

The role of *Bithynia tentaculata* in the transmission of larval digeneans from a gravel pit in the Lower Thames Valley

N.J. Morley*, M.E. Adam and J.W. Lewis

School of Biological Sciences, Royal Holloway, University of London,
Egham, Surrey, TW20 0EX, UK

Abstract

The freshwater snail, *Bithynia tentaculata* (Gastropoda: Prosobranchia), is frequently found in gravel pits and its role in the transmission of larval digeneans was assessed in one of these unstable water bodies from the Lower Thames Valley (UK) from June 1982 to December 1984. Eight species of cercarial and five species of metacercarial infections were reported from *B. tentaculata*, with up to 7.7% and 4.7% prevalence of infections, respectively, occurring in the snail, making it the most important host at this site. Seasonal peaks in cercarial infections occurred in late autumn/early winter but little seasonality was apparent in the occurrence of metacercarial infections. The life history characteristics of both hosts and parasites, which can affect intramolluscan digenean dynamics, are discussed.

Introduction

Gravel pits in south-east England are relatively young and unstable water bodies with hard and calcium-rich water. They do not stratify, are well oxygenated throughout the year, and are more or less sealed basins, the water being added by rain, springs, or slow seepage and filtration of ground water. The pits often have a steep sided profile and, due to rapid erosion, the zone of emergent and shallow water plants is narrow and discontinuous (Powell & South, 1978).

Some groups of molluscs are characteristic of certain types of habitat (Boycott, 1936; Macan, 1950) and larval digeneans can be considered as a potential ecological force in structuring freshwater communities (Gerard, 2001). Parasites in general may modify the outcome of competition between host species (Price *et al.*, 1986) and, in particular, digeneans can influence both the physiology and metabolism of their snail host (e.g. Hurd, 1990) which may have consequences for the life history of the host. However, transmission of digeneans is regulated directly and indirectly by the physical instability of the freshwater

environment and characteristic patterns of infection cycles can be identified.

Bithynia tentaculata is a common gravel pit snail (Powell & South, 1978). As such, evaluating its role in the transmission of larval digeneans in these unstable and artificially created water bodies would provide valuable information on snail–parasite relationships. The present paper is a continuation of an earlier study on the role of lymnaeid snails in the transmission of larval digeneans (Adam & Lewis, 1993) from this gravel pit in south-east England but focusing on cercarial and metacercarial infections in *B. tentaculata*.

Materials and methods

Monthly snail samples were collected with a hand net from a gravel pit near Wraysbury, Berkshire, UK (National Grid Reference TQ013728) during 1982–83 and the last six months of 1984. The gravel pit is utilized for angling purposes and comprises two lakes, which occasionally connect during rises in the water level. The water level during seasonal heavy outbreaks of rain can increase by up to 2 m above the norm and drop by 1 m during dry spells. The water does not stratify and is well oxygenated throughout the year. The shores are mainly steep and rapidly shelf towards the bottom and are

*Fax: +44 (0)1784 434326
E-mail: n.morley@rhul.ac.uk

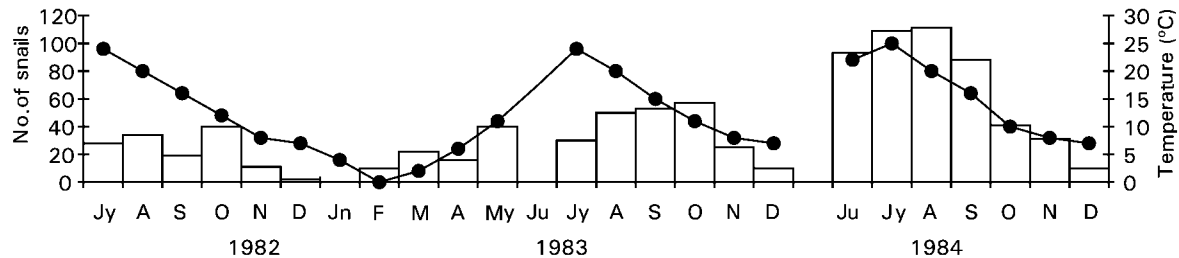


Fig. 1. The monthly abundance of *Bithynia tentaculata* and water temperature in the gravel pit, Wraysbury, July 1982 to December 1984. No samples were taken in June 1983.

consolidated with stones and cobbles to prevent erosion. The habitat is rich in fauna including a range of zooplankton, fish and birds. There is a dry gravel pit in close proximity used as a refuse tip which attracts large numbers of birds.

