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Effects of Lowhead Dams on Prosobranch Snails in Illinois

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Abstract

Numerous studies have addressed the effects of dams on fishes, freshwater mussels, and aquatic insects, but few have examined the effects on aquatic gastropods. I established four site-types centered around four lowhead dams and sampled habitat variables and aquatic gastropods once a summer from 2008 through 2011. Multivariate analysis of variance indicated that habitat varied immediately upstream and downstream from the dams, with resultant effects on gastropod fauna. Compared with reference sites, impounded areas had greater depths and silt deposition and less diverse substrate composition, substrate stability, and hydrologic diversity and sites immediately downstream from the dams had less substrate diversity and silt deposition and larger mean substrate size. Gastropod densities were lower in these areas than reference sites. The data collected during this study contributes insights into the effects of lowhead dams on riverine habitat and aquatic gastropods assemblages in the Midwest

Introduction

Aquatic gastropods are a diverse group of invertebrates that are vital components of stream ecosystems (Lysne et al. 2008; Johnson et al. *in press*). Not only does their sensitivity to stream disturbances make them good biological indicators of stream integrity, but they also occupy a central position in food webs by grazing on periphyton and providing a food source for predators. However, aquatic gastropods have become one of the most imperiled groups of organisms in North America. Nearly 75% of the approximate 700 species have become extinct or are endangered, threatened, or in need of conservation status (Johnson et al. *in press*). Among factors affecting the group are anthropogenic disturbances that result in habitat fragmentation and environmental degradation (Lysne et al. 2008; Johnson et al. *in press*).

Impoundments are one of the major sources of anthropogenic disturbances on streams (Baxter 1977). Dam effects include converting lotic habitats to lentic habitats, changing flow regime, altering physicochemical parameters, increasing siltation upstream from the dam and scouring substrates downstream from the dam (Kanehl et al. 1997; Tiemann et al. 2004; Tiemann et al. 2007. Additionally, dams alter aquatic assemblages (e.g., reduced native species richness and abundance and increased non-native species richness and abundance), and/or block movement of certain species, which results in restricted distributions and isolated populations (Baxter 1977; Kanehl et al. 1997; Taylor et al. 2001). Although several studies have addressed the effects of dams on fishes (e.g., Tiemann et al. 2004; Santucci et al. 2005; Slawski et al. 2008), freshwater mussels (e.g., Watters 1996; Vaughn and Taylor 1999; Tiemann et al. 2007), and aquatic insects (e.g., Doeg and Koehn 1994; Garcia de Jalon et al. 1994; Tiemann et al. 2005), relatively little is known about the effects of impoundments on aquatic gastropods (Neves et al. 1997). It is believed dams cause changes in the gastropod fauna by altering instream habitat and restricting distributions and isolating populations (Isom 1971; Neves et al. 1997). However, an in-depth field study similar to what has been done for fishes, freshwater mussels, and aquatic insects has yet to be done for aquatic gastropods. Data on how lowhead dams affect aquatic gastropods are important for the protection of this imperiled fauna.

The objectives of this study were to investigate whether lowhead dams (< 4 m in height) affect the habitat characteristics and aquatic gastropod faunas in four river basins in Illinois. Such a study will address conservation challenges listed in Brown et al. (2008) and Lysne et al. (2008). I predicted that habitat quality and aquatic gastropod abundance would be lower in impounded sites than in free-flowing sites. To test these hypotheses, I calculated indices for habitat quality and conducted area searches for aquatic gastropods at upstream and downstream treatment and reference sites centered around four dams throughout Illinois. Disseminating research findings so that all parties have access to the highest quality information is an important factor in aquatic gastropod conservation (Brown et al. 2008; Lysne et al. 2008).

