FOLIA PARASITOLOGICA (PRAHA) 28: 193–203, 1981.

BLOOD PARASITES OF BIRDS IN CENTRAL EUROPE. 2. LEUCOCYTOZOON

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Abstract. The paper summarizes the present store of knowledge about the incidence and ecology of *Leucocytozoon* in birds in Central Europe. *Leucocytozoon* is most frequently encountered in Corvidae, Columbiformes, Galliformes, Strigiformes and Turdidae. It is rare in Anseriformes, Muscicapidae and Passeridae and is almost absent in Hirundinidae and Sturnidae. Prior to 1945 *Leucocytozoon* was more abundant than after that year. The analysis of the dependence of *Leucocytozoon* incidence on some ecological properties of birds shows that the survival and transmission of the parasite in bird populations in Central Europe may be elucidated by using the ecological model of avian malaria (Beaudoin et al. 1971).

Along with parasites of the genera *Plasmodium* and *Haemoproteus*, *Leucocytozoon* belongs into the group of causative agents of the so-called "avian malaria". Today *Leucocytozoon* is considered as the most pathogenic genus of the protozoan blood parasites of birds, causing a grave disease — leucocytozoonosis in domestic and many wild bird species. The present paper summarizes data on the *Leucocytozoon* incidence in free-living birds in Central Europe. It is the second paper in the series of publications dealing with avian haematozoa in Central Europe. In the first paper the bibliography on this problem has been reviewed and the incidence of blood parasites in domestic birds, including *Leucocytozoon*, has been discussed (see Kučera 1981). The present paper is therefore directed at the incidence in wild birds.

MATERIAL AND METHODS

Data on the incidence of *Leucocytozoon* in birds in Central Europe have been obtained from papers of different authors. The bibliography of these papers and methods used in compiling the prevalence data are given in the previous paper of the series on blood parasites of birds in Central Europe (Kučera, 1981).

The data from 9 565 wild birds of 173 species were used for numerical evaluation.

RESULTS AND DISCUSSION

Leucocytozoon incidence in systematic groups of birds

As evident from Table 1 *Leucocytozoon* has been found in 58 bird species in Central Europe. Fig. 1 demonstrates the percent incidence of this parasite in particular orders and within the order of passerines, as well as in families of birds. The graph shows that in many systematic bird groups none or very insufficient prevalence data are available. This primarily applies to the orders Gaviiformes, Procellariiformes, Gruiformes, Cuculiformes, Caprimulgiformes and within Passeriformes to the families Oriolidae, Remizidae, Cinclidae and Bombycillidae. Likewise the data concerning Podicipediformes, Pelecaniformes, Ciconiiformes, Apodiformes, Coraciiformes, Pici-

formes, Alaudidae, Aegithalidae, Certhiidae, Sittidae, Troglodytidae and Laniidae are not conclusive enough, because they are based on material from less than 1 00 birds examined.

In groups, yielding data from more than 100 birds examined, *Leucocytozoon* is most abundant in Corvidae (26.7 %), Columbiformes (13.4 %), Galliformes (11.9 %), Strigiformes (9.9 %) and Turdidae (8.6 %). It is also relatively abundant in Prunellidae (5.9 %), Paridae (5.2 %), Motacillidae (3.3 %), Sylviidae (2.4 %), Emberizidae (1.6 %), Charadriiformes (1.5 %) and Fringillidae (1.4 %). It is rare in Muscicapidae (0.4 %) and Passeridae (0.2 %) and is almost absent in Hirundinidae (611 birds examined)

Table 1. Alphabetical list of bird species in which *Leucocytozoon* was found in Central Europe

Acanthis flammea (L.), *Accipiter gentilis* (L.), *A. nisus* (L.), *Anas acuta* L., *Anthus spinoletta* (L.), *A. trivialis* (L.), *Asio flammeus* (Pontoppidan), *A. otus* (L.), *Athene noctua* (Scopoli), *Bubo bubo* (L.), *Cairina moschata* (L.), *Caprimulgus europaeus* L., *Carduelis chloris* (L.), *C. spinus* (L.), *Circus aeruginosus* (L.), *Coccothraustes coccothraustes* (L.), *Columba palumbus* L., *Corvus corone* L., *C. frugilegus* L., *C. monedula* L., *Coturnix coturnix* (L), *Emberiza citrinella* L., *Erithacus rubecula* (L.), *Ficedula hypoleuca* (Pallas), *Fringilla coelebs* L., *Garrulus glandarius* (L.), *Lanius excubitor* L., *Loxia curvirostra* L., *Lyrurus tetrix* (L.), *Meleagris gallopavo* forma *domestica*, *Motacilla cinerea* Tunstall, *M. flava* L., *Milvus milvus* (L.), *Nucifraga caryocatactes* (L.), *Oenanthe oenanthe* (L.), *Parus ater* L., *P. caeruleus* L., *P. major* L., *P. montanus* (Baldenstein), *Passer domesticus* (L.), *Perdix perdix* (L.), *Phasianus colchicus* L., *Phoenicurus phoenicurus* (L.), *Phylloscopus collybita* (Vieillot), *Pica pica* (L.), *Prunella modularis* (L.), *Pyrrhula pyrrhula* (L.), *Rallus aquaticus* L., *Regulus regulus* (L.), *Strix aluco* L., *Sylvia atricapilla* (L.), *S. borin* (Boddaert), *Tetrao urogallus* L., *Turdus merula* L., *T. philomelos* C. L. Brehm, *T. torquatus* L., *T. viscivorus* L., *Vanellus vanellus* (L.).
Total: 58 species

