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Records of the Zoological Survey of India

Data Book for the study of the Chewing-Lice (Phthiraptera : Insecta In India and Adjacent Countries

by
K. V. LAKSHMINARAYANA

Issued by the Director
Zoological Survey of India, Calcutta

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Dedicated to my Parents

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INTRODUCTION

The Chewing-lice (the biting—, or bird—, or feather-lice) are secondarily apterous, dorso-ventrally flattened, obligatory ecto-parasitic insects on warm-blooded vertebrates, i.e., the birds and the mammals. There are about 2900 (Clay, 1974c) to 3000 (Pilgrim, 1970) known species in the world, and many are yet to be discovered or described. Their food chiefly consists of the feathers, hairs, some sebaceous matter, and at times the serum and blood. Their life cycle is quite simple with an egg, three nymphal instars, and the adult. The sexes are separate with pronounced sexual dimorphism in some. In few cases the males are unknown and may yet to be discovered, or the species might be parthenogenic ! In general, the females predominate over males in numbers.

The Chewing-lice cause dermatitis, rickettsiasis, loss of hair, or feathers, reduction in egg production atleast in poultry, bill deformity, and sickly appearance in cases of heavy infestation. They were known to act as intermediate hosts of the swift filarial worm (*Filaria cypseli*) by *Dennyus minor*, dog cestode by *Trichodectes canis*, transmission of typhus in Guineapig by *Trimenopon hispidum*, and infectious anaemia of horses by *Damalinia equi*, to quote a few. Emerson (1973) states that the eastern equine encephalomyelitis virus, and *Bedsonia* organisms in pheasants were also found in the chewing-lice of the respective hosts. This author further rightly pointed that the role of the chewing-lice in disease transmission is little explored, and that with the increased interest in the wild-life epizoology and diseases, we may have better understanding on this problem.

The Chewing-lice seldom live for long away from their hosts, thus they developed extreme host-specificity and obligatory parasitism. Not only they are host-specific, but they are also niche-specific on the host body. Ash (1960) states that the area of living, feeding, and oviposition are different in bird inhabiting species. Clay (1949c, 1950) categorised two ecological niches for the Ischnoceran bird-lice, viz., the head and neck niche, and the wing and abdominal niche. The head and neck inhabiting forms are not usually subjected for preening, while the wing and abdomen inhabiting forms are exposed to preening. Therefore, the head and neck inhabiting forms are broad, short. with circumfasciate head and round body with a dorsal genital opening in the female for convenient mating. On the other hand, the wing and abdomen inhabiting forms developed slender bodies to escape preening, with a ventral or ventro-terminal female genital opening, and the male

manipulates itself during mating. Occasionally, there occurred some migrations and subsequent settlement from one niche to another when it was found empty. Clay (1949c) illustrated this phenomenon in some interesting cases. For example, *Sturnidoecus*, the members of which are parasitic on the starlings (Passeriformes : Sturnidae) found an empty head niche, which is normally occupied by another genus *Philopterus* on other members of the Passeriformes. *Sturnidoecus* superficially resembles *Philopterus* in having short round body, large head, complicated head sutures, but the characters of its female genital region, shape of the alimentary canal, internal male genitalia, and spermatheca, however, resemble those of *Brueelia*, found in the wing and abdominal niche. Likewise, *Columbicola*, a genus found on pigeons and doves, though resembles the elongate forms of the wing and abdominal niche, its female genital opening remained dorsal as in the head and neck inhabiting forms, and it achieved the slender body by secondarily elongating its anterior region. Thus the female genital opening gives us a clue that *Columbicola* was originally an head inhabiting form. The feather structure often effects the head structure (Clay, 1949c, 1950) and in extreme cases even led to the asymmetry of the head as in *Struthiolipeurus* parasitic on ostrich, rhea and nandu (Lakshminarayana, 1970a, 1973b, 1979a,c). Eichler (1963) and Emerson (1973) added two more ecological niches viz., inside the gular pouches of the Pelecaniformes, and large quills of Procellariiformes, Galliformes, Charadriiformes and Psittaciformes.

Different species probably require different temperatures for the development, Ash (1960) considers that the host body itself might be providing variable temperatures, since the actual skin temperature differs markedly from that under the feather cover above. In any case, the host body covered by pelage, or plumage offers the parasite a very good shelter, food and insulates it from the external environmental fluctuations, to which the host itself is subjected to. Hence, the microclimatic conditions remain uniform for the parasite.

Parasites from one host species are isolated from those of another host species, since no two host species mingle with each other, the host itself acts as a barrier for the movement of the parasite. In other words, the host acts like a 'biological Island' similar to 'geographical Islands' separated by water (Clay, 1949c ; cf. Lakshminarayana, 1970a, 1977a). As a matter of fact, the hosts follow the traditional saying

that "the birds of the same feather flock together", and no two host species come to shoulder to shoulder contact to permit the transferance of the lice from one host species to the other, except in case of prey and the predator, the foster parent and its brood parasite. Experience shows that even in these cases the parasites of the prey over the predator, or those of the foster parent on the brood parasite have never established. Guimaraes (1974), however, believed that *Psittaconirmus*, a genus of parrot lice, has secondarily established on the birds of the prey, the Falconiformes. Whether it is a case of secondary establishment or parallel evolution needs to be investigated, since Chandler (1916) places Psittaciformes, and Cuculiformes together with Falconiformes on the basis of the feather structure. Incidentally, it may not be out of place to mention that Cuculiformes share with Falconiformes four genera of the chewing-lice (i.e., *Colpocephalum*, a wide spread genus on many bird orders, *Cuculiphilus*, *Cuculicola*, *Osborniella* and also a mite species, *Ornithonyssus bursa*). Secondary establishment might be possible in closely related host species though not as a general rule (Lakshminarayana, 1972a). The occurence of lice on unrelated hosts may be due to straggling also. Hopkins (1939) attributed straggling due to handling two host species together during transportation, to human error while collecting, to host species kept in close proximity as in zoos, during feeding, roosting, or breeding in company, or to polyoecism where the parasite could adopt to a wide range of related hosts, or carried from one to the other by phoresy, or during dust baths. Though some species of birds may have communal bath centres, Dr Biswas (in *litt.*) informs that he observed in Gir forest an instance where two species of quails maintained their individual dust bath centres.

COLLECTION & PRESERVATION

Generally, it is easy to collect the bird inhabiting forms than mammal infesting species of lice. At times two or more genera of lice may be found on birds (Fig. 1). Hand picking with a fine forceps, or with a brush dipped in alcohol would normally serve the purpose well. The mammal infesting species also could be hand picked by forceps, or by combing, or chemically extracted by dissolving pieces of the host skin in 10% KOH, and then examined for the lice under the microscope. Reference for elaborate techniques is invited to Lakshminarayana (1975b, 1980a).

The lice can be preserved in 70—90% alcohol, or mounted on slides. The present author adopts the following procedure for slide mounting, which eliminates passing of the material through different grades of alcohol. It involves (if not extracted by KOH treatment) heating the lice in 10% KOH in a test tube over a water bath. The specimens are washed well in distilled water, while pressing the body by the head of an entomological pin to remove the inner contents. The material

