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VERSITA

Parasitism of Odonata by *Arrenurus* (Acari: Hydrachnidia) larvae in the Lake Świdwie, nature reserve (NW Poland)

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Abstract
Larvae of a vast majority of water mite species are parasites of aquatic insects. Owing to this, they migrate to new localities, and are able to survive unfavourable environmental conditions. This also concerns species from subgenus *Arrenurus s. str.*, parasites of dragonflies. The detailed analysis of this phenomenon, however, has only been possible in the last several years, since the key to the identification of larvae from genus *Arrenurus* Dug. was published. In 2010, the parasitism of *Arrenurus s. str.* larvae on dragonflies in the Lake Świdwie reserve (NW Poland) was analysed. Larvae of 9 species of water mites were recorded on 107 imagines of dragonflies from 8 species. The following were identified as hosts of water mites for the first time: *Anax imperator*, *Libellula quadrimaculata*, and *Leucorrhinia caudalis*. The highest prevalence occurred in the case of: *Erythromma najas* and *Lestes dryas* (100%), *Coenagrion pulchellum* (96.5%), and *C. puella* (80.0%). *Coenagrion pulchellum* was infested by 9 species of parasites, *C. puella* by 6, and *Erythromma najas* and *Lestes dryas* by three species. The highest number of host species occurred in the case of *Arrenurus maculator* (5); followed by *A. cuspidator*, *A. batillifer* cf., *A. bicuspidator*, and *A. tetracyphus* (3 each); *A. papillator*, *A. tricuspidator*, and *A. bruzelii* (2 each), and *A. claviger* (1). Differentiation of preferences of particular parasites towards various parts of the host body was observed, probably related to the coevolution of parasites and hosts, and competition between the host species. The body sizes of the parasites suggest that approximately 50% of body size growth of water mites from subgenus *Arrenurus s. str.* occurs at the stage of parasitic larva.

Keywords
Odonata, dragonflies, damselflies, Hydrachnidia, water mites, *Arrenurus*, parasitism

Introduction

Larvae of vast majority of water mite species parasitize aquatic insects. At this stage, the dispersion of species occurs, along with a substantial growth in body size, and frequently surviving in unfavourable environmental conditions (Baker *et al.* 2006, Bohonak *et al.* 2004, Mitchell 1959, 1969, Zawal 2002, 2003a, b).

Depending on the insects infested by water mites, they latter can be divided into two groups. The first group includes parasites of insects permanently abiding in water, leaving this environment only periodically – beetles and true bugs (Cichocka 1995, Zawal 2002, 2003a). The other group parasitizes insects the larvae of which live in the water, and imagines permanently abide under water. Therefore, hosts of larvae, mainly imagines, are infested in a different way (Zawal 2003b). In the former case, it occurs in water, and in the latter, the life duration of the water mite larva involves two phases: preparasitic (phoretic) and parasitic. Due to phoresis in larvae and pupae of hosts, preparasitic larvae are carried to the terrestrial environment, where infestation and commencement of the parasitic phase occurs. This also concerns dragonflies parasitized by larvae of *Arrenurus* s. str. (Åbro 1990, Baker *et al.* 1991, Cassagne-Méjean 1966, Mitchell 1959, 1969, Münchberg 1936, Smith 1978, Stechmann 1976/77, 1978, Zawal 2004a, b, 2006a, b, Kulijer *et al.* 2012). Up to now, the host species of different *Arrenurus s. str.* species have not been precisely determined, mainly due to the lack of possibility to identify mite larvae. The application of an identification key (Zawal 2008) in this kind of work resulted in the preparation of several papers describing the parasitism of identified *Arrenurus s. str.* species on various species of Odonata (Baker *et al.* 2006, 2007, 2008, Baker and Zawal 2011, Kulijer *at al.* 2012, Zawal and Dyatlova 2006, 2008, Zawal and Jaskuła 2008, Zawal and Szlauer-Łukaszewska 2012). Knowledge on this issue, however, is still fragmentary, and urgently requires further studies

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Table I. Occurrence of larvae of recorded *Arrenurus s. str*. species on particular host species. **I** – index: P – prevalence (number of specimens and % of material), I – intensity (range of numbers and mean number of larvae on one host specimen). Mean values were provided for at least three values