and Sturnidae (169 birds examined). Positive finds of parasites without indication of prevalence data were reported from Anseriformes, Caprimulgiformes, Alaudidae and Laniidae. In Anseriformes the finding reported is evidently accidental (Zajíček 1968), because in other 231 representatives of this order no parasites of the genus *Leucocytozoon* have been found. A very rare incidence of these parasites in Anseriformes in Central Europe is rather interesting and has been already discussed in the previous paper of this series (Kučera 1981). From the economic view of great importance is the high rate of infection with *Leucocytozoon* in Galliformes which are important game birds in Central Europe. So far little attention has been paid to these parasites in Czechoslovakia, but there are papers (Fallis et al. 1974, Oliger 1940, Borg 1953 etc.) pointing out the considerable pathogenic influence of the parasites of this order on the wild species of Galliformes.

If we compare the data about *Leucocytozoon* incidence in Central Europe with those in North America (see Greiner et al. 1975) and SE Asia (Mc Clure et al. 1978), it is evident that in these regions *Leucocytozoon* occurs more frequently in Galliformes, Strigiformes, Corvidae, Paridae and Turdidae. Similarly as in Central Europe, *Leucocytozoon* in North America and SE Asia is rare in Passeridae, Sturnidae and Hirundinidae. Unlike the incidence in Central Europe, *Leucocytozoon* is more abundant in Anseriformes in SE Asia and very abundant in the same order in North America (see above).

From Africa only scattered data have been avilable so far. After summing up the data from papers of Bennett et al. (1974), Ashford et al. (1976), Bennett and Herman (1976), Wink and Bennett (1976) and Peirce et. al. (1977), who investigated almost 7000 birds in this region, we see that total prevalence of *Leuco-*

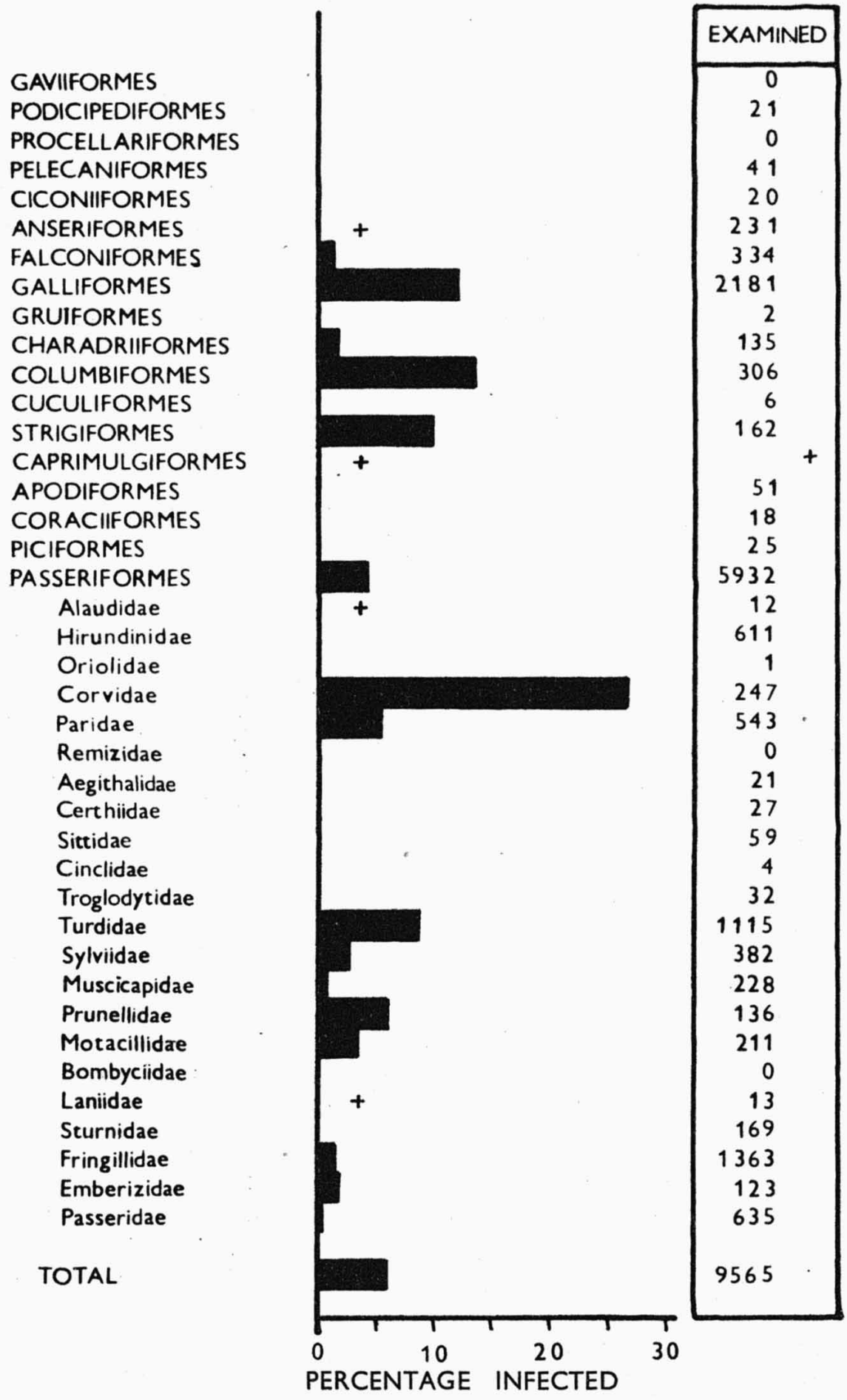

Fig. 1. Graph of *Leucocytozoon* incidence in systematic groups of birds in Central Europe (+ = positive finding with no prevalence data given).

