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Little is known about aquatic macroinvertebrate colonization of aquatic habitats within riparian zones of headwater streams in the midwestern United States. Many headwater streams and their riparian habitats in this region have been modified for agricultural drainage. Riparian habitat modifications caused by agricultural drainage may influence aquatic macroinvertebrate colonization within the riparian zones of headwater streams. However, the effects of agricultural drainage-induced riparian modifications have not been evaluated because others have focused on the impact of agricultural drainage on aquatic macroinvertebrates within the streams. We placed water-filled mesocosms in the riparian zones of two channelized and two unchannelized streams in central Ohio and sampled them from June to August 2009 to determine if differences in physical habitat, water chemistry, and aquatic macroinvertebrate colonization occurred between riparian zone types and among sampling dates. Canopy cover was greater in unchannelized than channelized riparian zones. Dissolved oxygen was greater in channelized than unchannelized riparian zones only during the latter half of the study. Turbidity and nutrients progressively increased throughout the study. Taxa richness was greater in unchannelized than channelized riparian zones. Copepod relative abundance, zooplankton relative abundance, and Shannon diversity index was greater in unchannelized than channelized riparian zones only during the latter half of the study. Abundance, taxa richness, culicid relative abundance, and dipteran relative abundance increased from the beginning of the study to the end. Our results indicate aquatic community colonization in the riparian zones of headwater streams is influenced by riparian habitat type and nutrients.

Keywords: mesocosms; aquatic insects; zooplankton; riparian zones; stream channelization; nutrients

Introduction

Little is known about aquatic macroinvertebrate colonization of aquatic habitats within riparian zones of headwater streams in the midwestern United States. Aquatic macroinvertebrates form an important component of headwater stream ecosystems

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in this region and colonize both the streams themselves and the adjacent riparian zones. Riparian zones of headwater streams can contain numerous types of aquatic habitats ranging from small treeholes to permanently flooded wetlands that can be colonized by aquatic macroinvertebrates. Many headwater streams and their riparian habitats in the midwestern United States have been modified for agricultural drainage (Smiley and Gillespie 2010). These modifications have resulted in a landscape containing straightened, enlarged, channelized streams with riparian habitats lacking woody vegetation and unchannelized streams having unmodified sinuous channels and woody riparian habitats. The amount and type of aquatic habitats adjacent to channelized headwater streams have also been influenced directly by agricultural drainage practices and indirectly by the concurrent changes in riparian habitat that occur as a result of these practices.

Agriculturally induced changes to riparian zones can lead to physical habitat changes within the streams, such as increased water temperatures and reductions of instream wood, that in turn result in changes to aquatic macroinvertebrate communities within streams (Allan 2004; Stone et al. 2005). Previous studies of headwater streams in the midwestern United States have documented decreased aquatic macroinvertebrate diversity, decreased abundance of pollution sensitive taxa, and increased abundance of tolerant taxa within channelized streams compared to unchannelized streams (Brookes 1988; Dovciak and Perry 2002; Smiley et al. 2010). Adult and larval aquatic macroinvertebrates inhabiting the adjacent riparian zones are also influenced by riparian habitat characteristics (Delettre and Morvan 2000). Riparian habitat alterations as a result of agricultural drainage include reductions of physical habitat diversity, shifts from woody to herbaceous riparian vegetation, and the loss of riparian aquatic habitats. However, previous research from the midwestern United States has focused on the headwater streams themselves and has not examined the variation in aquatic macroinvertebrate community structure between headwater streams possessing different riparian habitat characteristics.

Water-filled mesocosms and artificial containers (i.e. tires, cemetery urns, etc.) have been used to evaluate the influence of different habitat types and habitat variables on aquatic macroinvertebrate community colonization in forested and urban areas. Mesocosms and containers within forest habitats typically exhibited increased aquatic macroinvertebrate species richness, abundance, and different species composition than unforested habitats in Illinois (Kling et al. 2007; Yee and Yee 2007). Differences in aquatic community structure between forested and unforested habitats were attributed to increased detritus input (Kling et al. 2007; Yee and Yee 2007). Female mosquitoes exhibited preferences for ovipositing in nutrient-enriched mesocosms within forested habitats in southeastern Michigan (Reiskind and Wilson 2004). A literature review synthesizing results from the midwestern and southeastern United States indicated that shaded tires had greater mosquito species richness or abundance than unshaded tires (Yee 2008). These findings suggest that aquatic community structure and colonization within riparian zones should differ between headwater streams with different riparian habitat characteristics.

We placed water-filled mesocosms in the riparian zones of two channelized and two unchannelized streams in central Ohio and sampled them over a 45-day period to evaluate potential differences in physical habitat, water chemistry, and aquatic macroinvertebrate colonization between riparian zone types and among sampling periods. Specifically, our research question was: Does physical habitat, water chemistry, and aquatic macroinvertebrate colonization within mesocosms differ between riparian zones of channelized and unchannelized headwater streams and among sampling dates?

