J. Raptor Res. 53(1):000–000
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LICE INFESTATIONS OF STEPPE BUZZARDS (*BUTEO BUTEO VULPINUS*) DIFFER FROM THOSE OF COMMON BUZZARDS (*BUTEO BUTEO BUTEO*)

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ABSTRACT.—The Steppe Buzzard (*Buteo buteo vulpinus*), an eastern subspecies of the Common Buzzard (*Buteo buteo*), is a long-distance migrant raptor that breeds across eastern European and central Asian grasslands. The eastern European populations migrate through a geographic bottleneck in Israel and overwinter in eastern and southern Africa. To investigate how the metabolic demand of long-distance migration may affect their health, we trapped Steppe Buzzards ($n=28$) at Eilat, Israel, during the spring migration of 2016 and 2017 and collected their parasitic lice (Insecta: Phthiraptera). We compared their lice infestation levels to published data on nonmigratory or short-distance migratory Common Buzzards (*B. b. buteo*). These Common Buzzards were divided into two groups, free-living birds ($n=59$) and captive ones ($n=104$). All the Steppe Buzzards we examined harbored 1–4 species of lice. The Amblyceran lice that feed partially on living tissues and are thought to be relatively more virulent (*Laemobothrion maximum* and *Colpocephalum nanum*) were significantly more prevalent on Steppe Buzzards than on Common Buzzards (either free-living or in captivity). In contrast, the less-harmful Ischnoceran lice (*Craspedorrhynchus platystomus* and *Degeeriella fulva*) were either similarly or less prevalent on Steppe Buzzards than on the nonmigratory Common Buzzards, either free-living or in captivity. We hypothesize that this difference may mirror the metabolic demands of long-distance migration or, alternatively, our Eilat sample of Steppe Buzzards might have been biased in favor of the heavily infested individuals. In the Steppe Buzzard sample, we also detected a formerly unknown negative correlation between the abundance of *Laemobothrion maximum* and *Colpocephalum nanum*.

KEY WORDS: *Steppe Buzzard*; Buteo buteo vulpinus; *Common Buzzard*; Buteo buteo; *infestation*; *lice*; *migration*; *Phthiraptera*.

LAS INFESTACIONES DE PIOJOS DE *BUTEO BUTEO VULPINUS* VARÍAN DE LAS DE *B. B. BUTEO*

RESUMEN.—*Buteo buteo vulpinus*, una subespecie oriental de *B. buteo*, es una rapaz migratoria de larga distancia que cría en los pastizales del este de Europa y el centro de Asia. Las poblaciones del este de Europa migran a través de un cuello de botella geográfico en Israel y pasan el invierno en el este y sur de

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África. Para investigar como la demanda metabólica de un migrante de larga distancia puede afectar la salud de esta especie atrapamos individuos de *B. b. vulpinus* ($n = 28$) en Eilat, Israel, durante la migración de primavera de los años 2016 y 2017 y recolectamos sus piojos (Insecta: Phthiraptera). Comparamos los niveles de infestación con piojos con datos publicados de individuos no migratorios o migrantes de corta distancia de *B. b. buteo*. Los individuos de esta última subespecie fueron divididos en dos grupos, aves libres ($n = 59$) y aves cautivas ($n = 104$). Todos los individuos de *B. b. vulpinus* que examinamos albergaron entre 1 y 4 especies de piojos. Los piojos del suborden Amblycera *Laemobothrion maximum* y *Colpocephalum nanum*, que se alimentan parcialmente de tejidos vivos y que se cree que son relativamente más virulentos, fueron significativamente más prevalentes en *B. b. vulpinus* que en *B. b. buteo* libres o en cautivos. Por el contario, los piojos menos dañinos del suborden Ischnocera *Craspedorrhynchus platystomus* y *Degeeriella fulva* fueron igual o menos prevalentes en *B. b. vulpinus* que en los individuos no migratorios de *B. b. buteo* libres o cautivos. Hipotetizamos que esta diferencia puede reflejar las demandas metabólicas de la migración de larga distancia o, alternativamente, nuestra muestra de Eilat de *B. b. vulpinus* podría haber estado sesgada en favor de individuos fuertemente infestados. En la muestra de *B. b. vulpinus* también detectamos una correlación negativa previamente desconocida entre la abundancia de *Laemobothrion maximum* y la de *Colpocephalum nanum*.

