Journal of Cultural Heritage 59 (2023) 255–263

Contents lists available at ScienceDirect

Journal of Cultural Heritage

journal homepage: www.elsevier.com/locate/culher

Original article

Insecticidal gel bait for the decimation of *Ctenolepisma longicaudatum* (Zygentoma: Lepismatidae) populations in libraries, museums, and archives

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ARTICLE INFO

Article history:
Received 8 November 2022
Accepted 30 December 2022

Keywords:
Long-tailed silverfish
Control
IPM
Insecticidal gel bait
Population decline
Preventive conservation

ABSTRACT

The problem of bristletail *Ctenolepisma longicaudatum* (Zygentoma: Lepismatidae) in libraries, archives, and museums is increasing. It can cause damage to valuable and irreplaceable objects. We describe the effect of the use of insecticidal gel bait (active ingredient: indoxacarb) against *C. longicaudatum* populations in three libraries, seven archives, and seven museums in Norway and Austria. Pest activity was monitored with sticky traps to evaluate the effect of bait application. Significant declines in pest populations were observed at all locations when small bait droplets were applied either systematically throughout the buildings or strategically close to suspected aggregations. In addition, bait was successfully used to prevent infestation in a new museum building. The cost of treatment, measured by the amount of bait and work hours spent, was low, and bait application was conducted by either the professional pest control technicians or the local integrated pest management (IPM) manager. The use of insecticidal gel bait and its secondary effects is a cost-efficient alternative for population decimation; moreover, the method has a low probability of negative health issues for employees at the treated localities or damage to the objects. The application of bait is discussed in relation to its alignment with other IPM methods in libraries, archives, and museums.

Abbreviations
IPM Integrated pest management

1. Introduction

The long-tailed silverfish (*Ctenolepisma longicaudatum* (Escherich, 1905, Zygentoma: Lepismatidae)) has become an indoor nuisance pest in private homes in Europe during the last 5–10 years [1,2]. It is also considered an important problem for libraries, archives, and museums as there is the risk that it damage valuable and irreplaceable objects [3–7]. At particular risk are graphic collections, photographs, modern art made of paper, historic documents, and books (Fig. 1A–D). The first report of the introduction of this nuisance to Europe was from Spain [8]; subsequently, it gradually dispersed and has been recorded on a more regular basis in several countries [9, 10]. In other parts of the world comparable issues have not been observed, even though *C. longicaudatum* has been observed indoors throughout the 20th century in Africa and Australia [11], America [12,13], the Middle East [14], and the southernmost parts of Europe [15].

Commercially available insecticidal gel baits (hereafter only referred to as baits) are considered a safe and effective solution for the control of *C. longicaudatum* in private homes and public buildings [16]. Baits originally intended for ants or cockroaches have been documented to kill *C. longicaudatum* [17] through both pri-

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https://doi.org/10.1016/j.culher.2022.12.010