Methods

Four sites within the riparian zones of two channelized streams (A and B, Figure 1) and four sites within riparian zones of two unchannelized streams (C and D, Figure 1) within the Upper Big Walnut Creek watershed in central Ohio were selected for this experiment. We established two sites within the riparian zones of each stream. One site was located downstream at the watershed outlet and the other was located upstream as close to the headwaters as possible. Sites within a stream were separated by a mean distance of 1128 m (range 175–3000 m). All four streams were headwater streams with an average watershed size of 4.28 km^2 (range 3.89–4.54 km^2). Land use adjacent to the sites consisted of row-crop agriculture of corn, soybean, or wheat. The fields surrounding the channelized streams were large and systematically tile drained and those encompassing unchannelized streams were smaller and more sloping with natural surface drainage (Smiley et al. 2010). Channelized streams exhibited the straightened, over-enlarged channels typical of agricultural drainage ditches in the midwestern United States. Unchannelized streams possessed sinuous channels and variable bank heights that are expected within unmodified headwater streams.

The riparian zones of channelized streams were narrower than the riparian zones of unchannelized streams (Table 1). Riparian zones of channelized streams consisted mostly of herbaceous vegetation and the riparian zones of unchannelized streams were composed mostly of woody vegetation (Table 1). The riparian zones of channelized streams also provided less canopy cover, woody vegetation, woody vegetation taxa richness, and structural diversity than the riparian zones of unchannelized streams (Table 1).

We placed one white, plastic, 18.9 L mesocosm filled with 10.3 L of deionized water in the riparian zone of each site ($n = 4$ for each stream type). Specifically, deionized water was tap water that was treated with a combined activated carbon filtration-mixed bed ion exchange system designed to remove free chlorine, copper, and other contaminants to meet ASTM Type 2 specifications for deionized water. Our use of deionized water ensured that all mesocosms contained water with similar chemical characteristics and lacking aquatic macroinvertebrates at the beginning of the experiment. Prior to use each mesocosm was washed with hot water and soap, rinsed clean, and allowed to air dry. Mesocosms were placed at relatively flat locations at the top banks of the streams. Mesocosms were placed at a mean distance of 5 m (range 3–7 m) from the water's edge of both stream types. Mesocosms adjacent to channelized streams were a mean distance of 31 m (range 10–58 m) from the riparian zone edge and those adjacent to unchannelized streams were a mean distance of 44 m (range 17–58 m) from the riparian edge.

Aquatic macroinvertebrates were allowed to colonize the mesocosms for 45 days from July to August 2009. Every 3–4 days, we collected aquatic macroinvertebrates, water samples for turbidity measurements, and obtained measurements of water depth, water temperature, and dissolved oxygen from each mesocosm. Aquatic macroinvertebrates were collected from each mesocosm by first thoroughly mixing the water and then using 40-mL plastic jars to obtain three subsamples of

