

Bio-Ecology of the Louse, *Upupicola upupae*, Infesting the Common Hoopoe, *Upupa epops*

Authors: Agarwal, G. P, Ahmad, Aftab, Rashmi, Archana, Arya, Gaurav, Bansal, Nayanci, et al.

Source: Journal of Insect Science, 11(46) : 1-9

Published By: Entomological Society of America

URL: <https://doi.org/10.1673/031.011.4601>

The BioOne Digital Library (<https://bioone.org/>) provides worldwide distribution for more than 580 journals and eBooks from BioOne's community of over 150 nonprofit societies, research institutions, and university presses in the biological, ecological, and environmental sciences. The BioOne Digital Library encompasses the flagship aggregation BioOne Complete (<https://bioone.org/subscribe>), the BioOne Complete Archive (<https://bioone.org/archive>), and the BioOne eBooks program offerings ESA eBook Collection (<https://bioone.org/esa-ebooks>) and CSIRO Publishing BioSelect Collection (<https://bioone.org/csiro-ebooks>).

Your use of this PDF, the BioOne Digital Library, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Digital Library content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne is an innovative nonprofit that sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.



Bio-ecology of the louse, *Upupicola upupae*, infesting the Common Hoopoe, *Upupa epops*

G. P Agarwal^{a*}, Aftab Ahmad^b, Archana Rashmi^c, Gaurav Arya^d, Nayanci Bansal^e, A.K. Saxena^f

Department of Zoology, Government Raza Postgraduate College, Rampur (U.P.) 244901, India

Abstract

The population characteristics of the louse, *Upupicola upupae* (Shrank) (Mallophaga: Philopteridae: Ischnocera), infesting the Common Hoopoe, *Upupa epops* L. (Aves: Upupiformes), were recorded during 2007-08 in District Rampur, Uttar Pradesh India. The pattern of frequency distribution of the louse conformed to the negative binomial model. The lice and its nits were reared *in vitro* at $35 \pm 1^\circ \text{C}$, 75-82 % RH, on a feather diet. The data obtained was used to construct the life table and to determine the intrinsic rate of natural increase (0.035 female/day), the net reproductive rate was 3.67 female eggs/female, the generation time was 37 days, and the doubling time of the population was 19 days. The chaetotaxy of the three nymphal instars has also been noted to record their diagnostic characteristics. Information on egg morphology and antennal sensilla is also presented.

Keywords: Ischnocera, Phthiraptera, *Upupicola upupae*

Correspondence: ^{a*} dr.gpagarwal@rediffmail.com, ^b draftab.lifescience@rediffmail.com, ^c archana.rashmi@rediffmail.com, ^d guaravaryan18@gmail.com, ^e nanci.rampur@rediffmail.com, ^f akscsir@rediffmail.com.

*Corresponding author

Received: 9 November 2009, **Accepted:** 15 January 2011

Copyright : This is an open access paper. We use the Creative Commons Attribution 3.0 license that permits unrestricted use, provided that the paper is properly attributed.

ISSN: 1536-2442 | Vol. 11, Number 46

Cite this paper as:

Agarwal GP, Ahmad A, Rashmi A, Arya G, Bansal N, Saxena AK. 2011. Bio-ecology of the louse, *Upupicola upupae*, infesting the Common Hoopoe, *Upupa epops*. *Journal of Insect Science* 11:46 available online: insectscience.org/11.46

Introduction

The population characteristics of Phthiraptera on selected Indian birds have been recorded from time to time (Chandra et al. 1990; Singh et al. 1991; Trivedi et al. 1992; Saxena et al. 1995; Gupta et al. 2007; Beg et al. 2008; Khan et al. 2008; Rajput et al. 2009). Studies on the *in vitro* bionomics of avian lice have been performed by Wilson (1934, 39), Arora & Chopra (1959), Agarwal (1967), Williams (1970), Saxena et al. 1995, and Singh et al. 2001. In case of certain avian Ischnocera the data obtained from *in vitro* experimentation have been utilized to construct life tables to determine the intrinsic rate of natural increase (Beg et al. 2005; Saxena et al. 2007; Gupta et al. 2007; Saxena et al. 2009). Survey of literature revealed that bio-ecological studies on phthirapterans occurring on the Common Hoopae, *Upupicola epops* L. (Aves: Upupiformes: Upupidae), deserved investigations.