cytozoon parasites in birds in Africa accounts for about 5 %. The incidence of these parasites in birds in Central Europe and in those in tropical Africa does not differ too much. On the other hand, interesting are the data from South America, where Gabaldon et al. (1974, 1975 and 1976) revealed that *Leucocytozoon* in Venezuela is almost absent, although 21 201 birds had been investigated on the presence of blood parasites.

Leucocytozoon incidence in birds in Central Europe before and after 1945

The comparison between the incidence of avian blood parasites in Central Europe before and after 1945 is graphically depicted in Fig. 2. The graph shows a considerable decrease of the incidence of most blood parasites after 1945, including parasites of the genus *Leucocytozoon*. A similar phenomenon is described by Corradetti (1974) who revealed that after world war II parasites of the species *Plasmodium cathemerium* almost disappeared in *Passer italiae*, although they had been very abundant prior to 1945. The cited author explained this phenomenon by the effects of DDT application and by the use of other insecticides which had apparently decreased the occurrence of vectors of these protozoans. The situation in Central Europe investigated by us may be explained in a similar way. The decrease of the avian hematozoa in this region is most likely due to the wide application of insecticides and to the general deterioration of natural environment, resulting in the decreased number of vectors.

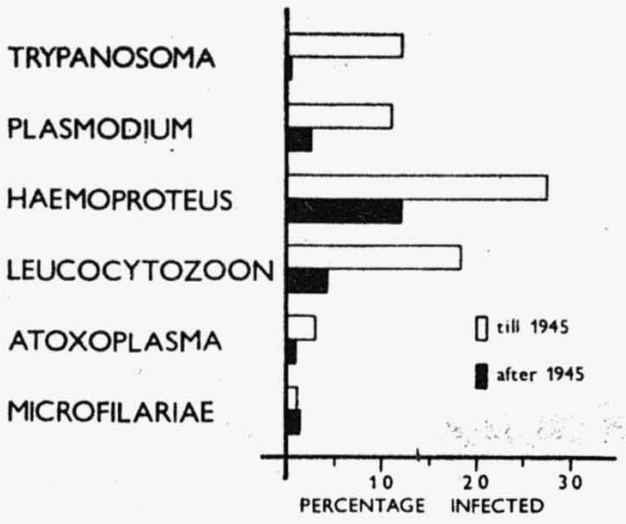

Fig. 2. Comparison of *Leucocytozoon* incidence in birds in Central Europe before and after 1945.

Leucocytozoon incidence in migratory and resident birds

The incidence of *Leucocytozoon* in resident, temporary migrant and migratory birds is graphically depicted in Fig. 3. In the total number of birds examined in Central Europe resident birds seem to be more infected than migratory birds. If we divide this number into Passeriformes and non-Passeriformes groups the result is roughly the same. The stay of migratory birds at overwintering sites in warmer regions does not seem to influence the incidence of *Leucocytozoon* parasites in a considerable way.

The problem of the dependence of avian hematozoa on the migratory abilities of their hosts has been already discussed in older literature where the wide distribution of avian malaria is explained by the fact that migratory birds are annually in contact with tropical and subtropical regions. This theory was supported by Manwell and Herman (1935) who concluded that migratory birds are more often infected with blood parasites than resident birds. This conclusion has been often discussed by other authors. Mohammed (1958) found the rate of infection with blood parasites to be 34 % in migrants and 32.5 % in resident birds in Egypt. On the other hand, Bennett and Fallis (1960) found a higher infection rate in resident than in migratory birds in North America. Likewise Burtikashvili (1976) reported blood parasites in Georgia (USSR) in 53.6 % of resident birds against 27.5 % in migratory

birds. This problem was discussed from a new angle by Bennett et al. (1978) who found a higher infection rate in resident birds in comparison with migratory birds in Canada. These authors concluded from their results and the analysis of data on prevalence of avian hematozoa from Central and South America that in the

