

PAPER**PATHOLOGY/BIOLOGY**

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Taphonomic Marks on Pig Tissue Due to Cadaveric Coleoptera Activity Under Controlled Conditions*

ABSTRACT: The aim of this work was to study taphonomic marks that cadaveric coleopteran can produce under controlled conditions. To evaluate this, pig trotters were initially exposed to adults of *Dermostes maculatus* De Geer at $21 \pm 5^\circ\text{C}$ and a 12:12-h day/night cycle. Observations were made and photographs taken every 4–5 days for 9 months. When feeding and reproducing, *D. maculatus* produced, in both adult and larvae stages, different types of marks such as holes, striations, scratches, and pits in several kinds of tissue such as integumental, connective, and muscular, in both their fresh and dried stages. Bite marks were also evident. The results in this study provide not only taphonomic but also biological and forensic information. This is the first time that this kind of experiment has been performed.

KEYWORDS: forensic science, forensic taphonomy, scavenger animals, controlled conditions, Coleoptera, *Dermostes maculatus*

Forensic taphonomy is the study of alterations that human or animal remains can suffer after death. These changes can result from different factors such as physical variables; environmental conditions; the stage of the corpse; the proliferation of seaweed, fungi, and plants; and the activity of scavenger animals, among others (1).

Several animals can produce these changes: vertebrates such as birds and mammals, as well as invertebrates, mainly insects. Among vertebrates, carnivores can leave different patterns of marks and, as a result, damages in the remains (2–10). When feeding, carnivore vertebrates can not only leave teeth marks or pecks, with different effects on the tissues, but they can also fracture, dismember, carry, and disperse body parts, depending on the species involved (11). Sutcliffe (12) reported that herbivore vertebrates can also produce alterations by chewing bones. The tooth marks and lesion patterns differ according to the kind of animal, and their analysis can lead to its identification (13–15). Consequently, if these physical and biological factors fail to be considered, a forensic analysis might lead to wrong interpretations and errors induced by the distortion or simulation of the original lesions (16–18).

Invertebrates can also feed on animal and human remains. Insects are an important group involved in carrion consumption and are thus of forensic interest. Aquatic invertebrates can grow upon bone remains and feed on soft parts. A case was reported

by Denic et al. (19) describing body wounds which had been initially confused with acid, but were finally identified as the result from cockroach activity. Some species of Formicidae have been observed to produce marks and lesions potentiated by formic acid (20). Ant postmortem artifacts and bites consist of irregularly shaped areas without skin, winding and scalloped, and may also include small punctuations and other lesions such as scratches. Their coloration usually goes from pink-orange to yellow and is disseminated in a diffused pattern over the skin surface. They can be confused with antemortem wounds such as abrasions or those consisting of small superficial holes produced by acids. Generally, there are no hemorrhages, but they can exist when layers of skin are removed from body parts which have suffered an accumulation of blood (congested body parts). Bites can be misinterpreted as resulting from a blunt object, and they can also disguise antemortem wounds in the neck (21,22). Derry (23) and Light (24) described the osteophagic behavior of termites upon human remains in archeological tombs, and Britt et al. (25) pointed out that they can influence taphonomic processes because they can colonize the burial place and damage bone remains. These authors also suggested that tineid moths (Lepidoptera) can be involved in the deterioration of bones.

The order Coleoptera includes a diversity of species with different trophic roles. Some coleopteran like dermestid, clerid, hispid, and silphid beetles can cause artifacts in human body parts (26). Studies performed by Ururahy-Rodrigues et al. (27) on one Scarabaeidae species suggested that they can cause postmortem wounds and changes in the ground surrounding the body, modifying its original position and the death or discovery scene. These alterations may be confused with the lesions or artifacts which may have actually caused death.

The order Coleoptera is an important group in forensic entomology. Thus, the study of the feeding habits and other biological aspects of scavenger species may represent a great

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contribution to forensic taphonomy. Furthermore, Mazzanti (28) indicated that making observations on the effects caused on skeletons by coleopteran can provide interesting contributions such as ecological and paleontological information. In order to add more information to the scant literature about insect activity relevant to taphonomy, the aim of this study was to conduct research into the artifacts that some scavenger beetles can produce on animal tissue. *Dermestes maculatus* was the species selected for this study because they have necrophagous habits, have been found in forensic cases and succession experiences, particularly in the stages of advanced decay and skeletonization, and are pests in museums and food industries, as well as other manufactures of animal origin. This study contributes data of significant application in biology, ecology, anthropology, and forensics, and the knowledge obtained could be useful in investigation related to animal carcasses and human remains.

