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Brief report

Low flea loads in birds' nests in tree cavities

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High flea (Siphonaptera) loads are typically found in birds' nests in nest boxes. Ten years of observations, involving Marsh Tit *Parus palustris*, Great Tit *Parus major* and Blue Tit *Parus caeruleus* nests in tree cavities in primeval forests of Białowieża National Park, Eastern Poland, demonstrated that the prevalence of fleas was below 10% of nests and that the intensity of flea infestation was low. Low flea loads may be typical for nests in tree cavities. Therefore, nest-box data about flea-host interactions should not be treated as representative for conditions in natural cavities.

1. Introduction

Fleas (Siphonaptera) constitute a substantial problem for birds nesting in nest boxes. Often over 80% of nests are infested and a nest may host several hundred fleas (Tripet & Richner 1997). Most data show negative effects of high flea loads on the reproductive performance of birds, and on the condition of nestlings and/or adults (Tripet & Richner 1997, 1999, Mazgajski *et al.* 1997, Tripet *et al.* 2002, Słomczyński *et al.* 2006, Tomás *et al.* 2007). It is postulated that, in order to avoid or to reduce the costs of flea infestation, birds have evolved several anti-flea adaptations, such as an avoidance of infested nest boxes (Rytkönen *et al.* 1998, O`Brien & Dawson 2005), a shift in breeding seasons (Oppliger *et al.* 1994), nest sanitation (Christe *et al.* 1996), usage of aromatic plants as repellents (Gwinner *et al.* 2000, Petit *et al.* 2002) and modifications of parental provisioning (Tripet & Richner 1997, Bouslama *et al.* 2001; Tripet *et al.* 2002).

Importantly, all the above mechanisms of flea avoidance have been tested using nest-box-breeding bird populations. Nest boxes are a relatively recent human-introduced resource, which differ from natural tree cavities in several respects, such as microclimate and safety (Wesołowski 2000, Wesołowski *et al.* 2002, Wesołowski & Tomiałojć 2005, Mazgajski 2007a). A reasonable question, therefore, is whether data collected from nest boxes can be generalised to natural cavities, whether the documented high flea loads are characteristic of nests in cavities in general, or whether the phenomenon of high flea loads concerns only nest boxes. There is a scarcity of data on natural cavities, but both the prevalence and intensity of flea infestation in nests in tree cavities may be negligible (Pung *et al.* 2000, Wesołowski & Stańska 2001). However, as these two were short-term studies, their results should be applied with caution.

In the present study we examined flea infestations in natural tree cavities, in order to evaluate the robustness of findings of Wesołowski and Stańska (2001) that suggested the prevalence and intensity of flea infestation in tree cavity nests was low. In order to draw general conclusions about flea infestations in tree cavities, we collected data on additional species and over a longer time period, and reviewed other studies done in other areas.

2. Material and methods

We sampled tree cavities occupied by three tit species in protected primeval temperate forests in the Białowieża National Park, Eastern Poland (Tomiałojć *et al.* 1984, Wesołowski 2007, Wesołowski *et al.* 2010). We intensively searched for the Marsh Tit *Parus palustris* nests in order to find cavities of all breeding pairs during 2000–2006 and 2008–2010 at four areas of deciduous forest, 33–54 ha each (plots C, K, M and W; for details, see Wesołowski *et al.* 2010). We made equally intensive searches in plots C and M for nests of the Blue Tit *Parus caeruleus* during 2005–2007 and for nests of the Great Tit *Parus major* during 2008–2010. In the same years, nests of these three species were also extensively searched in plots K and W. All plots had no nest boxes but contained an excess of natural cavities (Wesołowski 2007).

To assess parasite load, the detected nests were removed from the cavities a few days (occasionally up to two weeks) after the young had fledged or the brood had been depredated. A delay in the removal of nest material does not significantly affect the flea abundance (Wesołowski & Stańska 2001); no fleas were found glued to sticky tapes mounted in cavity entrances within 24 hours after fledging, irrespective of the length of delay in the nest removal. The nests were manually removed from cavities by pulling them through the entrance by using a 30-cm long pincers or a twig with rough surface long enough to reach the nest through the cavity opening. The pincer/twig tip was inserted deep into the nest material and then slowly turned around, winding up the nest material. When the material was firmly attached to the tool, it was gently pulled along with the attached nest through the cavity entrance. Occasionally this approach did not work; in these cases we used a piece of wire with an L-shaped end or a “lasso” made of a thick guitar string attached to a stronger wire. Whichever tool was used, we first detached the nest material from the cavity walls. As the nests of tits after fledging of the young are tight, compact structures, the whole nest could usually be removed in one piece. In the remaining cases nests were removed in fragments. The operation was considered completed when no visible remnants of nests material remained in the cavity. In a few cases the complete removal of the nest material was not possible because of the complicated structure of the cavity interior; these were excluded from analysis. The removed nests were placed in tightly-sealed, labelled plastic bags and kept in a refrigerator. Fleas detected at this phase were recorded on the labels as well.

