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Importance and role of neotaphonomic collections: the example of microvertebrate and experimental collection management

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Abstract

The development of taphonomy has improved our knowledge of site formation and palaeoenvironmental reconstructions. It has also stimulated many neotaphonomic analyses that bring clues to some of the alterations and modifications processes of fossilisation and accumulations. This article aims to show that such neotaphonomic analyses and experiments, by generating a lot of valuable material and associate data, need to be integrated into official collections for future preservation. We will focus here upon two examples of neotaphonomic collections: 1 owl pellet microvertebrate collections and 2 collections resulting from experimental work (simulation and monitoring). We detail some problems for incorporating such new type of materials in Museums and some requirements for their curation. In the era of open science, there is a need to improve the management and curation of such unconventional collections to incorporate them into future classical comparative research, training and education as well as exhibitions.

Keywords : Taphonomy; predation; experimentation; fossilisation; collections; curation.

Introduction

Taphonomy is the transdisciplinary science devoted to the study of the transition between biosphere and lithosphere (Efremov 1940). It gained its maturity since then and constitutes for palaeontologists and archaeologists an invaluable source of data concerning fossilisation and accumulating agents of artefacts and bones in all types of sites (Dominguez-Rodrigo et al. 2011; Fernández-Jalvo and Andrews 2016; Behrensmeyer et al. 2018).

Taphonomic studies can be divided into two main categories: 1) analyses of modern accumulations and experimental works (neotaphonomy or actuataphonomy or experimental taphonomy), and 2) study of fossil assemblages (palaeotaphonomy) (Briggs 1995; Efremov 1940). Both types of studies are devoted to the better understanding of the patterns and processes of accumulation and fossilisation. In general, neotaphonomic studies serve as modern referential database to better

understand the formation of fossil accumulations (palaeotaphonomy) based upon the principle of actualism (Andrews 1990, 1995; Denys 2002; Iniesto et al. 2013).

Numerous scientific publications have documented the constitution of a great corpus of modern referential data, either resulting from fieldwork or from laboratory experiments, and their application to palaeontological or archaeological materials. These studies are generally not accompanied by deposition of the collected or experimentally created materials in an official institution. Furthermore, it is impossible to have access to the reference collections and to consult them via databases or special funding agencies and programmes (e.g. Synthesys) or to find an official curator in charge of these data and specimens. Indeed, there is often active opposition to the storage of taphonomic collections, as for example at the Natural History Museum, London. Some reasons concern potential risks for insect damages or the limits in terms of collection technicians available for such tasks. Consequently, except by close contact with researchers and colleagues, it is also nearly impossible to see the specimens, associated datasets, protocols, images or materials resulting from some experiments and to compare them with replicas or fossil material.

In front of the growing evidence and the increase of research in neotaphonomy, this paper explores what is a neotaphonomic collection, its use and importance based upon the authors' experiments in vertebrate palaeontology and zoology curation. It also suggests strategies for managing and incorporating these datasets and samples into established institutions. Finally, this paper also considers the different types of collections that may interest anthropologists or palaeontologists involved in taphonomic issues.

What is a vertebrate neotaphonomic collection?

Terrestrial vertebrates are a major component of global biodiversity, including mammals, amphibians, reptiles, birds and fish, with more than 63.000 species described so far. They are characterised by a bony skeleton with a vertebral column, and they live in all continents and habitats on Earth. They are known to fossilise in great abundance in various types of palaeontological and archaeological sites of all ages.

Because soft tissues are rarely preserved in palaeontological or archaeological sites, bones and teeth are the elements that are most often recovered and then studied in these contexts. For zoological purposes, modern vertebrate skeletons are generally housed in osteological or comparative anatomy collections in Palaeontological or Zoological Departments of Institutions, thus representing valuable references which have an interest in identifying fossil specimens and for taxonomical studies (GBIF (<https://www.gbif.org>), CETAF (<https://cetaf.org>), Palaeontology databases like Palaeobiology database (<https://paleobiodb.org>) and others.

