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ANTHROPOGENIC MATERIALS IN THE NESTS OF PASSERINE BIRDS: DOES THE ENVIRONMENT MATTER?

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Background. For several past decades, a notable pollution of the environment by different kinds of solid waste has been noted. The number of studies addressing the issue of utilising debris for nest construction by various species of birds has increased over the past century. It is important to understand the extent to which anthropogenic transformation of the environment in the form of debris affects the nest-building behaviour of birds and the architecture of the nest itself. In our research we analyse how the pollution of the environment with solid household waste affects the appearance of the debris in bird nests.

Materials and Methods. Materials for this article included 520 nests of 44 passerines species. Nests were collected unevenly during the last two decades (2002–2024) in different types of habitats mainly across the western part of Ukraine and in Poland. Collected after the breeding season, nests were decomposed in a laboratory and nest components were identified as natural (grass, plant stems, tree leaves, grass roots, moss, mammals' hair, bird feather and others) and anthropogenic (threads, synthetic fibres, plastic ropes, fishing line, cigarette filters, paper, tissue, wires and others), and their percentage by volume was defined.

Results and Discussion. Birds in the human settlements used debris for nest construction more often. The number of nests with debris in natural environment was the lowest and debris were found there in very small amounts.

Even a sufficient amount of natural nest materials in the environment does not prevent birds from using debris. Part of nests collected in the natural environment included debris indicating environmental pollution in the surrounding area.

There was a significant difference in the presence, amount and number of kinds of debris in the nests collected in different environments.

In the natural environment far from human settlements, the proportion of nests with debris (6.6 %), the number of kinds (mean ± standard error 0.08±0.02; median value 0.00, Q1–Q3 values 0.00–0.00, n = 293) (further the numbers are presented as mean ± standard error; median value, Q1–Q3 values, n) and amount (0.07±0.04 % by volume; 0.00 %, 0.00–0.00 %, n = 293) were the lowest. In the natural environment far from human settlements, debris still was present in nests, indicating the presence of pollution in such territories and demonstrating birds' ability to use debris, intentionally or unintentionally, even if natural nest materials are readily available.

Nests with debris collected on the outskirts are relatively high (63.2 % of nests), the number of kinds (1.12±0.10; 1.00, 0.00–2.00, n = 163) and amount (4.90±0.85 % by volume; 0.10 %, 0.00–4.00 %, n = 163) in debris, which may indicate randomly polluted environment as well as a presence of garbage dumps outside human settlements.

Debris in bird nests usually appeared in populated areas, where it is available and accessible in significant quantities. Most frequently, debris was found in passerine bird nests within human settlements (87.5 % of nests), however some nests did not include debris. The number of kinds of anthropogenic materials (ANMs) incorporated in the nests was the highest in populated areas (2.22±0.19; 2.00, 1.00–3.00, n = 64); it was more numerous in cities and towns (3.04±0.30; 3.00, 2.00–4.00, n = 25) than in villages (1.69±0.21; 1.00, 1.00–2.00, n = 39). The amount of debris in the nests was also the highest in human settlements (5.52±0.89 %; 2.00 %, 0.10–8.50 %, n = 64), being higher in cities and towns (6.93±1.22 %; 6.00 %, 2.00–10.00 %, n = 25) than in villages (4.62±1.23 %; 1.00 %, 0.10–5.00 %, n = 39).

Turdus merula from human settlements used debris a lot (92.9 % of nests). On the outskirts, 40.0 % of nests still contained debris (we assume that the number of nests in every environment is 100%), whereas in natural environment its nests consisted only of natural materials. On the outskirts, blackbird nests contained fewer kinds (0.50±0.22; 0.00, 0.00–1.00, n = 10) and a smaller amount (0.08±0.05 %; 0.00 %, 0.00–0.10 %, n = 14) of debris than in human settlements (3.00±0.50; 3.50, 1.00–4.00, n = 14; 7.30±1.55 %; 7.50 %, 3.00-10.00 %, n = 14).

Conclusion. The environment affects the presence of debris in bird nests. In the anthropogenic environment (human settlements) the share of nests with debris, the amount and number of kinds of debris were the highest. Birds do not always use ANMs in the polluted environment. On the other hand, even when the amount of natural materials was sufficient, birds could include debris into their nests.

Keywords: nest composition, anthropogenic materials, debris, environment, passerines

INTRODUCTION

The environment in which birds live has changed greatly over the last century. Along with the growing human population and the associated amount of waste produced, the amount of different type of physical contamination component in environment is increasing (Jagiello *et al.*, 2020).

Nature in general, and particularly the animal kingdom, need to adapt to the resulting changes in environment (Lowry *et al.*, 2012). The initial response of individuals to human-induced environmental change is often behavioural. A better understanding of the mechanisms of behavioural responses and their causes and consequences could improve our ability to predict the effects of human-induced environmental changes on individual species and on biodiversity (Tuomainen & Candolin, 2011).