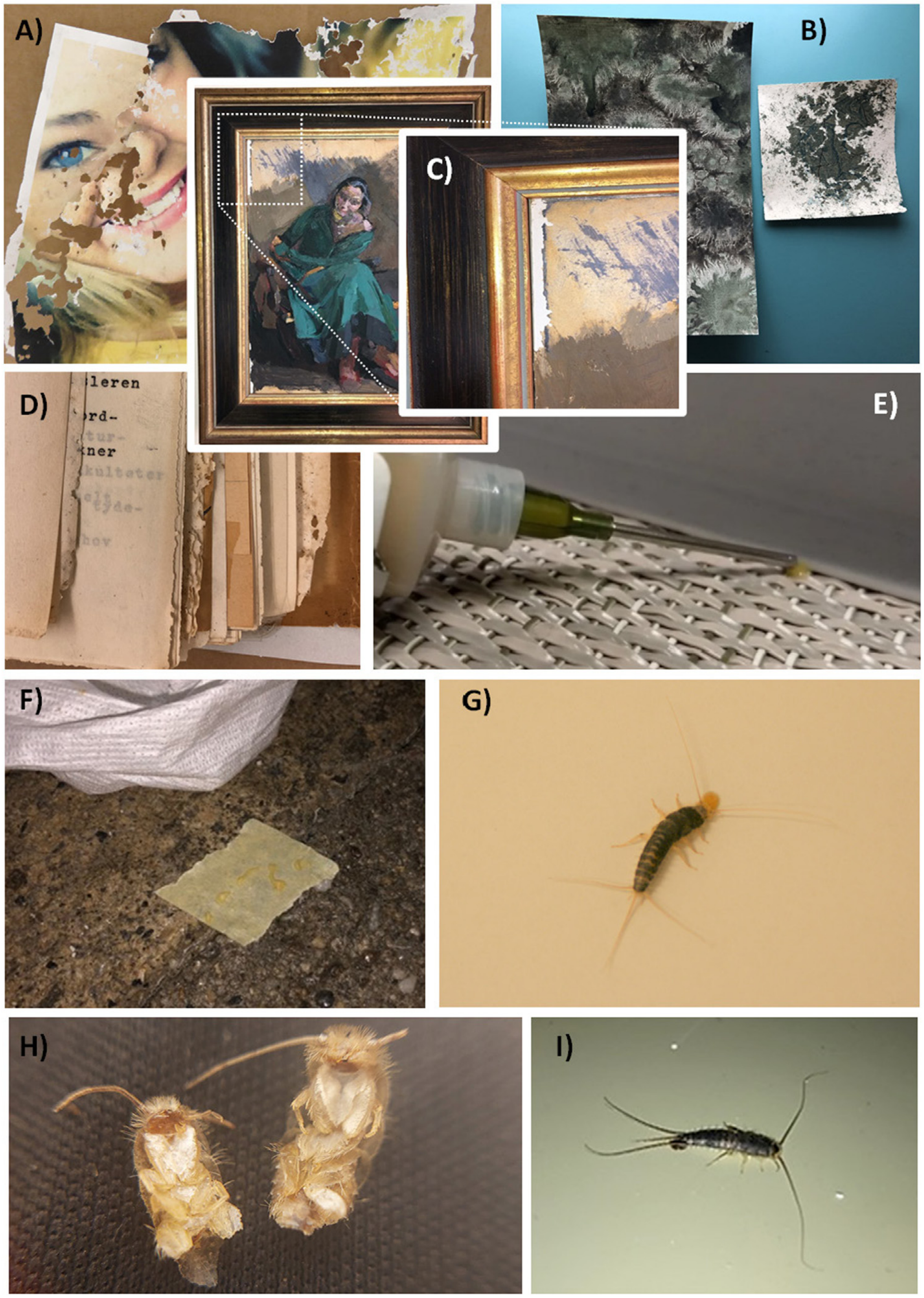

Fig. 1. Damage caused by *Ctenolepisma longicaudatum* and various aspects of control efforts for population decimation. The photographs show damage to: A) print, B) paper art, C) painting, and D) pages from an old book. During control efforts, insecticidal gel bait was applied directly on the floor using E) a needle applicator to allow sufficiently small drops, or F) by tape on the floor to possibly remove droplets. *C. longicaudatum* consumes the bait directly (G) or indirectly by consuming dead individuals. Image H) shows half-eaten *C. longicaudatum*, and I) a *C. longicaudatum* killed by bait in museum storage. Photographs: F), I): Pascal Querner, and B), D): Mónica Garrido.

mary poisoning (consumption of bait, Fig. 1E–G) and secondary poisoning (consumption of dead conspecifics containing toxins from the bait, Fig. 1H). Strategies for bait application have also been investigated in the laboratory, and their field efficiency has been confirmed [18]. The use of bait as a control strategy for *C. longicaudatum* appears to be a slow-acting method, i.e., a 90% reduction in 3–4 months, but the amount of bait needed for eradication is very small [16,18]. The gradual control effects from such small amounts of bait (Fig. 1E–G) are likely related to the behavior of *C. longicaudatum*. This species utilizes cracks and crevices throughout the entire building for foraging and dispersal [16], and exhibits partial aggregation based on chemical stimuli [19]. Although carbohydrate sources such as paper can serve as a food source to sustain activity and survival [20], *C. longicaudatum* requires a full diet with a surplus of proteins for growth and reproduction (Anders Aak et al., unpublished material). Given the limited availability of protein indoors, C. longicaudatum seeks out and quite intensively consumes dead insects, including conspecifics (Fig. 1H–I) [11,21,22]. Through the use of slow-acting active ingredients in baits, this dynamic “search, feed, and hide” behavior can, through the utilization of secondary poisoning, distribute toxins to the inaccessible spaces where this culprit thrives.

Integrated pest management (IPM) within the urban environment contributes to pest control and conservation by focusing on the deterrence of pest infestations and the reduction of pesticide application [5,23-25]. A holistic and safe IPM concept can be achieved by combining measures such as sealing the building against pest entry, adjusting the micro-climate to slow insect development, maintaining high hygiene standards to reduce available food sources, quarantining or treating incoming objects to prevent infestations, and monitoring of potential pest infestations [5,23,26,27]. Even if most aspects of IPM and preventive conservation are in place, control actions must be taken when pests are found in detection traps or if traces of damage appear on objects. In libraries, archives, and museums, priority is often given to chemical-free object treatment with physical methods such as heat, cold, or anoxia [5,23,28]. This type of treatment targets the insect's internal processes and physiology to increase mortality [29–32], but requires precise knowledge of the pest's whereabouts. In this respect, *C. longicaudatum* poses a new challenge for conservation because an infestation cannot be eradicated solely by treatment of the objects. The species spends most of its time on the move or hiding at suitable locations close to the objects they damage. When this behavior is combined with the structural complexity of buildings with historic and valuable collections, the difficulty increases further. On top of this, *C. longicaudatum* is often found below floorboards, in connection with the buildings' technical installations, or in ventilation and air conditioning systems (HVAC-rooms). This highly cryptic behavior and the ability to maintain relatively large, hidden populations within a building can make early detection and efficient control difficult [16,18,21].