Within 24 h of being transferred to the laboratory, snails were examined individually in beakers of water for emerged or emerging cercariae, the morphology and behaviour of which were noted. Infected snails were then dissected and the soft tissues transferred to watch glasses containing 0.7% saline. Larval digeneans, including rediae, sporocysts and metacercariae, were examined alive and fixed in 4% formalin. Immature or naturally emerging cercariae were anaesthetized for 10–15 min in 50 ml of distilled water containing one or two drops of 0.1% Nile blue sulphate or neutral red solutions. Various stages and species of larval digeneans were identified after Harper (1929), Khan (1960, 1961, 1962), Nasir & Erasmus (1964) and Blair (1977). Results were analysed with UNISTAT 4.5 using a Spearman Rank correlation coefficient.

Results

Bithynia tentaculata, which comprised 44% of the molluscan fauna recovered during the sampling period, was the most dominant species, with the remaining molluscan species forming only 15% or less of the population and included, in order of those most frequently occurring, *Planorbis carinatus*, *Sphaerium corneum*, *Lymnaea auricularia*, *L. peregra*, *P. planorbis*, *P. corneus*, *L. stagnalis* and *L. palustris*. The *B. tentaculata* population increased during the summer before slowly decreasing as winter approached (fig. 1).

Up to 7.7% of *B. tentaculata* harboured cercarial infections with eight species of cercariae occurring mainly in the larger snails in the size range of 8–12 mm. The most frequently occurring cercariae included *Notocotylus triserialis* Diesing 1839, *Cercaria albinea* Khan, 1960, *Cercaria parvus* Khan, 1961, *Cercariaeum bithynea* Khan, 1962, *Cercariaeum internale* Khan, 1962, *Cercaria Microcercous* sp., *Cercaria tarda* Khan, 1961, and *Cercaria C* Szidat 1924. No particular type of cercariae dominated and included were

examples of furcocercous cercariae (*Cercaria C*), microcercous cercariae (*Cercaria Microcercous* sp.), xiphidocercariae (*Cercaria parvus* and *C. tarda*), gymnocephalous cercariae (*Cercaria albinea*), monostome cercariae (*N. triserialis*) and the tail-less cercariaeum (*Cercariaeum internale* and *C. bithynea*).

