



Scavenging patterns in burned remains: an experimental forensic taphonomic study on charred pig carcasses inside a vehicle.

PATRONES DE CARROÑEO EN RESTOS QUEMADOS: UN ESTUDIO TAFONÓMICO FORENSE EXPERIMENTAL SOBRE CADÁVERES DE CERDO CARBONIZADOS DENTRO DE UN VEHÍCULO.

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ABSTRACT: Burning a body is a common criminal strategy aimed at hindering identification. Medico-legal examinations of biological remains exposed to fire present significant challenges in determining the victim's identity, the vitality of the body prior to exposure, and the cause of death. Although these issues are addressed in the literature, much of the available data is derived from non-systematic observations, such as those from cremation events or case reports with only approximate information on the fire's characteristics. In addition, vertebrate scavengers frequently interfere with forensic analyses by feeding on or dispersing human remains, complicating trauma assessment and postmortem interval (PMI) estimation. While recent studies have increasingly focused on scavenger activity, reports addressing scavenging in fire-altered remains remain scarce. This study investigates the taphonomic alterations caused by scavengers on two *Sus scrofa domesticus* (domestic pig) carcasses with different PMIs, both burned inside a vehicle. It describes the sequence of scavenger access, the species involved, and the alterations observed on thermally modified remains. The results indicate that scavengers consumed and dispersed burned biological remains regardless of the specimens' postmortem intervals.

KEY WORDS: FORENSIC EXPERIMENTAL TAPHONOMY, SCAVENGING, BURNED BIOLOGICAL REMAINS, *SUS SCROFA*

RESUMEN: La incineración de un cuerpo es una estrategia delictiva común destinada para dificultar su identificación. Los exámenes medicolegales de restos biológicos expuestos al fuego presentan importantes desafíos para determinar la identidad de la víctima, la vitalidad del cuerpo antes de la exposición y la causa de la muerte. Aunque estas cuestiones se han abordado en la literatura, gran parte de los datos disponibles proceden de observaciones no sistemáticas, como eventos de cremación o informes de casos con información aproximada sobre las características del fuego. Además, los carroñeros vertebrados interfieren con frecuencia en los análisis forenses al alimentarse o dispersar restos humanos, lo que complica la evaluación de traumatismos y la estimación del intervalo post mortem (IPM). Si bien estudios recientes han prestado una atención creciente a la actividad carroñera, los informes que abordan la carroña en restos alterados por el fuego siguen siendo escasos. Este estudio investiga las alteraciones tafonómicas provocadas por carroñeros en dos cadáveres de *Sus scrofa domesticus* (cerdo doméstico) con diferentes IPM, ambos quemados en el interior de un vehículo. Se describe la secuencia de acceso de los carroñeros, las especies implicadas y las modificaciones observadas en los restos térmicamente alterados. Los resultados indican que los carroñeros consumieron y dispersaron los restos biológicos quemados independientemente del intervalo post mortem de los especímenes.

PALABRAS CLAVE: TAFONOMÍA EXPERIMENTAL FORENSE, CARROÑEO, RESTOS BIOLÓGICOS QUEMADOS, *SUS SCROFA*

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1. INTRODUCTION.

Although fire-related forensic anthropology cases are relatively infrequent, thermally altered remains pose significant challenges in both victim identification and the reconstruction of peri- and postmortem events [1, 2].

Forensic anthropologists encounter these difficulties in various contexts. Their increasing involvement in disaster victim recovery and identification has led to a growing awareness of the effects of fire on human remains, making such knowledge more crucial than ever [3-6].

Burning a body is a commonly employed method of concealing criminal evidence [7-9]. While complete destruction is rare, fire significantly hampers identification efforts and often eliminates forensic clues related to the cause and manner of death [10]. In some cases, perpetrators return to the scene to destroy remaining evidence [2, 4]. Fire not only damages soft tissues and internal organs but can also reduce the entire body to bone fragments, thereby compromising or eliminating additional incriminating evidence [11-15]. Burned remains may also result from self-immolation [16] or accidental deaths [17], as reported in numerous cases [5, 18].

Understanding the thermal effects on biological remains is essential for reconstructing the processes that affect bodies exposed to fire, in both forensic and archaeological contexts [19-23]. Estimating the postmortem interval (PMI) in such contexts remains one of the cores yet most complex challenges in forensic pathology, particularly when scavenging activity is also present [24].

Evaluating the consequences of thermal alterations on biological remains is essential when assessing scavenger activity on carcasses. Experimental research demonstrates that thermal alterations vary significantly depending on the context of the fire, such as inside a vehicle, within a structure, or outdoors [25-28]. Furthermore, factors such as ventilation, fire temperature, and available fuel also influence combustion duration, and these conditions can fluctuate throughout the event [2, 10, 27, 29, 30, 31]. Experimental studies [20, 28, 32] have correlated specific physical alterations with temperature and duration. For instance, pugilistic postures typically occur at temperatures between 670-810°C, whereas internal organ exposure happens approximately 30 minutes after combustion initiates [10, 28].

Clothing can serve as a protective barrier, limiting thermal damage to the body [2, 25, 26; 27]. Similarly, an individual's body fat contributes to sustaining fires, even at low intensities, influencing burn patterns alongside body mass index. Temperature and exposure duration also significantly affect soft tissue preservation and skeletal calcination. Additionally, accelerants applied directly to a body intensify thermal disturbances, producing localized and concentrated damage [10, 25, 30]. Observations suggest that low-intensity fires cause greater soft tissue damage when exposure times are extended, potentially affecting bone integrity. Conversely, high-intensity fires with short durations generally damage the body's external surfaces, sparing internal tissues [2, 10].

Although experimental research has contributed valuable insights into thermally induced changes, field-based outdoor experiments remain scarce [23]. Approximately 45% of human skeletal remains examined by forensic anthropologists are recovered from outdoor environments such as forests, fields, riverbanks, or shallow graves [33, 34]. In these settings, up to 70% of remains exhibit postmortem modifications attributable to scavenger activity [35, 36].

