Ornis Hungarica 2015. 23(1): 58–65.
DOI: 10.1515/orhu-2015-0005

Louse (Insecta: Phthiraptera) infestations of the Amur Falcon *(Falco amurensis)* and the Red-footed Falcon

Imre Sándor Piross[1], Péter Fehérvári[2*], Zoltán Vas[2], Szabolcs Solt[3], Éva Horváth[3], Péter Palatitz[3], Cristina Giosele[4], Marco Gustin[4], Mario Pedrelli[4], R. Suresh Kumar[5], Nick P. Williams[6], Rina Pretorious[7], Zephne Bernitz[8], Herman Bernitz[9] & Andrea Harnos[1]

Imre Sándor Piross, Péter Fehérvári, Zoltán Vas, Szabolcs Solt, Éva Horváth, Péter Palatitz, Cristina Giosele, Marco Gustin, Mario Pedrelli, R. Suresh Kumar, Nick P. Williams, Rina Pretorious, Zephne Bernitz, Herman Bernitz & Andrea Harnos 2015. Louse (Insecta: Phthiraptera) infestations of the Amur Falcon *(Falco amurensis)* and the Red-footed Falcon. – Ornis Hungarica 23(1): 58–65.

Abstract Little is known about the louse species harboured by Red-footed and Amur Falcons despite the fact that various life-history traits of these hosts make them good model species to study host-parasite interactions. We collected lice samples from fully grown Amur (n=20) and Red-footed Falcons (n=59), and from nestlings of Red-footed Falcons (n=179) in four countries: Hungary, India, Italy and South Africa. We identified 3 louse species on both host species, namely *Degeeriella rufa, Colpocephalum subzerafae* and *Laembothrion tinnunculi.* The latter species has never been found on these hosts. Comparing population parameters of lice between hosts we found significantly higher prevalence levels of *D. rufa* and *C. subzerafae* on Amur Falcons. Adult Red-footed Falcons had higher *D. rufa* prevalence compared to *C. subzerafae*. For the first time we also show inter-annual shift in prevalence and intensity levels of these species on Red-footed Falcons; in 2012 on adult hosts *C. subzerafae* had higher intensity levels than *D. rufa*, however in 2014 *D. rufa* had significantly higher intensity compared to *C. subzerafae*. In case of nestlings both louse species had significantly higher prevalence levels than in 2014. The exact causes of such inter-annual shifts are yet to be understood.

Keywords: ectoparasite, lice, *Degeeriella rufa*, *Colpocephalum subzerafae*, *Laembothrion tinnunculi*, descriptive statistics

Összefoglalás A kék vércsék és az amúri vércsék tolltetű faunájáról és a fajok ökológiájáról keveset tudtunk, pedig különleges életmenet-sajátosságaik jó modellrendszerré teszik őket parazitaökológiai vizsgálatokra. Felnőtt amúri vércsékről, valamint felnőtt és fióka kék vércsékről gyűjtöttünk ektoparazita mintákat. A *Degeeriella rufa* és *Colpocephalum subzerafae* már korábban is ismert volt mindkét gazdafajról, azonban a *Laembothrion tinnunculi*-nak ez az első ismert elfordulása mindkét madárfajon. Mind a *D. rufa*, mind a *C. subzerafae* prevalenciája magasabb volt az amúri vércséken a kék vércsékhez viszonyítva. A felnőtt kék vércséken a *D. rufa* prevalenciája meghaladta a *C. subzerafae*-jét. 2012-ben a *C. subzerafae*, 2014-ben a *D. rufa* átlagos intenzitása volt magasabb. Mindkét vizsgált tetűfaj prevalenciája magasabb volt a fiókákon 2012-ben mint 2014-ben. Az eredmények alapján a tetvek abundanciája eltérést mutat évek között a kék vércse fiókákon. Ennek az évhatásnak a kialakító tényezői még nem ismertek.