Nest building is an energetically expensive activity (Mainwaring & Hartley, 2013). Usually, birds collect nesting material around the nest location in order to minimize nest-building energy costs (Collias & Collias, 1984; Mazgajski, 2007 cited in Mainwaring, Hartley, 2013), and typically make use of local materials (Hansell, 2000). Therefore, if the closest to the nest environment contains debris, birds can utilise it for the nest.

Urbanisation can affect different taxa of animals (Tsaryk *et al.*, 2024) including birds, influencing various aspects of avian nest design and composition. Previously, scientists reported the appearance of artificial materials in the nests of various bird species. Attempts were made to explain such behaviour and assess its benefits and risks. The appearance of ANMs in the nests of land and sea birds was reported across the globe. Nests of urban birds contain a wide variety of ANMs such as threads, pieces of cotton and fragments of plastic bags, cigarette butts and others (Antczak *et al.*, 2010; Bokotey, 1992; Franchuk, 2013, Hartwig *et al.*, 2007; Henriksen, 2000; Hnatyna, 2023; Igic *et al.*, 2009; Jagiello *et al.*, 2018, 2019, 2020, 2022, 2023; Radhamany *et al.*, 2016; Sarlin *et al.*, 2023; Seacor *et al.*, 2014; Suárez-Rodríguez *et al.*, 2013; Suárez-Rodríguez & Macías Garcia, 2014, 2017; Surgey *et al.*, 2012; Tavares *et al.*, 2016; Wang *et al.*, 2009 and others). Incorporation of debris in nests may be an increasing avian response to anthropogenic pollution (Jagiello *et al.*, 2020).

The 'availability hypothesis' (AVH) (Wang *et al.*, 2009; Antczak *et al.*, 2010) proposes that the most commonly available materials in the nesting environment are used by birds to construct their nests. Observational studies on house sparrow (*Passer domesticus*) (Radhamany *et al.*, 2016), great tit (*Parus major*) (Jagiello *et al.*, 2022), white stork (*Ciconia ciconia*) (Jagiello *et al.*, 2018) and brown booby (*Sula leucogaster*) (Tavares *et al.*, 2016) have found a positive association between the presence of environmental solid waste materials in the vicinity of nests and the ANMs in them. Several studies have highlighted a change in nesting materials along an urbanisation gradient (e.g., Wang *et al.*, 2009; Radhamany *et al.*, 2016; Reynolds *et al.*, 2016 cited in Sarlin *et al.*, 2023), while others did not find such effects (e.g., Townsend & Barker, 2014; Hanmer *et al.*, 2017 cited in Sarlin *et al.*, 2023), suggesting that nest design may exhibit species-specific or even city-specific differences (Sarlin *et al.*, 2023). The estimated total amount of twine within a nest buffer zone of osprey (*Pandion haliaetus*) did not predict whether a nest contained twine. The amount of twine was not correlated with the amount of twine found in their buffer zones (Seacor *et al.*, 2014).

Questions of using ANMs for construction of birds' nests increasingly attract the attention of researchers, as they allow to reveal the response of birds to a certain change in the environment, and this is relevant not only for predicting the impact of environmental transformation on birds, but also for understanding their behaviour.

Undeniably, the factors which influence debris incorporation in the nest by birds, the scale of this behaviour, and particular forms of use of debris in bird nests are aspects which require long-term standardized research (Jagiello *et al.*, 2019).

Thus, the purpose of this study was: 1) to reveal if the presence/absence of pollution in the close environment can predict the presence of debris in passerine birds' nests; 2) to analyse the frequency of use of debris by birds in three different environments (in the gradient of environmental pollution with solid waste) over the past two decades.

Working hypotheses: 1) we assume that the environment pollution with solid household waste in a certain way affects the presence of debris in nests of birds; 2) birds inhabiting populated areas incorporate debris in the construction of their nests more often.

MATERIALS AND METHODS

Materials for this article included 520 nests of 44 passerine species from 15 families (**Table 1**). About 75 % of nests have been collected personally by the author. Nests were collected randomly due to their visibility and accessibility, and purposely (nests in nest-boxes and nests of *Acrocephalus* warblers) unevenly during the last two decades (2002–2024). Nests were collected in different locations of mainly the western part of Ukraine (Volyn, Rivne, Ternopil, Khmelnytskyi, Lviv, Ivano-Frankivsk, Zakarpattia regions) and in three locations in Poland (Kraków city; near Dąbkowice settlement (West Pomeranian Voivodeship, NW Poland) and Nida valley near Umianowice village (Świętokrzyskie Voivodeship, in south-central Poland).