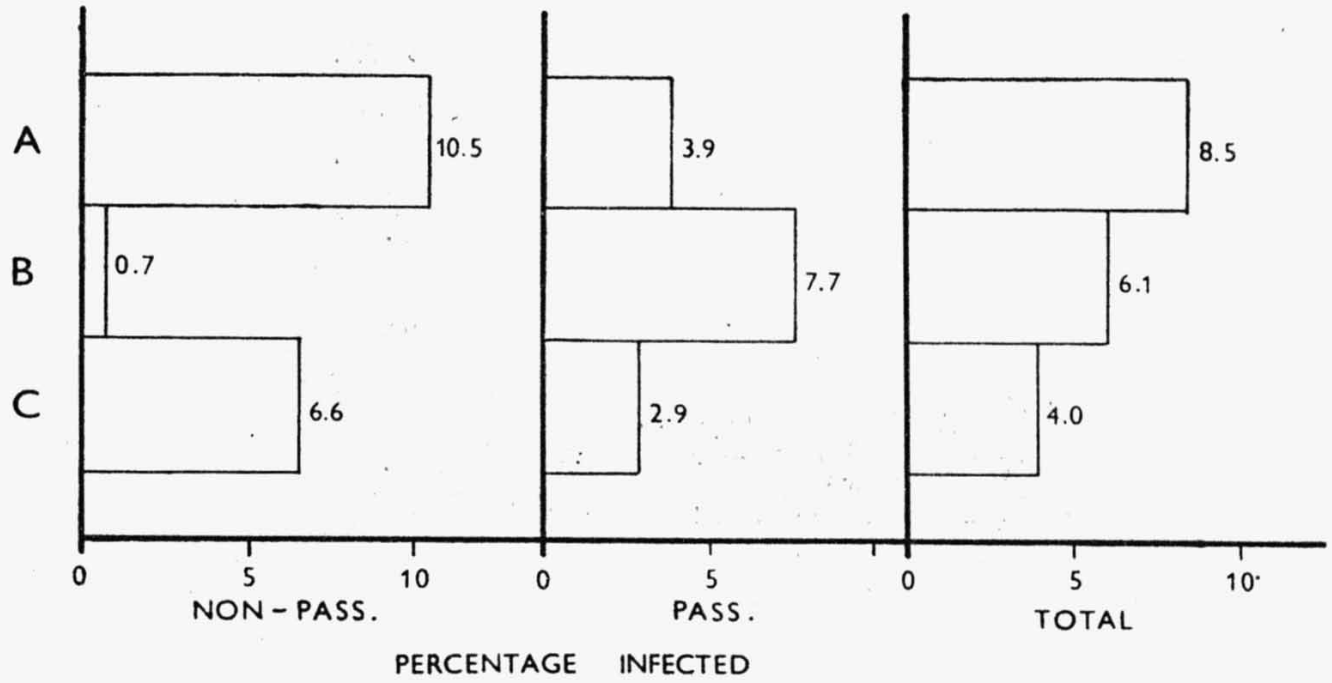

Fig. 3. Comparison of *Leucocytozoon* incidence in birds groups in Central Europe according to migration (A = resident birds; B = temporary migrants; C = migratory birds; NON-PASS = non-Passeriformes; PASS = Passeriformes.

migratory system between North and South America the intercontinental transport of avian hematozoa takes place very rarely and that the transmission of parasites to new uninfected birds is effected mainly in the summer nesting period. All these results and views indicate that the wide distribution of avian hematozoa in the moderate zone (i.e. in Central Europe as well) is caused by other mechanisms than migrations of some bird populations to subtropical or tropical zones (see below).

Leucocytozoon incidence depending on the nest ecology of birds

Fig. 4 demonstrates the seasonal dynamics of the *Leucocytozoon* incidence in the peripheral blood of passerines captured in several biotopically very similar localities in Bohemia. It is evident from the graph that in winter months (November—January) *Leucocytozoon* does not occur in the blood of passerines. In February the incidence of the parasites rises to the normal level of 4—5 %, at which it remains more or less throughout the warm season. Only in the autumn (September) a rapid rise of positivity of birds examined was recorded up to 18 %.

A similar type of seasonal dynamics was also detected by the author of this paper in related parasites of the genera *Haemoproteus* and *Plasmodium*. As the studies of Chernin (1952), Rogge (1966, 1968), Haberkorn (1968) and Beaudoin et al. (1971) show, the spring relapse is due to the influence of sexual hormones of birds in connection with the preparation for nesting, causing the transition of latent infections with avian malaria to acute state. The autumnal maximum is apparently caused by the fact that in this season young birds predominate, not yet having

