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Museum Pests in Mammal Furs: An Investigation of the Correlation Between Pests and Host Furs

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ABSTRACT

Insects are of great importance in the ecosystem. In some cases, however, they can be directly or indirectly harmful to humans. Pest insects in museums are good examples of such insects. Especially organic cultural heritage is often the target of these pests. To accomplish effective pest control, it is necessary to obtain knowledge on pest species and their effects. In this study, pest specimens including adults, larvae, pupae and exuviae materials (Total: 1323 specimens) were collected from 59 furs belonging to 12 species of mammals in Zoological Collection of University Istanbul (ZMUI). The species of these pests from various life stages were identified and the numbers were recorded. Further analyses were conducted through the means of Corresponding Analysis and a potential correlation between pest species and species of hosting furs was investigated 9 species of museum pests were identified; *Anthrenus verbasci* (Linnaeus, 1767), *Attagenus brunneus* Faldermann, 1835, *Dermestes maculatus* (DeGeer, 1774), *Lasioderma serricorne* (Fabricius, 1792), *Lepisma* sp., *Monopis* sp., *Ptinus clavipes* Panzer, 1792, *Stegobium paniceum* (Linnaeus, 1758) and *Tineola bisselliella* (Hummel, 1823). Among the pest species, *Anthrenus verbasci* is the species with the highest specimen count in the collection, as well as the most commonly distributed species. Museum pests are mainly observed on the furs of herbivore mammals. This observation is demonstrated with Corresponding Analysis. Also through Corresponding Analysis, a correlation between the species of pest insects and the diets of the species of hosting furs was demonstrated.

Key words: Museum Pests, Mammalian Furs, Corresponding Analysis, Turkey, ZMUI.

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INTRODUCTION

For scientific studies, especially the studies on organisms such as plants or animals, it has been a very important step to collect specimens of different groups and preserve them in a suitable state for further studying. In this sense, it is crucial to preserve the collection materials in the museum, for as long as possible, against both abiotic factors like weather conditions and biotic factors, such as mold or museum pest insects. The success of insects in environmental adaptation and the breadth of their nutrient repertoire can result in humans encountering harmful (pest) insects in many areas. Natural history museums, herbariums and various animal collections are preferred places for settlement and spread for insects which naturally feed on dead tissues or debris.

Insects that are museum pests come from a variety of orders and families. While some gnaw through wooden material like drawers or display cases. Some of them directly feed on mammalian furs or bird feathers. They can damage these specimens in different levels of severity, from mild scratches to the point of losing the entire specimen. Thus, they pose a serious threat. Museum pests should be treated with serious effort and caution (Trematerra & Pinniger, 2018). In recent years, conservators and other museum staff have worked to develop alternative strategies for preventing and controlling pests. In the light of such studies, Integrated Pest Management (IPM) strategies were developed and adopted with success (Natural Sciences Collections Association, 2022; The Museum Pests Working Group (MPWG), 2022; Trematerra & Pinniger, 2018). In addition, a guide for pest control has been released in Turkey as well (Prevention of Pests in Written Work Collections, Ministry of Written Works Institution of Turkey, Department of Book Hospital and Archives, Research and Development Unit, 2022; Koçak & Eskici, 2019).

