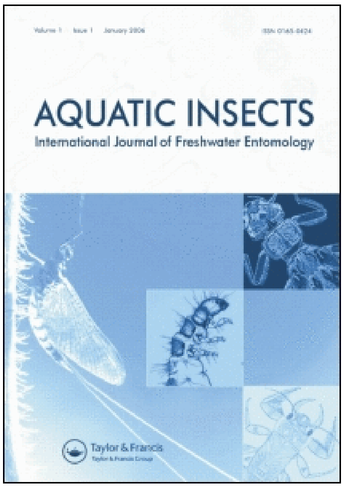

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Attachment site and infestation parameters of parasitic water mites on the whirligig beetle *Dineutus nigrior* Roberts (Coleoptera: Gyrinidae)

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Larval water mites parasitise a wide range of aquatic insects and may have a negative impact on host fitness. One host taxon susceptible to water mite parasitism is the whirligig beetle (Coleoptera: Gyrinidae). We made 11 collections of the whirligig beetle *Dineutus nigrior* Roberts from May to October of 2006 to investigate patterns of water mite parasitism on that host species. Mites were identified as of the genus *Eylais*. Mite intensity ranged from 1 to 11. Median intensity was 1.0 and ranged from 1.0 to 3.0 for individual samples. There did not appear to be temporal patterns in mite intensity. Prevalence was 30.9% but varied substantially over the sampling period ranging from 2.5 to 63.3%. Mites were attached to the metathoracic wings and the body tergites under the elytra. When all samples were considered there was equal use of wings and body tergites but there was temporal variation in the use of attachment sites.

Keywords: ectoparasitism; *Eylais*; Hydrachnidia; Hydradephaga

Introduction

Water mites (Acari: Hydrachnidia) are found in virtually all freshwater habitats. The larvae of many species are ectoparasitic, typically on aquatic insect hosts, while adults are typically free-living and predatory. Larval mites attach to the host with their mouthparts then begin to engorge by feeding on haemolymph and can negatively impact host survival and reproductive fitness (reviewed by Lanciani 1983; Smith 1988).

Water mites parasitise a wide range of aquatic insect taxa (Smith 1988), including the gregarious, surface-inhabiting whirligig beetles (Coleoptera: Gyrinidae) (e.g. Zawal 2003). Reports of water mites parasitising gyrinids are scarce (but see Svensson 1985; Zawal 2003; Fairn, Alarie and Schulte-Hostedde, in press). Here we investigate water mite parasitism on the whirligig beetle *Dineutus nigrior* Roberts. To our knowledge, water mite parasitism of this species has been reported on only one other occasion (Fairn et al., in press) and very little is known about this host–parasite system. We describe mite intensity, prevalence, and attachment site throughout the season where the host is active on the surface of the water to provide basic information about this host–parasite relationship.

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Methods

We collected adult *D. nigrior* from Swan Lake, a small lake (ca. 6 ha surface area, 8.5 m maximum depth) near Sudbury, Ontario, Canada. The lake was historically acidified by local sulphur deposition and is presently fishless. We quantified aspects of mite parasitism from 11 samples of *D. nigrior* collected from May to October of 2006, a period that encompassed the majority of the season where adults are active on the surface of the water (Istock 1966; Y. Alarie, personal observation). We used nets to opportunistically sample beetles that were observed swimming on the water surface. Specimens were transported alive to the laboratory and then euthanised with ethyl acetate fumes or 70% ethanol. We used all of the beetles collected on a particular date, or a haphazardly selected sub-sample of specimens collected. We searched the entire external body surface, the metathoracic wings, the body tergites under the elytra, and the undersides of the elytra for mites with the aid of an Olympus SZ30 dissecting microscope (Olympus, Tokyo, Japan). The number of attached mites was recorded for each beetle. We use the term intensity to refer to the number of mites on infested hosts, and prevalence to refer to the proportion of individuals infested by at least one mite. Prevalence and median intensity were calculated for each sample and for all samples pooled. Confidence intervals for prevalence were determined using Sterne's exact method (Reiczigel 2003).

Confidence intervals of prevalence were determined using the software Quantitative Parasitology 3.0 (Reiczigel and Rózsa 2001). All other analyses were performed using Statistica 6.0 (Statsoft, Inc, Tulsa, OK, USA).

Results

We examined 1223 beetles for larval mites. Sample sizes ranged from 43 to 301 and the number of infested beetles ranged from 3 to 124. We counted a total of 699 mites on hosts with 4–213 mites observed per sample (Table 1). The mites were identified as of the genus *Eylais* Latreille by Dr. Heather Proctor (University of Alberta) but could not be identified to species.

When all beetles collected over the sampling period were considered, 30.9% of specimens were infested by at least one mite. However, mite prevalence varied

Table 1. Number of beetles, number of mites, number of infested beetles, median mite intensity and range in intensity for each sample and when the samples were pooled.