It is difficult to target *C. longicaudatum* with traditional liquid pesticides, smoke generators, mists, fogs, or dust as the insects spend most of their time in hidden and inaccessible locations [22,25]. Such treatments also require repeated and building-wide application of toxins that risk the contamination of collections, as well as pose an unacceptably high risk to the employees' health [24,33,34]. The use of highly volatile gasses, such as phosphine or sulfuryl fluoride, necessitates strong safety measures [22,35] and may also lead to damage of museum objects through chemical reactions, such as metal corrosion [36,37]. It is therefore desirable to prevent and limit the use of pesticides in any type of collection [5]. The cautious and conservative use of insecticidal gel baits may still fit a safety focused approach toward control; moreover, by accounting for all local IPM aspects and conservation requirements, this method will likely contribute to the decimation of this new pest.

2. Research aim

With the aim of providing an IPM approach encompassing the improved handling of insect infestations in libraries, archives, and museums, we studied baits as a safe, low-cost, supplementary tool toward object conservation. The impact of bait application on *C. longicaudatum* populations was measured in four full-scale experiments that involved 17 different infested localities. The effects of the control efforts are quantified by the consistent use of sticky traps, and the cost and labor needed to reduce populations to acceptable levels are measured and discussed in an IPM setting.

3. Material and methods

3.1. Localities

The 17 different *C. longicaudatum* infestations were in Norway and Austria, which have experienced multiple infestations. The investigated localities varied considerably in building specifics; mostly, the localities had additional users located in the building, and they were partly open to public visitors (Table 1).

3.2. Experiments

3.2.1. Pest control with bait and effect measurements (Experiments 1–3)

In all three experiments the activity of *C. longicaudatum* was monitored prior to bait application, and the subsequent changes in population were followed for more than 1 year. The bait in use was Advion Cockroach (active ingredient; Indoxacarb; 0.6%) which is approved for use against crawling insects according to the Norwegian label. This bait has previously been used with success in other urban environments [16,18]. Sticky traps, also known as blunder traps, glue traps, sticky monitoring traps or delta-traps (~0.1 € per trap), were used as passive monitoring traps, and they were placed at the same positions in all trapping periods. Most traps were placed alongside walls, behind or underneath furniture. The cost of the treatment in the localities were calculated using the amount of bait, the number of man hours spent, and the hourly rate of pest control technicians and IPM managers.

The University Libraries at UiT—The Arctic University of Norway (Experiment 1) are in Tromsø, in the northern part of Norway, and consist of three divisions located in separate buildings: **Cultural and Social Sciences, Science and Health**, and **Psychology and Law**. The three libraries range from 2874 m^2 to 6400 m^2 in area and are interconnected with most other departments of the university through an underground corridor system. All libraries consist of visitor areas, storage rooms, office sections, wardrobes, and kitchen areas for the employees. Mostly, the libraries store books, journals, and magazines, together with some specialty objects such as antique maps, historic letters, university notes, paintings, various art objects, microfilms, and photographs. Bait was distributed at an approximate frequency of 1 micro-droplet (5–10 mg) per meter of skirting in rooms with detected *C. longicaudatum* activity and in all adjoining rooms. This was equivalent to more than 95% of the library treated. If possible, bait was placed at hidden locations in cracks and crevices. The three localities were followed thoroughly for half a year after bait application by replacing the traps every 14 days, whereas the remaining measurements were obtained through the established *C. longicaudatum* monitoring system. The catch was scored as one of four categories of life stage: 1) juveniles without scales; 2) juveniles with scales; 3) juveniles with styli at the end of the abdomen; and 4) adults.

The parts of *The National Archives of Norway* (Experiment 2) that participated in this study were the main archive in **Oslo** (Riksarkivet) and the six regional state archives in **Bergen, Stavanger, Hamar, Kongsberg, Trondheim,** and **Tromsø**. The size of the archives ranged from 2820 m^2 to 30,670 m^2. The archives consist of storage rooms and technical sections in combination with offices, visitor areas, wardrobes, and kitchen areas for the employees. The archives store documents, bound volumes, photographs, books, and specialty objects, such as maps, drawings, movies, and sound files, alongside digital records. Previous studies show distinct efficiency differences between sticky traps and bait as a control method [16]. Sticky traps were also used for control in 2017–2020, but as the control effect was limited (no clear reduction observed and method found too labor intense), bait was introduced at the end of 2020. Bait was distributed systematically in all rooms; i.e., 100% of the archives treated. Approximately 1 micro-droplet (5–10 mg) was used per meter of skirtings. The population was monitored through three periods: period 0, 1–2 months before bait placement; period 1, 2–4 months after bait placement; and period 2, 5–8 months after bait placement.

Table 1
Technical specification and information on the libraries, archives, and museums in Norway and Austria where *Ctenolepisma longicaudatum* was controlled with insecticidal gel bait.

