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Isospora, *Caryospora* and *Eimeria* (Apicomplexa: Eimeriidae) in Passeriform Birds from Czech Republic

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Summary. Passeriform birds were studied as hosts of monoxenous coccidia (Eimeriidae). 571 faecal samples from 46 species were examined. Coccidia were found in 210 samples (36.8%) from 34 host species (73.9% of examined species). 36 oocyst types mostly belonging to the genus *Isospora* were found (33 types); oocysts of the genera *Caryospora* and *Eimeria* were also noted. *Caryospora* is reported for the first time from the genus *Acrocephalus*. Infections were mostly single (91.4%), but multiple infections were also found. Problems of species determination in eimeriid coccidia from birds are discussed, as well as the possibility that every species of passerine bird in Central Europe can act as a host for at least one species of monoxenous coccidia.

Key words. Coccidia, Passeriformes, Eimeriidae, *Isospora*, *Caryospora*, *Eimeria*.

INTRODUCTION

Passerine birds have been known as hosts of monoxenous coccidia for one hundred years: in 1893 Labbé found oocysts in *Carduelis carduelis* (ex Levine 1982). However, unlike species from domestic fowl, the coccidia of free-living birds have not been intensively studied. The aim of this study was to ascertain which genera or species of monoxenous coccidia (Eimeriidae) occur in passerine birds from the Czech Republic and their level of infection.

MATERIALS AND METHODS

Passerine birds were net caught between 1988 and 1992 in different areas of the Czech Republic. They were kept in tissue bags for max. 1 hour and released. Faeces were removed, maintained in a 2% aqueous solution of potassium bichromate ($K_2Cr_2O_7$) at room temperature for 3 days to allow sporulation, and then stored at 4°C.

Each sample was examined directly without any flotation method. Oocysts were measured (n=10) using a calibrated ocular micrometer, drawn and photographed. The data were statistically processed and average, maximal and minimal lengths and widths of oocysts, as well as the standard error were determined.

Supposing that eimeriid coccidia are genus-specific parasites, the data obtained were compared with all descriptions and findings pertaining to a particular genus only. To compare data from different individuals of one genus, the multiple range test was used.

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RESULTS

A total of 571 individuals of 46 passeriform bird species belonging to 28 genera were examined. Oocysts of monoxenous coccidia (Eimeriidae) were found in 210 individuals (36.8%) of 34 species (73.9% of species infected) and 22 genera (78.6% genera infected). Thirty

seven oocyst types were found. Seven types were identified as previously described species, and for 5 types the identification was uncertain. A further 25 oocyst types found are probably new species (see Tables 1 and 2, Figs. 1-37). Most of the hosts released oocysts of the genus *Isospora* (two sporocysts in an oocyst; 99.0% of infected individuals); the genera *Caryospora* (one sporocysts in an oocyst) and *Eimeria* (four sporocysts in an oocyst) were also found (see Table 3). The majority of infections were single with only one type of oocyst (91.4% of infections), in a lesser extent double and triple infections with two types of *Isospora* or *Caryospora* and *Isospora* (see Table 4).

DISCUSSION

Despite the many extant descriptions of monoxenous coccidia from passeriform birds, species determination using oocysts is problematic. With the older descriptions being deficient, practically all findings of the genus *Isospora* were classified as *I. lacazei* (Labbé, 1893). Pellérdy (1974) stated that in addition to the house sparrow (*Passer domesticus*) 40 to 50 species of passeriform bird can host this *Isospora*. Actually, monoxenous coccidia are thought to be genus-specific (Levine 1982), although exceptions exist: *I. xerophila* infects 4 genera of the family Ploceidae (Barré and Troncy 1974), *Eimeria dispersa* from turkey (*Meleagris gallopavo*) can develop in the pheasant (*Phasianus colchicus*) and other members of the order Galliformes (Doran 1978). However, we cannot generalize this information, and without positive tests of infectivity for other genera we should consider monoxenous coccidia to be genus-specific (Long and Joyner 1984). Attempts to infect the canary (*Serinus canaria*, Fringillidae) with the oocysts of *Isospora* from house-sparrow (Passeridae) failed (Box 1970, Černá 1972), in the same way in that attempts to infect the canary with the oocysts from *Hesperiphona vespertina* (Khan and Desser 1971).