Kulcsszavak: ektoparazita, tolltetű, *Degeeriella rufa, Colpocephalum subzerafae, Laembothrion tinnunculi*, leíró statisztika

[1] Department of Biomathematics and Informatics, Szent István University, Faculty of Veterinary Science, 1078 Budapest, István utca 2., Hungary

[2] Department of Zoology, Hungarian Natural History Museum, 1088 Budapest, Baross utca 13., Hungary, e-mail: peter.fehervari@nhmus.hu
[3] MME/BirdLife Hungary, Red-footed Falcon Conservation Working Group, 1121 Budapest, Költő utca 21., Hungary
[4] LIPU/BirdLife Conservation Department, 43121 Parma, via Udine 3/A, Italy
[5] Department of Endangered Species Management, Wildlife Institute of India, Post Box 18, Chandrabani, Dehradun, 248 001, India
[6] UNEP/CMS Office, Abu Dhabi, Coordinating Unit of Raptors MoU, PO Box 555, Abu Dhabi, United Arab Emirates
[7] Endangered Wildlife Trust, Migrating Kestrel Project, Building K2, Pinelands Office Park, Ardeer Road, Modderfontein, 1645, Gauteng, South Africa
[8] Veterinary Consultant, P O Box 1276 Middelburg MPU,South Africa
[9] Department of Oral Pathology and Oral Biology. School of Dentistry, University of Pretoria, Pretoria, South Africa
*corresponding author

Introduction

Relationship of avian hosts and their ectoparasites has been widely studied from macroevolutionary (Vas *et al.* 2013, Rózsa & Vas 2015) to ecological perspectives (Brooke 2010, Brown *et al.* 1995). Lice (Insecta: Phthirapteta) are the only insects that complete their full life-cycle on the surface of their avian or mammalian hosts. They also have relatively low pathogenicity levels compared to other ectoparasites (Clayton & Tompkins 1994, 1995). Despite this, avian lice may have considerable effects on their hosts (Brown *et al.* 1995, Møller & Rózsa 2005) thus constitute an important aspect of avian evolutionary ecology. Comprehensive overviews of the genus and species composition of lice on various host species are available through worldwide and regional open source databases and checklists (Price *et al.* 2003, Vas *et al.* 2012). However, quantitative data describing population level parameters of ectoparasites are seldom reported. Moreover, studies aiming to assess aspects of louse life history often neglect inter-annual differences in these parameters (but see Hamstra & Badyaev 2009, Monello & Gomper 2009).

The Amur Falcon *(Falco amurensis)* and the Red-footed Falcon *(Falco vespertinus)* are closely related sister species of the Falconidae family (Fuchs *et al.* 2015). Both are small-bodied birds of prey exhibiting marked sexual dimorphism. The Amur Falcon breeds in east Asia from Transbaikalia to Amurland, southward to Eastern China, while the breeding area of the Red-footed Falcon extends from Central and Eastern Europe to Northern Central Asia (Ferguson-Lees & Christie 2001). They are both long-distance migrants wintering in similar habitats of southern Africa. During their annual migration cycle the Amur Falcon uses vast roosting sites in Nagaland (India) where many hundreds of thousands of birds can congregate (Kumar 2014). Their wintering areas may overlap with those of the Red-footed Falcon, where they can share roosting sites, making direct bodily contacts between the two species possible (pers. obs.). The louse faunae of Amur Falcons and Red-footed Falcons has been scarcely studied to date (but see Tendeiro 1988). According to Price *et al.*'s (2003) world checklist of lice, two common species were reported from Amur Falcons: *Degeeriella rufa* (Ischnocera: Philopteridae) and *Colpocephalum subzerafae* (Amblycera: Menoponidae) and both of them also can be found on Red-footed Falcons. The only other species known to occur on Red-footed Falcons is *Nosopon lucidum* (Amblycera: Menopo-

nidae). In this study we aim to a) describe the louse faunae of these two falcon species and, b) give precise population level estimates of louse infestations based on relatively large samples and c) investigate potential inter-annual differences in these parameters.

Materials and Methods

Louse samples from Amur falcons were collected in Nagaland, India in November 2013 and from South Africa in March 2014. Fully developed individuals were trapped and sampled at both locations. Red-footed Falcons were sampled in Körös-Maros National Park, Hungary (Kotymán *et al*. 2015) with the aid of MME-Birdlife Hungary's Red-footed Falcon Working Group. In 2012 fledglings in 2014 both fledglings and adult birds were sampled. Only nestlings 0-7 days prior to leaving the nest were sampled. At this stage the feathers flight feathers are fully developed and most of the contour feathers have appeared. Additionally 5 adult were sampled near Parma (Italy) in 2014.