Animals are among the most significant agents in destruction, disarticulation, and relocation of biological remains as part of their scavenging behavior. The loss of skeletal elements often results from scavengers transporting anatomical parts to their dens or other areas for consumption or abandonment [37-39]. Indeed, scavengers can drastically alter a forensic scene by consuming, disarticulating, and scattering biological material on the surface [40-42].

Even in cases of natural death, if internal organs are consumed by animals, determining the precise cause of death may become impossible [43, 44]. Therefore, identifying scavenger behavior is crucial to accurately assess its impact on the forensic record [39-42].

The objective of this study was to assess the impact of scavenger activity on two *Sus scrofa domesticus* carcasses, with different PMI, placed inside a car cabin and subsequently exposed to fire. Systematic monitoring over 134 days, from September 2023 to mid-January 2024, allowed for the identification of key scavenger species, their behavioral patterns, the type of alterations they inflicted, and the dispersal patterns of skeletal elements.

We assume that the presence of burnt and charred carrion might deter scavengers, as they largely rely on olfactory cues to evaluate the risks and benefits of consuming a resource [45, 46]. Therefore, we expected minimal modifications due to a reduced likelihood of incorporating charred remains into higher trophic levels. Additionally, we argue that scavengers may selectively access remain depending on the specimen's postmortem interval (PMI). Finally, the degree of thermal alteration observed in bones can serve as a reliable indicator of the specimen's stage of anatomical integrity

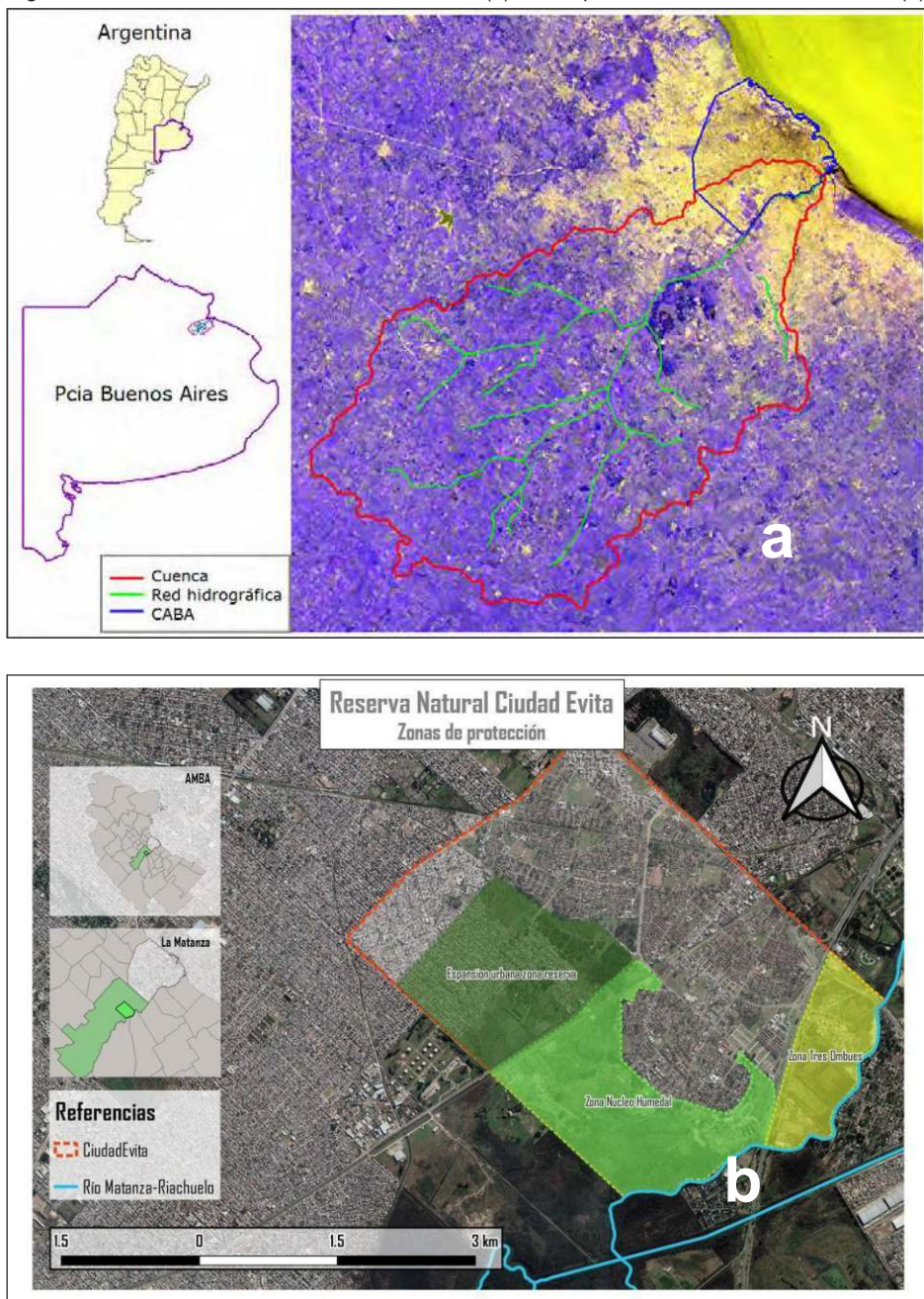
Taphonomic alterations observed in burned remains were documented in a wetland area on the outskirts of Buenos Aires. This study provides valuable insights for law enforcement agencies regarding the interpretation of fire-related forensic contexts, and represents, to date, the first systematic taphonomic investigation of burned carcasses located inside a vehicle in this region [46].