[Traducción del equipo editorial]

Long-distance migration most likely evolved independently along several different phylogenetic lineages of Accipitrid raptors (Nagy and Tökölyi 2014, Nagy et al. 2017). Some species, like the Common Buzzard (*Buteo buteo*), has both resident and long-distance migrant subspecies. Its European subspecies, *Buteo buteo buteo* (hereafter, Common Buzzard) is either resident or a short-distance migrant. Contrarily, the eastern subspecies, the Steppe Buzzard (*Buteo buteo vulpinus*) is a long-distance migrant breeding through the steppes of eastern Europe and central Asia and overwintering in eastern and southern Africa.

Migration is a period of exceptional metabolic demand for birds (Alerstam 1993, Berthold 2001) that likely affects levels of parasitism due to a trade-off between the high energetic costs of migration and immunocompetence (Møller and Erritzøe 1998, Råberg et al. 1998). Therefore, we expected that the infestation measures might differ between the two subspecies of buzzards.

Parasitic lice (Insecta: Phthiraptera) are contagious pathogens of birds that complete their whole developmental cycle (eggs, nymphs, imagoes) in the plumage of the host birds that provide their habitat and nutrients, and also act as their main natural enemy through defensive preening and grooming (Rózsa and Vas 2015). Infested birds may suffer a diversity of harms; lice can reduce the thermoregulation of the plumage (Booth et al. 1993), enhance the transmission of other pathogens (Bartlett 1993), and reduce both the sexual attractiveness (Clayton 1990, Moreno-Rueda and Hoi 2012) and longevity (Brown et al. 1995) of their hosts. Two louse suborders are widespread on birds: the Amblyceran lice that feed in part on living tissues (such as skin fragments and blood) and coevolve with the host immune system (Møller and Rózsa 2005), and the Ischnoceran lice that mostly feed on keratin and nonliving tissues and are not known to interact with the avian immune system.

The aim of the present study was to compare the lice infestation parameters between the two subspecies of buzzards mentioned above. Like several other European birds (Paperna et al. 2016), migratory Steppe Buzzards pass through a geographic bottleneck in Eilat, Israel, and overwinter in eastern and southern Africa. We trapped the buzzards during the spring migration seasons of 2016 and 2017 at Eilat, to measure their lice infestations.

To establish a baseline for meaningful comparisons, we also obtained published data on the lice infestations of Common Buzzards. A large proportion of these published data refer to captive birds examined in zoos, animal hospitals, or raptor rehabilitation centers. Infestations of recently injured birds (just after a traffic accident or gunshot wound) likely represent natural levels; however, most captive birds probably had spent long periods in captivity before being examined. Złotorzycka (1961) noted that birds in zoos tend to host reduced lice burdens, but Solt (1998) found that captive raptors with major limb injuries – a common condition in rehabilitation centers – are incapable of efficient preening and grooming and, therefore, tend to host particularly heavy burdens of lice. To account for this uncertainty, we divided the Common Buzzard data into two groups: infestations of free-living birds and infestations captive birds.