Many protocols and treatment methods are known to prevent or control these museum pest insects (Klein, 2008). These include applying pesticides, freezing the specimens, heat treatment, Anaxia, CO_2 or disinfecting with alcohol and such chemicals. However, an effective pest control can only be achieved if the appropriate methods are selected according to the specific types of insects. Because of that the first step in controlling museum pest insects is identifying the pest species that reside in the museum or collection. Knowing the species of pests gives us a lot of information about the life stages of the species, the period in which they feed on dead organic tissue (adults or larvae), what environmental conditions they prefer (temperature, humidity, etc.) and what are the times of spawning and hatching (bivalent or univalent). This information allows us to use their weakest points to fight these pests and to manage successful pest control. Furthermore, according to some publications, the species of pest insects may indicate various conditions of the collection environment (Notton, 2018). Thus, a correct identification of pest species also indicates what type of control method should be used or which environmental conditions should the material be stored in. In literature, many different publications may be found about museum pest insects that pose a danger to zoological collections (Suarez & Tsutsui, 2004; Klein, 2008; Pinniger, 2011; Querner, 2015; Notton, 2018; Trematerra & Pinniger, 2018). There are studies conducted on museum pests in Turkey (Koçak, & Eskici, 2019; Prevention of Pests in Written Work Collections, Ministry of Written Works Institution of Turkey, Department of Book Hospital and Archives, Research and Development Unit, 2022). However, none of these studies consider this situation for a natural history museum or a zoological collection. The goal of this paper is to identify the pest insect species found on mammalian furs and investigate if there is a correlation between the species of host mammal furs and pest insects.

In this research, pest insects found on mammalian furs in ZMUI (Zoological Museum of University Istanbul) were studied for their species identification and the existence of a specific fur preference of the pest insects was questioned. For this reason, the distribution of pest species on different species of mammalian furs were also analyzed in this study.

MATERIAL AND METHODS

This study was conducted on the collection of mammalian furs in the Zoological Collection of İstanbul University in Vezneciler, İstanbul. The study holds the record of being the first study that is conducted on pest insects in a zoological collection in Turkey. The diversity of animals in the fur collection in question was largely provided by Prof. Dr. Curt Kosswig, who holds an important place in the history of research on the Anatolian fauna. He performed many comprehensive studies and student excursions and greatly contributed to the collection (İshakoğlu-Kadıoğlu, 1998; Küçüker et al, 2018).

Our study is conducted on 59 mammal furs belonging to following species: *Caracal caracal* (Schreber, 1776) (n=1), *Capreolus capreolus* (Linnaeus, 1758) (n=2), *Cervus elaphus* Linnaeus, 1758 (n=1), *Felis catus* Linnaeus, 1758 (n=1), *Herpestes ichneumon* (Linnaeus, 1758) (n=3), *Hystrix* sp. (n=2), *Lepus europaeus* (Pallas, 1778) (n=23), *Lutra lutra* (Linnaeus, 1758) (n=4), *Martes foina* Erxleben, 1777 (n=2), *Meles meles* Linnaeus, 1758 (n=13), *Sus scrofa* (Linnaeus, 1758) (n=1), *Vulpes vulpes* (Linnaeus, 1758) (n=6).

These furs were collected from Anatolia and Thrace between 1940-1970 through various student excursions or as research projects for students. Furs are known to be prepared with various tanning methods, however, there are no records that indicate which chemical procedure is used for preparation. After tanning, furs of the same species were stored together in wooden closets. Each fur was wrapped in raw cotton fabric and has been stored that way since 2000. During the insect sampling, specimens found on the fur or between its hairs, in which they were most abundant, were collected with sieves and placed in lidded plastic containers. The containers were tagged according to which species of furs its contents were collected from. After collection, the containers were brought to the lab and each one of the pest specimens were inspected under stereozoom microscope and their species were identified. Species identification was carried out according to following publications: Jackson (1906), Bousquet (1990), Gorham (1991), Choe (2013), Hackston (2014) &

Notton (2018). Pictures of pest insects were taken with a Canon D600 camera under a Leica stereozoom microscope.

The data is recorded on Microsoft Excel, then used for creating tables and figures for better interpretation. Also with this data, Correspondence Analysis (CA) was used to analyze the correlation between museum pests and the host furs by the Past software 4.05 (Hammer et al, 2001).

RESULTS

Out of 1323 examined pest insects: 54 adults, 50 larvae, 1112 exuviae and 88 cocoons were found and investigated. In addition, 19 recognizable carcass remnants were identified and included in the study. *Attagenus brunneus*, *Anthrenus verbasci*, *Dermestes maculatus*, *Lasioderma serricorne*, *Lepisma* sp., *Monopis* sp., *Ptinus clavipes*, *Stegobium paniceum* and *Tineola bisselliella* are identified. The taxonomic details are as given below.