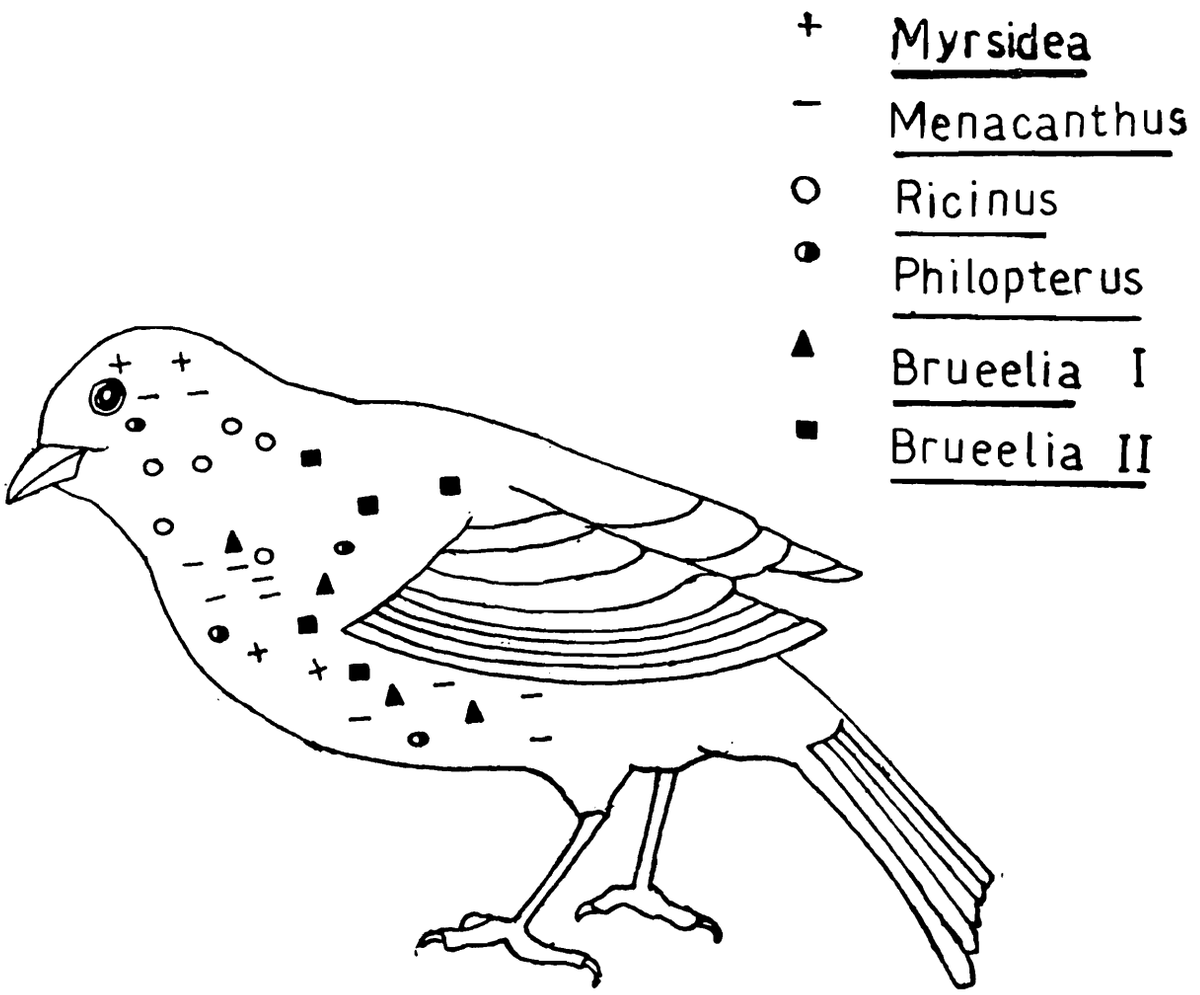


Fig. 1. A small Passerine bird showing the likely genera of Chewing-lice on it.

is then passed on into Glacial Acetic acid in an embryo dish. Staining is not normally required, since several species are heavily sclerotised, and if desired, can be stained in Acid Fuchsin, or Carbol-Fuchsin. They may then be passed once again through Glacial Acetic acid. Later the material may be passed through the Clove oil, and either mounted directly, or through a xylol stage, in Canada Balsam. For further details, attention is invited to Lakshminarayana (*op. cit.*).

ORIGIN, ANTIQUITY, AND SPECIATION

The Chewing-lice are believed to be very closely related to the Sucking-lice, and possibly evolved together (though not monophyletically) from the bark-, or book-lice, the Psocoptera (Corrodentia *auct.*) (Fig. 2). The presence of a sitophore or hypopharyngeal sclerites, lingual sclerites, and a sclerotized filament in these three groups only amongst all insects strongly supports this contention originally proposed by Packard (1887). The tentorium (Symmons, 1952), and possibly the spiracular structures (Webb. 1946) also lend further support to this theory. It is believed that the free-living, saprophagous, ground, nest, or burrow inhabiting psocopterans might have acquired the parasitic habit on the birds and mammals, when they were evolving or radiating from their reptilian ancestors.

Fossil lice are not so far reported, except for one report of eggs preserved in Baltic amber (Voigt, 1952). Hopkins (1949a) discussed the antiquity of lice in detail from various angles. This author concluded that the ancestors of the Amblycerophthirina (the most primitive member of the extant Chewing-lice) possibly began their life as ectoparasites of vertebrates during the Triassic Period (225—190 million years ago), and parasitized the early birds and mammals, and possibly their reptilian ancestors. The true Amblycerophthirina possibly evolved at least in Jurassic (190—135 m.y. ago), and the Ischnocerophthirina might have been in existance since early Cretaceous (135—65 m.y. ago), or even in Jurassic, and the Siphunculophthirina cannot be later than middle of Cretaceous. The evidence of Rhynchophthirina is too scanty, but it must have evolved earlier than Eocene epoch (54 to 38 m.y. ago), and possibly could have existed even in Cretaceous period.

The occurrence of a common genus like *Struthiolipeurus* on the African ostrich, the American Rhea, and nandu (now absolutely confined to different continents) indicates the parasitization from a remote common ancestor, or a neighbour, to a time before the continents were separated off from the Gondwana block. This genus is believed to have originated before the early Eocene. Likewise, the common occurrence of *Haematomyzus elephantis* (Rhynchophthirina) on wild Indian and African elephant populations speaks of its antiquity to a period of the Gondwana Land.

In the evolution, or speciation of the chewing-lice, two trends are evident. In the changing environment, the hosts have evolved at a

faster rate due to variations in macroclimate. The Chewing-lice possibly acquired specificity in a short time, and therefore passed on from one generation to the other. When the hosts were evolving at a faster rate, new or empty ecological niches were available to the lice on one hand, and at the same time they were quickly isolated on different related host groups or populations. These two factors, viz., the empty ecological niches, and isolation encouraged or brought out an equally rapid speciation or "accelerated evolution" in the Chewing-lice. Speciation in Nature, is however, a slow process and takes considerable time for the variations to get established. This is true for all the organisms. Though, the hosts were evolving at a faster rate, the microclimatic conditions available for the parasites with in the hair or feather cover were however, possibly remained uniform for considera-time, and therefore, the variations in the parasite species were built up at a slower rate on the resultant and evolving host species. Thus, the same or closely related parasite species were passed on to different evolving host groups. This slower rate of speciation in the parasite species is regarded as a "retarded evolution" as opposed to the "accelerated evolution" Accelerated evolution produced number of species (and genera), while retarded evolution produced species (or generic—) —complexes (Lakshminarayana, 1977a). Kéler (1958) considered accelerated evolution as dominant over the retarded evolution, which is limited to special cases. In addition to the host induced (specificity), and physical isolations playing active roles in the speciation of the lice, sexual isolation also played considerable part in their speciation. The changes in the position of genital opening, and the modifications in the male genitalia prevented interbreeding between closely related populations, or species at one time contiguous, later separated, and finally re-united (Lakshminarayana, 1977a, 1979 a,c). For example, *Goniodes mayuri* and *G. parviceps* are two sympatric species of lice on the peafowls in the Oriental Region. In the former, the male genitalia are symmetrical, and in the latter, asymmetrical. Lakshminarayana & Emerson (1971, 1978) showed that the asymmetrical genitalia in *parviceps* undoubtedly derived from the symmetrical ones in *mayuri*. *G. mayuri* was the more ancestral of the two species, occurring on the Indian peafowl populations, got separated from the populations of the peafowl in the Indo-Chinese Sub-region for sometime in earth's history. The peafowls in the Indo-Chinese Sub-region speciated into a green form to escape from the predators in the thick green forest belt consequent to the Himalayan uplift, by the alteration of its feather

structure. The populations of *mayuri* on the evolving green form also altered its head structure, and developed a heavily sclerotized and robust form. When the Indian peafowl and the green peafowl populations were re-united due to altered geographical conditions, their parasites also have had chances to mingle. *G. parviceps* populations which were transferred to the Indian peafowl from the green, being of stronger built than *G. mayuri* they could get established on it, and developed asymmetry in the male genitalia to prevent crossbreeding. Its male antenna also developed a sensory mechanism to distinguish its female from those of *mayuri*, though females of both are indistinguishable except for body build, from human point of view. Since the feather structure of the green form is an altered one, the weaker *mayuri* population could not get established on the green peafowl, and therefore was eliminated on it. Thus, we could encounter both *mayuri* and *parviceps* on the Indian peafowl, but only *parviceps* on the green peafowl populations.

Clay (1949c) quoting from Sikora & Eichler (1941) stated that the antennae play a dominant part in mating in the Ischnocerophthiran lice, and that the less common occurrence of sympatric species in the Amblycerophthiran lice may be due to the absence of sexual dimorphism in male antenna. The antennae perhaps apparently not playing an active part in the mating in the Amblycerophthiran lice.

Lakshminarayana (1977a, 1979a,c) outlined the significant role played by the asymmetry in the body parts, especially in the genitalia, in speciation of the chewing lice. It has also been shown that asymmetry is more common in the Amblycerophthran lice than in the Isch= nocerophthiran lice, as has been hither to thought of. In certain genera of the former, species with both symmetrical genitalia are met with, where as in some only species with asymmetrical genitalia alone are found. Perhaps, species or populations with symmetrical genitalia might have been excluded and eliminated in the speciation. This suggests genetic factors responsible for the development of the asymmetrical genitalia might be dominant over those responsible for symmetrical genitalia.

NOMENCLATURAL PROBLEMS

The Chewing-lice also, as in other insect groups, suffered to a great extent in the hands of the "splitters" and the "lumpers" not only at the generic and specific levels, but also at the suprageneric level.

Confusion on the authorship, and dates of priority also prevailed. Lakshminarayana (1976) reviewed the problem in detail, and listed all the taxa of the superfamily, family, subfamily, and tribes, their authors, and years of establishment.

