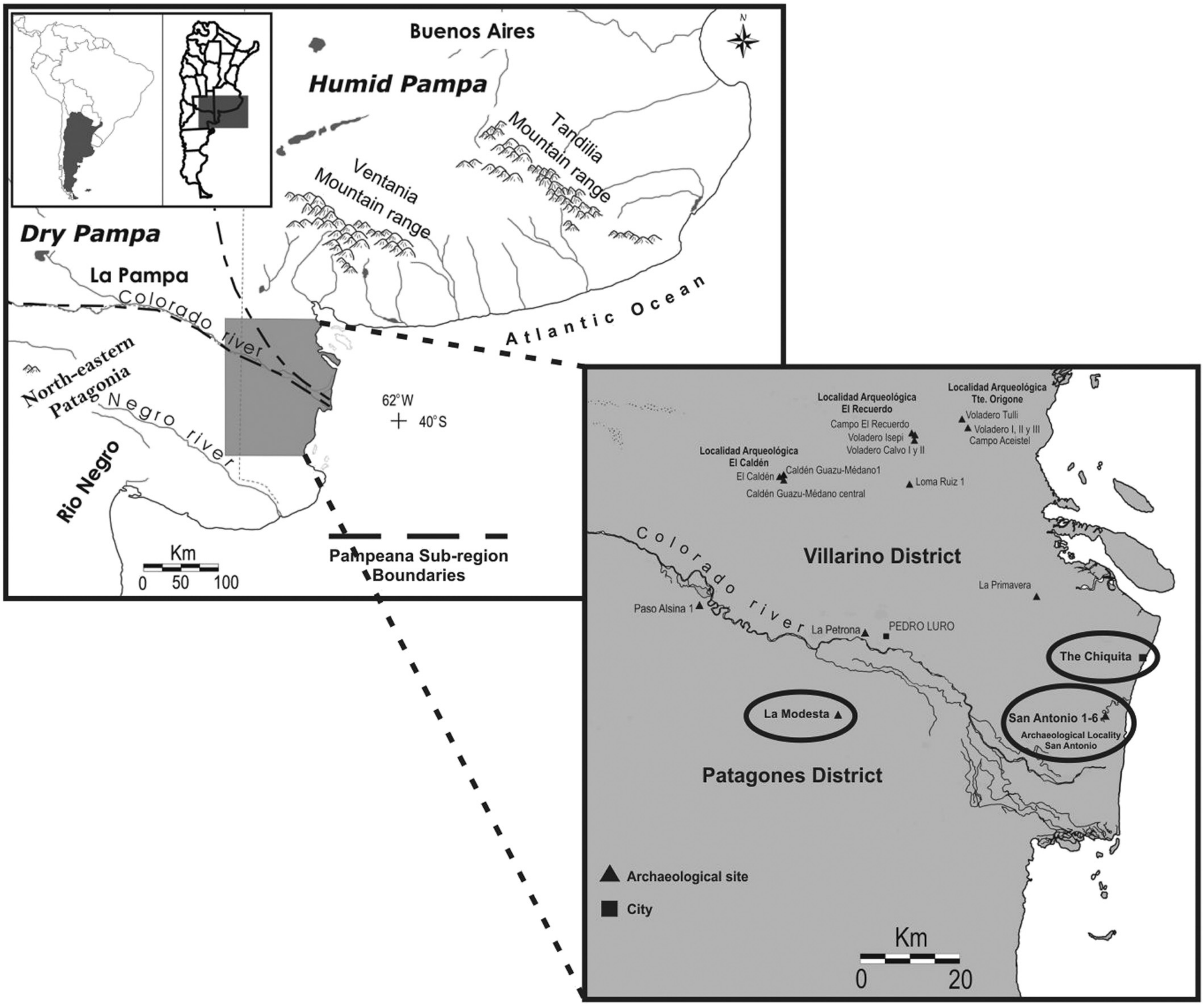

Fig. 1. The study area, localization of San Antonio Archaeological Locality, La Modesta site and the village (The Chiquita) where sea fish specimens were captured.

Table 1
Frequency of fish species in San Antonio 1 site ichthyoarchaeological assemblage.

Taxa	NISP	NISP%	MNI	MNI%
Sea catfish ("bagre de mar", *Genidens barbus*)	1412	80.09	133	84.18
White croaker ("corvina rubia", *Micropogonias furnieri*)	94	5.33	12	7.60
Black drum ("corvina negra", *Pogonias cromis*)	7	0.39	1	0.63
Sciaenidae indet.	34	1.92	1	0.63
Eagle ray ("chuchos", *Myliobatis* sp.)	19	1.07	1	0.63
Chondrichthyes ("condrictios")	20	1.13	2	1.27
Perch ("perca", *Percichthys* sp.)	177	10.03	8	5.06
Total	1763	100	158	100

perch (*Percichthys trucha*) was identified (NISP = 1877; MNI = 368). With regard to the representation of skeletal parts, bone specimens belonging to the axial and appendicular skeleton are present in similar frequencies, but cranial elements are nearly completely represented by otoliths (Table 2). Taphonomic analysis indicates that weathering (25.21%) and abrasion (25.14%) were the main processes that affected fish remains (Stoessel, 2015). Evidence of anthropic modification in the perch remains is also present: 248 bone specimens show thermal alterations (ca. 9%) and 21 have cutmarks (ca. 1%). These cutmarks were located on the precaudal vertebrae. The location of the cutmarks shows the same pattern observed in the San Antonio 1 site; they are transversely oriented when considering the longitudinal axis of the bone (Fig. 2). However, in this case, only a single cutmark per specimen was identified (Stoessel, 2015).

4. Materials and methods

The experimental work was conducted in several stages. First, sea fish were obtained from the coastal area (town of "The Chiquita") next to the San Antonio Archaeological Locality (Fig. 1). The fish were captured using modern day fishing techniques (e.g., fishing rod and bait) on a boat. Next, those specimens to be used in the experiment were classified by species. The sample included two species of Perciformes, white croaker and striped weakfish, and one of Siluriformes, sea catfish. A total of nine specimens of fish were processed for this experimental work: sea catfish (n = 3), white croaker (n = 3) and striped weakfish (n = 3). These species are commonly found in the zooarchaeological record of the lower stream of the Colorado River for the Late Holocene, and white croaker and sea catfish are the most abundant species of fish from the San Antonio Archaeological Locality (Table 1).

Table 2
Frequency of sea catfish (*Genidens barbus*) skeletal parts in San Antonio 1 site and frequency of perch (*Percichthys trucha*) skeletal parts in La Modesta site.