What is less common is the existence in these institutions of official registered collections made primarily for taphonomic purposes. Researchers in neotaphonomy generally preserve their own collections for use as reference material in their research. We will explore such types of collections because they can be of different nature. Globally it is possible to distinguish between three types of reference collections.

First, bones of various origins (different species, continents, climates, environments, geologic contexts, etc.) are accompanied, if possible, by a dataset and protocol of collection, and access can be arranged as references. These bones may be characterised by typical surface modifications and breakage pattern resulting from various biologic and nonbiologic taphonomic agents (see Fernández-Jalvo and Andrews 2016). One can cite bone assemblages recovered punctually or in specific

locations and environments displaying typical weathering, tooth marks, rounding, root marks, breakage patterns. In that case, the added taphonomic value consists precisely in the preservation of these modifications, and the documentation of their origins. These collections are often made by palaeontologists with the specific aim of providing a database for comparison with fossil assemblages, and in this category one can find collections of owl pellets or carnivore faeces, which are likely to be associated with identified predator species and precise geographic provenance.

Small mammal remains are also collected in large numbers as predation accumulations by zoologists and are used routinely in regional faunal inventories and in ecological studies of different types of predator species. There is an abundant available literature on this issue (see for example Denys et al. 2023 for northwestern Africa, or Glue 1967, 1974; Webster 1973 for the UK). These studies consist in the taxonomic identification of the prey species found in pellets and faeces on the basis of cranio-dental remains, but there is no indication where the skeletal elements are then preserved. Less usually, these predation assemblages are used as neotaphonomic reference collections, through the study of all skeletal elements, breakage and digestion traces. But the samples are generally huge and the taphonomic analysis is time consuming, discouraging many researchers from performing such in-depth studies. Since the pioneer work of Andrews (1990), neotaphonomic studies on small vertebrate assemblages have renewed the interest for owl pellets and carnivore faeces collections. When looking at recent literature, we can see an increasing number of such studies. They generate impressive numbers of skeletal elements and data on identified taxa, representation, fragmentation and digestion, as well as associated pictures (e.g. Andrews 1990; Souttou et al. 2012; Lloveras et al. 2014; Fernandez-Jalvo et al. 2016; Campmas et al. 2018; Fernandez and Montalvo 2017; Montalvo and Fernández 2019; Lebreton et al. 2020; Linchamps et al. 2021), which are generally not entered into official institutions collections, while all the samples and results of these studies constitute original reference material and improve future possibilities of taphonomic work.

Second, neotaphonomic vertebrate collections may result from experiments on bones, which involve the use of datasets and precise protocols. Such experiments can include the impact of 'natural' processes such as decay, in vitro and in vivo digestion, water and wind transport, weathering, trampling (Behrensmeyer 1978; Andrews 1995; Denys 2002; Fernández-Jalvo and Andrews 2003; Rozada et al. 2018; Gäh et al. 2020; Fernández-Jalvo et al. 2022; Denys et al. 2023). They can also refer to anthropic actions such as fracturing, burning, production and use of bone tools and ornaments, etc. (from former publications Brain 1981; Stiner 1991, to recent experiments Blasco et al. 2014; Cáceres et al. 2002; Mateo- Lomba et al. 2020; Reidsma 2022; Pineda et al. 2023). Similarly, associated samples, protocols and images are most often not mentioned as preserved in any institution. Other types of analyses were also conducted on modern bones from owl pellets, notably on the preservation of organic materials and DNA (e.g. Briggs and Mc Mahon 2016; Guimaraes et al. 2016), microstructure and chemical composition of prey-bones (e.g. Dauphin et al. 2015) with the final aim to better understand diagenesis processes in fossil context, as well as modalities of exceptional preservation. Other methods use also these collections for isotopic analyses as well as for the studies of dental microwear or organic and the research of organic dental residues in order to monitor ethnology and archaeology of bones exploitations as well as paleodiets or paleoenvironments (Gehler et al. 2012; Jeffrey et al. 2015). In future, other methods and techniques will develop and neotaphonomic collections stored with monitoring notes along a long time-span may become especially relevant to calibrate, for instance, the influence of anthropic disturbance or the current climate change situation.

