Journal of Mammalogy, 101(4):923–925, 2020
DOI:10.1093/jmammal/gyaa067
Published online June 22, 2020

Innovations that changed Mammalogy: dermestid beetles—the better way to clean skulls

Robert M. Timm,* Suzanne B. McLaren, and Hugh H. Genoways

Biodiversity Institute and Department of Ecology & Evolutionary Biology, University of Kansas, Lawrence, KS 66045, USA (RMT)
Section of Mammals, Edward O'Neil Research Center, Carnegie Museum of Natural History, Pittsburgh, PA 15206, USA (SBM)
University of Nebraska State Museum, University of Nebraska-Lincoln, Lincoln, NE 68588, USA (HHG)

**Correspondent: btimm@ku.edu*

The use of dermestid beetles to clean vertebrate skulls and postcranial skeletons is a technique that results in beautiful skeletal preparations. The widely distributed carrion beetle, *Dermestes maculatus* (Coleoptera, Dermestidae), often called the hide beetle, is the most commonly used species (Fig. 1). The innovation of using beetles that generally are thought of as pests in households, stored grain, and the food service industry, was discovered independently at least twice—in France in the 1870s and again in the United States in the early 1900s (Timm 1982). Mammalogists wrote many of the original published descriptions elucidating how to cultivate and effectively use dermestids to clean skulls and other skeletal material, and the first articles appeared in the pages of the *Journal of Mammalogy* (Hall and Russell 1933; Borell 1938). Most subsequent papers on improvements in dermestid husbandry also were written by mammalogists (Somer and Anderson 1975; Williams et al. 1977; Williams and Rogers 1989; Williams and Smith 1995).

The modern use of dermestids in museums can be traced to Charles Dean Bunker, a staff member in the University of Kansas Natural History Museum, in the mid-1910s. Bunker did not have a faculty appointment, but nonetheless had a great influence on a number of undergraduates who took great pride in calling themselves "Bunks' Boys." Several went on to have distinguished careers in the natural sciences including E. Raymond Hall, William H. Burt, Remington Kellogg, Jean Linsdale, R. A. Stirton, and Alexander Wetmore, among others.

Bunker laid out his discovery and the basics of using dermestids to clean skeletons in the early 1920s (Warner 2019). Over several years, he and the students were cleaning "several thousand skeletons of birds, mammals, reptiles and amphibians [and] we feel that we should pass our findings along" (C. D. Bunker, unpublished document, University of Kansas). Two of Bunker's undergraduate students—E. Raymond Hall, then a graduate student at the University of California, Berkeley, and Remington Kellogg, who was then at the U.S. Bureau of Biological Survey—followed up in perfecting the use of dermestids to clean skulls (Hall and Russell 1933).

Using dermestids to clean bones and teeth enhances the prospects for detailed studies and comparisons, accurate measurements, and long-term, pest-free storage. An active colony of dermestids can clean skeletal material thoroughly so that sutures, minute bones, and processes remain intact, and the arrangement of bones is readily visible. Teeth can be studied in detail and skeletons remain as articulated as desired. Prior to the use of beetles, boiling or odiferous bacterial action from maceration was used to soften and remove the flesh from bones. Small skulls, especially rodents, were wrapped in cheese cloth to prevent the loss of small bones that became disassociated from the skull. A technician then tediously removed the flesh and tendons by hand. Although much tissue can be removed this way, this process frequently results in loose teeth, the jugal of the zygomatic arch becoming dislocated, and other inadvertent damage (Williams et al. 1977). Thus, many older skeletal preparations in museums are not as valuable for researchers' use as are modern preparations. Larger skulls, especially ungulates and marine mammals, can effectively and safely be cleaned with hot, but not boiling, water.

Dermestids have been implicated in damage to bone in the paleontological literature, including insect damage seen in Pleistocene mammals as well as dinosaurs. However, dermestids rarely damage mature bone. In feeding trials with several different carrion beetle species, Holden et al. (2013) assessed bone damage and lack thereof in modern-day specimens compared to the damage seen in Pleistocene fossils from the Rancho La Brea tar pits. Damage to modern-day bone that is nearly identical to that observed in the La Brea fossils was done by tenebrionid beetles. Darkling beetles (*Eleodes* and other tenebrionids) are among the most common insects found in the tar pits, and beetles of the family Tenebrionidae are most likely to have been responsible for the damage seen in bones in the

prehistoric record. This emphasizes the importance of careful selection of the organism to clean skeletal material of modern mammals such that delicate structures are not damaged.