Methods

The study design is similar to that of Dean et al. (2002) and Tiemann et al. (2004). To assess effects of lowhead dams on the habitat characteristics and the aquatic gastropod assemblage, four site-types centered around four lowhead dams were sampled once a summer from 2008 through 2011 (Figure 1; Figure 2; Figure 3; Table 1). The four sites types included upstream reference, upstream treatment (e.g., impounded areas), downstream treatment, and downstream reference. Reference sites were free-flowing (e.g., appeared to be outside the zone of direct dam influence on flow), ranged from 55-100 m in width, 0.5-1.0 m in depth, and 100-200 m in length, and predominantly had gravel/pebble substrates. Impounded sites had no flow, ranged from 140-200 m in width, 0.5-2+ m in depth, and 150-400 m in length, and primarily had silted rocky substrates. Downstream treatment sites were located <0.5 km from the dam, ranged from 55-100 m in width, 0.5-2 m in depth, and 100-200 m in length, and had a diverse substrate composition, including gravel/pebble and cobble. Because no pre-impoundment data were available, I concluded treatment sites were more similar to reference sites than current conditions before being dammed due to substrate conditions and hydrology of the area. Also, I considered reference sites to be normal conditions for presently undammed portions of the rivers. Therefore, I believed the sites chosen acted as suitable and valid standards for their respective areas presently found in each basin. All dams had epilimnetic release.

Habitat at each site was assessed using the Qualitative Habitat Evaluation Index (QHEI) (Ohio EPA 1989) and the Stream Habitat Assessment Procedures (SHAP) (Illinois EPA 1994). These two qualitative habitat indices are designed to evaluate stream integrity and habitat quality, and were used by Tiemann et al. (2007). Both indices are multi-metric and provide empirical, quantified evaluations of stream habitat (Holtrop and Fischer 2002; Santucci et al. 2005) by scoring and rating habitat quality based on visual observational data that describe channel morphology, substrate, and flow characteristics. For each index, higher scores indicate better habitat quality for aquatic organisms. The QHEI has seven principal metrics (substrate, instream cover, channel morphology, riparian zone and bank erosion, pool-glide quality, riffle-run quality, and gradient) and the SHAP has 15 (bottom substrate, deposition, substrate stability, instream cover, pool substrate characterization, pool quality, pool variability, canopy cover, bank vegetative protection/stability, top of bank land use, flow-related refugia, channel alteration, channel sinuosity, width/depth ratio, and hydrologic diversity).

Live gastropods and shells of dead specimens were systematically collected by using quadrats (Stewart and Garcia 2002). At each site, at least five transects were uniformly spaced 5-m apart, perpendicular to the river channel and up to ten points were evenly established 0.5-m apart along the length of each transect. At each point, a 1 m^2 quadrat was placed on the streambed, and the substrate within the quadrat was examined for live gastropods by snorkel, feel, and excavation (Figure 4). Live individuals were identified to species, counted, and returned to the stream; abundance was standardized as number of individuals per square meter. A total of 50 points were sampled at each site. To minimize disturbance, transects were sampled from downstream to upstream, and points were sampled from near shore to far shore. Shells of each species from each site were deposited into the Illinois Natural History Survey (INHS)

Mollusk Collection, Champaign. Species were identified using Burch (1989), with common and scientific names following Turgeon et al. (1998), except I did not recognize subspecies.