Many authors now agree to group the chewing-lice (Mallophaga *s.l.*) and the sucking-lice (Siphunculata, or Anoplura *auct.*) in to a single order Phthiraptera Haeckel *sensu* Weber, 1939. Therefore, it has been proposed by Lakshminarayana (*op. cit.*) that erstwhile suborders Amblycera Kellogg, Ischnocera Kellogg (Mallophaga *s.l.*) and Siphunculata Latreille be conveniently emended to Amblycerophthirina, Ischnocerophthirina, and Siphunculophthirina respectively on par and tune with Rhynchophthirina Ferris. Emerson (*in litt.*) however, opines that this combination of both the chewing-and sucking-lice together in a single order is not acceptable.

The Chewing-lice as is understood now can be grouped in the aforesaid suborders viz., Amblycerophthirina, Ischnocerophthirina, and Rhynchopthirina. As already stated there is no uniformity in grouping the genera under different families and subfamilies. However, they may be broadly divided under the following families : mammal infesting families of Boopiidae, Gyropidae, Trimenoponidae, and the more recent addition Abrocomophagidae, the bird infesting families of Laemobothriidae, Menoponidae, Trinotonidae, Ricinidae, (Trochiliphagidae) Trochiloecedae under Amblycerophthirina ; bird infesting families of Heptasogasteridae, Philopteridae *s.l.* (except *Trichophilopterus* which is found on mammals) and mammal infesting family Trichodectidae under Ischnocerophthirina ; and the monogenic family Haematomyzidae (on elephants & warthogs) under Rhynchophthirina (fig. 2 & 3). In India, we encounter species belonging to Boopiidae, Laemobothriidae, Menoponidae, Ricinidae, Trinotonidae, Philopteridae, and Haematomyzidae.

As in the suprageneric categories, we find "splitters" giving specific names for populations from different regions, or hosts, due to their indifference to *Nomenclatural Rules*, or lack of contemporary literature, and erroneous host records on one hand, and the "lumpers" dumping all in few genera. Nitzsch (1818) was the first to have a clear conception of the group. Harrison (1916) first applied the *Principle of priority* for generic and specific taxa. Hopkins (1949a) and Hopkins & Clay (1952, 1953, 1955) examined almost all available type and general

collections, codified all the available names, properly delineated the species, and fixed the type-hosts, for the sucking-and chewing-lice respectively, indeed a stupendous task. In a series of papers Clay & Hopkins (1950, 1951, 1954, 1960) reviewed the literature from Linnaeus (1758) to Nitzsch (1818) and in many cases selected lectotypes where the type material is available, and designated neotypes where the types were lost. Price & Emerson (1966a, 1967), Price (1970a) supplemented the above works. Eichler (1963), and Złotorzycka (1972 a,b, 1976,

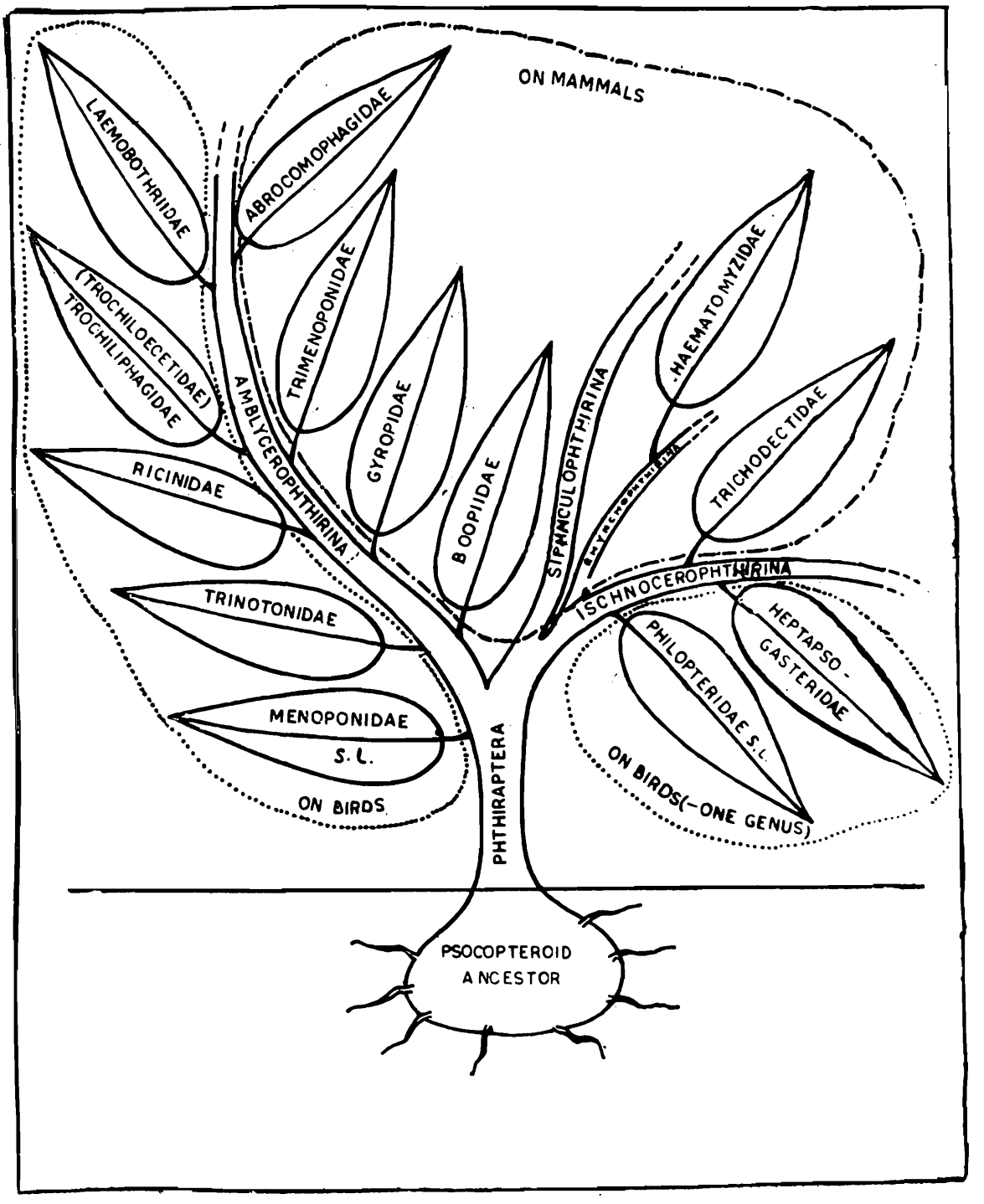


Fig. 2. Schematic representation of generally accepted sub-orders and families of Chewing-lice.