Examination of nest contents took place from a few days after the collection until early September. The nests were carefully dismantled manually and checked for the presence of larvae and imagines. All collected fleas were preserved in alcohol for identification. All fleas were identified by W. Wesołowska.

3. Results

Fleas extracted from nests belonged to three species: *Ceratophyllus sciurorum* (7 nests), *Ceratophyllus gallinae* (3 nests) and *Ctenophthalmus agyrtes* (1 nest). The prevalence of infestation in successful nests ranged from none in Blue Tits to ca. 4.3% in Great Tits (Table 1). Additional data from unsuccessful nests did not change these general trends; the overall prevalence amounted to 0% in Blue Tit ($n = 72$), 6.8% in Great Tit ($n = 133$) and 1.1% in Marsh Tit ($n = 279$). The intensity of infestation was also low: one Great Tit and one Marsh Tit nest contained more than 20 flea individuals. Most nests contained only 1–5 fleas.

4. Discussion

Flea infestation of tit nests in tree cavities within primeval temperate forests demonstrated that both prevalence and intensity of flea infestation were

Table 1. Prevalence of flea infestation in successful (i.e., produced fledged young) tits' nests in relation to habitat type in the Białowieża National Park, Eastern Poland.

Study area	Blue Tit		Great Tit		Marsh Tit	
	N nests	% infested	*N* nests	% infested	*N* nests	% infested
K – riverine, forest edge	2	0	8	0	34	5.9
C – oak-hornbeam, interior	23	0	17	0	56	0
M – oak-hornbeam, interior	36	0	26	7.7	98	0
W – oak-hornbeam, edge	10	0	18	5.5	73	0
Total	71	0	69	4.3	261	0.8

low. A combination of the present and Wesołowski and Stańska's (2001) data results in a sample of almost 700 nests of four cavity-nester species at four forest patches up to 5 km apart, and covers a period of 18 years. In all these cases the flea loads in natural cavities were low: less than 10% of nests were infested, and usually only single fleas were found. These results agree with findings of similar studies carried out in different regions and on different species (see below).

Our method of flea extraction may not have collected all fleas (see George 1989, Harper *et al.* 1992), thus underestimating the prevalence and intensity values. However, our data should yield results comparable to those obtained in other ectoparasite studies. We were unable to collect any fleas hiding in cavity crevices. But in the majority of nest-box studies cracks in boxes had not been inventoried either; instead, fleas had usually been extracted from nest material after removing the nests from the boxes (e.g., Mappes *et al.* 1994, Eeva *et al.* 1994, Dufva & Allander 1996, Rendell & Verbeek 1996, Tripet & Richner 1999, Mazgajski 2007b, Shutler & Campbell 2007, Mainwaring & Hartley 2008).

The exact methods of nest removal from the boxes had usually not been described, but we assume that nests had been collected in one piece after opening the box. We were usually able to remove the whole nest in one piece as well, but they had to be manually compressed in order to be able to pull them through the entrance. Rotating and twisting the nest material around a stick placed in the nest centre compacted the nest material and hindered movement of any organisms embedded in it. As both adults and larvae of fleas tend to stay in the internal parts of nests, near the nest cup (Rothschild & Clay 1952, Marshall 1981, Lehane 1991, Tripet & Richner 1999, Tripet *et al.* 2002) they would be immobilised in the nest material.

Moreover, hen flea larvae and freshly emerged imagines are negatively phototactic (Humphries 1968). Thus, when disturbed, they should attempt to hide in the nest material rather than to escape. Therefore, we do not believe that differences between the present and the nest-box studies were due to different efficiency of flea extraction.

Data on prevalence of fleas in tree cavities in other areas pertain only to woodpecker-made cavities. Fleas were found in only 5% (*n* = 49) of the Red-cockaded Woodpecker *Picoides borealis* cavities (Pung *et al.* 2000), some fleas were occasionally seen at the entrance of a cavity of the Northern Flicker *Colaptes auratus* (*n* = 1,650, K. Wiebe, pers. comm.), and no fleas were found in cavities of the Acorn Woodpecker *Melanerpes formicivorus* (non-systematic searches, *n* = 1,525; M. Stanback & W. Koenig, pers. comm.) and the Great Spotted Woodpecker *Dendrocopos major* (<150 nestlings; S. Mori, pers. comm.). Thus, fleas do not seem to constitute a significant problem for woodpeckers. However, woodpecker-made cavities could be of low quality for avian fleas, as woodpeckers usually excavate new cavities each season and have no nest material in their cavities (except a thin layer of wood chips). Hence fleas have to first colonise such cavities and then to reproduce in an environment almost devoid of hiding places, i.e., in conditions rather unfavourable for flea survival (Humphries 1968, Harper *et al.* 1992, Tripet & Richner 1999).

