Distribution of Lymnaeid Snail Hosts of the Giant Liver Fluke in Northeastern Minnesota

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Abstract

Lymnaeid snails are important intermediate hosts for many trematode parasites, such as the giant liver fluke, but little is known about their habitat associations. Lymnaeid snail surveys were conducted across St. Louis County and Lake County in 2015. 84 locations were sampled for snails and several habitat variables were measured (calcium carbonate, substrate type, lake area, pH, etc.). ArcGIS data was queried to obtain landscape variables such as cover type near sampling locations. *Lymnaea megasoma*, *L. stagnalis*, *L. elodes*, *L. catascopium*, and *Fossaria* spp. were found in the study area. *Lymnaea megasoma* *L. elodes*, and *Fossaria* spp species were associated with higher CaCO$_3$ concentrations compared to locations without these species. *L. megasoma* was associated with smaller proportions of open water on the landscape scale, suggesting this species favors quiet bays and stagnant channels. *Fossaria* spp. were not found in close association with open water suggesting this species inhabits small woodland ponds and vernal pools. No giant liver fluke cercariae were found during this survey. However, xiphidiocercariae and strigea cercariae were found in the study area. Xiphidiocercariae cercariae were not associated with higher CaCO$_3$ concentrations (mean with cercariae = 59 ppm; without cercariae = 58 ppm). Strigea cercariae were associated with higher CaCO$_3$ concentrations (mean with cercariae = 91 ppm; without cercariae = 58 ppm). Infection with either one of these cercariae decreased survival time in *L. megasoma*. *L. megasoma* warrants further study as this species is restricted to the Great Lakes basin and may be an important wildlife parasite intermediate host in this area.

Cover photo: Shells of two *Lymnaea stagnalis*, an *L. elodes*, and an *L. catascopium* at Island Lake Reservoir near Duluth, Minnesota, USA. (Photo credit: J. Trevor Vannatta).
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Introduction

The giant liver fluke (*Fascioloides magna*) is a common parasite of white-tailed deer (*Odocoileus virginianus*) and other cervids in the Great Lakes region (Pybus 2001). An infected deer sheds parasite eggs in its pellets. Then, a larval parasite emerges from the egg and infects a lymnaeid snail. The parasite’s progeny leave the snail and encyst on aquatic vegetation. Cysts are ingested by deer, migrate to the liver, mature, and begin shedding eggs (Fig. 1). Giant liver flukes primarily harm cervid hosts when migrating through the liver tissue. Although this migration triggers a mild immune response in white-tailed deer, the fluke does not appear to increase mortality in this species (Presidente et al. 1980). However, there is disagreement whether fluke infection in moose (*Alces alces*) leads to increased mortality (Murray et al. 2006, Lankester and Foreyt 2011). Moose infected with giant liver flukes can have >50% of the liver tissue damaged and flukes may introduce secondary infections (Karns 1972, Lankester 1974).

Figure 1. *Fascioloides magna* life cycle. Solid arrows indicate the normal life cycle progression. The hollow arrow indicates the dead-end host, moose, in which the parasite does not successfully reproduce.
Several basic biological questions regarding giant liver fluke and their hosts remain under-researched. In particular, the distribution and habitat requirements of lymnaeid snail hosts is poorly understood in the Great Lakes region. Despite many species of lymnaeid snails being present in the Great Lakes region, little research has suggested which species may be the primary intermediate host for giant liver fluke (Foreyt and Todd 1978, Laursen 1993, Laursen and Stromberg 1993), and distributional data for these species is only available at a coarse scale (Baker 1911, Hubendick 1951, Clarke 1973, Laursen et al. 1992, Perez et al. 2004). Additionally, fine scale distribution data is sparse for giant liver fluke and only recently has the fluke’s distribution been closely examined in Minnesota’s moose range (Vanderwaal et al. 2014, Maskey 2011, Peterson et al. 2013, Vannatta in prep). Substantial field data on intermediate snail hosts and deer infection are also still needed.