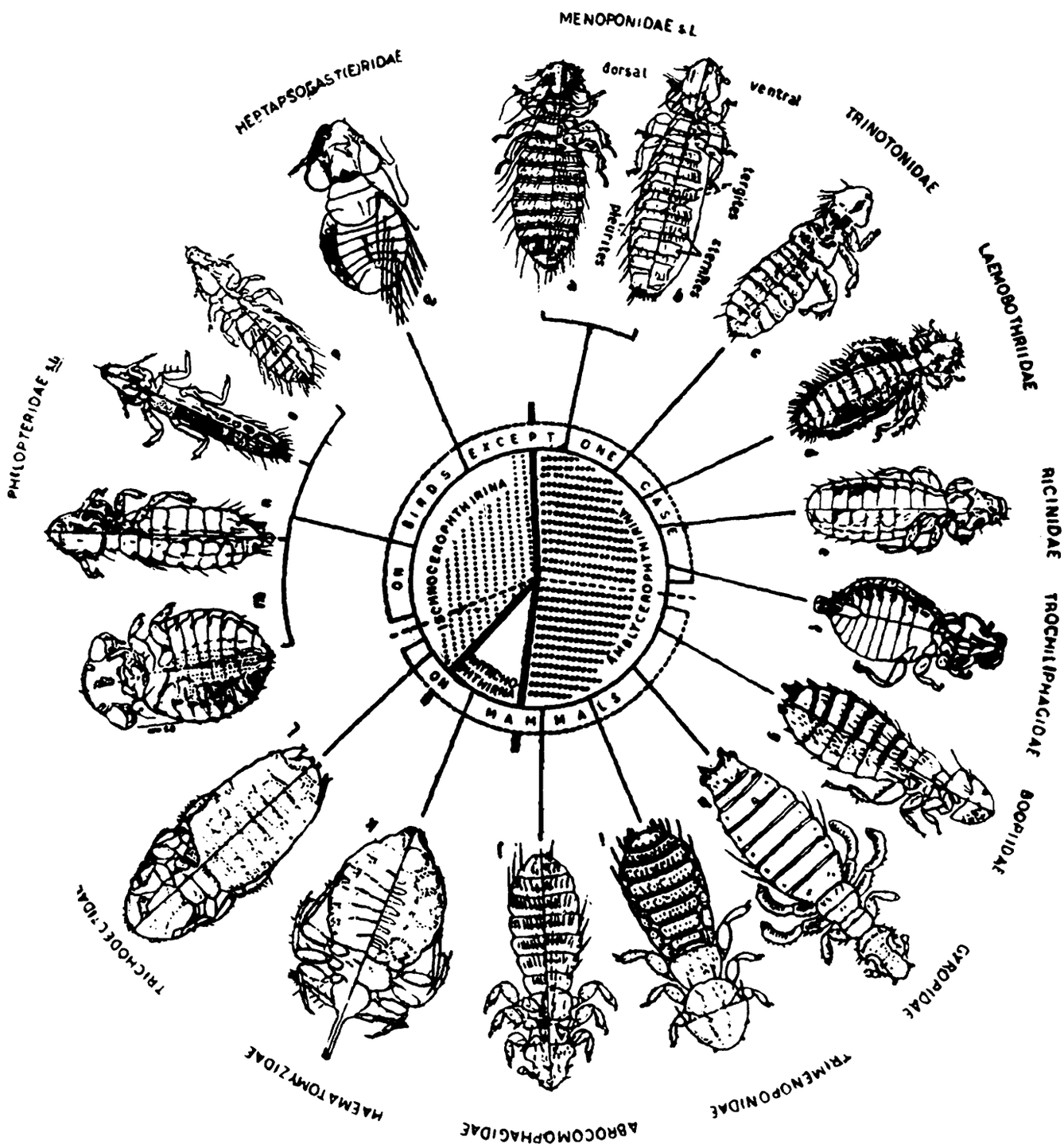


Fig. 3. Chart showing the Representative members of various families of Chewing-lice (Lakshminarayana, in press).

1977, 1978) Złotorzycka *et al.* (1974) are excellent treatises, but unfortunately little understood by many who are not familiar with German and Polish languages. The conspectus of the classification in Eichler (1963) will be very handy to a beginner. Clay (1969, 1970a) are most

useful works to any taxonomist for the identification of Amblycerophthiran genera and Blagoveshtchenskii (1967) for the Ischnocerophthiran genera. The recent revisionary works of many authors are provided with exhaustive synonymy, good descriptions, coupled with neat figures, a trend set by Hopkins, Clay, Carriker, Price & Beer, Emerson, etc. In many of the papers attempts have been made to cross check the observations on the lice with those of the host-relations or evolution.

CHECK-LIST, HOST-LIST, SYNOPTIC LISTS

The Chewing-lice, as pointed out earlier, are parasitic on such hosts as birds, whose range of distribution is quite wide, often extending into different zoogeographical regions. Therefore, it is likely that the same species might occur in other regions on the same host, and have been reported under the same or a different name. The earlier workers ignored this fact, and described several species from the local populations, which resulted in a long list of synonymies, causing confusion.

Check-Lists, Synoptic-Lists, Host-Lists, etc., will give a general idea on the fauna to a beginner, and also enable us to cross check our identification with the fanua elsewhere on a particular host(s). Kellogg (1900, 1908), Harrison (1916), Bedford (1932), Hopkins (1949a), Hopkins & Clay (1952, 1953, 1955), Emerson (1972 a-d, 1973), are some of this kind. In so far as India and adjacent countries are concerned, although Gaiger (1910, 1915) for the parasites of Indian domestic animals including lice, Bhattacharjee (1939) for Burma, Seneviratna (1963) for Sri Lanka, Ansari (1956 f,g) for Indo-Pakistan, Emerson (1971) for Nepal, and Emerson (1973) broadly for Asian species, are available, they are far from complete. Lakshminarayana (1979b, 1982b) presented the synoptic lists of the chewing-lice reported upto 1979, together with host and regional indices for the known species from Afghanistan, Bangladesh, Bhutan, Burma, India, Nepal, Pakistan, Sri Lanka, and border areas of Tibet, Szechwan, & Yunnan (China). These lists will undoubtedly help any new comer to this field of study.

BRIEF HISTORICAL REVIEW

Lakshminarayana (1972b) gave a detailed outline of the work carried out in India and adjacent. Briefly, it may be reproduced here under :

"Denny (1842) gave a historical account of lice from Biblical times. Recently, Kèler (1960) in his "Bibliographie der Mallophagen" referred to three works of pre-Christian Era, viz., Herakleitos Ephesius (500 B.C.), Aristotle (350 B.C.), and Diophanes of Bithynia (100 B.C.). Lice have however, been known from much earlier times in India. Rao (1957) pointed out in *Manava Dharma Sastra* (Vedic Period) flies, mosquitoes, lice and bugs were classed amongst the animals that breed in sweat (svedaja). Seal (1915, 1958) has drawn attention to Umasvati's classification of animals in *Tatvathadigama* (circa 40 A.D.) in which the lice were classed under *Trapusarja* and *Karpasasthika*, on the basis of their sense organs. In the Sangam literature of South India (a period from 3000 B.C. to 1915 A.D., according to some, and from 4 A.D, to 8 A.D. according to others) are found plentiful references to birds, their habitats along with references to insects like ants, bees, wasps, dragonflies, white-ants, lice and scorpions. Emperor Asoka (273—232 B.C.) was known to have established a number of veterinary hospitals whose inmates include various birds, and their scourges were well known to the doctors of the hospitals. Moghul Emperors seem to have a fair knowledge of birds. Salim Ali (1927) quoted Abul Fazal, a contemporary to Akbar, and the author of *Fauna of Hindustan,* who referred in his work that Kashmir valley was infested with such undesirables as gnats, fleas, and lice etc. In ancient India, several birds like domestic hen, geese, pigeons (for carrying post), peacock, 'parrots' (probably paroqueets) and mynahs were domesticated, their habits and diseases were carefully observed, the lice even entered in proverbial literature"

For example, we have a proverb in Telugu as *"Penuku pettanamichchina tala tega korukun"* meaning thereby, if authority is vested with lice they will bite or shave off the head continuously (or thoroughly). We do not know whether the louse referred to is our head-louse, or that of sheep. Undoubtedly, this proverb was coined after observing the falling of hair in patches due to louse biting in sheep, or due to different varieties of alopecia in man, the etiology of which is not difinite. It was however attributed to the human society as a simile, thereby indicating "if authority is vested in unworthy, they either mismanage or exploit their authority !" It is further stated in Lakshminarayana (*op. cit.*).

"The first scientific report of lice on Indian birds apparently dates back to J. C. Fabricius (1775) wherein he described the habitat of *Pediculus vulturis*/*Laemobothrion vulturis* (J. C. Fab.)/as "Indiae orientalis vulturibis" It was followed by *Pediculus tantali* (J. C. Fab.) from the painted stork, *Tantalus leucocephalus*/*Ibis leucocephalus* / (Pennant) / from Tranquebar by the same author (1798), Rudow (1869) described *Lipeurus himalayensis* / *Reticulipeurus himalayensis* (Rudow)/from the western horned pheasant, *Tragopan hastingii* / *T Melanocephalus* (J. E. Gray). Few other references to Indian Mallophaga are seen in the writings of Giebel (1874), Piaget (1869-1915), Walker (1871), Kellogg (1908), Gaiger (1910, 1915) and Paine (1912). It is believed that these reports were probably from material collected from animals in zoo gardens or from museum skins. Kellogg and Paine (1914) were the first to study material actually collected from India by the Indian Museum. This was followed by another short list by Kellogg & Nakayama (1915). Since then several workers, chiefly from outside India, have either studied material exclusively from Indian Region, or incidentally in the course of their revisionary works. A complete bibliography on Indian Mallophaga is so far not available, though Kéler (1960) listed some of them ; an up-todate bibliography is presented for first time by the the present author (Lakshminarayana, 1970)"

We owe a great deal to the western taxonomists for the work on chewing-lice from this region, the chief source being the excellent collections of Dr. R.N. Meintertzhagen. Amongst the Regional workers, mention should be made to the pioneers like Drs. Qadri, Sen, Ansari, Arora & Chopra, and Rakshapal. At present the most active taxonomists in India are Dr. Tandan (since retired) & his school in Lucknow University, and Drs. Lakshminarayana & Rai in the Zoological Survey of India (the latter now moved on deputation to the Hqrs. of the Department of Environment, Government of India, New Delhi), while Dr. Agarwal and his students at Banaras University, Varanasi, are working on the morphology, histology, and bionomics. Dr. Rao *et al.*, studied the mouth parts in detail, while Drs. Mukerji and Sen-Sarma studied the various systems in *Haematomyzus elephantis.*

The number of known genera and species to-date (excluding the unpublished records of Lakshminarayana & Rai) are as follows :

TABLE 1

Families	Number of Genera	Number of Species
(Suborder AMBLYCEROPHTHIRINA)		
1. Boopiidae	2	2
2. Laemobothriidae	2	5
3. Menoponidae	26	172
4. Trinotonidae	1	4
5. Ricinidae	1	7
(Suborder ISCHNOCEROPHTHIRINA)		
6. Philopteridae *s. l*	67	369
7. Trichodectidae	3	16
(Suborder RHYNCHOPHTHIRINA)		
8. Haematomyzidae	1	1
Total	103	576

The relative proportion of the chewing-lice from India and adjacent countries in relation to the known world fauna on the group is presented in Fig. 4.