2. ECOLOGICAL FRAMEWORK.

The region belongs to the Wetlands of the Pampas, specifically the Subregion of Lagoons of the Humid Pampas, which corresponds to the eastern sector of this ecoregion, located within the Province of Buenos Aires and the southern

part of Santa Fe. The landscape is characterized by anthropogenic plantations, natural grasslands, and extensive wetlands associated with the floodplain of the Matanza River. This creates an ecologically significant environment in the middle portion of the Matanza-Riachuelo Basin (Fig. 1).

Figure 1: Location of the Matanza Riachuelo basin (a), Municipal Reserve Area of Ciudad Evita (b).



The Matanza-Riachuelo Basin spans approximately 2,047 km² and is drained by a typical lowland river. Over its 75-kilometer course, the river passes through 14 municipalities within the Greater Buenos Aires metropolitan area. According to the latest census (2022), the basin is home to 5.8 million people, representing roughly 15% of Argentina's population. Topographically, the area lies within the Matanza River's floodplain and is characterized by low elevation and minimal slope, making it highly susceptible to recurrent flooding.

The area is characterized by grasslands, dominated by herbaceous graminoids such as *Lolium arundinaceum*, and are located at slightly elevated positions and are distributed in isolated patches occupying higher ground. However, this area is still prone to waterlogging during certain times of the year. The vegetation consists largely of exotic species, including *Pinus sylvestris* (Scots pine), which provides shelter for a modest but expanding presence of native flora such as *Celtis tala*. This native tree now covers a significant portion of the landscape. Additionally, the area is home to *Iris pseudacorus* (yellow iris), an invasive ornamental species commonly found in wetland environments. These patches of exotic forest extend across more than 200,000 m² [47], often interspersed with bulrushes (*Schoenoplectus californicus*). Beyond these vegetational features, the wetland system functions as a dynamic ecological unit, shaped by seasonal or permanent water accumulation, which promotes hydromorphic soils and supports plant and animal species adapted to these conditions. These wetlands provide key ecosystem services, including flood mitigation, aquifer recharge, and water purification through sediment and pollutant capture. The high primary productivity and biogeochemical cycling in these areas also contribute to climate regulation and resilience to extreme weather events. From a socioecological perspective, they offer forage resources, support beekeeping and fisheries, and contribute to the landscape's scenic and recreational value. The provincial wetland inventory identifies these functions as critical for sustainable management and urges their integration into territorial planning through a landscape ecology lens, aligning with international conservation frameworks such as the Ramsar Convention and the Sustainable Development Goals [48].

Faunal diversity within the wetland matrix is notable and includes a wide range of taxonomic groups. Among mammals, the most frequently observed or historically recorded species are *Myocastor coypus* (coypu),

Hydrochoerus hydrochaeris (capybara), *Lagostomus maximus* (vizcacha), *Cavia aperea* (pampas guinea pig), and armadillos such as *ChaetophRACTUS villosus* (big hairy armadillo). Carnivorous mammals include *Lycalopex gymnocercus* (Pampas fox), *Leopardus geoffroyi* (Geoffroy's cat), *Conepatus chinga* (hog-nosed skunk), and *Didelphis albiventris* (white-eared opossum). Bird species adapted to aquatic and terrestrial environments are abundant and include *Rhea americana* (greater rhea), *Eudromia elegans* (elegant-crested tinamou), *Anas platalea* (shoveler), *Fulica armillata* and *F. leucoptera* (coots), *Coscoroba coscoroba* (coscoroba swan), and *Chloephaga sp.* (sheldgeese). Reptilian fauna is represented by *Salvator merianae* (Argentine black and white tegu). Ichthyofauna is equally diverse, featuring both euryhaline and freshwater species such as *Mugil sp.* (mullet), *Pogonias courbina* (black drum), *Synbranchus marmoratus* (swamp eel), *Hoplias argentinensis* (wolf fish), *Rhamdia quelen* (catfish), *Pimelodus maculatus* (yellow catfish), *Australoheros facetus* (chanchita), *Hypostomus commersoni* (armored catfish), *Oligosarcus jenynsii* (dientudo), *Corydoras paleatus* (cory catfish), and *Odontesthes bonariensis* (silverside) [47].

In this context, several sectors of the basin, including the Ciudad Evita Nature Reserve (Municipal Ordinance 24.247/2015), function ecologically as wetlands. This area serves critical roles in hydrological regulation, biodiversity support, and nutrient processing [49].

3. METHODOLOGY.

The study was conducted at the facilities of the Martín Miguel de Güemes National Gendarmerie School (ESCUGEN) (34°44'25"S, 58°31'40"W) as part of the research program Forensic Taphonomic Models: A GIS-Based Approach for Designing and Analyzing Forensic Data in the Province of Buenos Aires (Buenos Aires Metropolitan Area). The initiative was implemented by the Department of Criminalistics and Forensic Studies (IUGNA – ESCUGEN) and funded under Decree DDNG 77, within the framework of the 2016–2020 Institutional Strategic Plan. Additional support was provided through a Research and Academic Extension grant (DI-2023-50446557-APN-SSFY/CMMSG) from the Ministry of Security of the Nation (2023) (Fig. 2).

Figure 2: Location of the vehicle and Experimental Unit 4 A and B within the experimental area



A prospective observational design was employed to investigate taphonomic processes within a confined vehicular environment over a 134-day period. Two *Sus scrofa domesticus* specimens weighing approximately 80 kg each—designated as Experimental Units EU4A and EU4B—were used as proxies for human cadavers [50]. Specimens were obtained from the Bioterium of Maimónides University and the National Institute of Agricultural Technology (INTA). Euthanasia was performed via anesthetic sedation in accordance with international ethical protocols [51]. Decomposition was assessed using the Total Body Score (TBS) system developed by Megyesi et al. (2005), which provides a macroscopic score from 3 to 35 based on external morphological changes [52]. TBS scoring was applied exclusively to both specimens prior to combustion. No TBS values were recorded following fire exposure, in accordance with the model's limitations.