Order: Coleoptera

Family: Dermestidae

Attagenus brunneus Faldermann, 1835 (Brown-Black Carpet Beetle - Fig. 1) Adult, 1; Larva, 3; Exuvia, 68; Pupa, 0; Carcass, 2.

Anthrenus verbasci (Linnaeus, 1767) (Varied Carpet Beetle - Fig. 2) Adult, 33; Larva, 41; Exuvia, 968; Pupa, 0; Carcass, 13.

Dermestes maculatus (DeGeer, 1774) (Fur Beetle - Fig. 3) Adult, 9; Larva: 6; Exuvia, 76; Pupa, 0; Carcass, 4.

Family: Anobiidae

Lasioderma serricorne (Fabricius, 1792) (Cigarette Beetle - Fig. 4) Adult, 1; Larva, 0; Exuvia, 0; Pupa, 0; Carcass, 0.

Stegobium paniceum (Linnaeus, 1758) (Drugstore Beetle - Fig. 5) Adult, 3; Larva, 0; Exuvia, 0; Pupa, 0; Carcass, 0.

Family: Ptinidae

Ptinus clavipes Panzer, 1792 (Spider Beetle - Fig. 6) Adult, 2; Larva, 0; Exuvia, 0; Pupa, 0; Carcass, 0.

Order: Lepidoptera

Family: Tineidae

Monopis cf crocicapitella. Only 1 individual is found. This individual does not possess enough characteristic information for definitive species identification. No other larvae, pupae or exuviae belonging to this species were found. This individual is thus reported here but disregarded from calculations and analyses.

Tineola bisselliella (Hummel, 1823) (Webbing Clothes Moth - Fig. 7) Adult, 1; Larva, 0; Exuvia, 0; Pupa, 88; Carcass, 0.

Order: Zygentoma

Family: Lepismatidae

Lepisma sp. Adult, 3; Larva, 0; Exuvia, 0; Pupa, 0; Carcass, 0.

These individuals were identified as adult *Lepisma* sp. However, they do not possess important characteristic information for species identification.

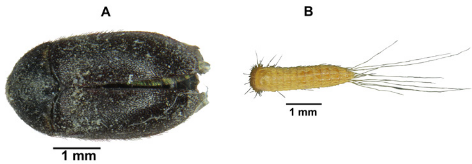

Fig. 1. Dorsal view of *Attagenus brunneus,* adult (A) and larva (B).

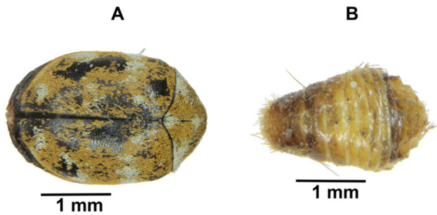

Fig. 2. Dorsal view of *Anthrenus verbasci* species, adult (A) and larva (B).

Fig. 3. Dorsal view of *Dermestes maculatus,* adult (A) and larva (B).

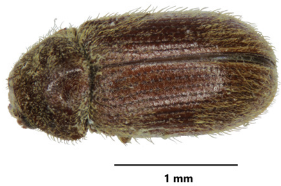

Fig. 4. Dorsal view of *Lasioderma serricorne,* adult.

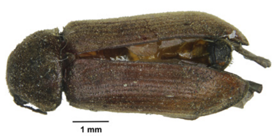

Fig. 5. Dorsal view of *Stegobium paniceum,* adult.

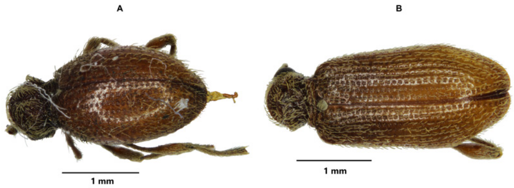

Fig. 6. Dorsal view of *Ptinus clavipes,* female (A) and male (B) adults.