In identifying oocysts from passerine birds, the morphology is still of utmost importance, despite the fact that their length, width and shape may change during infection and as a function of inoculum (Cheissin 1947, 1957). The oocyst and sporocyst size varies amongst host individuals of one species, or among different species of one genus (Gardner and Duszynski 1990). Precise information on size (average length and width, maximum and minimum size, number of measurements, standard error) in combination with morphological characteristics could facilitate species identification. However, in much of the older descriptions this information is missing, so species-identification is difficult. Another problem is represented by descriptions which mention several genera of birds as hosts of one species of *Isospora*. More detailed data, e. g. experiments with infections by one oocyst or biochemical data are difficult to obtain due to problems with accessibility and rearing of hosts as free-living birds.

One of the most complicated examples are the *Isospora* in the house-sparrow. The above mentioned species *I. lacazei*, as which earlier findings from sparrows were considered, is believed to be a parasite of the goldfinch (*Carduelis carduelis*) (Levine 1982). As a sparrow parasite however, *I. passeris* was established (Levine 1982), its description being given previously by Levine and Mohan (1960). Scholtyseck (1954) stated two length frequency maxima of oocysts from sparrows (24 μm and 34 μm). Milde (1979) supposed that the sparrow is the host of two species of *Isospora* on the basis of such maxima (24 μm and 28 μm) and of the ultrastructure of intestinal and extraintestinal stages. Grulet et al. (1982) described 12 species of *Isospora* from sparrows on the basis of oocyst morphology. According to Landau (1989, pers. com.) this speciation took place in isolated populations of sparrows which later fused. Experiments with infections by one oocyst to exclude the influence of intraspecific variability were not carried out. The numbers of oocysts measured are very low (10 or less), and was unable to detect the morphological differences presented by the authors. I found two length frequency maxima of oocysts (21 μm and 30 μm) and two morphological forms. These results lead me to conclude that there are only two species of *Isospora* in the house-sparrow from the Czech Republic.

The observation of the genus *Caryospora* is of special interest. Some species of this genus have a direct life-cycle but are also able to survive in an intermediate host (*Caryospora bubonis*) (Stockdale and Cawthorn 1981). Species from snakes can complete a large part of their life cycle in rodents: *C. bigenetica* and *C. simplex* (Wacha and Christiansen 1982, Upton et al. 1984); but not all *Caryospora* from snakes are able to do this (Upton et al. 1983, Upton and Sundermann 1990). *Caryospora* from passeriform birds are probably monoxenous because of the feeding habit of their hosts; unfortunately, information about their life cycles are not available. There are only three descriptions of the genus *Caryospora* from Passeriformes: in *Dives atrogularis* (Icteridae) (Pellérdy 1967), in the robin *Erithacus*

Table 1

Monoxenous coccidia found in passeriform birds (Nomenclature by Hudec 1983)