Ectoparasite samples were collected by using the most widespread sampling method (Johnson & Clayton 2003, Rózsa 2003). The birds' plumage were treated with pyrethrin powder (marketed drug in veterinary practise for pet birds), and then we moved through gently the birds' plumage with a forceps above a white tray for a standard 5 minutes sampling time. Lice were collected per hosts into a 1.5 ml centrifuge tube containing 70% ethanol. In case of Red-footed Falcon nestlings, we excluded all individuals where the parents were treated with pyrethrin in previous years. The identification of lice was carried out by specialists using a stereoscopic microscope.

Descriptive statistics and statistical tests were calculated using Quantitative Parasitology 3.0 (Reiczigel *et al.* 2005). Following Rózsa *et al.* (2000) the prevalence, mean and median intensity of the infestation and their 95% confidence intervals are reported. To compare prevalences we used an exact unconditional test described in (Reiczigel *et al.* 2008).

Results

A total of 20 Amur Falcons were sampled and three louse species were identified: *Degeeriella rufa*, *Colpocephalum subzerafae* and *Laembothrion tinnunculi*. To our knowledge, this is a new host record for *L. tinnunculi* that was present in two birds (1 female, 1 nymph).

We identifed three louse species form the samples taken from the 238 Red-footed Falcons. The two most prevalent species were *Degeeriella rufa* and *Colpocephalum subzerafae*. *Laemobothrion tinnunculi* was found on 3 adult birds (one from Italy and two from Hungary) represented by a male, a female, and nymphs in two of the samples, and only nymphs in the third sample. The descriptive statistics of infestations are presented in *Tables 1–3*.

Comparing the infestation of the two most common lice on fully grown Amur and Red-footed Falcons, both *D. rufa* and *C. subzerafae* were more prevalent on Amur Falcons (p-value=0.0045) while there was no significant difference in mean (p-value=0.2515) or median intensity (p-value=0.547) between the two host species (see also *Tables 1–2*).

Examining the infestation patterns of the two most prevalent louse species on adult Red-footed Falcons, *D. rufa* was found to

N=20	*D. rufa*	*C. subzerafae*	*L. tinnunculi*
Prevalence	90%	70%	10%
95% CI	68%–98%	47%–86%	1%–31%
Mean intensity	4.39	2	1
95% CI	3.28–6.06	1.43–2.71	NA
Median intensity	3	1.5	1
CI	95.1%: 2–5	99.3%: 1–3	NA

Table 1. Descriptive statistics and their confidence intervals of the louse infestations of fully grown Amur Falcons. N is the number of birds. Calculating the confidence intervals for *L. tinnunculi* was not possible

1. táblázat Az amúri vércséken talált tetűfajok, azok leíró statisztikái és a becsült paraméterek konfidencia intervallumai (CI). N a madarak egyedszáma. A *L. tinnunculi* esetén nem lehetett konfidencia intervallumot számolni

N=59	*D. rufa*	*C. subzerafae*	*L. tinnunculi*
Prevalence	56%	20%	0.034%
95% CI	43%–68%	12%–33%	NA
Mean intensity	6.79	12.08	3.5
95% CI	4.21–12.03	4.17–37.08	NA
Median intensity	2	3.5	3.5
CI	95.8%: 2–3	98%: 1–13	NA

Table 2. Descriptive statistics and their confidence intervals of the louse infestations of fully grown Red-footed Falcons. N is the number of birds. Calculating the confidence intervals for *L. tinnunculi* was not possible

2. táblázat A kék vércséken talált tetűfajok, azok leíró statisztikái és a becsült paraméterek konfidencia intervallumai (CI). N a madarak egyedszáma. Az *L. tinnunculi* esetén nem lehetett konfidencia intervallumot számolni

be more prevalent (p-value=0.0001), while its mean (p-value=0.5127) and median intensity (p-value=0.325) do not significantly differ from that of *C. subzerafae (Table 2).*

In 2012, there was no difference in prevalence between *D. rufa* and *C. subzerafae* on Red-footed Falcon nestlings (p-value=1), but the mean (p-value=0.0006) and median intensity (p-value=0.002) for *C. subzerafae* was significantly higher. On the other hand, in 2014 the prevalence of *D. rufa* exceeded (p-value=0.0003) that of *C. subzerafae* while there was no significant difference in their median and mean intensities (p-value=0.5724 and 0.633, respectively).