Third, collected bones or their images may result from long-term eco-taphonomic monitoring performed in same localities during one or several years (Andrews 1995; Andrews and Fernández-Jalvo 2019; Andrews and Whybrow 2005; Behrensmeyer 1978; Behrensmeyer et al. 2007, Global Weathering Project <https://taphonomyworkinggroup.wordpress.com/2017/12/16/global-weathering-project-protocols/>). Some studies aim to follow the global change at the aim of a region during long-term observations (Escribano et al. 2016).

In all these cases, the different types of collections generate a lot of material and associated data. These include lists of anatomical elements and the species to which they belong, data on their provenance, data on the results of various methods and analyses accompanied by associated digital pictures, SEM pictures or chemical and physical spectra resulting from various types of analyses (infra-red spectra, EDS, etc.). These data can be applied to any damages induced on the bone surfaces or microstructures. However, at present, there is no available protocol for the preservation of these materials, while they need to be adapted for future research and perennial conservation and access.

What is the use of such collections?

Like other types of scientific collections, there are three modes of use that concern: 1) research, 2) training and education and 3) wide public communications and exhibitions.

Research

The naturalist collections resulting from surface collections are employed as references for descriptions of conditions, patterns and processes of modifications of bones and other artefacts. Some articles describe these modifications only but generally one can see a direct application to a peculiar fossil assemblage of the same region (Andrews 1990; Pinto Llona and Andrews 1999; Linchamps et al. 2021; Marin-Montfort et al. 2022). In general, these studies focus upon a type of predator or prey and apply their results to answer hypotheses related to site formation, following the principle of actualism. As an example, the studies about the harfang snow owl (*Bubo scandiacus*) accumulations relate directly to European and Scandinavian glacial periods small vertebrate accumulations (Royer et al. 2019). The monitoring of predation and its effects on wild large mammal bones from the primary forest of Bialoweza also correspond to this approach (Fosse et al. 2012; Fourvel et al. 2014). Similarly, Berger and Clarke (1995) and more recently Behrensmeyer et al. (2007) analysed food remains of crowned eagles (*Stephanoaetus coronatus*) from different geographic areas (South Africa and Ivory Coast) that predated upon monkeys, and they concluded that these raptors were responsible for killing the young individual of *Australopithecus africanus* and bringing its remains to the tufa shelter in Taung (South Africa), one of the Cradle of Humankind sites. The development of studies and collections of mammalian carnivore bone accumulations in repositories like dens, lairs, also allow to provide better understanding of human evolution and the use of its habitats and characterise each predator actions (Domínguez-Rodrigo et al. 2022 and references herein).

Neotaphonomic experiments are designed generally to answer directly the causes of unknown type of artefact or modification marks on bones. Darwin (1881) was puzzled by in situ burial of objects in his garden at Down house, and he showed experimentally that they were buried by earthworms, and this was subsequently shown to apply to burial of small mammal bones (Armour-Chelu and Andrews

1994). They are applied to peculiar fossil sites. Many scientific articles include both experiments and their implications for a fossil site (Domínguez-Rodrigo 1997; Lev et al. 2020). Bone collections resulting from artificial breakages by various types of tools or burning experiments are also to be preserved and data be accessible to researchers for comparison purposes. Some other taphonomic experiments in zoological gardens or experimental fields may also concern various disciplines like anthropology, and forensic sciences (Gutiérrez 2021; Udoni 2021).