Materials and Methods

To perform this study, adults of *Dermestes maculatus* were selected from a culture established in 2010. The colony was obtained from pig carcasses used in field succession experiments performed in Bahía Blanca, Argentina. The adults were taken from cadavers when 10% of the total specimens were available. Fifteen adults were placed inside a 2-kg glass container filled with *c.* 3 cm of sand. The neck of the container was greased with baby oil to prevent insects from escaping. To allow ventilation and eliminate excess humidity and fungal growth, the opening was covered with a piece of voile mesh secured with a rubber band. Protection and a water source were provided by introducing a piece of cotton sprayed with distilled water. To evaluate taphonomic marks, we boiled pig trotters in a pot for 10 min and then exposed for 24–36 h to open-air temperature and humidity, sheltered from the rain, and covered with a piece of voile material to protect them from scavengers. The trotters were photographed for control purposes and then introduced to insects.

Four replicates were carried out. Containers were maintained in a room at $c. 21 \pm 5^\circ\text{C}$ and 12:12-h day/night cycle. Insect activity was observed and photographed every 4–5 days for 9 months. Larvae and pupae were cultured in the same container with the exception of some generations of pupae which were cultured separately to obtain adults for other experiments. Photographs were taken with a NIKON COOLPIX L20 camera (Nikon Inc., Beijing, China).

Results

Dermestes maculatus, both in adult and in larval stages, ate skin, flesh, tendon, cartilage, and bone from the trotters supplied. First, the beetles started carving pits and undulations in soft tissues, and then rounded-oval holes (Fig. 1a). In time, these holes increased in size and number until they joined and formed irregular shapes. Also, mandible impressions appeared in cartilage (Fig. 1b). Examination with greater magnification showed that hole margins were not perfectly rounded because of the insect bites (Fig. 2).

The spaces between the phalanges of the trotters, as well as their ventral skin and the keratin of hooves, were used as a refuge and food source by beetles (Fig. 3). At this point, no holes were observed in bones, which, together with the remaining tissue, were used as refuge. The insects consumed the tissue layers located under the skin, which gave the skin a lighter tone. After

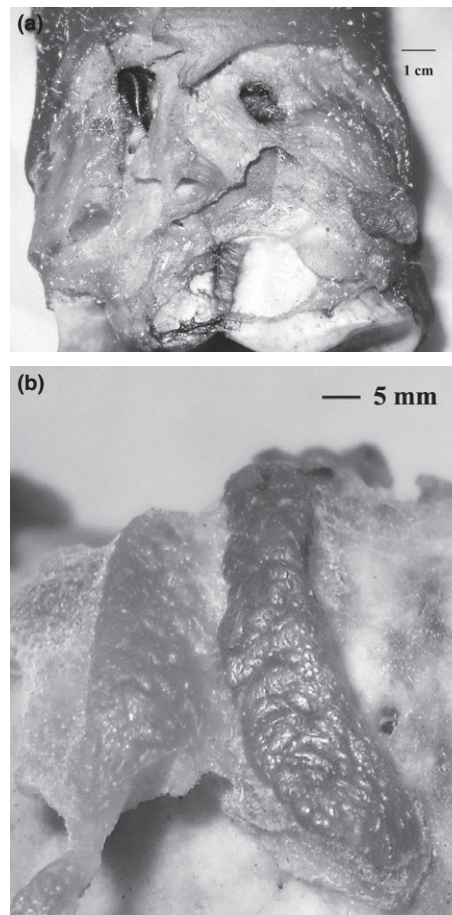


FIG. 1—(a) Larvae inside holes at the initial stages. (b) Marks left in cartilage as a result of mandible impressions.

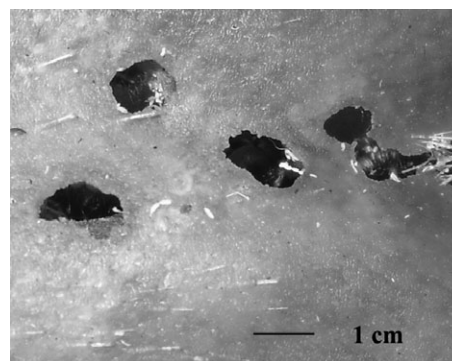


FIG. 2—Irregular borders of holes due to insect bites on the dorsal side of the trotter.

c. 6 months, when little soft tissue remained, the beetles started to eat bones. Daily observations showed increasing amounts of holes on the soft tissues, and almost 9 months later, all tissue had vanished, the bones being easily observed in both ventral and dorsal views (Fig. 4). Borders of the carpal spongy bones were found gnawed, with mandible marks superimposed on large marks; furthermore, one clear pit and others at an early stage of development were identified laterally on the same bone (Fig. 5a). The metacarpal spongy bones also evidenced mandible impressions (Fig. 5b–d).

