Chapter 11
Modern Bone Distribution in the Pampas of Argentina: Taphonomic Implications for the Regional Archaeological Record

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Abstract In this paper, we present the results of naturalistic taphonomic observations made in different environmental contexts of the Pampas region. The objective of this study is to evaluate the formation processes of bone assemblages in differently sized vertebrates. In the hills, medium-sized vertebrates dominate the assemblages and the main accumulating agents are carnivores. In the shallow lakes and fluvial valleys, bones of large-sized vertebrates are predominant and accumulate mainly by natural death and discard of the carcasses by local farmers. The coast shows a more uniform representation of small, medium, and large-sized vertebrates, which is related to high biodiversity and good visibility of the bones deposited in this environment. Finally, the information from the plains indicates a similar representation of medium and large-sized vertebrates, both deposited by natural deaths. Results from the taphonomic analysis suggest higher destruction rates of bones of small-sized animals, and the likelihood of preservation and burial of animal bones varies in each of the environments. The mixing of bone remains with the archaeological deposits is dependent on these variables.

Keywords Naturalistic taphonomy · Vertebrate bone assemblages · Regional archaeology · Fossil record · Pampas region

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11.1 Introduction

Taphonomic research at a regional scale in modern ecosystems has had an important development since the mid-1970s, mainly in African environments which were considered analogous to Plio-Pleistocene landscapes (Hill 1976; Behrensmeyer 1978, 1993; Tappen 1995; Behrensmeyer and Dechant Boaz 1980; Gifford 1984; Blumenschine 1988; Domínguez-Rodrigo 2001; Faith and Behrensmeyer 2006). One of the main objectives of these studies was to determine the natural processes that control the deposit, modification, and preservation of bones from recent vertebrates to improve the understanding of the ecological information contained in the fossil record of early hominid sites and its potential biases. These studies inspired some South American archaeologists, especially those working with hunter-gatherer sites from Patagonia. Here, a regional approach to taphonomy was encouraged by Borrero and colleagues (Borrero 1988, 1989, 1990, 2001; Borrero and Martin 1996; Borrero et al. 1991; Belardi and Carballo Marina 2003; Borella 2004; Cruz 2015). Instead of looking for past environmental analogous, these researchers proposed to carry out a taphonomic analysis in the same region where archaeological research was being undertaken. The basic goal of this approach is to understand the dynamics of the environment at a large spatial scale, particularly the processes responsible for bone deposit and preservation in different landscapes. Additionally, the researcher seeks to understand the impact of the natural "bone rain" (sensu Haynes 2018: 113) on the regional archaeological record (Borrero 1989, 2001, 2014).

In the Pampas region, our research team has recently begun to develop naturalistic taphonomy at a broad spatial scale (Massigoge et al. 2015; Gutiérrez et al. 2016, 2018). The late development of this perspective in the region is due in large part to the impact of agriculture and livestock on the natural environments. The significant differences between the modern and prehistoric environments have prevented researchers from taking a more comprehensive look at the analogous in the modern ecosystem. However, we have shown that valuable information can be obtained through the development of actualistic taphonomy in modern environments such as the Pampas. The main objective of our naturalistic research is to understand the formation of bone assemblages of different classes of vertebrates. This taphonomic knowledge will be useful to both understanding the biases and limitations of the faunal record when used for inferring past environments and live communities, as well as evaluating the potential of the faunal record to provide information on specific processes and ecological conditions. The objectives are to (a) determine the causal processes and agents of accumulation and modification of bone assemblages; (b) establish if differences exist in the rates of natural bone deposit ("bone rain"), in different environments; (c) evaluate the processes that lead to the preservation and burial of the bones; and (d) identify the potential for contamination of archaeological sites by naturally deposited bones in each environment.

11.2 Regional Setting

The Pampas region is a vast plain covered by grasslands (398,966 km^2), located in the central east of Argentina (Fig. 11.1). The southeast of the Pampas has a temperate-humid climate and contains a diversity of geomorphological landforms and environments, including two hill systems (Tandilia and Ventania). The general relief is flat, with a moderate slope towards the Atlantic coast. A complex drainage network, with headwaters in the plains and the hills, carves into Quaternary sediments, intensifying towards the ends of the mouth of the river's which flow into the ocean (Matteucci 2012). Also, there are numerous permanent and temporary shallow lakes. Major changes to the coastline occurred during the end of the Pleistocene (between 12,000 and 10,000 ^{14}C yrs BP) when the sea level was approximately 60 m below its current location (Ponce et al. 2011). During the Holocene, large sand dunes formed along the coast, and loess and loess-like sediments covered older eolian deposits in the plains (Fidalgo et al. 1991; Zárate and Rabassa 2005).

The vegetation of the Pampas grasslands was formerly dominated by tussock grasses and scattered shrubs (Soriano et al. 1992; Miñarro et al. 2008). Today, the most common genera of grasses are *Stipa*, *Piptochaetium*, *Paspalum*, and *Bothriochloa*

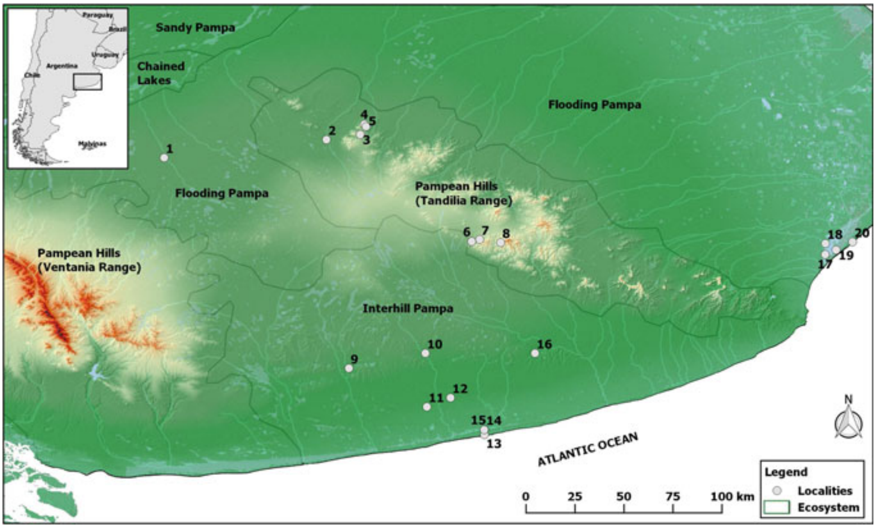

Fig. 11.1 Map of study area showing the location of transect localities. (1) General La Madrid, (2) Arroyo Tapalque, (3) Las Vertientes, (4) Cerro Largo, (5) Cerro San Cayetano, (6) Estancia La Tinta, (7) Cerro La Tinta, (8) La Juanita, (9) Arroyo Seco, (10) Arroyo Cristiano Chico, (11) Laguna Las Toscas, (12) Arroyo Cortaderas, (13) Balneario San Cayetano, (14) Laguna Salada San Cayetano, (15) San Cayetano vegetated dunes, (16) Laguna La Salada, (17) Recreo San Gabriel, (18) Estancia Nahuel Ruca, (19) Laguna Arsa, (20) Playa Puesto 1. Limits of the environmental ecosystems adapted from Matteucci (2012)

(Paruelo et al. 2007). Most natural vegetation has been replaced by modern-day agricultural crops (Bilenca and Miñarro 2004; Matteucci 2012).

From the end of the Pleistocene, the Pampas underwent a mass extinction of large mammals and a minor extinction and retraction of smaller sized taxa during the Holocene (Politis and Pedrotta 2006; Barnosky and Lindsey 2010; Prevosti et al. 2015). The introduction of livestock in the 16th century, and agriculture by the end of the 19th century, have intensely modified the original landscape and affected the vertebrate communities (Bilenca et al. 2017). Along with an array of livestock, Europeans also introduced wild species such as the European hare (*Lepus europaeus*) and Wild boar (*Sus scrofa*) (Soriano et al. 1992).