The genera and species reported country-wise are as follows :

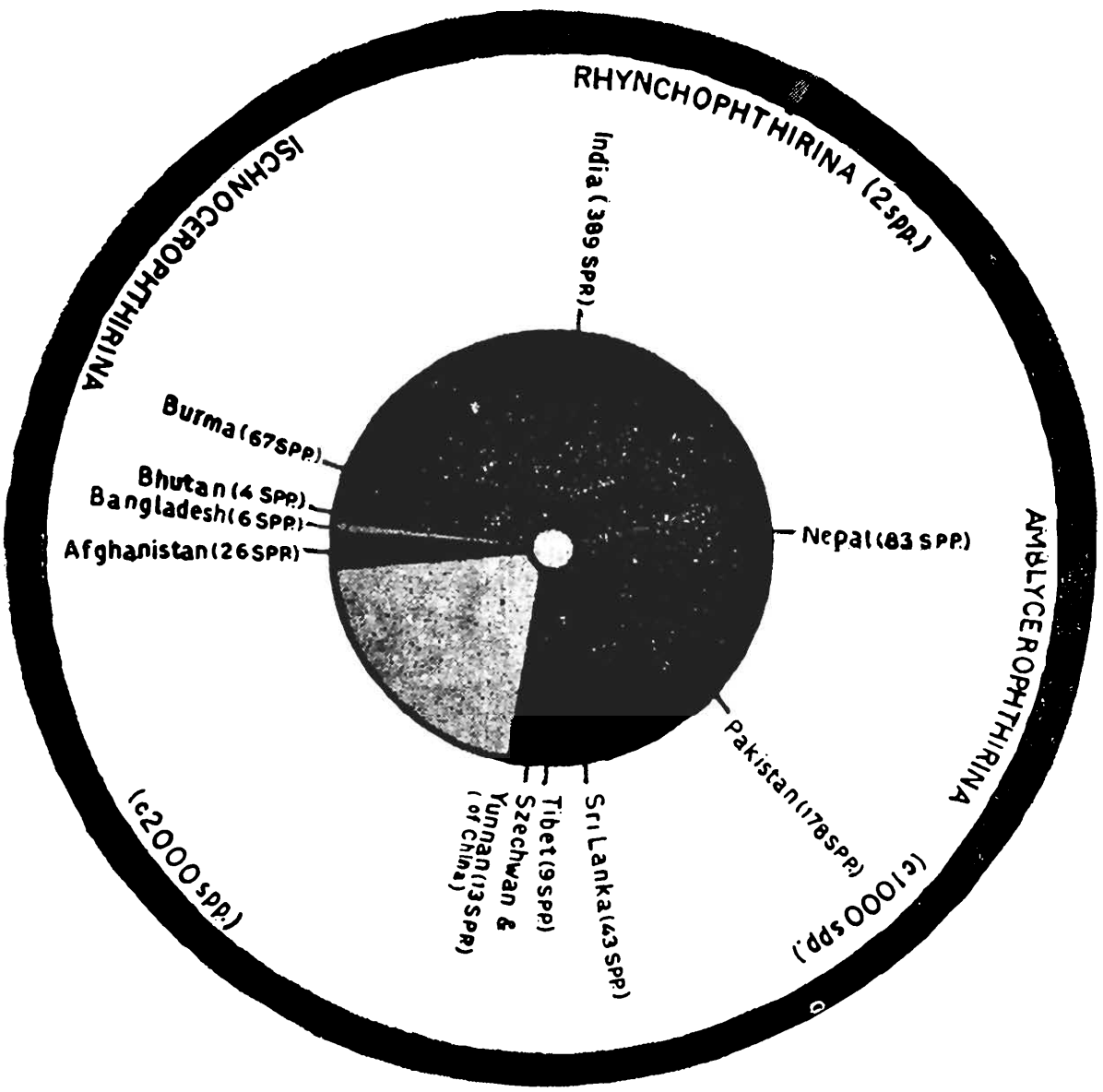
TABLE 2

Country-wise figures of known genera & species

	Genera	Species
AFGHANISTAN	11	26
BANGLADESH	5	6
BHUTAN	4	4
BURMA	36	68
CHINA		
Yunnan	8	7
Szechwan		8
Tibet		9
Kashgar		1
INDIA	85	389
NEPAL	34	83
PAKISTAN	27	178
SRI LANKA	8	43

Our knowledge on the avian parasites from India and adajacent countries is considerable, while it is practically insignificant in so far

as mammal infesting species are concerned, although we have a rich mammalian fauna. Partly it may be due to lack of interest in the Indian entomologists, and partly due to the difficulty in procuring the material for study. However, it is a virgin field for future taxonomists, and the lacunae shown in Lakshminarayana (1972b) (fig. 5) for the avian lice also need to be filled. Drs. Qadri, Ansari and Tandan paid attention to the north and north-western India and Pakistan, while Drs. Lakshminarayana, Rai, and Sen paid attention to eastern and north-eastern India. Collections made by Dr P. V R. Rao and Dr P. K. Rajagopalan (formerly of Virus Research Centre, Pune)



COUNTRY-WISE DISTRIBUTION OF THE CHEWING-LICE (PHTHIRAPTERA INSECTA)
As on 1980. The outer circle representing the world record

Fig. 4. Chart showing country-wise distribution of the Chewing-lice as on 1980.

from Andhra Pradesh, and Karnataka respectively, together with those collected from other parts of India including Andaman & Nicobar Islands by the Zoological Survey of India scientists have been studied or under study in the Zoological Survey of India. It is hoped that our Indian Universities will come forward to undertake studies on this long neglected group.

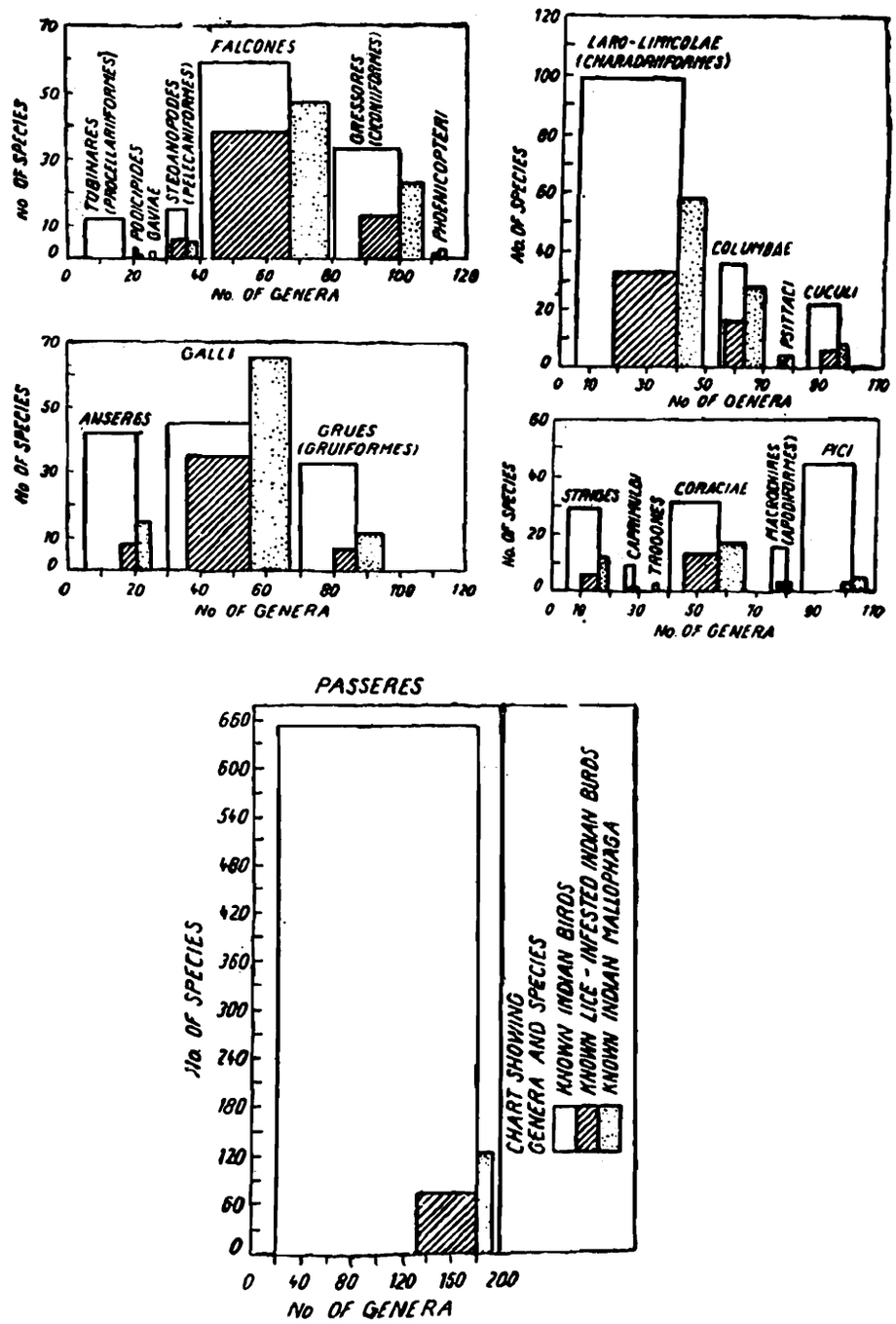


Fig. 5. Chart showing the number of genera and species Chewing-lice reported from various bird orders (after Lakshminarayana, 1974) showing the scope for research.