Debris in the environment is most often observed in and around human settlements, but is largely absent far beyond them. Therefore, we divided all nest collection stations into three categories depending on their distance from settlements: nests within the borders of settlements (cities, towns and villages) (12.3 %), on the outskirts – up to 1 km outside the settlements (31.4 %), and nests in the natural or close to the natural environment far away from settlements (56.3 %) (**Table 1**). We assume 1 km away from settlements as a buffer zone (this fact should be taken into account in the course of results interpretation), as that territory may still be affected with anthropogenic activity in the form of pollution. Debris may be transferred there from settlements by wind. Additionally, spontaneous dumps can be found on the edge of settlements, especially villages. Environmental solid waste pollution positively associates with human presence and urbanization intensity (Jagiello *et al.*, 2022). Therefore, we assume that the occurrence of debris increases along the row "natural environment – outskirts – human settlements".

Nests were collected after the breeding season. Each nest was air-dried for one or two weeks at room temperature and placed into a plastic bag of a suitable size. Individual nest materials were extracted using laboratory forceps and separated into categories, such as natural (grass, plant stems, tree leaves, grass roots, moss, mammalian hair, bird feathers and others) and anthropogenic (kinds of debris: threads, synthetic fibres, synthetic fluff, cotton wool, ropes, fishing line, cigarette butts, paper, tissue, wires and others). In this article we define "anthropogenic materials (ANMs)" as synthetic or man-changed materials that were brought into the environment by humans in the form of pollution. These also include artificial, synthetic materials, debris and solid household waste.

To assess the amount of each component, we calculated their percentage by volume value (the author's method) as it gave a better (than just weight) understanding of material quantity regardless of their unit weight. In this procedure, all the nest components were evenly spread on a paper sheet within a square frame divided into 100 identical smaller squares (10×10). Each of these smaller squares represents 1 % accuracy, ensuring precise measurement of the material. Artificial materials were identified, analysed and collected.

Systematics of birds is presented according to Handbook of the Birds of the World and BirdLife International (2024).

Table 1. **Number of analysed passerine nests and the type of environment they were collected from**

No	Species	Family	total	Nests materials		Environment type			
				only natural	include debris	natural	outskirts	village	city, town
1	*Alauda arvensis*	Alaudidae	1	1			1		
2	*Anthus trivialis*	Motacillidae	2	1	1	1	1		
3	*Motacilla alba*		2		2		1	1	
4	*Lanius collurio*	Laniidae	44	29	15	24	17	3	
5	*Lanius excubitor*		2		2		2		
6	*Sturnus vulgaris*	Sturnidae	8	7	1	7		1	
7	*Troglodytes troglodytes*	Troglodytidae	4	4		4			
8	*Prunella modularis*	Prunellidae	1	1			1		
9	*Locustella luscinioides*	Locustellidae	1	1		1			
10	*Locustella fluviatilis*		6	6		6			
11	*Acrocephalus paludicola*	Sylviidae	3	3		3			
12	*Acrocephalus palustris*		23	21	2	16	7		
13	*Acrocephalus scirpaceus*		23	22	1	22	1		
14	*Acrocephalus schoenobaenus*		28	28		28			
15	*Acrocephalus arundinaceus*		19	18	1	17	2		
16	*Sylvia nisoria*		6	5	1	5	1		
17	*Sylvia atricapilla*		22	19	3	18	2		2
18	*Sylvia borin*		6	6		6			
19	*Sylvia communis*		9	9		9			
20	*Sylvia curruca*		11	10	1	11			
21	*Sylvia* sp.		1	1		1			
22	*Phylloscopus collybita*		3	3		2	1		

End of the Table 1

23	*Ficedula hypoleuca*	Muscicapidae	29	17	12	10	19		
24	*Ficedula albicollis*		12	12		11	1		
25	*Muscicapa striata*		6	3	3	2		4	
26	*Phoenicurus phoenicurus*		11	5	6	5	4	2	
27	*Phoenicurus ochruros*		1		1			1	
28	*Luscinia luscinia*		2	2			2		
29	*Turdus pilaris*	Turdidae	6	3	3	3	2		1
30	*Turdus merula*		40	23	17	16	10	2	12
31	*Turdus philomelos*		27	23	4	18	4	5	
32	*Turdus viscivorus*		1		1		1		
33	*Lophophanes cristatus*	Paridae	1		1	1			
34	*Periparus ater*		4	3	1	4			
35	*Cyanistes caeruleus*		2	1	1	2			
36	*Parus major*		75	38	37	26	49		
37	*Remiz pendulinus*	Remizidae	1		1		1		
38	*Sitta europaea*	Sittidae	3	3		1	2		
39	*Fringilla coelebs*	Fringillidae	18	4	14	7	2	6	3
40	*Chloris chloris*		22	4	18	2	17	2	1
41	*Linaria cannabina*		30	4	26	2	11	11	6
42	*Coccothraustes coccothraustes*		2	1	1	2			
43	*Pyrrhula pyrrhula*		1	1		1			
44	*Emberiza schoeniclus*	Emberizidae	1	1			1		
	Totally		520	343	177	294	163	38	25