Date	*n* beetles	*n* mites	*n* infested	Median intensity (IQR)	Range in intensity
May 8	301	213	106	1.5 (1.0–2.0)	1–10
May 22	70	90	36	2.0 (1.0–3.0)	1–11
June 16	87	121	55	1.0 (1.0–3.0)	1–11
June 26	196	180	124	1.0 (1.0–2.0)	1–10
July 11	79	35	23	1.0 (1.0–2.0)	1–3
July 25	84	20	9	1.0 (1.0–4.0)	1–5
August 21	95	10	4	3.0 (2.0–3.0)	1–3
September 4	159	5	4	1.0 (1.0–1.5)	1–2
September 16	61	4	3	1.0 (1.0–2.0)	1–2
October 4	48	13	9	1.0 (1.0–2.0)	1–3
October 21	43	8	5	2.0 (1.0–2.0)	1–2
All samples	1223	699	378	1.0 (1.0–2.0)	1–11

substantially over the sampling period ranging from 2.5 to 63.3% (Figure 1). There was a general trend of an increase in prevalence in the early part of the sampling period (early May to late June), a sharp decline in prevalence from early July to early September, and then a slight increase in later September to the end of October (Figure 1).

Mite intensity ranged from 1 to 11 but most infested individuals (80.2%) had only one or two mites (Figure 2).When all samples were considered, the median intensity was 1.0. For individual samples median mite intensity ranged from 1.0 to 3.0. While maximum intensity was greater in the first samples of the season there did not appear to be temporal patterns in median mite intensity (Table 1).

When all mites collected over the sampling period were considered, approximately half were on the body and half on the wings (51.5% wings, 48.5% body tergites; exact binomial test for difference from 1:1, $p = 0.761$). However, there was substantial temporal variation in the relative use of attachment sites (Figure 3). The proportion of mites on the body increased from the first sample until the July 11 sample when all mites were on the body. In the period from July 25–September 4 the majority of mites were on the wings, and then the proportion on the body began to increase until virtually all of the mites were on the body at the end of the sampling period (Figure 3).

Discussion

Mites were present on adult *D. nigrior* throughout the sampling period. However, there was substantial variation in prevalence. The increasing mite prevalence from the first sample on May 8 until mid–late June could suggest that mites were attaching to the host during that period.

The decline in prevalence in July and August may be due to the emergence of the new adult cohort. *Dineutus nigrior* emerge in summer and fall (Istock 1966) and we first observed teneral specimens at this site in early July (E. Fairn, personal observation). Members of the emerging cohort would not have had as much time to become parasitised

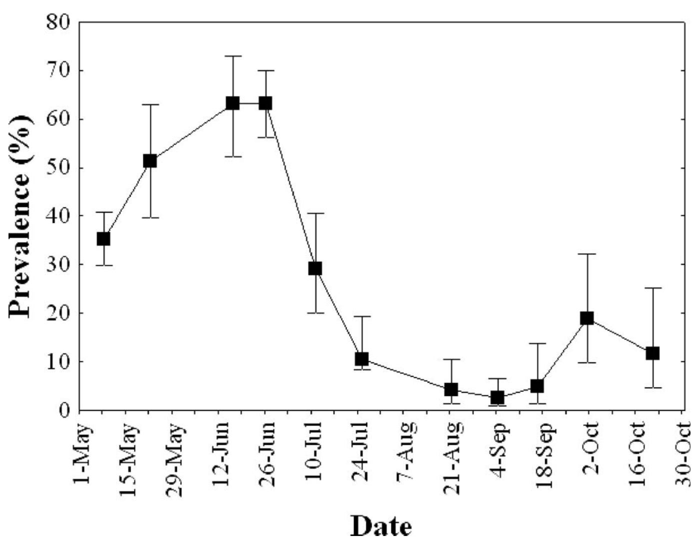

Figure 1. Temporal variation in mite prevalence in *Dineutus nigrior* population. Bars represent 95% confidence intervals.

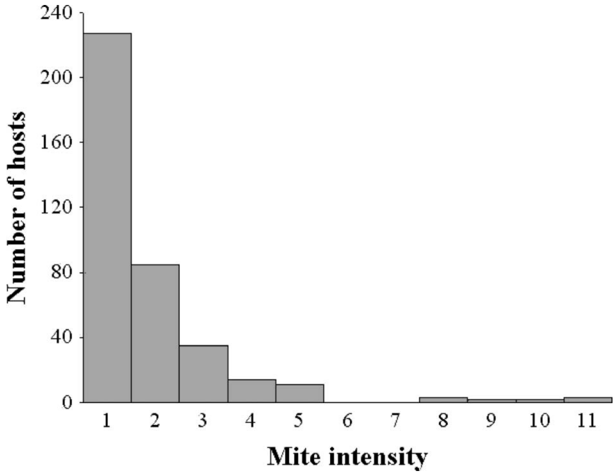

Figure 2. Frequency distribution of mite intensity on *Dineutus nigrior* hosts when all samples were pooled. $N = 378$.