		Building size (m^2)	Area used by institution (%)	Number of floors	Number of rooms	Single (s) or multi (m) users in building	Number of employees	Exhibition, storage, other area (%)	Climate control	Construction year (expansion)	Coordinates
Libraries	Psychology and Law	39 000	7	4	63	m	13	81, 6, 12	no	2004	69.6816, 18.9709
	Science and Health	36 085	9	4	55	m	16	60, 23, 16	no	1991	69.6823, 18.9783
	Cultural and Social Sciences	9237	69	5	249	m	21	71, 5, 24	1 room	1982	69.681, 18.973
Archives in Norway	Oslo	32 000	96	14	350	s	176	0, 69, 31	yes	1978 (2009)	59.967, 10.735
	Bergen	7609	98	4	163	m	19	0, 72, 28	yes	1921 (2012)	60.381, 5.360
	Hamar	3188	88	2	56	s	12	0, 41, 59	yes	1991	60.795, 11.067
	Kongsberg	4500	99	2	85	m	7	0, 56, 44	yes	1993	59.684, 9.652
	Stavanger	2835	100	4	12.	s	15	0, 77, 23	yes	2017	58.932, 5.703
	Trondheim	8300	100	2	120	m	15	0, 70, 30	yes	1988	69.681, 18.971
	Tromsø	4500	88	3	86	s	6	0, 68, 32	yes	1993	69.681, 18.972
Museums	Artothek des Bundes	4500	22	1	4	m	5	60, 20, 20	yes	1962	48.1108, 16.2302
	Archive for the History of Technology	5 000	100	1	5	s	15	0, 100, 0	no	1950	48.1217, 16.1737
	State Collections of Lower Austria	5750	61	3	10	m	30	0, 100, 0	yes	2015	48.1201, 15.3657
	Salzburg Museum	13 000	50	1	2	m	25	0, 80, 20	yes	1970	47.4653, 13.0405
	MdM Mönchbergs	2400	100	4	20	s	30	95, 0, 5	yes	2004	47.4758, 13.0223
	Museum of Art	14 000	100	4	4	s	3	0, 100, 0	yes	2012	48.0523, 16.2540
	MUNCH	26 300	93	13	420	s	615	62, 12, 26	yes	2021	59.906, 10.758

The six museums in Austria (Experiment 3) contain a wide variation of objects and span many of the themes commonly found at museums throughout the world. The size of the localities ranges from 2400 m^2 to 14,000 m^2, and they typically consist of exhibition or storage rooms combined with technical sections and areas for the employees. **Artothek des Bundes** in Vienna administers modern and contemporary art, paintings, graphic prints, and sculptures for exhibition; it also lend items to different institutions (such as ministries) and private individuals. The **Archive for the History of Technology** (TMW Breitensee) in Vienna is a museum storage facility that holds a major part of the Vienna Technical Museum's collection. Both the **State Collections of Lower Austria** and the **Salzburg Museum** stores objects such as paintings, sculptures, graphic art, photographs, and folkloristic objects covering the areas of archeology, art, and cultural history. The **Museum der Moderne Mönchbergs** stores and displays modern and contemporary visual arts, whereas the **Museum of Art** houses a collection of fine art including paintings, decorative objects, sculptures, drawings, and graphics. In the museums, bait was distributed in a strategic manner using the relative numbers of trapped individuals as a trigger for application. Bait was distributed only in rooms with high *C. longicaudatum* activity, equating to a treatment coverage of between 4% and 84% of the area in the six museums. Infestation levels were checked up to five times per year with traps in place for 1 to 5 months at a time.

3.2.2. Pest prevention with bait (Experiment 4)

Munchmuseet in Oslo, Norway has recently moved from an old and smaller locality (7500 m^2) to a brand new and much larger facility (26,300 m^2). The presence of *C. longicaudatum* was confirmed in the old locality during a 2-week trap period, which captured 26 individuals in 100 sticky traps placed at locations with suspected activity. The risk of transferring *C. longicaudatum* during the moving process was therefore considered to be very high. The new *Munchmuseet*, named **MUNCH**, consists of storage and exhibition rooms in combination with technical sections, conservation laboratories, and office facilities with a canteen for the employees, wardrobes, restaurants, and bars. MUNCH stores mostly graphics, oil painting, drawings, and sketches, but also specialty objects such as Edvard Munch's art equipment, furniture, and personal belongings. The museum also houses a small library. In the new and empty locality, a pest control company distributed approximately 1 micro-droplet (<5 mg) per meter of skirting, adding to a total of 150 g bait used in 26,300 m^2 prior to the main moving process. The bait in use was Advion Ant (active ingredient; Indoxacarb; 0.05%). Droplets were mainly placed in cracks and crevices acting as natural bait stations. As many as 157 traps were evenly distributed at strategic locations with potential *C. longicaudatum* activity, and the monitoring was conducted at five regular 2-week intervals encompassing approximately 1 year. The first trapping period was concluded prior to the main moving process and bait application, the second trapping period was conducted 2 weeks after bait placement, and the last three were performed at regular intervals thereafter.