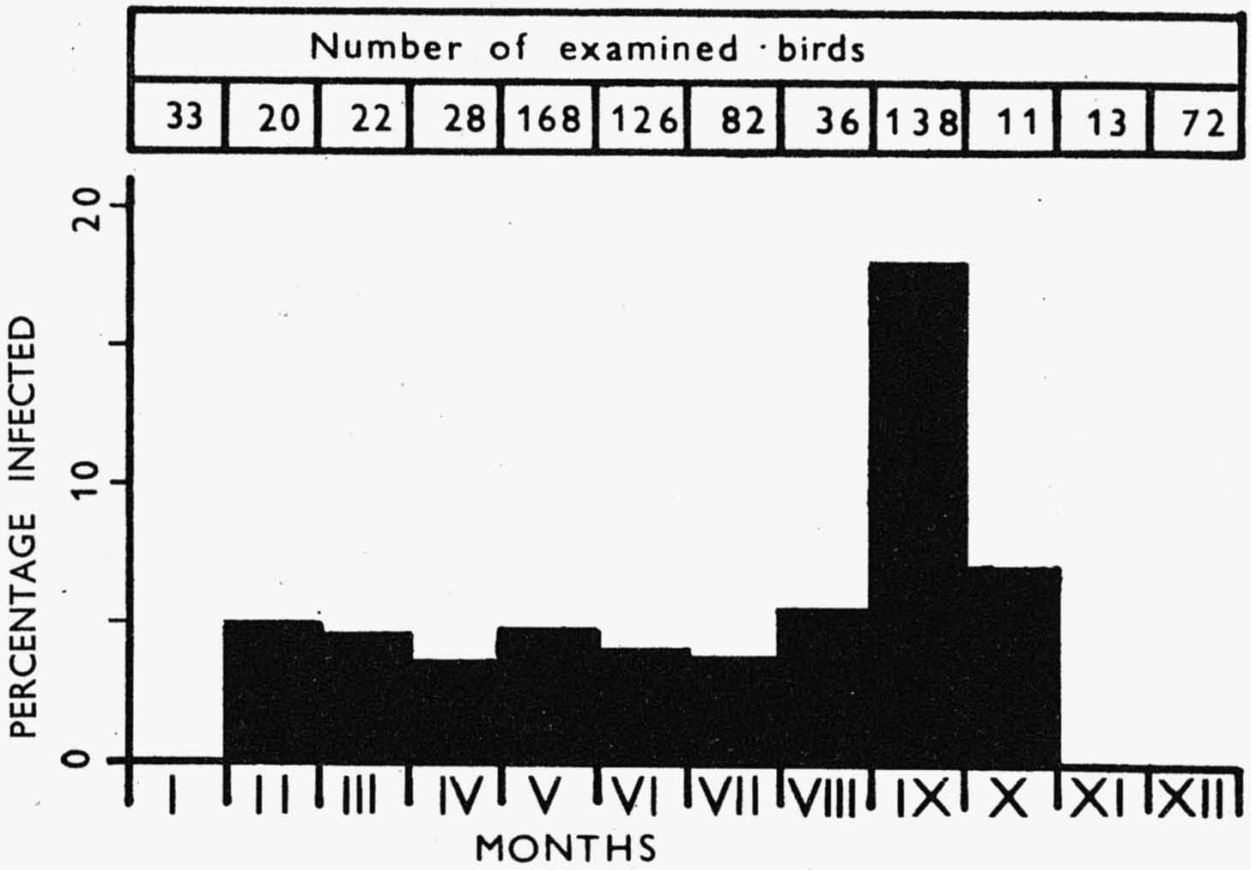

Fig. 4. *Leucocytozoon* incidence in peripheral blood of passerines in Bohemia in different months of the year (seasonal dynamics).

developed any immunity against the parasites and if infected at all, the disease is primarily in an acute phase and therefore easily detected in blood smears (see below).

Borg (1953) and Bennett and Fallis (1960) ascertained the maximum of *Leucocytozoon* incidence in the peripheral blood of birds in Sweden and Canada in May, June and July, namely at the peak of nesting activity of birds. Our results may be distorted by the fact that they have been based on the material dating from several years and from several different localities, though similar in biotope character. It would be profitable to compare the incidence of these parasites with the occurrence of their vectors. However, the species of simuliids transmitting *Leucocytozoon* among the birds in Central Europe are unknown. Hájková-Hlisnikovská (1962) studied the seasonal dynamics of blackfly occurrence in two localities near Prague, which are similar in biotopes (stream valleys) to the localities where the author of this paper carried out his investigations of birds. The occurrence of blackflies in those localities was recorded by the cited author in the period between March and October and this is well corresponding with the *Leucocytozoon* incidence ascertained.

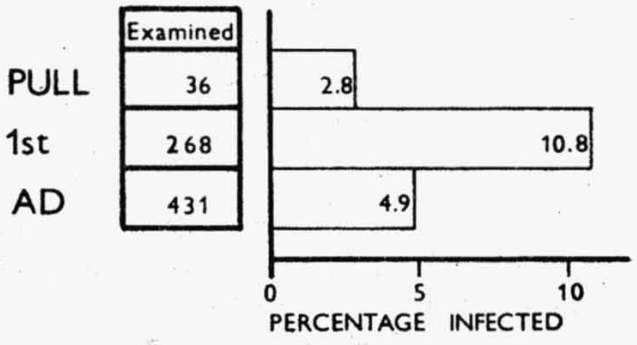

Fig. 5. *Leucocytozoon* incidence in peripheral blood of passerines of different age in Bohemia (PULL = nestlings; 1st = first-year birds; AD = adult birds).

Fig. 5 demonstrates the *Leucocytozoon* incidence in passerines of different age (similar material as in the graph 4: see material and methods given in the first pa-

per of the series (Kučera 1981). It is interesting that unlike the parasites *Haemoproteus* and *Plasmodium*, *Leucocytozoon* is also relatively often found in nestlings. It is likely caused by the fact that the prepatent period of this parasite is much shorter (4 to 5 days in *L. fringillinarum*, after Fallis and Desser 1974) than the average stay of the passerine nestlings in the nest (14 days up to 3 weeks).

The course of the infection with *Leucocytozoon* is characterized by a relatively short patent period, when the gametocytes occur in larger numbers in the peripheral blood, and by a very long chronic period lasting several years, when the parasites can be found in the blood smears very rarely (see Fallis and Desser 1974). In this way it may be explained why the young birds of the current year appear to be more infected than adult birds, in which the infection is in chronic form.