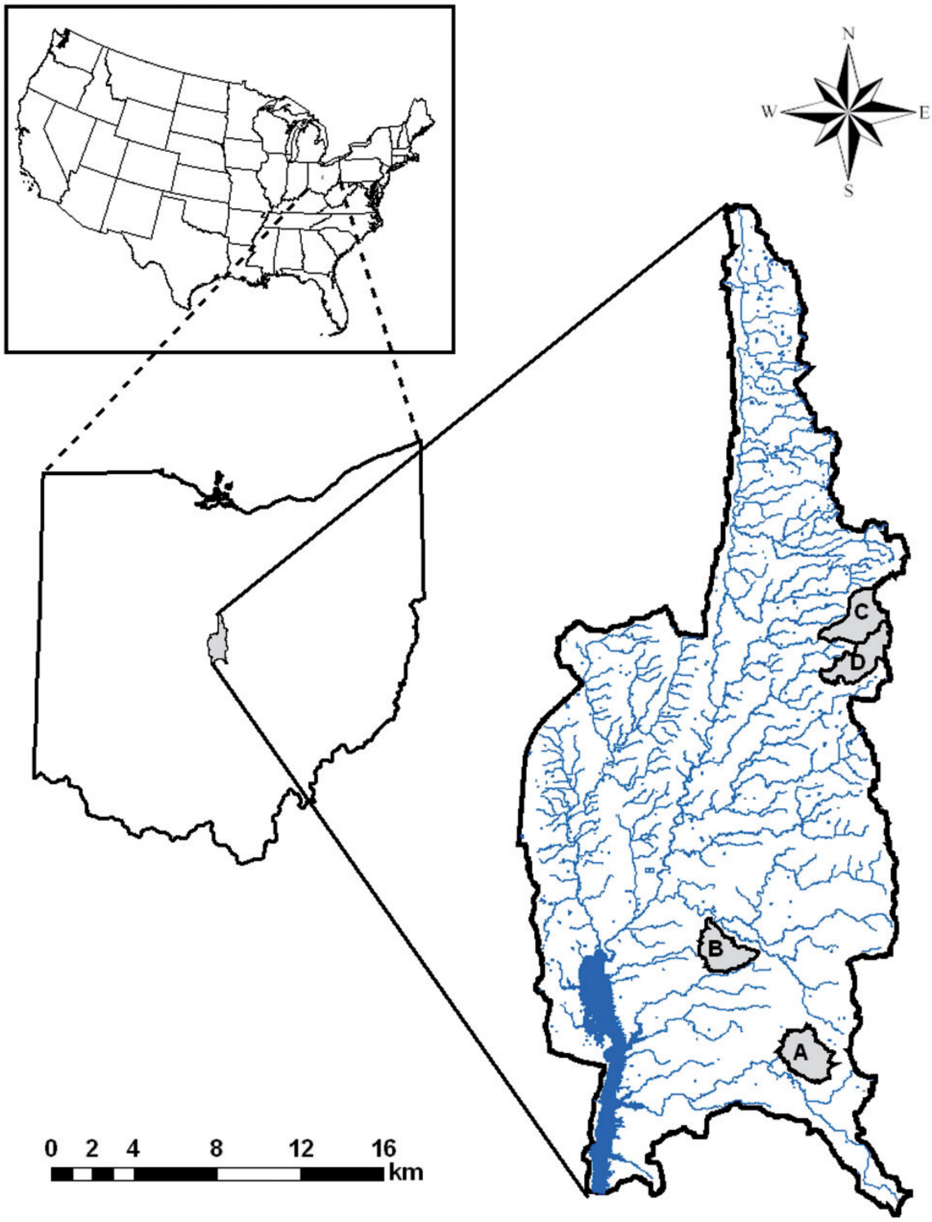

Figure 1. Location of study sites within the Upper Big Walnut Creek watershed, Ohio, and the United States. Watersheds A and B are channelized headwater streams and each stream contains two sampling sites. Watersheds C and D are unchannelized headwater streams and each stream contains two sampling sites.

macroinvertebrates from three different areas within the mesocosm. This collection methodology is similar to the dipping methodology used by public health professionals. This sampling method was selected because it enabled us to obtain a representative sample from each day without defaunating the mesocosms and it also

Table 1. Means (SD) of riparian habitat variables from channelized and unchannelized headwater streams within the Upper Big Walnut Creek watershed, Ohio, USA.

	Channelized	Unchannelized
Riparian width (m)	33.8 (13.5)	101.1 (75.2)
Ratio of woody to herbaceous vegetation	0.41 (0.56)	1.64 (0.31)
Percentage canopy cover (%)	12.7 (23.5)	77.5 (21.5)
Woody vegetation richness (# genera)	2.50 (2.89)	11.25 (1.71)
Woody vegetation density (#/m^2)	0.10 (0.15)	0.90 (0.20)
Simpson's riparian structural diversity	2.61 (1.05)	5.43 (0.67)

Notes: Riparian widths were measured with aerial photos taken in 2006 (5 sites) or an RTK unit in 2009(3 sites). Means and SD for all other response variables were calculated from data collected in 2009 with methods as described in Smiley et al. (2009). Ratio of woody to herbaceous vegetation is the sum of the percent of woody vegetation present in four height strata in 12 quadrats in each site divided by the percent of herbaceous vegetation present in each stratum. Simpson's riparian structural diversity is the Simpson's diversity index calculated based on percentages of the occurrence of herbaceous and woody vegetation within four height strata.

resulted in equal sampling efforts among riparian zone types and sampling days. We also collected a grab sample for turbidity measurements with a 40-mL plastic jar. Turbidity measurements were conducted in the laboratory with a turbidity meter. We used a meter stick to measure water depth and a multiparameter meter to measure water temperature and dissolved oxygen. Canopy cover above each mesocosm was measured with a convex spherical densiometer on days 0, 14, 31, and 45. A 0.95-L glass jar was used to collect a water sample for nutrient and pesticide measurements from each mesocosm on days 0, 14, and 31.

We added deionized water after all sampling was completed if the water level was below 10.3 L to ensure the hydrology of the mesocosms was similar between riparian zone types. We only needed to add water on four sampling days. We added an average of 1.9 cm (0.4–3.5 cm) of water to all mesocosms on days 3 and 7. We also added an average of 1.6 cm (0.1–3.0 cm) of water to two mesocosms on day 28 and to five mesocosms on day 31. Preliminary analyses indicated mean water depths between riparian zone types differed only on the last two sampling days. On days 42 and 45 mean water depths were greater in mesocosms within unchannelized riparian zones (mean 28.5 cm, SD 1.8) than channelized riparian zones (mean 24.9 cm, SD 1.2). These results suggest that differences in hydrology between riparian zone types were not great enough to influence aquatic macroinvertebrate colonization.

Nutrient concentrations were determined colorimetrically. Ammonium and nitrate plus nitrite were determined by application of the copperized-cadmium reduction method and dissolved reactive phosphorus was determined by the ascorbic acid reduction method (Parsons et al. 1984). Total nitrogen and total phosphorus analyses were performed on unfiltered samples following alkaline persulfate oxidation (Koroleff 1983) with subsequent determination of nitrate plus nitrite and dissolved reactive phosphorus. Dissolved organic carbon was determined by heated persulfate oxidation using a total organic carbon analyzer with in-line sample acidification and sparging (Menzel and Vaccaro 1964). Concentrations of six herbicides (acetchlor, alachlor, atrazine, atrazine desethyl, metolachlor, and simazine), seven fungicides (azoxystrobin, chlorothalonil, dithiopyr, metalaxyl, myclobutanil, triadimefon, and vinclozoline), and one insecticide (malathion) within the water samples were determined using gas chromatography following standard protocols for pesticide analyses (US EPA 1995).

