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Journal of the Canadian Association for Conservation (J.CAC), Volume 40
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Journal de l'Association canadienne pour la conservation et la restauration (J. ACCR), Volume 40
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Le *J.ACCR* est un journal révisé par des arbitres qui est publié annuellement par l'Association canadienne pour la conservation et la restauration des biens culturels (ACCR), 207, rue Bank, bureau 419, Ottawa (Ontario) K2P 2N2, Canada; Téléphone : (613) 231- 3977; Télécopieur : (613) 231-4406; Adresse électronique : coordinator@cac-accr.com; Site Web : <http://www.cac-accr.ca>.

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Slugs as Potential Pests of Paper

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An instance of damage to paper by slugs is presented in this report. Slugs were found in the basement of the National Research Restoration Centre of Ukraine in Odessa. The room appeared to have optimal indoor conditions; however, upon further examination it was found that slugs were inhabiting a microclimate zone, where a large amount of condensation was observed on the cold water pipes. The slugs had damaged newspapers, softcover books, and paper envelopes containing photos. It appears that they ate paper with food, oils and other contamination in the absence of their usual food sources. The slug damage resulted in holes and other losses in the paper as well as contamination by mucus tracks and excrement. Given this, we can conclude that slugs are potential pests of works of art on paper that are stored in damp basements and ground floors.

Un cas de dommage par des limaces sur des objets de papier est présenté dans ce rapport. Des limaces ont été trouvées dans le sous-sol du Centre national de recherche en restauration de l'Ukraine à Odessa. La pièce affectée semblait avoir des conditions environnementales intérieures optimales. Cependant, après un examen plus approfondi, il a été constaté que les limaces ont occupé une zone de microclimat où une grande quantité de condensation a été observée sur les conduites d'eau froide. Les limaces ont endommagé des journaux, des livres à couverture souple et des enveloppes de papier contenant des photographies. Il semble qu'ils aient mangé du papier souillé de nourriture, d'huile et autres contaminants en l'absence de leurs sources habituelles de nourriture. Les dommages produits par les limaces comprennent des lacunes et autres pertes dans les objets de papier ainsi que de la contamination par du mucus et des excréments. Compte tenu de cela, nous pouvons conclure que les limaces sont des ravageurs potentiels d'œuvres d'art sur papier qui sont stockés dans les sous-sols humides et des rez-de-chaussée.

Manuscript received September 2015; revised manuscript received January 2016.

Introduction

Numerous works of art come to the Odessa Branch of the National Research Restoration Centre of Ukraine for conservation and restoration treatment. Among these are works of art on paper including engravings, lithographs and pastels. Many of these exhibit signs of biological damage, such as degradation of cellulose fibres, staining, holes and losses in the paper, and contamination by excrement. This damage can be caused by various live organisms: mammals (mainly rodents), insect pests (particularly silverfish, book lice and cockroaches) and, under certain conditions, microscopic fungi, actinomycetes and bacteria. All of these pests can cause substantial damage to paper artifacts and records in museums and archives. Slugs, however, have never been recognized as a threat to museum collections. This report will present interesting data resulting from a case of paper damage attributable to slugs (*Limacidae*). Awareness of this risk may be particularly relevant for the museums and archives of the former Soviet Union, because the majority of art works are still stored in the basements and ground floors of the museums and archives there.

Slug Morphology and Life Cycle

Before discussing the damage caused by slugs, it is important to understand some basic biological information regarding the species.¹⁻³ Slugs are classified as gastropods, a branch of the mollusc species. These organisms are widespread throughout the world.

Slugs are soft-bodied organisms, often shell-less, with elongated, slime-covered bodies. Adults are typically between

2 and 15 cm long, but some species can grow up to 20 cm. Most slugs are dark or light grey, tan, green, or black; some have darker spots or patterns. The slug's body has three basic parts: a head, a mantle and a muscular tail. On the head are a mouth and two pairs of tentacles. The eyes are located on the upper, longer pair of tentacles (ocular tentacles) while the lower pair has a sensory function (sensory tentacles). Slugs eat with help of a radula, a rasping tongue covered with numerous chitinous teeth. A pneumostome, or breathing pore, is located on the thick, leathery mantle. Numerous mucus-secreting glands are situated on the head and tail.

Slugs are hermaphroditic. Throughout the year, slugs may lay up to 500 eggs in small groups of 10–40 in damp, shaded, sheltered areas. The eggs are translucent or clear, and oval or round in shape, and are laid in jelly-like masses. Development of the eggs continues for 2–4 weeks. New born slugs differ from the adults only in their size. The average development time from egg to adult is five months. Adults usually live from one to two years.