Host species	n	+	Parasite species (notes)
Hirundo rustica	2	0	(none)
Delichon urbica	4	4	*Isospora* sp. type 1 (probably new species)
Anthus trivialis	2	0	(none)
Anthus pratensis	1	0	(none)
Motacilla cinerea	10	10	*Isospora* sp. type 2 (probably new species)
Motacilla alba	2	1	*Isospora* sp. type 2 (probably new species)
Troglodytes troglodytes	9	5	*Isospora* sp. type 3 *(probably new species)*
Prunella modularis	11	2	*Isospora* sp. type 4 (probably new species)
		1	*Isospora* sp. type 5 (probably new species)
Erithacus rubecula	37	15	(5 double infections)
		14	*I. erithaci* Anwar, 1972 (type 6)
		6	*C. jiroveci* Černá, 1976 (type 7)
Phoenicurus ochruros	6	1	*Isospora* sp. type 8 (probably new species)
Turdus merula	19	7	*I. turdi* Schwalbach, 1959 (type 9)
Turdus philomelos	5	1	*I. turdi* Schwalbach, 1959 (type 9)
		2	?*I. robini* McQuistion et Holmes, 1988 (type 10)
Locustella naevia	1	1	*Isospora* sp. type 12 (probably new species)
Acrocephalus schoenobaenus	8	3	*Isospora* sp. type 12 (probably new species)
Acrocephalus palustris	6	3	(1 triple, 1 double infection)
		2	*Isospora* sp. type 12 (probably new species)
		2	*Isospora* sp. type 13 (probably nes species)
		2	*Caryospora* sp. type 14 (probably new species)
Acrocephalus scirpaceus	9	4	(2 double infections)
		4	*Isospora* sp. type 15 (probably new species)
		2	*Isospora* sp. type 12 (probably new species)
Acrocephalus arundinaceus	2	0	(none)
Hippolais icterina	81	64	*Isospora* sp. type 16 (probably new species)
Sylvia curruca	4	1	?*I. sylviae* Schwalbach, 1959 (type 17)
Sylvia communis	6	3	(1 double infection)
		2	?*I. sylviae* Schwalbach, 1959 (type 17)
		2	?*I. sylvianthina* Schwalbach, 1959 (type 18)
Sylvia borin	10	4	(2 double infections)
		2	?*I. sylviae* Schwalbach, 1959 (type 17)
		3	?*I. sylvianthina* Schwalbach, 1959 (type 18)
		1	*E. depuytoraci* Černá, 1976 (type 19)
Sylvia atricapilla	19	10	(2 double infections)
		7	?*I. sylviae* Schwalbach, 1959 (type 17)
		5	?*I. sylvianthina* Schwalbach, 1959 (type 18)
Phylloscopus collybita	9	5	(2 double infections)
		5	*Isospora* sp. type 20 (probably new species)
		2	*Isospora* sp. type 21 (probably new species)
Phyloscopus trochilus	6	1	(1 double infection)
		1	*Isospora* sp. type 20 (probably new species)
		1	*Isospora* sp. type 21 (probably new species)
Regulus regulus	1	0	(none)
Regulus ignicapillus	1	0	(none)
Muscicapa striata	2	1	*Isospora* sp. type 22 (probably new species)
Ficedula hypoleuca	1	1	*Isospora* sp. type 23 (probably new species)
Aegithalos caudatus	5	1	*Isospora* sp. type 24 (probably new species)
Parus palustris	6	0	(none)
Parus montanus	6	0	(none)
Parus ater	1	0	(none)
Parus caeruleus	66	3	*Isospora* sp. type 25 (probably new species)
Parus major	106	2	*Isospora* sp. type 25 (probably new species)
		3	*Isospora* sp. type 26 (probably new species)
Sitta europaea	7	3	?*I. sittae* Golemanski, 1977 (type 27)
Certhia familiaris	2	1	*Isospora* sp. type 28 (probably new species)
Lanius collurio	6	1	*Isospora* sp. type 29 (probably new species)
Passer domesticus	52	24	*Isospora* sp. type 30 (undescribed species)
			Isospora sp. type 31 (undescribed species)
Fringilla coelebs	13	5	*I. fringillae* Yakimoff et Gousseff, 1938 (type 32)
		1	*Isospora* sp. type 33 (probably new species)
Fringilla montifringilla	1	1	(1 double infection)
		1	*Isospora* sp. type 33 (probably new species)
		1	*Isospora* sp. type 34 (probably new species)
Serinus serinus	2	0	(none)
Carduelis	6	0	(none)
Pyrrhula	9	6	*I. perroncitoi* Carpano, 1937 (type 35)
Coccothraustes coccothraustes	1	0	(none)
Emberiza citrinella	5	4	*Isospora* sp. type 36 (probably new species)
Emberiza schoeniclus	3	1	?*Isospora* sp. Mačulskij, 1941 (type 37)