Parasite	I	Host							
		***Anax imperator* Leach**	***Coenagrion puella* (L.)**	***Coenagrion pulchellum* (Vander L.)**	***Enallagma cyathigerum* (Charp.)**	***Erythromma najas* (Hansem.)**	***Lestes dryas* Kirby**	***Libellula quadrimaculata* L.**	***Leucorrhinia caudalis* (Charp)**
A. batillifer Koen.(?)	P	1 (25.0)	1 (4.5)	1 (0.7)	–	–	–	–	–
	I	328	2	18	–	–	–	–	–
A. bicuspidator Berl.	P	–	1 (4.5)	5 (3.4)	–	–	–	–	1(10.0)
	I	–	1	2–12 (6.2)	–	–	–	–	59
A. bruzelii Koen.	P	–	2 (9.1)	9 (6.2)	–	–	–	–	–
	I	–	1–4	1–12 (4.8)	–	–	–	–	–
A. claviger Koen.	P	–	–	1 (0.7)	–	–	–	–	–
	I	–	–	1	–	–	–	–	–
A. cuspidator (O.F. Müll.)	P	–	10 (45.5)	77 (52.7)	–	–	11 (91.7)	–	–
	I	–	3–105 (28.7)	1–109 (19.9)	–	–	79 (6.6)	–	–
A. maculator (O.F. Müll.)	P	–	10 (45.5)	65 (44.5)	1 (25.0)	1 (25.0)	12 (91.7)	–	–
	I	–	2–136 (30.2)	1–61 (12.8)	10	5	21 (1.8)	–	–
A. papillator (O.F. Müll.)	P	–	–	1 (0.7)	–	–	12 (91.7)	–	–
	I	–	–	1	–	–	4–34 (12.5)	–	–
A. tetracyphus Piers.	P	–	2 (9.1)	5 (3.4)	–	–	–	1 (3.8)	–
	I	–	1–2	1–27 (7.8)	–	–	–	1	–
A. tricuspidator (O.F. Müll.)	P	–	–	1 (0.7)	–	2 (50.0)	–	–	–
	I	–	–	1	–	16–28	–	–	–

Table II. Place of attaching of parasites on the host body – number of larvae, total and mean (mean values were provided for at least three values). Abdomen I, abdomen II... – consecutive abdominal segments, loose – loose next to the host. *1 case, **2 cases

Place of attachment	*Anax imperator* Leach	*Coenagrion puella* (L.)	*Coenagrion pulchellum* (Vander L.)	*Enallagma cyathigerum* (Charp.)	*Erythromma najas* (Hansem.)	*Lestes dryas* Kirby	*Libellula quadrimaculata* L.	*Leucorrhinia caudalis* (Charp)
head and neck	–	14 (4.7)	20**	–	–	–	–	–
prosternum	–	33**	58 (9.7)	–	–	–	–	6*
mesosternum	–	91 (10.0)	725 (11.7)	2*	2*	–	1*	14*
metasternum	120*	185 (23.0)	975 (14.6)	3*	3*	139 (12.6)	–	14*
abdomen I	–	58**	205 (8.5)	–	–	–	–	–
abdomen II	–	56**	66 (7.3)	–	–	–	–	–
abdomen III	–	25**	2*	–	–	–	–	–
abdomen IV	–	–	22*	–	4*	–	–	–
abdomen V	–	–	1*	–	2*	–	–	–
abdomen VI	44*	–	2*	–	12*	–	–	–
abdomen VII	130*	–	2*	–	8*	–	–	1*
abdomen VIII	20*	–	–	–	1*	–	–	–
loose	–	69**	48*	–	–	111(9.3)	–	24*

involving the highest possible number of species of dragonflies and geographical areas.

The objective of this paper is the determination of the parasitism of water mite larvae on dragonflies in the Lake Świdwie reserve, where the degree of infestation of adult dragonflies reached very high values in June 2010.

Materials and Methods

Adult dragonflies used for the study were captured in NW Poland, in the Lake Świdwie reserve (53°33´N, 14°22´N), on Lake Świdwie and in the surrounding alder forests and meadows. They were captured by means of an entomological net, every month from May to October 2010. A total of 673 specimens were collected. Infested specimens were only recorded in June. Therefore, the reference point for the analyses of parasitism was material collected in this month, including 147 imagines (59♀♀ and 88♂♂).

Water mite larvae were removed with tweezers. Their number on different body regions of the hosts was recorded. The body length of water mite larvae was measured from the frontal part of the gnathosoma to the end of the idiosoma. Three size groups were distinguished: <350 μm, 350–450 μm, and >450 μm. A total of 3249 water mite larvae from genus *Arrenurus* were collected. The water mite larvae were identified using the key by Zawal (2008).

Two indices were used in the statistical analysis: 1. prevalence of infestation (percentage of infested hosts/parts of host body), 2. intensity of infestation (number of parasites on a given host/parts of host body).

Statistical significance was determined by means of the Kruskal-Wallis test. The calculations were performed in Statistica 10.0 software (licence No. AXAP111F136614FA-0).

Results

In the Lake Świdwie reserve, 9 species of water mites from subgenus *Arrenurus s. str*. were recorded at the stage of parasitic larva. One parasitic species (*Arrenurus* cf. *batillifer*) has not been so far described at the larval stage. Therefore, it is not possible to identify it accurately. Because the material included larvae clearly differing in terms of morphology and not matching any existing descriptions (Vajnštajn 1980, Zawal 2008), and *A. batillifer* was the most numerous species from the genus occurring in the reserve as adult specimens, the differing larvae were recognised as *A. batillifer*. This, however, requires verification through the description of morphology of larvae reared from eggs laid by a female. This is why all the references to larvae in this article are accompanied by “cf”.

Infested specimens were only recorded in June. A total of 147 imagines of dragonflies (59♀♀ and 88♂♂) belonging to 12 species were collected then. Larvae of water mites were recorded on 107 specimens representing 8 species (Table I, II).