Macroinvertebrate samples were preserved with a 70% ethanol-rose bengal solution. Organisms were then identified and counted from preserved samples with a dissecting microscope. Insect larvae were identified to family and zooplankton were identified to subclass or order with standard taxonomic references (Merritt and Cummins 1996; McCafferty 1998; Thorp and Covich 2001). The small size of most animals prevented their identification to genus or species. We calculated the abundance (number of captures), taxa richness (number of different taxa), Shannon diversity index (Magurran 1988), and percent of each taxa (# of each taxa/total number of captures) for each mesocosm on each sampling day.

We used a two-factor repeated measures analysis of variance (ANOVA) coupled with the Student–Neuman–Keuls (SNK) test to determine if physical habitat variables (turbidity, canopy cover, dissolved oxygen, and water temperature), water chemistry (nutrients), and community response variables differed among riparian zone types or sampling days and if the effect of riparian zone types differed by sampling days. The assumptions of normality and equal variance were not met for any response variable despite log $x+1$ transformation or arcsine square root transformation. Therefore, we conducted two-factor repeated measures ANOVA with rank transformed values. Rank transformation is commonly recommended in these situations and its use with a parametric test is the equivalent of a nonparametric two-factor repeated measures ANOVA (Conover 1999). All statistical tests were conducted with Sigma Stat 3.1 (Systat Software 2004) and a significance level of $p < 0.05$ was used.

Results

Differences in canopy cover above the mesocosms occurred between riparian zones of channelized and unchannelized streams (Table 2). Canopy cover was greater in unchannelized riparian zones ($60.94 \pm 35.00\%$, mean $\pm$ SD) than channelized riparian zones ($4.10 \pm 8.61\%$, mean $\pm$ SD). Differences in turbidity occurred among sampling days (Table 2). In general, turbidity progressively increased from day 0 through day 45 (Figure 2). Significant interaction effects indicated that trends in mean dissolved oxygen and water temperature between riparian zone types differed among sampling days (Table 2). Mean dissolved oxygen did not differ between riparian zone types from days 0 to 24 and day 45 (Figure 3). Mean dissolved oxygen was greater in channelized than unchannelized riparian zones from days 28 to 42 (Figure 3). Differences in mean water temperature between riparian zone types only occurred on days 0, 10, and 17. Mean water temperature was greater in unchannelized (26.4 ± 0.5°C, mean $\pm$ SD) than channelized riparian zones (22.6 ± 1.2°C, mean $\pm$ SD) on day 0. On days 10 and 17 mean water temperature was greater in channelized (21.9 ± 0.9°, mean $\pm$ SD) than unchannelized riparian zones (19.0 ± 0.8°C, mean $\pm$ SD).

Concentrations of dissolved organic carbon, ammonium, nitrate plus nitrite, total nitrogen, and total phosphorus within the mesocosms differed among sampling days, but not between riparian zone types (Table 2). Dissolved organic carbon, total nitrogen, and total phosphorus exhibited progressive increases from day 0 to 31

Table 2. *P* values from two factor repeated measures ANOVAs conducted to determine the influence of riparian zone type (RT), sampling day (D), and the interaction effect of riparian zone type and sampling day on physical habitat and water chemistry response variables within mesocosms placed in the riparian zones of channelized and unchannelized headwater streams in the Upper Big Walnut Creek watershed, Ohio, USA (July–August 2009).

Response variables	RT	D	RT × D
Physical habitat			
Turbidity	0.164	**<0.001**	0.959
Canopy cover	**0.015**	0.920	0.834
Dissolved oxygen	**0.028**	**<0.001**	**0.025**
Water temperature	0.756	**<0.001**	**<0.001**
Water chemistry			
Dissolved organic carbon	0.604	**<0.001**	0.181
Ammonium	0.729	**<0.001**	0.627
Nitrate plus nitrite	0.545	**0.027**	0.983
Total nitrogen	0.854	**<0.001**	0.663
Soluble reactive phosphorus	0.356	0.397	0.397
Total phosphorus	0.474	**<0.001**	0.676

Note: Bold values are those <0.05.

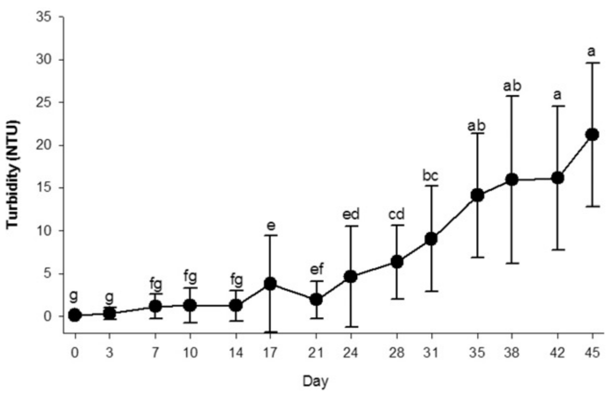

Figure 2. Means (SD) of turbidity among sampling days in the mesocosms within riparian zones of headwater streams in the Upper Big Walnut Creek watershed, Ohio, USA (July–August 2009).