SELECTIVE LITERATURE & BIBLIOGRAPHIES

Literature collection is a stupendous task, especially to a taxonomist. In many smaller centres of Research, works like the *Zoological Records* and *Index-catalogue of Medical and Veterinary Zoology* and the like essential for taxo-ecological studies will not be available. Published papers on this group including those from India and adjacent countries are very much scattered and not easily accessible. Fortunately, we have Kéler (1960) partly supplemented by Eichler (1963), Eichler & Złotorzycka (1969), and Eichler *et al.* (1976). Lakshminarayana (1972b, 1975) covered many of the papers dealing with fauna from India and adjacent countries. An up-to-date bibliography on fauna from India and adjacent countries is provided here and indicated with a x sign. Papers dealing with host-parasite relationships from the region and those published after Eichler *et al.* (1969, 1976) are indicated by an asterisk, and other works which are useful to a beginner are indicated by an o under references. In so far as the bibliography is concerned, perhaps, a phthirapterologist is better placed now than the others. The Check-Lists of Hopkins & Clay, Emerson, and Lakshminarayana (*vide supra*) briefly give the first reference in which genera and species have been described and their synonymy.

KEYS FOR IDENTIFICATION

A generalized key is provided here for all the suborders, and families of Amblycerophthirina and Ischnocerophthirina ; the key given for suborder Rhynchophthirina serves for the monogenic lone family Haematomyzidae ; family keys within the suborder Siphunculophthirina is not provided as they are outside the purview of the present work. Keys for the identification of genera and species are normally provided by the different authors especially in their revisionary studies from time to time. Attention, is however invited to the more recent keys in Blagoveshtchenskii (1964 ; 1967), Clay (1947, 1969, 1970a), Emerson & Price (1976), and Złotorzycka (1972a, 1976, 1977, 1978). Lakshminarayana (1970a) presented key for the Indian genera.

Key to the suborders of Phthiraptera & families of Amblycerophthirina & Ischnocerophthirina

1. Head normal or specialized ; antenna with 3-5 segments, laterally placed, 3rd normal ;

mandibles if present, normal, or modified, or absent ; maxillary palp absent. Thoracic segmentation present or obliterated. Post spiracular setae without 2 minute associate setae 2

— Head normal ; antenna 4-5 segmented, 3rd pedunculate, concealed in a ventral groove or fossa ; mandibles dorsoventrally articulated with dorsal ginglymus, and ventral condyle ; maxillary palp present, 2-4 segmented. Meso-metathorax usually separated by a suture ; tarsi 1 or 2 segmented ; claws single or paired. Post-spiracular setae of atleast one abdominal segment associated with two minute setae, or rarely with a single minute sensillum only, and in such a case with a single tersal claw on legs II & III. (Crop simple ; paired testes with 2-3 follicles ; ovarioles 3-5 on each side) ... ... Suborder *Amblycerophthirina* = (*Amblycera*) 4

2. Mandibles present. Thoracic segmentation present ; or obliterated ; claws single or paired 3

— Mandibles absent ; antenna 3-5 segmented, eversible mouth parts, highly modified for piercing & sucking ; (piercing is effected by a dorsal stylet, i. e. possibly modified hypopharnyx or fused maxillae (?), middle stylet or modified anterior part of the salivary duct, and a ventral stylet or the modified labium, in a sac). Thoracic segmentation obliterated ; tarsi single segmented ; claws single, which work against a tibial process. Abdomen IX segmented. A dorsal pair of mesothoracic, and six pairs of abdominal spiracles on segments III-VIII. (A pair of testes with 2 follicles ; ovarioless 5 on each side). (Parasitic on mammals incl. man) ... Suborder *Siphunculophthirina* = (*Siphunculata* or *Anoplura auct.*)

3. Head normal, circumfasciate, or specialized ; antenna 3-5 segmented ; mandibles normal, placed at right angles of the head with an anterior ginglymus and posterior condyle. Prothorax separate ; meso-metathorax partially or completely fused ; thoracic sutures little visible, or invisible ; tarsi one or two segmented ; claws single or paired. (Crop

with a sac-like diverticulum, with or without a neck ; testes with 2 follicles each side ; ovarioles 5 on each side). (Parasitic on birds & mammals) ... ... Suborder *Ischnocerophthirina* = (*Ischnocera*)...14

— Head modified into a rostrum, or proboscis ; antenna 5-segmented ; mouth parts at the tip of the rostrum ; mandibles rotated by 180°, with the dentated face away from each other, with a claw-like first tooth, protruding through two lateral openings of the rostrum ; mandibular condyle articulating with the ventral and not the lateral wall of the head. Thoracic segmentation and sutures absent ; tarsi apparently single segmented with a faint indication of a pretarsal lobe ; claw single, but not working against a tibial process for clasping ; a pair of mesothoracic and six pairs of abdominal spiracles on II-VII. (Alimentary canal, a straight tube as in Siphunculophthirina ; testes bilobed on either side ; ovarioles five on each side). (Parasitic on elephants & wart-hogs. Monogenic family *Haematomyzidae* with two species) ... Suborder *Rhynchophthirina*

4. Legs II & III with paired tarsal claws ... 5
   Legs II & III with a single tarsal claw ... 11
5. Maxillary palp 4 or 5 segmented. Mesothorax reduced, or fused with pro-, or metathorax, or free ; if mesonotum is fused with pronotum, or free, a pair of setae not on elevated tubercles, if fused with metanotum with several normal setae present. Tergum I always reduced ; pleurite I reduced, or absent. Abdominal spiracles five pairs. (On Marsupials & rodents in South & Central America) ... ... Family : *Trimenoponidae*
— Prothorax distinct from mesothorax. Abdominal spiracles six pairs on segments III-VIII 6
6. Meso-, and metanota separate ... 7
— Meso-, and metanota fused ... 9
7. Antenna 5 segmented ; maxillary palp 2-4 segmented. Meso-notum with a pair of spiniform setae on elevated tubercle, bordered anteriorly by a sclerotized arc ; metanotum usually fused with tergum I ; mesosternum well sclerotized with spiniform setae or simple setae. Gonoapophyses present. Male

genitalia complicated. (On marsupials of Australia & New Guniea, and one species found on dog (Canidae) throughout the world) ... ... Family : *Boopüdae*

— Antenna 4-5 segmented. Metanotum not fused with tergum I; spiniform setae on lateral protruberances of the mesonotum absent; mesosternum without spiniform setae. Gonapophyses absent. Male genitalia asymmetrical, or symmetrical ... 8

8. Alveoli of the head setae 26 & 27 closely approximated; antenna with I & II segments normal, lying in a ventral fossa; maxillary palp 4 segmented. Thorax normal, transverse pronotal carina present except in the genus *Rediella*; meso-metathorax not fused; similar to the abdominal segments. Abdomen with intersegmental indentations or notches; six pairs of abdominal spiracles on segments III-VIII. Male genitalia usually symmetrical, but in certain genera asymmetrical. (Parasitic on birds) ... Family : *Menoponidae s. l.*

— Alveoli of the head setae 26 & 27 not closely approximated; antenna with I & II segments with distal expansion. Thorax strongly developed with two sternal plates bearing many setae; meso-metathorax with distinct sutures, looking different from the abdominal segments. Abdominal sternites IV-V with thick, or scattered brushes of setae; last segment of Male trilobed, simple in Female; Male genitalia asymmetrical. Very large species rivalling Laemobothriidae. (On Anseriformes & Phoenicopteriformes) ... ... Family : *Trinotonidae*

9. Antennal capsules bulbous, open ventrally; lateral swellings present; temples sculptured with inter rows of peg-like projections; pulvinus absent; oral opening very large, extends backwards to the antennal base; labial palp present; mentum with bladder like lobe conspicuous in untreated specimens. Meso-metanota fused; thoracic lateral contour continuous with that of abdomen; metanotum not fused with tergum I; tibiae of II & III with terminal dorsal patch of microtrichia. Abdomen with lateral margins not interrupted. (Very large species. Parasitic on Falco-

niformes, Gruiforms, Ciconiiformes, & *Opisthocomus* of Galliformes) .. Family : *Laemobothriidae*

— Antennal capsules not bulbous; lateral swellings not produced; temples not sculpured; labrum with usually protrusible hyaline extensions (pulvinus) attached at each side; labial palp undeveloped; oral opening moderate. Metanotum fused with tergum I; tibiae of II & III without terminal dorsal patch of microtrichiae. Abdomen with slight lateral notches, or indentations at the junction. 10

10. Head normal in shape, not constricted in the middle; mouth parts normal. Abdomen with 6 pairs of spiracles. (Parasitic on Passeriformes) ... ... Family : *Ricinidae*