3.3. Statistics

Data were analyzed using SigmaPlot 14.0 software (Systat Software Inc. San Jose, CA, USA). The level of significance was set to 0.05, and values are presented as the average and standard error (±SE). Linear regression was used to correlate the treatment cost and area treated within the different localities. The Austrian localities were excluded from this analysis because bait was complementary in a larger and more extensive IPM system and could therefore be applied at a very low cost. Repeated-measures analyses of variance (rm-ANOVA) on ranks were used to analyze devel-

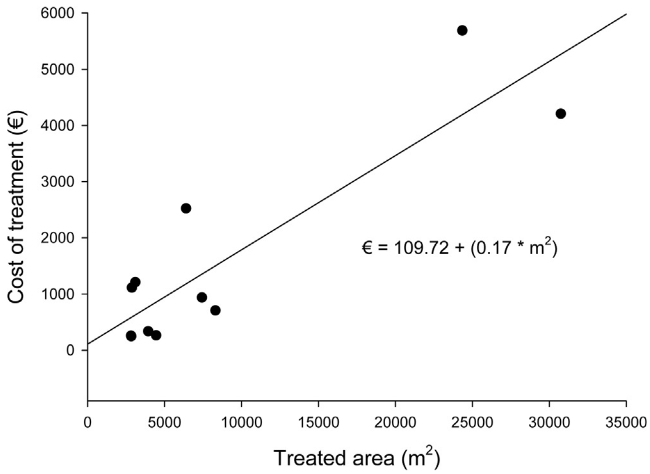

Fig. 2. The relationship between the size of infested buildings (libraries, archives, and museums in Norway) and the cost of *Ctenolepisma longicaudatum* treatment using bait.

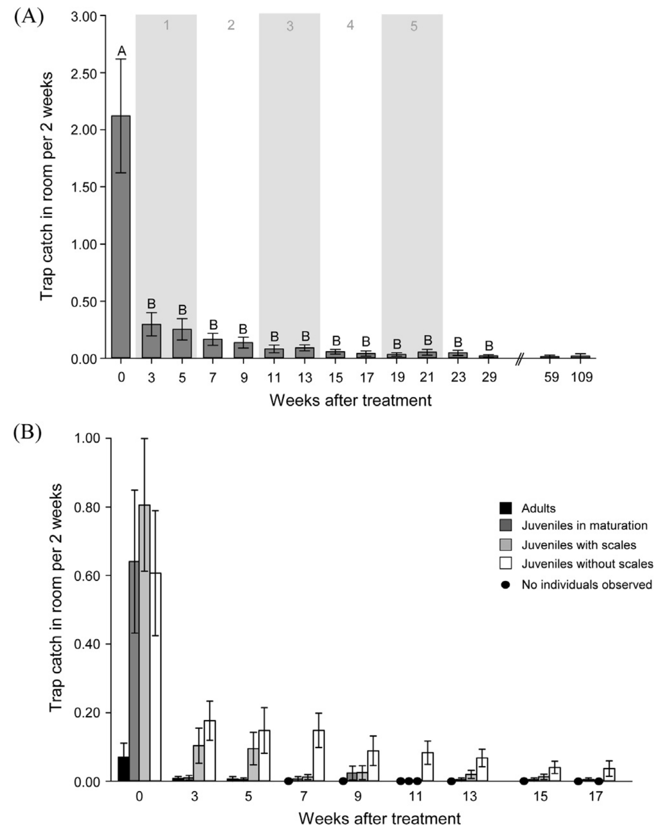

Fig. 3. Treatment of *Ctenolepisma longicaudatum* infestations with insecticidal gel bait in three libraries at UiT—The Arctic University of Norway (38, 52, and 64 traps in three libraries): (A) development of infestations and (B) changes in development stages in different weeks after treatment. The varied shaded gray and white background color represents an approximation of 1 to 6 months (for direct comparisons with experiments 2 and 3). Different letters indicate significant differences between measurements of different periods (Tukey test, $p < 0.05$).

opment of *C. longicaudatum* populations in different localities before and after treatment with bait. This statistical test is typically used for evaluation of effects through time because the analysis separates out subject variance from error variance. To isolate and identify the significant differences, we used an all pairwise multiple comparison procedure (Tukey Test). To compare the relative decrease in population size at the different localities following bait placement, we used the percentage decline in the trap period that ended 8–12 months (average of 9 months) after bait application. In experiment 1, the population development was measured as the average number of individuals per trap in a room over a 2-week period. In experiments 2 and 3, the population development was measured as the average number of individuals per trap in a building section per month.

4. Results

In the 17 investigated localities, we observed infestations of *C. longicaudatum* in a variety of building types throughout many geographical regions of both Norway and Austria. The year of building construction ranged from 1921 to 2021, the size ranged from 2400 m^2 to 39,000 m^2, the number of floors and rooms from 1 to 14 and 2–420, respectively, and finally the number of employees from 3 to 615 (Table 1). The labor and cost to treat the infestations were correlated with size of the localities, with a cost increase of ~0.17 € per m^2 observed (linear regression; $R^2 = 0.778$, $p < 0.001$, Fig. 2). Labor was the main driver of the control cost as the bait itself comprised only 5%–17% of the total cost. A pest control technician required an average of 11.8 ± 1.6 min per 100 m^2 to administer the bait. At some locations, this time also included the inspection of monitoring traps (Table 2). The average amount of bait administered at the locations was 1.25 ± 0.13 g per 100 m^2.