At present, wild large-sized vertebrates are scarce. The populations of the native ungulates that once constituted the main prey for Holocene hunter-gatherers (Guanaco—*Lama guanicoe*—and Pampas deer—*Ozotoceros bezoarticus*), are now reduced to small groups confined in reserves (Soriano et al. 1992; Martínez and Gutiérrez 2004). The small-sized vertebrate community however is abundant, including fish, amphibians, reptiles, birds, and mammals (Soriano et al. 1992; Matteucci 2012).

Carnivores represent an important agent in the accumulation and modification of the bone assemblages. Among the carnivorous mammals in the Pampas, there are canids, felids, mustelids, and mephitids. The canids include the Pampas fox (*Lycalopex gymnocercus*), Gray fox (*Lycalopex griseus*) and Dog (*Canis familiaris*) (Nowak 1991). The felids comprise the Mountain lion (*Puma concolor*), Eyra cat (*Puma yaguarondi*), Jaguar (*Panthera onca*), Geoffroy's cat (*Leopardus geoffroyi*) and Pampas cat (*Leopardus colocolo*) (Nowak 1991; Lucherini et al. 2004). The mustelids include the Neotropical otter (*Lontra longicaudis*), Lesser grison (*Galictis cuja*) and Patagonian weasel (*Lyncodon patagonicus*) (Nowak 1991). The Mephitidae Family encompasses the Molina's Hog-nosed skunk (*Conepatus chinga*). Except for the Domestic dog, these carnivores are identified in the fossil record since the Late Pleistocene.

11.3 Materials and Methods

Based on the diversity of environments in a relatively restricted area, we distributed taphonomic transects along five large environments: hills, shallow lakes, river valleys, plains, and coast (Fig. 11.2). The starting and ending position of each taphonomic transect was georeferenced in the field. Transects were walked by two individuals. All transects were 10 m wide. The length was variable depending on the landscape, and uninterrupted transects were finalized at 500 m. Each transect was partitioned in 50 m samples and the following variables were recorded: sediment type; slope; potential for burial of faunal material; type and distribution of vegetation; bioturbation; presence of living animals or modern human activity; archaeological materials; and visibility based on land cover (excellent visibility: without vegetation cover; very good visibility: 1–25%; good visibility: 26–50%; regular visibility: 51–75%; and poor visibility: 76–100%). Faunal remains were classified as follows: disarticulated bone (a specimen unrelated to another specimen by soft tissue); occurrence of articulated bones (two or more specimens joined by soft tissue, comprising less than 75% of the animal skeleton); and carcasses (specimens joined by soft tissue, comprising more than 75% of the animal skeleton). We also recorded if the bones were scattered or concentrated. A "concentration" is defined here as any assemblage of at least five remains (including disarticulated, occurrence of articulated bones, and carcasses) from the same or different individuals distributed in a small area (approximately 100 m^2) (Cruz 2007).

Except for domestic ungulate bones, which were analyzed in the field, all faunal remains were collected and analyzed in the laboratory. Each finding was recorded on a data sheet with specimen or carcass ID numbers and the following variables: taxon; presence of soft tissue; element; fusion state; completeness; articulation between elements; burial state (following Behrensmeyer and Dechant Boaz 1980); inclination; and taphonomic modifications, which included weathering stage; sedimentary abrasion; carnivore and rodent marks; root etching; manganese stains; and trampling (Behrensmeyer 1978; Haynes 1980; Binford 1981; Shipman 1981; Grayson 1984; Lyman 1984; Olsen and Shipman 1988; Behrensmeyer et al. 2003; Gutiérrez and Kaufmann 2007).

The bone assemblage was divided in three body size categories: small-sized vertebrates (<1 kg); medium-sized vertebrates (1–20 kg); and large-sized vertebrates (>20 kg). In the case of taphonomic analyses, we only studied those specimens that could be assigned to a taxonomic category. Finally, Ntaxa was obtained by counting the identified number of non-overlapping taxa (Grayson 1991).

11.4 Results

A total of 221 transects were conducted, covering an area of 1,046,130 m^2. The highest visibility was recorded along the coast, varying from poor to regular in the rest of the environments. Vertebrate remains were identified as disarticulated bones (n = 3055), occurrences of articulated bones (n = 76), and carcasses (n = 22). Burial was only identified in disarticulated bones (3.2%). The proportions of buried remains for the different environments are distributed as follows: river valleys (13.2%), shallow lakes (4.3%), plains (2.1%), hills (1.4%) and coast (1.4%). Shallow lakes contained the maximum density (0.0051/m^2) of remains and the plains the lowest density (0.0017/m^2) (Table 11.1). Different taxonomic classes were identified, among which the mammals (69.4%) dominate in all environments. Other categories identified in lower frequencies include birds (17.6%), fish (2%), reptiles (1.8%), and amphibians (0.1%). A total of 9.1% of the specimens could not be determined at any taxonomic level (Table 11.1). The total sample analyzed for taphonomic modifications include 2702 bone remains, distributed as follow: 352 small-sized vertebrates, 1224

(a) (b) (c) (d) (e) (f)

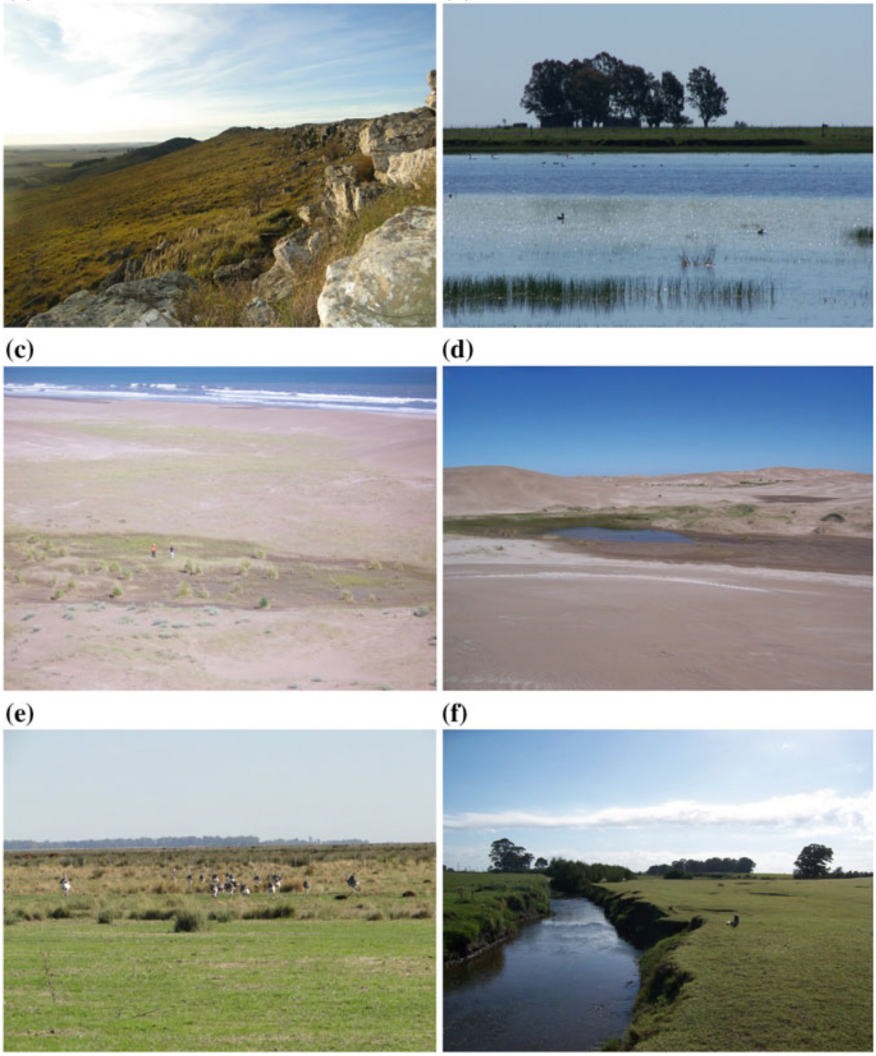

Fig. 11.2 Examples of surveyed environments: **a** hills, **b** shallow lakes, **c** coast: backshore, **d** coast: active dunes, **e** plains, **f** river valleys