Anatomic unit, region and element				San Antonio 1: Catfish			La Modesta: Perch		
				MNE	MAU	MAU%	MNE	MAU	MAU%
Cranium	Neurocranium	Dorsal region	Mesethmoid	5	5	3.47	–	–	–
		Ventral region	Exoccipital	3	1.5	1.04	1	0.5	0.11
			Basioccipital	12	12	8.33	24	24	5.59
			Otolith	288	144	100	858	429	100
	Branchiocranium	Oromandibular region	Dentary	18	9	6.25	6	3	0.69
			Quadrate	17	8.5	5.90	8	4	0.93
			Premaxilla	1	0.5	0.34	5	2.5	0.58
			Articular	–	–	–	1	0.5	0.11
		Hyoid region	Ceratohyal	6	3	2.08	1	0.5	0.11
			Epihyal	6	3	2.08	–	–	–
			Urohyal	10	10	6.94	–	–	–
			Opercle	4	2	1.38	1	0.5	0.11
			Interopercle	2	1	0.69	–	–	–
			Hyomandibular	2	1	0.69	–	–	–
Post-cranium	Axial skeleton	Vertebral column	Precaudal vert.	174	14.5	10.06	847	56.46	13.16
			Caudal vert.	178	5.74	3.98	125	6.57	1.53
	Appendicular skeleton	Dorsal spine	Dorsal spine	8	8	5.55	–	–	–
		Pectoral spine and gardle	Pectoral spine	70	35	24.30	–	–	–
		Caudal fin	Hypural	1	1	0.69	–	–	–
Total				805		–	1877		

Although bones of weakfish are absent at this locality, they are present in another nearby site named La Primavera (Stoessel, 2012a). Also, in sites of the Middle Holocene such as La Modesta, remains of perciform taxa (perch) that have a similar morphology to the species used in this experimental work were recovered.

The processing of the specimens followed the guidelines of Willis et al. (2008), who conducted an experiment in which 37 sea fish of different sizes and morphologies (coho salmon, summer flounder and hardhead catfish) were processed using lithic artifacts and metal knives. These specimens were processed by the authors, but only one of them had experience in fish butchering. The decision to utilize Willis and collaborator's methods was based on the fact that their study included some of the same species as our study (e.g., catfish) but also because the morphology and bone structure of the other species in their study are similar to those recorded at the lower basin of the Colorado River.

Willis et al. (2008) used two different methods, based on the ethnographic and ethnohistorical literature from the Northwestern Pacific and Alaska. The first, applied to coho salmon and summer flounder, consisted of the following steps: a) An incision is made from the anus to the pectoral spine; next, the head and viscera are removed; b) The initial incision is extended to the caudal fin and the fish is laid open with the vertebral column exposed. Then cuts are made laterally on both sides of the vertebral column, and c) finally this section and caudal fin are cut. As a result of this butchering technique, most of the cutmarks are found in the neural and haemal spines of vertebrae and, in a lower frequency, ribs, pterygiophores, postcleithra, and indeterminate fragments (Table 3; Willis et al., 2008).

In the second method, applied to the hardhead catfish, the steps are slightly different: a) Initial incision is made along the length of the dorsal spine, from the gill to the caudal fin. Following the initial incision, long strokes are made to separate the fillets; b) The same incision is made along the anal fin, and the ventral portion of the fillet is removed. Finally, c) A cut is made in the posterior section of the gills to completely remove the fillet. The head and viscera are removed. The same process is used to remove the blind-side fillet. Unlike the other method, the vertebral column, ribs and fin remain articulated (Willis et al., 2008). The highest frequency of cutmarks is found in vertebrae, mainly in the haemal and neural spine, and in the transverse processes. Other cutmarks were found in the ventral part of the Weberian apparatus, as a result of the removal of the skull, the pectoral and dorsal spines, and the cleithrum (Table 4).

In this paper, minor adaptations of these methods were made to improve the processing conditions and to obtain primary processing units:

- Method A: descaling, evisceration, separation of head, filleting, separation of scapular girdle, vertebral column and caudal fin, separation of anal and dorsal fins and pelvic girdle (Fig. 3, Table 3).
- Method B: separation of dorsal and pectoral spines, filleting, evisceration, separation of head, pelvic girdle and anal fin (Fig. 3, Table 4).

As stated before, the employment of each method was selected on the basis of the morphology and bone structure of fish (see Willis et al., 2008). In this sense, Method A was used for the Perciformes processing (white croaker and the striped weakfish), and Method B was employed for Siluriformes processing (sea catfish). In both cases, fish of different size and weight were used (Table 5). Four people with no experience in butchering participated in the processing activities. Table 5 details which operator processed each specimen.

The obtained fish were processed using lithic artifacts made ad hoc. The lithic tools represent both the typological groups as well as the raw materials recovered from the archaeological record of the area for the Middle and Late Holocene (Armentano, 2012; Santos Valero, 2017). In these sense, lithic artifacts used for the processing included cores and primary decortication flakes with no further modification of edges by percussion or retouch. These were made from two different raw materials (two types of flint - variegated and brown - and basalt). Each specimen was processed with lithic artifacts made of the same raw material, in some cases a core and a flake were used, and in other cases only flakes (Table 5; Fig. 4). Table 5 provides information on some characteristics (e.g., edge angle and edge length) of the tools. This information is reported in order to provide background information about the basic variables that were part of the experiment.

Once the fish were processed, the bones were cleaned in two stages. First, they were baked and the meat attached to the bones was extracted. Secondly, bones were left for approximately 15 days in water with enzymatic soap and then were thoroughly cleaned. Small wooden sticks were used for these tasks so as not to produce marks on the specimens.