METHODS

We trapped 28 Steppe Buzzards in the date palm (*Phoenix dactylifera*) plantations of Kibbutz Eilot and Kibbutz Samar, north of Eilat, Israel, during the periods 13–29 April 2016 and 25 March–29 April 2017 using bal-chatri traps (Berger and Mueller 1959) baited with live laboratory mice (*Mus musculus*). After taking measurements and ringing, we sprayed each bird with a commercial household insecticide (Panzi Pet Piret Mix, Panzi-Pet Ltd, Budapest, Hungary: 0.3% piperonilbutoxid, 0.3% permethrin, 0.08% pyrethrin I and II), held the bird on its back above a white surface for about 10–15 min, and ruffled its plumage. Lice began to leave the plumage after 6–8 min, either by falling off the bird or (the Amblycerans) by climbing onto the hand of the researcher holding the bird's legs. Lice were collected with tweezers and stored in vials containing 95% alcohol. Specimens were identified under a (Olympus SZ61) stereo microscope following descriptions and illustrations of Clay (1958), Price and Beer (1963), Nelson and Price (1965), Price et al. (2003), Dik and Ozkayhan (2007), Dik (2006), and Dik et al. (2013).

We obtained data on the lice infestations of Common Buzzards in Poland (Złotorzycka 1961), Italy (Demartis and Restivo de Miranda 1978), Romania (Rékási and Kiss 1980 Adam 2003, Adam and Daroczi 2006, Adam 2007), Spain (Pérez et al. 1996), northwestern Turkey (Girisgin et al. 2013), and Portugal (Tomás et al. 2016). We retrieved the number of host and parasite individuals, and the prevalence and mean intensity of infestation from these sources, and recorded them separately for free-living and captive birds. Data from Austria (Kutzer et al. 1980) were excluded due to the vagueness of the collection methods.

We here describe the prevalence, mean and median intensity, and index of discrepancy (Rózsa et al. 2000) of lice infestations hosted by the Steppe Buzzards we sampled. Confidence intervals for prevalence were calculated using Sterne's method (Reiczigel 2003). For Steppe Buzzards, we also provide 95% bias-corrected and accelerated bootstrap confidence limits for mean intensity, exact confidence limits for median intensity, and 95% bias-corrected and accelerated bootstrap confidence limits for the index of discrepancy. For the Common Buzzard samples we calculated only prevalence, confidence interval, and mean intensity, and we lack other infestation measures due to the absence of individual infestation data in the literature. For the same reason, it was impossible to statistically compare mean intensities of parasite species across samples. Second, we compared the prevalence of the four louse species across the three samples using the unconditional exact test of Reiczigel et al. (2008). Third, because the two Amblyceran species were exceptionally prevalent in our Steppe Buzzard samples (see below), we transformed the abundance values using $\log_{10}(n+1)$, and tested for potential interactions between their abundances using Spearman rank correlation. Statistical procedures were carried out using the software Quantitative Parasitology (QPweb; Reiczigel et al. 2015).

RESULTS

All the 28 Steppe Buzzards we trapped carried at least one of the four common species (Fig. 1) of buzzard lice (one louse species: $n = 5$ birds; two species: $n = 16$ birds; three species: $n = 6$; four species: $n = 1$ bird). We obtained