Data were pooled for analysis at the site-type level (Tiemann et al. 2004; Tiemann et al. 2007). The Shapiro-Wilk test was used to evaluate distributions of means for normality and the Levene's test to examine homogeneity of variance (Milliken and Johnson 1984; Zar 1999). Nonnormal variables were $\log_{10}$ transformed (Zar 1999). Separate two-way (site-type and stream) multivariate analysis of variance (MANOVA) tests were performed to investigate effects of lowhead dams on habitat characteristics. Wilk's lambda (λ) was used to test for significance, with the error term being the two-way interaction (Zar 1999). Significant MANOVAs were followed with a step-down analysis of covariance (ANCOVA) to examine the contribution of individual variables to the MANOVA (Tabachnick and Fidell 1983). Step-down analysis helps avoid inflated Type I error from non-independent *F* tests (Tabachnick and Fidell 1983). In this procedure, dependent variables (e.g. individual QHEI and SHAP variables) are tested in a series of ANCOVAs where the most significant dependent variable is tested first in a univariate analysis of variance (ANOVA) after appropriate adjustment of alpha. Each successive dependent variable is tested with the higher significant dependent variables as covariates to determine if the new dependent variable significantly adds to the combination of dependent variables already tested (Tabachnick and Fidell 1983). Separate analysis of variance (ANOVA) tests were performed on densities of each snail species. Pearson's correlation coefficient was calculated to examine potential relationships of statistically significant habitat variables with gastropod densities, and Tukey's studentized range test was used for pairwise comparisons among site-types (Zar 1999). All statistical tests were calculated using the Statistical Analysis System, Version 8.1 (SAS Institute, Incorporated, Cary, NC). Because of multiple tests, sequential Bonferroni correction of $\alpha = 0.05$ was applied where appropriate to help control overall experimental Type I error rate (Rice 1989).

Results

MANOVA indicated that habitat characteristics varied significantly among site types ($\lambda = 0.01$; $n = 64$; $P < 0.0001$). Step-down ANCOVA indicated depth ($F = 93.64$, $P < 0.001$), silt deposition ($F = 51.49$, $P < 0.001$), substrate composition $F = 43.39$, $P < 0.001$), substrate stability ($F = 32.39$, $P = 0.002$), and hydrologic diversity ($F = 16.29$, $P < 0.001$) contributed most to variation among site types. Tukey's test revealed that QHEI and SHAP scores were higher in reference sites than at treatment sites, and that downstream treatment sites had higher QHEI and SHAP scores than at upstream treatment sites (Table 1). Reference sites and downstream treatment sites had shallower depths, less silt deposition, more diverse substrate composition, higher substrate stability, and higher hydrologic diversity than impounded sites. Tukey's test also showed that reference sites had more diverse substrate composition and higher hydrologic diversity but also more silt deposition than downstream treatment sites.

Taxa occurring in less than 5% of all samples were eliminated from analyses (Gauch 1982. Two pleurocerids (*Elimia livescens* – Figure 5; *Pleurocera acuta* (– Figure 6) and one viviparid (*Campeloma decisum* – Figure 7) were retained for statistical analysis (Table 1). ANOVAs showed that densities of *E. livescens* ($F = 34.13$; $P < 0.001$) and *P. acuta* ($F = 11.28$; $P < 0.001$) differed significantly among site types, but *C. decisum* ($F = 2.98$; $P = 0.11$) did not. Tukey's test revealed that densities of both *E. livescens* and *P. acuta* were higher at reference sites than at either upstream or downstream treatment sites, and that downstream treatment sites were higher than at upstream treatment sites (Figure 8). Densities of *E. livescens* and *P. acuta* were positively correlated with substrate composition [*E. livescens* - (r = 0.56; $P < 0.001$); *P.*

acuta - (r = 0.43; $P < 0.001$)], substrate stability [*E. livescens* - (r = 0.36; P = $P < 0.001$); *P. acuta* - (r = 0.32; $P < 0.001$)], and hydrologic diversity [*E. livescens* - (r = 0.36; $P < 0.001$); *P. acuta* - (r = 0.34; $P < 0.001$)], and negatively correlated with silt deposition [*E. livescens* - (r = 0.32; $P < 0.001$); *P. acuta* - (r = 0.28; $P = 0.002$)].

Discussion

The habitat results from our study are similar to those reported from other lowhead dam studies (e.g., Tiemann et al. 2004; Tiemann et al. 2007). Upstream treatment sites had lower QHEI and SHAP scores than reference sites and downstream treatment sites, indicating that impounded areas had poor habitat quality and lacked habitat diversity. Impounded areas had greater depths and silt deposition and less diverse substrate composition, substrate stability, and hydrologic diversity when compared to reference sites. By blocking water movement, dams reduce water velocity and hinder water's ability to transport sediment, which typically settles out in the impounded area (Kondolf 1997; Wood and Armitage 1997).