(Figure 4). Nitrate plus nitrite and ammonium were the least on day 0 and the greatest on day 14 (ammonium) or 31 (nitrate plus nitrite, Figure 4). No differences in soluble reactive phosphorus concentrations were observed among sampling days or between riparian zone types (Table 2). No significant interaction effects occurred for any nutrient variable (Table 2). Pesticide concentrations in all water samples were less than the detection limits (0.25 μg/L).

Macroinvertebrate taxa richness differed between riparian zone types (Table 3). Macroinvertebrate taxa richness was greater in unchannelized than channelized riparian zones (Table 4). Macroinvertebrate abundance, taxa richness, percent

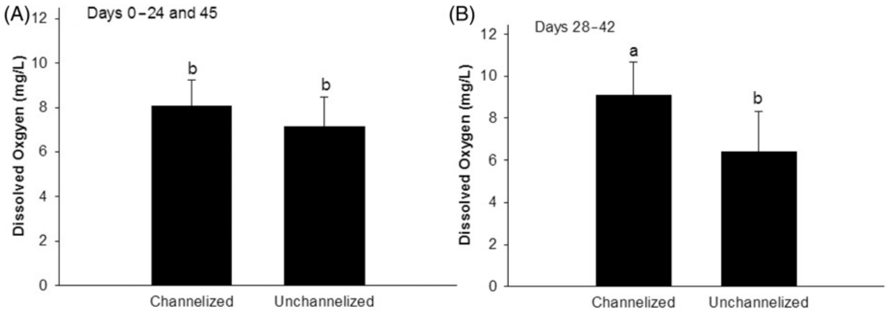

Figure 3. Means (SD) of dissolved oxygen in the mesocosms of riparian zones of channelized and unchannelized headwater streams in the Upper Big Walnut Creek watershed, Ohio, USA on days 0–24 and 45 (A) and on days 28–42 (B).

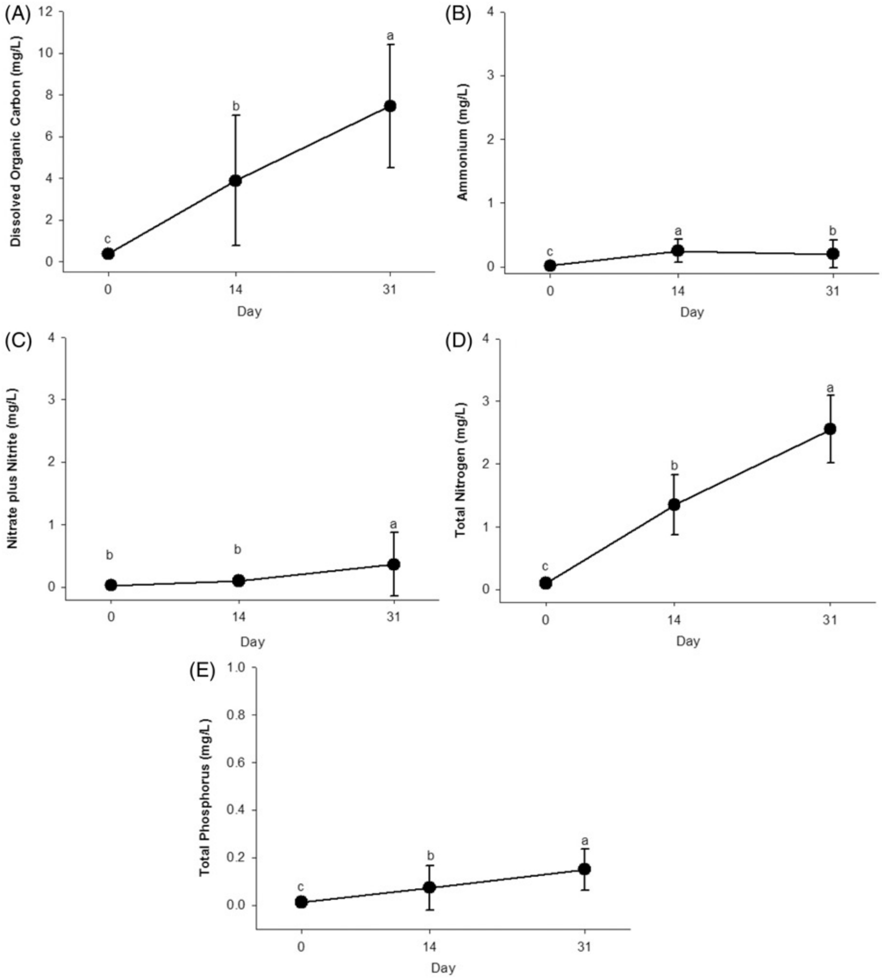

Figure 4. Means (SD) of dissolved organic carbon (A), ammonium (B), nitrate plus nitrite (C), total nitrogen (D) and total phosphorus (E) among sampling days in mesocosms within the riparian zones of headwater streams within the Upper Big Walnut Creek watershed, Ohio, USA (July–August 2009).