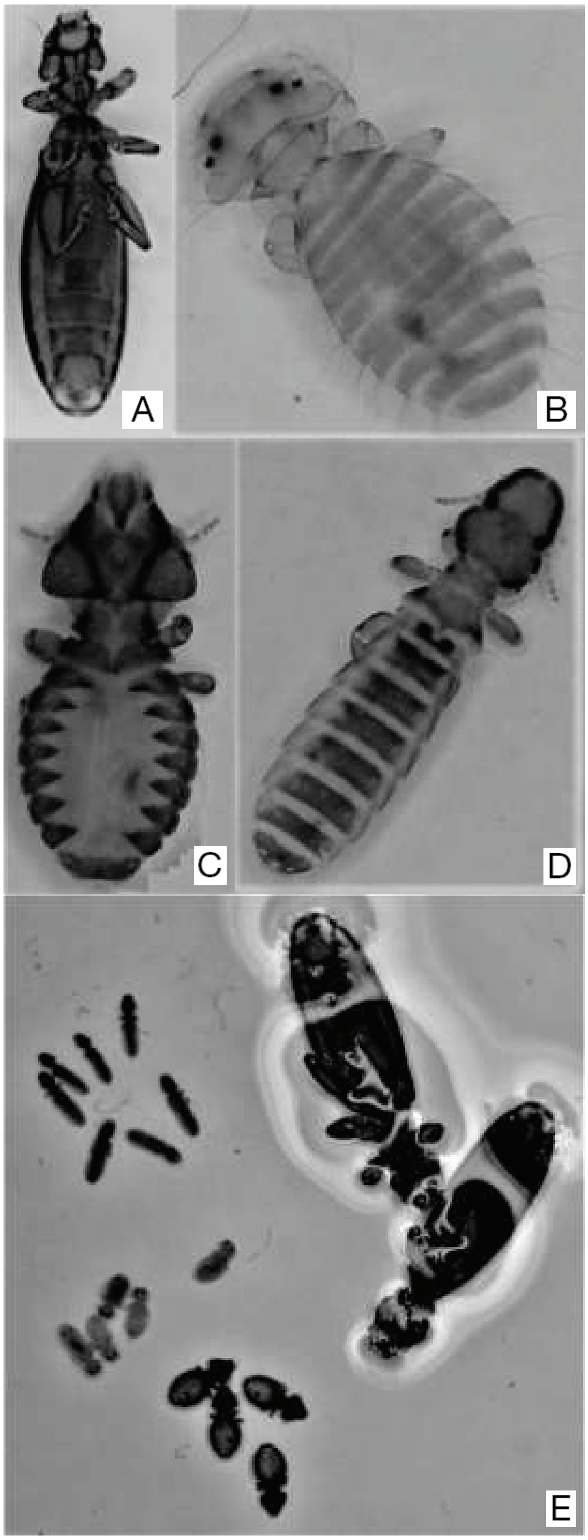

Figure 1. Specimens of buzzard lice in alcohol (70%) under stereo microscope (A) *Laemobothrion maximum*, (B) *Colpocephalum nanum*, (C) *Degeeriella fulva*, (D) *Craspedorrhynchus platystomus*, (E) a mixed sample of the four lice species showing body-size differences (photos by Ofir Strutzer).

Table 1. Infestation indices of the four species of lice hosted by Steppe Buzzards and Common Buzzards (95% CI in parentheses). Prevalence is the proportion (0–1 scale) of infested birds, while intensity is the number of parasites hosted by an infested bird (without the zero values of non-infested birds). The Index of Discrepancy measures parasite aggregation along a 0–1 scale by comparing the observed and the hypothetical uniform distributions.

	Steppe Buzzards (n = 28)				Free-living Common Buzzards (N = 59)		Captive Common Buzzards (N = 104)	
Louse Species	Prevalence	Mean Intensity	Median Intensity	Index of Discrepancy	Prevalence	Mean Intensity	Prevalence	Mean Intensity
Laemobothrion maximum	0.536 (0.355–0.718)	10.80 (6.47–18.00)	7.0 (2–16)	0.709 (0.605–0.814)	0.034 (0.006–0.116)	7.50	0.212 (0.143–0.302)	7.36
Colpocephalum nanum	0.714 (0.518-0.858)	17.85 (9.7– 33.1)	8.0 (3–20)	0.713 (0.635–0.809)	0.169 (0.090–0.287)	5.30	0.096 (0.051–0.167)	30.60
Degeeriella fulva	0.607 (0.409–0.771)	20.88 (10.9–42.1)	12.0 (3–20)	0.733 (0.632–0.852)	0.593 (0.463–0.713)	82.37	0.269 (0.191–0.364)	141.32
Craspedorrhynchus platystomus	0.250 (0.119–0.446)	9.71 (5–18.7)	7.0 (1–29)	0.835 (0.731–0.917)	0.627 (0.494–0.747)	20.43	0.163 (0.102–0.249)	18.00

lice infestation data for 59 free-living and 104 captive Common Buzzards from the published literature (Table 1).