Table III. Distribution of larvae of recorded *Arrenurus s. str*. species on particular host body parts. In – index: P – prevalence (number of specimens and % of material), I – intensity (range of numbers and mean number of larvae). Mean values were provided for at least three values. Abdomen I, abdomen II… – consecutive abdominal segments, loose – loose next to the host

Place of attachment	In	Parasite								
		A. batillifer?	*A. bicuspidator*	*A. bruzelii*	*A. claviger*	*A. cuspidator*	*A. maculator*	*A. papillator*	*A. tetracyphus*	*A. tricuspidator*
head and neck	P	–	–	–	–	3 (2.1)	3 (2.4)	–	–	–
	I	–	–	–	–	8–9 (8.7)	1–4 (2.3)	–	–	–
prosternum	P	–	1(10.0)	–	–	15 (10.4)	2 (1.6)	–	–	–
	I	–	6	–	–	1–31 (6.0)	1	–	–	–
mesosternum	P	1(14.3)	2 (13.4)	8 (57.1)	–	62 (43.1)	15(12.0)	–	4 (36.4)	–
	I	14	1–14	1–7 (4.0)	–	1–39 (11.4)	1–37 (4.8)	–	1–7 (2.5)	–
metasternum	P	2 (28.6)	5 (38.4)	4 (28.6)	–	56 (38.9)	63 (50.4)	11 (78.6)	4 (36.4)	–
	I	5–120	1–14 (9.0)	1–6 (2.7)	–	1–55 (9.4)	1–57 (8.0)	5–34 (12.5)	2–20 (7.0)	–
abdomen I	P	–	–	–	1	2 (1.4)	23 (18.4)	–	–	–
	I	–	–	–	1	8–12	1–46 (10.5)	–	–	–
abdomen II	P	–	–	–	–	1 (0.7)	11 (8.8)	–	–	–
	I	–	–	–	–	1	1–36 (11.0)	–	–	–
abdomen III	P	–	–	–	–	–	2 (1.6)	–	1 (9.1)	–
	I	–	–	–	–	–	5–20	–	2	–
abdomen IV	P	–	–	–	–	–	1 (0.8)	–	–	1 (16.7)
	I	–	–	–	–	–	22	–	–	4
abdomen V	P	–	–	–	–	–	–	1 (7.1)	–	1 (16.7)
	I	–	–	–	–	–	–	1	–	2
abdomen VI	P	1 (14.3)	–	–	–	–	–	–	1 (9.1)	1 (16.7)
	I	44	–	–	–	–	–	–	2	12
abdomen VII	P	1 (14.3)	1(10.0)	–	–	1 (0.7)	–	–	–	2 (33.3)
	I	130	1	–	–	1	–	–	–	1–8
abdomen VIII	P	1 (14.3)	–	–	–	–	–	–	–	1 (16.7)
	I	20	–	–	–	–	–	–	–	2
loose	P	1 (14.3)	2 (13.4)	2 (14.3)	–	4 (2.8)	5 (4.0)	2 (14.3)	1 (9.1)	–
	I	2	1	1–4	–	20–55 (31.7)	2–29 (15.4)	6–9	1	–