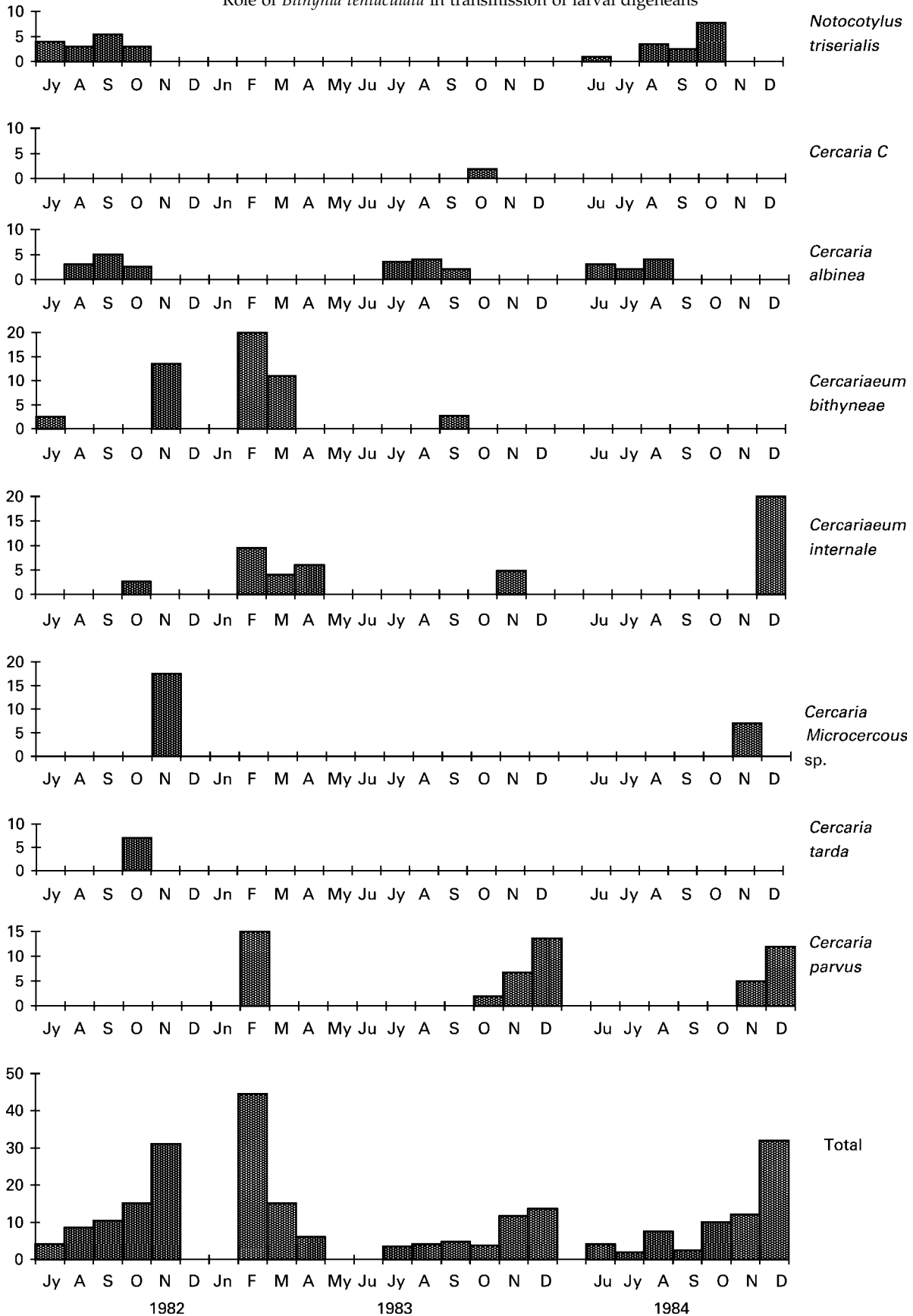
Some cercarial species showed a seasonal pattern of occurrence over the sampling period with both *N. triserialis* and *C. albinea* occurring mainly during the late summer, and *C. parvus* during the early-mid winter (fig. 2). Other species occurred intermittently or were only rarely found in isolated months. Overall, the cercarial occurrence peaked during late autumn and early winter. No cases of concurrent infections were recorded from any snail host. There was a significant positive correlation between *B. tentaculata* abundance and cercarial prevalence ($r_s = 0.4356$, $P = 0.0148$), which also occurred for two other snail species, namely *Lymnaea peregra* and *L. auricularia*, both of which are predominantly utilized by digeneans in the gravel pit ($r_s = 0.8613$, $P < 0.0001$ and $r_s = 0.8291$, $P < 0.0001$ respectively).

Bithynia tentaculata was the most widely utilized second intermediate host in the molluscan population with up to five species of metacercariae being recorded, resulting in a prevalence of 4.7%. In all molluscan species the prevalence values of metacercariae increased with host size and in most cases only the upper third of the size classes (8–12 mm) was infected. The dominant species were 'echinostome' metacercariae, followed by *C. bithynea*, *C. internale*, *C. albinea*, *Asymphyllodora tincae* Modeer, 1790, and *C. Microcercous* sp.

Despite *B. tentaculata* being the most widely utilized second intermediate host, there was little pattern shown in the prevalence of infections apart from 'echinostome' metacercariae. Echinostomes were mainly found in the late summer–early autumn and were most frequent, though discontinuous, during 1983 (fig. 3) with mean monthly prevalence values being relatively higher during 1982/83 compared with 1984. The intensity of 'echinostome' metacercarial infections was low, with a mean of 0.08 (range 1–16 cysts). The majority of other metacercarial species showed intermittent or single occurrences during the sampling period (fig. 3) and there was no

Fig. 2. The monthly prevalence of cercarial infections in *Bithynia tentaculata* in the gravel pit, Wraysbury, July 1982 to December 1984. No samples were taken in June 1983.

