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Short communication

Composition, structure and pattern of helminth assemblages associated with central European storks (Ciconiidae)

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ABSTRACT

The composition, structure and pattern of helminth assemblages associated with the storks (Ciconiidae), ibises and spoonbills (Threskiornithidae) are poorly understood. Here we analyze the prevalence, intensity and diversity of the helminth component communities associated with the white stork *Ciconia ciconia* and black stork *Ciconia nigra*, and notice the findings of helminths on Eurasian spoonbill *Platalea leucorodia* and glossy ibis *Plegadis falcinellus* obtained in the Czech Republic in years 1962–2013. Comparison with datasets from multiple European countries supports the existence of well-defined local helminth component communities, which are subject to strong geographic variation. The estimated diversity of the helminth component communities reached 11.0 ± 1.6 (*C. ciconia*) and 12.5 ± 5.4 (*C. nigra*) species, with the Berger–Parker dominance index reaching only 0.24 and 0.21, respectively. Typically, the dominant species (*Chaunocephalus ferox*, *Tylodelphys excavata* and *Dictymetra discoidea* in *C. ciconia*, and *Cathaemasia hians* and *Dicheilonema ciconiae* in *C. nigra*) were considered as local, with intermediate host species available onsite. Altogether 10 of the 11 species with known life cycle were capable to complete their life cycle locally, which is in strong contrast with the situation in Czech egrets and herons. In *C. ciconia* and *C. nigra*, the highest helminth load was in juveniles, whereas *Echinostoma sudanense*, absent in the juveniles, was associated with intermediate hosts absent in the study area. Relative prevalence and frequency of helminths associated with male and female *C. ciconia* was similar to each other. The first systematically collected evidence of the intra-annual changes of the helminth assemblages in storks is provided.

1. Introduction

Component communities of helminths associated with the storks, ibises and spoonbills are poorly understood. Several (usually small) cohorts of white stork *Ciconia ciconia* and black stork *Ciconia nigra* were studied in Europe [1–6]; wood storks *Mycteria americana* and a single jabiru *Jabiru mycteria* were examined in Brazil [7]. For European ibises and spoonbills, the data are completely absent; some information may be inferred from studies conducted on Threskiornithidae species resident in the Americas. Moderate infections of storks by helminths such as *Chaunocephalus ferox* and *Tylodelphys excavata* were suggested to be among the frequent causes of death in young storks due to the deep ulceration and severe catarrhal changes in the small intestine [6], or causing severe weight restriction as shown for *Chaunocephalus ferox* in Spanish *C. ciconia* [8]. Severe infections of storks by *Cathaemasia hians* were shown to be lethal as well [6,9,10].

Here in this report, we analyze a prevalence, intensity and diversity of helminth assemblages associated with both the Czech stork species (*C. ciconia* and *C. nigra*), with notes on helminths found when examining the incidentally collected Threskiornithidae species (Eurasian spoonbill *Platalea leucorodia* and glossy ibis *Plegadis falcinellus*). Age-, sex- and season-related changes in helminth assemblages are addressed. This report represents the first systematically collected evidence for the diversity of stork helminth component communities and on selected drivers of their changes.

2. Material and methods

Central-European storks (Ciconiidae), ibises and spoonbills (Threskiornithidae) represent large long-legged wading birds subject to long-distance migratory movements. In the Czech Republic, three species are recognized as nesters (*C. ciconia* and *C. nigra* nesting regularly, and *P. leucorodia* nesting irregularly), occurring frequently also during migration. Besides them, occasional observations are known for *P. falcinellus* and African sacred ibis *Threskiornis aethiopicus*. All the four species examined are listed in Annex I of the EU Birds Directive as well as in Appendix II of the Bern and Bonn Conventions. The

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ecological characteristics of the four species examined are provided in Table S1.

In years 1962–2013, we examined 107 birds of the families Ciconiidae and Threskiornithidae. All the birds originated from the Czech Republic (48°39′N–50°59′N, 12°19′E–18°29′E), primarily eastern parts of the country. The birds consisted of 91 *C. ciconia*, 14 *C. nigra*, one *P. leucorodia* and one *P. falcinellus*. The birds for the study were supplied dead, usually wounded or hunted, for preparation into the collection of the Commenius Museum (Přerov, Czech Republic). The material was examined and the data were analyzed as described [11].

Some data on this dataset were already published: The finding of *Patagifer bilobus* in the single *P. falcinellus* specimen was reported by Faltýnková et al. [12], and the majority of the records were included in the recently published checklists of Czech helminths [13–15] and in the conference abstracts.