Training and education

Neotaphonomic microvertebrate collections are used in colleges and universities for teaching purposes. For instance, at the MNHN Paris and at the University of Bournemouth, some MSc courses that utilise intact or dissected owl pellet collections include comparative vertebrate anatomy, zooarchaeology and taphonomy. Students are asked to sort through the pellets and identify the bones and other remains, and determine the species to which the skulls belong. They observe alterations in bone surfaces and relate them to the type of predator, and study variations in specific composition between assemblages from different localities. This provides students a hands-on learning experience to address the concepts of foods webs, predator-prey relationships, ecology, digestion, breakage modifications, etc. (Figure 1)

Many Master thesis degrees, PhD students and second year veterinary students also begin their training in taxonomy, taphonomy and small mammal diversity with owl pellet assemblages in a research lab in MNHN Paris. It is not possible to cite all the works that have been produced over the past 20 years, but we can cite Bruderer and Denys (1999), Cacciani (2004), Denys et al. (2004). Some of these works have been recently published (Rey-Rodríguez et al. 2019; Linchamps et al. 2021). The corresponding assemblages are housed and catalogued in MNHN collections.

Pedagogic taphonomic collections are always necessary for training students, as they provide examples of how bones and other remains can be modified by biotic and abiotic agents, as well as the processes that occur after burial. Such a collection exists for the MSc students of the teaching module of Taphonomy at the Institut de Paléontologie Humaine (IPH, MNHN, Paris) (Péan and Patou-Mathis oral comm.) but none was developed for small vertebrates and neotaphonomic collections. A collection of pellets produced by nocturnal and diurnal raptors, as well as carnivore excrements that contain predated and digested small mammals, exists at the Natural History Museum of London (Andrews 1990), together with large mammal remains collected by Peter Andrews in Wales (Andrews and Fernández-Jalvo 2019) along a large monitoring period of more than 30 years. This exceptional taphonomic collection joins another special collection generated by Anthony Sutcliffe, consisting of taphonomic examples collected all over the world. Unfortunately, none of these collections are accessible for teaching or research once Peter Andrews retired in 2000. This is in contrast to the taphonomic collections of large mammals created by A.K. Behrensmeyer, both in Kenya and in Washington, that are currently being organised and curated in order to be consulted by visitors, students and researchers, with grants funded by The Smithsonian Institution to facilitate these visits. More modestly, without an associated subsidy yet, neotaphonomic collections of macro- and microvertebrates are also being created at the Museo Nacional de Ciencias Naturales (MNCN) based on monitoring in the field (including pellets and scats of African and European predators) and experimentation in the Laboratory of Environmental Analyses and Taphonomy (LeaT) for teaching and research consultancy. There are also large collections made by researchers at the Complutense University of Madrid (i.e. Manuel Domínguez-Rodrigo, Jose Yravedra) from different large predators

(wolves, bears, hyaenas, lions) also having problems to store them, but directly used for teaching future zooarchaeologists.

However, collections used for teaching are generally small and in palaeontology practicums the focus is mainly taxonomical. Besides, the material used is usually considered as 'expendable' since specimens may be damaged or lost during lab sessions.

Exhibitions

Taphonomic collections are rarely exhibited in Museums. However, attentive visitors can find in some cases bones or lithic objects displaying some information about their origin or modifications. In some cases, the taphonomic history of a site may be presented to the public. For example, in the Ditsong Museum where R. Dart and B. Brain, pioneers of taphonomy, were working, an exhibition shows modern predators and bones and explains the origins of the Taung Child's death by predation (Berger and Clarke 1995; Berger and McGraw 2007). The questions asked by visitors to these institutions show that there is interest in finding explanations about fossilisation, site formation and human behaviours on bones and other objects even though the experimental neotaphonomic collections are not exhibited. In archaeological exhibits there are often displays of methods and results, and although the essential steps of screening, sorting, identifying, bone surface observations are not shown, there is still interest in such studies.

Management and integration to official institutions

Because taphonomic collections are of various types and contain multi-taxon assemblages, it may be difficult to integrate them into official institutions. However, there should be dedicated space for such type of collections, either within osteological collections (Zoology, Comparative Anatomy) or within palaeontological and zooarchaeological collections. It is important that the collections and associated datasets become officially catalogued with paper records and labelling, and incorporated into the official records of the institution. For example, the Andrews collections at the NHM in London have been assigned catalogue numbers and recorded on paper, and are also accessible online. However, the 11 notebooks from his fieldwork have not yet been copied. On the other hand, Sutcliffe's field notes have been transcribed and may be available on request after their publication. Once taphonomic collections are assigned an official catalogue number, it is crucial to cite this number in any scientific publication that references the collection. This not only increases the visibility of the collection, but also facilitates comparison and even enables researchers and institutions to request loans of specimens from each other.