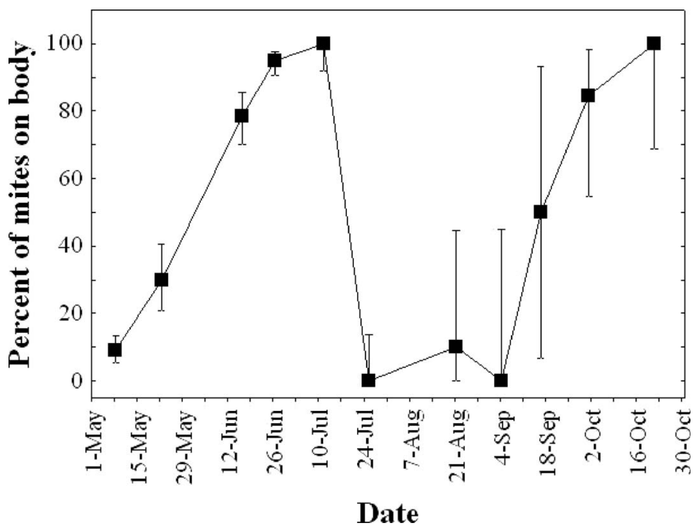

Figure 3. Temporal pattern of proportion of mites on body of *Dineutus nigrior* hosts. Bars represent 95% confidence intervals.

and thus may have lower prevalence. Thus, as the new cohort makes up a larger proportion of the adult population in the summer, mite prevalence may decrease. This decline could also be caused by mites detaching from hosts after completing engorgement as we observed mites detaching from *D. nigrior* hosts from this population starting in early July.

The slight increase in prevalence in the last two samples of the season, combined with the fact that larval mites were attached to teneral hosts in those samples (E. Fairn, personal observation), suggests that larval mites were present in the environment and attaching to members of the new cohort. *Dineutus nigrior* enter a hibernation period generally in November (Istock 1966) and some *Eylais* species that attach to hosts in the late summer and fall are known to survive the winter on the host either engorging slowly or by exhibiting developmental arrest then resuming engorgement the following spring (Lanciani 1970a). Thus, *D. nigrior* may be infested by water mites even throughout the dormant period.

The breeding season in *D. nigrior* is from approximately May to August (Istock 1966; E. Fairn, personal observation), thus mites were parasitising hosts during the reproductive period, and prevalence was relatively high for much of the mating season. There is evidence that water mites, particularly large mites such as *Eylais* and *Hydrachna* species, can totally eliminate or greatly reduce egg production (Davids and Schoots 1975; Smith 1977; Lanciani 1982). Also, male insects parasitised by mites may have decreased mating success (Forbes 1991). Thus, mite parasitism may impact reproductive fitness and sexual selection in *D. nigrior*.

Most infested hosts had low mite intensity but even low intensity may be sufficient to negatively affect host fitness. For example, there is evidence that a single mite may be sufficient to cause mortality (Smith 1977) and a reduction in egg production (Davids and Schoots 1975) in insect hosts. The potential for low mite intensity to negatively impact host fitness is particularly likely in this system as *Eylais* mites are large mites and exhibit a large degree of engorgement while on the host, and thus may have a particularly strong impact on the host (Smith 1988).

Larval *Eylais* mites are thought to require atmospheric oxygen and thus are typically restricted to the air-bathed area under the elytra (Lanciani 1970b). All mites observed on *D. nigrior* in this study were on the body tergites under the elytra or on the metathoracic wings. Mite attachment to metathoracic wings of water beetles is relatively rare (Lanciani 1970b) but is thought to be more common in species that inhabit permanent water bodies as dispersal is likely less important (Lanciani 1970b). Mites attached to the metathoracic wings could directly interfere with flight ability and as gyrinids use flight for dispersal (van der Eijk 1983), mite parasitism could prevent or impede dispersal in *D. nigrior*.

The cause of the temporal variation in attachment site is not known. Some *Eylais* species exhibit attachment site specificity on water beetle hosts (Lanciani 1970a,b). Thus, there could be multiple *Eylais* species infesting this population of *D. nigrior*, one or more that attach to the metathoracic wings, and one or more that attach to the body. If these species exhibit different phenology then it could result in the observed temporal variation in attachment site. Mite species that attach to the wings may evolve a life cycle where parasitism occurs during periods when the air temperature is too low to be conducive to flight to decrease the risk of being damaged or detached when the host flies (Lanciani 1970b). For example, *Eylais harmani* Lanciani attaches to the wings of water beetle hosts but detaches from the host in early spring before the air temperature increases sufficiently to allow efficient flight (Lanciani 1970b). This may account for the heavier utilisation of wing attachment sites in the early in this system. However, it is also possible that these beetles were parasitised by one or more *Eylais* species that are not attachment site specific. In this case the temporal variation in attachment site use could be due to preference for one site over the other, shorter engorgement duration on one attachment site, or seasonal change in optimal attachment site.

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