The present report supplements information on the population characteristics, *in vitro* bionomics, life table statistics, egg morphology, and chaetotaxy of three nymphal instars of an ischnoceran louse, *Upupicola upupae* (Shrank) (Mallophaga: Philopteridae: Ischnocera) infesting *U. epops*.

Materials and Methods

Thirty *U. epops* were live trapped in the district Rampur (28° 49' 12" N 79° 1' 11" E, in Uttar Pradesh state of India) during 2007-08 and subjected to delousing, at first manually and then by fumigation (Saxena et al. 2007). The examined birds were released in the wild in district Rampur after delousing. The louse load was placed in 70% alcohol and separated according to sex and stage. The population

parameters (prevalence, mean, sample mean abundance, variance, exponent of negative binomial, and index of discrepancy) were computed (Rozsa et al. 2000). The quality of fit between the observed and expected frequencies was determined by χ^2 . The egg laying sites were recorded by visual inspection. Feathers bearing eggs were gently cut and subjected to scanning electron microscopy. Freshly laid eggs and adults were reared *in vitro* condition (35± 1° C, 75-82 % RH, feather diet) to record the bionomics on the lines adopted by Gupta et al. (2007) and Saxena et al. (2007). The data obtained from *in vitro* experimentation was used to construct the life table and to compute the intrinsic rate of natural increase. Different instars of nymphs were examined using light microscopy for recording the chaetotaxy. The adults were also examined using SEM.

Results

Population characteristics

Only one phthirapteran species *U. upupae* was recovered from 30 Common Hoopae in the district Rampur during 2007-08. Its prevalence was 40% (n=30). A total of 468 specimens were recovered (mean intensity- 39.0; sample mean abundance- 15.6; range of infestation 7-83). The male female ratio of adults was 1:1.3. The adult nymph ratio was 1: 1.4. The ratio of three nymphal instars was 1:0.8:0.7.

The pattern of frequency distribution was skewed (variance to mean ratio – 39.33). The value of the exponent of the negative binomial (k) and the index of discrepancy (D) were 0.12 and 0.715, respectively. The pattern of frequency distribution of *U. upupae* conformed to the negative binomial model ($\chi^2 = 13.21$, $P > 0.05$).

Table 1. Lifetable, fecundity and rate of natural increase of Common Hoopae louse (*Upupicola upupae*).

X	lx	mx	lxmx	Xlxmx	rmx	e-rmx	e-rmxlxmx
0-22	Immature stage of <i>U. upupae</i> (Common hoopae)						
23-24	pre-oviposition period						
25	1.00	0.000	0.00	0.00	0.875	0.417	0.000
26	1.00	0.000	0.00	0.00	0.910	0.403	0.000
27	0.98	0.000	0.00	0.00	0.945	0.389	0.000
28	0.96	0.128	0.12	3.44	0.980	0.375	0.046
29	0.92	0.195	0.18	5.20	1.015	0.362	0.065
30	0.92	0.073	0.07	2.01	1.050	0.350	0.024
31	0.86	0.313	0.27	8.34	1.085	0.338	0.091
32	0.84	0.333	0.28	8.95	1.120	0.326	0.091
33	0.80	0.280	0.22	7.39	1.155	0.315	0.071
34	0.78	0.416	0.32	11.03	1.190	0.304	0.099
35	0.76	0.413	0.31	10.99	1.225	0.294	0.092
36	0.70	0.480	0.34	12.10	1.260	0.284	0.095
37	0.62	0.235	0.15	5.39	1.295	0.274	0.040
38	0.58	0.406	0.24	8.95	1.330	0.264	0.062
39	0.58	0.483	0.28	10.93	1.365	0.255	0.072
40	0.48	0.513	0.25	9.85	1.400	0.247	0.061
41	0.48	0.163	0.08	3.21	1.435	0.238	0.019
42	0.42	0.507	0.21	8.94	1.470	0.230	0.049
43	0.38	0.354	0.13	5.78	1.505	0.222	0.030
44	0.36	0.311	0.11	4.93	1.540	0.214	0.024
45	0.26	0.258	0.07	3.02	1.575	0.207	0.014
46	0.20	0.224	0.04	2.06	1.610	0.200	0.009
47	0.10	0.000	0.00	0.00	1.645	0.193	0.000
48	0.02	0.000	0.00	0.00	1.680	0.186	0.000
	15.00	6.085	3.67	132.52			1.052