Impounded areas had lower gastropod abundance than reference sites and downstream treatment sites. Based on the correlation data, reductions in gastropod densities in the impounded areas are likely the result of degraded habitat conditions. Gastropod densities were negatively correlated with silt deposition and positively correlated with substrate composition, substrate stability, and hydrologic diversity. Aquatic gastropods, such as *Elimia livescens* and *Pleurocera acuta*, typically prefer free-flowing environments with clean heterogeneous substrates (Dazo 1965). Some aquatic gastropods have experienced dramatic reductions in their ranges because of impoundments (Neves et al. 1997; Brown et al. 2008). When a basin contains multiple dams, as does each of the four basins in this study, populations can become disjunct and fragmented (Tiemann et al. 2004; Tiemann et al. 2007). Pleurocerids are hindered by poor dispersal capabilities, thus recolonization is difficult (Brown et al. 2008).

Downstream treatment sites also differed from reference sites. When compared to reference sites, the areas immediately downstream from the dams had less substrate diversity and silt deposition and larger mean substrate size (e.g., more cobble and less gravel/pebble). It is likely water flowing over these dams have scoured finer substrates, which accounted for the larger mean substrate size. A coarsening of substrate can result from streambed erosion by release waters with a light sediment load and increased velocity (Kondolf 1997; Camargo and Voelz 1998).

The areas immediately downstream from the dams had lower gastropod abundance than reference sites, but more than impounded areas. These downstream treatment sites had clean substrates, but it was coarser and not as heterogeneous has reference sites. Coarse substrates typically do not offer organisms much protection during high flow events. Perhaps aquatic gastropods are routinely scoured from these areas. Marcoinvertebrates inhabiting degraded streambed substrates are subjected to scouring (Newcombe and MacDonald 1991; Camargo and Voelz 1998).

The data collected during this study contributes insights into the effects of lowhead dams on riverine habitat and aquatic gastropods assemblages in the Midwest. The data suggests that lowhead dams cause differences in habitat immediately upstream and downstream from an impoundment, which can result in reductions in aquatic gastropods abundances that are similar to fishes (Santucci et al. 2005; Tiemann et al. 2004), freshwater mussel (Dean et al. 2002; Tiemann et al. 2007), and aquatic insects (Doeg and Koehn 1994; Tiemann et al. 2005). Snail populations are hindered by habitat fragmentation and inability to recolonize, and effects are compounded by direct habitat degradation (e.g., loss of grazing substrate) and physical scouring of snails.

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Table 1. Aquatic gastropod densities (individuals/meter^2) and habitat-quality indices, by site-type. Site-types include upstream reference (UR), upstream treatment (UT), downstream treatment (DT), and downstream reference (DR).

Stream	Variable	UR	UT	DT	DR
Rock River	*Pleurocera acuta*	14.7	0	0.2	11.8
	Campeloma decisum	1.7	0	0	4.3
	QHEI	73	39	59	71
	SHAP	140	63	102	132
Fox River	*Elimia livescens*	12.7	0	0.3	7.8
	Pleurocera acuta	2.1	0	0	3.2
	Campeloma decisum	1.2	0.4	0	1.8
	QHEI	83	39	65	72
	SHAP	133	58	97	137
Kankakee River	*Elimia livescens*	23.4	0	0.7	21.5
	Pleurocera acuta	12.8	0	0.6	11.6
	Campeloma decisum	11.4	0.1	0.7	7.8
	QHEI	75	36	51	77
	SHAP	135	64	91	133
Vermilion River	*Elimia livescens*	57.9	0	1.2	47.3
	Pleurocera acuta	0	0	0	1.3
	QHEI	81	32	53	77
	SHAP	138	72	108	138