**Project objectives**

In light of both the ecological and veterinary significance of lymnaeid snails in Minnesota, this project seeks to determine:

1. the distribution of lymnaeid snails in northeastern Minnesota
2. the habitat preferences of lymnaeid snails
3. the distribution and infection prevalence of giant liver fluke parasites in lymnaeid snails

**Methods**

Aquatic habitats were sampled across St. Louis County and Lake County in Minnesota. 84 sampling sites were surveyed by hand and dip net for snails (Fig. 2). Water measurements (pH, ...
water hardness as CaCO₃, water surface temperature) and a 1 m² vegetation quadrat was taken at each location. An additional 1 m² quadrat was taken around each snail. Sampling points were buffered by 10, 25, 50, 100, 200, and 500 m and analyzed for cover type composition using ArcMap 10.3 and the Geospatial Modelling Environment (GME) (Fig. 3). Lake characteristics (e.g. lake length, width, surface area, etc.) were obtained from the DNR LakeFinder (URL: http://www.dnr.state.mn.us/lakefind/index.html) and the Minnesota Geospatial Commons (URL: https://gisdata.mn.gov/) and also analyzed.

Snails were collected and taken to the University of Minnesota – Duluth. *Lymnaea* spp. snails were weighed and stored in 100 mL specimen containers (Fig. 4). Containers were filled with lake water collected from sampling locations. *Fossaria* spp. snails were kept in petri dishes with a piece of filter paper and small amount of lake water. Water was replaced twice a week and snails were fed lettuce once a week. Twice weekly, snails were placed under bright fiber optic lights to induce shedding of trematode cercariae (Caron et al. 2008). Cercariae were stained with neutral red (0.001%) and identified using the criteria of Schell (1970). Snails were maintained until death. After death, length and width measurements were taken for all snails (Perez et al. 2004). Snails that died within one week of capture were considered capture related mortalities and were not included in survival statistics.

**Results and Conclusions**

Five species of lymnaeid snails were found in the study area (Fig. 5). No snails were found infected with giant liver flukes. This is likely due to the very low infection prevalence in snail
Figure 4. An individual *L. megasoma* in a specimen cup under artificial illumination.

Figure 5. (A) *L. megasoma*, (B) *L. stagnalis*, (C) *L. elodes*, and (D) *Fossaria* spp. Only one specimen of *L. catascopium* was found and is not pictured.
hosts (0.16% to 2%; Erhardova-Kotrla 1971, Laursen and Stromberg 1993). However, other trematodes were found (Fig. 6). *Lymnaea megasoma* and *L. stagnalis* were the most common and widely distributed snail species (Fig. 7). *L. elodes*, *L. catascopium*, and *Fossaria* spp. were also found (Fig. 7). Eight and five *L. megasoma* individuals were found infected with xiphidiocercariae and strigea cercariae, respectively (Fig. 6). The strigea parasites found in the study area are most likely intestinal parasites of waterfowl (Olsen 1974). However, the xiphidiocercariae found could represent any number of parasite families parasitizing vertebrates (Olsen 1974). Little research has focused on *L. megasoma* as a host for trematode parasites, but this species may be an important trematode intermediate host in the Great Lakes region. Also, one individual of *L. elodes* was found infected with strigea cercariae and one individual *L. stagnalis* was found infected with brevifurcate-apharyngeate cercariae.

Both trematode infected and uninfected snails survived in the laboratory. *L. megasoma* and *Fossaria* spp. survived significantly longer than *L. stagnalis* (mean ± 95% confidence interval = 52 ± 6 and 45 ± 10 compared to 18 ± 2; *L. megasoma* > *L. stagnalis*, \( t_{67} = 5.67, p < 0.00005;\) *Fossaria* spp. > *L. stagnalis*, \( t_{29} = 4.84, p < 0.00005\) under the specified laboratory conditions (Fig. 8). Additionally, *L. megasoma* infected with trematode cercariae survived for a significantly shorter time than uninfected snails (Fig. 9; one-tailed t test, \( t_{47} = 3.50, p = 0.0005\) for xiphidiocercariae infections and \( t_{46} = 2.42, p < 0.01\) for strigea infections). The ecological consequences of higher mortality in trematode infected *L. megasoma* is unknown. As an herbivore and detritivore, *L. megasoma* may play a role in nutrient turnover as other snails do (Dillon Jr. 2000). The *L. megasoma*-trematode relationship warrants further investigation.