From the moment the insects started to feed, fecal pellets and shavings from eaten tissue could be seen accumulating on different parts of the trotters, substrate, and cotton.

Pupae were found buried in the substrate or on it, under or between the cotton fibers, and between exuviae and shavings, but not in bones (Fig. 6).

None of the effects found in the trotters exposed to insects were seen in the control samples.

Some of the artifacts described in this section were also observed in colony cultures reared on cow beef.

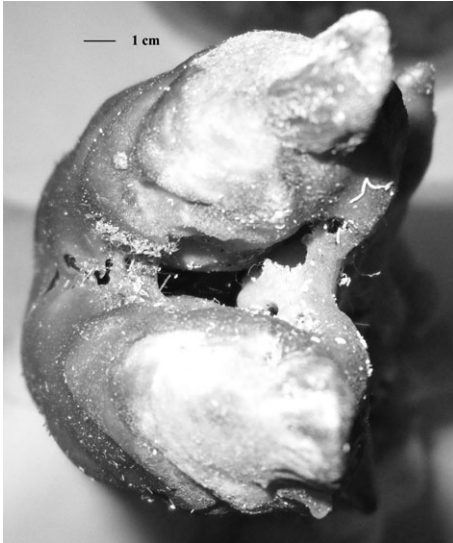


FIG. 3—Spaces between phalanges and hoofs used as a refuge and food source by dermestid beetles.

Discussion

Little attention is given to marks which insects make on corpses or their remains, and although further research is needed, more concern is shown in connection with vertebrate scavenger activity. In this work, *Sus scrofa* L. pig extremities were used as a biomodel because the decomposition pattern of domestic pigs is quite similar to that of the human body. Furthermore, these pigs are easily obtained; their digestive, cardiovascular, and integumentary systems and other body parts are also comparable to human ones; their slaughter is not complicated, and it does not entail ethical issues. Using these pigs as biomodels allows better comparison and extrapolation of results to those from human models (30,31). The trotters were exposed to *D. maculatus* under laboratory-controlled conditions to describe the artifacts which this species can produce not only when feeding but also when reproducing or completing its life cycle. A percentage of dermestids was taken into consideration because, if all specimens or a large number of them had been taken away from the carcass, the processes of decomposition and succession that were taking place could have been altered (32).

Field experiences have demonstrated that the arrival of dermestids is variable and may happen during the first days of decomposition (personal observation, 33). Trials at the beginning of this study showed some small scratches on skin and connective tissue before the elimination of the pig extremities as a consequence of fungus formation, which could indicate that dermestids can produce marks in the earlier stages of decomposition. For the purposes of the present study, in order to prevent fungus formation, the action of other contaminants, and the disguising of marks, the trotters had to be boiled and partially dehydrated. Furthermore, some reports have described skin beetles as consumers of partially wet tissue (25,34), whereas

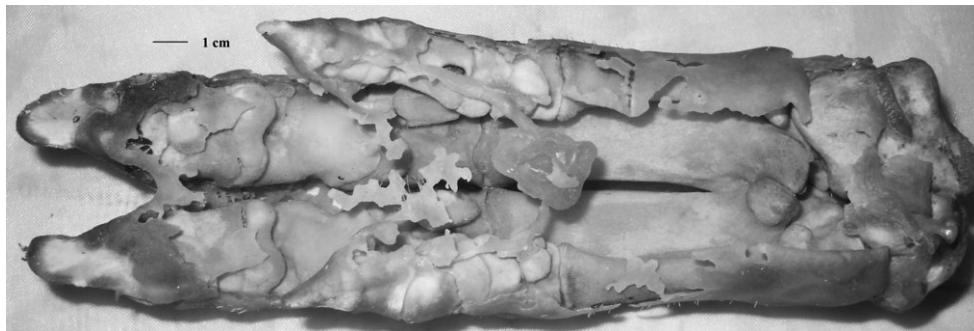


FIG. 4—Ventral view of the pig trotter after 9 months of insect activity. Remnants of skin and bones are easily observed.

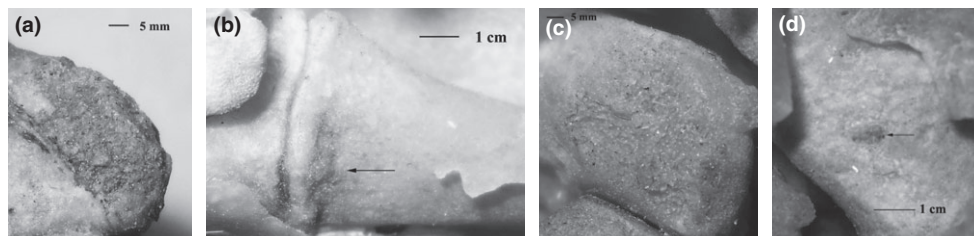


FIG. 5—(a) Detail of the intensively gnawed carpal spongy bone with mandible marks superimposed on large marks. All topography is the result of consumption. (b) Mandible marks on metacarpal spongy bone. These effects are indicated by an arrow. (c) Mandible marks on metacarpal spongy bone. (d) An incipient pit (arrow) and other effects on surrounding areas of the carpal spongy bone.