The prevalence of *D. rufa* on Red-footed Falcon nestlings was significantly higher in 2012 than in 2014 (p-value=0.0308), but the mean (p-value=0.5107) and median intensities (p-value=0.5107) showed no significant differences. In case of *C. subzerafae* the prevalence (p-value<0.0001), and both the mean (p-value<0.0001) and median intensities (p-value<0.001) were significantly

N=95	*D. rufa*	*C. subzerafae*
Prevalence	78%	78%
95% CI	68%–86%	68%–86%
Mean intensity	3.66	6.73
95% CI	3.07–4.53	5.58–8.28
Median intensity	2	5.5
CI	99.9%: 2–4	99.5%: 4–7

Table 3. Descriptive statistics and their confidence intervals of the louse infestations of Red-footed Falcon nestlings in 2012. N is the number of nestlings

3. táblázat Kék vércse fiókákon 2012-ben talált tetvek leíró statisztikái és azok konfidencia intervalluma. N a madarak egyedszáma

N=84	*D. rufa*	*C. subzerafae*
Prevalence	63%	34%
95% CI	52%–73%	25%–45%
Mean intensity	3.28	2.86
95% CI	2.57–4.4	2–4.31
Median intensity	2	2
CI	95.1%: 2–2	96.9%: 1–2

Table 4. Descriptive statistics and their confidence intervals of the louse infestations of Red-footed Falcon nestlings in 2014. N is the number of nestlings

4. táblázat Kék vércse fiókákon 2014-ben talált tetvek leíró statisztikái és azok konfidencia intervalluma. N a madarak egyedszáma

higher in 2012. Moreover, the distribution of *D. rufa* and *C. subzerafae* infestation classes on nestlings was significantly different in the two years (Goodness-of-fit tests: χ^2:120.09, df=80, p=0.002 and χ^2:112.06, df=48, p<<0.001, respectively. see also *Figures 1-2*).

Discussion

We recorded the occurrence of the same three louse species on both Amur and Red-footed Falcons. *L. tinnunculi,* which can be found on several species in the genus *Falco*, is reported here for the first time to infest Amur Falcons and Red-footed Falcons. *Laemobothrion* species differ in many characteristics from other lice. They have considerably larger body size (Price *et al.* 2003) and appear to be more mobile, while their intensity tend to be low. We hypothesize that *Laemobothrion* lice might have a peculiar life cycle that calls for innovative new methods to be developed.

Both of the two smaller louse species had significantly higher prevalences on Amur Falcons than on Red-footed Falcons. The host species have similar body and bill sizes, possess similar plumage patterns in