At all locations, there was a persistent decline in number of *C. longicaudatum* specimens after the introduction of the bait. At *The University Library at UiT* (Experiment 1), where the pest populations were studied in detail, we found a significant decline in the second trapping period 3 weeks after bait placement, followed by further smaller declines until the final measurement after 2 years (rm-ANOVA on ranks; $\chi^2 = 96.2$, df = 12, $p < 0.001$, Fig. 3A). The continuous decline revealed a substantial long-term decimation effect. The demography of the populations also changed during the monitoring period (Fig. 3B). All *C. longicaudatum* stages initially declined, but the later measurements were strongly dominated by the smaller stages; only a single adult specimen was observed between week 6 and week 109.

At *The National Archives of Norway* (Experiment 2), we observed a significant reduction in *C. longicaudatum* in both periods following the bait application (rm-ANOVA on ranks; $\chi^2 = 46.1$, df = 2, $p < 0.001$, Fig. 4).

C. longicaudatum in *Museums in Austria* (Experiment 3) also declined in numbers following bait application. A significant reduction in populations occurred the last three periods (rm-ANOVA on ranks; $\chi^2 = 35.0$, df = 4, $p < 0.001$, Fig. 5).

Because all experiments yielded significant reductions in population sizes after 8 to 12 months, this period was used to evaluate the effectiveness of the bait application approach. In the systematic treatments (experiments 1 and 2), 90% reduction was achieved in eight out of ten localities and more than 80% reduction was achieved at all localities (Table 2). Full eradication was achieved in five of these ten localities. In the strategic treatments (experiment 3), 90% reduction was reached in only three out of six museums. In the remaining three museums, only 4%–14% of the locality was treated.

The preventive bait used at *MUNCH* (experiment 4) was successful. Prior to the main moving process, we observed one *C. longicaudatum* in the traps, and a second individual was detected just after placement of the bait (Table 3). Thus, this meant that *C. longicaudatum* was the first registered pest in the new museum, although the observations indicated a minor infestation only. No individuals were observed in the monitoring traps in the 12 months after bait application.

Table 2
Description of resources (traps and bait) and cost (man hours and bait) required to control *Ctenolepisma longicaudatum* in different libraries, archives, and museums in Norway and Austria. “Bait distribution” describes the amount of bait used in the treated areas; “area treated” indicates the percentage of the locality treated with bait; and “relative decline” indicates the reduction in population size in the whole locality approximately 8 months after bait treatment.

	# of traps	# of *C. longicaudatum* caught	Bait used (g) [a]	Bait distribution (g/m²)	Area treated (%)	Relative decline (%)	Man hours [b]	Labor cost (€)	Bait cost (€)
The University Library at UiT—The	38	27	59	0.021	>95	100	9	920	195
Arctic University of Norway	52	162	64	0.021	>95	98	10	1000	213
(Experiment 1)	64	250	133	0.021	>95	100	19	2080	445
The National Archives of Norway	255	96	510	0.017	100	80	50	3700	510
(Experiment 2)	149	189	15	0.008	100	83	12	880	60
	108	27	40	0,014	100	91	3	220	40
	83	59	45	0.010	100	100	3	220	45
	83	2	30	0.011	100	100	3	220	30
	209	24	120	0.014	100	95	8	590	120
	101	4	40	0.010	100	100	4	300	40
Museums in Austria	57	131	3	0.006	50	93	1	60	10
(Experiment 3)	29	10	3	0.015	4	96	1	60	10
	126	130	3	0.006	14	88	1	60	10
	31	62	3	0.005	10	60	1	60	10
	108	238	20	0.010	83	96	4	240	40
	345	136	6	0.012	4	52	1	60	10
MUNCH (Experiment 4)	157	2	310	0.012	100	100	40	5370	320

[a] Advion Cockroach was used in all places except for Munch, where Advion Ant was used.
[b] Man hours for distribution of bait in treated rooms. For experiment 2, man hours for inspection of traps are included.

Table 3
Monitoring of *Ctenolepisma longicaudatum* before and after the application of insecticidal gel bait in MUNCH. In total, 157 traps were positioned in the same rooms for 2 weeks in each sampling period. Bait was placed in the ninth week of the investigation period.

Weeks	0	10	25	48	64
Ctenolepisma longicaudatum	yes	yes	no	no	no
Bait present	no	yes	yes	yes	yes
Moving process	minor	minor	main	finalized	finalized
Museum activity	closed	closed	preparation	open	open

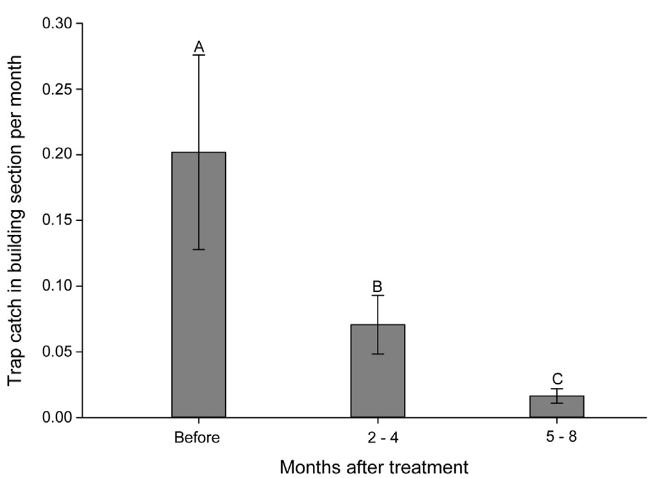

Fig. 4. Treatment with insecticidal gel bait and development of infestations of *Ctenolepisma longicaudatum* in the seven units of The National Archives of Norway: Oslo, Bergen, Stavanger, Hamar, Kongsberg, Trondheim, and Tromsø (255, 149, 83, 108, 83, 209, and 101 traps in the respective localities). Different letters indicate significant differences between measurements for different periods (Tukey test, $p < 0.05$).