Fig. 7. Dorsal view of *Tineola bisselliella,* A. adult B. pupa.

Table shows how many of each pest species were found on each fur (Table 1). These numbers are the sum of all life stages of the pest species (adult, larva, exuvia, pupa, carcass). *A. verbasci* (total no: 1055) has the highest individual numbers in terms of adults, larvae and exuviae. In addition, it was identified on 11 of the 12 species of mammal furs. *L. serricorne* has the lowest individual number. It was found on one fur belong to *L. europaeus.* Count of different life stages of different pest species are showed in Fig. 8 and the distribution and density of pests on host furs are showed in Fig. 9. *A. verbasci* has the highest count of exuviae and larvae. *T. bisselliella* has the highest count of pupae. The correlation between museum pests and the host furs was given by Correspondence Analysis (CA) (Fig. 10). According to CA, mammal species of *C. elaphus, L. europaeus, Hystrix* sp., *S. scrofa* and *M. meles* have high correlations with the pest species. In contrast, *M. foina* and *H. ichneumon* have lower correlations.

Table 1. Species and numbers of furs and the pests found on them.

Host / Pest	Number of furs in the collection	*Attagenus brunneus*	*Anthrenus verbasci*	*Dermestes maculatus*	*Lasioderma serricorne*	*Lepisma sp.*	*Ptinus clavipes*	*Stegobium paniceum*	*Tineola bisselliella*	Total number of species
Caracal caracal	1		1	1						2
Capreolus capreolus	2		20						25	3
Cervus elaphus	1	1	41							2
Felis catus	1	5	15	27					1	4
Herpestes ichneumon	3		1	5						2
Hystrix sp.	2	2	8				1	1	1	5
Lepus europaeus	23	33	774	1	1	3	1	1	7	8
Lutra lutra	4	4	7	2						3
Martes foina	2			1						1
Meles meles	13	19	84	30				1	32	5
Sus scrofa	1	10	73	10					11	4
Vulpes vulpes	6		31	18					12	3
Total specimen count	59	74	1055	95	1	3	2	3	89	

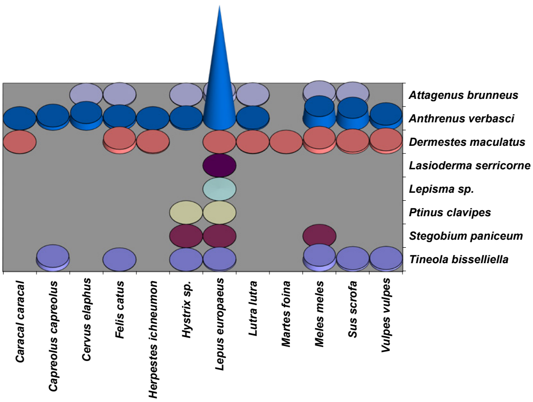

Fig. 8. Count of different life stages of different pest species.

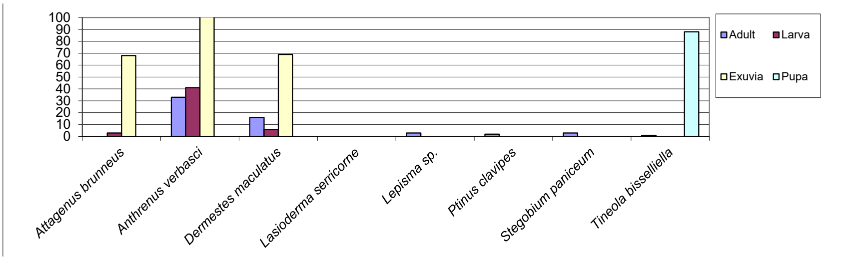

Fig. 9. The distribution and density of pests on host furs.