n - number of examined individuals;
+ - number of infected individuals

Table 2

Description of oocysts found in passerine birds

Oocysts							Sporocysts			
Type	x	min/max	SEl	SEw	shape	polar body	shape	Stieda body	substieda body	residuum
1	27.0x23.7	24.0-31.3x19.5-26.3	0.26	0.25	ellipsoidal	big	ovoid	prominent	small	compact
2	20.8x18.7	16.5-26.5x16.5x21.0	0.24	0.16	ellipsoidal	medium	ellipsoidal	prominent	small	compact
3	24.0x21.5	19.0-29.0x17.0-25.2	0.32	0.26	subspherical	big	ovoid	prominent	medium	diffuse
4	20.1x19.3	18.5-22.0x18.0-21.0	0.26	0.27	subspherical	present	ovoid	flat	medium	diffuse
5	26.1x20.7	21.0-29.4x19.0-21.0	0.95	0.21	ellipsoidal	present	ellipsoidal	medium	small	transient
6	19.0x18.3	16.0-22.0x16.0-22.0	0.18	0.18	subspherical	present	pyriform	prominent	big	diffuse
7	18.2x17.0	16.5-21.0x15.0-18.9	0.14	0.17	subspherical	present	ovoid	small	medium	diffuse
8	19.9x19.1	18.0-22.0x18.0-21.0	0.71	0.56	subspherical	present	ovoid	small	medium	transient
9	18.8x17.2	16.5-21.4x15.0-19.7	0.17	0.20	subspherical	present	ellipsoidal	small	medium	diffuse
10	27.8x20.9	23.1-32.0x19.0-21.7	1.06	0.23	ovoid	present	ovoid	prominent	small	compact
11	23.4	21.5-25.5	0.48		spherical	small	ovoid	wide	medium	diffuse
12	26.0x23.0	22.0-30.0x16.0x27.3	0.19	0.33	subspherical	present	wide	wide	medium	diffuse
13	20.1x17.7	18.0-21.0x16.5-21.0	0.32	0.37	subspherical	present	wide	prominent	big	compact
14	31.8x24.3	28.0-35.7x20.0-27.3	0.40	0.33	ellipsoidal	present	ovoid	prominent	small	compact
15	21.3x20.1	16.8-25.2x14.7-25.1	0.55	0.72	subspherical	present	ovoid	prominent	small	diffuse
16	26.8x24.8	19.5-33.6x18.0-31.5	0.13	0.13	subspherical	present	ovoid	prominent	medium	transient
17	30.1x26.1	25.5-33.6x21.0-30.0	0.26	0.25	ellipsoidal	present	ellipsoidal	prominent	small	compact
18	26.1x25.0	21.0-29.4x21.0-27.3	0.24	0.21	subspherical	present	ovoid	wide	medium	diffuse
19	15.3x13.5	15.0-15.5x13.0-14.0	0.20	0.12	subspherical	present	ellipsoidal	small	absent	diffuse
20	27.6x26.3	22.8-35.7x21.0-31.5	0.42	0.36	subspherical	present	ellipsoidal	prominent	big	diffuse
21	29.3x26.3	25.2-33.6x22.0-30.0	0.60	0.72	ovoid	present	ovoid	prominent	small	compact
22	20.4x19.4	19.0-21.5x18.0-21.0	0.26	0.30	subspherical	small	ovoid	wide	small	diffuse
23	21.2	19.5-22.0	0.38		spherical	present	ovoid	small	medium	diffuse
24	28.2x25.7	25.6-29.9x21.4-29.2	0.45	0.64	subspherical	present	ovoid	prominent	small	compact
25	26.8x24.1	23.8-30.0x21.5-26.6	0.32	0.26	subspherical	present	ovoid	prominent	medium	compact
26	29.7x26.1	25.5-33.6x23.0-29.6	0.35	0.40	subspherical	present	ellipsoidal	wide	small	transient
27	21.4x21.2	19.5-25.0x19.5-23.5	0.35	0.30	subspherical	small	ovoid	prominent	medium	diffuse
28	26.0x21.8	24.0-27.0x20.0-24.0	0.38	0.40	subspherical	big	ovoid	prominent	small	compact
29	24.3x19.3	22.5-27.0x18.0-21.0	0.40	0.39	ovoid	big	ovoid	prominent	small	compact
30	22.3x21.2	15.0-27.0x15.0-26.5	0.28	0.25	subspherical	present	ovoid	prominent	small	compact
31	30.1x29.4	29.4-32.0x27.0-31.5	0.34	0.46	subspherical	present	ellipsoidal	wide	medium	transient
32	21.8x20.8	18.1-25.2x18.0-25.2	0.28	0.29	subspherical	present	ovoid	small	medium	diffuse
33	26.2x23.0	24.0-29.6x19.7-26.3	0.45	0.38	ellipsoidal	1 - 2	ovoid	prominent	small	compact
34	18.0x15.2	16.5-19.7x13.3-16.5	0.33	0.32	ellipsoidal	present	long	small	small	diffuse
35	23.5x22.5	19.5-27.0x18.0-27.0	0.27	0.29	subspherical	small	ovoid	flat	small	diffuse
36	29.6x27.3	23.1-35.7x22.0-33.6	0.56	0.42	subspherical	small	ellipsoidal	flat	big	diffuse
37	25.9x23.5	21.0-28.5x19.5-27.0	0.72	0.70	ellipsoidal	big	ovoid	prominent	small	compact