— Head deeply emarginated laterally; mouth parts modified for piercing; abdomen stout. (Parasitic on humming birds) ... Family : *Trochiliphagidae* (= *Trochiloecetidae*)

11. Maxillary palp 2 or 4 segmented. Leg I without tarsal claw, II & III with single modified claw. (Parasitic on mammals) ... Family : *Gyropidae partim* (*Gliricolinae*)

— Maxillary palp 2, 3, or 4 segmented. Leg I with tarsal claw or claws 12

12. Maxillary palp 2 segmented. Abdominal spiracles 5 pairs on segments III-VII. (Parasitic on mammals) ... ... Family : *Abrocomophagidae*

— Maxillary palp 3 or 4 segmented. Abdominal spiracles 6 pairs on segments III-VIII ... 13

13. Maxillary palp 3 segmented, All legs with simple unmodified claw. (Parasitic on mammals) ... ... Family : *Gyropidae partim* (*Protogyropinae*)

— Maxillary palp 3 or 4 segmented. Leg I with modified tarsal claw for clasping the hairs; legs II & III often with enlarged claw. (Parasitic on mammals). ... ... Family : *Gyropidae partim* (*Gyropinae*)

14. Antenna 3 (?)-5 segmented. Tarsi with single claw. Gonoapophyses present. (Long neck to the diverticulum of the crop) (Parasitic on mammals) ... ... Family : *Trichodectidae*

— Antenna 5 segmented. Tarsi with paired claws 15

15. Mesothorax fused completely with metathorax to form pterothorax. Abdominal segments normal, except that apparent I which is probably fused I & II. (Parasitic chiefly on birds, except the genus *Trichophilopterus*, which is parasitic on lemurs) ... Family : *Philopteridae s. l.*

— Mesothorax sometimes separated completely from the metathorax. Abdominal segments reduced. Genitalia complicated. (Parasitic on Tinamiformes) ... ... Family : *Heptapsogasteridae*

MORPHOLOGY

All taxonomical papers in general deal with the external morphology. Many useful references have been indexed in Kéler (1960), Eichler (1963), Eichler *et al.* (1969, 1973). Blagoveshtchenskii (1949, 1955, 1956), Clay (1946, 1947b, 1949b, 1951a, 1954, 1958a, 1962a 1966a, 1969, 1970a), Dhanda (1961), Eichler (1963), Kéler (1938, 1939, 1952), Qadri (1936b,c), Schmutz (1955), Snodgrass (1944), Symmons (1952), and Webb (1946) are inevitable works for morphological studies.

Mukerji & Sen Sarma (1955) studied the morphology of the elephant louse, *Haematomyzus elephantis* in detail. Rao *et al.* (1975) studied the mouth parts of the chewing-lice. Since there is no uniformity in the terminologies used, and the interpretations given to various body parts, especially of the head, the present author prepared a glossary of taxonomic characters (Lakshminarayana, in press) in which not only the various parts were outlined, but their relative taxonomic and evolutionary significances also were given. The role of asymmetry was discussed in Lakshminarayana (1973a,b, 1977a, 1979b), and Lakshminarayana & Emerson (1971, 1978). The trends in the evolution of the sitophore sclerite and male genitalia were discussed in the *Laemobothrion-complex* (Lakshminarayana, 1970b).

ANATOMY

Papers dealing with internal organization of the chewing-lice were listed in Kéler (1960), Eichler (1963), Eichler *et al.* (1969, 1973). Mukerji & Sen Sarma (1955) studied the anatomy of the elephant louse, *Haematomyzus elephantis*. Srivastava (1974), and Agarwal & his school studied this aspect in detail on the poultry louse, *Numidilipeurus lawrensis tropicalis* (Agarwal & Saxena, 1978, 1979b, 1980 ;

Saxena & Agarwal, 1980a-c) dealing with the crop teeth, tracheal, vasular and genital systems.

HISTOLOGY

A reference again is invited to Kéler (1960), Eichler (1963) and Eichler *et al.* (1969, 1973) for information on this subject. The histology of various organs in *Haematomyzus elephantis* was discussed in Mukerji & Sen Sarma (1955). Srivastava (1974), and Saxena and Agarwal (1979, 1980d) also discussed on this problem with reference to *N. l. tropicalis*. Agarwal & Saxena (1977) worked out the histology of peri-oesophageal nephrocytes in some lice.

BEHAVIOUR

Rakshapal (1959) observed the behaviour of the pigeon louse, *Columbicola columbae*. Agarwal & Saxena (1980) studied the feeding behaviour of *N. l. tropicalis*. Ash (1960) discussed the subject very well. Clay (1949c) discussed the behaviour and its impact on the morphological evolution. Lakshminarayana & Emerson (1971, 1978) discussed on the probable changes brought about in two sympatric species of *Goniodes* consequent to the evolution, isolation, and reunion of two species of its host genus viz., *Pavo* in the Oriental Region. Lakshminarayana (1973b) also attributed the morphological changes due to feeding habit in the head asymmetry in *Struthiolipeurus*. It was contended that an ancestral form originally parasitic probably on Falconiformes, and similar to the genus *Falcolipeurus* secondarily parasitized Struthioniformes and Rheiiformes developed the asymmetry due to the feather structure in the latter group of hosts.

BIONOMICS

Ansari (1944a,b) studied the bionomics of the lice of domestic chicken. Ash (1960) is a very useful work. Arora & Chopra (1957, 1959) studied the biology of *N. l. tropicalis*. Agarwal (1967) studied the bionomics of *Falcolipeurus frater*. Again Agarwal & Saxena (1978, 1979a) studied the seasonal dynamics of *N. l. tropicalis* and its feeding habits (Agarwal & Saxena, 1980a). Rai & Lakshminarayana (1980) discussed techniques for *in vitro* studies on the chewing-lice. Evaluation of secondary infestations on the basis of immature stages was discussed in Lakshminarayana (1972a).

DEVELOPMENT

Ansari (1954) studied the pre-imaginal instars of the chewing-lice

and applied the *growth principles.* Agarwal (1967) studied the development of *Falcolipeurus frater.* Agarwal & Gupta (1970) studied the effect of low temperatures on the viability of the eggs and development in *F. frater.* Rai & Lakshminarayana *(op. cit.)* may be useful for rearing artificially.

CYTOTAXONOMY

Practically very little of the chromosomal pattern in the chewing-lice is known. Perhaps, this group provides a fertile field for research to a cyto-taxonomist. It is however advised, that one should take up studies on the group only when large populations of the lice are available, preserving a few of them (preferably both sexes) for routine identification, and the host correctly identified. Omission of these criteria will often not only leads to erroneous results, but also cause confusion, because very often a particular host (especially a bird) may harbour more than one species of the parasite, and only a specialist can identify properly the species.

DISTRIBUTION & HOST-RELATIONSHIP

The chewing-lice are host-specific with life tied down to their host(s). Consequently, they evolved hand in hand with their respective hosts. Availability of empty niches on the body of the evolving hosts gave them chances of isolation from related populations, and gave an impetus for accelerated speciation. Evolution of hosts due to their macroclimatic fluctuations is however not an over night phenomenon. Therefore, the hosts offered a uniform food and shelter for considerable time, and hence the microclimatic fluctuations for the chewing-lice were naturally remained at a low ebb. In a uniform climate, they evolved at a slower rate than their hosts, or has under went 'retarded evolution' While the accelerated evolution produced more number of species and genera, the retarded evolution resulted in the production of species and generic complexes. Thus, closely related hosts are often parasitized by closely related species and genera of the chewing-lice. In a way each reflects the evolution of the other. In cases where the host relationships are under question, often the lice give us an indication as to the exact relationship, or serve as 'live-' or 'biological-indicator' species. Several papers on host-parasite relationship have appeared and were listed in Kéler (1960) Eichler (1963), Eichler *et al.* (1969, 1973). Most of the recent revisionary works carry the observations on the host relationship, and

some of the more interesting papers not listed in the above works, or published thereafter, are listed here and indicated with an asterisk.

On the basis of the distribution of the parasite genera and species some ground rules were framed and may be of use, and therefore cited here under :

1. *Harrison's Rule* (1915) states that when a parasite genus is distributed over a number of related hosts, the size of the parasite is correlated to the size of the host.

2. *Clay's hypothesis* (1949) provided a reasonable explanation to the above rule. Clay recalls Wetmore's theory that larger birds have lower body temperatutures ; and Bergmann's law that larger individuals are found in colder climate. Thus, the larger is the host, the lower is its body temparature, hence it offers a colder climate to the parasite, which therefore tends to be larger.

3. Eichler (1941, 1945) quotes *Fahrenholz Rule* which states that the ancestors of the present day parasite species must have been parasites of the ancestors of the present day hosts.

4. Eichler (1941, 1945) extended *Szidat Rule* for trematodes to the Chewing-lice. This rule says that the primitive hosts are parasitized by primitive parasites, and advanced hosts are parasitized by advanced parasites.