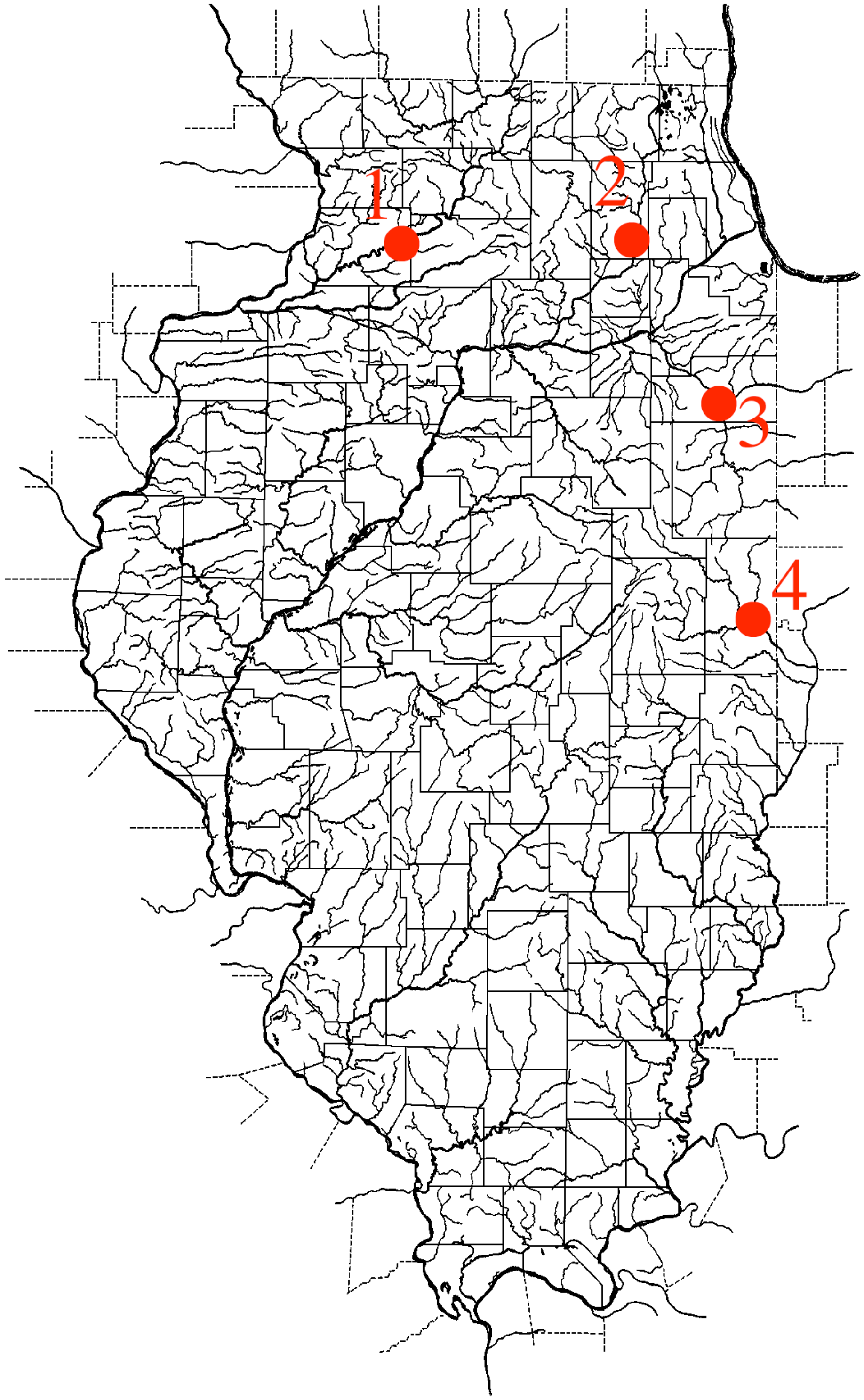

Figure 1. Locations (circles) of the lowhead dams for this study. Streams include 1) Rock River, 2) Fox River, 3) Kankakee River, and 4) Vermilion River.