Type - number of oocyst type (see table 1); x - average length and width; min/max -minimal and maximal length and width; SEl - length standard error; SEw - width standard error

Table 3

Level of coccidia infection found in passeriform birds

Taxon	n	%	+
Eimeriidae	210	36.8	100
Isospora	208	36.4	99.0
Caryospora	8	1.4	3.8
Eimeria	1	0.2	0.5

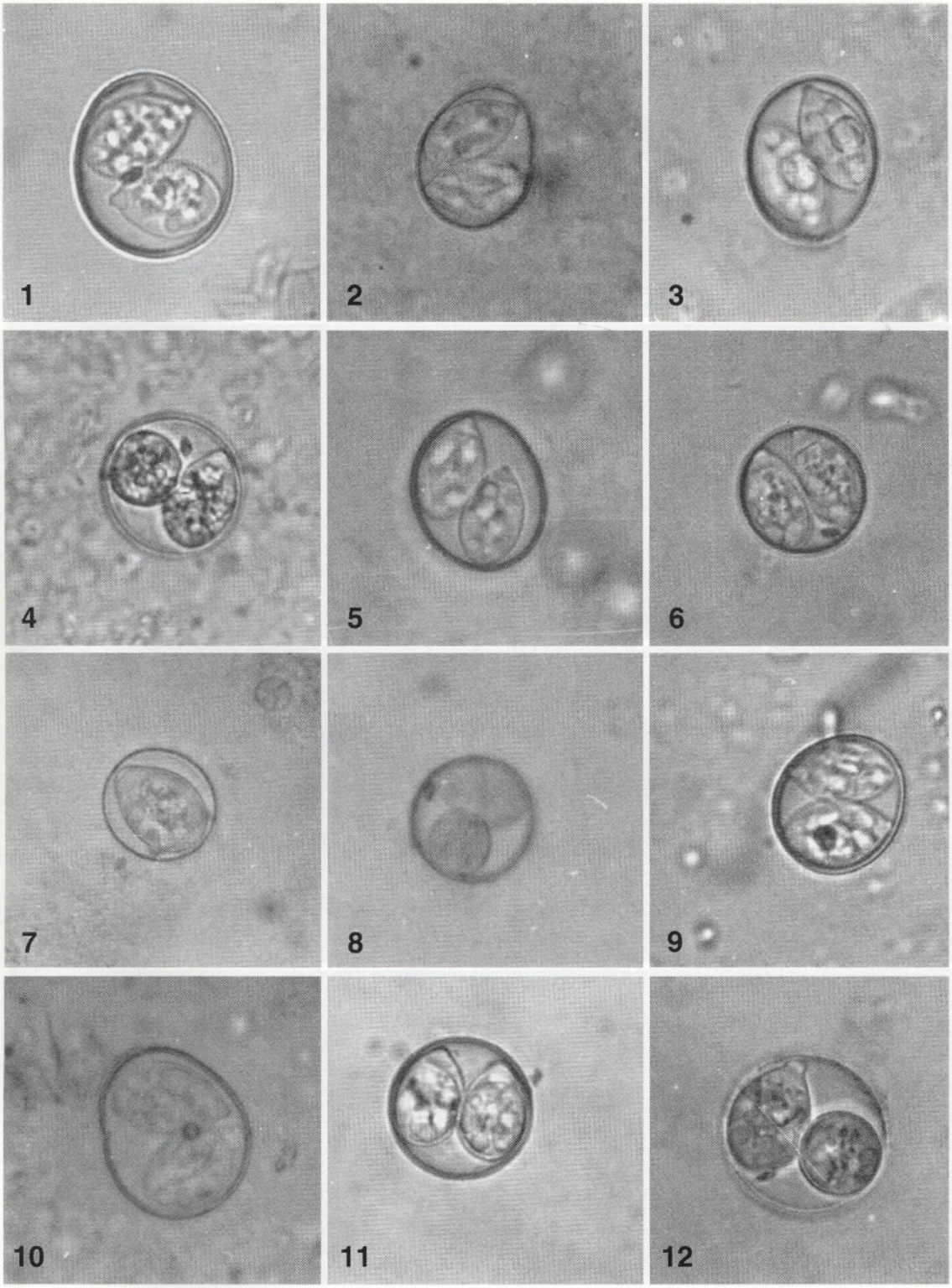
n - number of infected individuals; % - percent of examined individuals; + - percent of infected individuals