The care, cultivation, breeding, and use of dermestids for cleaning bones are both a science and an art; it is not simply a matter of throwing the bones to the bugs. Before being placed in a dermestid colony, the animal's body is skinned, eviscerated, and the larger muscle masses removed. Knowledge of the dermestids' life cycle also is an important factor in colony management. Most feeding is done by the larval state, which includes molting through several instars, with the smallest instar being only a few millimeters in length. Although the adults do a small amount of feeding, their main role is reproduction and egg-laying. Dermestids prefer to feed on tissue that is dried, but not too dry. Temperature and humidity control also are critical, and the beetles are extremely sensitive to mold, mites, and other pests. One of the most damaging pests in a dermestid colony is the red-legged ham beetle (*Necrobia rufipes*), which feeds on the eggs of other beetles. Without attention to these details, a colony can be wiped out in short order.

Dermestid beetles do present complications, and their reputation as pests is not unfounded. The English Elizabethan era geographer, Richard Hakluyt (1552–1616), wrote in his *Travels* that in 1593, a wooden clipper ship carrying a cargo of dead penguins was made unseaworthy by the hundreds of thousands of tunnels bored into the wooden hull by pupating dermestid larvae after feeding on the penguins (Timm 1982). "Vigilance" is the watchword for any museum with a dermestid colony because these beetles can become destructive pests in a collection of study skins, pinned insects, fabrics, and any other collections composed of organic materials. This is the reason that many museums place their dermestid colonies in facilities separate from the main museum building (Williams et al. 1977). There is a subdiscipline of museology that specializes in the control of insect pests in museums, especially dermestid beetles and clothes moths (Genoways and Schlitter 1988; Trapaga 2008/2009).

Cleaning formalin- and alcohol-preserved specimens requires extra steps, including: soaking in water, removing some of the excess tissue by hand, and coating the remaining tissue with bacon grease or cod liver oil. However, excellent preparations can be obtained with an active beetle colony and care taken to prepare the specimens. In the 1980s, dermestids were discovered to be feeding on embalmed human bodies in the mausoleum of a local cemetery. Mammalogists at a nearby large natural history museum collected these dermestids to increase the genetic diversity in their captive colony and facilitate the cleaning of formalin-preserved specimens.

The beetles also pose a unique health problem for colony managers. Persons exposed to the room's air over a period of time may develop a host of disagreeable symptoms such as itching of the skin, hives, irritation of the eyes and respiratory passages, cold sweat, weakness, headaches, and nausea, that are an allergic reaction to the beetles. Floating in the air as fine, imperceptible dust (known as "frass"), the allergens include microscopic particles of beetle excreta and

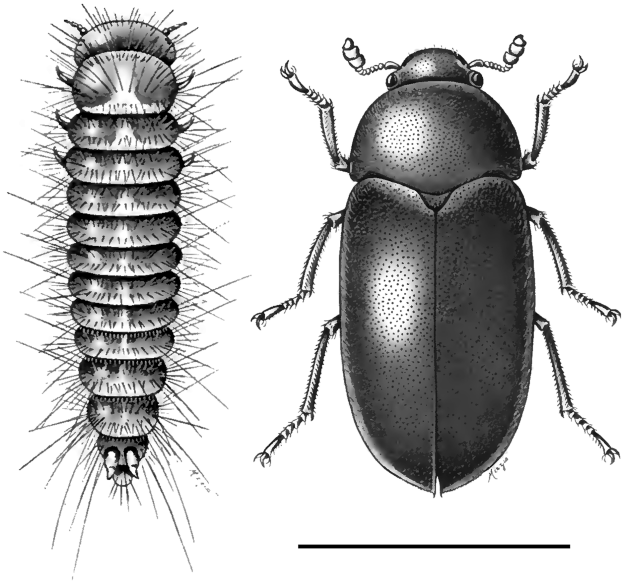

Fig. 1.—Mature larva (left) and adult (right) of the carrion beetle *Dermestes maculatus*, the species commonly used in museums in the United States for preparation of skeletons. Scale = 1 cm. Image courtesy of the Field Museum.

shed exoskeletons, including fragments of urticating setae. For some, protection can be provided by wearing a surgical mask and gloves. Another partial solution to this problem is confining the dermestid colony in a separate container—a bug box or dermestarium—to reduce exposure to the air in the room while also concentrating the dermestids for more effective cleaning of the skeletal material (Vorhies 1948; Williams et al. 1977; Hinshaw 2020). Some facilities may have hoods in which aquaria used as dermestariums can be contained under negative pressure, further reducing the potential for exposure to frass. Using cotton to cushion the skeletal material also will help in keeping the frass from becoming airborne (Somer and Anderson 1975).