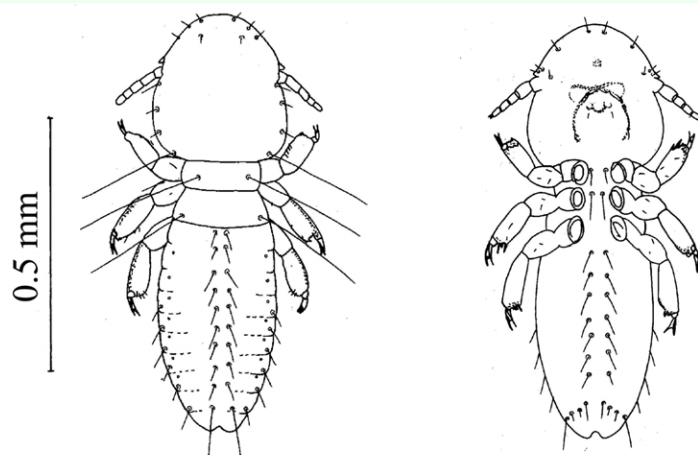
X = age of individuals; lx = age-specific longevity (probability at birth of a female being alive at age X when lo is taken as unity); mx = maternal frequency (average number of female eggs produced per day by a female aged X)

In vitro bionomics and life table statistics

The adults of *U. upupae* inhabit the wings and crest feathers of *U. epops*. The nymphs usually occupy the basal part of neck feathers. Most of the eggs of this louse occurred on the wings and crest feathers (Figure 4A).

The incubation period of the eggs was 5.25 ± 0.97 days (range 4-7 days, n = 88). The duration of three nymphal instars was 5.08 ± 0.85 days (range 4-7 days, n = 74), 5.54 ± 0.84 days (range 4-7 days, n = 55), and 6.04 ± 1.89 days (range 5-7 days, n = 25). The lifespan of adult females (15.0 ± 6.28 days, range 2-24 days, n = 50) was longer than that

of males (10.96 ± 3.92 days, range 1-21 days, n = 50). An adult female laid an average of 6.1 eggs during its lifespan, at a rate 0.35 egg/f/day (*in vitro* condition; $35 \pm 1^\circ$ C, 75-82% RH, feather diet). These data were utilized to construct the life table of the louse after making certain assumptions. The intrinsic rate of natural increase (rm) was determined as 0.035/day (Table 1) by the equation $\sum e^{-rmx}lxmx = 1$ (where e is the base of natural logarithm, x is the age of individuals in days, lx is the number individual alive at age x, and mx is the number of female offsprings produced/female) (Howe 1953). The net reproductive rate ($R_0 = lxmx$) was 3.67 female eggs/female. The generation time ($T =$



log e Ro/rm) was found to be 37.15 days. The doubling

First instar: (0.8- 0.9 mm) (Figure 1). The head is longer than it is broad, the anterior margin is round, and a faint pre-antennal suture extends across the head; the post antennal region is widest immediately behind eyes. Only the cutting edges of the mandibles show slight pigmentation. The hypopharynx and gular plate are not distinct. The antennae are filiform and five segmented in which the fifth segment is shortest and the second segment is broadest. The prothorax is rectangular and on the pronotum a long seta is present on each side. The pterothorax is larger than the prothorax and its posterior margin is slightly concave and bears one long setae on each postero-lateral angle. The first pair of legs is shorter than the others. The claws of meso- and meta-thoracic legs are longer and more slender than those of the pro-thoracic legs. Each leg is provided with a number of setae.

segment II. The abdomen is broadest at segment V-VI, and segment IX-X and XI segment taper posteriorly. Segment II is slightly longer than the others and segment XI is the shortest and its posterior margin is emarginated. In the first instar segments IX and X are not fused, unlike the adult. A pair of spiracles is present on segment III-VIII. The tergal, sternal, and pleural chaetotaxy and measurements of the first instar nymph are given in Table 2.

Second instar nymph: (1.18- 1.23 mm) (Figure 2). The second instar differs from the first instar in shape, size pigmentation, and chaetotaxy. The head is not as rounded anteriorly as in the previous instar and the narrow pre-antennal suture has become more distinct (Figure 2). Coni are also better developed. Mandibles are pigmented; the hypopharynx is delineable and the gular plate is also differentiated. In the prothorax there is very little change in shape; it however, shows pigmentation of the pronotum and the seta has grown longer and shifted nearer the posterolateral angle on each side. In the pterothorax the posterior margin shows greater concavity, and pteronotum is fully pigmented. Two setae are added each side to the already existing seta; these seta are long and extend up to the posterior margin of segment IV. Ventrally

Table 2. Showing chaetotaxy of first , second and third instar of *Upupicola upupae*.