Example 1: curation choices in owl pellet assemblages in MNHN Paris.

In the Vertebrate Zoology Mammals and Birds collection unit in the MNHN, there is a long tradition of collecting owl pellet assemblages from various parts of the world. The best preserved small mammal skulls (Figure 2) are available as specimens of taxonomic comparisons, especially for tropical regions. With the development of neotaphonomic approaches in the 1990's, these collections have gained a supplementary attraction in order to better understand damages on bones during ingestion and digestion by predators (e.g. Mayhew 1977; Dodson and Wexlar 1979; Korth 1979; Denys 1985; Andrews 1990).

Because the assemblages of micromammals resulting from predation are composed of a great number of different small anatomical elements (Figure 2), we encountered challenges in curating and incorporating these collections into the museum's official records and online database. Different solutions were discussed with the curators: 1- incorporate each bone separately, 2- incorporate when possible each pellet or faeces individually without detailing its content, 3-incorporate only the group of pellets or faeces under a single catalogue number.

Solutions 1 and 2 are ideal for the preservation of such type of collection, but they are also high time consuming and require the involvement of many technicians to label each bone and list the content of each pellet or faeces. Moreover, the researcher in charge of the supervision of these listings needs to be an expert not only in osteology but also in small mammal taxonomy to ensure accurate taxonomic identifications. By the fact, a single pellet of *Tyto alba* or *Bubo bubo* generally contains between 1 to 10 skull fragments of small mammals and some other microvertebrates and arthropods (e.g. Campmas et al. 2018; Lloveras et al. 2018; Lebreton et al. 2020; Linchamps et al. 2021). The post-cranial elements may belong to different taxa and their precise attribution to one or another taxon is not easy. For all these reasons, Solution 3 was chosen, which involves gathering under a single official catalogue number each sample of owl pellets that were studied and published in scientific journals. This solution was also adopted for the pellet and scat collections at the NHM of London, and even large mammal bones were recorded in groups from unique taphonomic experiments.

As an example, an analysis was conducted on an assemblage of 33 pellets of *Bubo bubo* collected in Alzon, France, which involved sorting, identifying, and counting skeletal elements (Denys 2017). The skeletal elements were placed in LAB boxes (also used for zoological collections) and zip bags (Figure 3). Before being sorted and studied, they were given a provisional catalogue number (here 1997–10) and were put in a deep freeze (ideally -20°C or more) during a month to kill all insects and other organisms that may potentially be destructive to the pellets, such as moths and carpet beetle larvae, or fungi. During the study, the content of each intact or fragmented pellet was preserved in a small LAB box, and eventually accompanied by a special paper form filled and/or an Excel file. When bones come from a nest, where trampling by the owls themselves (especially juveniles) can destroy them, they are sorted by bone element and put either in boxes or bags. Each of these bags kept the provisional catalogue number and each pellet kept an arbitrary number. The photographed specimens (digital camera or SEM) were put back to the corresponding box of bag. Finally, when the scientific publication is in the way of acceptance, an official catalogue number from the MNHN Paris zoological collection was provided, with a link to the paper catalogue (Figure 3: here number MNHN-ZM-2020-578). This official number is available in the PDF of the publication and reported on each box of the collection to allow further preservation and consultation by visitors. Such types of collection can also be loaned to other researchers on demand.

In order to facilitate further integration of pellets in the future, we have created a form to fill out for the person in charge of opening owl pellets or carnivore faeces during a study (Figure 4). One form is required for each pellet/faeces. It allows later a better counting of skeletal elements and should be kept for future entry in a computer database.