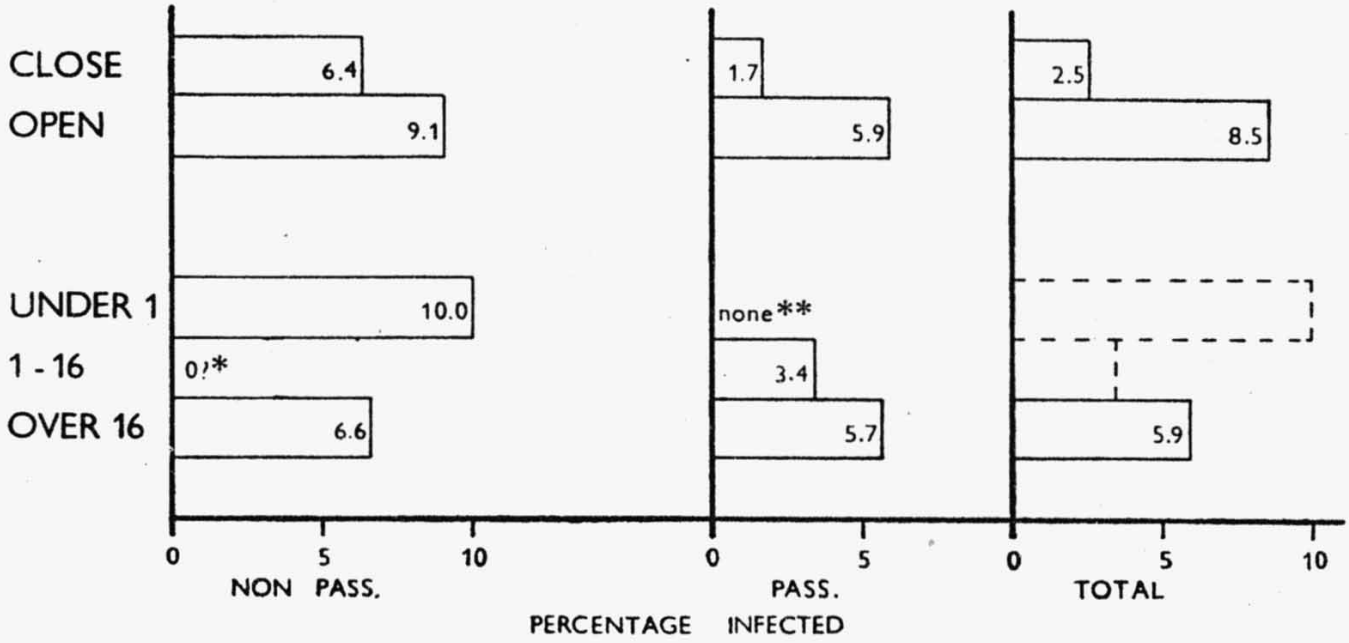

Fig. 6. Comparison of *Leucocytozoon* incidence in bird groups in Central Europe according to the nest type and duration of the nestlings' stay in the nest (CLOSE = birds with closed type of nest; OPEN = birds with open type of nest; UNDER 1 = birds whose young stay in the nest less than one day after hatching; 1—16 = the scope of the duration of the nestlings' stay in the nest; OVER 16 = duration of the nestlings' stay in the nest longer than 16 days; NON-PASS = non-Passeriformes, PASS = Passeriformes *, ** = insufficient prevalence data—see the text).

Fig. 6 shows the incidence of *Leucocytozoon* parasites in the birds in Central Europe, grouped according to the nest type and to the duration of stay of nestlings in the nest. It is evident from the graph that *Leucocytozoon* is most frequent in those birds which build open nests. This fact was pointed out in birds in Ethiopia by Ashford (1974), who also found a general predisposition to blood parasites in birds with open nests. In case of passerines it has been established that the blood parasite incidence depends on the length of stay of nestlings in the nest: the longer the stay in the nest, the greater the predisposition to blood parasites. In non-passerines this dependence cannot be proved due to the large numbers of nidifugous birds, whose nestlings leave the nest soon after hatching and due to a small sample of birds with the stay in the nest shorter than 16 days. The above mentioned phenomena may be explained by the ecology of vectors. The simuliids apparently prefer feeding on nestlings which are an easy prey for them because they are not fully feathered yet and because they cannot move freely in the nest. For this reason the *Leucocytozoon* incidence in birds with open nests is much higher than in those with closed nests.

Moreover, the longer are the nestlings in the nest, the greater is the probability of their infection with blood parasites.

Fig. 7 demonstrates the comparison of the *Leucocytozoon* incidence in birds grouped according to the nesting biotope. Surprising is the very low infection rate detected in aquatic birds. This phenomenon is all the more interesting if we consider that the vectors of *Leucocytozoon*, the simuliids, are in their biology closely associated with running waters. Of interest is also a relatively low incidence of *Leucocytozoon* in anthropophilic birds, apparently caused by low occurrence of blackflies in human settlements. The differences in the *Leucocytozoon* incidence in other bird groups (wood birds, shrub birds and birds of forest-free regions), between non-Passeriformes and Passeriformes indicate considerable differences in various systematic groups of birds.