Table 11.1 Characteristics of the studied sample and taxonomic distribution of the bone assemblages by environment

Environments	Hills		Shallow lakes		Coast		Plains		River valleys		Total	
N transects	40		25		118		9		29		221	
Sampled area (m^2)	179,310		126,670		576,900		27,950		135,300		1,046,130	
Total number of remains	692		646		1465		48		302		3153	
Disarticulated bones	678		626		1414		46		291		3055	
Articulated bones	12		9		48		1		6		76	
Carcasses	2		11		3		1		5		22	
Density of remains	0.0039		0.0051		0.0025		0.0017		0.0022		0.0003	
Taxonomic category	N	%	N	%	N	%	N	%	N	%	N	%
Fish	0	0	15	2.3	48	3.3	0	0	1	0.3	64	2
Amphibians	0	0	1	0.2	1	0.1	1	2.1	1	0.3	4	0.1
Reptiles	53	7.7	0	0	3	0.2	0	0	0	0	56	1.8
Birds	28	4.0	51	7.9	472	32.2	0	0	4	1.3	555	17.6
Undetermined	1	0.1	40	6.2	47	3.2	0	0	1	0.3	89	2.8
Large (>20 kg)	0	0	0	0	13	0.9	0	0	1	0.3	14	0.4
Medium (1–20 kg)	17	2.5	2	0.3	261	17.8	0	0	0	0	280	8.9
Small (<1 kg)	10	1.4	9	1.4	151	10.3	0	0	2	0.7	172	5.5
Mammals	601	86.8	524	81.1	755	51.5	45	93.8	262	86.8	2187	69.4
Undetermined	0	1.3	4	0.6	12	0.8	0	0	0	0	25	0.8
Large (>20 kg)	183	26.3	429	66.4	295	20.1	20	41.7	182	60.3	1108	35.1
Medium (1–20 kg)	406	55.2	87	13.5	295	20.1	25	52.1	78	25.8	867	27.5
Small (<1 kg)	12	4.0	4	0.6	153	10.4	0	0	2	0.7	187	5.9
Undetermined	10	1.4	55	8.5	186	12.7	2	4.2	34	11.3	287	9.1
Total	**692**		**646**		**1465**		**48**		**302**		**3153**	**100**

medium-sized vertebrates, and 1126 large-sized vertebrates. The results of this study will be presented considering each environment: hills, shallow lakes, coast, plains, and river valleys. A brief geomorphological and ecological characterization based on published information of each environment is also included.

11.4.1 Hills

11.4.1.1 Environmental Characteristics

The hills landscape in which this research was developed belongs to the Tandilia Range. This environment presents a series of discontinuous elevations intersected by valleys, streams, semi-permanent watercourses and undulating plains. In general, the Tandilia Range contains low peaks (<520 masl), with extensive slopes which are more pronounced towards the top of the hills. The stratigraphy includes a lower portion crystalline base igneous and metamorphic rock, and an upper portion of sedimentary rocks (Dalla Salda 1999). The hills are surrounded and partially covered by late Cenozoic eolian sediments (Zárate and Rabassa 2005). Above these sediments, pedogenetic processes formed the current soils from the end of the Pleistocene and throughout the Holocene. These soils are fully developed in the surrounding plains and can be found with different degrees of development. Likewise, water erosion of rocks has generated various types of platforms, shallow openings (rock shelters), caves, and hollows (Flegenheimer and Zárate 1989; Martínez et al. 1999). Currently, the hills environment is dominated by fluvial and pluvial erosive processes that are more pronounced when vegetation is scarce or in the sectors where mining takes place. Runoff during periods of intense rains generates an important material drag and loss of soil (Campo de Ferreras and Piccolo 1999). Ecological records of the faunal communities in the central sectors of the Tandilia Range shows the presence of 224 vertebrate species: 187 birds, 21 mammals, 12 reptiles, 3 amphibians, and 1 fish (http://www.ecoregistros.org).

11.4.1.2 Taxonomic Diversity

Forty transects were conducted in the hills, covering a total of 179,310 m^2. The density of remains is 0.0039/m^2, and the visibility is regular. Vertebrate remains were classified as disarticulated bones (n = 678), occurrences of articulated bones (n = 12), and carcasses (n = 2) (Table 11.1). Taxonomic classes are distributed by mammals (86.8%), reptiles (7.7%), birds (4%), and undetermined taxa (1.4%) (Table 11.1). Medium-sized mammals are the most abundant group (Table 11.1; Fig. 11.3). European hare (*Lepus europaeus*) is the species with the highest frequency of bone remains recovered in this size category (79.1%) (Online Resource 1). The second most abundant taxonomic class is reptiles, exclusively assigned to Black and White tegu (*Tupinambis merianae*). Among the birds, medium-sized are predominant (60.7%), with the Chicken (*Gallus gallus*) being the most frequent (Table 11.1). Hills present an Ntaxa of 20, subdivided into the following classes: mammals (Ntaxa = 14), birds (Ntaxa = 5), and reptiles (Ntaxa = 1).

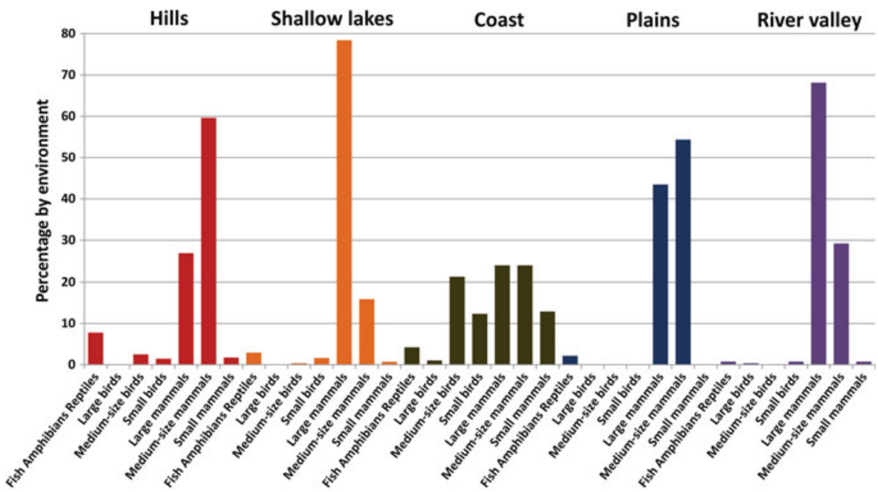

Fig. 11.3 Frequency of vertebrate classes in each environment

11.4.1.3 Taphonomic Modifications

A total of 681 bone remains were analyzed for taphonomic modifications, distributed as follows: 22 small-sized vertebrates, 476 medium-sized vertebrates, and 183 large-sized vertebrates. The bone assemblage recovered in the hills is characterized by a high frequency of carnivore marks (38%) (Table 11.2; Figs. 11.4 and 11.5d). Medium-sized vertebrates show the highest frequency (40.1%), followed by large-sized vertebrates (34.4%) (Table 11.2). Weathering (Fig. 11.5a) and fragmentation are taphonomic modifications that are well represented in this environment (34.9 and 40.5%, respectively). Bone assemblages of small-sized vertebrates do not show evidence of weathering. Medium-sized vertebrates present the highest percentage in Stage 0, although some remains reach as high as Stage 5 (Fig. 11.6). The weathering profile of large-sized vertebrates is more advanced, with all stages present. Despite its low total frequency (5.1%), the percentage of the chemical deterioration stands out in relation to other environments, mainly in small-sized vertebrates (22.7%) (Table 11.2).