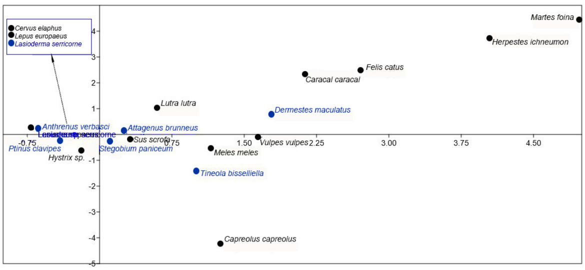

Fig. 10. The correlation between hosts and pests are shown through Corresponding Analysis (CA).

DISCUSSION

In our study, a total of 59 furs, belonging to 12 mammal species from the zoological collection were examined. All pests found on these furs are recorded by their species and number of individuals per species (Table 1). Results of these examinations show that total individual numbers in terms of adults, larvae and exuviae are the highest for *A. verbasci* (total count: 1055) compared to other pest species (Fig. 8). The natural habitat of this insect, which is also known as varied carpet beetle, is originally dried bird nests (Nisimura & Numata 2003). However, it is recorded as a pest species in museums and there are many publications about its life cycle and control methods (Nisimura & Numata 2003; Kumar et al, 2013).

A. verbasci is a 2-3 mm beetle, which is a cosmopolitan species, being recorded throughout Europe, Africa, America, Asia and Australia (Tezcan et al, 2004). As seen in Fig. 9, *A. verbasci* is the most abundant pest species in the collection. It was found on 11 of the 12 species of furs, only absent from the fur of beech marten. As this species is a widespread, dominant pest, it can be said that our findings are in line with previous studies (Yıldırım, 2013).

The second most abundant pest in the collection is *D. maculatus* (total count: 95) (Fig. 8). Many species in the genus *Dermestes* are known to be pests. *Dermestes* sp. are an invasive group of pests that originated from Asia and introduced to Europe later on with human activity and are known to be a capable of dealing considerable economical damage (Manachini, 2015). It was found on 9 of the 12 species of furs in the collection with a total number of 95 (Fig. 9). When compared to *A. verbasci* in terms of total individual counts, *D. maculatus* is seen to have 10 times less potential for distribution. On the other hand, *D. maculatus* is the only pest species that was found on the fur of beech marten.

The pest with the third highest number of individuals is *T. bisselliella* (total count: 89) (Table 1.). *T. bisselliella* is found on 7 of the 12 species of furs in our study (Fig. 9). This species has the highest number of pupae (Fig. 8). According to Choe (2013), adult individuals of *T. bisselliella* do not share the same food source with the larvae. In reference to this information, it can be said that the pests that are actually harming the collection in *T. bisselliella*'s case are only the larvae. This explanation also further supported by the fact that only 1 adult is found on the furs as opposed to the very high count of pupae. The absence of *T. bisselliella* adults on the furs appears to be because the adults do not use the fur as a source of food. These findings also appear to be in line with previous studies.

Another pest species, *A. brunneus,* has a high count of exuviae and larvae but low count of adults (Fig. 8). As the adult stage of this beetle life cycle is as low as 2 weeks, while the larva stage is around 2 years, this difference between the count of life stages also seems to be expectable (Story, 1985).

In our study, 4 out of 9 pest species (*A. verbasci*, *D. maculatus, T. bisselliella, A. brunneus*) were observed to have high numbers as dominant species, compared to the rest. One of the pest species found in low numbers is *P. clavipes*. There were found to be only 2 adult individuals of this species, one of which being male and other one being female (Fig. 6). This is a species that had only been recorded from Turkey once before, from another city (Uşak) and not from a museum, but from a wheat storehouse (Zengin & Karaca, 2019). In that paper, there is no description or figures to represent this species. It is important to note that *Ptinus clavipes* is morphologically similar to *Ptinus tectus*. Therefore, the characteristics used for the species identification is given in this paper. The specimen in this study demonstrates the clear identification character to tell the two species apart: vestiture of scutellum is denser and whiter in color than rest of the elytra, as can be seen in Fig. 6 (Bousquet, 1990; Gorham, 1991). Also, the species *P. clavipes* is reported as a first time record from İstanbul, as it was not mentioned in the previous study, also conducted in Istanbul (Dikmen & Özuluğ, 2018).