We found that Amblyceran lice (*Laemobothrion maximum* and *Colpocephalum nanum*) were more prevalent on the Steppe Buzzards that on either free-living or captive Common Buzzards (Fig. 2, Table 1). In contrast, Ischnoceran lice were either equally, or less prevalent on the Steppe Buzzards than on the Common Buzzards.

Although our sample of Steppe Buzzards was relatively small, the birds we trapped hosted significant infestations of *L. maximum* and *C. nanum*. Log-transformed abundances were weakly negatively related (Spearman rank correlation, correlation coefficient -0.4, P = 0.038, based on 5000 Monte Carlo replications; Fig 3).

Discussion

Comprehensive population-level surveys of wild raptors' ectoparasite fauna are rare in the literature (but see San-Martín Órdenes et al. 2005, Liébana et al. 2011, Saxena 2017). This is not true for raptors brought to veterinary clinics and rehabilitation centers; however, the infestation levels of injured and captive birds likely differ from natural levels.

Overall, Steppe Buzzards we captured on spring migration at a migratory bottleneck in the Middle East were apparently more heavily infested with lice than comparable Common Buzzards, either free-living or captive/injured birds. This difference was attributed to the high levels of Amblyceran lice. Amblycerans are presumed to be more virulent than Ischnocerans for several reasons, including that they (1) more readily feed on living tissues, such as host blood, (2) more readily act as vectors of microbial pathogens, (3) more commonly coevolve with host immune capabilities (4) may physically damage feather quills to live inside them (*Colpocephalum* spp. only), and (5) are much larger than any other species of lice (*Laemobothrion* spp. only).

In contrast, Ischnocerans mostly feed on nonliving tissues, such as the keratin microstructures of feather. Though this may harm the birds' thermal insulation (Booth et al. 1993), this effect is likely not a major threat for birds wintering in Africa.

The reasons Amblyceran lice were so prevalent in the Steppe Buzzards trapped during spring migration at Eilat are unknown. We propose two possible explanations that are not mutually exclusive. First, the metabolic stress of long-distance migration may increase certain infestations in birds. Second, biased sampling might have been responsible for the high infestation levels experienced at Eilat. A large number of Steppe Buzzards pass high above Eilat during spring migration, and many of them stay overnight in the local palm plantations (*cf.* Yosef et al. 2002). However, only a few individuals remain at Eilat to hunt for prey during the day. These individuals may be the particularly weak and/or heavily infested individuals. Future research will show whether these speculations were correct.

We documented a weak negative interaction between the two Amblyceran species that has not been reported to date. Assuming this relationship was not an artifact of our sample size or sampling method, further research should clarify the mechanism responsible for this pattern. At present, we cannot exclude the possibility that it might be the result of either direct (Bush and Malenke 2008) or host-mediated competition (Reiczigel and Rózsa 1998) between lice, or of a predatory interaction between the two ectoparasites (Durden 1987).