11.4.2 Shallow Lakes

11.4.2.1 Environmental Characteristics

Geological evidence indicates that the current shallow lakes in the Pampas region are located in basins of varying ages, modeled by deflation and accumulation processes during dry and humid climates of the Late Pleistocene and Holocene (Frenguelli

Table 11.2 Distribution of taphonomic modifications by environment and taxonomic class size

Taphonomic modifications	Environments											
	Hills		Shallow lakes		Coast		Plains		River valleys		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Weathering	**238**	**34.9**	**222**	**34.4**	**617**	**52.4**	**32**	**69.6**	**86**	**32.3**	**1195**	**44.2**
Small vertebrate	0	0	0	0	125	40.3	0	0	0	0	125	35.5
Medium vertebrate	90	18.9	12	13.5	282	50.7	14	56.0	0	0	398	32.5
Large vertebrate	150	82.0	210	49.0	210	67.5	18	90.0	86	47	674	59.9
Root etching	**27**	**4**	**17**	**2.6**	**13**	**1.1**	**1**	**2.2**	**18**	**6.8**	**76**	**2.8**
Small vertebrate	0	0	0	0	3	1	0	0	0	0	3	0.9
Medium vertebrate	22	4.6	3	3.4	7	1.3	1	4	1	1.3	34	2.8
Large vertebrate	5	2.7	14	3.3	3	1	0	0	17	9.3	58	2.1
Carnivore marks	**259**	**38.0**	**81**	**12.5**	**135**	**11.5**	**6**	**13.0**	**30**	**11.3**	**511**	**18.9**
Small vertebrate	5	22.7	3	21.4	26	4.7	0	0	0	0	34	9.7
Medium vertebrate	191	40.1	14	15.7	71	12.8	3	12	13	16.7	292	23.9
Large vertebrate	63	34.4	64	14.9	38	12.2	3	15	17	9.3	185	16.4
Rodent marks	**3**	**0.4**	**1**	**0.2**	**1**	**0.1**	**0**	**0**	**0**	**0**	**5**	**0.2**
Small vertebrate	1	4.5	0	0	0	0	0	0	0	0	1	0.3
Medium vertebrate	2	0.4	0	0	0	0	0	0	0	0	2	0.2
Large vertebrate	0	0	1	0.2	1	0.3	0	0	0	0	2	0.2
Trampling	**9**	**1.3**	**18**	**2.8**	**2**	**0.2**	**0**	**0**	**6**	**2.3**	**35**	**1.3**
Small vertebrate	0	0	0	0	1	0.3	0	0	0	0	1	0.3
Medium vertebrate	3	0.6	1	1.1	0	0	0	0	0	0	4	0.3
Large vertebrate	6	3.3	17	4	1	0.3	0	0	6	3.3	30	2.7

(continued)

Table 11.2 (continued)

Taphonomic modifications	Environments											
	Hills		Shallow lakes		Coast		Plains		River valleys		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Chemical deterioration	**35**	**5.1**	**11**	**1.7**	**20**	**1.7**	**0**	**0**	**13**	**4.9**	**79**	**2.9**
Small vertebrate	5	22.7	0	0	3	1	0	0	0	0	9	2.6
Medium vertebrate	28	5.9	0	0	5	0.9	0	0	0	0	33	2.7
Large vertebrate	2	1.1	11	2.6	12	3.9	0	0	13	7.1	38	3.4
Thermal alteration	**1**	**0.1**	**0**	**0**	**4**	**0.3**	**0**	**0**	**1**	**0.4**	**6**	**0.2**
Small vertebrate	0	0	0	0	0	0	0	0	0	0	0	0
Medium vertebrate	1	0.2	0	0	0	0	0	0	0	0	1	0.1
Large vertebrate	0	0	0	0	4	1.3	0	0	1	0.5	5	0.4
Abrasion	**8**	**1.2**	**34**	**5.3**	**701**	**59.6**	**0**	**0**	**13**	**4.9**	**756**	**28.0**
Small vertebrate	0	0	5	35.7	216	18.4	0	0	0	0	221	62.8
Medium vertebrate	8	1.7	10	11.2	406	73	0	0	0	0	424	34.6
Large vertebrate	0	0	19	4.4	79	25.4	0	0	13	7.1	111	9.9
Manganese staining	**4**	**0.6**	**60**	**9.3**	**7**	**0.6**	**0**	**0**	**3**	**1.1**	**74**	**2.7**
Small vertebrate	0	0	0	0	1	0.3	0	0	0	0	1	0.3
Medium vertebrate	4	0.8	1	0.2	0	0	0	0	0	0	5	0.4
Large vertebrate	0	0	59	0.1	6	1.9	0	0	3	1.1	68	6.0
Calcium carbonate coating	**14**	**2.1**	**29**	**4.5**	**0**	**0**	**0**	**0**	**0**	**0**	**43**	**1.6**
Small vertebrate	0	0	0	0	0	0	0	0	0	0	0	0
Medium vertebrate	7	1.5	0	0	0	0	0	0	0	0	7	0.6

(continued)

Table 11.2 (continued)

Taphonomic modifications	Environments											
	Hills		Shallow lakes		Coast		Plains		River valleys		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Large vertebrate	7	3.8	29	6.8	0	0	0	0	0	0	36	3.2
Butchering marks	**9**	**1.3**	**14**	**2.2**	**1**	**0.1**	**1**	**2.2**	**9**	**3.4**	**34**	**1.3**
Small vertebrate	0	4.5	0	0	0	0	0	0	0	0	0	0
Medium vertebrate	0	0	0	0	0	0	0	0	0	0	0	0
Large vertebrate	8	4.4	14	3.3	1	0.3	1	5	13	7.1	37	3.3
Fracture	**276**	**40.5**	**196**	**30.3**	**430**	**36.5**	**33**	**71.7**	**143**	**53.8**	**1078**	**39.9**
Small vertebrate	12	54.5	2	14.3	135	43.5	0	0	0	0	149	42.3
Medium vertebrate	203	42.6	0	0	145	26.1	16	64.0	28	35.9	392	32.0
Large vertebrate	61	33.3	194	45.2	150	48.2	17	85.0	115	62.8	537	47.7

1956; Tricart 1973; Dangavs 2005). The size of the shallow lakes fluctuates, with dimensions ranging from <1 to 150 km^2. Small shallow lakes (<1 km^2) dominate the region (Dangavs 2005). The characteristics of this environment (shape, size, aggregation, distribution, hydro-chemical table, etc.) are highly dynamic and controlled by direct pluvial inputs, surface runoff and, above all, free groundwater (Quirós et al. 2002; Dangavs 2005; Grosman 2008; Grosman and Sanzano 2008). In the shallow lakes, aquatic birds such as herons, ducks, grebes, and coots are frequent (Darrieu and Bó 1992). A total of 53 native species of freshwater fish have been identified in the shallow lakes, including Pejerrey (*Odontesthes bonariensis*), Carp (*Cyprinus carpio*), Catfish (*Pimelodella laticeps*), and Tararira (*Hoplias malabaricus*) (Grosman 2008).