Statistical analysis. Experimental data were processed by methods of variation statistics using Origin 2018 and Statistica 8.0 software. The studied indexes are presented as follows: in the text, as absolute (n) and relative (part, %) nest frequencies; in Figures 2 and 3, as well as in Tables 2 and 4 as the median, lower and upper quartiles (Q1-Q3), minimum and maximum (Min-Max). For presenting average value (mean) and standard error additionally descriptive statistics for Excell was used. Comparison of data groups based on frequencies was carried out using the χ^2 test with Bonferroni correction, applying a critical significance level of $\alpha = 0.0167$; for *Turdus merula* data, Yates' correction was used. Data on the number of varieties and the percentage composition of debris were analyzed using the non-parametric Kruskal–Wallis analysis of variance (ANOVA) with *P* values determined by Dunn's multiple comparison post-hoc test. A critical significance level of $\alpha = 0.05$ was applied. Spearman Rank Order Correlation was used to analyse the linear relationship between the nesting environment and the presence of debris in the nests of *Turdus merula*.

RESULTS

More than 87 % of nests in the vicinity of the human settlements contained ANMs (**Fig. 1**). The share of nests with debris collected on the outskirts is also high (63.2 %). In the natural environment far from human settlements the proportion of nests with debris was the lowest (6.6 %).

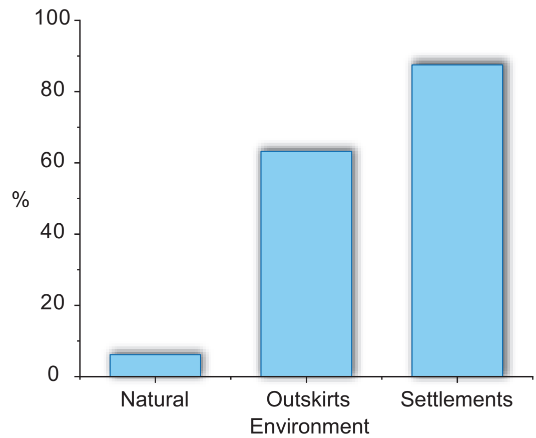

Fig. 1. Part (%) of nests with debris in different environments

Chi-square test with Bonferroni correction revealed significant differences in the presence of debris collected in different environments. The difference was found between natural/outskirts ($P < 0.0001$), natural/settlements ($P < 0.0001$) and outskirts/settlements ($P < 0.001$). But the difference between villages/cities ($P = 0.0997$) was not significant (**Table 3**).

There were cases when the debris was not found in the construction of the nests even if it is present in the surroundings – 12.5 % nests in the frame of human settlements did not comprise debris. There is information about nesting of the linnet (*Linaria cannabina*) in 1979 in the vicinity of landfill on the territory of military vehicle parking in the town of Brody (Lviv region, western part of Ukraine). There was no debris in the construction of 16 nests, though there was a landfill in the vicinity (Horban, 1994). It is possible that linnets found all necessary natural materials, or they did not see or have experience of using debris for nest building. In our research (30–40 years later) practically all nests on the outskirts and within settlements contained debris. The amount of debris in nests was as follows: 13.0±5.6 % (5.00 %, 0.10–15.00 %, n = 11) and 3.0±0.7 (2.00, 2.00–4.00, n = 11) kinds of debris in the outskirts and 9.9±2.7 % (5.00 %, 2.00–18.00 %, n = 15) and 2.5±0.3 (2.00, 2.00–4.00, n = 15) within settlements.

In some cases, there is sufficient amount of natural materials in the natural environment with just subtle traces of presence of debris and birds incorporate debris in the nest. A good example are warblers of genus *Acrocephalus*, which breed in the reedbeds or other high vegetation along water bodies and use different kinds of wetland vegetation for building their nests. We found one nest of great reed warbler (*Acrocephalus arundinaceus*) in the meadow of river in vicinity of a railway hub which contained up to 15 % (by volume) of glass wool. This material largely resembled *Typha* fluff, but had different physical properties. It must be said that fledglings successfully left the nest. In two other nests of marsh warbler (*Acrocephalus palustris*) on the outskirts, there was fishing line and in others threads (of four colours), thin rope and synthetic fiber in amount of 5 %.

Out of 31 nests of great tit (*Parus major*) collected in the vicinity of Biology and Geography Research Station (Shatskyy National Nature Park) in the pine wood with birch, blueberry, heather and herbs near the local road with sufficient amount of natural materials, 27 (87.1 %) comprised 7 kinds of debris in total (threads in 11 nests, ropes – in 3, fibres – 7, synthetic fluff – 16, cotton wool – 4, fragments of polyethylene – 4, fishing line – 7), on average (in the nests with debris) 1.96±0.19 (2.00, 1.00–2.00, n = 27). The amount of debris was from minimal up to 50 %, on average 12.9±2.7 % (5.00 %, 1.00–20.00 %, n = 27).

The number of kinds of ANMs incorporated in the nests of passerine birds was the highest on the outskirts and within human settlements. They were more numerous in cities and towns than in villages; while in the natural environment only three kinds of debris were detected (**Fig. 2**, **Table 2**).