Table 4

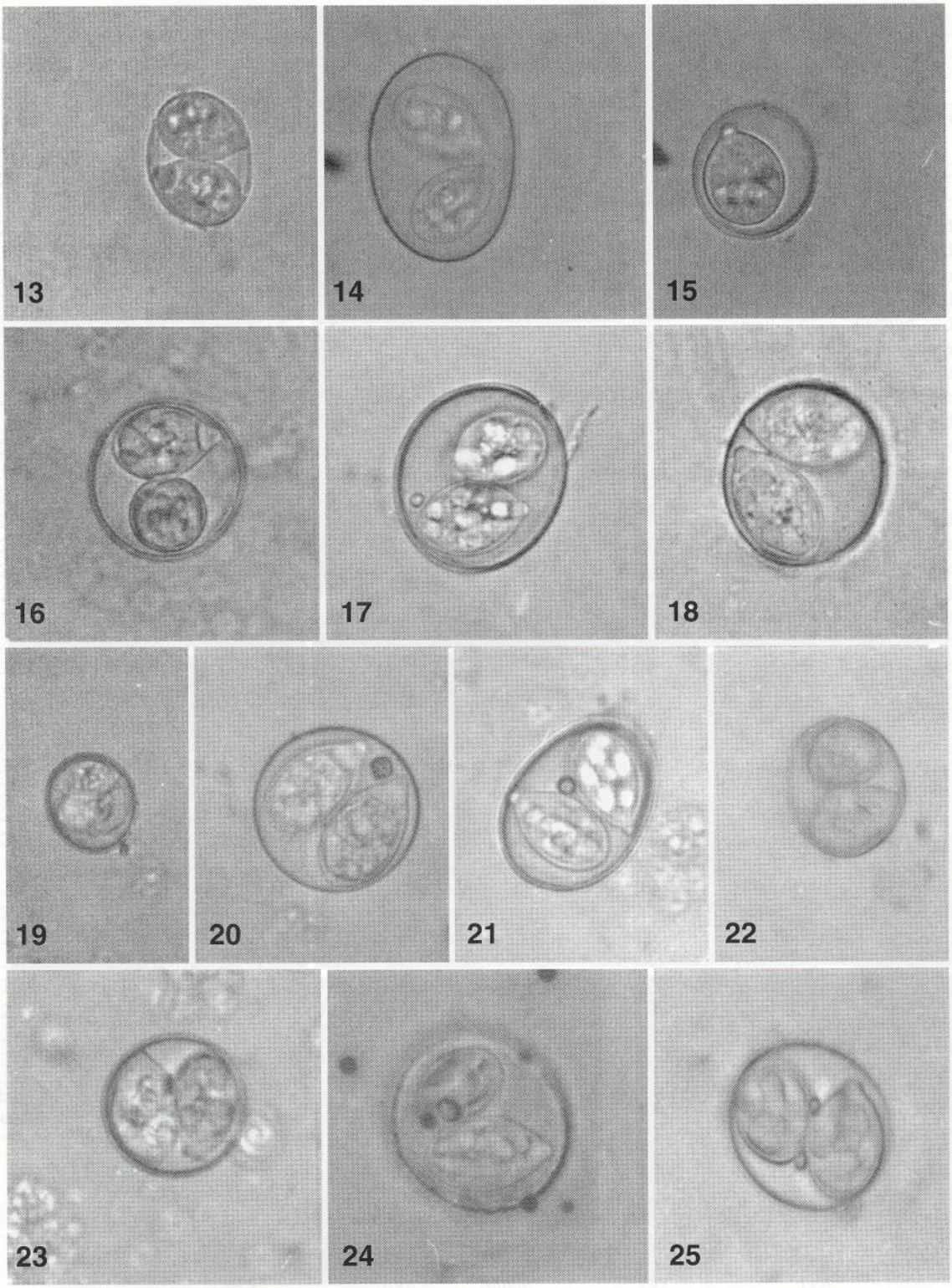
Frequency of different infection type

Infection type	n	%	+
Single	192	33.6	91.4
Double	17	3.0	8.1
Triple	1	0.2	0.5