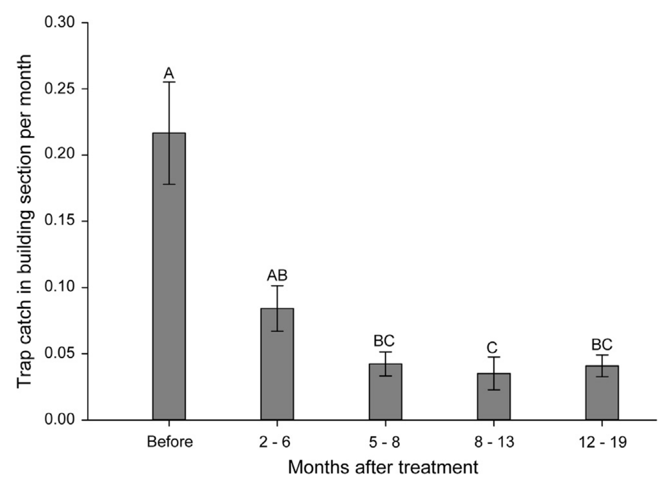

Fig. 5. Treatment with insecticidal gel bait and development of infestations of *Ctenolepisma longicaudatum* in the six museums of Austria: Artothek des Bundes, Archive for the History of Technology, State Collections of Lower Austria, Salzburg Museum, MdM Mönchbergs, and Museum of Art (57, 29, 126, 31, 108, and 345 traps, respectively). Different letters indicate significant differences between measurements of different periods (Tukey test, $p < 0.05$).

5. Discussion

The present study shows that bait is an applicable, low cost and efficient method for the management of *C. longicaudatum* in libraries, archives, and museums. These findings are in line with previous studies describing the control of nuisance infestations in other types of urban environments such as homes and offices [16,18]. Here, we have documented its usefulness in different-sized localities where *C. longicaudatum* has the potential to cause physical damage to valuable and irreplaceable objects.

In libraries, archives, and museums, the abiotic conditions and inadequate access to nutrition normally prevents high levels of insect activity. Unfortunately, *C. longicaudatum* can use carbohydrate molecules in paper, books, art, and other items as a sugar source and a part of their diet [20]. The feeding habits of *C. longicaudatum* are problematic as the insects contaminate and chew on valuable objects [3,5,7,22,35]; however, this is advantageous when considering control methods. Most commercially available baits contain sugars as feeding stimulants and therefore release the automatic feeding response when sacchariferous food sources are encountered by *C. longicaudatum* [11]. This ensures the ingestion of the bait (primary poisoning); consequently, when individuals die, they become attractive and consumable poisoned protein sources [16–18]. Closely related bristletail species also consume conspecifics to obtain essential symbiotic microorganisms [19,38-40], and because protein sources are limited in indoor environments, feeding on dead conspecifics (secondary poisoning) may frequently occur. Such chains of poisoning even encompass tertiary poisoning in cockroaches [41–43] and may have been an important factor behind the bait success in this study.

When considered as an urban ecosystem, the libraries, archives, and museums form a complex pest situation owing to the three-dimensional complexity of the habitat and the pattern of continuous in- and out-flux of objects. The main introduction path at a museum is likely through packaging material and wood pallets associated with new acquisitions, the return of loaned items, or the transfer of whole exhibits. The pathway is different for archives as they experience a continuous introduction of potentially contaminated heritage materials. At libraries, the dispersal risk runs in both directions through the extensive lending and return of items; although digitalization is increasing, libraries still hold large amounts of paper-based materials capable of harboring *C. longicaudatum*. Despite large variations in the studied localities and their populations, the differences in the dispersal possibilities, and the bait application method (systematic or strategic), *C. longicaudatum* infestations were easily decimated. A general reduction in population size at any location contributes to the reduction in the overall dispersal risk and can therefore remove unfortunate and chronic infestation patterns. The efficient decimation of population may therefore prevent *C. longicaudatum* from becoming an endemic issue in cultural heritage institutions. Both Aak et al. (2020b) and the present study show that bait also quickly removes adults from infested localities. This is of particular interest for conservation, because it quickly lowers the reproductive potential of established populations and almost instantly reduces their potential to damage objects on display or in storage by removing the largest individuals.