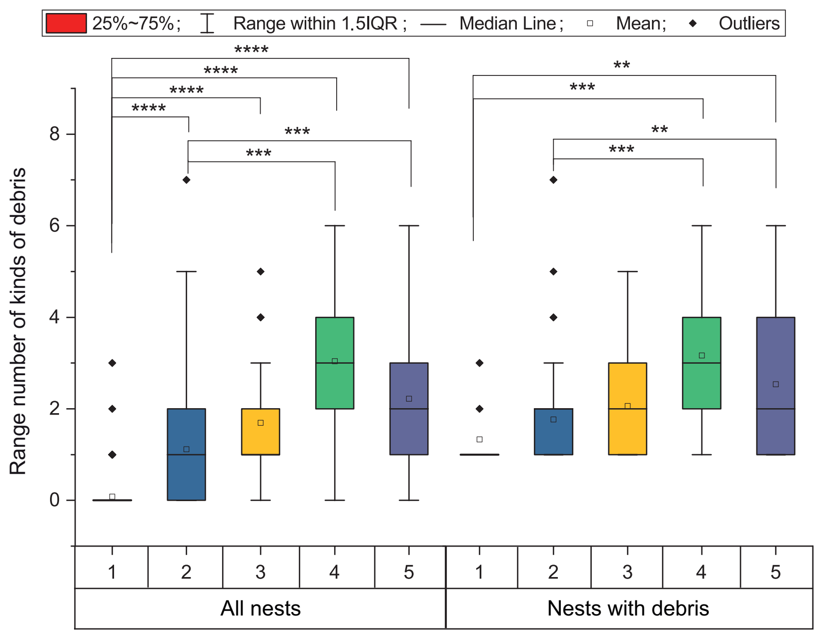

Fig. 2. Average number of kinds of debris per one nest in different environments: 1 – natural; 2 – outskirts; 3 – villages; 4 – cities, towns; 5 – human settlement. Significance: * – P <0.05; *** – P <0.001; **** – P <0.0001

Table 2. **Number of kinds of debris**

Environment	All nests				Nests with debris			
	Median	Q1–Q3	min–max	n	Median	Q1–Q3	min–max	n
Natural	0.00	0.00–0.00	0–3	293	1.00	1.00–1.00	1–3	18
Outskirts	1.00	0.00–2.00	0–7	163	2.00	1.00–2.00	1–7	103
Settlements	2.00	1.00–3.00	0–6	64	2.00	1.00–4.00	1–6	56
Villages	1.00	1.00–2.00	0–5	39	2.00	1.00–3.00	1–5	32
Cities, towns	3.00	2.00–4.00	0–6	25	3.00	2.00–4.00	1–6	24

Kruskal–Wallis ANOVA with Dunn's post-hoc analysis revealed significant difference in the number of kinds of debris in the nests collected in different environments for all nests (with and without debris) and also only for nests with debris. For all nests the difference ($P < 0.0001$) between natural/outskirts, natural/settlements ($P < 0.0001$) and outskirts/settlements ($P < 0.001$) was found significant, whereas the difference between villages/cities was not significant ($P = 0.338$). For nests that comprise debris the difference between natural/settlements ($P < 0.001$) and outskirts/settlements ($P < 0.01$) and villages/cities ($P < 0.05$) was found significant, while the difference between natural/outskirts was not significant ($P = 0.611$) (**Fig. 2**, **Table 3**).

Table 3. **Statistics of presence, amount and number of kinds of debris in nests of passerine birds in different environments (for nests with debris)**

Relations	Presence of debris		Number of kinds of debris (for nests with debris)		Amount of debris (for nests with debris)	
	Chi-square with Bonferroni correction	Significance	Kruskal–Wallis ANOVA with Dunn post-hoc analysis (z values)	Significance	Kruskal–Wallis ANOVA with Dunn post-hoc analysis (z values)	Significance
Natural / outskirts	174.84	P <0.0001	1.64	NS	2.62	P <0.05
Natural / settlements	211.58	P <0.0001	3.64	P <0.001	3.40	P <0.01
Outskirts / settlements	12.94	P <0.001	3.42	P <0.01	1.51	NS
Villages / cities, towns	2.71	NS	2.74	P <0.05	0.184	NS

Note: NS – not significant

The amount of ANMs (% by volume) in the nest was the highest in human settlements (for nests with debris), and on the outskirts (for all nests in these two environments) and the lowest in the natural environment (**Fig. 3**, **Table 4**).