Finally, cutmarks produced on the bone specimens throughout the butchering sequence were recorded. Each bone specimen was analyzed in order to detect cutmarks. For identification, general characteristics (e.g., V-shaped, clusters of similar, subparallel grooves, attributes such

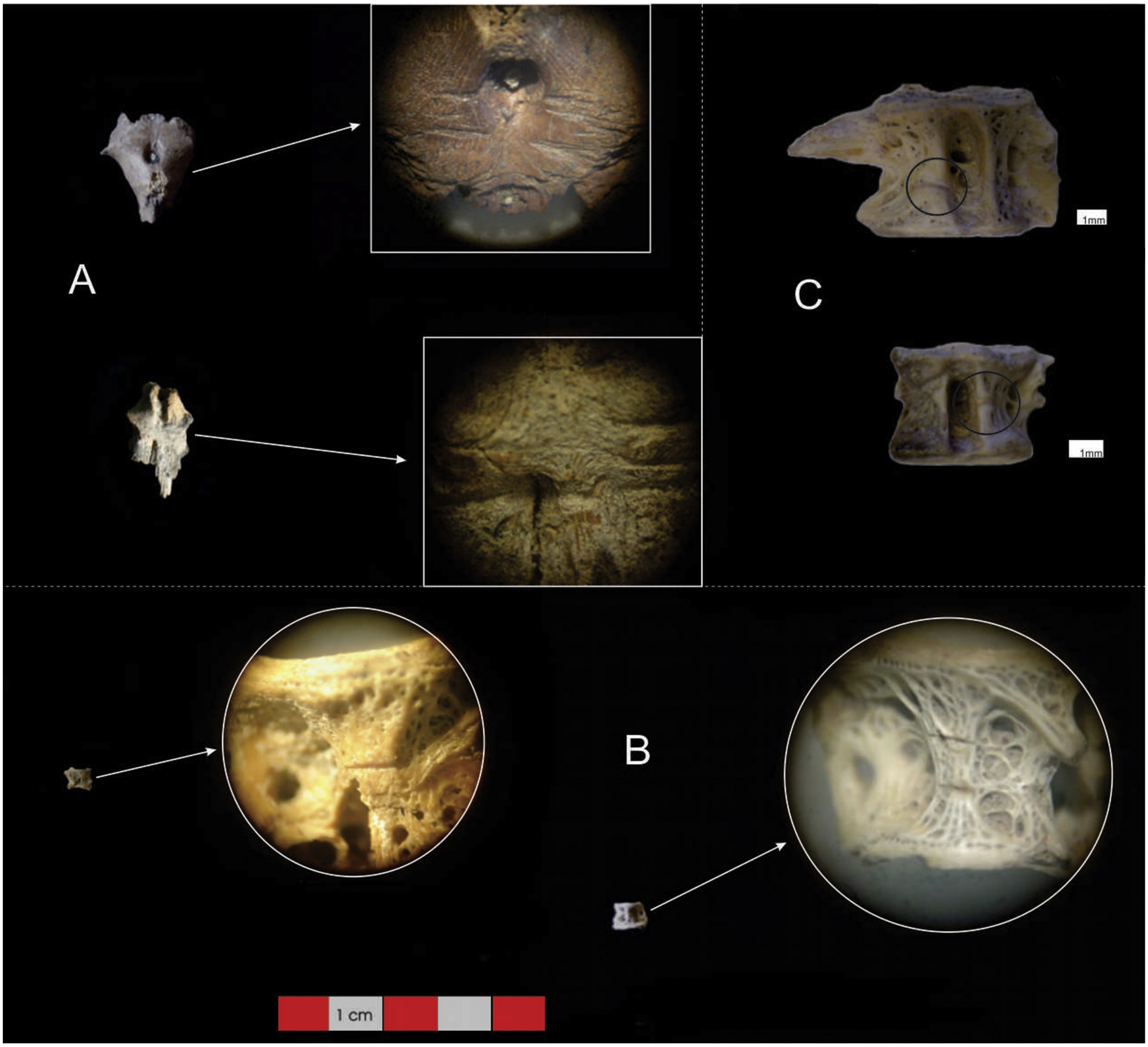

Fig. 2. Cutmarks on archaeological specimens from San Antonio 1 and La Modesta sites; A: Basioccipital; B: Caudal vertebrae. C: Precaudal vertebrae. A and B: scale = 1 cm; C: scale = 1 mm.

as flake scars, slices, and notches associated to the grooves, etc.) were considered (see Shipman, 1988; Shipman and Rose, 1983; Olsen and Shipman, 1988). Given the fact that the relevant information for the purpose of this paper primarily involves the presence and location of cutmarks on bone specimens, a binocular magnifier Motic ST-39 (Motic, Richmond, British Columbia, Canada) at ×20 and ×40 magnification was used, and formal aspects of cutmarks were not analyzed in greater depth (e.g., SEM microscope). A single operator performed this part of the experimental work.

5. Results

The results presented here are discriminated by butchered species, indicating the tools and raw materials that were used, and the distribution of the cutmarks on the bone specimens that were produced in each butchering stage.

5.1. *White croaker*

The raw material used for the processing of white croaker specimen 1 was basalt. Descaling was performed with a core and the rest of the activities with a single flake of the same raw material. Cutmarks were found on the spines of the precaudal and caudal vertebrae of this specimen; in the latter there were also some parallel traces found on the vertebral centra. These traces were produced during the filleting stage (Table 3 and Fig. 5).

A brown flint core was used for the descaling activities in the white croaker specimen 2 and a single flake of the same raw material used for the other activities. Cutmarks were identified on some elements of the gill arches that were caused by the separation of these skeletal parts from the rest of the carcass. Other cutmarks were found on the spines of precaudal and caudal vertebrae. There were also parallel cutmarks on the centra of the caudal vertebrae. These were also produced in the filleting stage (Table 3 and Fig. 5).

Table 3
Method A. Processing stages and bone specimens on which cutmarks were recorded. Willis et al. (2008) procedures and those developed in this paper are compared.

Procedure used by Willis et al. (2008)	Cutmarks	Procedure used in this work	Cutmarks
A	Post-cleithrum	A	Opercle
- Incision from the anus to the pectoral spine. - Removal of head and viscera.		- *Descaling* - *Evisceration*: Incision from the anus to the pectoral spine. Removal of viscera - *Separation of head*	Preopercle Elements of gill arches
			Cleithrum
B	Haemal and neural spines	B1	Haemal and neural spines and vertebrae centrum
- The initial incision is extended to the caudal fin.	Ribs	- *Filleting*: The initial incision is extended to the caudal fin.	Pterygiophores
- The fish is open. - Cuts are made laterally on both sides of the vertebral columns.	Pterygiophores	The fish is open. Cuts are made laterally on both sides of the vertebral column.	
		B2	Supracleithrum
		- *Separation of scapular girdle*	Posttemporal
C		C	
- Separation of vertebral column and caudal fin		- *Separation of vertebral column and caudal fin*	
		D	Pterygiophore
		- *Separation of dorsal and anal fins and pelvic girdle*	Basipterygium

Two variegated flint flakes were used to process the white croaker specimen 3. One of the flakes was used for descaling and the other one for the rest of the activities. Cutmarks were found on the opercle and the preopercle of this specimen and were produced when the skull was separated from the rest of the body; they were located on the supracleithrum and post-temporal, and they were produced when the scapular girdle was separated. Cutmarks were also found on the branchiostegal rays, caused by the separation of the hyoid arch elements from the rest of the skull. Pterygiophores and the basipterygium also had cutmarks as a consequence of separating the fins. Fractures were also observed in this case, produced while the pelvic girdle was being separated from the rest of the body. Cutmarks were also found on the spines of precaudal and caudal vertebrae. In the caudal vertebrae there were also cutmarks on the centra as a consequence of filleting activities (Table 3 and Fig. 5).