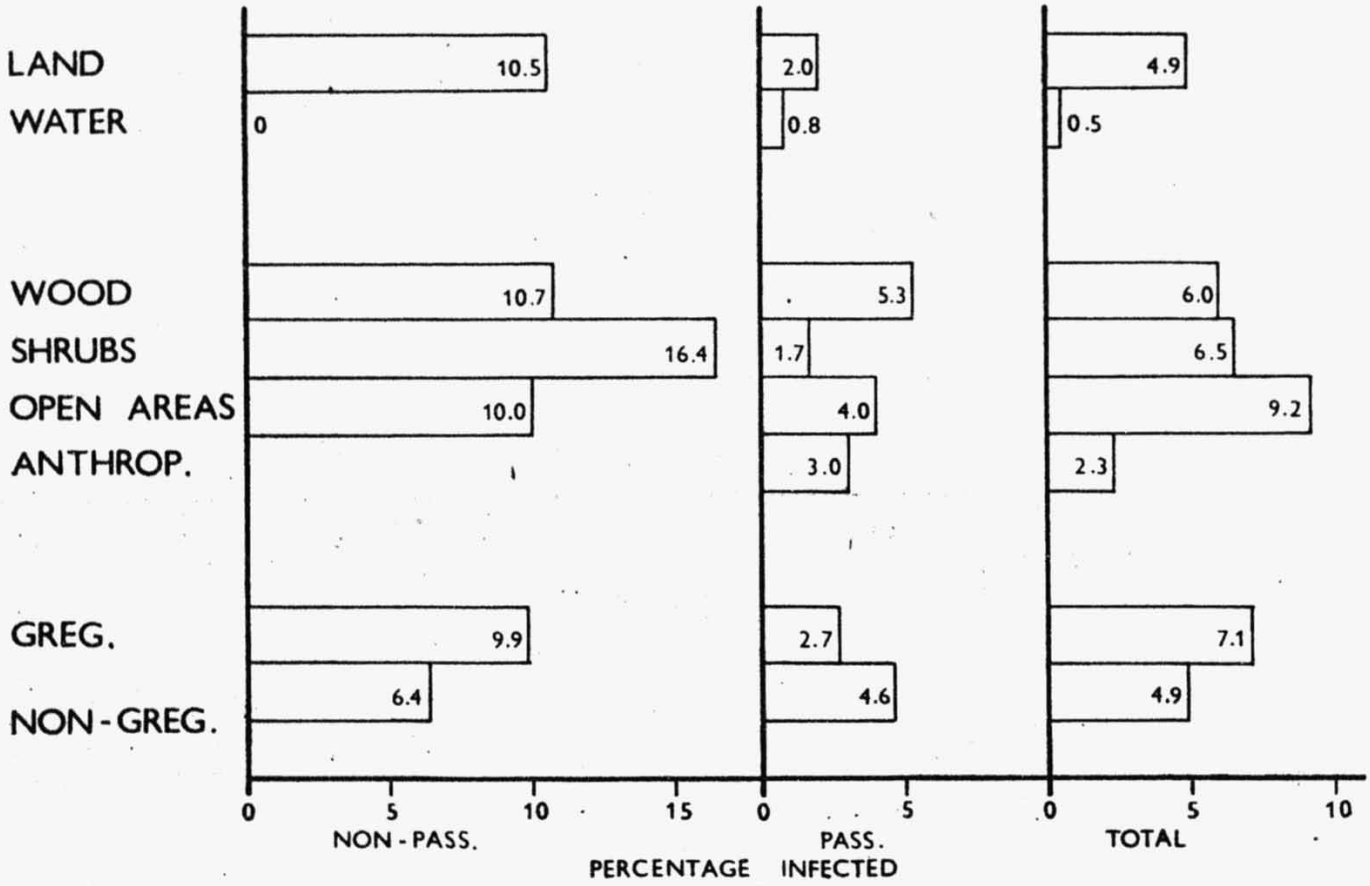

Fig. 7. Comparison of *Leucocytozoon* incidence in bird groups according to the nesting biotope (LAND = terrestrial birds, WOOD = wood birds, WATER = aquatic birds, SHRUBS = shrub birds, OPEN AREAS = birds in the field and other open biotopes; ANTHROP = anthropophilic birds; GREG = gregarious birds; NON-GREG = non-gregarious birds; NON-PASS = non-Passeriformes; PASS = Passeriformes).

Ashford (1974) found that in birds in Ethiopia the incidence of blood parasites greatly depends on the gregariousness of birds. Gregarious birds were much more predisposed to blood parasites than non-gregarious birds. Likewise Mohammed (1958) arrived at the same conclusion in Egypt. In case of birds in Central Europe a similar dependence may be revealed only in birds other than passerines, while among the passerines it is vice versa (see Fig. 7). Among the non-Passeriformes a high infeciton rate is encountered in Galliformes which are characterized by gregarious way of life. On the other hand, markedly gregarious groups of passerines

such as Hirundinidae and Passeridae, possess a relatively low number of parasites of the genus *Leucocytozoon* (see Fig. 1). These birds, however, build closed nests and therefore the incidence of blood parasites in them is low (see above).

Ecological model of *Leucocytozoon* in birds in Central Europe

After analysing the dependence of the *Leucocytozoon* incidence on some ecological properties of their hosts (see above) important facts are evident which help elucidate the survival and transmission of these parasites in the bird populations in Central Europe. Fig. 3 and the above discussion demonstrate that the transmission of *Leucocytozoon* by vectors takes place mainly during the nesting period within the nesting area, i.e. in our case in Central Europe. The stay of migratory birds at overwintering sites in warm regions, however, does not essentially affect the occurrence of these parasites.

