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Research Note

Trematode parasites as indicators of an animal component in the diet of the Water Vole *Arvicola amphibius*

A. M. MCCARTHY*, J. C. LITTEN-BROWN, M. A. COLLINS

Higher Education Animal Sciences, Canterbury College (East Kent College Group), New Dover Road, Canterbury, Kent, CT1 3AJ, United Kingdom, *E-mail: *andrew.mccarthy@eastkent.ac.uk*

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Summary

The intestinal trematode fauna of the Water Vole *Arvicola amphibius*, (previously *A. terrestris*), was investigated to determine whether it might provide evidence of an animal component in the diet of this aquatic herbivorous small mammal. Interrogation of the electronic Host-Parasite Database of the Natural History Museum London revealed the presence of fourteen species of intestinal trematode in water voles, infection with each of which would require the ingestion of tissue from an animal intermediate host. The results obtained using these parasite indicators provide convincing evidence of animal components in the diet of *A. amphibius* and support anecdotal reports of water voles feeding on animal material in the field.

Keywords: Trematodes; Parasite Indicators; *Arvicola amphibius; Arvicola amphibius*; Host Diet; Rodents; Cricetidae; Intestinal Helminths

Introduction

Parasites have long been used as indicators to provide information on numerous facets of the biology of their hosts. For example, Williams *et al*. (1990) provide a review of studies of the use of parasites as biological indicators of the population biology, migrations, phylogenetics and diet of fish species. A recent study Preti *et al*. (2020) used spiral valve parasites of Blue Shark *(Prionace glauca)* and Common Thresher Shark *(Alopias vulpinus)* as indicators of the feeding behaviour and ecology of their hosts. In the present communication we report on a study which set out to determine whether the intestinal trematode parasites of the Water Vole, *Arvicola amphibius* (formerly *Arvicola terrestris*), might be used to provide evidence of an animal component in the diet of this mammal. *A.amphibius* is a small aquatic rodent with a widespread geographical distribution across the northern Palaearctic region from northern Spain and mainland Britain, through Scandinavia and across Russia to eastern Siberia (Woodroffe *et al*., 2008). The species is currently of conservation concern in the United Kingdom having disappeared from ninety four percent of its former sites, this thought to be, at least in part, a result of predation by an introduced mustelid, the American Mink *Neovison vison,* (Mammal Society, 2022). The water vole's diet is described as predominantly vegetarian comprising mainly grasses, common reeds *Phragmites*, sedges and less frequently rushes and dicotyledons (nettles *Urtica dioica* and dead nettles *Lamium album*), and very exceptionally insects, molluscs, crayfish and fish (Woodroffe *et al*., 2008).

If reports of animal components in the diet of *A. amphibius* are valid then it could be expected that the intestinal helminth parasite fauna of water voles would reflect this in containing species whose transmission would depend on the ingestion of animal intermediate hosts. A paper located by one of us suggested initial support

* – corresponding author

for his hypothesis. Skvortzov (1934) working in the region of the Volga and Vetluga Rivers in Russia reported on *Arvicola terrestris* naturally infected with 37-collar-spined adult echinostome trematodes that he described as *Echinoparyphium sisjakowi*, a species which Yamaguti (1958) re-assigned to the genus *Echinostoma* and which Kanev *et al*. (1995) considered identical to *Echinostoma jurini* (Skvortzov, 1924) whose life cycle they described. The second intermediate hosts were found to be molluscs, frogs and freshwater turtles (terrapins), which suggests that infection of water voles could only occur via ingestion of such animals.

Materials and Methods

In order to further investigate the presence of trematodes with animal intermediate hosts in water voles a search was carried out of the online Host Parasite Database of the Natural History Museum London, U.K. This database comprises of a detailed computerized collection of records dating back to its origins with the helminthologist H.A. Baylis in 1922, (Gibson *et al*., 2005). The database includes more than a quarter of a million host-parasite records extracted from 28,000 references.

Initially the database was searched for all geographical localities for all trematode records using the host name *"Arvicola terrestris"*, this being the previously widely used binomial for the species now known as *Arvicola amphibius*. The latter name returned no records from the database. The helminthological literature was then searched for the details of the life cycle of each trematode species/family found, and those requiring the ingestion of an animal second intermediate or paratenic host for their transmission was noted.

Results and Discussion

The results of the database search and additional details on the intermediate hosts of each trematode species found are summarized in Table 1.

The table includes fourteen species of trematode recorded for

Table 1. Intestinal trematode parasites from the water vole *Arvicola terrestris (= Arvicola amphibius)* recorded in the Host Parasite Database of the Natural History London, together with the intermediate hosts for each species the ingestion of which would be necessary for acquisition of infection by the vole.