We believe that the low prevalence and infestation intensity of fleas are characteristic for nests in tree cavities in general. In our study area these variables remained consistently low, irrespective of habitat-type, tree-species, bird-species or seasonal variation (this study and Wesołowski & Stańska 2001). This was not due to a general scarcity of fleas in the Białowieża National Park (Wesołowski & Stańska 2001). These authors compared nest-box nests of the Collared Flycatcher *Ficedula albicollis* and tree-cavity nests of the Marsh Tit (both within the same nest-box plot, but the tits did not use nest boxes). The former were infested by fleas at high rates, approaching those found in nest-box studies in other areas (see above), but not the latter, suggesting that the type of nest was responsible for these differences.

There are consistent differences between tree cavities and nest boxes, and these affect the survival and reproduction of fleas. Non-excavated natural cavities used by birds are usually in living trees (Bai *et al.* 2005, Remm *et al.* 2006, Wesołowski 2007, Cockle *et al.* 2010). Such cavities are usually moist and can get soaked by rain water (Wesołowski *et al.* 2002, Radford & Du Plessis 2003). Moreover, even without rain, the cavity walls are often moist due to oozing sap water (Wesołowski *et al.* 2002). Nest boxes, in contrast, may remain water-proof even during heavy rain (Wesołowski 2011).

The rate of disappearance of nest material constitutes another difference between tree cavities and nest boxes. Old nests tend to disappear rapidly from tree cavities due to intensive activity of decomposing organisms. They often disappear completely between subsequent breeding seasons (Wesołowski 2000, Hebda & Mitrus 2011). On the other hand, old nest material decays slowly, and tends to accumulate, in nest boxes (Møller 1989, Mazgajski 2007a).

The differences between cavities and nest boxes have profound consequences for fleas. As ectotherms, fleas are dependent on external temperature. In warmer conditions they can develop faster and produce more generations each year (Cotton 1970, Tripet & Richner 1999, Harper *et al.* 1992, Walker *et al.* 2003). Fleas are also negatively affected by nest moisture: moister nests are less frequently colonised by fleas (Heeb *et al.* 2000) and contain lower numbers of fleas (Eeva *et al.* 1994). The fast disappearance of nest material from cavities might negatively affect flea survival as well; it is reasonable to assume that high level of activity of decomposing organisms, combined with the loss of overwintering substrate, will increase their mortality rate. Thus, nests in moist and cool tree cavities constitute a poor-quality flea habitat. In such conditions fleas would be unable to build up large populations.

Tree cavities may be consistently poor flea habitat, i.e., the low prevalence and intensity of flea infestation in natural cavities may be a general phenomenon. If this hypothesis is true, flea infestations in natural conditions are usually of only minor importance as a selective factor shaping the life histories and behaviour of cavity-nesting birds: they will have no need to develop special anti-flea mechanisms. Thus, high flea loads in birds' nests may be a novel consequence of birds using a new type of nest site, viz. nest boxes. Only with the shift to nest boxes do populations need to deal with high parasite loads – for the first time in their evolutionary history. If this scenario is correct, the selective pressures acting on birds breeding in natural cavities and nest boxes appear different (Wesołowski & Stańska 2001). Birds breeding in cavities first of all have to avoid nest predators (major source of nestling mortality; Wesołowski & Tomiałojć 2005) and can practically ignore fleas, whereas nest-box users may not have to pay attention to predators, as nest boxes are intentionally designed to be predator proof, but may have considerably higher ecto-parasite loads (Wesołowski 2011).

The evidence summarized above suggests that flea loads in tree cavities are typically low, and that high numbers of fleas are not typical for cavity-nesting species. High numbers reported in many studies may represent a sampling bias: almost all data come from nest-box studies. However, this hypothesis should be tested by comparing flea infestations in cavity-nesting birds breeding simultaneously in the same areas but differing in nest type (cavity vs. nest box). We predict that, independent of habitat type or geographical location, the flea load will be lower in cavities than in nest boxes.

Data available from tree cavities suggest the nest-box data may not be representative for ancestral conditions. Thus, the latter should not be uncritically generalised to the former, and inferences on adaptive value of behaviour of cavity-nesting birds based on nest-box studies should be made with caution.

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