Role of *Bithynia tentaculata* in transmission of larval digeneans



correlation between *B. tentaculata* abundance and metacercarial prevalence of infections ($r_s = 0.2251$, $P = 0.1397$), which was in contrast to the positive correlation recorded in *L. peregra* ($r_s = 0.7697$, $P = 0.0002$), *L. auricularia* ($r_s = 0.8053$, $P < 0.0001$) and *Sphaerium corneum* ($r_s = 0.6963$, $P = 0.0001$).

Discussion

The gravel pit at Wraysbury bears the features of a eutrophic lake, with abundant vegetation and a relatively rich variety of fauna. The diverse molluscan population found at this site is characteristic of eutrophication (Boycott, 1936). Over the course of the sampling period the site exhibited a wide range of temperatures (0–25 °C) and fluctuating water levels providing an unstable environment for the resident invertebrate and vertebrate community. The high abundance of *B. tentaculata* in comparison with other molluscs is likely to be associated with the oxygen levels in the water being more suitable for prosobranch molluscs. *Bithynia tentaculata* demonstrated an increasing abundance over the sampling period and this species population overall was found to be univoltine and iteroparous. Calow (1978) considered such a situation to be due to an increase in reproduction by parent snails with much less reproductive effort than in semelparous conditions.

It is clear from the present study that seasonal changes in the monthly prevalence of cercarial and metacercarial infections in *B. tentaculata* are related to seasonal temperature and the abundance and changing size structure of the snail population. These results are comparable with the seasonal changes in the prevalence of digenean infections at this site reported for *Lymnaea auricularia* and *L. peregra* (Adam & Lewis, 1993). However, *B. tentaculata* demonstrates an obvious peak in prevalence during the late autumn/early winter period, which does not occur in the case of lymnaeids (Adam & Lewis, 1993). There is a high degree of first intermediate host specificity between the digeneans and *B. tentaculata*, with little evidence of host switching between other molluscan species. The life cycles of most of these cercariae also follow different courses from those occurring in the lymnaeid snails. Thus *Cercariaeum* spp., *Cercaria Microcercous* sp., and *C. albinea* have unknown life cycles, but for *Cercariaeum* spp. and *C. albinea* they are likely to be autogenic (permanent species with entire life cycles within the aquatic ecosystem) with the definitive host probably being fish (Williams, 1980). Fish are also definitive hosts of *Asymphylogora tincae* (Evans, 1978; Van de Broek & de Jong, 1979), whilst on the other hand *Notocotylus triserialis*, *Cercaria parvus* and *C. tarda* are allogenic parasites (life cycle using temporary resident vertebrate host species) of birds (Pike, 1968). The occurrence of the allogenic species *Cercaria C* (syn. *Diplostomum pseudospathaceum*) in the month of October