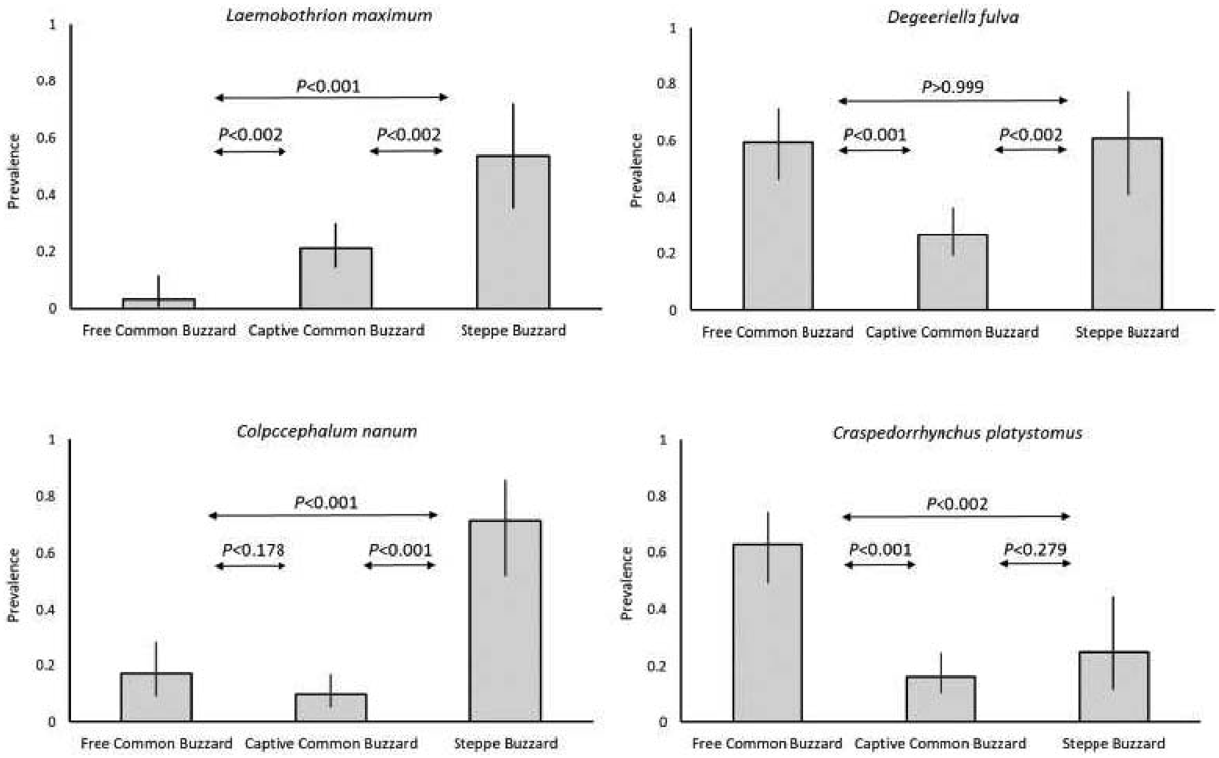

Figure 2. Prevalence and 95% confidence intervals (error bars) for the four louse species in the samples of Steppe Buzzards and Common Buzzards. Statistical comparisons were carried out using the unconditional exact test of Reiczigel et al. (2008).

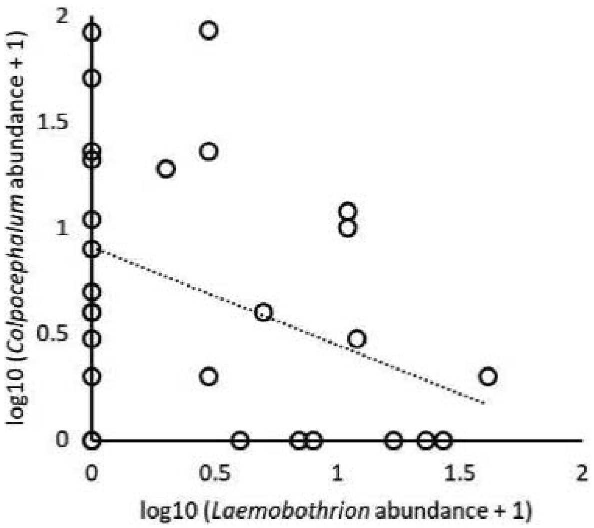

Figure 3. A slight negative correlation between the abundance of *Laemobothrion maximum* and *Colpocephalum nanum* fitted with a linear trendline.

ACKNOWLEDGMENTS

These data were collected in the framework of senior school science theses of Ofir Strutzer and Reut Tabibi. Bird trapping was permitted under bird-ringing license A75 to Reuven Yosef. The work of LR was supported by the grants from the National Scientific Research Fund of Hungary (OTKA/NKFI 108571) and GINOP-2.3.2-15-2016-00057. We thank two anonymous reviewers and the editor for improving an earlier version of this report.

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Received 25 February 2018; accepted 3 July 2018
Associate Editor: Sean S. Walls

Queries for rapt-53-01-12

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