Slug Ecology

Such slug species as *Limacus flavus* (Linnaeus, 1758) and *Limacus maculatus* (Kaleniczenko, 1851) are common inhabitants of the urban environment and thus can be considered *synanthropic*, or living in close association with humans. Slugs can be frequently found in gardens and parks, cellars and ground floor rooms, underground conduits and greenhouses, and are considered major pests of agricultural and horticultural production. Most slugs prefer habitats with

moist and cool conditions, but can be found in interior spaces with normal temperature and humidity conditions within isolated microclimate zones where environmental conditions differ from the surrounding room or building.⁴ Such microclimate zones, may be found in plumbing pipe runs, areas where condensation accumulates, and even in damp soil in flower pots.

Damage Resulting from Slug Infestation

In the autumn of 2012 and winter of 2013, *Limacus* sp. (likely *L. flavus*) were found in the basement of the National Research Restoration Centre of Ukraine (Odessa) despite indoor conditions (temperature between 19–21°C and relative humidity about 45–60%) not usually favoured by slugs (**Figure 1**). It appears that the slugs were coming up through cracks in the floor from their habitat in a damp cellar beneath, where condensation on cold water pipes provided them with favourable living conditions. During the day the slugs hid in the floor cracks and behind water pipes, and then at night they actively searched for food. This was evidenced by the numerous typical mucus tracks and excrement on the floor. Sometimes these traces were found on shelves 40–50 cm above the floor.

Apparent slug damage affected newspaper (**Figure 2**), softcover books (**Figure 3**), and paper envelopes containing photos (**Figure 4**). In the absence of their usual food substrates (decaying plant materials, mushrooms and carrion), the slugs were probably attracted to traces of food, oils, or sweat on the paper. Since newspaper that had been used to package food products suffered the most damage, it was concluded that these traces were a contributing factor in attracting the slug pests. This was further supported by the observation of localized round and elliptical food stains and oily sweat residues on the paper around the areas of loss.

The most severe damage was observed on the contaminated newspaper (**Figure 2**). The slugs produced many holes extending right through the paper. Less severe damage was observed on the thick offset paper of the paperback covers (**Figure 3**) and on an envelope made of

black paper (**Figure 4**). This damage was more local and limited in size. No preference for specific ink or surface finishes on the paper was observed: the paperback cover was white, the photo paper envelope was black, and a damaged fragment of newspaper was printed with blue, yellow, red and black inks. In all cases, damage was observed on the surface paper layers. Because the damage was discovered after the slugs were eliminated, it was not possible to determine the time it took for the slugs to damage the paper.

Paper damaged by slugs has a characteristic appearance. First, the surface of the paper is grazed in round or oval shaped areas with irregular borders, some of which merge or are eventually eaten through the entire paper thickness, forming large uneven holes. As the slug consumes the paper, the slug's radula shift the cellulose fibres towards the edge of the hole, resulting in a small raised bead of fibres around the perimeter of the hole (the bead is clearly visible on **Figures 3** and **4**). Such damage to paper looks very similar to the damage inflicted by silverfish (*Lepismatidae*), another pest which can affect museum storage; however, in the case of silverfish damage, there is no raised bead of fibres around the edge of the losses (**Figure 5**).

Mucus tracks and excrement also contaminated the paper in this case. The slug's mucus is composed mainly of water, with dissolved mineral salts, proteins and carbohydrates. The mucus also contains the mucopolysaccharide *mucin*, which is responsible for its viscosity. These residues may in turn contain bacteria and microscopic fungi, which could result in additional biodeterioration.

If deposited on works of art or documents, the mucus and excrement would be removed. No treatment methodology was worked out in this case, however, as the papers damaged by mucus deposits were not works of art and therefore were not a priority for conservation treatment.

Infestation Response

Slugs were observed in the basement at the National Research Restoration Centre of Ukraine (Odessa branch) on two



Figure 1. Slugs in the basement of the National Research Restoration Centre of the Ukraine. The small white spots on the body of the slug are parasitic slug mites (*Riccardoella* sp.).

separate occasions. In the first instance, obvious damage to paper occurred. Since the slugs were active at night, they went unnoticed until a newspaper left on the table was chewed. After this damage was noticed, more attention was paid to the specific mucus tracks. Closer inspection showed that the mucus tracks led to cracks in the floor near a cold water pipe. This area was then monitored first thing in the morning and late in the day, and three slugs were observed and caught. Soon we found more damage to other works. Six months after the first instance, a fourth slug was caught in the same room. In both instances, the slugs were found hiding in the cracks in the floor near the pipe. All four slugs were disposed of by hand-picking. Cracks around the cold water pipe were patched after the second occurrence. No further slugs have been observed since this repair work was done.