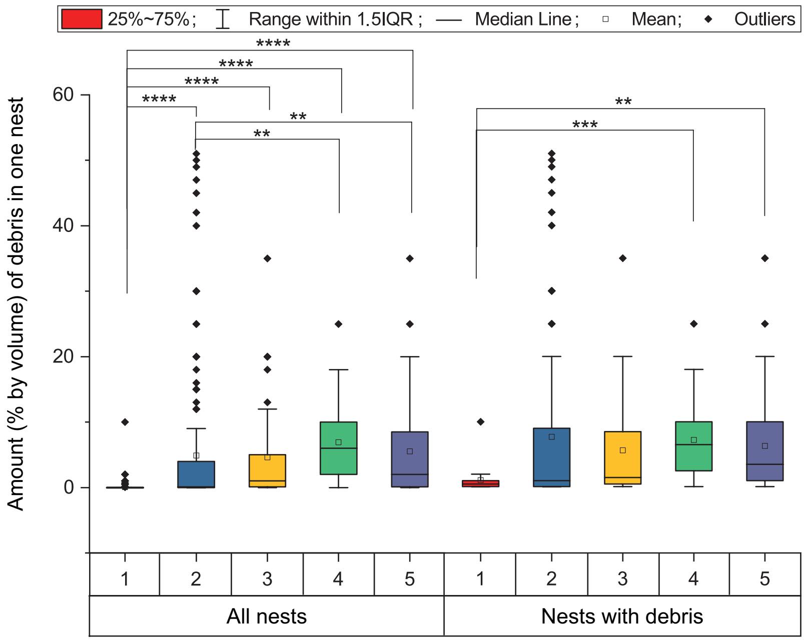

Fig. 3. Amount (% by volume) of debris per nest in different environments: 1 – natural; 2 – outskirts; 3 – villages; 4 – cities, towns; 5 – human settlement. Significance: ** – P <0.01; *** – P <0.001; **** – P <0.0001

Kruskal–Wallis ANOVA with Dunn's post-hoc analysis revealed significant difference in the amount of debris in the nests for all nests and for nests with debris in natural/outskirts (P <0.05) and natural/settlements (P <0.01) environments. However, the difference between outskirts/settlements and villages/cities was not significant (**Table 3**).

Table 4. **Amount of debris (% by volume) in the nests of passerine birds**

Environment	All nests				Nests with debris			
	Median	Q1–Q3	min–max	n	Median	Q1–Q3	min–max	n
Natural	0.00	0.00–0.00	0.00–10.00	293	0.50	0.10–1.00	0.10–10.00	18
Outskirts	0.10	0.00–4.00	0.00–51.00	163	1.00	0.10–9.00	0.10–51.00	103
Settlements	2.00	0.10–8.50	0.00–35.00	64	3.50	1.00–10.00	0.10–35.00	56
Villages	1.00	0.10–5.00	0.00–35.00	39	1.50	0.50–8.50	0.10–35.00	32
Cities, towns	6.00	2.00–10.00	0.00–25.00	25	6.50	2.50–10.00	0.10–25.00	24

Potential interspecies differences within the passerine order will be examined in our further research. This study focused primarily on one species – the blackbird – which had an appropriate number of nests in different types of environment (see **Table 1**).

Turdus merula often used debris for nest construction on the outskirts and in human settlements, whereas in natural environment its nests consisted only of natural materials (**Fig. 4**). Practically all blackbird nests in human settlements contained a large amount of debris.

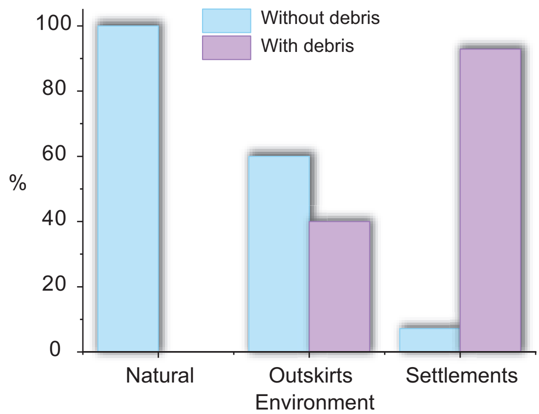

Fig. 4. The proportion of nests of *Turdus merula* with debris in different environments. The number of nests in every environment is 100 %

We found all strong Spearman Rank Order Correlation between environment/presence of debris as the nest materials (R = 0.797, P <0.0001), between environment/number of kinds of debris (R = 0.810, P <0.0001), and between environment/amount of debris in the nest (R = 0.817, P <0.0001).

Kruskal–Wallis ANOVA with Dunn post-hoc analysis revealed significant differences in the presence of debris in nests from different environments, but differences in the amount and number of kind of debris in nests were significant only between natural/settlements and outskirts/settlements environments (**Table 5**).