5.2. Striped weakfish

A basalt core was used for the descaling of striped weakfish specimen 1 and a flake from the same raw material was used for the other activities. Cutmarks were found on a pterygiophore and on the apophyses of precaudal vertebrae and they were produced during the filleting stage (Table 3 and Fig. 5).

A variegated flint flake was used for the descaling of striped weakfish specimen 2, and another flake, made of the same raw material, was used for the other activities. In this case, cutmarks that made when the skull was separated from the body were found on the cleithrum. Other marks were found on a pterygiophore as a consequence of the removal of a fin, and on the apophyses and spines of precaudal vertebrae as well as on a thickened part of the caudal vertebrae. These cutmarks were produced as a consequence of the filleting process

Table 4
Method B. Processing stages and bone specimens on which cutmarks were recorded. Willis et al. (2008) procedures and those developed in this paper are compared.

Procedure used by Willis et al. (2008)	Cutmarks	Procedure used in this work	Cutmarks
A		A	Haemal and neural spines and vertebrae centrum
- Incision along the length of the dorsal spine, from the gill to the caudal spine.	Haemal and neural spines, transverse processes	- *Separation of dorsal and pectoral spines* - *Filleting*: - Incision along the length of the dorsal spine, from the gill to the caudal fin.	Ribs
- Following the initial incision, long strokes are used to separate the fillets.		- Following the initial incision, long strokes are used to separate the fillets.	
B	Haemal and neural spines, transverse processes	B The same process is made in the ventral portion.	Haemal and neural spines and vertebrae centrum
- The same process is made in the ventral portion.			Ribs
C	Cleithrum	C Cut is made to the gills to completely remove the fillet.	Cleithrum
- Cut is made to the gills to completely remove the fillet.	Weberian apparatus		
- The head and viscera are removed.	Pectoral and dorsal spines	- *Evisceration*: viscera are removed	Weberian apparatus
		- *Separation of head* D	
		- *Separation of pelvic girdle and anal fin*	

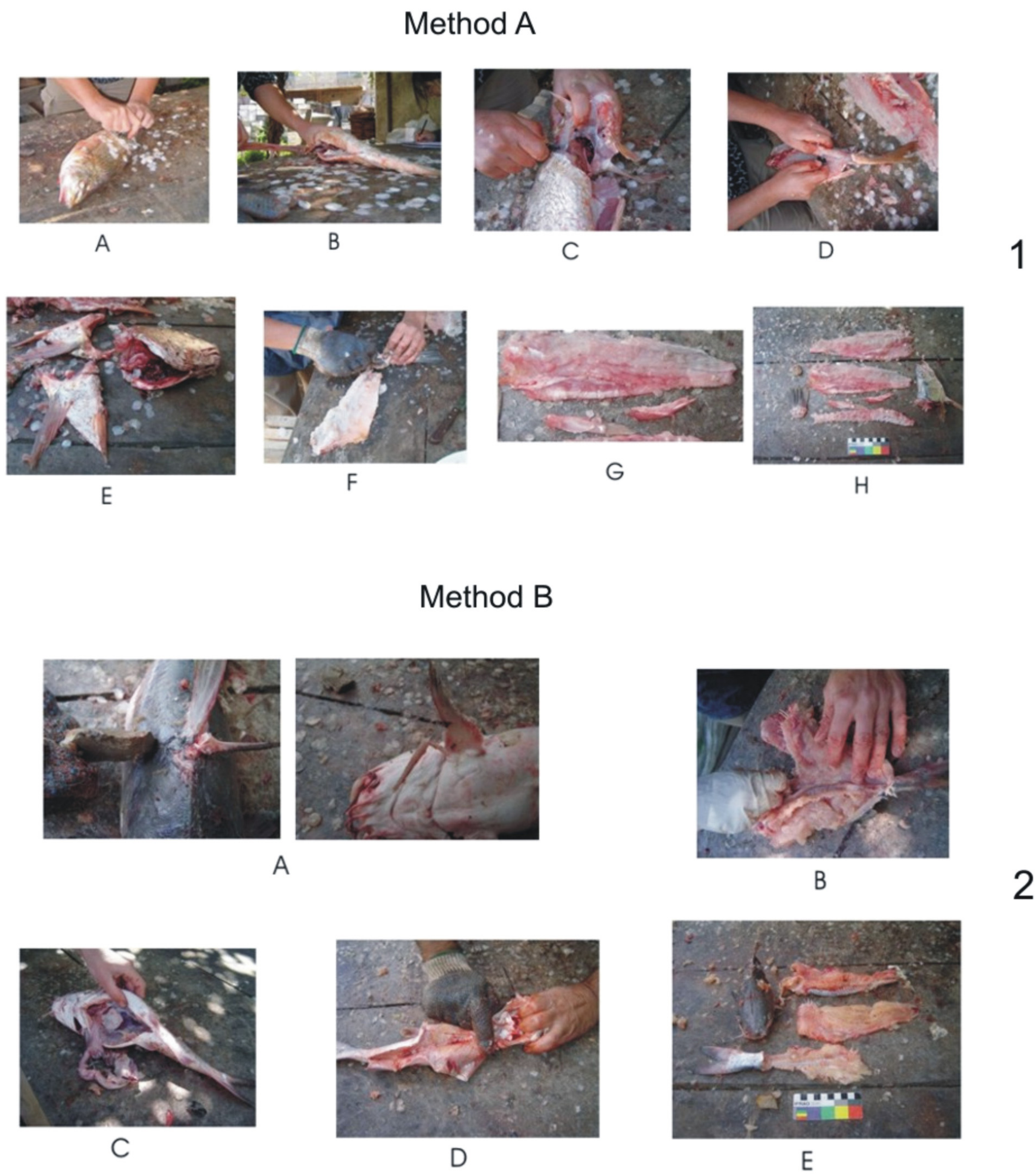

Fig. 3. Butchering sequence: 1: Method A. Processing stages of the butchering sequence on Perciforme species (perch-like fish): A: descaling; B: evisceration; C: separation of head; D: filleting; E: separation of scapular girdle; F: separation of vertebral column and caudal fin; G: separation of anal and dorsal fins and pelvic girdle; H: primary processing units obtained. 2: Method B. Processing stages of the butchering sequence on Siluriforme species (catfish): A: separation of dorsal and pectoral spines; B: filleting; C: evisceration; D: separation of head, pelvic girdle and anal fin; E: primary processing units obtained.