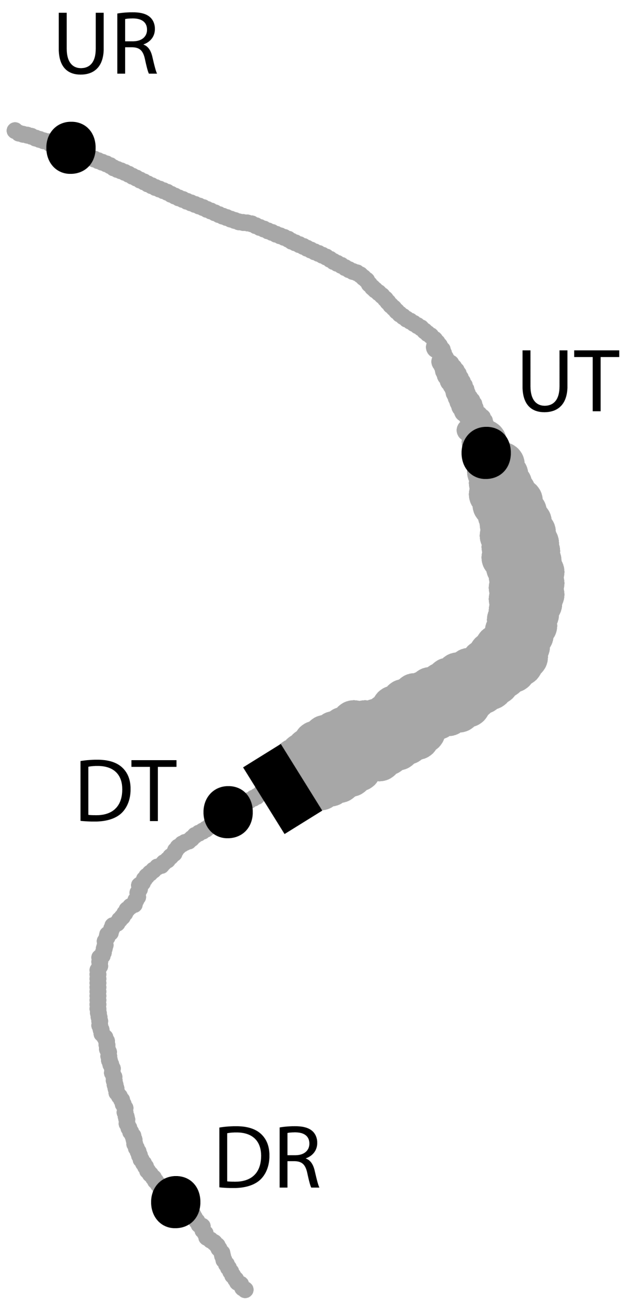

Figure 2. Typical study design layout for the four site-types (UR – upstream reference; UT – upstream treatment; DT – downstream treatment; DR – downstream reference) centered on a given dam (black rectangle).

Figure 3. Example of a lowhead dam (<4 m height). Pictured is a lowhead dam on the Vermilion River, Vermilion County, Illinois.