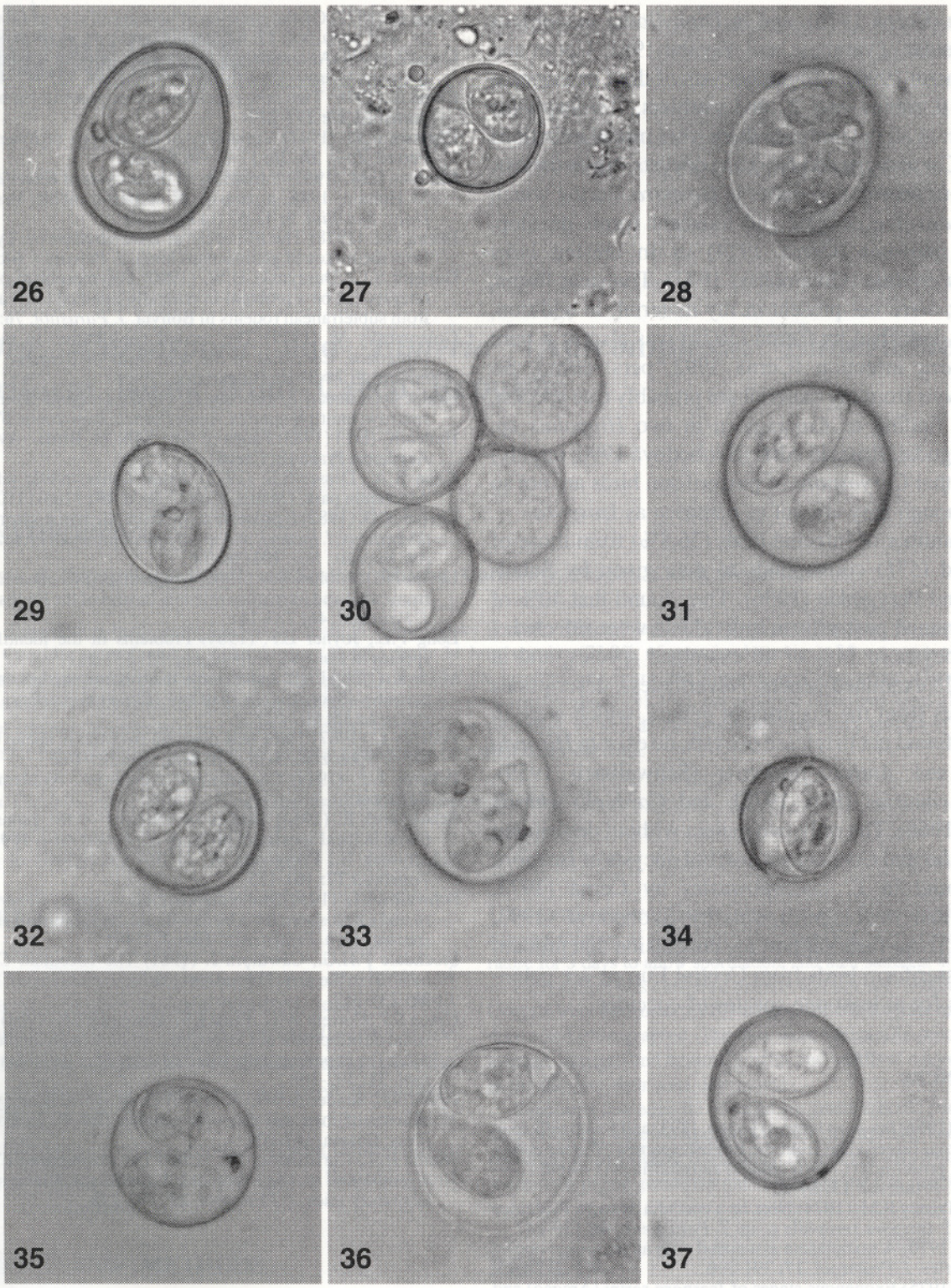
n - number of infected individuals; % - percent of examined individuals; + - percent of infected individuals



