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CASE REPORT

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Collembola of the Grave: A Cold Case History Involving Arthropods 28 Years After Death

ABSTRACT: This report describes a cold case in which a cadaver of a 28-year-old female was exhumed in February 2005 from a cemetery in Battle Creek, Michigan. She had sustained a gunshot wound to the head and was found dead in her home on November 15, 1977. The body of the victim was subsequently embalmed and then buried at a depth of 1.8 m in an unsealed casket that was placed inside an unsealed cement vault. The exhumation yielded thousands of live specimens of a single species of the order Collembola or spring tails, *Sinella* (*Coecobrya*) *tenebricosa* (Entomobryidae). This species is considered to be a "tramp" species, cosmopolitan in the United States and Canada. Due to the ideal environmental conditions at the site, the population of this species underwent growth and development inside the casket for a number of years. Collected with the Collembola were large numbers of Acarina (mites) of the Family Glycyphagidae, and fly puparia, *Conicera tibialis* Schmitz (Order: Diptera, Family: Phoridae), also known as coffin flies. These invertebrates are sometimes mentioned by forensic investigators as occurring on corpses in graves, but aspects of their life history are rarely described. The species of Collembola that was found surviving and reproducing on this corpse in a casket exhumed after 28 years was the oldest reported grave site occurrence for any collembolan species based on a survey of the literature back to 1898.

KEYWORDS: forensic science, forensic entomology, arthropods, Collembola, Acarina, Phoridae

Once in a great while the unique opportunity to observe and research a subject that has laid dormant for many decades presents itself. In the following account we are reporting on the arthropod fauna associated with a cadaver that was exhumed 28 years after her death. This case provides important information to forensic entomologists, biologists, and pathologists regarding arthropods associated with decomposed bodies far beyond the normal postmortem interval, as well as the environmental factors that may have led to their occurrence.

Case History

A 28-year-old female had sustained a gunshot wound to the head and was found dead in her home on November 15, 1977. An autopsy was performed at that time and the manner of death was termed a homicide. However, the lack of evidence and suspect information resulted in this case going cold. The body of the victim was subsequently embalmed and buried at a depth of 6 feet in an unsealed casket that was placed inside an unsealed cement vault at Oak Hill Cemetery in Battle Creek, Michigan. Information leading to the perpetrator of the crime became known in 2004; however, the investigating agency was unable to locate an autopsy report associated with the victim. Therefore, law enforcement officials requested the body be exhumed and a second examination performed.

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The cadaver was exhumed on February 15, 2005. The vault rested 1.8 m down at the base and had 1.2–1.5 m of soil on top. Condition of the surrounding ground was quite damp and there was moisture in the vault, which caused the casket to rust (Fig. 1). The casket was transported to Sparrow Hospital in Lansing, Michigan, where a forensic autopsy on a severely decomposed body took place. During the autopsy, samples were collected by one of us (RWM) from the surface of the cadaver that contained large numbers of arthropods, mostly Collembola (springtails), Acarina (mites) of the Family Glycyphagidae, and Diptera puparia of the family Phoridae (coffin flies). These arthropod specimens were returned to the Department of Entomology laboratory at Michigan State University for identification.

Discussion

It was necessary for us to search the literature of over 100 years to find any information on Collembola inhabiting grave sites. Two publications, one in 1898 by Motter (1), and the other one in 1902 by Folsom (2), yielded information on the species collected as well as other arthropod species associated with grave sites. During the summers of 1896–97, Motter was director of a team that made 150 exhumations within the city limits of Washington, DC. He stated that his work was undertaken to, "determine, if possible, the bearings of Megnin's, *Application of Entomology to Legal Medicine*" (3). Among the fauna found associated with human cadavers by Motter (1) was the order Thysanura (now Order Collembola). These animals which are only 1–2 mm long were collected in large numbers. The collections were turned over to a well known Collembola authority, Dr. Justus Watson Folsom, then at the University of Illinois.

The Washington, DC, graves that were exhumed by Motter (1) ranged in age from 1 year 11 months to 21 years old. Folsom (2) published the results of his identifications in a paper entitled,

FIG. 1—*Close up of the casket after its removal, which displayed rust stains and showed signs of the surrounding moist environment.*

TABLE 1—*Collembola species identified by Folsom (2) from exhumations.*

Isotomidae
Isotoma fimetaria (L.), often confused in NA with *candida*, *stella*, and *nivalis*
Isotoma sepulcralis (Folsom) = *Proisotoma* (*Proisotoma*) *sepulcralis* (Folsom)
Entomobryidae
Entomobrya lucifuga Folsom = *Sinella* (*Sinella*) *cavernarum* (Packard)
Sinella (*Sinella*) *tenebricosa* (Folsom) = *Sinella (Coecobrya) tenebricosa* (Folsom)
Pseudosinella argentea (Folsom)
Pseudosinella candida (Folsom) = *Lepidocyrtus* sp. (Christiansen & Bellinger)

"Collembola of the Grave." In his paper he listed six species from cadavers, five of which he listed and described as new to science. Later, corrections in his determinations were made (Table 1). Folsom (2) commented that of the 5600 specimens he examined, 97% consisted of *Proisotoma* (*Proisotoma*) *sepulcralis* with the other five species making up only 3% of the total fauna.