The experiment comprised two phases. In Phase 1, EU4A (PMI: 104; TBS: 29) was dressed in standard clothing and positioned in the driver's seat of a 1980 *Rastrojero P.* diesel vehicle—an Argentine-manufactured model. The vehicle's openings were sealed using woven wire mesh to prevent access by scavengers. The specimen was left undisturbed for 104 days.

In Phase 2, a freshly euthanized pig carcass, EU4B (PMI: 0; TBS: 3) also dressed, was placed in the front passenger seat next to EU4A. Combustion was initiated by spraying 10 liters of naphtha inside the cabin. The fire lasted approximately

1.45 hours, reaching estimated peak temperatures between 800–1200 °C. Upon extinguishment, both specimens remained in situ for 30 days and were subject to systematic post-combustion observation.

Due to the limitations of the TBS system in thermally altered remains (where protein denaturation, bone calcination, and tissue carbonization obscure external features [10]), the Charred Body Score (CBS) proposed by Gruenthal et al. [29] was employed. This system evaluates three anatomical regions independently: head and neck (maximum of 11 points), torso (12 points), and limbs (9 points), facilitating a region-specific assessment of thermal damage.

Animal interactions were recorded as discrete events, defined as any encounter between a scavenger and EU4A or EU4B. Events were categorized into five behavioral types: a) *Prowling*, locomotor activity around the experimental units (EUs); b) *Exploration*, direct physical contact with the EU; c) *Marking*, urination or scent deposition; d) *Feeding*, active consumption of tissue and; e) *Dragging*, disarticulation and transport of remains beyond anatomical context.

For each species, the temporal duration of individual events was recorded in minutes. The Interaction Index (II), proposed by Nasti [46], was calculated as the ratio of total interaction time to the number of events for each species:

$$II = \frac{\text{Total Minutes}}{\text{Number of Events}}$$

Monitoring was conducted using two motion-triggered Gadnic Huntertrail 99 CAM infrared cameras, programmed with 5-second delay intervals. Images and videos were processed using Wild.ID Trap software to identify species, classify behavior, and log event timing. Temporal classification followed solar cycles: a) *Daytime*, between sunrise and sunset; b) *Nighttime*, between one hour after sunset and one hour before the following sunrise and c) *Crepuscular*, within one hour before sunrise or after sunset. Sunrise and sunset data for each calendar day were obtained using Moonrise software.

Disarticulation was assessed by anatomical region, assuming a complete skeleton as 100%: a) *Skull and mandible*: 10%; b) *Axial skeleton and ribs*: 30%; c) *Forelimbs*: 30% and d) *Hind limbs*: 30%.

Scavengers were classified by body mass following Delaney-Rivera et al. [53]: *large* (≥ 40 kg), *medium* (11–40 kg), and *small* (≤ 10 kg).

Environmental parameters were obtained hourly from the Meteostar weather station. Interior microclimatic conditions were recorded using a HOBO MMHY data logger. Statistical analyses were conducted using Statgraphics Centurion 19.0, IBM SPSS, and XLSTAT.

Geospatial data were processed in ArcGIS Pro 3.0. Kriging interpolation was applied to visualize temperature and humidity gradients within the cabin. Temporal trends were analyzed using repeated-measures ANOVA, with statistical significance set at $\alpha = 0.05$.

4. RESULTS.

Animal activity on carcasses plays a crucial role in recycling proteins, lipids, and carbohydrates into the food web, constituting a key component of the taphonomic processes following death [54]. Numerous species participate in this chain, and accurate identification of scavengers requires comprehensive knowledge of carcass conditions, geographic and climatic context, potential local fauna, and the ethological traits of each species [55].

The first scavenger observed was the Geoffroy's cat (*Leopardus geoffroyi*), seen prowling around experimental unit EU4B on postmortem day one (PMI 1), and CBS: 12. This species continued to return daily until PMI 7, when the Pampa's fox (*Lycalopex gymnocercus*) was first recorded. On PMI 8, the domestic cat (*Felis silvestris catus*) also began interacting with the same remains of EU4B (Fig. 3).

Figure 3: a) *Leopardus geoffroyi* in the EU4B (PMI: 3 days and CBS: 3 points); b) specimen of *Felis catus catus* scavenging the body of the carbonized EU4B (MPI: 9 days and a CBS: 9 points).



Between PMI 9 and 15, *Lycalopex gymnocercus* and *Canis familiaris* interacted with EU4A (CBS 28–31), 3 involving *Leopardus geoffroyi*, and 11 involving *Felis silvestris catus* on EU4B (CBS 12–15). Additionally, three avian species were recorded feeding on insect larvae associated with both carcasses: the hornero (*Furnarius rufus*), the common

canary (*Serinus* sp.), and, most notably, the great kiskadee (*Pitangus sulphuratus*).

From PMI 16 onward, when EU4B had reached a CBS 22, two *Lycalopex* individuals were observed actively scavenging its skeletal remains. Both *Lycalopex* and

Didelphis albiventris were accessed and fed on EU4B and EU4A, the latter having reached PMI 122 and CBS 31 (Fig. 4).

By PMI 24, EU4A (CBS 32) consisted solely of fragmented and charred bones scattered across the vehicle's cabin. In contrast, EU4B (PMI 24; CBS 29) had been fully disarticulated and dragged outside the vehicle. The skull and

several ribs were located approximately 2 meters south of the vehicle, while parts of the torso and limbs were found to the north (Fig. 5).

On PMI 26, both *Lycalopex gymnocercus* and *Didelphis albiventris* were observed scavenging the remaining skeletal elements of EU4A (CBS 32).

Figure 4: a) *Lycalopex gymnocercus* and b) *Didelphis albiventris* scavenging scattered burnt remains to EU4A (PMI: 122 days and CBS: 32 points).