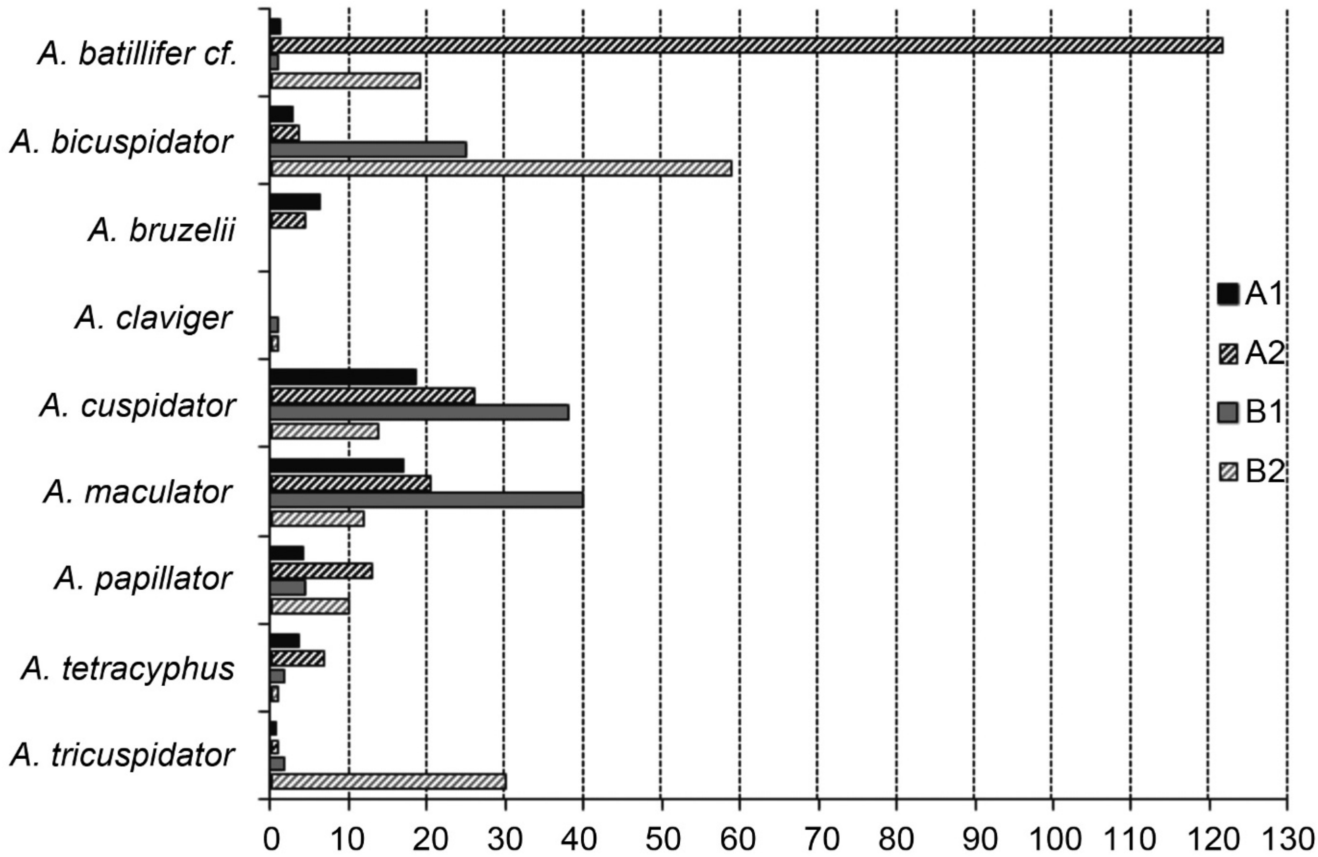

Fig. 1. Infestation of males (A) and females of dragonflies (B). 1 – mean % of specimens of a given sex infested by a given water mite species, 2 –mean number of water mite specimens on a dragonfly specimen

They were not recorded on: *Lestes sponsa* (Hansem.), *Brachytron pratense* (O.F. Müll.), *Somatochlora flavomaculata* (Vander L.), and *Leucorrhinia pectoralis* (Charp.). The Kruskal-Wallis test revealed statistically significant differences between the degree of infestation of particular species: H (11, N = 147) = 52.04642 ($p<0.0001$).

Prevalence for particular species amounted to: *Erythromma najas* and *Lestes dryas* –100% each, *Coenagrion pulchellum* – 96.5%, *C. puella* – 80.0%, *Enallagma cyathigerum* – 50.0%, *Anax imperator* – 50.0%, *Leucorrhinia caudalis* – 10.0%, and *Libellula quadrimaculata* – 7.7%. The highest mean numbers of parasites occurring on a single host of a given species occurred on *Anax imperator*, followed by *Leucorrhinia caudalis*, *Coenagrion puella*, *C. pulchellum*, *Lestes dryas*, *Erythromma najas*, *Enallagma cyathigerum*, and *Libellula quadrimaculata* (Table II). The total numbers of *Erythromma najas*, *Enallagma cyathigerum*, and *Anax imperator* amounted to two individuals, and of *Leucorrhinia caudalis* 10 individuals (one infested). Therefore, data for those species are largely uncertain.

Coenagrion pulchellum was infested by 9 species of parasites, *C. puella* by 6, *Erythromma najas* and *Lestes dryas* by three species, and *Anax imperator*, *Libellula quadrimaculata*, and *Leucorrhinia caudalis* by one parasitic species (Table I).

The highest number of hosts occurred in the case of *Arrenurus maculator* – 5. *A. cuspidator*, *A. batillifer* cf., *A. bicuspidator*, and *A. tetracyphus* had 3 hosts each, *A. papillator*, *A. tricuspidator*, and *A. bruzelii* – 2 hosts, and *A. claviger* – 1 host species (Table I). Statistically significant differences in the intensity of infestation of particular host species were only recorded in 5 species of water mites: *A. maculator* (H (7, N = 118) = 51.79049 ($p<0.0001$)), *A. cuspidator* (H (7, N = 118) = 63.96197 ($p<0.0001$)), *A. batillifer* cf. (H (7, N = 118) = 20.65077 ($p = 0.0043$)), *A. papillator* (H (7, N = 118) = 108.5866 ($p<0.0001$)), and *A. tricuspidator* (H (7, N = 118) = 78.90657 ($p<0.0001$)).

No clear differences were observed in the infestation of both sexes in particular host species (Fig. 1). Such differences are visible in relation to particular parasitic species, whereas the general rule is more frequent but less intensive infestation of males than females (Fig. 2). Exceptions are *A. bicuspidator* and *A. tricuspidator*, infesting males more intensively, as well as *A. bruzelii*, *A. batillifer* cf., and *A. tetracyphus*, usually infesting females (Fig. 2). Statistically significant differences in infestation of both sexes of the host were obtained for: *A. cuspidator* (H (1, N = 83) = 6.895266 ($p = 0.0086$)) and *A. tetracyphus* (H (1, N = 7) = 3.962264 ($p = 0.0465$)). *A. maculator* was close to such significance (H (1, N = 73) = 3.238448 ($p = 0.0719$)).

Clear statistically significant differences were observed in the intensity of infestation of particular body parts of the hosts (H (12, N = 2496) = 639.6571 (p<0.0001)). The general rule was preference for thoraxal segments, followed by the first abdominal segments and middle abdominal segments. On *Coenagrion puella* and *C. pulchellum*, parasites were mainly located on thoraxal segments and frontal abdominal segments, on *Leucorrhinia caudalis* mainly on thoraxal segments, on *Erythromma najas* mainly on rear abdominal segments, on *Anax imperator* on the metasternum and rear abdominal segments, and on *Lestes dryas* exclusively on the metasternum (Table III). Statistically significant differences occurred only for *Coenagrion puella* (H (12, N = 507) = 62.12614 (p<0.0001)), *C. pulchellum* (H (12, N = 1313) = 555.9424 (p<0.0001)), and *Lestes dryas* (H (12, N = 156) = 127.2141 (p<0.0001)).