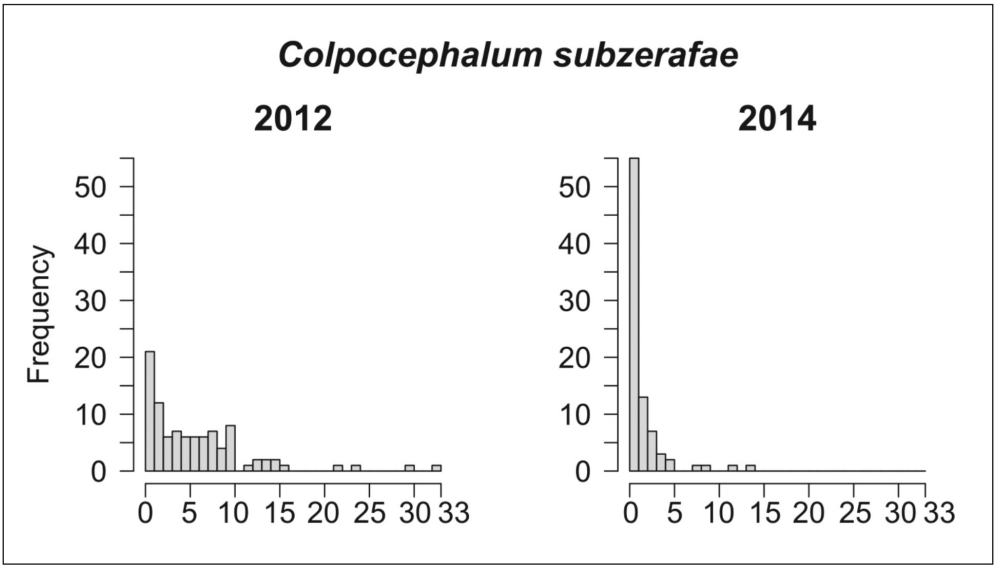

Figure 1. The distribution of *D. rufa* infestation classes on sampled Red-footed Falcon nestlings. The number of sampled birds is 95 in 2012 and 84 in 2014

1. ábra A *D. rufa* tetűfaj fertőzöttségi osztályainak eloszlása kék vércse fiókákon. A mintázott fiókák száma 2012-ben 95 példány, 2014-ben 84 példány

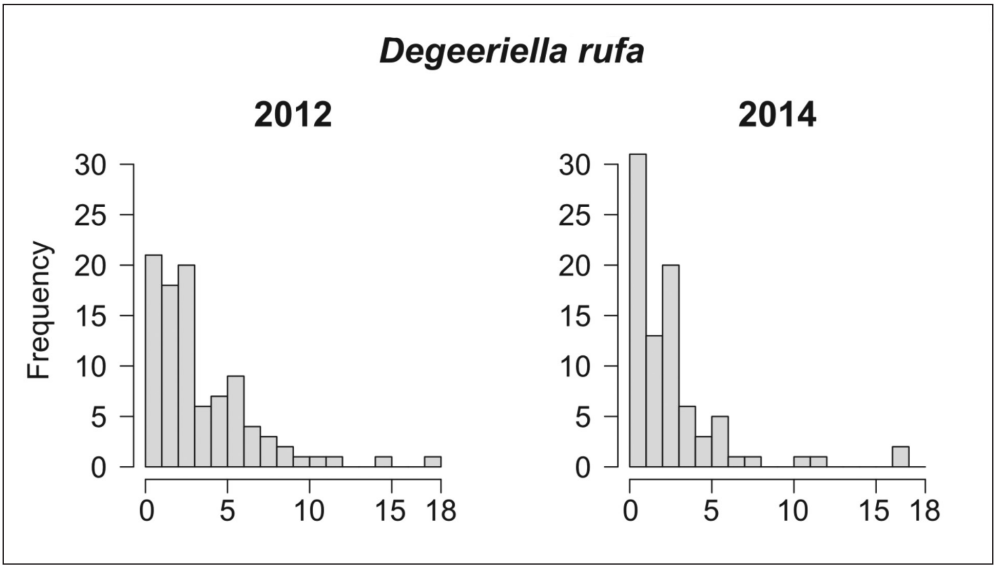

Figure 2. The distribution of *C. subzerafae* infestation classes on sampled Red-footed Falcon nestlings. The number of sampled birds is 95 in 2012 and 84 in 2014

2. ábra A *C. subzerafae* tetűfaj fertőzöttségi osztályainak eloszlása kék vércse fiókákon. A mintázott fiókák száma 2012-ben 95 példány, 2014-ben 84 példány

every age and sex groups, thus making it unlikely that they provide considerably different habitats for lice. Increased rate of horizontal transmission (lice infesting unrelated hosts) due to coloniality (Rózsa *et al.* 1996) or frequency of congregations of the hosts is hypothesized to increase ectoparasite prevalence. In our case, samples were collected from Amur Falcons at the two largest known migratory (Nagaland, India: >1 million birds present) and wintering (Newcastle, South Africa: 5–10 thousand birds present) roost sites of the species, while in case of Red-footed Falcons the sampled individuals were taken from breeding colonies (10–200 adult individuals present) making the number of birds 2–5 orders of magnitude lower. This in itself may cause differences in prevalence. However, Red-footed Falcons are also known to aggregate in large numbers at pre-migratory roost sites (Borbáth & Zalai 2005, Fehérvári *et al.* 2014). Seasonality may also have an effect on louse population parameters (Monello & Gomper 2009). Amur Falcons were sampled in the non-breeding period while Red-footed Falcons were only sampled in the breeding season, thus the observed pattern may also be attributed to different infestation levels at different stages in their life cycle.