Table 3. *P* values from two factor values from two-factor repeated measures ANOVAs conducted to determine the influence of riparian zone type (RT), sampling day (D), and the interaction effect of riparian zone type and sampling day on aquatic macroinvertebrate community response variables within mesocosms placed in the riparian zones of channelized and unchannelized headwater streams in the Upper Big Walnut Creek watershed, Ohio, USA (July–August 2009).

Response variables	RT	D	RT × D
Abundance	0.167	**<0.001**	0.558
Taxa Richness	**0.045**	**<0.001**	0.123
Percent Cladocera	0.204	0.063	0.063
Percent Copepoda	**0.047**	**0.004**	**0.032**
Percent Ceratopogonidae	0.356	0.460	0.460
Percent Chironomidae	0.356	0.460	0.460
Percent Culicidae	0.362	**<0.001**	0.959
Percent Psychodidae	0.356	0.460	0.460
Percent Diptera	0.416	**<0.001**	0.988
Percent Zooplankton	**0.016**	**<0.001**	**<0.001**
Shannon diversity index	**0.003**	**<0.001**	**<0.001**

Note: Bold values are those <0.05.

Table 4. Means (SD) of aquatic macroinvertebrate community response variables from mesocosms placed within riparian zones of unchannelized and channelized headwater streams in the Upper Big Walnut Creek watershed, Ohio, USA (July–August 2009).

	Channelized	Unchannelized
Abundance	1.64 (3.45)	3.39 (4.29)
Taxa Richness	**0.27 (0.48)**	**0.95 (0.96)**
Percent Cladocera	0.00 (0.00)	1.47 (5.84)
Percent Copepoda	**0.36 (2.67)**	**18.2 (31.6)**
Percent Ceratopogonidae	0.00 (0.00)	0.13 (0.95)
Percent Chironomidae	3.21 (16.96)	0.00 (0.00)
Percent Culicidae	21.4 (41.4)	36.7 (41.6)
Percent Psychodidae	0.00 (0.00)	0.22 (1.67)

Note: Bold values indicate response variables that differ between riparian zone types ($p < 0.05$, see Table 3).

Culicidae, and percent Diptera differed among sampling days (Table 3). Increases in macroinvertebrate abundance and taxa richness occurred on day 21 and then again on day 38 (Figure 5). Increases in percent Culicidae and percent Diptera occurred on day 10 and then again on days 38 and 42 (Figure 5). Significant interaction effects occurred for percent Copepoda, percent Zooplankton, and Shannon Diversity Index (Table 3). No difference in mean percent Copepoda and percent Zooplankton occurred between riparian zone types on days 0 to 21 and day 24 (Figure 6). Mean percent Copepoda and percent Zooplankton were greater in unchannelized riparian zones than channelized riparian zones on day 21 and days 28 to 45 (Figure 6). Mean Shannon Diversity Index did not differ between riparian zone types from days

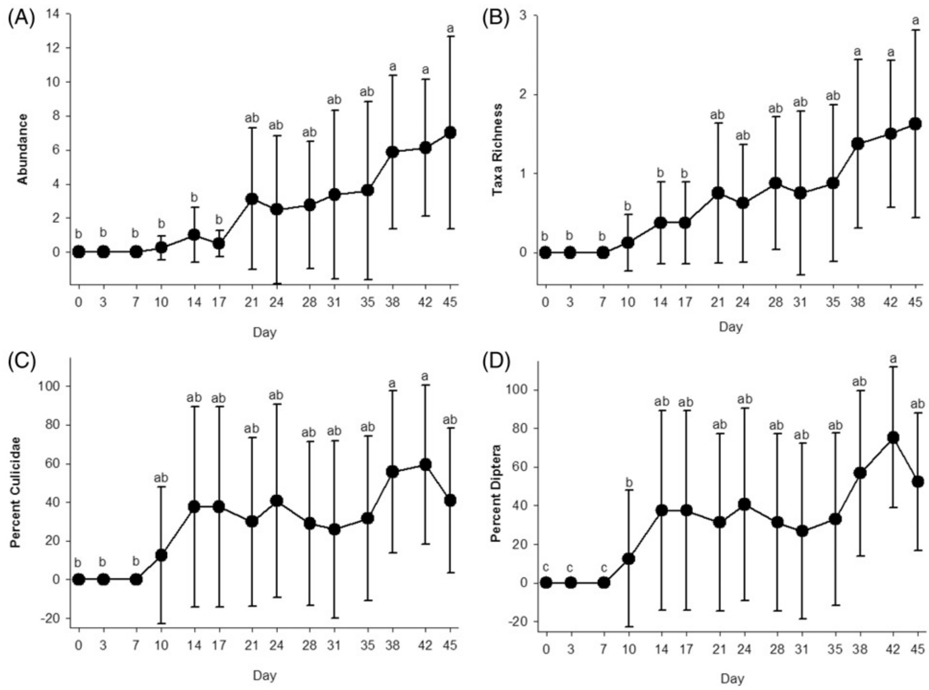

Figure 5. Means (SD) of macroinvertebrate abundance (A), taxa richness (B), percent Culicidae (C), and percent Diptera (D) among sampling days in mesocosms within riparian zones of headwater streams in the Upper Big Walnut Creek watershed, Ohio, USA (July–August 2009).