Among the parasitic species recorded, five of them (*Arrenurus papillator*, *A. bicuspidator*, *A. bruzelii*, *A. cuspidator*, and *A. tetracyphus*) were almost exclusively located on thoraxal segments (previous Kruskal-Wallis test: H (12, N = 169) = 143.5463 (p<0.0001); H (12, N = 52) = 33.22485 (p = 0.0009); H (12, N = 104) = 82.66020 p<0.0001; H (12, N = 1014) = 632.8934 (p<0.0001); H (12, N = 91) = 37.91304 (p = 0.0002)), and in the case of very intensive infestation (*A. cuspidator*), they also moved to the first abdominal segments and neck and head. *A. maculator* was located on thoraxal segments and the first half of the abdomen (H (12, N = 780) = 383.6421 (p<0.0001)), *A. batillifer* cf. on the thorax and segments of the rear half of the abdomen (H (12, N = 26) = 13.60502 (p = 0.3266)), and *A. tricuspidator* exclusively on the rear half of the abdomen (H (12, N = 26) = 13.60571 (p = 0.3266)) (Table III). In the case of *A. batillifer* cf., parasitizing on abdominal segments was only limited to *Anax imperator* (Table I, II). The distribution of *Arrenurus maculator* and *A. cuspidator* on the body of the hosts was interesting. Occurring individually on a given host, they preferred thoraxal segments, and particularly the mesosternum and the frontal part of the metasternum. In the case of co-occurrence on the same host, *A. cuspidator* was located on the mesosternum and the frontal part of the metasternum, and *A. maculator* mainly on the rear part of the metasternum and abdominal segments. Only in one case, *A. maculator* occurred on the mesosternum, and *A. cuspidator* on the metasternum.

The body size of water mite larvae varied from 147 to 1846 μm. The widest range of the values occurred for *A. papillator*. It was also distinguished by the largest larvae and the largest mean body size and median body size. Relatively wide ranges of body size and presence of larvae with large sizes were also typical of *A. cuspidator*, *A. bicuspidator*, and *A. tricuspidator*. *A. cuspidator* and *A. bicuspidator* were distinguished by relatively low values of the average and median, and *A. tricuspidator* by high values. The remaining parasitic species were distinguished by smaller