Inter-annual differences in prevalence and intensity of the two common louse species were detected in both adult and nestling Red-footed Falcons. We emphasize that the samples were taken from the same population, at the same location and from similar aged nestlings in the two years. We believe our data shows for the first time shifts in population parameters of avian lice species between years. It is plausible that such changes may have been caused by abiotic factors such as different average temperature or humidity, or by changes in host attributes such as deviating nestling sex ratios. In any case, such inter-annual fluctuations may be a key feature to further the understanding of host-parasite interactions.

Our results shed light on species composition and various aspects of ectoparasite demography in avian-host parasite systems. Albeit the currently used methodology to obtain ectoparasite samples yield valuable results, we believe that even a simple evaluation of infestation on a relatively large sample of hosts shows that invasive ectoparasite collection has its limits. We urge future studies to investigate the possibility of developing a precise, reliable non-invasive method to collect louse species that may allow to better enhance our understanding of host-parasite systems.

Acknowledgements

We thank Gábor Balogh, László Kotymán, Péter Őze, Lajos Rózsa, Rebeka Saliga, Gergely Simon, for their assistance in field. We also thank Lokeshwar Rao head of the Forest Force of Nagaland State Forest Department, Hemant Kamdi, and Zuthonglo Patton of the Nagaland State Forest Department for providing invaluable resources and guidance while working in India. This study was partly financed by 2012–2018 Conservation of the Red-footed Falcon in the Carpathian Basin (LIFE11/NAT/HU/000926) www.falcoproject.eu, by OTKA (Grant No. 108571) and the expedition to Nagaland, India sponsored by the Coordinating Unit of the Convention on Migratory Species (CMS) Memorandum of Understanding on the Conservation of Migratory Birds of Prey in Africa and Eurasia (Raptors MoU).

References

Borbáth, P. & Zalai, T. 2005. Kék vércsék *(Falco vespertinus)* őszi gyülekezése a Hevesi-síkon [Autumn roost site of Red-Footed Falcons in the Heves Plains]. – Aquila 112: 39–44. (in Hungarian with English Summary)

Brooke, M. de L. 2010. Vertical transmission of feather lice between adult Blackbirds *Turdus merula* and their nestlings: a lousy perspective. – Journal of Parasitology 96(6): 1076–1080. DOI: 10.1645/GE-2513.1

Brown, C. R., Brown, M. B. & Rannala, B. 1995. Ectoparasites reduce long-term survival of their avian host. – Proceedings of the Royal Society of London Series B: Biological Sciences 262(1365): 313–319. DOI: 10.1098/rspb.1995.0211

Clayton, D. H. & Drown, D. M. 2001. Critical evaluation of five methods for quantifying chewing lice (Insecta: Phthiraptera). – Journal of Parasitology 87(6): 1291–1300. DOI: 10.1098/rspb.2005.3396

Clayton, D. H. & Tompkins, D. M. 1994. Ectoparasite virulence is linked to mode of transmission. – Proceedings of the Royal Society of London Series B: Biological Sciences 256(1347): 211–217. DOI: 10.2307/3677133

Clayton, D. H. & Tompkins, D. M. 1995. Comparative effects of mites and lice on the reproductive success of Rock Doves *(Columba livia)*. – Parasitology 110(02): 195–206. DOI: 10.1017/S0031182000063964

Fehérvári, P., Lázár, B., Palatitz, P., Solt, S., Nagy, A., Nagy, K. & Harnos, A. 2014. Pre-migration roost site use and timing of post-nuptial migration of Red-footed Falcons *(Falco vespertinus)* revealed by satellite tracking. – Ornis Hungarica 22(1): 36–47. DOI: 10.2478/orhu-2014-0009

Ferguson-Lees, J. & Christie, D. A. 2001. Raptors of the world. – Houghton Mifflin Harcourt, pp. 992

Fuchs, J., Johnson, J. A. & Mindell, D. P. 2015. Rapid diversification of falcons (Aves: Falconidae) due to expansion of open habitats in the Late Miocene. – Molecular Phylogenetics and Evolution 82: 166–182. DOI: 10.1016/j.ympev.2014.08.010