Figure 3. Slug damage to a softcover book.

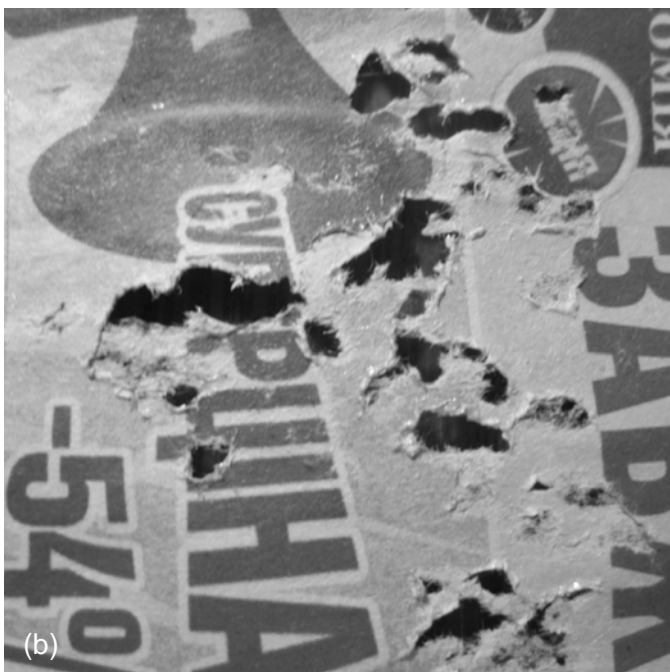


Figure 2. Slug damage to newspaper: (a) surface grazing, (b) holes.



Figure 4. Slug damage to a black paper photograph envelope.

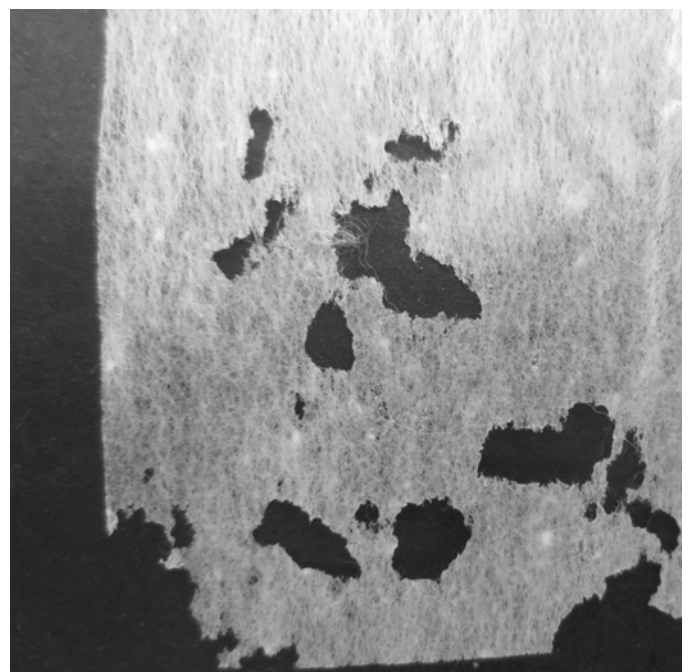


Figure 5. Damage to paper by silverfish (*Lepisma saccharina* L.).

Pest Management Recommendations for Slugs

Should evidence of slugs be discovered in museum or archives storage, a combined integrated pest management (IPM) approach may be the most effective means of control.

Detection and Prevention

Indicators of the presence of slugs include mucus tracks on floors, walls, or furniture (**Figure 6**). Sometimes, especially early in the morning or late at night, it is possible to see slugs crawling indoors.

Slugs can be introduced into the museum or archives in different ways. Typically they are tracked in soil on shoes. They may also arrive on fruits and vegetables, flower bouquets, seedlings, or potted plants. Good preventive conservation housekeeping standards can help to minimize this risk.

In order to prevent slug damage of works of art on paper the following measures are recommended: change shoes inside or wear protective shoe covers, and ban fruits, vegetables, bouquets and flower pots in the museum and archives. It is also worth noting that the elimination of microclimate zones that create conditions favourable for slugs would make it impossible for the pests to inhabit the room. In low humidity conditions they become sluggish and soon die.