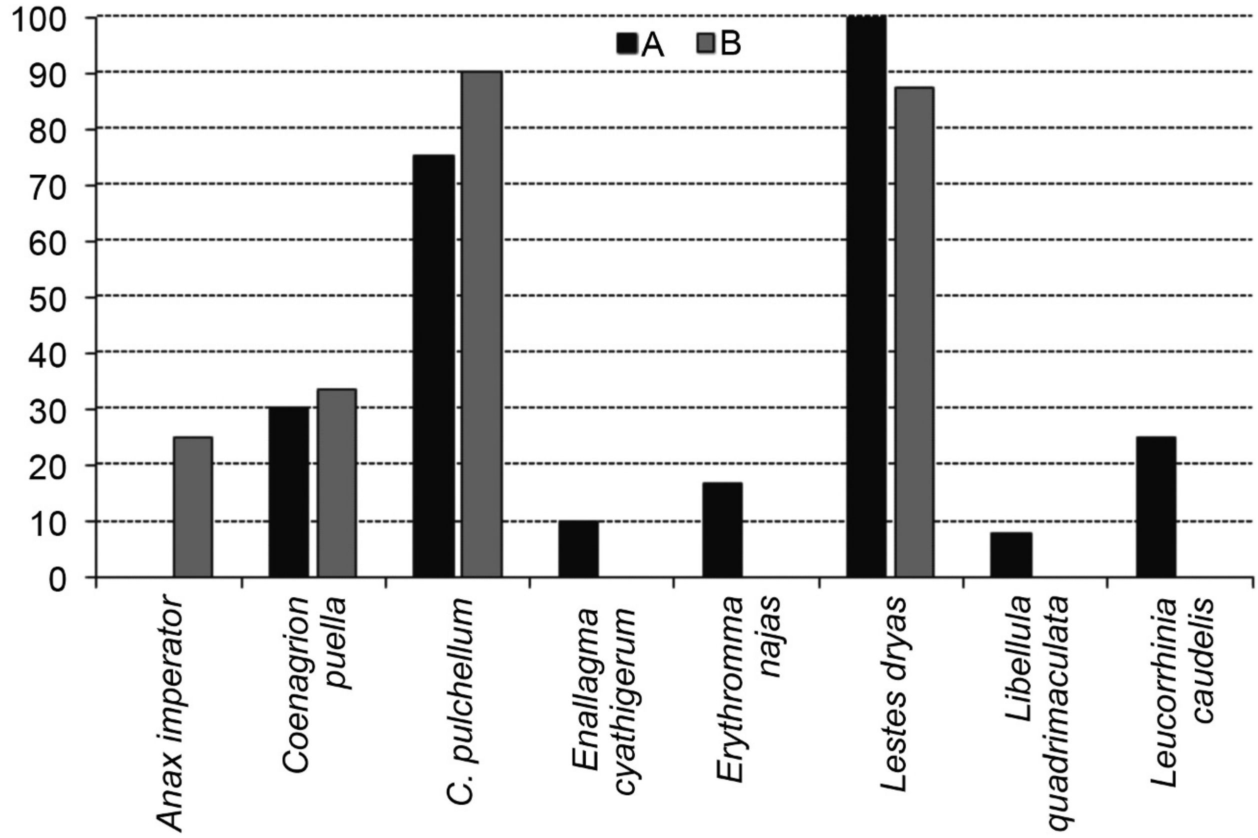

Fig. 2. Mean number of parasitic specimens on one specimen of particular host species. A – males, B – females

ranges of larval body size, and lower values of the average and median (Table III).

The analysis of the number of larvae with varied body sizes revealed that four species (*A. bicuspidator*, *A. bruzelii*, *A. cuspidator*, and *A. tetracyphus*) had two density peaks (the smallest and largest larvae), two species (*A. batillifer* cf. and *A. maculator*) were distinguished by the prevalence of larvae with the smallest body sizes, and two species (*A. papillator* and *A. tricuspidator*) by the prevalence of the largest larvae (Fig. 1).

Discussion

In the Lake Świdwie reserve, 9 species of water mites from subgenus *Arrenurus s. str*. were recorded at the stage of parasitic larva on adult Odonata. The number is high in comparison to the areas studied in those terms before, where 4–7 species were recorded (Baker *et al.* 2006, 2007, Zawal and Dyatlova 2006, 2008, Zawal and Szlauer-Łukaszewska 2012). This suggests high species diversity of the parasites analysed in the study area.

All *Arrenurus s. str*. species (*A. batillifer* cf., *A. cuspidator*, *A. maculator*, *A. bicuspidator*, *A. tricuspidator*, *A. bruzelii*, and *A. tetracyphus*) recorded as imagines in the Lake Świdwie reserve (Zawal unpubl. data) were also recorded at the stage of parasitic larva. Two other species were also recorded at this stage. This suggests that studying the parasitism of water mite larvae on dragonflies is a good method for supplementing faunistic studies from a given area, especially that sometimes results obtained by those methods are very divergent (Buczyński *et al.* 2012, Zawal and Szlauer-Łukaszewska 2012).

A very high percentage of infested species (66.7%) was recorded among dragonflies occurring in the study area. The exceptionally high degree of concordance of lists of species of water mites and dragonflies recorded in the field with the list of species remaining in mutual parasitic relations, with simultaneous record of parasitism exclusively in June, suggests a high degree of synchrony of the development of water mites and dragonflies, resulting in shortening of the infestation period. It is an untypical phenomenon, because in majority of cases, the infestation period extends over even several months (Kulijer *et al.* 2012, Mitchell 1965, Münchberg 1935, Stechmann 1976/77, 1978, Zawal 2004a, b, 2006a, b, Zawal and Dyatlova 2006). This probably results from the character of Lake Świdwie which is a shallow water body with very diversified vegetation, located among fens. The diversity of vegetation results in high species diversity of fauna. The low depth and open area result in fast warming of the water on sunny days, particularly in spring and early summer months, when the rush vegetation is still not fully developed. Temperature is probably the synchronising factor.

High prevalence of hosts and high intensities of their infestation were only recorded for three species: *Coenagrion pulchellum*, *C. puella*, and *Lestes dryas*. The remaining dragonfly species were scarce. Therefore, the analysis of infestation would be unreliable. *Coenagrion pulchellum* and *C. puella* are among dragonfly species with the most extensive distribution in the study area (Buczyński 2012, Buczyński and Zawal 2007, 2012, Dąbkowski *et al.* 2007, Mrowiński and Zawal 2004, Musiał 1988, Zawal *et al.* 2004) as well as throughout Poland and Europe (Bernard *et al.* 2009, Dijkstra 2006) – and are almost always intensively infested. The degree of infestation, however, is usually much lower (Baker *et al.* 2006, 2007, 2008, Kulijer *et al.* 2012, Zawal 2004a, 2006a, b, Zawal and Dyatlova, 2008, Zawal and Szlauer-Łukaszewska 2012). The high degree of infestation in the Lake Świdwie reserve is probably caused by the aforementioned synchrony of the infestation period resulting from a uniform, fast increase in water temperature in the entire lake studied. The very high degree of infestation of *Lestes dryas* is somewhat surprising. According to literature data, the species should be infested much more seldom (Baker *et al.* 2007, Zawal 2004a, 2006a). This results from the fact that all of the captured specimens of the species came from one locality, which additionally strengthened the synchrony of the infestation period.