0 to 31 (Figure 6). Mean Shannon Diversity Index was greater in unchannelized riparian zones than channelized riparian zones from days 35 to 45 (Figure 6).

Discussion

Our results suggest that the physical characteristics of the water within mesocosms were influenced by riparian zone type. Canopy cover was greater in unchannelized riparian zones than channelized riparian zones, and dissolved oxygen within the mesocosms was greater in channelized riparian zones. Unchannelized riparian zones had greater amounts of canopy cover than channelized riparian zones because of greater amounts of woody vegetation within the unchannelized riparian zones. We attribute periodic decreases in dissolved oxygen within mesocosms in unchannelized riparian zones to greater detritus input into mesocosms as a result of greater canopy cover. Although differences in water temperature in the mesocosms occurred periodically between riparian zone types, our results did not confirm the reductions in water temperature expected to occur with increasing canopy cover. We believe our water temperature results were influenced by the time these measurements were collected. We were not able to measure water temperatures simultaneously and measurements were obtained between 9:00 am and 3:30 pm. Mesocosms measured before 12:00 pm (mean 19.5°C) had lower water temperatures than those measured

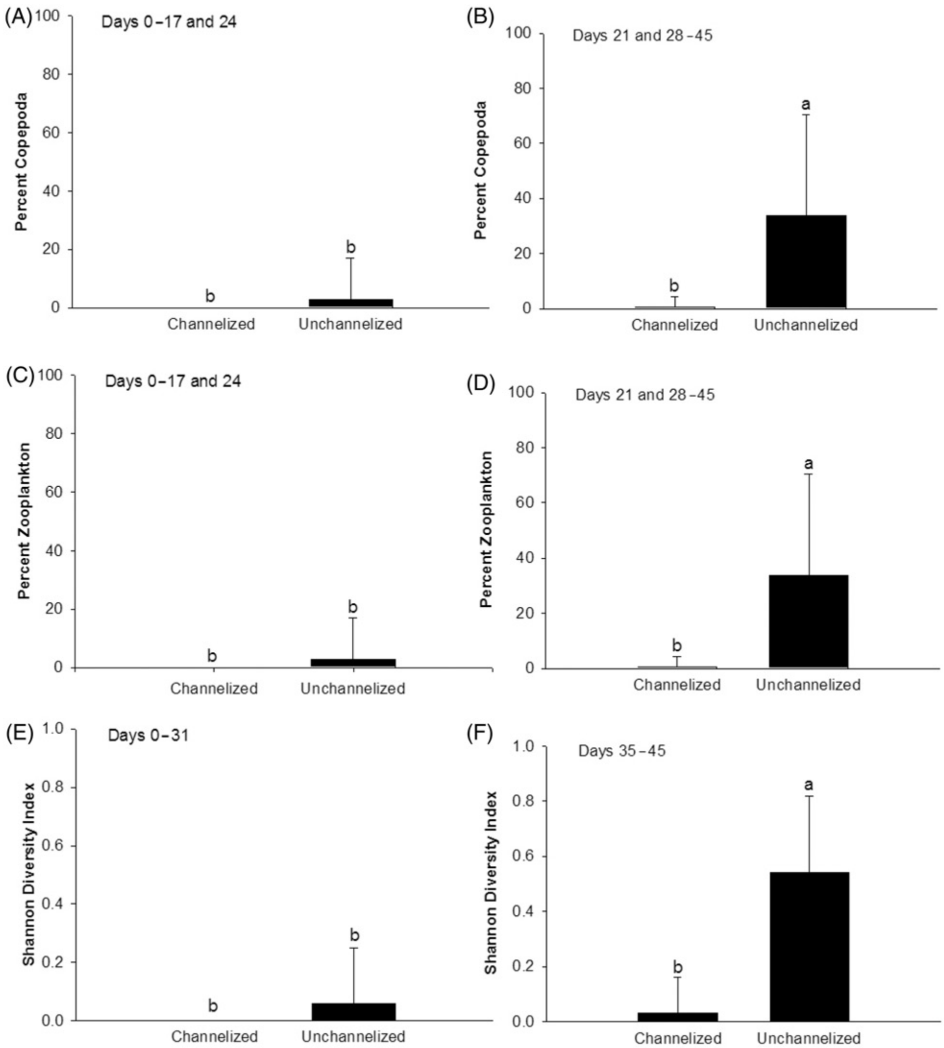

Figure 6. Means (SD) of percent Copepoda (A, B), percent zooplankton (C, D) and Shannon diversity index (E, F) in mesocosms within riparian zones of channelized and unchannelized headwater streams in the Upper Big Walnut Creek watershed, Ohio on days 0–17 and day 24 (A, C), day 21 and days 28–45 (B, D), days 0 to 31 (E), and days 35–45 (F).

after 12:00 pm (mean 23.2°C). We believe that simultaneous measurements would have revealed a water temperature difference between riparian zone types.