Region	First instar			Second instar			Third instar		
	Tergal	Pleural	Sternal	Tergal	Pleural	Sternal	Tergal	Pleural	Sternal
Prothorax	1,1			1,1		1,1	1,1		1,1
Pterothorax	1,1			3,3		1,1	4-5,4-5		1,1
						1,1			1,1
II	1,1	0,0	2	1,1	0,0	2	1,1	0,0	6
	1,1			1,1			4		
III	1,1	0,0	2	1,1	0,0	2	6	0,0	4
IV	1,1	0,0	2	1,1	0,0	2	6	2,2	4
V	1,1	2,0-2	2	1,1	2,2	2	6	2,2	4
VI	1,1	2,2	2	1,1	2,2	2	4	2,2	4
VII	1,1	2,2	2	1,1	2,2	2	4	2,2	2
VIII	1,1	2,2	2	1,1	2,2	2	1,2,1	4,4	2
IX	1,1	2,2	6	1,1	2,2	2	2	2,2	1,4,1
X	1,1	2,2	6	1,1	2,2	2	1,1	1,1	1,4,1
XI	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

pro-, meso-, and meta-sternal plates are distinct and two setae are present on each external plate. Legs are well developed and slightly pigmented on the dorsal side of the femur and tibia. The abdomen showed an increase in length and breadth (Figure 2). Lateral pigmented areas have appeared on segment II-IV. Both segmentation and chaetotaxy of the abdomen almost remain as in the previous instars; there is, however, slight difference in the number of pleural setae.

Third instar nymph: (1.39-1.42) (Figure 3). The third instar nymph resembles the second

instar nymph. Pigmentation on head and thorax becomes darker and the pigmented areas on the abdomen have increased and so have the number of setae. The head is slightly more pointed anteriorly than the second instar nymph and the coni is now prominent (Figure 3). The hypopharynx and gular plate are further differentiated .The thorax is similar in shape to that of the second instars nymph, but it is further pigmented (Figure 3). The prothorax bears two setae, one on each postero-lateral angle. In the pterothorax 1-2 setae are added and now 5 setae are present on the posterior margin of pterothorax (on each side).

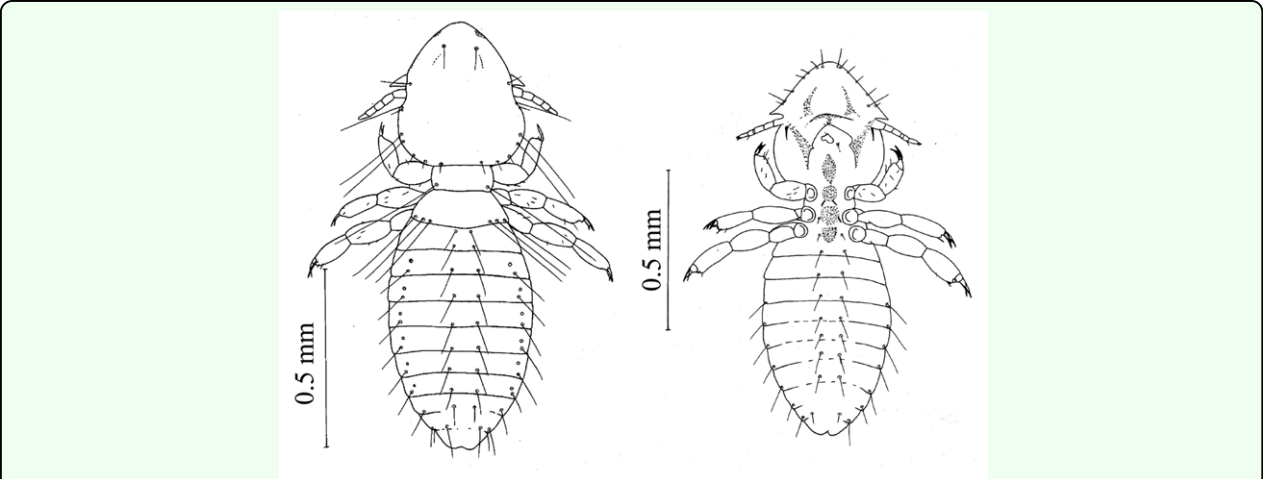


Figure 2. Dorsal and ventral views of 2nd instar *Upupicola upupae*. High quality figures are available online.