5. *Eichler's Rule* christened by Hopkins in Eichler (1945) states that isolated hosts do not harbour many parasites, while host groups with number of genera and species harbour not only many species, but also many genera of parasites.

6. *Hopkins' Principle* (Hopkins, 1949) christened by Lakshminarayana (1972a) states that one correspondance of a louse between two hosts whose hypothetical relationship is under examination means very little. Two such correspondances establish the probability that the relationship may be genuine, and three such correspondances come very close to certainity.

7. If one examines the distribution pattern of the chewing-lice on various bird orders, (fig. 6) it is evident that paleontologically older groups (hence more primitive) often harbour large number of parasite

genera, as compared to the later and younger groups. Isolated host groups, or evolutionarily static or dwindling groups, however, harbour fewer parasite species and genera. Rapidly evolved host groups like Psittaciformes also harbour more genera and species.

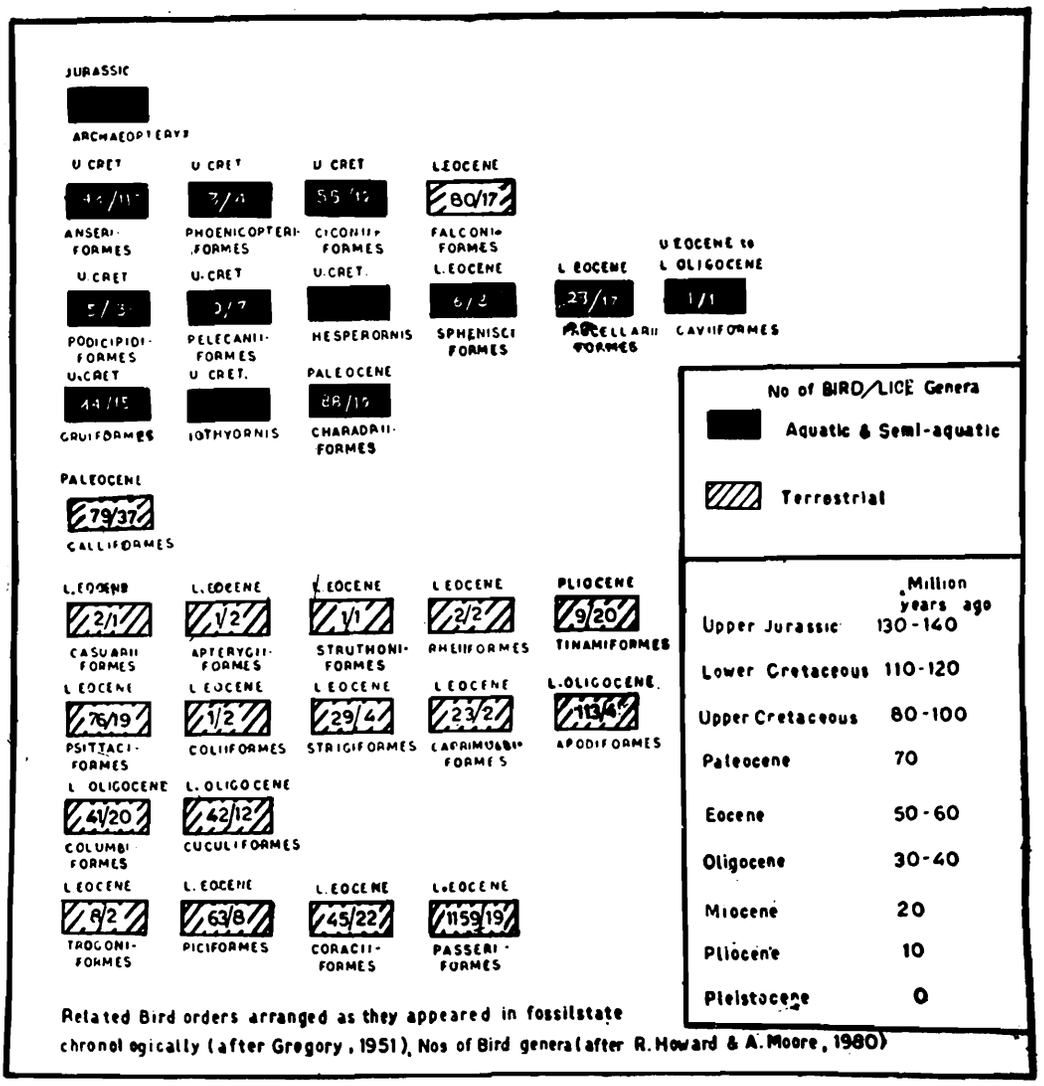


Fig. 6. Chart showing bird orders in various geological periods and their representative number of genera Chewing-lice.

8. It is evident from fig. 6 and Table 3, that excluding the universally represented genus *Colpocephalum* and secondarily established genera on both aquatic and semiaquatic and terrestrial group of birds, the now generally accepted genera are distributed as follows: 65 genera of lice are found on 278 genera of the first group of birds and 168 genera of lice on 1774 of the second group of birds. This position reflects that 24% of lice have evolved on aquatic and semi-aquatic birds, while 9.5% have evolved on terrestrial birds.

TABLE 3

Bird Order	Number of known		
Aquatic & Semi-aquatic	Bird genera	Bird species	Parasite genera
1. Anseriformes	44	147	11
2. Phoenicopteriformes	3	5	4
3. Ciconiiformes	55	113	12
4. Podicepidiformes	5	20	3
5. Pelecaniformes	9	61	7
6. Gruiformes	44	226	15
7. Charadriiformes	88	330	19
8. Sphenisciformes	6	18	3
9. Procellariiformes	23	103	17
10. Gaviiformes	1	5	1
Terrestrial			
1. Galliformes	79	262	37
2. Falconiformes	80	287	17
3. Casuariiformes	2	4	1
4. Apterygiiformes	1	3	2
5. Struthioniformes	1	1	1
6. Rheiiformes	2	2	2
7. Psittaciformes	76	333	19
8. Coliiformes	1	6	2
9. Strigiformes	29	143	4
10. Caprimulgiformes	23	101	2
11. Trogoniformes	8	37	2
12. Piciformes	63	384	8
13. Coraciiformes	45	201	22
14. Passeriformes	1159	3851	19
15. Apodiformes	113	418	4
16. Columbiformes	41	334	20
17. Cuculiformes	42	144	12
18. Tinamiformes	9	46	20

Bird orders arranged as they appeared in fossil state under aquatic and Semi-aquatic and Terrestrial groups ; Number and Bird genera and species are after Richard Howard & Alick Moore, 1980. *A complete Checklist of the birds of the world,* [Oxford University Press] Oxford : 701 pp.

9 Lakshminarayana (1972b) suggested that the hosts may be divided into true hosts, pseudo-hosts, and non-hosts True hosts are those where the parasite species consistently spends its life on them which may be primary, or secondary, permanent or temporary Pseudo-hosts are those, where a few nymphs of paracites may be

borne if forced to spend on them, due to identical feather structure, but they do not attain maturity. Non-hosts are those, on which no development or reproduction takes place, but the longevity may be prolonged for some days.

In case of secondary infestations, it is difficult for us to verify whether an infestation is primary or secondary, especially on the wild hosts, because we cannot rear them in the laboratory. Lakshminarayana (1972a) suggested a method of evaluation in such cases. If a parasite was consistently reported on a host other than the natural one, or immature stages were recorded at different intervals on it, and the parasite was reported from different parts of the host range, we can safely conclude that the parasite established successfully on the secondary host.

Certain group of hosts like bats and whales have not been reported as hosts for the chewing-lice, although other sucking forms like ticks, mites, (and some diptera on the former) are known from them. The chewing-lice also are known to adopt phoresy for their distribution from one host to the other at times. Salim Ali (1936) posed a question whether birds employ ants to get rid of their chewing-lice, a fact worth investigating. It is interesting to add that some birds which feed on ants also are hosts for the chewing-lice.

Clay (1949c, 1950, 1976) discussed not only the distribution of the chewing-lice on different avian host orders, but also their geographical distribution. Hopkins (1949a) outlined it for mammal infesting specics. Lakshminarayana (1970, 1972b) presented the distribution of the chewing-lice on different bird orders in India and adjacent figuratively, which also indicates the lacunae in our knowledge (fig. 5). It was further stated that we knew only eight species of chewing-lice from mammals of this region, which means we know nothing of the mammal infesting species on our rich mammalian fauna. Thus there is ample scope for research work not only on bird infesting forms, but an entirely virgin field is open for future research on mammal infesting forms in this region.

HOST COLLECTION & IDENTIFICATION

The chewing-lice are obligatory parasites and therefore, they can be collected only when the host is collected. Closely related hosts harbour closely related parasite species, or even subspecies (Harrison,

1915 ; Eichler, 1949), or sympatric species (Lakshminarayana & Emerson, 1971, 1978 ; Lakshminarayana & Price, 1980). Hence, proper host collection, preservation and identification will help the parasitologist a long way in providing correct identification of the parasite in question. Biswas (1968 a-b, 1980 a-b) provide useful information for the collection and preservation of the birds and mammals for identification purposes.

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