The investigation of correlation between pests and host furs shows that the fur with the most pest diversity is *L. europaeus*. All the pest species inhabited these furs (Fig. 9). The fact that the number of hare furs (23) is higher when compared to other species of furs contributed both to the diversity and total number of pests found on it.

The total number of different pest species found on hare furs (8 different species) are also higher than other mammal furs (Table 1., Fig. 9). The fur species observed to have the least diversity of pests is *M. foina* (Table 1., Fig. 9). Furs of beech marten are also the only furs that the most abundant pest, *A. verbasci* is absent from. The fact that this widespread pest is absent from these furs is crucial. The pest species found on furs of *M. foina* is *D. maculatus*. *D. maculatus* is found on 9 out of 12 species of furs.

The Correspondence Analysis demonstrates four important points. First one is the (0) point at where the horizontal and vertical axes intersect. At this central point, it can be seen that the pest species *A. verbasci, L. serricorne, Lepisma* sp., *P. clavipes* and *S. paniceum* are in close relation with the furs of *Lepus europaeus, Cervus elaphus* and *Hystrix* sp. In other words, the furs which are infested the most by pests are European hare, red deer and porcupine furs. These animals, which pests are mostly on, are herbivores. The second grouping in the analysis shows that *A. brunneus* is in close relation with *L. lutra* and *S. scrofa* furs. Both the common otter and the wild boar are omnivores. In the third group, the relation between the pest *T. bisselliella* and the fur of *M. meles* is demonstrated. *C. capreolus* also groups with *T. bisselliella,* but it can also be seen that this is the most distant fur in relation to other furs. This is the result of the fact that *T. bisselliella* is the only pest to infest *C. capreolus* (Roe deer). Honey badger is an omnivore whereas the roe deer is an herbivore. In the fourth grouping, the close relation between the pest *D. maculatus* and the furs of *C. caracal* and *V. vulpes* can be seen, while the furs of *H. ichneumon* and *M. foina* show distant relation with the pests. These animals are carnivores (Fig. 10).

High humidity and a temperature of 18-25ºC is known to provide a good environment for development of pests (Richardson & Goff, 2001). Given the fact that all of the furs had been under the same environmental conditions; the difference of distribution and abundance between the 4 most abundant pest species (*A. brunneus, A. verbasci*, *D. maculatus, T. bisselliella*) and the rest of them (*L. serricorne*, *Lepisma* sp., *P. clavipes*, *S. paniceum*) suggests that even if the conditions are favorable, not all pests would be found on all species of furs.

According to Querner (2015), species of the genus *Ptinus* prefer museum materials that are of plant origin. Thus, the fact that *P. clavipes* is found on an animal fur in this study is surprising. However, as explained above, groupings of the Corresponding Analysis (Fig. 10) suggest that there may be a noticeable fur preference of pest insects, according to the diets (herbivore, carnivore and omnivore) of the mammalian furs. Given these findings, and the fact that *P. clavipes* was discovered on the fur of an herbivore animal, it appears reasonable to expect *P. clavipes* to be found on the furs of herbivore animals in museums. Physical properties of the furs can be considered among the reasons for the grouping observed in the results of CA analysis. These physical characteristics may include the hardness or softness of the skin and hair of the mammalian fur, as well as the density or sparsity of the hairs. Many factors, such as these, could have contributed to the uneven distribution of pests in mammalian furs. Evaluating or proving these possibilities is not within the scope of our study and may be the subject of future research. However, this study discovered a relationship between the species of infested furs and the pest insects that infest them.

CONCLUSION

In conclusion, in our study, which is conducted on mammalian furs in the zoological collection of Istanbul University, insects that are known to be museum pests were identified and their distribution in terms of the animal furs is put forward. We discovered a potential preference of the pest insects for mammalian furs. One of the species of museum pests, *Ptinus clavipes,* is reported as a first time record from İstanbul, as well as a first time record from a museum in Turkey.

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