Hamstra, T. L. & Badyaev, A. V. 2009. Comprehensive investigation of ectoparasite community and abundance across life history stages of avian host. – Journal of Zoology 278(2): 91–99. DOI: 10.1111/j.1469-7998.2008.00547.x

Kotymán, L., Solt, Sz., Horváth, É., Palatitz, P. & Fehérvári, P. 2015. Demography, breeding success and effects of nest type in artificial colonies of Red-footed Falcons and allies. – Ornis Hungarica 23(1): 1–21. DOI: 101515/orhu-2015-001

Kumar, R. S. 2014. Flight for freedom. – Saevus 3(3): 24–31.

Møller, A. P. & Rózsa, L. 2005. Parasite biodiversity and host defenses: chewing lice and immune response of their avian hosts. – Oecologia 142(2): 169–176. DOI: 10.1007/s00442-004-1735-8

Monello, R. & Gomper, M. 2009. Relative importance of demographics, locale and seasonality unerlying louse and fela parasitism of racoons *(Procyon lotor)*. – Journal of Parasitology 95(1): 56–62. DOI: 10.1645/GE-1643.1

Palatitz, P., Fehérvári, P., Solt, S. & Barov, B. 2009. European Species Action Plan for the Red-footed Falcon *Falco vespertinus* Linnaeus, 1766. – European Comission, pp. 51

Price, R. D., Hellenthal, R. A., Palma, R. L., Johnson, K. P. & Clayton, D. H. 2003. The chewing lice: World checklist and biological overview. – Illinois Natural History Survey, pp. 501

Reiczigel, J., Lang, Z., Rózsa, L. & Tóthmérész, B. 2005. Properties of crowding indices and statistical tools to analyze parasite crowding data. – Journal of Parasitology 91(2): 245–252. DOI: 10.1645/GE-281R1

Reiczigel, J., Lang, Z., Rózsa, L. & Tóthmérész, B. 2008. Measures of sociality: two different views of group size. – Animal Behaviour 75(2): 715–722. DOI: 10.1016/j.anbehav.2007.05.020

Rózsa, L., Reiczigel, J. & Majoros, G. 2000. Quantifying parasites in samples of hosts. – Journal of Parasitology 86(2): 228–232. DOI: 10.1645/0022-3395(2000)086[0228:QPISOH]2.0.CO;2

Rózsa, L., Rékási, J. & Reiczigel, J. 1996. Relationship of host coloniality to the population ecology of avian lice (Insecta: Phthiraptera). – Journal of Animal Ecology 65: 242–248. DOI: 10.2307/5727

Rózsa, L. & Vas, Z. 2015. Host correlates of diversification in avian lice. – In: Morand, S. Krasnov, B. R. & Littlewood, D. T. J. (eds.) – Parasite Diversity and Diversification. Evolutionary Ecology Meets Phylogenetics. – Cambridge University Press, pp. 215–229.

Saumier, M. D., Rau, M. E. & Bird, D. M. 1988. The influence of *Trichinella pseudospiralis* infection on the behaviour of captive, nonbreeding American Kestrels *(Falco sparverius)*. – Canadian Journal of Zoology 66(7): 1685–1692. DOI: 10.1139/z86-325

Tendeiro, J. 1988. Etudes sur les *Colpocephalum* (Mallophaga, Menoponidae) parasites des Falconiformes I. Groupe zerafae Price & Beer [On the *Colpocephalum* (Mallophaga, Menoponidae) parasites of the Falconiformes I. Group zerafae Price & Beer]. – Bonner Zoologische Beitrage 39(2–3): 77–102. (in French with English Summary)

Vas, Z., Fuisz, T. I., Fehérvári, P., Reiczigel, J. & Rózsa, L. 2013. Avian brood parasitism and the ectoparasite richness – scale dependent diversity interactions in a three level host-parasite system. – Evolution 67(4): 959–968. DOI: 10.1111/j.1558-5646.2012.01837.x

Vas, Z., Rékási, J. & Rózsa, L. 2012. A checklist of lice of Hungary (Insecta: Phthiraptera). – Annales Historico-Naturales Musei Nationalis Hungarici 104: 5–109.