The current exhumation performed in February 2005 yielded thousands of specimens of a single collembolan species, *Sinella* (*Coecobrya*) *tenebricosa* (Fig. 2). Folsom's later paper identified what Motter had found with respect to Collembola and reported that <1% of all the species he collected were *S. tenebricosa* (24 specimens), whereas 97% consisted of another species not found at our grave site (2). The grave conditions for both Oak Hill Cemetery and Washington, DC, cemeteries were similar, where the depth of caskets was *c.* 1.5–1.8 m deep with moist soil conditions. The age of the burials varied, with the longest burial time recorded from this latter site being 21 years old, in contrast to our Oak Hill Cemetery grave of 28 years.

FIG. 2—*Close-up of* Sinella (Coecobrya) tenebricosa (Collembola).

Sinella (*Coecobrya*) *tenebricosa* is considered to be a "tramp" species, cosmopolitan in the United States and Canada. It is usually collected in protected areas such as caves, wood piles, and greenhouses. Recently (2004), a number of specimens were taken from piles of wood chips in Kalamazoo County, Michigan during the winter (R. Snider). They were well established and reproducing in the central core where the chips were warm and moist all year.

Sinella tenebricosa is described in Christiansen and Bellinger (4) as being a maximum of 2.0 mm long, white without pigment and lacking eyes. The antennae are quite long, about half as long as the body. Likewise, the legs and furcula (springing mechanism) are long, similar to those species found on the surface and in caves. Besides the lack of eyes and pigment, how then does this species become classified as a "soil species" and inhabit grave sites?

From studies on the soil fauna and its movements we can put forth the following hypothesis. Collembolans usually require high humidity for egg viability. The fact that the Kalamazoo River runs near the Oak Hill Cemetery (*c.* 800–1200 m away) most likely contributed to a higher water table and therefore increased soil moisture in this grave yard. The life cycle of Collembola is usually very fast, *c.* 30 days or less at 15°C. When a species such as *S. tenebricosa* hatches, its length is *c.* 0.25 mm or less. The small size and elongate body at the time of hatching allows for the animal to make use of soil pores and tunnels made by worms and other burrowing arthropods while they are foraging for food. In the case of the genus *Sinella* spp., yeast is commonly used in the laboratory to culture various species. It is assumed that in the soil habitat, this species feeds on a like group of organisms.

Using minirhizotrons equipped with video cameras in agricultural soils, Collembola populations were observed from July to December, 1986 (5). *Folsomia candida* Willem was the dominant species studied with a body length of 2 mm. Young individuals were seen moving in soil pores and old root channels in large numbers at 40–90 cm depths. In addition to the video monitoring, soil core samples were taken up to 120 cm depths, and by mid-summer adult specimens were collected at these depths (5).

This evidence presents the following scenario. Following the suggestion that Collembola are part of the soil fauna that invade cadavers after burial (3), *Sinella* (*Coecobrya*) *tenebricosa* may be established in the cemetery soil over time. Juveniles move throughout various depths utilizing old root channels where fungal and yeast/molds grow on decaying plant residues. The humidity and CO_2 levels are conducive to reproduction and high egg production. Over time, some individuals move into the moist vault and eventually into the casket where cadaver tissues and clothing provide a suitable substrate for fungal/yeast/mold growth. At this site the species has ideal conditions for growth and development and the population may increase significantly.

Collected with the Collembola were large numbers of Acarina (mites), Suborder Acaridida, Family Glycyphagidae. Krantz (6) stated that many glycyphagid species are found in wild mammal nests and most are unknown in the adult stages. Additionally, Motter (1) reported Acarina from cadavers. Among the genera found were: Gamasidae; *Gamasus* sp., *Holostaspis* sp., *Iphis* sp., *Uropoda* sp., *Hypopus* sp., Tyroglyphidae; *Tyroglyphus* sp., Oribatidae;

FIG. 3—*Mass of phorid puparia found on the remains within the casket (exhumed from Michigan in 2005).*

Hoplophora sp. It is assumed that the Acarina populations were introduced both while the cadaver was exposed to air and when buried.

A third arthropod species, *Conicera tibialis* Schmitz (Order: Diptera, Family: Phoridae), also known as coffin flies, was collected from the casket in different stages of pupariation (Fig. 3). This species can invade coffined corpses within 1 year of burial (7–9). Phorids can be found in damp environments, often associated with decomposing organic material such as human corpses. As a result, this family becomes an important component in legal investigations (e.g., 10–12). Their minute length of 1.5–2.5 mm allows them to excavate through soil and other small crevasses to colonize corpses for oviposition (8,13). *C. tibialis* can produce a number of generations on the corpse without emerging toward surface for copulating, as they will mate within the coffin and complete their entire life cycle beneath the ground (9,14,15).

The most interesting aspect of this case was that a species of Collembola (*Sinella tenebricosa*) was found surviving and reproducing on a corpse in a casket exhumed after 28 years, the oldest reported occurrence for any collembolan species based on a survey of the literature back to 1898. In previous studies, this species has rarely been found occurring in such large numbers on cadavers, generally <3%. Moisture played a major factor in the occurrence and survival of this species in the casket, as they never would have been present under dry conditions.

The potential role of Collembola in forensic entomology investigations requires further research. A number of species have been shown to feed on different foods (e.g., fungal hyphae and spores, bacteria, plant material, minerals, and pollen), and may select different size food particles, depending on mouthpart size. In addition, certain soil species are specific as to soil type, and they also have shown variation in dietary components related to seasonal availability of foods in the field (16,17). This information could prove to be useful if a buried corpse that had been colonized by Collembola at one field site, or during a specific season of the year, had then been exhumed and translocated to a different field site with a soil type different from the original one, or moved during a different season. In this case, an entomologist specializing in soil Collembola may be able to determine if the body had been transported from one location to another, or during a given season, based on the presence and/or absence of a particular species or group of species.

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