Table 5. **Statistics of presence, amount and number of kinds of debris in nests of *Turdus merula* in different environments**

Relations	Presence of debris		Number of kinds of debris (for all nests)		Amount of debris (for all nests)	
	Yates corrected Chi-square with Bonferroni correcntion	Significance	Kruskal–Wallis ANOVA with Dunn post-hoc analysis (z values)	Significance	Kruskal–Wallis ANOVA with Dunn post-hoc analysis (z values)	Significance
Natural/ outskirts	4.80	P = 0.0284	1.36	NS	1.25	NS
Natural/ settlements	22.57	P <0.0001	4.61	P <0.0001	4.69	P <0.0001
Outskirts / settlements	5.54	P = 0.0186	2.75	P < 0.05	2.93	P <0.05

Note: NS – not significant

Blackbird nests on the outskirts contained a smaller number of kinds of debris in the nests (0.50±0.22; median value 0.00, Q1–Q3 values 0.00–1.00, n = 10) than in human settlements. The detected ANMs included a single small thread, a small piece of aluminium foil, a piece of polyethylene foil, and a piece of fishing line. The amount of debris in nests on the outskirts was also insignificant (0.08±0.05 %; 0.00 %, 0.00–0.10 %, n = 10). In contrast, within human settlements, nests contained more kinds of debris (3.00±0.50; 3.50, 1.00–4.00, n = 14). Here the variety of debris was high (a variety of thread of different length and colours – in 5 nests, synthetic fibres of various colours – in 8 nests, ropes – in 9 nests, wet wipe, polyethylene foil – in 11 nests, fishing line, stripes of synthetic mesh – in 2 nests) and the amount also was higher (7.30±1.55 %; 7.50 %, 3.00–10.00 %, n = 14). If debris was present in the environment, *T. merula* often incorporated it into their nests.

DISCUSSION

The current levels of environment pollution with solid waste is high, especially in the human settlements and on the outskirts, but some trash can also be found close to natural habitats. As it was shown earlier (Hnatyna, 2023) not every kind of debris is suitable for construction of nests. ANMs are usually used because of their resemblance to naturally occurring nesting materials (Antczak *et al.*, 2010; Townsend & Barker 2014; Biddle *et al.*, 2018). Birds show selectivity and choose debris which resemble natural materials commonly used for nest building of specific bird species. Some kinds of solid waste such as threads, ropes, synthetic fluff are commonly used for nest construction of passerine birds. However, other kinds, such as plastic or glass bottles, cans, metal caps, ceramic materials and others which differ in appearance and physical properties from traditional natural materials, were not found in the examined passerine nests. It means that pollution with solid debris does not always provide suitable nest material for passerine birds.

There are some combinations of presence of debris in the environment and in the nest. If ANMs are absent in the environment, the bird cannot incorporate them into the nest. Thus, nests in natural, or close to natural environments, without traces of human activity in the form of pollution will be built completely of natural materials.

Debris in bird nests usually appears in populated areas, where it is available, accessible, especially in significant quantities. As it was expected, most often debris is found in birds' nests within human settlements (87.5 % of nests) and the number of kinds and amount (% by volume) of debris is the highest. Nevertheless, a small number of nests (12.5 %) within human settlements did not contain any debris. The reasons for this can be explored in further studies.

On the outskirts, the share of nests with debris was relatively high (63.2 %), which may indicate not only randomly polluted environment around, but also a presence of garbage dumps outside or on the edges of human settlements, especially in the villages without organized garbage collection and disposal. The number of kinds and amount (% by volume) of debris demonstrated intermediate values.

Logically, in the natural environment far from human settlements, the proportion of nests with debris was the lowest (6.6 %). The same was true for the number of kinds and amount (% by volume) of ANMs. However, debris still was present in nests, which suggests that birds use ANMs not only in the case of shortage of natural materials and indicates the presence of pollution even far away from human settlements.

In natural environment, nests of *Turdus merula* consisted of natural materials. Debris was used for nest construction on the outskirts and practically all blackbird nests in human settlements contained a large amount of debris. One of the hypotheses for the use of artificial components in birds' nests is the lack of natural materials (Antczak *et al.*, 2010; Jagiello *et al.*, 2023). This might be true particularly for big cities, where the environment is considerably changed by anthropogenic activity. This was the case for the blackbird. Interestingly, one nest found in the downtown of a big city (the historical part of Krakow city) did not contain any debris. On the other hand, a blackbird nest collected in a pine forest on the coast of the Baltic Sea comprised a high amount of debris (up to 20 % by volume), even though natural materials were available in abundance.

CONCLUSIONS

Nest building behaviour of birds depends on anthropogenic pollution of environment. The environment affects the presence of debris in bird nests.

There was a significant difference in the presence, amount and number of kinds of debris in the nests collected in different environments.

The proportion of nests with debris, the number of kinds and amount of debris in the nests of passerine birds was growing along the row "natural environment – outskirts – human settlements", being the highest in the latter type of environment as the most polluted by solid waste.

In the natural environment far from human settlements, debris still was present in nests, indicating the presence of pollution in such places and demonstrating birds' ability to use debris, intentionally or unintentionally, even if natural nest materials are readily available.

The presence of debris in nests on the outskirts may indicate randomly polluted environment and often a presence of garbage dumps outside human settlements.

Debris in bird nests usually appeared in populated areas (more frequently in cities than in villages), where it is available and accessible in significant quantities. However, birds do not always use ANMs for nest building even in the areas with high levels of pollution with solid waste.