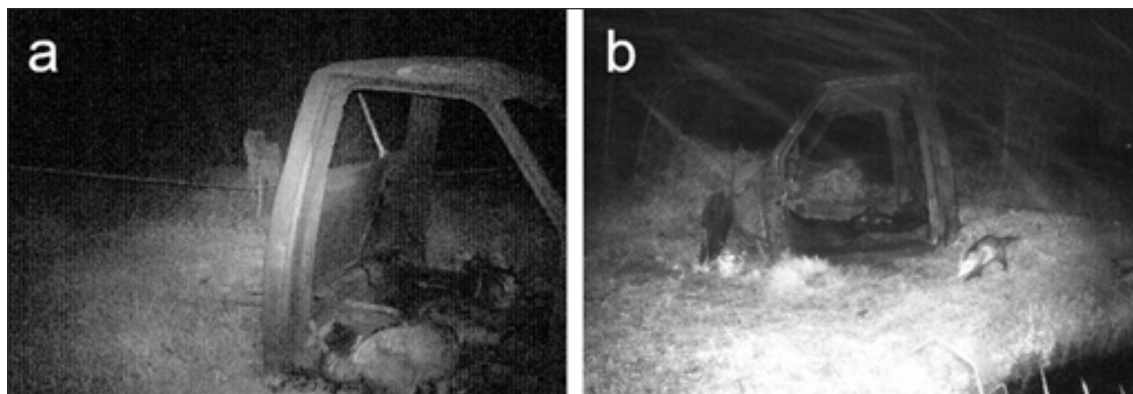


Figure 5: Skeletonized UE4B remains scattered outside the cockpit car (PMI: 24 days and CBS: of 29 points).



Figure 6 summarizes the total scavenging events by species across both experimental units. For EU4B, *Lycalopex gymnocercus* and *Leopardus geoffroyi* exhibited comparable frequencies, followed by *Felis silvestris catus*. Conversely, *Lycalopex* was the dominant scavenger on EU4A, followed by *Canis familiaris* and *Didelphis albiventris*. Among birds, *Pitangus sulphuratus* accounted for the

greatest number of interactions.

Table 1 show *Lycalopex*, *Canis* primarily exhibited feeding and dragging behaviors on EUA, whereas *Didelphis* was observed feeding exclusively. The II identified *Canis* (0,2) as the most impactful scavenger (based on four events), followed by *Lycalopex* and *Didelphis* (see Discussion).

Figure 6: Percentage of total events for all species over EU4A and EU4B

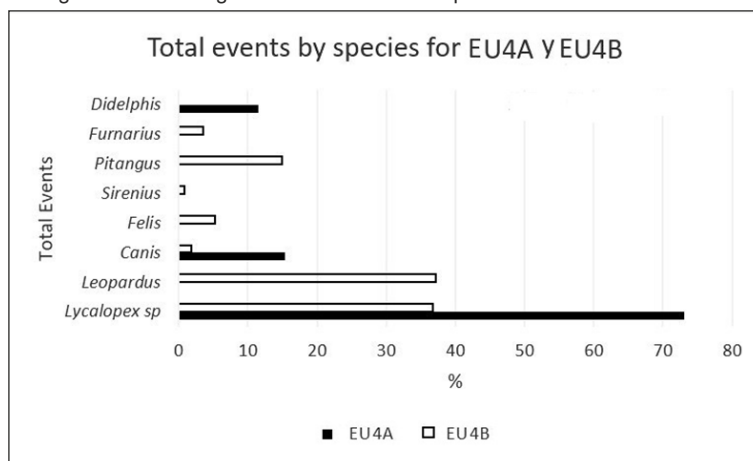


Table 1: Number and duration (in hours, minutes and seconds) of events by species in the EU4A. II (interaction index– total time/total events)

Specie	Prowls	Exploration	Mark	Feeding	Dragging	Total Time	N° Events	IE
<i>Lycalopex sp</i>	00:19:30	00:00:00	00:00:35	00:07:45	00:07:25	00:27:30	19	0,014
<i>Canis sp</i>	00:05:48	00:00:00	00:00:04	00:01:30	00:01:20	00:08:42	4	0,2
<i>Didelphis sp</i>	00:00:00	00:00:00	00:00:00	00:00:35	00:00:00	00:00:35	3	0,011

In relation to EU4B, both *Lycalopex* and *Leopardus* recorded 84 total events each; however, *Leopardus* exhibited a lower II (0.16), indicating frequent but brief interactions totalling

approximately 13 hours. In contrast, *Felis silvestris catus* had the highest II (0.38), remaining near EU4B for extended periods without notable physical manipulation (Table 2).

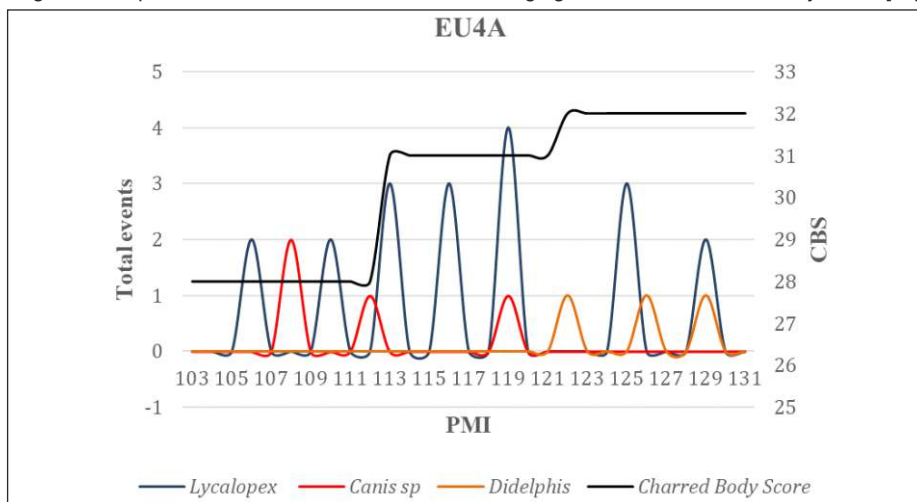
Table 2: Number and duration (in hours, minutes and seconds) of events by species in the EU4B. II (interaction index– total time/total events)