11.4.2.2 Taxonomic Diversity

Twenty-five transects were conducted in this environment, covering a total of 126,670 m^2. Visibility is regular and the density of remains is 0.0051/m^2. Vertebrate remains were classified as disarticulated bones (n = 626), carcasses (n = 11), and occurrences of articulated bones (n = 9) (Table 11.1). Taxonomic classes are distributed in mammals (81.1%), birds (7.9%), fish (2.3%), amphibians (0.2%), and indeterminate taxa (8.5%). Large-sized mammals are predominant (Table 11.1;

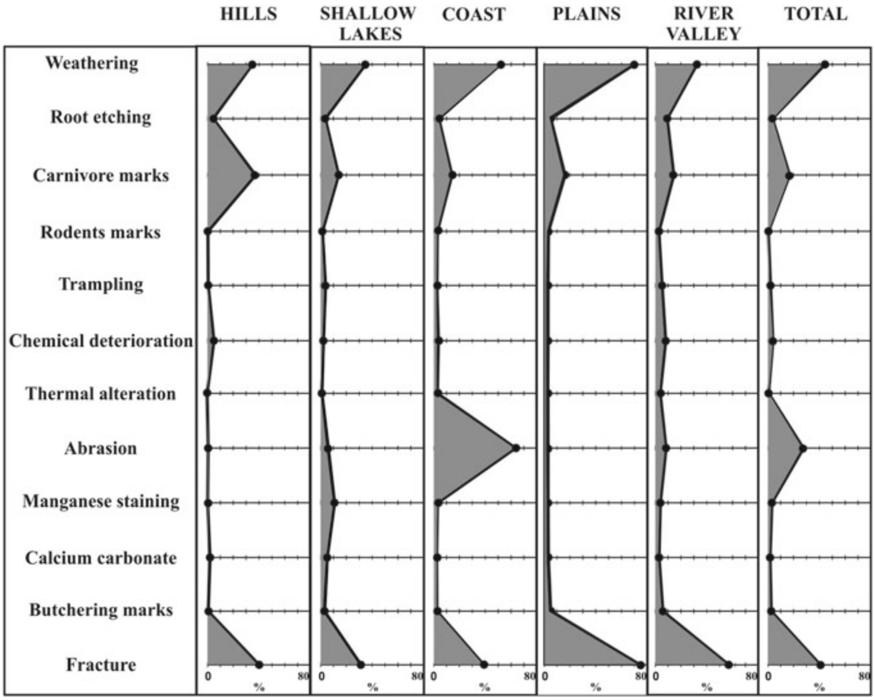

Fig. 11.4 Taphogram comparing taphonomic variables in the surveyed environments

Fig. 11.3). Undetermined domestic ungulates are the taxonomic category with the highest frequency of bone remains recovered within this size category (32.6%), followed by Cow (*Bos taurus*; 26.1%) (Online Resource 1). The second most abundant taxonomic class is birds, with a high percentage of indeterminate specimens (78.4%). Among the fish, the Order Siluriformes is predominant (66.7%). The total Ntaxa for the shallow lakes is 14, with a distribution by classes that shows the highest value for mammals (Ntaxa = 9), followed by birds (Ntaxa = 3), and then fish and amphibians (Ntaxa = 1).

11.4.2.3 Taphonomic Modifications

A total of 532 bone remains were analyzed for taphonomic modifications, distributed as follows: 14 small-sized vertebrates, 89 medium-sized vertebrates, and 429 large-sized vertebrates. Bone specimens mainly present modifications resulting from weathering (34.4%) (Table 11.2; Fig. 11.4). This process is manifested to a greater extent in large (49%) and medium (13.5%) vertebrates (Table 11.2). All small-sized vertebrates are in Stage 0 (Fig. 11.6). In the medium-sized category, the weathering profile only reaches Stages 1 and 2. For large-sized vertebrates,

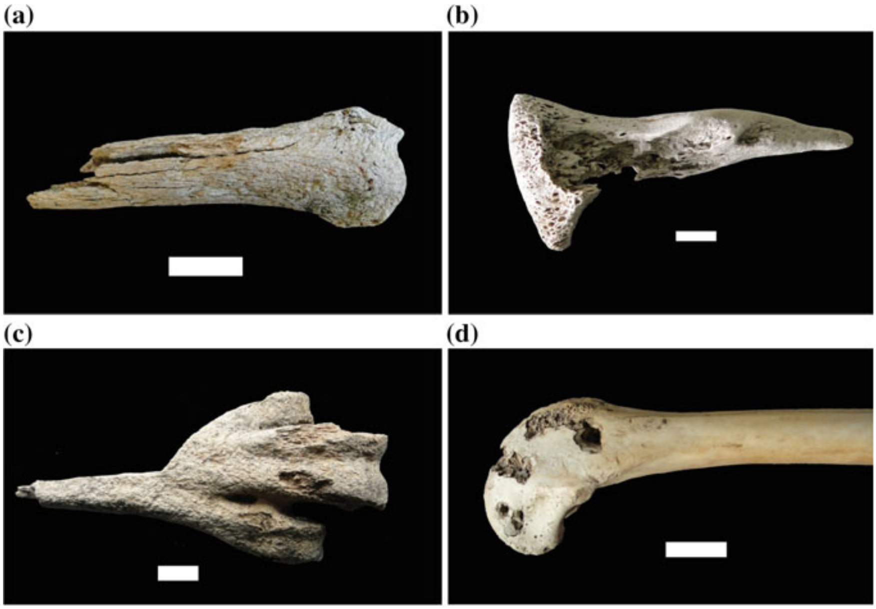

Fig. 11.5 Examples of taphonomic modifications. **a** Weathering on the distal radius of Canidae (coast); **b** abrasion on undetermined bone of large-sized mammal (fluvial valleys); **c** chemical deterioration on the distal tarsometatarsus of *Rhea Americana* (fluvial valleys), **d** carnivore punctures on the distal femur of *Lepus europaeus* (hills)

all stages are present, with a gradual decrease towards the more advanced stages. Other recurrent modifications are fragmentation (30.3%) and carnivore tooth marks (12.5%) (Table 11.2; Fig. 11.4). Fragmentation dominates in large-sized vertebrates (45.2%), while carnivore marks have similar frequencies in the three size categories (Table 11.2). With smaller frequency, but more important than in other environments, manganese (9.3%), abrasion (5.3%) (Fig. 11.5b), and calcium carbonate (4.5%) are observed.

11.4.3 Coast

11.4.3.1 Environmental Characteristics

The Pampas coast includes sandy beaches, cliffs, dune fields, and freshwater shallow lakes. During the Late Pleistocene and Holocene, the coastline has changed its position due to marine transgressions. Stabilization of the current environment occurred after the Middle Holocene (Ponce et al. 2011). The dune ridges are characterized by sand burial and wind erosion. Vegetation occurs only in the interdune areas, where