Currently, the MNHN collections have integrated seven published neotaphonomic samples, but about 20 other assemblages still need to be incorporated. The catalogue numbers are reported into an Excel file as well as year of collect, name of the collector, geographic origin, predator, associated publication, but not the whole data corresponding to these assemblages (ie: taxa and faunal list,

bone frequencies, digestion, breakages). Such collections belong to official registers of the MNHN and to throw or remove this collection will need an official reform procedure.

Example 2: Experiments management in MNCN-CSIC

Experiments using small mammal remains have also been done for trampling and compression efforts as well as weathering and cremation. When high breakage is recorded in small mammal fossil assemblages and the predator involved show low rates of destruction (such as Barn owls *Tyto alba*) it is important to contrast potential trampling traits. In order to contrast hypotheses proposed by Andrews (1990) on diagnostic traits to distinguish trampling in small mammal assemblages, an experiment at the LeaT-MNCN was performed and compared to a fossil site case (Wonderwerk in South Africa: Fernández-Jalvo et al. 2022) using a compression instrument. Experiments with small mammal carcasses, owl pellets or individual skeletal elements have also been research subject in Master degree's student grants (eg: see de los Reyes et al. submitted, this issue) especially bones exposed to cremation at a muffle furnace (Figure 5).

Weathering cracking in small mammal teeth from Vizcacha (*Lagostomus*, Rodentia) mandibles has also been obtained by reproducing the parameters of Pampean climate (Tomassini et al. work in progress) in a climatic chamber. Results and pictures of these experiments are available online (see <https://www.mncn.csic.es/en/investigaci%C3%B3n/servicios-cientifico-tecnicos/laboratory-environmental-analyses-and-taphonomy-leat> and Back to the past YFJ_TAPHOS-TWG-3.1.pdf and publications therein at the end of this webpage).

Samples obtained from laboratory experiments (or monitoring collections) are collected as removed from the experiments and kept in boxes labelled and put in drawers of the neotaphonomic collection cabinets (Figure 6). These drawers include publication(s) from the experiment and all available information which is also recorded in computer databases and available to visitors.

Other types of associated collections and curation problems

All referential material and experimental studies generate associated multiformat digital images and graphs as well as numerical data. Some of these data and images may be directly related to a sample. When it bears a collection number, the link must be preserved through databases. Some other images may be displayed in scientific journals or books and become perpetuated, like for instance the Atlas of taphonomic modifications (Fernández-Jalvo and Andrews 2016). Generally, these images are stored by the researcher because few data and images repositories are yet available in Museums and Universities. Moreover, the way in which small mammal fossils are stored in institutions or their treatments for various analyses sometimes damages the specimens for posterior taphonomic research (Fernández-Jalvo and Marin-Monfort 2008). Some fragile fossil or modern bones and species (e.g. bats and birds) may be sometimes preserved in an inadequate way which can make it difficult or even impossible to check for taphonomic modifications such as digestion. For example, in the past, a common way of preserving fossil small mammal teeth with their corresponding reference numbers was to mount them on plasticine. As time passed, the oil from this material seeped into the fossils and made them transparent; the plasticine also hardened, resulting in the fossils breaking when removal was attempted. Hygrometry and temperature may also be important parameters to preserve such types of specimens. We must always keep in mind that such material may also be reconsidered in the future for more sophisticated methods of analyses as well as organic, mineral matter and DNA extraction.

Taphonomic processes accumulate over time and so it is sometimes necessary to include long-term studies in experimental taphonomy. Weathering of bone has been shown to occur at different rates in different climates: up to 15 years in tropical climate (Behrensmeyer 1978), more than 15 years in subtropical climate (Andrews and Whybrow 2005), and more than 30 years in temperate climate (Andrews and Fernández-Jalvo 2019). These lengths of time raise difficulties, and so far it has only been possible to bring one such monitoring experiment to completion, that of the 15 year period of weathering in tropical environments. This period of time was not long enough for the two non-tropical experiments; for after 15 years in subtropical environments, bones were only about half way through the weathering modifications, and in temperate environment they were only about one fifth of the way through. Long-term monitoring of this kind transcends the limits of individual workers and requires departmental approach with observations and collected specimens and associated data passed from person to person over time in the same Institution.