Among the dragonfly species analysed by us, three were recorded for the first time as hosts of water mite larvae: *Anax imperator*, *Libellula quadrimaculata*, and *Leucorrhinia caudalis*. Zawal 2004b observed phoretic larvae of *Arrenurus* sp. on a *Libellula quadrimaculata* larva. Therefore, our data can be treated as a confirmation of the parasitism. It generally seems that Anisoptera are infested by water mites much less intensively than Zygoptera (Åbro 1990, Baker *et al*. 1991, Cassagne-Méjean 1966, Davids 1997, Kulijer *et al.* 2012, Mitchell 1959, 1969, Münchberg 1936, 1963, Smith 1978, Stechmann 1976/77, 1978, Zawal 2004a, b, 2006a, b, Zawal and Szlauer-Łukaszewska 2012). Larvae of *Arrenurus s. str*. as parasites are clear opportunists, and treat Anisoptera as facultative hosts. Exceptions are *Arrenurus papillator* and *A. pustulator*, preferring host species from genera *Cordulia* Leach and *Sympetrum* Newm. (Cassagne-Méjean 1966, Davids 1997, Münchberg 1936, 1963, Stechmann 1976/77, 1978, Zawal and Jaskuła 2008), although their parasitism was also recorded on Zygoptera (Davids 1997, Zawal and Dyatlova 2006). The opportunism of *Arrenurus s. str*. water mite larvae is confirmed by the fact that the highest number of parasitic species in the Lake Świdwie reserve was recorded on the most numerous and most frequently encountered dragonfly species (*Coenagrion pulchellum*, *C. puella*).

Majority of water mite larvae found (*Arrenurus maculator*, *A. cuspidator*, *A. bicuspidator*, *A. tricuspidator*, *A. bruzelii*, *A. batillifer* cf., *A. papillator*) are species with wide spectra of host species (Davids 1997). Our data extend their lists even more: *Arrenurus batillifer* cf. was recorded for the first time on *Anax imperator*, *A. bicuspidator* on *Leucorrhinia caudalis*, *A. cuspidator* on *Lestes dryas*, *A. maculator* on *Lestes dryas*, and *A. papillator* on *Coenagrion pulchellum*.

Arrenurus claviger has been so far only known as a parasite of *Ischnura elegans* (Vander L.). In the case of *Arrenurus* *tetracyphus*, no host was known (Baker *et al.* 2006, Davids 1997, Zawal and Dyatlova 2006, 2008, Zawal and Szlauer-Łukaszewska 2012). Therefore, *Coenagrion pulchellum* is a new, second known host for *Arrenurus claviger*, and *Coenagrion puella*, *C. pulchellum*, and *Libellula quadrimaculata* constitute a list of host species for *Arrenurus tetracyphus*.

In spite of the existence of statistically significant differences in the intensity of infestation by particular parasitic species, it is too early at the present stage of the study to identify their clear preferences towards host species. Certain suggestions can only be provided in relation to *Arrenurus maculator* which seems to prefer *Coenagrion puella* as a host, and for *Arrenurus cuspidator* preferring *Coenagrion pulchellum*. This is confirmed by earlier data according to which *C. pulchellum* was much more intensively infested by *Arrenurus cuspidator* than by *A. maculator* (Zawal and Dyatlova 2008). Also those suggestions, however, require confirmation in our studies.

Neither the literature data nor those obtained in this study provide a uniform image in relation to the infestation of dragonflies of differing sexes. Zawal (2004a), Baker *et al.* (2008), and Zawal and Dyatlova (2008) presented data suggesting clear preferences in relation to the infestation of females in *Coenagrion puella* and *C. pulchellum*. However, they were not confirmed in other papers (Zawal 2006a, b). It seems that the degree of infestation of sexes depends on a number of local conditions, such as: the number of parasites and hosts co-occurring in a given environment, the degree of synchronisation of hatching of parasites and transformation of hosts, and the structure of the host's population. The determination whether the preference of parasites towards the sex of the hosts exists can only occur by means of the analysis of a large amount of data from various environments, or by means of an experiment.

Differences in infesting particular body parts of hosts can depend on several factors (Baker *at al*. 1991, Zawal 2003b): preferences of particular parasitic species, availability of space for parasitizing, trophic differences on particular body parts of the host, diversity of mortality of parasites, competition between parasitic species, or the simple order of taking places by parasites. They can also constitute a compilation of such factors. Because no differences in the size of parasites occurring on various body parts of the host were observed, the thesis on trophic differences was not confirmed, and all the remaining ones seem to be equally probable. Based on the results obtained and literature data (Baker *et al.* 2007, Zawal 2004a, 2006a, Zawal and Dyatlova 2008), two types of hosts can be distinguished: with parasites on the thorax and the first abdominal segments, and with parasites on the thorax and rear abdominal segments. The former ones include: *Coenagrion puella*, *C. pulchellum*, *Lestes dryas*, and *Leucorrhinia caudalis*, and the latter ones: *Anax imperator* and *Erythromma najas*. In the first case, the preference of parasites to inhabit the thorax can result from lower mortality of parasites located on this part of the body (legs of the dragonfly protect parasites against mechanical damage), or the order of places taken by parasites (the thorax is the first tagma of the body favourable for inhabiting which emerges from the exuvium). The first abdominal segments are inhabited next, when there's no more space on the thorax.