Trematode species (Family in brackets)	**Intermediate Host**	**Geographical Location**
Brachylaima aequans (Brachylaemidae)	Terrestrial snails	Bulgaria
Corrigia vitta (Dicrocoelidae)	Ants	United Kingdom
Alaria alata (Diplostomatidae)	Amphibians (Tadpoles and Frogs)	Asian USSR (CIS) North Baraba
Pharyngostomum cordatum (Diplostomatidae)	Amphibians and reptiles	European USSR (Russia) Volga Delta
Echinostoma miyagawi (Echinostomatidae)	Freshwater molluscs, fish	Azerbaidzhan (Zakabkazya) European USSR (CIS) Russia (Transcaucasus)
Echinostoma revolutum (Echinostomatidae)	Freshwater molluscs, fish	Ukraine Moldavia Asian USSR (CIS) North Baraba European USSR (CIS) Russia (Transcaucasus)
Euparyphium melis (Echinostomatidae) *(syn. Isthmiophora melis)*	Freshwater fish and amphibians	Asian USSR (CIS) Taimira
Isthmiophora melis (Echinostomatidae)	Freshwater fish and amphibians	Bulgaria
Posterocirrus clethrionomi Lecithodendriidae)	Aquatic insect larvae	Ukraine, Moldavia
Opisthorchis felineus (Opisthorchiidae)	Freshwater fish	USSR (CIS), Asian USSR West Siberia
Opisthorchis longissimus (Opisthorchiidae)	Freshwater fish	Kazakstan
Plagiorchis arvicolae (Plagiorchiidae)	Freshwater insect larvae and nymphs	Bulgaria, Ukraine, Moldavia, USSR (CIS)
Plagiorchis elegans (Plagiorchiidae)	Freshwater insect larvae and nymphs	Bulgaria
Plagiorchis vespertilionis (Plagiorchiidae)	Freshwater insect larvae and nymphs (Trichopteran larvae, dragonfly nymphs, ephemerid larvae, *Culex* mosquito larvae)	Asian USSR (North Baraba, Taimira)
Skrjabinoplagiorchis polonicus (Plagiorchiidae)	Freshwater insect larvae and nymphs	Ukraine, Moldavia

A. terrestris (=*A. amphibius*) requiring the ingestion of a range of animal material from freshwater invertebrates to fish and amphibians, providing evidence of an animal component in the diet. Not included in Table 1 are species of Notocotylid and Psilostome trematodes whose cercariae encyst in the external environment (eg. on aquatic vegetation) and therefore do not necessarily require the ingestion of an animal intermediate host for infection of the water vole to occur. Interestingly, although not the subject of the present study, the host parasite database also contains records from *A. terrestris* (= *A. amphibius*) of representatives of other groups of helminth gut parasites (acanthocephalan, cestode, and nematode) all which do require the ingestion of parasite transmission stages from an intermediate, or paratenic, host for infection to take place. It is both interesting, and important, to consider whether the Water Vole represents a functional definitive host for the helminth parasites shown in Table 1, or whether these occurrences simply reflect opportunistic "dead-ends" from a transmission perspective. There would seem to be nothing to suggest that *A. amphibius* does not represent a functional final host. The aquatic nature of this vole would ensure that eggs laid by adult worms in the intestine would have a good probability of being deposited in water, in the animal's faeces, thus enabling development, hatching and continuation of the aquatic life cycle. In addition, in the case of echinostomes for example it is known that cricetid rodents have been used successfully as laboratory hosts for these helminths (Huffman *et al*., 1988; Souza *et al*., 2017) suggesting their suitability as definitive hosts.

It is suggested that the results of the present study based on trematode gut parasite indicators provide convincing evidence of an animal component in the diet of water voles, thereby supporting anecdotal reports based on occasional observations of water vole behaviour in the natural environment. One such report on field observations on the Kennet and Avon Canal in Wiltshire, U.K. has provided some evidence that water voles eat frogs' legs whilst discarding the bodies (BBC, 2010). It states that this behaviour coincided with the voles' breeding season and suggested that the reason might be the procurement of a source of protein by pregnant females because their diet lacked sufficiency of this nutrient. Interestingly, the report also refers to records of sheep in low calcium environments in northern Scotland (Shetland Islands) eating wading birds in order to obtain calcium from the bones. Whilst this may be a surprising finding, Furness (1988) states that the characteristic appearance of Arctic Tern chick corpses found on the Island of Fowa was thought to be caused by predation by sheep. Similarly, on the Island of Rhum, Red Deer were observed predating Manx Shearwaters (Furness, 1988). Whilst this author believed that this was in order to obtain calcium, a logical suggestion as bones were the main body part ingested, other minerals such as phosphorus and magnesium are more likely to be limited, apart from during lactation or when actively growing antlers, according to Bazely (1989).

The inclusion of an animal component in the diet of what were once thought to be exclusively herbivorous mammals is an interesting phenomenon. The data presented in the present study based on intestinal trematode indicators would seem to leave little doubt that such occurs in the case of water voles. However, the extent to which it occurs, and under what circumstances, in this species will likely only be known through future detailed field observations. It may also be the case that approaches other than field observations, such as stable isotope biogeochemistry, might be employed to address the question of obligatory herbivory versus opportunistic omnivory.

Conflict of Interest Statement

The authors declare no conflicts of interest in the preparation of this paper.

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