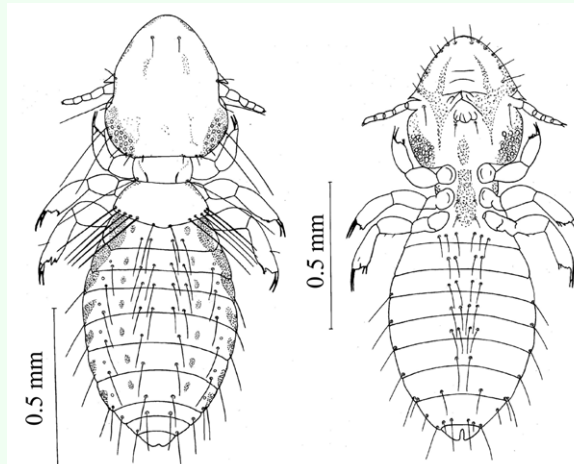


Figure 3. Dorsal and ventral views of 3rd instar *Upupicola upupae*. High quality figures are available online.

The abdomen shows increase in pigmentation (Figure 3). Lateral pigmented areas representing the pleurites are present from segment II-VIII. Besides these, there are oval pigmented areas in segments II-VIII, one on each side. There is no change in segmentation. However, there is marked increase in the number of tergal, pleural, and sternal setae (Table 2).

Egg morphology. The egg shell of *U. upupae* is a miniature rice grain like structure. The egg chorion does not show any sculpturing or projections. The dome shaped opercular disc is also smooth in nature and bears 28-30 button shaped micropyles, which are not arranged in single line (irregularly placed), along the rim of operculum (Figure 4B, C). The stigma remains concealed in the cementing material.

Antennal sensilla. The second flagellomere of antenna bears two distinct placodean sensilla (saucer shaped structure having central groove with numerous radiating ridges separated by grooves) and a pit sensilla (coelomic sensilla). The apical end of second

flagellomere bears 10 tactile sensilla (seta and pegs) of varying length (Figure 4D, E).

Discussion

Two phthirapteran species reportedly infest the *U. epops* (Price et al. 2003). During the present study only one ischnoceran louse (*U. upupae*) was recovered. The presence of the amblyceran louse, *Menacanthus fertilis* was not recorded. The frequency distribution pattern of *U. upupae* on *U. epops* was aggregated and conformed to the negative binomial model. Rekasi et al. (1997) computed that frequency distribution pattern of 21 (out of 27) species occurring on 13 birds conformed to negative binomial model. On the other hand Saxena et al. (2007), Gupta et al. (2007), Beg et al. (2008), and Rajput et al. (2009) found that negative binomial distribution was found to be a good fit in case of only one louse (out of 19). The sex ratio of *U. upupae* was female biased, like most of the other phthirapterans (Marshall 1981). Reasons responsible for skewed sex ratio have been discussed by Gupta et al. (2007).

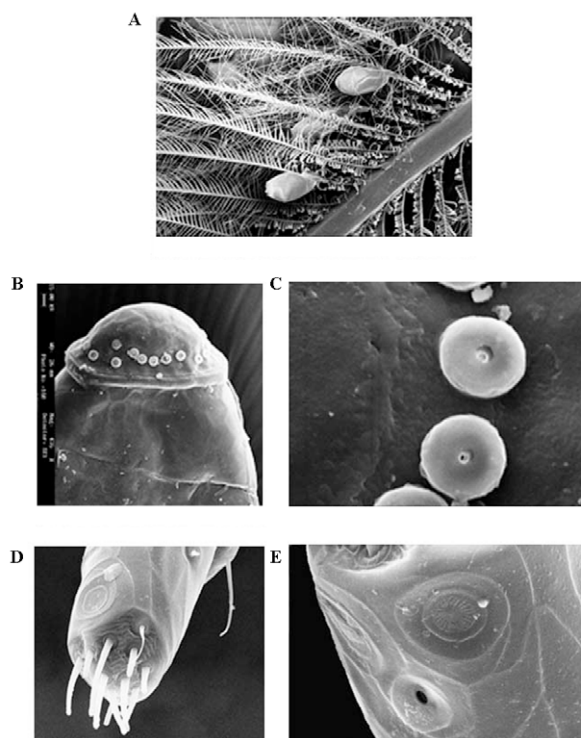


Figure 4. (A) Photograph showing egg laying pattern of *Upupicola upupae*. (B) Scanning electron microscope photograph of the anterior portion of the egg of *Upupicola upupae*. (C) Enlarged view of Figure B, showing detailed nature of micropyles. (D) SEM photograph of the third flagellomere of *Upupicola upupae*, showing the sensilla present on the apical end and antero-lateral surface. (E) More enlarged view of Figure D to show the nature of placodean sensilla and pit organ.. High quality figures are available online.