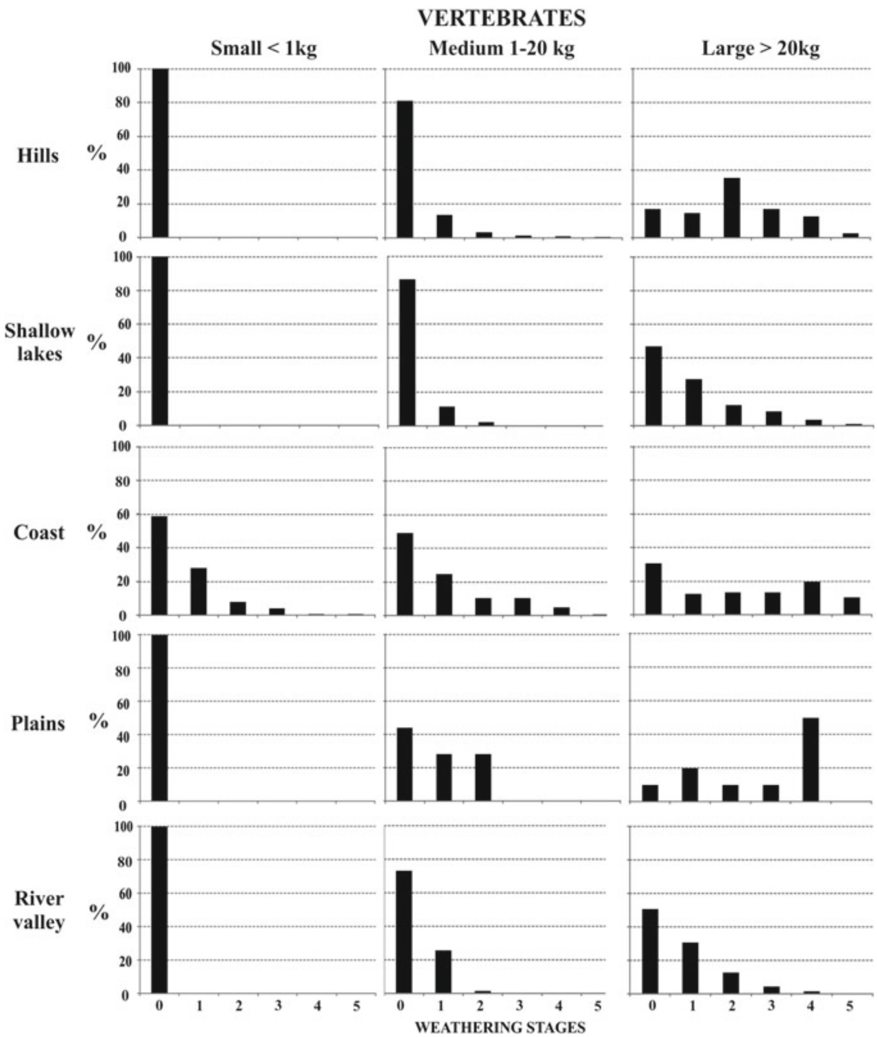

Fig. 11.6 Weathering profile per environment and class size

the freshwater table is at or just below the sand surface (Marcomini and López 2013). In the interdune areas, both in the active and stabilized dunes, the high level of the freshwater table and the obstruction of rainfall drainage by the dunes causes the formation of marshes and temporary shallow lakes, where abundant vegetation and fauna can be found. Behind the dune field, larger shallow lakes form, as the dunes impede the drainage of some watercourses from the plains (Frenguelli 1931; Bértola et al. 2009).

The environmental characteristics provide a nesting ground for numerous species of migratory birds (Darrieu and Camperi 2001). Among the marine species that breed in this coastal zone are the Kelp gull (*Larus dominicanus*), the Olrog's gull (*Larus belcheri*), the South American tern (*Sterna hirundinacea*), the Royal tern (*Sterna maxima*) and the Sandwich tern (*Sterna sandvicencis*). A small rodent that exclusively inhabits the coastal dunes of the Buenos Aires province is the Tuco-tuco (*Ctenomys australis*) (Celsi et al. 2010). The reptiles in the coastal dunes include lizards (e.g., *Liolaemus multimaculatus*, *L. wiegmanni*, *L. gracilis*), amphisbaena, snakes and vipers (e.g., *Liophis poecilogyrus* and *Philodryas aestivus*). Anurans (e.g., *Hyla pulchella*) inhabit the lower sectors where there is abundant vegetation and humidity. Among the marine fauna, Sea lions (*Otaria flavescens* and *Arctocephalus australis*) and Magallanic penguins (*Spheniscus magellanicus*) occasionally appear along the beach (Pütz et al. 2007). Currently, the Pampas coast is vulnerable to the erosive processes produced mainly by the circulation of off-road vehicles and the extraction of sand for urban construction.

11.4.3.2 Taxonomic Diversity

One hundred and eighteen transects were conducted in this environment, covering a total of 576,900 m^2. The density of remains is 0.0025/m^2, and there is excellent visibility. Vertebrate remains were classified as disarticulated bones (n = 1414), occurrences of articulated bones (n = 48), and carcasses (n = 3) (Table 11.1). Taxonomic classes are distributed by mammals (51.5%), birds (32.2%), fish (3.3%), reptiles (0.2%), amphibians (0.1%), and indeterminate taxa (12.7%) (Table 11.1). Mammals and birds are the most abundant taxonomic classes. Among mammals, large and medium-sized mammals share the same frequency (39.1%), including the Order Pinnipedia (38.6%) and European hare (30.5%), which are the best taxonomic categories represented, respectively (Table 11.1; Fig. 11.3; Online Resource 1). The Tuco-tuco (*Ctenomys* sp.) presents a high frequency of specimens and is the only small-sized mammal identified (Online Resource 1). The medium and small-sized categories of birds also presented similar percentages (Fig. 11.3). Magellanic penguin (*Spheniscus magellanicus*) is the most abundant identified species (85.1%). Fish is the third most abundant taxonomic class, with a high occurrence of bony fish (Actinopterygii; 47.9%) (Table 11.1). The total Ntaxa for the coast is 29, with the higher values for mammals (Ntaxa = 16), followed by birds (Ntaxa = 7), fish (Ntaxa = 4), and amphibians and reptiles (Ntaxa = 1 for both Classes).

11.4.3.3 Taphonomic Modifications

A total of 1177 bone remains were analyzed for taphonomic modifications, distributed as follows: 310 small-sized vertebrates, 556 medium-sized vertebrates, and 311 large-sized vertebrates. The main taphonomic modification in the coast is abrasion (59.6%) (Fig. 11.4), which occurs primarily in medium-sized vertebrates (73%) (Table 11.2). Another process that stands out is weathering (52.4%), with high frequencies for all three size categories (Table 11.2). Regarding the weathering profile, both the small and medium-sized vertebrates show a similar profile, with slightly more advanced stages in the medium-sized vertebrates. The weathering pattern for large-sized vertebrates is more homogenous, with similar frequencies for all the stages (Fig. 11.6). Bone fragmentation (36.5%) was identified in large (48.2%), small (43.5%), and medium-sized (26.1%) vertebrates. Finally, carnivore marks (11.5%) were equally represented in medium (12.8%) and large-sized (12.2%) vertebrates (Table 11.2).

11.4.4 Plains

11.4.4.1 Environmental Characteristics

This landscape consists of a flat plain with only slight undulations and a maximum elevation of around 200 masl (Fidalgo et al. 1991; Zárate and Rabassa 2005). The plains are composed of loess and loessoid sediments of Late Cenozoic age (Zárate 2005; Zárate and Rabassa 2005). Because the fine soil texture causes a low infiltration of water, during the periods of high water levels, surface laminar runoff occurs until it reaches the permanent river valleys (Munguía and Campo de Ferreras 2003). During events of excessive rainfall, the surface of the interfluvial plains environment is affected by water erosion. The soils are highly fertile, so almost all the landscape is exploited for agricultural and livestock purposes (Moscatelli and Puentes 2000). A census of birds and mammals in the Pampas grassland of the province of Buenos Aires showed the presence of 39 species of birds (e.g., *Rhea americana*, *Rhynchotus rufescens*, *Chloephaga rubidiceps*, *Pluvialis dominica*, *Sturnella defilippi*, *Vanellus chilensis*, *Milvago chimango*, *Anthus correndera*) and 15 of small mammals belonging to 9 Families (Didelphidae, Dasypodidae, Canidae, Mustelidae, Felidae, Cricetidae, Caviidae, Myocastoridae and Leporidae) (Comparatore et al. 1996).

11.4.4.2 Taxonomic Diversity

Nine transects were conducted in the plains, covering a total of 27,950 m^2. The density of remains is 0.0017/m^2, and there is very good to poor visibility. Faunal remains include disarticulated bones (n = 46), occurrences of articulated bones (n = 1), and carcasses (n = 1) (Table 11.1). The following taxonomic categories are present: mammals (93.8%), amphibians (2.1%), and undetermined *taxa* (4.2%) (Table 11.1). In the case of mammals, the medium and large-sized vertebrates are the most frequent (Table 11.1; Fig. 11.3). Plains vizcacha (*Lagostomus maximus*) and Cow (*Bos taurus*) are abundant (Online Resources 1). The total Ntaxa is 5, assigned to mammals (Ntaxa = 4) and amphibians (Ntaxa = 1).

11.4.4.3 Taphonomic Modifications

A total of 46 faunal remains were analyzed for taphonomic modifications, distributed as follows: 1 small-sized vertebrate, 25 medium-sized vertebrates, and 20 large-sized vertebrates. Fragmentation and weathering affected a high percentage of the specimens (71.7 and 69.6%, respectively) (Table 11.2; Fig. 11.4). Both processes are expressed with greater intensity in large-sized vertebrates (between 85 and 90%) (Table 11.2). Regarding the weathering profile, all small-sized vertebrate bones are in Stage 0 (Fig. 11.6). In medium-sized vertebrates, the absence of weathering predominates, and this process only reaches Stages 1 and 2. For large-sized vertebrates, the highest percentage of bones are in Stage 4 (Fig. 11.6). Again, the carnivore tooth marks are a frequent modification (13%), affecting to a greater extent the large (15%) and medium-sized (12%) vertebrates (Table 11.2).