Minnesota lymnaeid snails had similar morphological characteristics when compared to previous studies (Fig. 10 A-C; Clarke 1973). However, many *L. megasoma* individuals were smaller than the adult species standard of 35 mm (Clarke 1973). We suggest lowering the standard to 30 mm and incorporating a shell width to length ratio when keying out Minnesota’s lymnaeid snails. Width:length shows a strong correlation for many species and could be useful for identification keys (Fig. 11).

Figure 6. (A) Xiphidiocercariae and (B) Strigea cercariae shed from *L. megasoma*. 
Figure 7. Sampling locations in which lymnaeid snails were found. Blue polygons are State Parks. Arrows point to parks which were sampled.
Figure 8. Mean Survival in number of days for snails under laboratory conditions. Error bars represent 95% confidence intervals.

![Graph showing survival in days for different snail species](image)

Figure 9. Survival of *L. megasoma* with and without certain trematode infections. Difference between uninfected survival and infected snail survival were statistically significant. Error bars represent 95% confidence intervals.

![Graph showing survival in days for different trematode infections](image)
Figure 10. Boxplots of shell length, width, and width:length ratio for four Minnesota lymnaeid snails.

- **Shell Length**
- **Shell Width**
- **Width:Length Ratio**

Species: Fossaria spp., L. elodes, L. stagnalis, L. megasoma
Significantly higher concentrations of CaCO$_3$ where associated with *L. megasoma* presence compared to locations without *L. megasoma* (Fig. 12; one-tailed t test, $t_{82} = 3.18$, $p = 0.001$). *L. elodes* and *Fossaria* spp. were also associated with significantly higher CaCO$_3$ ($t_{82} = 2.64$, $p = 0.005$ and $t_{82} = 9.14$, $p < 0.00005$, respectively). This relationship was not significant for *L. stagnalis* ($t_{82} = 1.29$, $p = 0.1$) which may partly explain this species wide distribution (Hubendick 1951). For trematode species, strigea cercariae were associated with higher CaCO$_3$ concentrations ($t_{82} = 1.94$, $p = 0.03$) and xiphidiocercariae were not ($t_{82} = 0.07$, $p = 0.5$). Both parasites were found exclusively in *L. megasoma* except for one *L. elodes* with a strigea infection. The association between strigea and higher CaCO$_3$ may be related to snail CaCO$_3$ associations or its definitive host’s behavior. Aquatic plants which respond to calcium could create foraging habitat for strigea definitive hosts. For xiphidiocercariae, the lack of a relationship with calcium suggests snail hosts are not the primary determinant of parasite habitat.
On the landscape scale, *L. megasoma* was associated with less open water compared to all other areas (Fig. 13). This result was consistent across buffer zones (10, 25, 50, 100, 200 and 500 m) and Land Cover datasets (GAP level 3, GAP level 2, the USGS Land Use Land Cover dataset {LULC}, and the Nation Land Cover Dataset {NLCD}) but 95% confidence intervals were often overlapping. This result suggests *L. megasoma* could often be a resident of calm back bays and small ponds surrounded with more land and less open water (Fig. 14). Locations with *L. stagnalis* consistently averaged higher proportions of open water despite overlapping 95% confidence intervals (Fig. 15). *Fossaria* spp. had little to no aquatic habitat in any buffer areas, supporting previous research in which this species was common in ephemeral water habitats and vernal pools (Fig. 16; Laursen et al. 1992).

Figure 13. Proportion of cover types (LULC above and NLCD below) within a 25 m buffer zone of locations with (white) and without (gray) *L. megasoma*. Error bars present 95% confidence intervals.
Figure 14. Location where *L. megasoma* was found in the center of the buffer zones showing the small lake and back bay in which specimens were found. NLCD raster (top) and FSA 2013 aerial photo (below) showing same location on Little Wilson Lake, Lake County, Minnesota.
The findings of this study support those of other snail habit studies and suggest that more research is needed regarding the lymnaeid snail species, *L. megasoma*, and its potential importance as a parasite intermediate host in the Great Lakes region. A comprehensive understanding of this and other lymnaeid snail species’ habitat associations will better guide management decisions relating to disease ecology and its importance in various ecosystem processes.
Literature Cited


Erhardtova-Kotrla, B. 1971. The Occurrence of Fascioloides magna (Bassi, 1875) in Czechoslovakia.