Pay attention to the possibility of slugs inhabiting soil found outside the museum or archive building such as the courtyard or any flowerbeds at the entrance (**Figure 7**).

Prompt attention to elimination of the slugs will help to discourage their subsequent appearance.

Possible entry points and sources of shelter for slugs (such as microclimate zones) must be identified and monitored. Careful inspection of all works of art on paper and storage furnishings in any problem areas identified is important. Particular attention must be paid to the works located near any observed mucus tracks.

Measures must be taken to protect all paper from slug damage. This may include storage of works of art on paper in closed cabinets and boxes which slugs cannot penetrate.

Pest Control Methods

Some of the methods that are commonly used to eliminate slugs in agriculture and gardening can be used to eliminate slugs in museums and archives. Hand-picking, bait and traps are the safest methods of reducing the presence of slugs in museum or archives.

Hand-picking

First, it is necessary to find the areas where the pests are taking shelter. As noted above, they prefer to hide in dark and damp places, so the room should be carefully inspected, paying special attention to microclimate zones with favourable conditions for these organisms. Any slugs found must be collected in a jar of concentrated saline solution, or they can be captured live and released away from the building.



Figure 6. Mucus track on a wall in the basement of the National Research Restoration Centre of the Ukraine.



Figure 7. Numerous mucus tracks of slugs in the courtyard of the National Research Restoration Centre of the Ukraine (Odessa).

Baits and Traps

Flat wooden planks, pieces of cardboard or small flower pots can serve as traps. They should be placed in the immediate vicinity of the slugs' shelter, in dark and damp places. Lettuce leaves, stems and leaves of fennel, small pieces of vegetables or fruits, citrus peel soaked in water and even pet food can all be used as baits for the traps. Baited traps are useful for both monitoring and eliminating the slugs.

Use of Molluscicides

According to integrated pest management best practices, molluscicides should be used only when non-chemical means are ineffective. The molluscicides must be selected and applied in a way that minimizes their possible harm for art works, for people and for the environment. They are commonly prepared as bait by mixing with cereal bran, flour or sand granules, or used in liquid form to wet the bait.^{5,6}

The most common molluscicide is based on metaldehyde. Metaldehyde is a specific contact and systemic molluscicide which is used to both attract and to kill slugs, snails and other gastropods in agriculture, homes and gardening.⁷ It is the cyclic tetramer of acetaldehyde and is known under various commercial names. Other effective molluscicides used to kill slugs include methiocarb and iron phosphate.^{1,5,6}

All molluscicides are also toxic to humans. Staff should be warned about their use and should avoid contact with skin, eyes and the respiratory tract. Bait stations with molluscicide should be placed next to the slugs' shelters in order to help to prevent contact with artworks and cabinets or shelves and other museum equipment. Note that over time the molluscicide loses its effectiveness (this time will differ from one pesticide to another). Therefore, in order to deal effectively with the slugs, the molluscicide must be refreshed periodically following the manufacturer's recommendations. Physical and biological factors can also have a negative impact on the properties of the molluscicide. The bait stations with molluscicide are by necessity placed near the slugs' shelter, which tend to be damp. This can lead to issues related to high humidity, including mould or dissolution of the pellets, necessitating frequent replacement. Consulting a professional extermination company may be warranted.

Conclusion

In conclusion, a new and previously undocumented pest risk for works of art on paper was discovered at the National Research Restoration Centre of Ukraine in Odessa. Biodeterioration of paper by slugs was observed in a basement level room despite normal museum storage environmental conditions. Upon further study, it was found that the presence of the slugs was attributable to microclimate zones. The slugs damaged newspaper, softcover books, and paper envelopes for photos. The slugs apparently ate paper with food, oils and other contaminants in the absence of their usual food substrates. The damage appeared in the form of holes and losses in the paper, as well as deposits of mucus and

excrement. Given this, slugs appear to be potential pests of works of art on paper stored in damp basements and ground floors. This risk is particularly relevant for the museums and archives of the former Soviet Union, because the vast majority of art works are still stored in the basements and ground floors of the museums and archives. In the Ukraine, for example, works of art are stored in the basements or ground floors in more than 37% of the museums.⁸ Means of identification of the slugs, monitoring for their activity, prevention and elimination, implemented in accordance with museum integrated pest management best practices are the key to managing the threat to collections posed by slugs.

Acknowledgements

We appreciate the contribution of Dr. Igor Balashov, the Department of Invertebrate Fauna and Systematics of Schmalhausen Institute of Zoology (Kyiv, Ukraine) for slug identification.

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