Conclusion

The role of Museums and Universities collections is to preserve our Heritage. The values of collections for research, society and culture have been long commented (Suarez and Tsutsui 2004; Mann et al. 2021). As taphonomic studies contribute significantly to our understanding of the formation of fossil sites and our origins, they must be now given greater recognition and consideration. For each neotaphonomic reference collection, it is essential to provide open and transparent access to their origins, techniques of collection, preparation and consolidation, and generated analyses through official databases and registered collections. These considerations align with the new obligations for open science and data sharing. By achieving a consensus on the curation procedures for neotaphonomic collections, we may reach a global connection useful to research and teaching. Furthermore, our commitment is to pay more attention to the dissemination of scientific knowledge to society through exhibitions or online platforms.

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Figures



Figure 1. Msc students training with owl pellets in MNHN Paris (@Sandrine Grouard courtesy).



Figure 2. Rodent skulls extracted from *Bubo bubo* pellets from Alzon (France) roosting area before entrance into the MNHN collection. The number 1997–10 corresponds to a provisional number attributed before catalogue number for storage before taphonomic study.



Figure 3. Example of *Bubo bubo* assemblage from Alzon with LAB boxes harbouring two labels: official catalogue registration number of the Zoology Mammals collection: MNHN-ZM-2020-578, and the initial study number: 1997-10.

Taphonomic and taxonomic study of pellets or faeces

Predator species:

Location:

Roosting/nesting/den site description:

Pellet/faeces number:

External aspect (color, apparent elements, etc.):

Maximum Length and width:

Small vertebrate skeletal elements:

Skull:

Mandible:

Femur:

Tibia:

Ulna:

Humerus:

Pelvis:

Scapula:

Others (phalanxes, metapodials, calcaneum, talus, etc.):

Identified taxa and corresponding bones:

Skeletal remains number (MNE):

Minimum number of individuals (MNI):

Other elements (splinters of large mammal bones, insects, plants, etc.):

Photographed specimens (morphometry, taphonomy):

SEM Pictures, CT Scanned, 3D, DNA, etc.:

Figure 4. Example of form to fill for raptor pellet/carnivore excrement collections