For the maintenance of the *Leucocytozoon* parasites in the bird populations in Central Europe mainly responsible are the so-called spring relapses of these parasites (see above). During such relapses, apparently due to a rising sexual activity of the birds, chronic infections change into phases when the gametocytes of parasites begin to appear in the peripheral blood of the birds. Thus the infection of vectors at the beginning of the new season and the transmission to other susceptible birds is facilitated.

The dependence of the *Leucocytozoon* incidence on the duration of the nestlings' stay in the nest and the high infection of the young birds (see Figs. 5 and 6 and the above discussion) suggest that the major number of infected birds has been apparently infected early in their life, during their stay in the nest.

Beaudoin et al. (1971) analysed the seasonal dynamics of the avian plasmodia incidence and compared the plasmodia incidence in migratory and non-migratory birds in Pennsylvania, USA. Because of this analysis and the known facts about the spring relapses the cited authors drafted an ecological model elucidating the transmission and maintanance of avian malaria in the bird populations of North America. The basis of their model is the supposition that the biological reservoirs of avian plasmodia are birds in which these parasites can survive the period when the transmission by insect vectors is impossible. They also emphasized the importance of spring relapses of chronic infections in the transmission of avian plasmodia to non-infected vector populations at the beginning of the period favourable to parasite transmission. The supposition that the biological reservoirs are birds and not vectors elucidates the wide distribution of avian malaria, because the bird populations are less affected by unfavourable climatic conditions than the vector populations which are often considerably decimated. In favourable conditions the plasmodia transmission, according to the model of the cited authors, reaches the level at which the number of newly infected birds equals or exceeds the number of infected birds which have died. On the other hand, in unfavourable conditions, when no transmission is possible, the number of non-infected susceptible birds increases during bird reproduction, the parasites surviving in the reservoir birds. As soon as the climatic conditions improve and vectors appear the transmission is in process again and it is the higher the larger is the number of susceptible bird population.

The above facts about parasites of the genus *Leucocytozoon* in birds of Central Europe indicate that the ecological model of Beaudoin et. al. (1971), originally concepted for the parasites of the genus *Plasmodium*, may be applied to *Leucocytozoon*. Due to a far higher incidence, however, the bird population infected with *Leucocytozoon* will be larger than in the case of plasmodia. The author detected the

highest incidence of *Leucocytozoon* in September in 18 % of passerines which were newly infected in this period and in which the infection was still acute. However, also the percentage of birds, in which the infection was already chronic, should be taken into account. The data obtained in the spring indicated that at least 5 % of passerines were with chronic infection, the infection rate being 25 % of the total passerine population in Czechoslovakia. This is a rough estimation, however, because as mentioned above, the *Leucocytozoon* incidence is different in different systematic groups of birds.

In contrast to *Plasmodium*, the number of bird population infected with *Leucocytozoon* during the winter will decrease sharply, because a higher number of infected birds will die than that of the non-infected birds due to the considerable pathogenic effects of *Leucocytozoon*. Likewise, the spring relapses will be encountered earlier in the case of *Leucocytozoon* than in the case of *Plasmodium*.

КРОВЕПАРАЗИТЫ ПТИЦ ЦЕНТРАЛЬНОЙ ЕВРОПЫ.
2. *LEUCOCYTOZOON*

Я. Кучера

Резюме. Работа подытоживает данные о наличии и экологии паразитов рода *Leucocytozoon* у птиц в Средней Европе. *Leucocytozoon* чаще всего встречается у Corvidae, Columbiformes, Galliformes, Strigiformes и Turdidae. Редко встречается у Anseriformes, Muscicapidae и Passeridae и почти отсутствует у Hirundinidae и Sturnidae. До 1945 г. обилие этих паразитов было выше чем после этого года. Анализ зависимости наличия *Leucocytozoon* от некоторых экологических свойств птиц показал, что выживание и передачу этих паразитов в популяциях птиц в Средней Европе можно объяснить с помощью экологической модели птичей малярии, составленной Бодуэном и др. (Beaudoin et al. 1971).

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Received 15 February 1980.

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FOLIA PARASITOLOGICA (PRAHA) 28: 203—204, 1981.

6th National Seminar on Diptera

The 6th National Seminar on Diptera was held in Cikháj near Žďár n. S. from 22nd to 24th October, 1980. These meetings of Czechoslovak dipterologists have been organized regularly every two years since 1970. The organizer of the 6th Seminar was the Faculty of Biology of Animals and Man, J. E. Purkyně University in Brno. The seminars on Diptera serve for the exchange of new knowledge, show the present state of research of Diptera and deal with concrete measures for a further development of this branch in Czechoslovakia. Like at the previous seminars, a great attention was paid to the groups of Diptera of economic and parasitic importance.

The seminar was attended by 42 participants from research institutes, universities and museums. They read 35 reports, one third of which concerned medical and veterinary dipterology (4 reports dealt with mosquitoes, 5 with synanthropic flies, 2 with black flies, and 1 with warble flies and midges). The reported topics were: the research of mosquitoes in large towns and in Lower Elbe region, factors involved in