(Table 3 and Fig. 5).

Brown flint was used to process the striped weakfish specimen 3. A core was used for descaling and a flake for the other activities. Cutmarks were found on the cleithrum, and they were produced when the skull was separated from the body. Cutmarks and fractures were also found on a basipterygium, corresponding to the separation of the pelvic girdle, and on a branchiostegal ray from when the elements of the hyoid arch were separated. Finally, cutmarks were found on the spines and apophyses of precaudal vertebrae and on the spines and centra of the caudal vertebrae related to filleting activities (Table 3 and Fig. 5).

5.3. Sea catfish

In the processing of sea catfish specimen 1, a brown flint flake was used for all the activities. Cutmarks were observed on the ceratohyal when the skull was removed during the branchiostegal rays separation; the cutmarks that were found on the cleithrum were produced when the scapular girdle was extracted. Fractures observed on the dentary were likely caused by the cleaning activities and not by processing. Cutmarks and fractures were found on the precaudal vertebrae and on the spines and centra of caudal vertebrae as a consequence of the filleting process (Table 4 and Fig. 5).

Table 5
Characteristics of the fish specimens used for the study (length and weight) and the lithic tools used for the processing of each one of them. Cores indicated in brackets are those from which flakes listed in the same cell come from.

Specimen	Length (cm)	Weight (kg)	Tool	Lithic raw material	Edge angle	Length edge (mm)	Tool classes
White croaker 1 (operator 1)	60	2.15	Core # 3	Basalt	62°	30	Pebble core
			Flake # 2 (Core # 11)	Basalt	38°	32	Secondary flake
White croaker 2 (operator 1)	50	0.98	Core # 5	Brown flint	87°	42	Pebble core
			Flake # 13 (Core #5)	Brown flint	39°	26	Ridged flake
					84°	12	
White croaker 3 (operator 2)	68	3.04	Flake # 13 (Core # 10)	Variegated flint	79°	33	Primary flake
			Flake # 8 (Core # 10)	Variegated flint	38°	26	Primary flake
Striped weakfish 1 (operator 3)	43	0.5	Core # 11	Basalt	86°	38	Pebble core
			Flake # 8 (Core # 11)	Basalt	43°	26	Angular flake
						19	
Striped weakfish 2 (operator 4)	46	0.5	Flake # 12 (Core # 10)	Variegated flint	74°	29	Angular flake
			Flake # 16 (Core # 10)	Variegated flint	56°	30	Secondary flake
Striped weakfish 3 (operator 4)	46	0.8	Core # 5	Brown flint	87°	42	Pebble core
			Flake # 2 (Core # 5)	Brown flint	31°	21	Ridged flake
Sea catfish 1 (operator 2)	42	0.8	Flake # 8 (Core # 5)	Brown flint	52°	27	Angular flake
Sea catfish 2 (operator 4)	41	0.8	Flake # 4 (Core # 11)	Basalt	53°	20	Primary flake
Sea catfish 3 (operator 3)	47	1.2	Flake # 19 (Core # 10)	Variegated flint	44°	23	Angular flake
			Flake # 3 (Core #10)	Variegated flint	38°	19	Primary flake
					59°	14	

A basalt flake was used for all the processing activities of sea catfish specimen 2. Cutmarks were found on the cleithrum, produced when the skull was separated from the rest of the body, and fractures were observed on the dentary. In this case, as was mentioned in previous cases, these fractures may have been produced during the cleaning process. Cutmarks were observed on ribs and on the spines of caudal vertebrae that were caused by the filleting activities (Table 4 and Fig. 5).

Two variegated flint flakes were used to process sea catfish specimen 3. The first one was used to open the upper part and to separate the head from the body, and the lower part was opened with the second flake. This one was then used to process the rest of the fish. Cutmarks were found on the cleithrum, and are the byproduct of the scapular girdle separation. The cutmarks found on the Weberian apparatus were produced when the skull was separated from the precaudal vertebrae. In addition, cutmarks were also found on the ribs and the caudal vertebrae, which were produced during the filleting of the specimen (Table 4 and Fig. 5).

6. Discussion

As mentioned above, the butchering sequence adopted in this paper is slightly modified from the one proposed by Willis et al. (2008). A pattern was observed in the generation of cutmarks in the different stages of the butchering process. The results obtained regarding the location of cutmarks on bone specimens according to Willis et al. (2008) butchering stages and those of this paper are compared in Tables 3 and 4. These tables also present the results obtained from the application of the two methods that were used here according to the

Fig. 4. Lithic tools used for the processing stages: A: Brown flint flake and core used to process white croaker number 2; B: Variegated flint flakes used to process sea catfish number 3; and C: Basalt core and flake used to process stripped weakfish number 1 (see Table 5 for the characteristics of these artifacts).