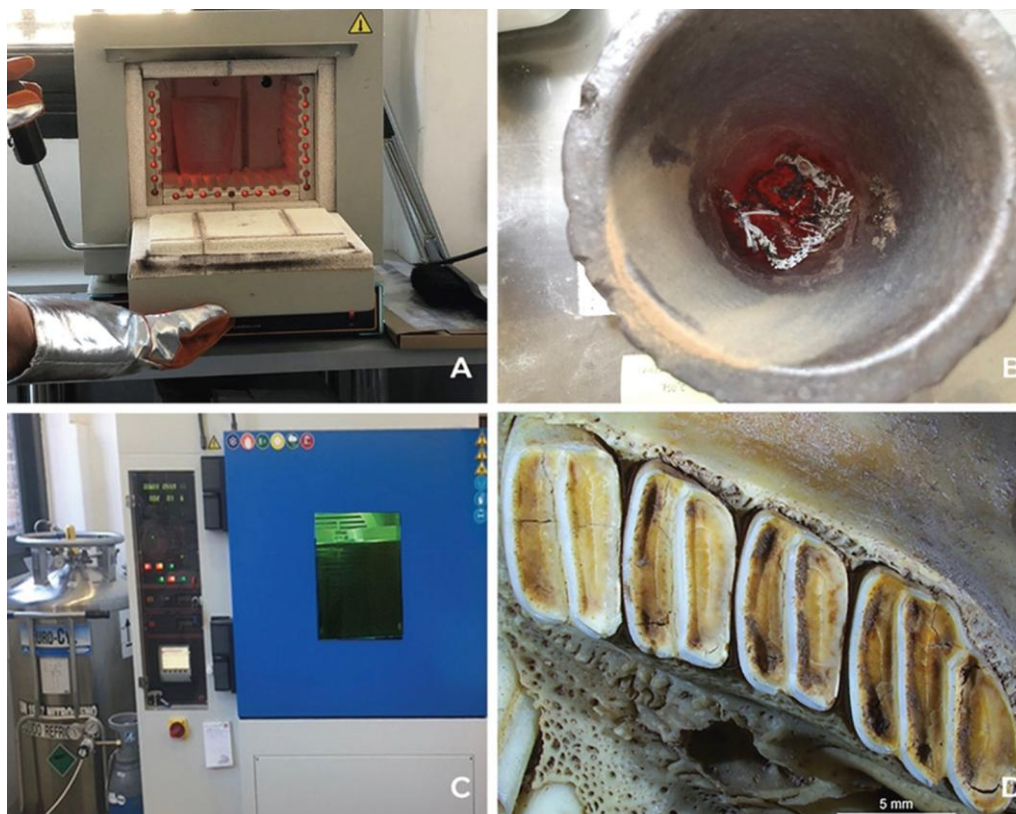


Figure 5. A and B. Mouse carcass burnt at 900°C in a muffle-furnace. The soft tissue, skin and hair consumed and skeletal elements obtained a characteristic white-calcined colour due to exposure to such high temperatures. C: climatic chamber. D. *Lagostomus* mandible teeth weathered (cracked) after 3 months climate simulation (research in progress).

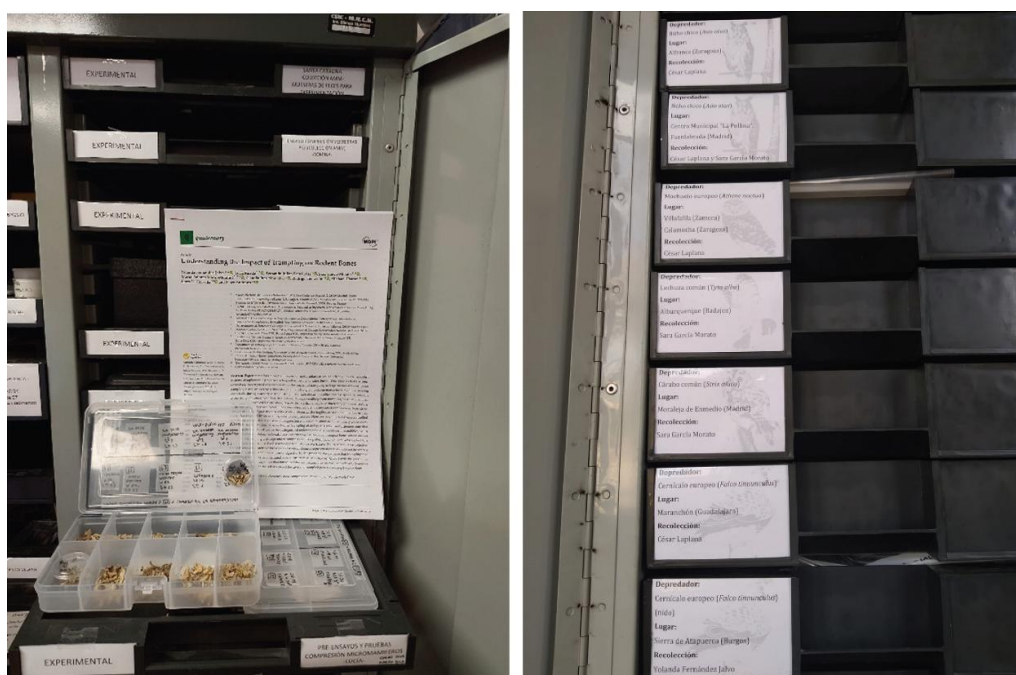


Figure 6. Left: samples from experiment of compression simulating trampling, boxes to keep the different trials and the accompanied publication. Right: samples collected from the nature with indication of the predator, geographical location and collector.