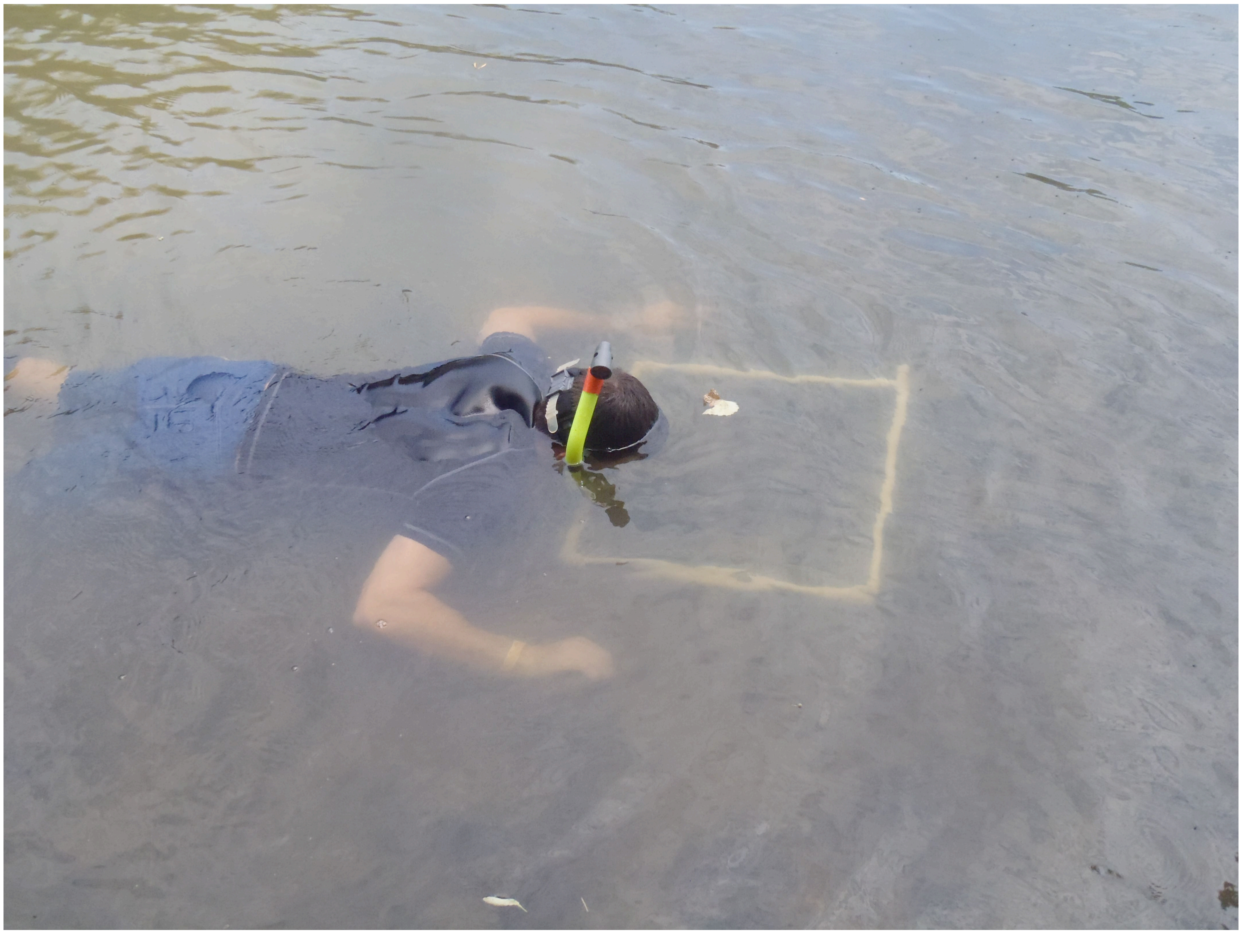

Figure 4. Counting snails via snorkeling in the Kankakee River, Kankakee County.

Figure 5. *Elimia livescens*

(drawing by Emily Damstra).

Figure 6. *Pleurocera acuta*

(photo by Steve Cringan).

Figure 7. *Campeloma decisum*

(photo by Jeremy Tiemann).