Especie	Prowls	Exploration	Marck	Feeding	Dragging	Total Time	N° Events	IE
<i>Lycalopex sp</i>	28 (03:00:51)	0	0	55 (15:06:42)	1 (00:00:06)	18:07:39	84	0,21
<i>Leopardus sp</i>	37 (03:37:36)	0	1 (00:00:03)	46 (10:17:50)	0	13:55:26	84	0,16
<i>Canis sp</i>	3 (00:24:06)	0	0	0	2	00:24:06	5	0,048
<i>Felis silvestris</i>	2(00:00:03)	0	0	10 (04:59:32)	0	04:59:33	12	0,38
<i>Serinus sp</i>	1 (00:24:39)	0	0	1 (00:24:39)	0	00:49:18	2	0,24
<i>Pitangus sp</i>	21(01:31:11)	0	0	13 (02:16:45)	0	03:47:56	34	0,10
<i>Furnarius sp</i>	2(00:4:55)	0	0	6 (01:07:39)	0	01:12:34	8	0,14

Although all scavenger species—both mammals and some birds—interacted with both experimental units, mammals had a more substantial impact in terms of carcass modification and disturbance. Figure 7 presents the total mammalian scavenger events post-ignition on EU4A (PMI 104; CBS 32) over the 30-day observation window. *Canis*

familiaris accessed the remains on 4 occasions, while *Lycalopex* was involved in 19 events. *Didelphis* appeared less frequently and only during the final phase of the study. Neither *Leopardus geoffroyi* nor *Felis catus* were observed scavenging EU4A.

Figure 7: Sequence of total events of mammal scavenging over EU4A. Cherred Body Score [29].

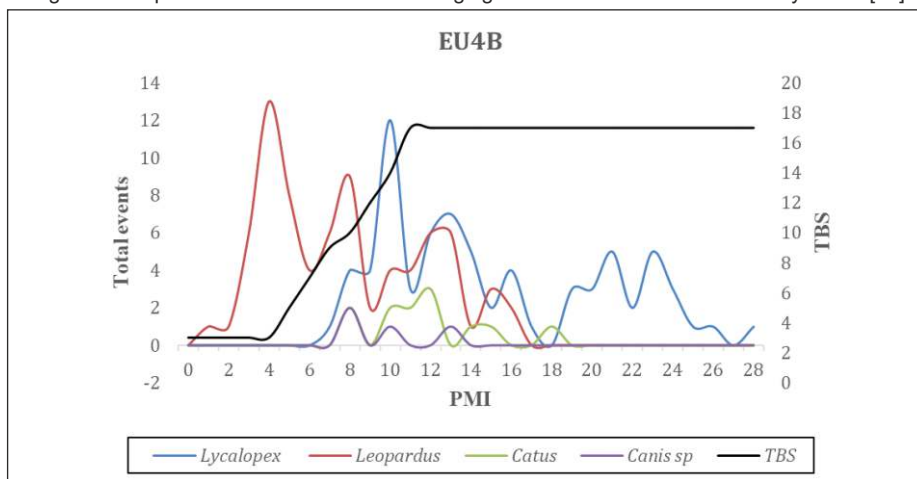


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Figure 8 illustrates scavenger access to EU4B over the 30-day monitoring period. *Leopardus* was highly active in the

early phase, peaking on PMI 1–3 (CBS 3–6), and continued interacting until PMI 18 (CBS 20). *Felis silvestris catus*—and to a lesser extent *Canis familiaris*—were more active during intermediate CBS stages (around CBS 16). Notably, *Lycalopex gymnocercus* was the only mammal to consistently interact with both EU4B and EU4A. Excluding avian scavengers, *Lycalopex* remained the sole species interacting with remains during the most advanced stages of decomposition and thermal alteration.

Figure 8: Sequence of total events of scavenging mammal over EU4B. Total Body Score [52].

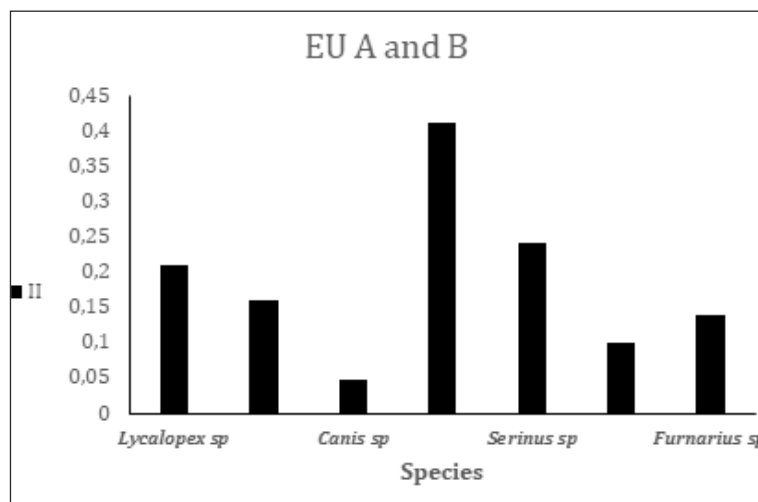


5. DISCUSSION.

Regarding scavenger behavior, the main mammal species observed show distinct activity patterns. *Lycalopex* (7–10 kg), predominantly nocturnal and crepuscular, occasionally exhibits daytime activity [46]. *Leopardus* (4–7 kg), also nocturnal and crepuscular, likely competes with *Lycalopex* for

resources. *Lycalopex*'s gregarious nature and larger size explain its greater and more consistent access to EU, reflected by a higher II. *Leopardus* exhibits frequent visits but shorter contact periods. *Felis* displays high interaction indices despite fewer visits, indicating prolonged scavenging during each event (Fig. 9).