The material from the Lake Świdwie reserve and earlier data from stagnant waters (Baker *et al.* 2007, Zawal 2004a, 2006a, Zawal and Dyatlova 2008) suggest that particular host species are distinguished by the use by parasites of different body parts. This correlates with microhabitat preferences of host larvae, and particularly with the place and manner of laying eggs by their imagines. *Lestes sponsa* prefers environments with a vertical structure of vegetation (littoral, shallow water rush vegetation). In this species, water mite larvae inhabit almost exclusively the abdomen. *Platycnemis pennipes* larvae mainly occur among elodeids, *Ischnura elegans* among elodeids and in rushes, and their eggs are frequently laid on leaves and stems of plants located at the water surface. In this species, water mites occur on the thorax and abdomen, but prefer the abdomen. *Enallagma cyathigerum* and *Erythromma najas* prefer places with well developed vegetation with floating leaves on which imagines sit during laying eggs. Substantially more water mites inhabit thoraxal segments than abdominal segments. *Coenagrion pulchellum* occurs in water bodies with well developed submerged vegetation, used as a place of laying eggs – water mites occur almost exclusively on the thorax. Simplifying the issue, a certain rule can be determined: the more vertical position of the host during laying eggs, the more parasites are located on abdominal segments. The situation is similar in Anisoptera: water mites inhabit the rear abdominal segments of species which approximate the abdomen to water during laying eggs (*Anax imperator*). This is probably related to the species distinctiveness of parasitofauna, and the location of parasites maximising the possibility of their return to water.

The comparison of the places of attaching of particular parasitic species with the most intensively used body parts of particular host species is interesting. Parasitic species mainly attaching themselves to thoraxal segments (*Arrenurus papillator*, *A. bicuspidator*, *A. bruzelii*, *A. cuspidator*, and *A. tetracyphus*) occurred on dragonfly species in which the thorax was the most intensively infested. Those preferring rear abdominal segments (*A. tricuspidator*) occurred on dragonflies in which the abdomen was the most intensively infested. *Arrenurus batillifer* cf. occurred on the thorax of *Coenagrion puella* and *C. pulchellum*, and on the thorax and rear abdominal segments of *Anax imperator*. This comparison, based on the biology or reproduction of dragonflies, suggests the possibility of co-evolution of parasites and hosts, maximising the possibility of the return of parasites to the aquatic environment.

The co-occurrence of *Arrenurus cuspidator* and *A. maculator* at the stage of parasitic larva is also interesting. The species, if occurring separately on particular hosts, take similar places on their bodies (thoraxal segments). In the case of the co-occurrence on one host, *A. maculator* occupies further places in relation to the mesosternum. This specific "pushing" of *A. maculator* by *A. cuspidator* probably results from the competition of those two closely related species, and was mentioned earlier by Baker *et al.* 2007.

Depending on the life strategy, body growth of particular water mite species mainly occurs at the stage of parasitic larva – like in genera *Hydrachna* Müll. and *Eylais* Latr., or both at the stage of parasitic larva and deutonymph – like in genera *Piona* Koch and *Arrenurus* Dug. (Cichocka 1995, Davids 1973, 1997, Mitchell 1969, Zawal 2002, 2003a, b). Adult specimens of the species identified by us reach body sizes much larger than the largest sizes of larvae (Viets 1936). This suggests that a substantial part of growth in body size occurs at the stage of deutonymph. In comparison to earlier data (Baker *et al.* 2008, Zawal and Dyatlova 2008, Zawal and Jaskuła 2008, Zawal and Szlauer-Łukaszewska 2012), the ranges of sizes of water mite larvae in the Lake Świdwie reserve are larger, mainly in terms of maximum body sizes. This suggests that in the case of water mite species belonging to subgenus *Arrenurus s. str.*, a part of body growth larger than was thought so far – approximately 50% – occurs at the stage of parasitic larva. This particularly concerns: *A. papillator*, *A. bicuspidator*, *A. tricuspidator*, *A. bruzelii*, and *A. cuspidator*.

Parasitizing water mite larvae were only found in June. This suggests a high degree of synchronisation of the moment of infestation. Such short, synchronised infesting periods are an exceptional phenomenon resulting from uniform temperature occurring in the entire lake. The infesting period is more frequently extended in time (Kulijer *et al.* 2012, Mitchell 1965, Münchberg 1935, Stechmann 1976/77, 1978, Zawal 2004a, b, 2006a, b, Zawal and Dyatlova 2006).

In larvae of *Arrenurus batillifer* cf. and *A. maculator*, small body sizes were recorded. Therefore, infestation must have occurred relatively not long (several days) before the moment of capturing, and the larvae did not reach their full body sizes yet. For *Arrenurus papillator* and *A. tricuspidator*, larvae of various body sizes were collected. The infestation must have been more distant in time (approximately two weeks), and the larvae reached sizes permitting their further transformation. In *Arrenurus bicuspidator*, *A. bruzelii*, *A. cuspidator*, and *A. tetracyphus*, larvae of both small and large sizes were observed. This suggests two moments of infestation (infestation of dragonflies by water mites can only occur once, at the moment of metamorphosis of the dragonfly), first for small larvae and second for large ones. Analysing particular species of water mites, two different moments of infestation in the same environmental conditions can be distinguished. Species such as: *A. batillifer* cf., *A. maculator*, *A. bicuspidator*, *A. bruzelii*, *A. cuspidator*, and *A. tetracyphus* begin the period of hatching of larvae and infestation earlier than *A. papillator* and *A. tricuspidator*, whereas part of them (*A. bicuspidator*, *A. bruzelii*, *A. cuspidator*, and *A. tetracyphus*) have a second, later by approximately two weeks, period of hatching and infestation.

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