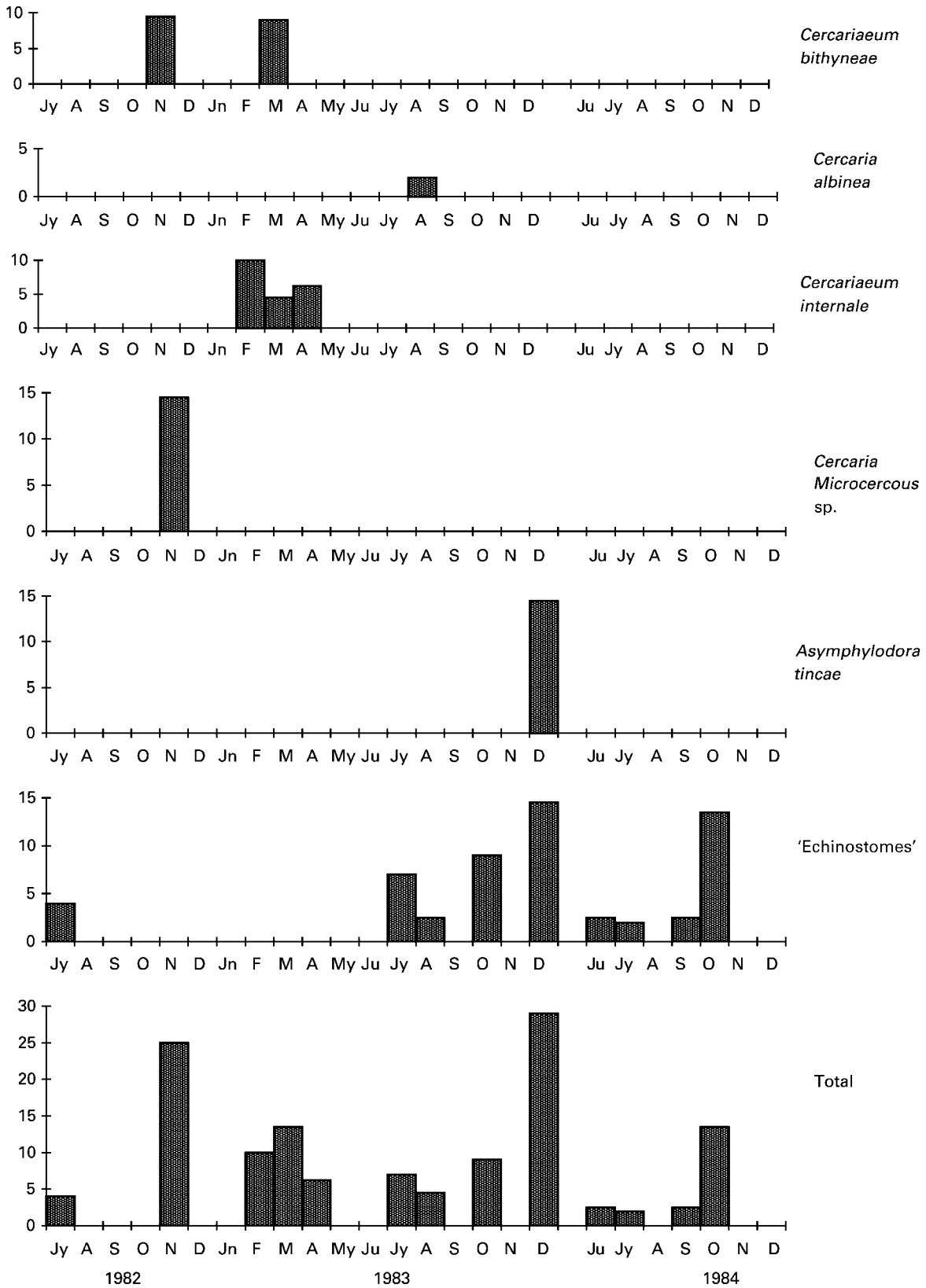
1983 is unusual as *B. tentaculata* is an atypical host for this digenean, which is normally restricted to lymnaeid snails (Niewiadomska, 1996). The latter population did not significantly decline during the month of October (Adam & Lewis, 1993), yet no infections with *Cercaria C* (referred to as *Diplostomum spathaceum* in their study) were reported. The reasons for its single occurrence within the *B. tentaculata* population therefore remains unknown.

'Echinostomes' were found to be the most prevalent metacercariae within *B. tentaculata*. Yet this snail species is not the first intermediate host for any echinostome species in the Wraysbury gravel pit so that all metacercariae found within the tissues of *B. tentaculata* must have originated from infected snails in the surrounding water. Only the lymnaeids *L. auricularia* and *L. peregra* were the first intermediate hosts for echinostomes in this locality and they included *Echinoparyphium recurvatum*, *Echinostoma revolutum*, *Hypoderaeum conoideum* and *Cercaria Z* (Adam & Lewis, 1993).