The incubation period of eggs, duration of three nymphal stages and the adult lifespan of *U. upupae* does not show any departure from the other ischnoceran species studied, so far (Wilson 1934, 1939; Arora and Chopra, 1959; Agarwal 1967; Williams 1970; Saxena et al. 1991; Singh et al. 2001; Gupta et al. 2007; Saxena et al. 2007, 09). The rate of egg production of different species recorded by the aforesaid workers varied from 0.4 to 2.0 eggs/female/day. In case of eight avian lice the data obtained from *in vitro* experimentation have been utilized to construct a life table and to determine the intrinsic rate of natural increase, as well as the doubling time of the population (Beg et al. 2005; Saxena et al. 2007; Gupta et al. 2007; Saxena et al. 2009). The intrinsic rate of natural increase of different species

determined by the aforesaid workers varied from 0.033 to 0.074. Thus, *U. upupae* ($r_m = 0.037$) appears to be a slow breeder in this context. The present report provides further information on the distribution of *U. upupae* on host bird, the egg laying sites, and the egg morphology. The eggshell of *U. upupae* differs from that of *Degeeriella regalis* (V. Khan, Govt. Raza P. G. College, Rampur, personal communication) as the operculum of the latter bears hexagonal ridges and only 14-16 micropyles.

Specific studies on the morphology of nymphal instars have been made by Modrejewska and Zlotorzyska (1987) and Mey (1994). Price and Hellenthal (1986) have highlighted the importance of nymph morphology for determining the louse

relationship. Smith (2000) has further noted the ontogenic transformation in shape of head of three instars of nymph of four avian lice and recommended the use of nymph morphology to establish the phylogeny of bird lice. The present study provides the diagnostic features of three instars of nymphs of *U. upupae*. Three instars of nymphs of *U. upupae* differ not only in size, segmentation, chitinization, but also in gradual accumulation/displacement of setae on different parts of body. In adult females of *U. upupae* the three segments (IX, X, XI) become fused.

Acknowledgements

The authors are indebted to the Principal, Govt. Raza P.G. College, Rampur (U.P) for providing laboratory facilities; to Chief Wild Life Warden of U. P. (India) for permission for to catch the birds; and to the CSIR, New Delhi for providing financial support to Dr. A. K. Saxena in the form of project no. 37/(1298)/07/EMR II.

References

Agarwal GP. 1967. Studies on the bionomics and life-history of *Falcolipeurus frater* (Giebel: 1874) (Mallophaga: Ischnocera). *Indian Journal of Zootomy* 8(1): 21-40.

Arora GL, Chopra NP. 1959. Observation on life history of *Lipeurus tropicalis* Peters (Mallophaga: Ischnocera). *Research Bulletin Punjab University* 10(2): 179-187.

Beg S, Kumar S, Gupta N, Khan V, Saxena AK. 2005. Life table of *Philoptereus lahorensis* (Phthiraptera: Mallophaga) infesting crows. *Rivista di Parassitologia XXII (XVI) N 1*: 14-49.

Beg S, Gupta N, Kumar S, Khan V, Bhatnagar S, Saxena AK. 2008. Occurrence of Phthiraptera on the house crow *Corvus splendens* (Passeriformes: Corvidae). *Entomon* 33: 75-78.

Chandra S, Agarwal GP, Singh SPN, Saxena AK. 1999. Seasonal changes in a population of *Menacanthus eurysternus* (Mallophaga: Amblycera) on the common Myna, *Acridotheres tristis*. *International Journal of Parasitology* 20(8): 1063-1065.

Gupta N, Kumar S, Saxena AK. 2007. Prevalence and population structure of lice (Phthiraptera) on Indian red avadavat. *Zoological Science* 24: 381-383.

Howe RW, 1953. The rapid determination of the intrinsic rate of increase of an insect population. *Annals of Applied Biology* 40(1): 134-151.