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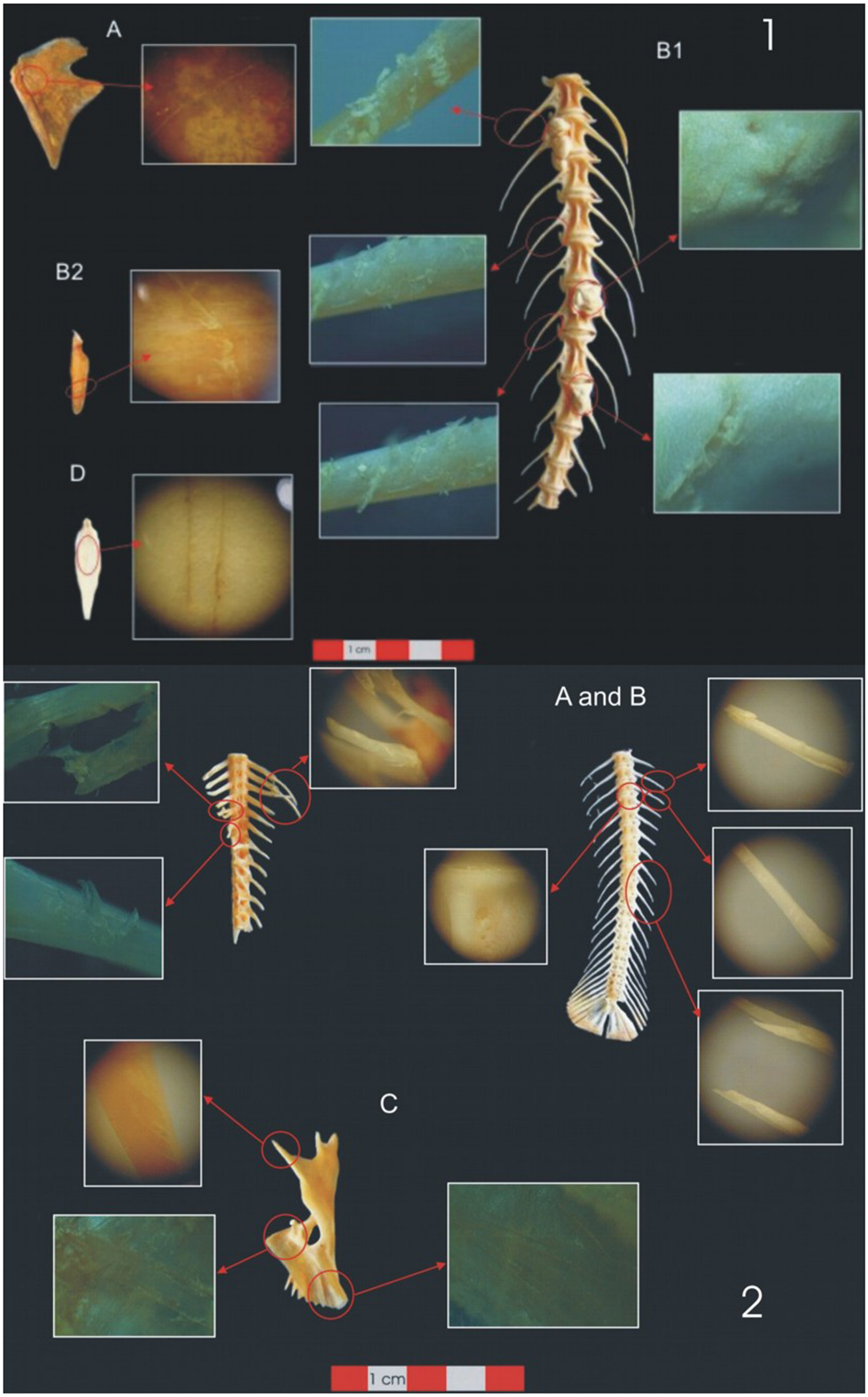

(caption on next page)

Fig. 5. Cutmarks obtained in butchering sequence: 1: Cutmarks obtained in each stage of the processing of the fish using Method A; A: Cutmarks in an opercle that were produced in the following stages: evisceration and/or separation of the head; B1: Cutmarks in the haemal and neural spines and vertebrae centra produced in the filleting stage; B2: Cutmarks in the supracleitrum produced in the separation of the scapular girdle stage; D: Cutmarks on a pterygiophore produced during the separation of dorsal and anal fins and pelvic girdle stage; 2: Cutmarks that were recorded in each processing stage while using Method B; A and B: Cutmarks on haemal and neural spines and vertebrae centra produced in the separation of dorsal and pectoral spines and filleting stages; C: Cutmarks on the cleithrum produced during the separation of the head stage.

morphology of the processed fish (Perciformes and Siluriformes).

Based on the butchering sequence applied in this paper, it was observed that the most frequent cutmarks found on Perciformes, using Method A, were located on the spines and centra of precaudal and caudal vertebrae, as a consequence of the filleting stage. At the same time, the separation of the skull from the rest of the body also generated cutmarks on some bones such as the cleithrum, opercle and preopercle. Frequent cutmarks were also observed on the pterygiophore and basipterygium as a consequence of the removal of the fins (Table 3 and Fig. 5). If these results are compared with those obtained by Willis et al. (2008), there are obvious similarities in the location of the cutmarks, principally in the vertebrae (Table 3).

The stages involved in the processing of Siluriformes using Method B, and the bones on which the cutmarks were found, are compared in Table 4. Taking into account the butchering sequence that was used, cutmarks were more frequently found on the spines and centra of precaudal and caudal vertebrae, as well as on the ribs, as a consequence of filleting. Cutmarks found on the cleithrum were produced during removal of the skull (Table 4 and Fig. 5). These cutmarks also present the highest frequency in the Willis et al. (2008) experiment. These authors also found several cases where the Weberian apparatus presented cutmarks. By contrast, only one specimen with cutmarks on the Weberian apparatus was detected in the experiment presented here. In general terms, the results obtained here indicate that independent of specimen size, raw materials employed, and people involved in the butchering process, cutmarks were consistently found on the precaudal and caudal vertebrae in all cases, both in Perciformes and in Siluriformes. In the latter, cutmarks were also found on the cleithrum of all the processed specimens. Therefore, the variables that were previously mentioned would not have influenced the generation of cutmarks and their presence could be related to the morphology of the species and to the processing method.

Results show that the proportion of cutmarks linked to the different processing stages is variable. In the case of Perciformes, the highest frequency of cutmarks was produced in the filleting stage ($N = 227$[2]) and a lower proportion in the separation of the girdles stage ($N = 37$), evisceration ($N = 25$) and removal of the skull ($N = 11$). Descaling and the separation of the caudal fin from the backbone did not produce cutmarks (Fig. 6). In regards to the Siluriformes, the largest percentage of cutmarks corresponds to the filleting stage ($N = 148$), followed by the removal of the skull ($N = 17$). In this case, unlike Perciformes, no cutmarks were recorded in the evisceration stage, during the separation of the dorsal and pectoral spine, or during the separation of the pelvic girdle and the anal fin (Fig. 6).

Finally, independent of the type of prey and butchering method, it is observed that cutmarks were mostly produced in the filleting stage. The largest number of cutmarks were produced during this latter stage ($N = 375$), and involved the haemal and neural spines, and vertebrae centra.

Differences appeared when the results obtained from the experimental work were compared to the ichthyoarchaeological record recovered from the study area. The analysis of cutmarks found on the archaeological specimens showed that some of them are found on the basioccipital of siluriformes such as sea catfish (Fig. 2). However, the experimental removal of the skull using Method B did not produce cutmarks on the basioccipital but on the Weberian apparatus. Therefore, perhaps the removal of this anatomical unit was performed either following another procedure, or the cutmarks were produced in a different stage of processing, possibly during evisceration. During the experiment, while performing the evisceration stage, some anatomical units were modified, that were also more likely to be affected during other processing stages, such as skull extraction. Also, skull cutmarks could be the result of activities related with brain procurement. The latter activity has been observed by Stewart (1994) in the Lake Turkana (Kenya) camps, where fisherman removed the brain causing fractures and cutmarks in some elements of Siluriformes anatomical units (Stewart and Gifford-Gonzalez, 1994). Nevertheless, in this case, the cutmarks are located in other bones (e.g., postcleithra, parasphenoid), not the basioccipital.