In human settlements, birds used debris for nest construction more frequently. The number of nests with debris in natural environment was the lowest and debris was found in very small numbers and amount.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: the author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Animal Rights: this article does not contain any experimental studies with animal subjects.

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АНТРОПОГЕННІ МАТЕРІАЛИ У ГНІЗДАХ ГОРОБЦЕПОДІБНИХ ПТАХІВ: ЧИ ВПЛИВАЄ ДОВКІЛЛЯ?

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Обґрунтування. Протягом останніх кількох десятиліть фіксують помітне засмічення навколишнього середовища побутовими відходами. У науковій літературі за останнє століття дедалі частіше можна знайти інформацію про використання антропогенних матеріалів для побудови гнізд різних видів птахів. Важливим є розуміти, наскільки антропогенна трансформація середовища

у вигляді засмічення впливає на гніздобудівну поведінку птахів і на архітектуру самого гнізда. У наших дослідженнях ми аналізуємо, яким чином стан довкілля (засмічення твердими побутовими відходами) впливає на появу сміття у складі гнізд птахів.

Матеріали і методи. Матеріалами для написання цієї статті слугували 520 гнізд 44 видів горобцеподібних птахів, зібрані нерівномірно протягом останніх двох десятиліть (2002–2024) у різних типах біотопів переважно на заході України та в Польщі. Ми поділили середовище на природне чи умовно природне – околиці населених пунктів – населені пункти (села, містечка, міста), припускаючи, що вони суттєво відрізняються за рівнем наявності сміття зі збільшенням його кількості в цьому ряді. Зібрані після гніздового сезону гнізда були розкладені на окремі компоненти в лабораторних умовах. Матеріали гнізд були визначені як природні (злаки, стебла рослин, листки дерев, корені, мох, волосся та шерсть ссавців, пір'я птахів тощо) й антропогенні (види сміття: нитки, синтетичні волокна, штучний пух, шнурки, рибальська волосінь, фільтри від викурених цигарок, папір, тканина, дріт тощо). Обчислено відсотковий об'єм матеріалів антропогенного походження.

Результати. Птахи використовують сміття для побудови гнізд. Було виявлено достовірну різницю в наявності, кількості видів та об'ємній частці сміття у гніздах птахів у біотопах різного рівня засмічення.

Кількість гнізд з антропогенними матеріалами у природних біотопах була найнижчою, і для побудови гнізд сміття було використано поодиноко та в невеликій кількості. У природному середовищі далеко за межами населених пунктів найнижчими були частка гнізд з антропогенними матеріалами (6,6 %), кількість видів сміття (середнє арифметичне ± похибка середнього арифметичного 0,08±0,02; медіана 0,00 %, квартилі Q1–Q3 0,00–0,00, n = 293) та їхня об'ємна частка (0,07±0,04 %; 0,00 %, 0,00–0,00 %, n = 293). Проте навіть за достатньої кількості природних матеріалів птахи використовували сміття як гніздові матеріали, що може свідчити про забруднення середовища також далеко за межами населених пунктів і що птахи використовують сміття (спеціально/випадково) навіть коли є природні матеріали.

Гнізда зі сміттям на околицях населених пунктів виявлено у значній кількості (у 63,2 % гнізд); вони містили кілька різновидів сміття (1,12±0,10; 1,00, 0,00–2,00, n = 163) у помірній кількості (4,90±0,85 %; 0,10 %, 0,00–4,00 %, n = 163), що може свідчити про засмічення середовища та, часто, про наявність стихійних смітників на околицях населених пунктів.

Сміття у гніздах птахів найчастіше виявляли в населених пунктах, де воно наявне, доступне і у значній кількості: 87,5% гнізд, зібраних у межах населених пунктів, містили сміття у своєму складі. Середня кількість різновидів антропогенних матеріалів (2,22±0,19; 2,00, 1,00–3,00, n = 64) (більша у містах (3,04±0,30; 3,00, 2,00–4,00, n = 25), ніж у селах (1,69±0,21; 1,00, 1,00–2,00, n = 39) та об'ємна кількість (5,52±0,89 %; 2,00 %, 0,10–8,50 %, n = 64) (більша у містах (6,93±1,22 %; 6,00 %, 2,00–10,00 %, n = 25), ніж у селах (4,62±1,23 %; 1,00 %, 0,10–5,00 %, n = 39) була найвищою.

Висновки. Середовище впливає на наявність антропогенних матеріалів у гніздах птахів. У трансформованих біотопах (населені пункти) частка гнізд зі сміттям, кількістю різновидів антропогенних матеріалів і їхня об’ємна частка були більшими. Птахи не завжди застосовують сміття за браку природних компонентів. Виявлено, що навіть за достатньої кількості природних матеріалів птахи використовують штучні. І навпаки, навіть у досить засміченому середовищі знайдено гнізда, які повністю складалися з природних матеріалів.

***Ключові слова**:* гніздові матеріали, матеріали антропогенного походження, засмічене середовище, горобцеподібні птахи

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