A time-lapse video of *D. maculatus* cleaning the skeleton of a gray squirrel (*Sciurus carolinensis*) is available for download (here), and as Supplementary Data SD1. This video condenses a few days of dermestid feeding activity to 19 seconds.

While some institutions still employ maceration and boiling as cleaning techniques, others have tried alternative arthropods in the cleaning process—ants, mealworms, and crayfish also can remove the tissue from bones. Maiorana and Van Valen (1985) at the University of Chicago described their use of sow bugs (mixed colony of *Armadillidium vulgare* and *Porcellio scaber*) to remove the flesh from small carcasses, which they found effective. However, by far, the use of dermestid beetles is the most common and useful modern technique for the safe preparation of vertebrate skeletal material.

Dermestid beetles work 24 hours, 7 days a week without pay at a job that is somewhat unpleasant for a human to undertake and the quality of preparation is excellent in an effectively managed colony. Beetles can be used to clean the smallest shrews and bats up to very large land mammals that can be fitted into the space where a colony is housed. Often looked upon as just a

pest, dermestids have become a valued innovation in the pursuit of scientific knowledge and are the unsung heroes of natural history museums.

Acknowledgments

Rosanne Miezio's masterful renderings of the adult and larval *Dermestes maculatus* used as Fig. 1 provide essential images of the subject of this article. Original video courtesy of the Field Museum, Chicago. M. G. Girard's efforts in improving the video and figure used herein are most appreciated. E. J. Heske and L. A. Ruedas critically reviewed an earlier draft of this manuscript, considerably improving it.

Supplementary Data

Supplementary data are available at *Journal of Mammalogy* online.

Supplementary Data SD1.—Time-lapse video of the flesh from a gray squirrel (*Sciurus carolinensis*) carcass being devoured by dermestid beetles (*Dermestes maculatus*). Actual duration of time lapse, 3 days. Original video courtesy of the Field Museum, Chicago.

Literature Cited

Borell, A. E. 1938. Cleaning small collections of skulls and skeletons with dermestid beetles. Journal of Mammalogy 19:102–102.

Genoways, H. H., and D. A. Schlitter. 1988. Pest control management for mammal collections. Pp. 531–558 in Management of mammal collection in tropical environment (B. K. Tikader, ed.). Zoological Society of India. Calcutta, India.

Hall, E. R., and W. C. Russell. 1933. Dermestid beetles as an aid in cleaning bones. Journal of Mammalogy 14:372–374.

Hinshaw, S. H. 2020. Dermestarium. https://webapps.lsa.umich.edu/ummz/mammals/dermestarium/default.asp. Accessed 27 March 2020.

Holden, A. R., J. M. Harris, and R. M. Timm. 2013. Paleoecological and taphonomic implications of insect-damaged Pleistocene vertebrate remains from Rancho La Brea, southern California. PLoS ONE 8:e67119.

Maiorana, V. C., and L. M. Van Valen. 1985. Terrestrial isopods for preparing delicate vertebrate skeletons. Systematic Zoology 34:242–245.

Somer, H. G., and S. Anderson. 1975. Cleaning skeletons with dermestid beetles—two refinements in the method. Curator 17:290–298.

Timm, R. M. 1982. Dermestids. Field Museum of Natural History Bulletin 53:14–18.

Trapaga, A. 2008/2009. Museum of Vertebrate Zoology: integrated pest management (IPM) program manual. University of California. Berkeley.

Vorhies, C. T. 1948. A chest for dermestid cleaning of skulls. Journal of Mammalogy 29:188–189.

Warner, C. H. 2019. Birds, bones, and beetles: the improbable career and remarkable legacy of University of Kansas naturalist Charles D. Bunker. University Press of Kansas. Lawrence.

Williams, S. L., R. Laubach, and H. H. Genoways. 1977. A guide to the management of Recent mammal collections. Special Publication, Carnegie Museum of Natural History 4:1–106.

Williams, S. L., and S. P. Rogers. 1989. Effects of initial preparation methods on dermestid cleaning of osteological material. Collection Forum 5:11–16.

Williams, S. L., and H. C. Smith. 1995. Effect of osteological processing treatments on dimensions and moisture absorption potential of rodent skulls. Collection Forum 11:46–57.

Submitted 7 April 2020. Accepted 29 May 2020.

Associate Editor was Luis A. Ruedas.