Figure 9: Interaction Index (II) by species on EU4A and EU4B.



Solitary and primarily diurnal, *Felis* actively avoids nocturnal species such as *Lycalopex* and *Leopardus*. *Canis* (11–40 kg) rarely approached EU4B during early decomposition stages but scavenged actively once remains became skeletonized (PMI 130; CBS 32).

These behavioral dynamics support the notion that competitive displacement and temporal niche partitioning occur among sympatric scavenger species in semi-urban habitats. Furthermore, the extended presence of *Lycalopex* across both early and late PMI stages suggests opportunistic flexibility in feeding strategies, likely driven by carcass accessibility and minimal human disturbance.

Although documented felid scavenging cases are infrequent [56], *Felis catus* scavenging primarily involves superficial soft-tissue consumption with minimal skeletal modification, resembling *Lynx rufus* patterns more closely than typical domestic cat behaviors [38]. *Felis catus*'s smaller size and reduced bite force limit its capability to penetrate bony structures. However, both *Felis catus* and *Leopardus* accessed EU4B early in the decomposition process, a behavior noted in other contexts [57]. Their absence in later decomposition stages (EU4A) suggests a preference for fresher tissue [56].

The early involvement of felids also highlights their potential forensic relevance in the initial postmortem interval, particularly in settings where other scavengers are temporarily absent or delayed. This challenges prior assumptions that felids are exclusively late-stage scavengers and may assist in refining temporal models for forensic PMI estimation.

The scavenger-induced disarticulation sequence observed at EU4B begins with soft tissue consumption, followed by anatomical dismemberment and dispersal outside the vehicle. Specifically, scavengers first consumed neck, chest, and abdominal tissues, exposing the sternum, ribs, and dorsal vertebrae. Subsequently, the abdominal and pelvic tissues were consumed, leading to disarticulation at the dorsolumbar junction. Finally, dorsolumbar portion vertebrae and hind limb tissues were consumed. This sequence aligns with observations by other authors (e.g., [58, 41]). On PMI 19, EU4B remained 50% articulated, progressing to 90% disarticulation by PMI 30. The scavenger's success in overcoming clothing barriers to access pelvic or shoulder regions greatly influenced this sequence. Anatomical peculiarities, such as those found in pigs, may also affect disarticulation patterns [46]. Similar ecological studies reported complete disarticulation within comparable PMI periods (autumn-winter: 14 days; spring-summer: 20–23 days; see [46]).

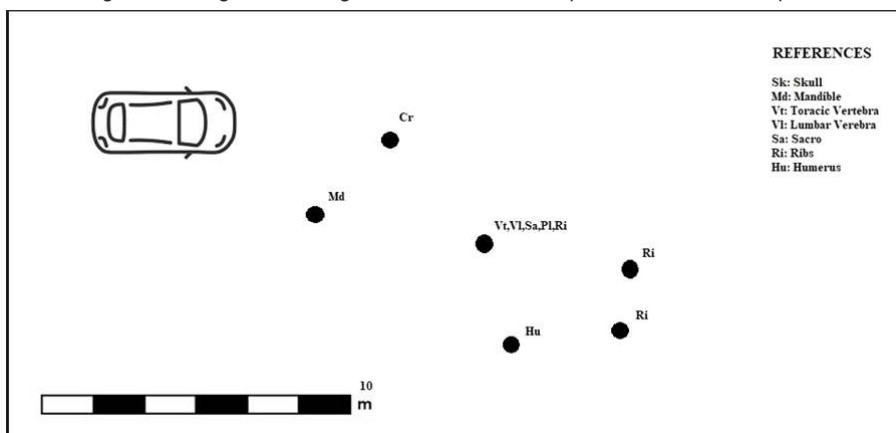
The results emphasize that scavenger-driven anatomical disruption is not random but reflects a patterned and staged progression influenced by both environmental conditions and body positioning. This predictable sequence may assist in reconstructing postmortem manipulations, including whether movement occurred pre- or post-burning.

Dispersion of remains covered approximately 314 m², predominantly northward, beginning on PMI 21 and concluding by PMI 28 (Fig. 10). The scavenger-induced alterations depend significantly on animal characteristics, density, variety, and distribution. Given the study area's natural yet spatially constrained habitat, limited animal

density and species diversity are expected. However, the observed directional bias in bone dispersal may also reflect scavenger escape routes, carcass orientation, or terrain

features, which should be considered in forensic reconstructions of outdoor death scenes.

Figure 10: Diagram showing the vehicle and the dispersion of anatomical parts.



The pre-fire condition of remains is also relevant, influencing forensic reconstructions of death circumstances. While heat-induced bone changes are not completely reliable indicators, notable differences exist between bones burned with tissue and dry bones [19; 59]. Bodies burned inside vehicles typically exhibit limited soft-tissue loss in the torso, calcination of extremities, and charring on the skull front

consistent with high-temperature exposure [60]. Skeletal representation with non-burned joints suggests combustion occurred prior to complete skeletonization, whereas alterations in smaller bones (phalanges, carpals, tarsals, etc.) may indicate secondary depositions from previously skeletonized or dry bones Fig.11.