11.4.5 River Valleys

11.4.5.1 Environmental Characteristics

The river valleys constitute early development watersheds integrated by a small number of irregular tributaries conditioned mostly by rainfall (Fidalgo et al. 1991; Fidalgo 1992). They do not present fluvial terraces but rather flood plains—poorly defined- that are only covered during maximum flood periods (Frenguelli 1950; Fidalgo et al. 1991). In the upper section of the river valleys, the sedimentary deposits are shallow, with ravine walls reaching a maximum of 2 m in height. In the lower basins, boxed meanders form deep ravines typically reach up to 8 m high (Campo de Ferreras and Piccolo 1999). The process of widening of the river valleys and the development of ravines can be intensified in some sectors by cattle trampling, which generates numerous gullies that are later eroded by surface runoff (Marini and Piccolo 2005). Unlike lentic environments (shallow lakes), lotic environments (rivers and streams) are characterized by basins of erosion and transport (Dangavs 2005). The freshwater species that inhabit this environment are the same as those of the shallow lakes. The rivers of the Pampas region work as ecological corridors for tropical species that expand their austral distribution in favor of increased humidity and temperature (Doumecq Milieu et al. 2012).

11.4.5.2 Taxonomic Diversity

Twenty-nine transects were conducted in this environment, covering a total of 135,300 m^2. The density of remains is 0.0022/m^2, and the visibility is regular. The vertebrate remains include disarticulated bones (n = 291), occurrences of articulated bones (n = 6), and carcasses (n = 5) (Table 11.1). Taxonomic classes include mammals (86.8%), birds (1.3%), fish (0.3%), amphibians (0.3%), and undetermined taxa

(11.3%) (Table 11.1). Mammals are the most abundant taxonomic classes (86.8%), being the large-sized mammals the category with the highest frequency (69.5%); however, the medium-sized category presents a high percentage (42.8%). Undetermined domestic ungulates are the mammals more represented within the large size category (43.4%), followed by Cow (*Bos taurus*; 21.4%), Sheep (*Ovis aries*; 12.63%) and Horse (*Equus caballus*; 2.7%). In the medium-sized category, Dog (*Canis familaris*; 44.9%) and Plains vizcacha (*Lagostomus maximus*; 33.3%) predominate (Table 11.1; Fig. 11.3; Online Resource 1).

11.4.5.3 Taphonomic Modifications

A total of 226 bones were analyzed for taphonomic modifications, distributed as follows: 183 large-sized vertebrates, 78 medium-sized vertebrates, and 5 small-sized vertebrates. The most frequent taphonomic modification is fractures (53.8%), affecting mainly large-sized vertebrates (62.8%) (Table 11.2; Fig. 11.4). Another process that shows a high frequency is weathering (32.3%); again, affecting both medium and large-sized vertebrates (Fig. 11.6). In medium-sized vertebrates, Stages 1 and 2 are recorded, but in low frequencies. For large-sized vertebrates, there is a gradual decrease of weathering from Stages 0 to 4 (Fig. 11.6). Carnivore tooth marks were recorded in 11.3% of the total remains, with the highest percentage in the medium-sized vertebrates (Table 11.2). Like in the hills, chemical deterioration (Fig. 11.5c) presents an important frequency (4.9%) but affects only large-sized vertebrates (Table 11.2).

11.5 Discussion

The main objective of this taphonomic research is to contribute to the understanding of the formation processes that configure the modern and fossil vertebrate bone assemblages in the Pampas region. To accomplish this objective, it is essential to estimate the natural “bone rain” and to measure the potential preservation of the remains of different vertebrates in distinctive environmental contexts (Behrensmeyer et al. 2000; Miller et al. 2014). Due to the characteristics of our work, we do not have direct information about the causes of animal deaths. However, considering ecological information and indirect data from our taphonomic modifications, in the case of large-sized vertebrates, which correspond mostly to livestock, the deaths are mainly due to diseases and environmental stress. Moreover, based on the record of butchering marks, killing for human consumption should also be considered as a cause of death for this size category. Regarding small and medium-sized vertebrates, natural deaths can include predation by small and medium-sized carnivores (Perovic and Pereira 2006).

In all environments, disarticulated bones (>95%) dominate over articulated ones, which suggest a low anatomical integrity of the carcasses. In addition to the microbial decomposition (DeVault et al. 2003), the early decay of carcasses may be accelerated by carnivore action, which is observed in all environmental contexts. Another taphonomic process that could favor the disintegration of carcasses is water transport, although this process is only prevalent in particular environments, such as the coast and the river valleys.

The comparison of the taxonomic richness (Ntaxa) contrasts with the current faunal biodiversity at a regional scale, which indicates a greater abundance of birds. In our sample, the mammals, especially large and medium-sized, are the more abundant in all the environments. There is also a low representation of fish and amphibians in the aquatic environments. Likewise, in the hills and coast, few reptiles were identified, which is also inconsistent with the current faunal biodiversity of these environments. The bias against smaller-sized taxa has also been noted in other naturalistic taphonomic studies, and it is mainly attributed to a greater bone destruction of these vertebrates (Behrensmeyer et al. 1978, 2003; Behrensmeyer and Dechant Boaz 1980; Borrero 2000; Miller et al. 2014). Different types of destruction processes where observed in our study, in particular, a high degree of weathering and carnivore action. The advanced stages of weathering observed in large-sized vertebrates (mainly mammals) suggest a prolonged surface exposure time related to a greater resistance of destruction processes. As other researchers have already noted, this taphonomic aspect establishes that large-sized vertebrate bone assemblages are more prone to time averaging (Behrensmeyer 1982; Borrero 2007; Cruz 2015). In relation to carnivore action, several ecological experiments point to a high effectiveness of scavenging on small-sized vertebrates in different types of environments (steppe, agricultural fields, temperate forests, tropical forests, tundra, grasslands, desert mountains); with a loss of 60–100% of the carcasses (DeVault et al. 2003; Schlacher et al. 2013).

In general, the density of vertebrate remains is low. This suggests that the chances of naturally deposited bones in the archaeological record at a regional scale are also low. However, there may be specific environments where "bone rain" is more likely, and in consequence, can have a higher impact on the archaeological record. To evaluate these specific situations; we will discuss the differences in the bone assemblages from each of the surveyed environments.

In the shallow lakes and river valleys, there is a greater frequency of large-sized mammal remains (mainly cow) and a low representation of birds and fish. Since animals are attracted to water sources, natural deaths due to etho-ecological reasons and carnivore predation can contribute to the deposition of vertebrate remains in these environments. However, in the case of livestock, one of the factors that explain its high representation is the common practice among farmers to discard the carcasses into bodies of water. This process establishes a high degree of uncertainty in the interpretation of the natural deposit rate of vertebrate remains in shallow lakes and river valleys.

As for the taphonomic processes acting in the shallow lakes and river valleys, weathering, carnivore action, and trampling are important. Although trampling is registered in a low percentage, its frequency is greater than in the other environments, which could be due to recurrent visits by livestock in search of water. In the case of shallow lakes, a higher frequency of manganese stains and calcium carbonate is observed. This is related to greater humidity and the susceptibility of these environments to periodic water fluctuations. On the other hand, in the fluvial valleys, there is a greater frequency of root etching and chemical deterioration. The presence of these modifications suggests the occurrence of re-exposure of skeletal remains, which is consistent with sedimentary erosion in these contexts. Likewise, in both aquatic environments, the highest percentage of buried bones was recorded, which could be the result of fluvial and lacustrine sedimentation and trampling.