3. Results and discussion

We collected a total of 11,400 individuals of 17 species of helminths. The particular component communities were represented by 9294 individuals (10 species) from *C. ciconia*, 2086 individuals (8 species) from *C. nigra*. We also collected 11 individuals (3 species) from *P. leucorodia* and 9 individuals (1 species) from *P. falcinellus*. The Chao-1 estimator (based on the number of host individuals counted once for each helminth species recorded) indicated the presence of 11.0 ± 1.6 helminth species in *C. ciconia*, and 12.5 ± 5.4 species in *C. nigra*. Nevertheless, the infracommunities of *C. ciconia* were less diverse than those of *C. nigra*, as indicated by the mean frequencies 1.1 and 2.5 species per host individual examined, respectively (Table 1).

Rarefaction of the two datasets (Fig. S1) indicated a high level of completeness of the component communities examined. Note the differences between the rarefaction curves generated based on the helminth prevalence (Fig. S1A,C,E) and frequency (Fig. S1B,D,F), specifically for the *C. nigra* adults (Fig. S1E–F), suggesting that the prevalence of helminth species is a better predictor of data complexity than their frequencies. The helminth assemblages consisted of several highly dominant species but also numerous species occurring at very low frequency, some forming singletons even in a dataset of 91 examined *C. ciconia* carcasses. In both stork species, the dominant species were represented by *Chaunocephalus ferox* (relative prevalence 34% in *C. ciconia* and 71% in *C. nigra*) and *Tylodelphys excavata* (34% and 64%, respectively). Some other dominant species were found prevalently (or exclusively) in only one of the host species, such as *Dictymetra discoidea* in *C. ciconia*, and *Cathaemasia hians* and *Dicheilonema ciconiae* in *C. nigra*. The most prevalent species belonged also to those occurring at the highest intensities. Thus the Berger–Parker dominance index reached only 0.24 (*C. ciconia*) and 0.21 (*C. nigra*) when calculated based on the prevalence, but reached 0.67 (*C. ciconia*) and 0.70 (*C. nigra*) when calculated based on the frequency. Relative prevalence and frequency of helminth species were very similar to each other in *C. ciconia* as well as in *C. nigra*

Table 1
Prevalence (n), relative prevalence (%), intensity (I), and frequency (F) of helminth infections in the Czech storks (Ciconiidae), ibises and spoonbils (Threskiornithidae). Selected species diversity indices are indicated. The significance of differences between the *Ciconia ciconia* and *C. nigra* datasets was tested by Shannon *t*-test with bias correction term.

	Ciconia ciconia (n = 91)				*Ciconia nigra* (n = 14)				*Platalea leucorodia* (n = 1)		*Plegadis falcinellus* (n = 1)	
	n	%	I	F	n	%	I	F	n	I (F)	n	I (F)
Digenea												
Cathaemasia hians	4	4.4	1.8	7	7	50.0	9.7	68				
Chaunocephalus ferox	31	34.1	47.8	1483	10	71.4	22.4	224				
Echinochasmus spinulosus	1	1.1	1.0	1								
Echinostoma revolutum	3	3.3	2.3	7								
Echinostoma sudanense	1	1.1	4.0	4								
Patagifer bilobus									1	1.0	1	9.0
Metorchis xanthosomus									1	4.0		
Duboisia syriaca	2	2.2	14.5	29	2	14.3	8.5	17				
Diplostomum volvens					1	7.1	1.0	1				
Hysteromorpha plataleae									1	6.0		
Tylodelphys excavata	31	34.1	239.4	7422	9	64.3	192.6	1733				
Bilharziella polonica					1	7.1	2.0	2				
Apharyngostrigea cornu	2	2.2	1.0	2								
Nematoda												
Capillaria sp.	5	5.5	1.4	7								
Chordocephalus parvepapillatus					1	7.1	10.0	10				
Dicheilonema ciconiae					4	28.6	7.8	31				
Cestoda												
Dictymetra discoidea	23	25.3	14.4	332								
Number of helminth species recorded	10				8				3		1	
Prevalence:												
Number of helminth species recorded per host individual examined	1.13				2.5							
Chao-1 ± SD	11.0 ± 1.6				12.5 ± 5.4							
Dominance	0.237				0.207							
Equitability	0.728				0.839							
Fisher's alpha	2.737				3.242							
Berger–Parker dominance index	0.301				0.286							
Shannon *t*-test (*t*; d_f; *p*)	-0.08; 71.8; >0.05											
Frequency:												
Number of helminth individuals recorded	9294				2086							
Dominance	0.665				0.703							
Equitability	0.274				0.309							
Fisher's alpha	1.107				1.054							
Berger–Parker dominance index	0.799				0.831							
Shannon *t*-test (*t*; d_f; *p*)	-0.38; 2785.4; >0.05											