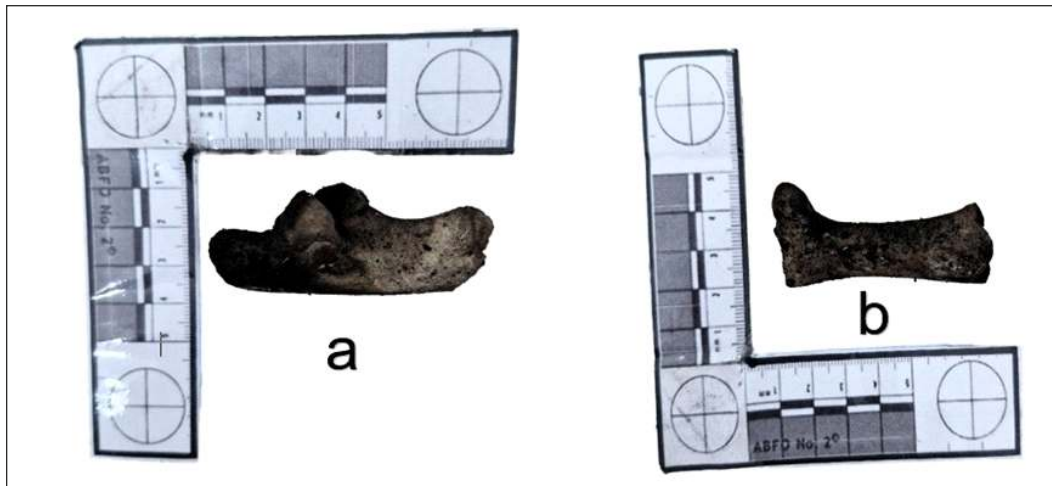
Figure 11: Scapulae and humerus from EU4B showing surfaces without traces of burning



Uneven combustion patterns further support scenarios involving already disarticulated remains (Fig. 12). Identifying heat-induced alterations on dry bones helps exclude thermal exposure as the cause of death, facilitating forensic interpretations. Moreover, clothing and personal items on

skeletonized remains provide additional clues regarding the body's state prior to combustion [21]. Therefore, integrating thermal, anatomical, and behavioral taphonomic indicators enables a more nuanced reconstruction of peri- and postmortem events in burned body contexts.

Figure 12: a) A heel from EU4A showing surfaces with traces of burning and (b) Phalanx with traces of burns.



6. CONCLUSION.

Experimental studies employing biomodels have significantly advanced our understanding of perimortem events associated with thermal alteration. Fire is frequently used to obscure or destroy forensic evidence [21; 52; 61]. One of the primary challenges in forensic investigations is victim identification, which can be complicated not only by fire effects and the postmortem interval (PMI), but also by taphonomic factors such as scavenging, which can drastically modify the body's morphology [23].

Although research in this field has progressed considerably over the past three decades [66; 63], most studies have focused on laboratory-based experiments investigating heat-induced macroscopic changes to bone, their correlation with temperature and exposure duration, and the most suitable analytical methods [20; 21; 22; 64; 65]. Despite this substantial body of work, relatively few experimental studies have been conducted under outdoor conditions [62; 64; 66].

In this context, the present study aims to expand forensic knowledge regarding scavenged, thermally altered remains through field-based experimentation. The specimen labeled EU4A experienced 104 days of thanatological progression inside a vehicle cabin before being subjected to incineration was scavenged by *Lycalopex*, *Canis* and as lesser extent *Didelphis*. The earliest scavengers observed accessing

EU4B were *Leopardus* and *Lycalopex* on day 1 of the PMI, followed by *Felis* and *Canis* on day 7, and *Didelphis* on day 25. However, *Lycalopex* and *Canis* were the primary agents responsible for consumption and anatomical disruption in both experimental units. Scavenging activities involving disarticulation, dragging, and dispersal of EU4B's remains persisted for 30 days, ultimately covering an area of 314 m² surrounding the vehicle. *Lycalopex* was the dominant contributor to this process, followed by *Canis*.

Avian scavengers were also documented feeding on burned soft tissues—likely attracted by insect larvae—particularly *Furnarius* (ovenbird) and *Pitangus* (great kiskadee). EU4A's remains were predominantly consumed by *Canis*, with *Didelphis* playing a lesser role even after 135 days of PMI.

Preliminary observations suggest that fire-related alterations on skeletal elements may reflect the decomposition stage at the time of burning. For instance, articulations in EU4B exhibited no evidence of thermal damage, whereas EU4A showed burn traces on the joint regions of carpal bones, phalanges, ribs, and vertebrae. This pattern suggests that fire affected anatomical elements that were already skeletonized or undergoing advanced decomposition.

Research involving the burning of whole bodies [67; 68] underscores the complexity of combustion processes, as burn rates vary depending on anatomical region and tissue

composition [68]. Our findings highlight the importance of distinguishing between remains burned with intact soft tissue and those burned in a decomposed or skeletonized state. Such differentiation can enhance reconstructions of events spanning the PMI and the thermal incident.

In summary, this study underscores the value of field-based experimental research in complementing controlled laboratory findings. There is a clear need for additional experimental studies employing both simultaneous and diachronic designs to improve our understanding of burned human remains. A more refined understanding of how combustion interacts with decomposition is critical for improving PMI estimation. Currently, the applicability of traditional PMI estimation methods to fire-modified remains remain uncertain. Identifying specific decomposition patterns and rates in charred bodies can significantly aid forensic investigators in planning recoveries and reconstructing perimortem and postmortem events [31].

Finally, ecological perspectives remain underutilized in forensic taphonomy. We strongly advocate for the integration of concepts, study designs, and expertise from related disciplines. Biological remains are subject to extensive modification by scavengers, leading to the destruction of tissues, dispersal of skeletal elements, and scattering of personal effects [68]. Integrating forensic case data with controlled experimental research provides a critical foundation for generating new insights essential for interpreting complex forensic contexts.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT.

Atilio Nasti: Writing – original draft, Writing – review & editing, Supervision, Project administration, Investigation, Formal analysis, Conceptualization. **Iván Díaz:** Formal analysis, writing – original draft, Writing – review & editing, Conceptualization.

ACKNOWLEDGEMENTS.

The authors would like to express their gratitude to the authorities, staff, and students of IUGNA for their support and assistance during the research activities.

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