Figs. 1-12. Oocyst type - host species. 1. *Isospora* sp.- *Delichon urbica*, 2. *Isospora* sp.- *Motacilla cinerea*, 3. *Isospora* sp.- *Troglodytes troglodytes*, 4,5. *Isospora* sp.- *Prunella modularis*, 6. *Isospora erithaci* - *Erithacus rubecula*, 7. *Caryospora jiroveci* - *E. rubecula*, 8. *Isospora* sp. - *Phoenicurus ochruros*, 9. *Isospora turdi* - *Turdus merula*, 10. *Isospora* sp. - *T. philomelos*, 11. *Isospora* sp. - *Locustella naevia*, 12. *Isospora* sp. - *A. schoenobaenus*. Magnification 1000 x



Figs. 13-25. Oocyst type - host species. 13. *Isospora* sp. - *Acrocephalus palustris,* 14. *Isospora* sp. - *A. scirpaceus*, 15. *Caryospora* sp. - *A. palustris*, 16. *Isospora* sp. - *Hippolais icterina*, 17. *Isospora* sp. - *Sylvia curruca*, 18. *Isospora* sp. - *S. borin*, 19. *Eimeria depuytoraci* - *S. borin*, 20. *Isospora* sp. - *Phyloscopus collybita*, 21. *Isospora* sp. - *P. collybita*, 22. *Isospora* sp. - *Muscicapa striata*, 23. *Isospora* sp. - *Ficedula hypoleuca*, 24. *Isospora* sp. - *Aegithalos caudatus*, 25. *Isospora* sp. - *Parus caeruleus*. Magnification 1000 x



Figs. 26-37. Oocyst type - host species. 26. *Isospora* sp. - *Parus major*, 27. *Isospora* sp. - *Sitta europaea*, 28. *Isospora* sp. - *Certhia familiaris*, 29. *Isospora* sp. - *Lanius collurio*, 30,31. *Isospora* sp. - *Passer domesticus*, 32. *Isospora fringillae* - *Fringilla coelebs*, 33,34. *Isospora* sp. - *F. montifringilla*, 35. *Isospora perroncitoi* - *Pyrrhula pyrrhula*, 36. *Isospora* sp. - *Emberiza citrinella*, 37. *Isospora* sp. - *E. schoeniclus*. Magnification 1000 x

rubecula (Černá 1976), and in *Diphyllodes magnificus* (Paradiseidae) (Varghese and Yayabu 1981, Upton and Sundermann 1990). I found oocysts of the *Caryospora*-type in 6 robins and 2 reed-warblers, *Acrocephalus palustris*; in all but one case there were mixed infections of both *Caryospora* and *Isospora* oocysts. Nevertheless, anomalous sporulation exists in *Isospora*, during which *Caryospora*-like oocysts and transient forms develop, e.g. in sparrows (Černá 1974) or in crested larks *Galerida cristata* (Golemanski 1977). Transient forms, however, were not present in my material; in addition, the case described by Černá (1974) was also of a pure *Caryospora* infection (Černá 1992, pers. com.). So *Caryospora* from my material are probably true species. Another finding of *Caryospora* in two *Hippolais* sp. from Ongudai, Russian Altai (Svobodová 1990, unpub.) indicate that *Caryospora* of passeriform birds are not so rare, although they are not as common as *Isospora*.

The number of infected birds (36.8%) from those of examined (571) corresponds to data given by Scholtyseck and Przygodda (1956). They found that 40% of 632 examined passeriform individuals were infected. I found oocysts in 74% of 46 examined species, and in 86% of 28 examined genera. Nevertheless, descriptions of oocysts from the majority of genera, which were in my case found not to release oocysts, do exist in *Hirundo rustica* and *Anthus pratensis* (Schwalbach 1959), *Serinus canarius* (Box 1975), and *Carduelis chloris* (Anwar 1966). The only two genera without description are *Regulus* and *Coccothraustes*; but oocysts of *Isospora* were found in *C. coccothraustes* by Černá (1973, unpub.) and in *R. ignicapillus* by Svobodová (1993, unpub.). These facts support my conclusion that probably all passeriform birds from Central Europe are potential hosts for at least one species of coccidia.

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