Regarding the other cutmarks recorded in the ichthyoarchaeological record, those observed on the caudal vertebrae are oriented transversely compared to the vertebrae centra (Fig. 2). However, in the experimental results, cutmarks were parallel to the longitudinal axis and produced during the filleting stage. The archaeological pattern may be related to the segmentation of the spine in a transverse way or to the separation of the caudal fin.

The possibility of recognizing cutmarks from the archaeological specimens may be mediated by other factors. Among them, as Willis et al. (2008) mention as part of their experiment, most of the cutmarks were found on the haemal and neural spines, as well as on the transverse process of the vertebrae (see also Willis and Boehm, 2015), that on account of their fragility are not generally preserved in archaeological assemblages. If these elements remain preserved in the archaeological record, they are likely to be fragmented, separated from the vertebrae centra and, as with pterygiophores and ribs, they are elements that present a low degree of taxonomic identification. This situation is reflected in the results obtained from both the experiment presented here and the representation of skeletal units (e.g. vertebrae) recovered from the archaeological record of the study area.

Willis et al. (2008) also point out that the cutmarks tend to be small and not very deep, a situation that also coincides with the results obtained during the experimental work performed here and with the observed in the archaeological specimens. Certainly, all these processes influence the preservation and later detection of cutmarks on the bone surfaces. The low frequency of cutmarks that was recorded on archaeological specimens could also be the result of different post-depositional processes. As previously described in this paper, taphonomic effects such as root-etching, abrasion and weathering affected the archaeological remains, and this may cause anthropic evidence as cutmarks to become less visible or imperceptible. In addition, experimental work carried out by Willis and Boehm (2014) shows that the process of burial contributes to the lack of visibility of cutmarks present in fish specimens. This study showed that the number of visible cutmarks on fish bones decreases after a short burial period (2.25 years), particularly in species that have more fragile bones or in cases where the marks are more superficial.

Other aspects that may influence the identification and location of cutmarks on fish specimens are, on the one hand, the relative experience of the researchers to identify modifications on aquatic bone surfaces and, on the other hand, the degree of magnification employed to study these remains (Archer and Braun, 2013).

Bone modifications related to culinary practices should also be considered in how they might affect cutmark survival, especially the

[2] In all cases these quantities represent the total number of cutmarks, regardless the number of bone specimen in which they were recorded.

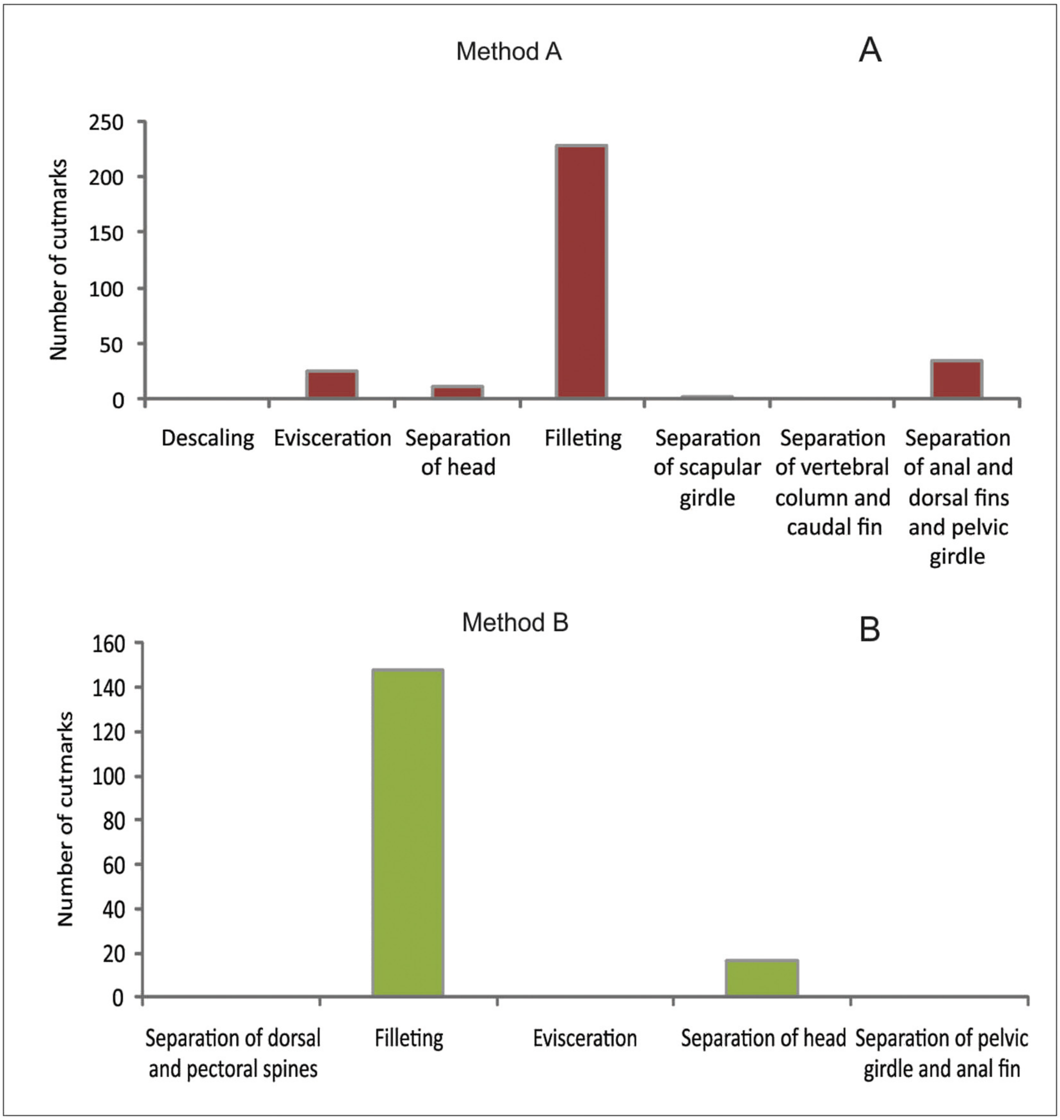

Fig. 6. Number of cutmarks produced in butchering sequence: A: Number of cutmarks produced in each processing stages corresponding to Method A; B: Number of cutmarks produced in each processing stages corresponding to Method B.

effects of thermal alteration on bone surfaces. For example, techniques such as roasting or boiling may influence the preservation and detection of cutmarks (Stewart and Gifford-Gonzalez, 1994; Nicholson, 1996; Steffen and Mackie, 2005; Nurminen, 2015).