Although indoor pesticide use poses a health risk [24,33], bait is certainly the least harmful pesticide approach. Bait offers strong control with small amounts of bait that contains low concentrations of active ingredients [44,45]. Bait droplets were also often applied in cracks and crevices to minimize potential human contact. The maximum amount of bait used at a single location in this study was 0.02 g per m^2, which is equivalent to only 0.1 g of active ingredient in an entire building of 1000 m^2. Bait treatments therefore provide precise and safe support to the conservation systems already in place. The lack of full eradication in some of the treated *C. longicaudatum* populations in this study may be a consequence of the complexity of the habitat, the small amount of bait used, the absence of control efforts in neighboring units within multiuser buildings, or new introductions. It is very demanding to study these aspects of control, although we observed that the effect of bait treatment on many occasions was improved with increased effort. A fortified bait approach will elevate the risk of toxin exposure, and there is a need to strike a balance between the amount of bait used, its distribution in the building, the protection needs of objects, and the protection of the employees. The strategy should lean heavily toward the employees' side of this equation because this study shows that even small bait quantities are effective in large and complex buildings. Our results also point to a sustained effect for as long as a 2-year period at some locations. Field-collected bait is still effective after approximately 40 months (Anders Aak et al., unpublished material). These observations surely warrant further studies, although it is likely that a few minor applications of bait are sufficient for the long-term control of *C. longicaudatum*. Bait application is also known by all professional pest control technicians and consequently allows outsourcing of the control effort if needed. When considering bait use, a cost–benefit analysis necessitates the consideration of local resource availability combined with collection policies [5], and should account for national variances in legislation, labor cost, the quality of pest control contractors, and the local focus on health and safety issues.

In libraries, archives, and museums, quarantine routines for imported objects is an essential tool because the biology of *C. longicaudatum* means that the introduction of objects poses a high risk of contamination. Bait can be used in quarantine zones to target newly introduced individuals and thereby prevent establishment. The preventive use of pesticides is in general not wanted, but such use of bait can be justified if both the risk of introduction and the potential for damage is high. This was the case at *MUNCH*, where the need for extensive quarantine routines would have severely impacted the efficiency of the moving process. The source of the observed minor infestation at *MUNCH* may have been the moving process; although, as moving was only partially started when we detected the first specimen, *C. longicaudatum* may also have been introduced through construction materials.

IPM aims to combine different control measures in an optimal way [5,24,25]. The common use of freezing, heat, or anoxic treatments of objects [5,23] should not be affected by the use of bait, whereas three general measures might interact with this method. First, **cleaning** is an important part of all conservation and IPM systems. The removal of dust, fungal spores, minor food items, and other organic debris will, in general, prevent contamination and eliminate potential food sources for many of the common indoor pest species [5,23] as well as *C. longicaudatum*. By removing alternative food sources while the bait remains in place, the probability of bait consumption and subsequent control success will increase [18]. Second, the **monitoring** of insect pests is another measure that is often combined with visual inspections to catalog and map the long-term pest situation [5,23,26,27,46-48]. Traps placed on the floor are also effective in monitoring *C. longicaudatum* [21]; such mapping of spatial distribution may allow more strategic bait placement and help to define risk zones depending on the activity and the type of materials stored or exhibited. Third, the regulation of the **indoor climate** [47] toward dry conditions and low temperatures may reduce insect survival and hamper development and population growth [25,49,50]. In this respect, it is interesting that another bristletail species, *Lepisma saccharinum* Linnaeus, 1758, can alter its dietary preference from sugars to proteins at higher temperatures [51]. Bait consumption in *C. longicaudatum* might therefore be impacted by temperature manipulation, but further studies are required to confirm this. Finally, it has been observed that *C. longicaudatum* often co-occur with different bristletail species such as L. *saccharinum, C. calvum* (Ritter, 1910), and *C. lineatum* (Fabricius, 1775) [4,6,21,52,53], but these species may require conditions (high humidity or temperature) not commonly found in the storage or display rooms for cultural heritage items. Situations with mixed species or different abiotic conditions may affect general bait functionality through variations in the degree of primary and secondary consumption of the toxins. Currently we suspect that most silverfish species will consume bait and experience comparable population decline to *C. longicaudatum.*

6. Conclusions

In the present study, the application of insecticidal gel bait is shown to be an efficient control strategy. An understanding of the interactions between different objects that require protection and the biology and different control methods of pest species is crucial for successful management. If applied properly, a bait strategy may counter many of the challenges connected to *C. longicaudatum* control in complex environments and effectively utilize the foraging habits of this pest. Therefore, bait appears to be a low-risk and favorable tool that can be easily incorporated in the currently used conservation strategies of libraries, archives, and museums.

Acknowledgment

Lars Erik Lørdahl, academic librarian at the Humanities and Social Sciences library (University of Oslo) and Dr. Reiner Pospichiel provided valuable comments on the manuscript. Stein Norstein and Erik Thomas Gjølme in Anticimex, Stein-Birger Østmo in Rentokil skadedyrkontroll, and Morten Wilhelmsen and Tom Arild Jensen in Nokas skadedyrkontroll supplied the information regarding man-hours and cost of the control efforts. The pest control technicians performed impeccable and efficient work at the different localities.

Funding

Pascal Querner is funded by the Austria Academy of Science grant Heritage_2020-043_Modeling-Museum.

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