Most archaeological sites from the Pampas region are found near fluvial valleys and shallow lakes. Carnivores or fluvial transport can destroy or transport bones from carcasses. At the same time, in these locations there are high chances of burial because of trampling and bioturbation. Common bioturbation processes include disturbance by plants and burrowing mammals that can favor the rapid burial of the bones and thus the contamination of archaeological deposits with modern remains. A clear example of this mixture is the presence of domestic ungulates remains in archaeological deposits dated to pre-Hispanic periods (e.g., Messineo et al. 2013; Scheifler and Messineo 2016). This process is particularly important for discussing topics in the regional archaeology record, for example, if Guanacos were available in the Pampas when the Europeans arrived (Tonni and Politis 1980; Silveira and Crivelli Montero 1982; Crivelli Montero et al. 1987–88). Our results indicate that contamination of archaeological sites with naturally deposited bones is expected in fluvial valleys and shallow lakes. The presence of introduced fauna in a pre-Hispanic site warns us of this mixture, and that it is important to consider that the same processes of contamination with native taxa can occur in the present and in the past.

As for the hills, there is a dominance of remains of medium-sized mammals (mainly European hare) followed by large-sized mammals (mainly domestic ungulates). The high frequency of carnivore marks on the different vertebrate size categories, in particular, the medium-sized mammals, suggests that this agent played an important role in the formation of bone assemblages in this environment. The accumulation of bones is related in part to the ethology of carnivores to transport their prey to rock shelters and cavities. Although we do not know the particular carnivore species responsible for the accumulation of remains, we consider that both medium and small-sized carnivores could be involved, probably canids, felines, mustelids, and mephitids (Gutiérrez et al. 2016). Taphonomic studies with camera traps in hill environments of South Africa have shown that the same rock shelter can be used in a short period of time by multiple animals (e.g., Brown hyaena, Wild boar, Badger, Jackal, Porcupine, Leopard), generating complex palimpsests (Bountalis and Kuhn 2014). The important taphonomic role of carnivores in the Pampas hills can explain in part the high density of remains, many of which appear as part of bone concentrations, and the high taxonomic richness. The taxonomic variability partly reflects the diet of these predators. Likewise, previous studies have shown that along the hills, some of the remains of domestic fauna are transported directly from nearby farm houses located along the base of the hills. These locations act as resource catchment areas for carnivores (Gutiérrez et al. 2016: 267).

Another modification registered in the hills is weathering, which is more frequent and shows more advanced stages in large-sized vertebrates. The differences in the weathering profiles among the size categories may be due to their differences in resistance to destructive processes, an aspect that was discussed earlier. However, the characteristics of the hills may also condition the intensity of weathering. Smaller-sized vertebrates come mainly from sheltered locations, such as the base of rock walls or cavity interiors, while the remains of larger vertebrates were more frequent along the hilltops (where livestock tend to graze). Another prominent aspect of this environment that conditions bone preservation is pluvial erosion (Campo de Ferreras and Piccolo 1999), which may help explain in part the low percentage of buried bones.

Regarding the possibilities of contamination of archaeological sites in the hills, the transport of prey by carnivores will enhance the possibilities of mixing bones deposited naturally with archaeological remains, since these are also favorable places for human occupations (Mazzanti 2006). Even though our results indicate low burial possibilities, the recurrence in the use of these spaces by carnivores over time suggests that, in the long term, the impact of the natural bone rain on the archaeological record may be significant, especially when considering the shallow deposits in this environment (Martínez and Mazzanti 2017).

With respect to the coast, the taxonomic richness and the more even representation of vertebrates of different body sizes better reflects the natural diversity of living fauna. This could be in part because of the excellent visibility (Massigoge et al. 2015). However, sampling bias cannot be ruled out, since this environment was the largest surveyed area, which could have also increased the richness values in the sample. Much of the bone assemblage from the coast is dominated by penguins. As discussed in a previous paper from this environment (Massigoge et al. 2015), the abundance of penguin remains is related to the beaching of this seabird during seasonal migration. Other well-represented taxa are the Tuco-tuco and Sea lions. The Tuco-tuco is a small endemic rodent, with high population densities, that builds underground galleries in the dunes near the coast (Mora et al. 2006). The high representation of this rodent differs from that recorded in other naturalistic studies, where there is a bias against burrowing animals (Miller et al. 2014). In our case, we consider that the high frequency of Tuco-tuco remains in the coastal transects is because eolian action along the active dunes destroys their burrow systems and exposes the skeletal remains of individuals who died inside the burrows.

After the deposit of carcasses in the coastal environment, different natural processes contributed to soft tissue decay, disarticulation, spatial dispersal of bones, and finally, bone destruction. Taphonomic information points to an important role of abrasion caused by sand particles transported by water and wind. This suggests relatively long exposure times to atmospheric agents, coinciding with advanced weathering profiles for all size categories of vertebrates. Regarding the modifications by carnivores, the coast presents similar percentages to the rest of the environments, with the exception of the hills. The low percentage of carnivore marks in these types of open environments could be related to the fact that transects did not intercept carnivore dens. A prominent effect identified in previous studies, however, suggests that carnivore action along the coast is an important variable, especially when considering the transport of bones from the beach to the interior sites (Massigoge et al. 2015; Gutiérrez et al. 2016). Comparatively, ecological information on the East coast of Australia shows that scavengers (carnivores, reptiles, and birds) act as important biological vectors among different environments, taking advantage of the carrion deposited on the beach and moving the carcasses or depositing their scats or pellets in terrestrial context (Schlacher et al. 2013).

Archaeological sites from the Pampas coast mainly consist of surface assemblages composed almost exclusively of lithic artifacts in the blowout depressions of active dunes (Bonomo 2005). Our results show that there are high chances of the natural incorporation of modern bones into these assemblages, especially in the sites located close to the shoreline (Massigoge et al. 2015). In some transects along the coast, we recorded both lithic artifacts and modern faunal remains (Massigoge et al. 2015). This mixture could have also occurred in the past if some of the environmental conditions remained the same.

Finally, in the plains, a very low diversity of species is observed, with a clear predominance of medium-sized vertebrates (mainly Plains vizcacha) and large-sized vertebrates (primarily Cow). It is important to mention that most of the remains of Plains vizcacha were recorded just in a few transects that crossed an area with a high concentration of their burrows (Rafuse et al. 2019). Due to this situation, and the small size of the sampled area in the plains environment, it is not possible to ensure that the taxonomic representation registered so far is representative of the plains. As for the acting taphonomic processes, it is important to recognize the percentage and high frequency in advanced stages of weathered bones. This process may help to explain in part the high fragmentation of the sample. Weathering data, together with a low percentage of buried bones, suggests prolonged exposure times. Although the results of the plains are preliminary, the chances of bone preservation and burial appear to be lower in this environment.

11.6 Conclusions

The naturalistic taphonomic research in the Pampas region presented here is designed to help better understand the natural formation processes of the fossil record, particularly those processes affecting different classes of vertebrates. While sampling is still needed, particularly in some environmental contexts, our results show some interesting trends. First, Pampean carnivores have an important role in the accumulation, dispersal, and destruction of bones, especially smaller-sized vertebrates (<20 kg). Second, rock shelters and cavities of the hills present a higher rate of natural accumulation of bones, since they are places commonly occupied by carnivores. Third, the chances of burial of modern bones are higher in the river valleys and shallow lakes and lower for the rest of the environmental contexts. Forth, weathering contributes to bone destruction in all the environmental contexts but appears more frequently in the coast and the plains. Fifth, more advanced weathering stages in large-sized vertebrate indicate the importance of time-averaging on surface assemblages of these animals.

Sixth, bone destruction, primarily by carnivores and weathering, is more intense for small-sized vertebrates. Lastly, in general, the impact of the natural "bone rain" would be more substantial in the hills and shallow lakes. So far, our results suggest that taxonomic representation in the archaeofaunal assemblages from the Pampas region can only be confidently used for subsistence and paleoenvironmental interpretations after careful consideration of taphonomic biases, particularly those related to body size and mixing of cultural and natural bones. Future studies should focus on testing these general trends, especially through longitudinal taphonomic studies of carcasses of different-sized vertebrates, combined with controlled experiments on particular processes and agents.

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