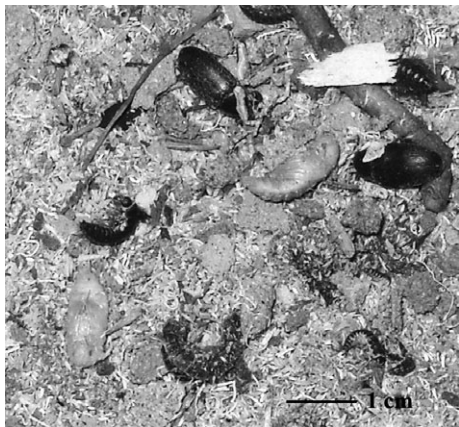


FIG. 6—Pupae over substrate, between exuviae and shavings.

other authors performed heating treatments to disinfest tissue when carrying out experiments under controlled conditions (35–40).

We found *D. maculatus* beetles to initially prefer soft tissues such as muscle, cartilage, tendon, and integument; their activity produced undulations, small pits, and finally rounded-oval holes which gradually assumed irregular shapes. Schroeder et al. (41) observed only small rounded edges on the remnant skin of a dead body caused by *D. maculatus*.

Other results evidenced in this work show that beetles frequently used the spaces between and under the phalanges of the pig trotters and that the skin seemed to become translucent. Continuous observation throughout the experiment demonstrated that areas eaten by insects matched lighter skin areas and that those still with connective or muscular tissue could be seen through the skin, looking reddish or darker.

In this study, the fecal pellets and shavings were soon seen accumulating over the trotters, substrate, and cotton. Their identification is important because they could be used as a forensic indicator of beetle presence, as suggested by Schroeder et al. (41).

We also found that, when soft tissue became scarce, scratches, mandibular marks, undulations, and pits appeared on the bones. Indeed, Britt et al. (25) and Schroeder et al. (41) found a variety of dermestid traces such as grooves, mandibular marks, and incipient pits at different stages of development on dinosaur and human bones. We found no holes or tunnels in bones during the period evaluated, contrary to reports by Di Donato and Del Papa (16) with *D. peruvianus*. This could be explained by the fact that damage inflicted to the bones depended on the amount of soft tissue provided (42,43) and on the species involved (44).

The species in the genus *Dermestes* can build chambers of different materials, particularly firm substrate, to pupate, or they can do so within the last larval cast without the need of a chamber (45,46). In our study, pupation was seen occurring in different places, but not in bones. The presence of materials such as sand, wood, and cotton, usually employed to rear colony cultures (personal observation), may have been preferred by the larvae to pupate, instead of bones. This last observation agrees with that of Martin and West (47), who mentioned that pupal chambers in bones were uncommon and had only been identified in fossil bones. Furthermore, Kreyenberg (45) has indicated that dermestids prefer to pupate away from their food source to prevent cannibalism. This could also explain the presence of few, incom-

plete pits on bones, found at different stages in this study. Besides, more time might be needed for pupal chamber formation. Regarding this, the information published until now has been based on fossil bones or bones related to forensic cases, but those bones could have experienced many changes until the moment they were found.

Benecke (26) has reported that Histeridae and Silphidae can cause lesions that resemble close-range or long-range gunshot wounds. Although no similar conclusions could be made herein because legal permission to use firearms is not easily obtained, the detailed examination of marks with more magnification showed irregular borders and mandible impressions resulting from insect bites. Britt et al. (25) also took photographs of *D. maculatus* mandibles and their marks in bones. These findings could help relate different species to corpses or remains. Future research might focus on comparing marks to different types of weapons, when permission to use them is obtained.

No quantitative measurements of beetle marks have been recorded for this paper, but such information is currently being obtained as part of a different study. Furthermore, a different methodology must be used because marks can change due to beetle action.

Although the replicates have not been compared quantitatively, the qualitative analysis indicated that they were similar.

In conclusion, *D. maculatus*, in both adult and larval stages, is a scavenger capable of producing artifacts in different tissues of pig extremities, as observed under controlled conditions. This novel data could not only be useful when studying or presenting cases of animal carcasses, but it could also be extrapolated to case studies involving human remains, as well as scientific research. This could help professionals to conduct more effective work, as well as contributing more information to taphonomy and other forensic sciences.

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