Another factor that should be taken into account in the frequency of cutmarks on bone units is related to the ability of the butcher. Recent experiments demonstrate that there is an important difference in the frequency of produced marks when the process of butchering is performed by novice or experienced butchers (Willis and Boehm, 2015). This work proved that a novice butcher can produce a greater number of cutmarks (ca. 50%) than an experienced one. Taking this into account, in our case, the lack of experience in fish processing could have influenced the high frequency of identified cutmarks (Fig. 7). When comparing operators, differences in the frequency of cutmarks generated in each processing stage are observed. However, despite these differences, a pattern in the stages under which cutmarks were generated is recorded (Fig. 7).

7. Conclusions

Experimental studies of fish processing are scarce (Wheeler et al., 1989; Colley, 1990; Willis et al., 2008; Willis and Boehm, 2014, 2015). This paper represents a step towards redressing this situation. The results obtained show that by applying two different processing methods, cutmarks from butchering are generated on the bone specimens. According to the employed method and the corresponding fish species being processed (e.g., Method A: white croaker and striped weakfish; Method B: sea catfish), a different pattern regarding the presence of cutmarks according to the different butchering stages is noted. The application of Method A produced a greater number of marks and almost all butchering stages are represented. In contrast, Method B produced cutmarks in only two stages of the butchering sequence. Filleting cutmarks are the most represented marks in both methods. In general terms, this pattern coincides with those registered by Willis et al. (2008). However, there are differences between these experimental studies and those results observed archaeologically in the study area. Based on the data presented here, the archaeological evidence does not coincide with the material expectations derived from the experimental work discussed here. These results may have been caused by differences in the procedure involved in the butchering stages of the carcasses. It is also possible that the methods that were employed in the past simply generated small numbers of cutmarks. In this sense, there may have existed different butchering methods and/or particular cooking procedures employed for consumption of fish that required a low investment

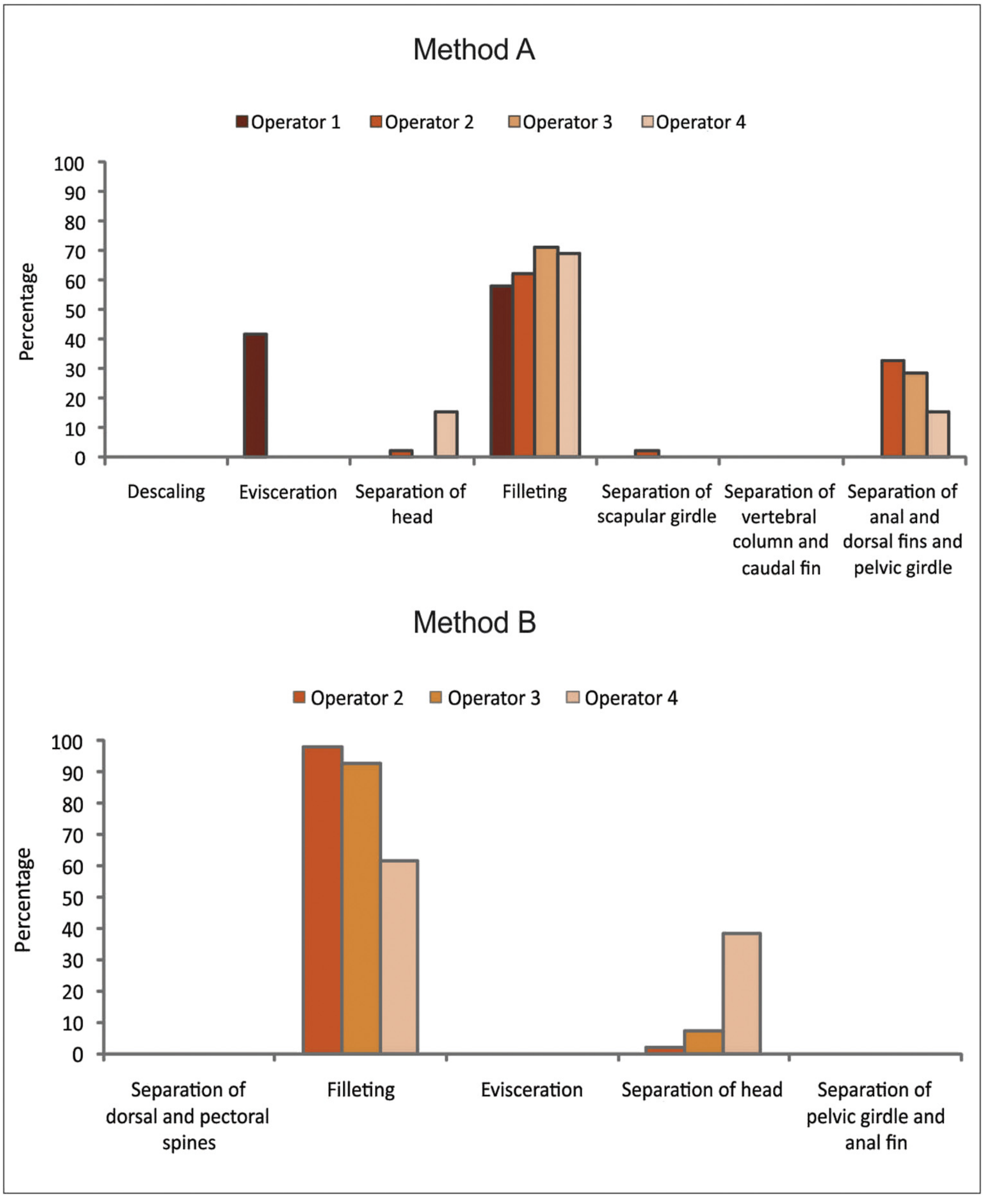

Fig. 7. Cutmark frequency generated by operators in each processing stage from both methods.

in carcass processing, and consequently left fewer cutmarks. Also, the scarce visibility of marks may be the result of taphonomic processes.

The results obtained have provided a pattern of cutmark distribution on fish bone surfaces according to different processing stages that should be evaluated based on the analysis of new ichthyoarchaeological contexts and new experimental work involving alternative butchering methods to those employed in this paper. Also, the patterns obtained from the experimental work presented here are useful to evaluate processing techniques in other archaeological contexts of neighboring areas or regions (e.g., Pampa and North-Patagonia) where similar fish species with evidence of processing and consumption were recorded.

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