The occurrence of an independent larval digenean fauna in *B. tentaculata* has previously been observed in other types of aquatic habitats (e.g. Wesenberg-Lund, 1934). Indeed there are general transmission features of digeneans which are related to various types of standing water with the number of cercarial species increasing with the number of host species (Wesenberg-Lund, 1934). However the prevalence of cercarial infections is usually low in large lakes compared to small pools where there are commonly fewer host species but the prevalence of infection can be high (Crews & Esch, 1986). Brown *et al.* (1988) considered that habitat predictability, as emanates from the seasonal hydrodynamic features of the water body, has a major regulatory role in determining levels of infection. Despite the unstable nature of the gravel pit at Wraysbury, the diversity of the digenean fauna of *B. tentaculata* is comparable with other studies in standing water types. However, the relatively steep shores and deep water of the gravel pit would appear to reduce the overall prevalence of infection in the molluscan population compared to shallower localities which attract more wildfowl and wading birds.

The seasonal occurrence of sporocyst-developing cercariae (*C. tarda*, *C. parvus*) in *B. tentaculata* coincided with the absence of redia-developing cercariae (*N. triserialis*, *C. bithynea*, *C. internale*, *C. albinea*) and were usually less prevalent. This may be the result of active antagonism between the two types of intramolluscan stages. The prevalence of sporocysts appears to decline with the appearance of redia in the molluscan population and may be a feature of certain snail-digenean communities (Heyneman & Umathevy, 1968). This could be associated with predation by rediae on the intramolluscan stages of other digenean species (Lie *et al.*, 1965) or to the availability of the definitive

Fig. 3. The monthly prevalence of metacercarial infections in *Bithynia tentaculata* in the gravel pit, Wraysbury, July 1982 to December 1984. No samples were taken in June 1983.



host, with peaks in digenean prevalence being associated with optimum seasonal activity of the host population.

The restriction of larval digenean infections, whether active or passive, to large sized snail hosts is an important transmission feature in relation to snail population dynamics. Apart from host density, the suitable size range of intermediate hosts is decisive and, in the case of *B. tentaculata* infections, these were present in only the top third of size classes. This may be due to 'gigantism' of the molluscan host induced by the larval digeneans or mortalities of juvenile snails resulting from cercarial or miracidial invasion. Nevertheless, for metacercariae which depend on the snail host being eaten by the definitive host, a larger second intermediate host is an advantage because it can be more easily spotted by the target host.

Although the prevalence of cercarial and metacercarial infections in *B. tentaculata* is close to that of its lymnaeid counterparts in the Wraysbury gravel pit, the intensity of infections is low, even though it is the most abundant snail species. The presence of only a small number of intramolluscan stages, both cercarial and metacercarial, in the visceral mass may be due to effective host immunity or to a demographic requirement of the parasite infra-populations avoiding any overcrowding of successive stages in the host.

There are several factors limiting the transmission of larval digeneans in molluscan intermediate hosts in the Wraysbury gravel pit. The majority of digeneans are parasites of birds associated with water bodies. The natural density of birds in the Wraysbury region is low because the area is densely populated and urbanized. The gravel pit itself is used for angling purposes and is unsuitable as a feeding ground for birds because of its depth and steep sides. This prevents any significant aggregation of birds around the water body and therefore contact between snail hosts and parasites is reduced. This may explain the discontinuous occurrence of certain digenean species during the sampling period, which in turn may be related to the temporary residency by migratory birds or birds visiting the nearby rubbish pit. Therefore it can be seen that even when the molluscan population is large and diverse, presenting a good range of potential hosts for numerous and diverse parasite transmission strategies, gravel pits are not ideal locations for the transmission of larval digeneans.