Khan V, Kumar S, Gupta N, Ahmad A, Saxena AK. 2008. Prevalence of phthirapteran ectoparasites on selected poultry in the district Rampur (U.P.). *Indian Veterinary Journal* 85: 447-448.

Marshall AG. 1981. The ecology of ectoparasitic insects. Academic Press.

Smith VS. 2000. Basal ischnoceran louse phylogeny (Phthiraptera: Ischnocera: Goniodidae and Heptapsogasteridae). *Systematic Entomology* 25: 73-94.

Mey E. 1994. Beziehungen Zwischen larvemorphologie und systematik der adulti bei den vogel-Ischnozeren (Insecta, Phthiraptera, Ischnocera). *Mitteilungen aus dem Zoologischen Museum in Berlin* 70: 3-84.

Modrzewska M, Zlotorzyska J. 1987. Studies on morphology of nymphs of selected

- Amblycera and Ischnocera (Mallophga). *Poiskie Pismo Entomologiczne* 57: 657-672.
- Price RD, Hellenthal RA, Palma RL, Johnson KP, Clayton DH. 2003. The chewing lice: World checklist and biological overview. *Illinois Natural History Survey Special Publication* 24: X-501.
- Price RD, Hellenthal RA. 1996. Taxonomic importance of first instar chewing lice (Phthiraptera: Trichodectidae) from pocket gophers (Rodentia: Geomyidae). *Annals of the Entomological Society of America* 98: 570-578.
- Rajput S, Joshi VD, Gupta N, Khan V, Saxena AK. 2009. Population dynamics of Phthiraptera on Indian Bank Myna, *Acridotheres ginginianus*. *Entomon* 34(2): 99-102.
- Rekasi J, Rozsa L, Kiss BJ. 1997. Patterns in the distribution of avian lice (Phthiraptera: Amblycera, Ischnocera). *Journal of Avian Biology* 28: 150-156.
- Rozsa L, Reiczigel J, Majoros G. 2000. Quantifying parasites in sample of host. *Journal of Parasitology* 86: 228-232.
- Saxena AK, Trivedi MC, Rawat BS, Kumar A. 1991. Bionomics of poultry louse, *Lipeurus lawrensis tropicalis* Peters (Phthiraptera: Ischnocera). *Journal of Zoological Research* 4: 27-32.
- Saxena AK, Kumar A, Surman, Singh SK. 1995. Prevalence of *Menopon gallinae* Linne. (Phthiraptera: Amblycera) on poultry birds of Garhwal. *Journal of Parasitic Disease* 19(1): 69-72.
- Saxena AK, Kumar S, Gupta N, Singh R. 2007. Population expansion of the poultry fluff louse *Goniocotes gallinae* (De Geer. 1778). (Isochnocera, Phthiraptera, Insecta). *Zoological Science* 24: 327-330.
- Saxena AK, Gupta N, Kumar S, Khan V, Arya G, Saxena S. 2009. Intrinsic rate of Natural increase of five Ischnoceran lice (Phthiraptera: Insecta). *Entomological News* 120(4): 385- 391.
- Singh SK, Surman, Kumar A, Saxena AK. 2001. *In vitro* biology of a pigeon louse, *Columbicola columbae* (Phthiraptera: Ischnocera). In: Malhotra SK, Chauhan RS, editors. *Prof. V.N. Kapoor commemoration Volume*, pp. 54-56. Ankit Publications.
- Smith VS. 2000. Basal ischnoceran louse phylogeny (Phthiraptera: Ischnocera: Gonioididae and Heptapsogasteridae). *Systematic Entomology* 25: 73-94.
- Trivedi MC, Saxena AK, Rawat BS. 1992. Incidence of Mallophaga on poultry in Dehradun (India). *Angewandte Parasitologie* 33: 69-78.
- Wilson FH. 1934. The life cycle and bionomics of *Lipeurus heterogrophus* Nitzsch. *Journal of Parasitology* 20: 304-311.
- Wilson FH. 1939. The life-cycle and bionomics of *Lipeurus caponis* (Linn.). *Annals of the Entomological Society of America* 32(2):318-320.
- Williams RT. 1970. *In vitro* studies on the environmental biology of *Goniodes colchici* (Denny) (Mallophaga: Ischnocera). I. The effects of temperature and humidity on the bionomics of *G. colchici*. *Australian Journal of Zoology* 18:379-389.