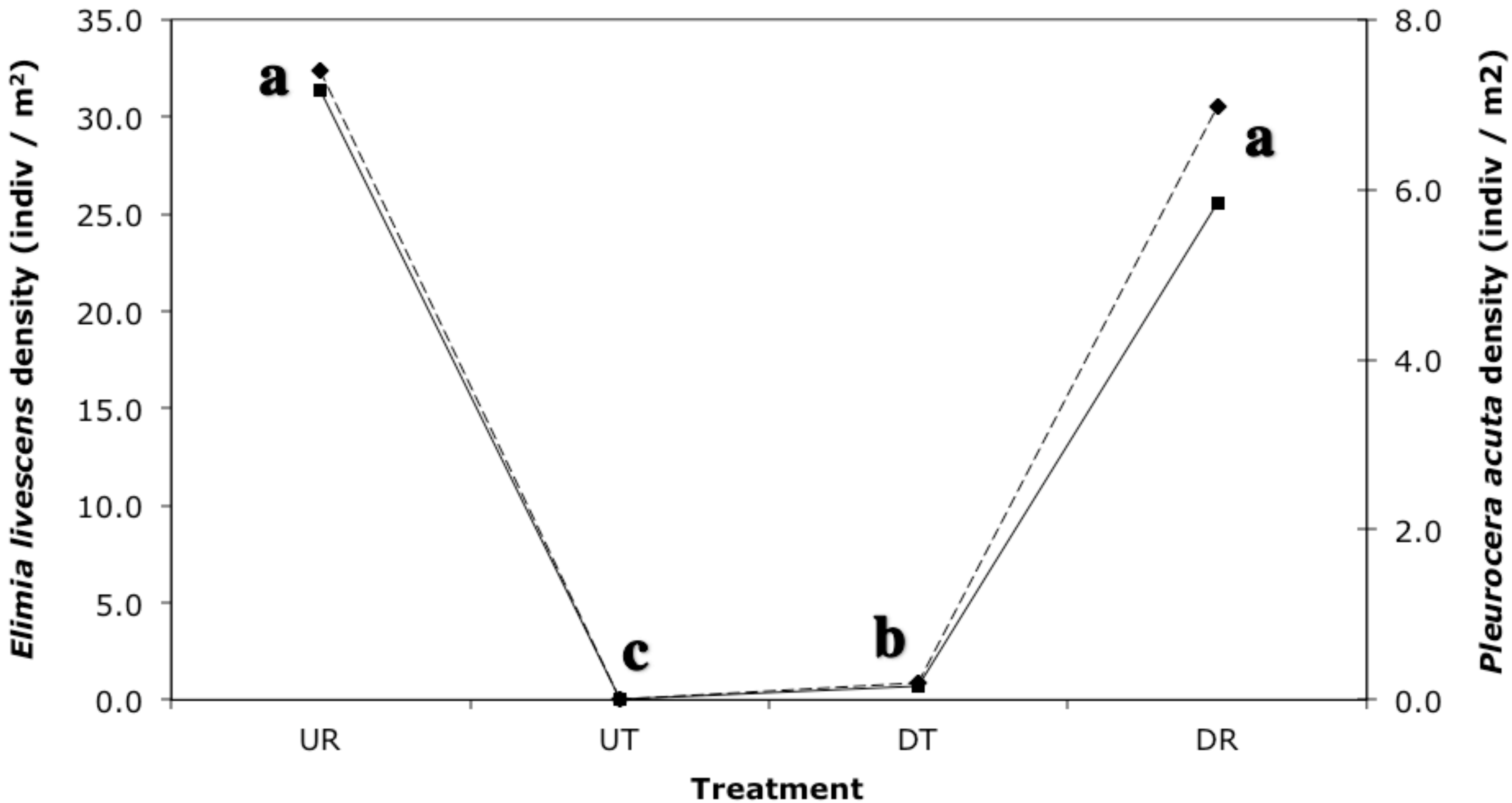

Figure 8. Mean density (+SD) of *Elimia livescens* (solid lines with squares) and *Pleurocera acuta* (dashed line with diamonds) per site type (UR = upstream reference, UT = upstream treatment, DT = downstream treatment, and DR = downstream reference). Density is individuals/m^2. The lowercase letters indicate significant groupings according to Tukey's test.