References

- Adam, M.E. & Lewis, J.W. (1993) The role of *Lymnaea auricularia* (Linnaeus) and *Lymnaea peregra* (Muller) (Gastropoda: Pulmonata) in the transmission of larval digeneans in the lower Thames Valley. *Journal of Molluscan Studies* **59**, 1–6.
- Blair, D. (1977) A key to cercariae of British strigeoids (Digenea) for which the life cycles are known, and notes on the characters used. *Journal of Helminthology* **51**, 155–166.
- Boycott, A.E. (1936) The habitats of freshwater Mollusca in Britain. *Journal of Animal Ecology* **5**, 116–186.
- Brown, K.M., Leathers, B.K. & Minchella, D.J. (1988) Trematode prevalence and the population dynamics of freshwater pond snails. *American Midland Naturalist* **120**, 289–301.
- Calow, P. (1978) The evolution of life-cycle strategies in freshwater gastropods. *Malacologia* **17**, 351–364.
- Crews, A.E. & Esch, G.W. (1986) Seasonal dynamics of *Halipegus occidualis* (Trematoda: Hemiuridae) in *Helisoma anceps* and its impact on fecundity of the snail host. *Journal of Parasitology* **72**, 646–651.
- Evans, N.A. (1978) The occurrence and life history of *Asymphylodora kubanicum* (Platyhelminthes: Digenea: Monorchidae) in the Worcester–Birmingham canal, with special reference to the feeding habits of the definitive host *Rutilus rutilus*. *Journal of Zoology* **184**, 143–153.
- Gerard, C. (2001) Structure and temporal variation of trematode and gastropod communities in a freshwater ecosystem. *Parasite* **8**, 275–287.
- Harper, W.F. (1929) On the structure and life-histories of British fresh-water larval trematodes. *Parasitology* **21**, 189–219.
- Heyneman, D. & Umathevy, T. (1968) Interaction of trematodes by predation within natural double infection in the host snail *Indoplanorbis exustus*. *Nature* **217**, 283–285.
- Hurd, H. (1990) Physiological and behavioural interactions between parasites and invertebrate hosts. *Advances in Parasitology* **29**, 271–318.
- Khan, D. (1960) Studies on larval trematodes infecting freshwater snails in London (UK) and some adjoining areas. Part II. Gymnocephalous cercariae. *Journal of Helminthology* **34**, 305–318.
- Khan, D. (1961) Studies on larval trematodes infecting freshwater snails in London (UK) and some adjoining areas. Xiphidiocercariae (stylet). *Zeitschrift für Parasitenkunde* **21**, 71–87.
- Khan, D. (1962) Studies on larval trematodes infecting freshwater snails in London (UK) and some adjoining areas. Part V. Pharyngeal, longifurcate, distome furcocercariae. *Journal of Helminthology* **36**, 59–66.
- Lie, K.J., Basch, P.F. & Umathevy, T. (1965) Antagonism between two species of larval digeneans in the same snail. *Nature* **206**, 422–423.
- Macan, T.T. (1950) Ecology of freshwater Mollusca in the English Lake District. *Journal of Animal Ecology* **19**, 1–8.
- Nasir, P. & Erasmus, D.A. (1964) A key to the cercariae from British freshwater molluscs. *Journal of Helminthology* **38**, 245–268.
- Niewiadomaska, K. (1996) The genus *Diplostomum* – taxonomy, morphology and biology. *Acta Parasitologica* **41**, 55–66.
- Pike, A.W. (1968) The distribution and incidence of larval trematodes in the freshwater fauna of the Wentloog level, South Wales. *Journal of Zoology* **155**, 293–309.
- Powell, A. & South, A. (1978) Studies on the mollusc faunas of gravel-pit lakes in S.E. England. *Journal of Molluscan Studies* **44**, 327–339.
- Price, P.W., Westoby, M., Rice, B., Atsatt, P.R., Fritz, R.S., Thompson, J.N. & Mobley, K. (1986) Parasite mediation in ecological interactions. *Annual Review of Ecology and Systematics* **17**, 487–505.

Van de Broek, E. & De Jong, N. (1979) Studies on the life cycle of *Asymphylodora tincae* (Modeer 1790) (Trematoda: Monorchiiidae) in a small lake near Amsterdam. Part 1. The morphology of various stages. *Journal of Helminthology* **53**, 79–89.

Wesenberg-Lund, C. (1934) Contributions to the development of the Trematoda Digenea. Part 2. The biology of the freshwater cercariae in Danish freshwaters. *Memoires de l'Academie Royale des Sciences et des Lettres*

de Danemark, Copenhagen, Section des Sciences. 9me Serie, Tome 5 (3), 1–223.

Williams, E.A. (1980) *The morphology and development of larval digeneans from the freshwater snail Lymnaea peregra (Muller)*. PhD thesis, University of London.

(Accepted 3 October 2003)

© CAB International, 2004