Our experiment began with deionized water exhibiting exceptionally low turbidity and nutrient values. Although we did not quantify detritus amounts, we observed increasing amounts of detritus and organic matter accumulating in the mesocosms in both riparian zone types as the experiment progressed. The only input of water into the mesocosms during the experiment came from rainwater or deionized water added to maintain hydrology. Thus, the increases in turbidity and nutrients within the mesocosms were not influenced by runoff water from the adjacent agricultural fields or stream water. These findings suggest that temporal increases in turbidity, dissolved organic carbon, ammonium, nitrate plus nitrite, total nitrogen, and total phosphorus within the mesocosms were a function of increasing detritus input.

Our results are consistent with those of others who conducted mesocosm experiments in terrestrial ecosystems and documented that habitat type influences the physical and chemical characteristics of the water within mesocosms. Differences in water temperature, pH, dissolved oxygen, percent algae, and percent detritus were found between artificial ponds in a large open field versus those in edge habitats transitional between an open field and a mixed hardwood-evergreen forest in Toronto, Canada (Williams et al. 1993). Greater concentrations of nitrate and nitrite and lower pH occurred within mesocosms within forested lowland swamp habitats than those in urban and pasture habitats in New Zealand (Leisnham et al. 2007). Our results and those of Williams et al. (1993) and Leisnham et al. (2007) suggest that water-filled mesocosms within forested habitats with greater canopy cover and detritus inputs will have different physical and chemical characteristics than those within non-forested habitats with lesser canopy cover and detritus inputs.

We also observed that aquatic macroinvertebrate colonization of the mesocosms differed between riparian zone types and over time. Our results are consistent with others (Blaustein et al. 1999; Leisnham et al. 2004, 2007; Kling et al. 2007; Yee and Yee 2007) who have also found that aquatic community colonization differs among habitat types within terrestrial ecosystems in the midwestern United States, Israel, and New Zealand. Mesocosms placed within forested habitats possessed greater taxa richness and abundance of aquatic macroinvertebrates than those within industrial and prairie habitats within the Midewin National Tallgrass Prairie in Illinois (Yee and Yee 2007). Tires within hardwood forest possessed greater species richness and abundance of aquatic macroinvertebrates than tires within an automobile repair facility (i.e. unforested habitat) in central Illinois (Kling et al. 2007). Mesocosms placed in forested habitats had a greater species richness and abundance of aquatic macroinvertebrates than unforested habitats on Mount Carmel in Israel (Blaustein et al. 1999). Mesocosms within open grass habitat and artificially shaded mesocosms within grass habitats had greater abundances of immature mosquitoes than mesocosms within forested lowland swamp habitats in New Zealand (Leisnham et al. 2004). Mesocosms placed in forested lowland swamp habitats exhibited greater species richness of aquatic macroinvertebrates and non-mosquito taxa than pasture or urban habitats in New Zealand (Leisnham et al. 2007). However, forested lowland swamp habitats in New Zealand had a lesser abundance of aquatic macroinvertebrates and non-mosquito taxa than pasture land (Leisnham et al. 2007).

Our aquatic macroinvertebrate results are also consistent with those who have observed differences in aquatic macroinvertebrate community colonization between shaded and unshaded mesocosms, tires, and other aquatic habitats. Yee (2008) summarized results from the midwestern and southeastern United States and found that 50% of the studies documented dramatic differences in larval mosquito species richness and abundance between shaded and unshaded tires. Greater abundances of Chironomidae and predatory Diptera occurred in unshaded than in shaded seasonal ponds in Minnesota, and Copepoda preferred shaded rather than unshaded seasonal ponds (Hanson et al. 2009). Mosquitoes and aquatic insect predators occurred more frequently in shaded than unshaded artificial containers in Japan (Sunahara et al. 2002). Mesocosms in open canopy habitats had greater abundance, species richness, and oviposition activity of aquatic beetles than closed canopy habitats in Virginia

(Binckley and Resetarits 2009). Conversely, Mokany et al. (2008) did not observe significant effects of shade on aquatic macroinvertebrate richness or abundance within mesocosms placed in a Eucalyptus forest in Australia.

Others have attributed differences in aquatic macroinvertebrate communities between habitat types and shaded/unshaded habitats to an oviposition preference for shaded environments (Yanoviak 2001), greater nutrient inputs from plant-based detritus (Kling et al. 2007; Leisham et al. 2007; Yee 2008), and/or microclimatic variations (Kling et al. 2007). We attribute the observed differences in aquatic community colonization between riparian zone types to a combination of changes in canopy cover and dissolved oxygen. We attribute the observed differences in aquatic community colonization among sampling days as a result of increases in turbidity and nutrient levels (i.e. ammonium, dissolved organic carbon, nitrate plus nitrite, total nitrogen, and total phosphorus) that created habitat conditions more suitable for aquatic macroinvertebrate colonization as the experiment progressed.

Zooplankton colonization of our mesocosms and subsequent differences in relative abundances between riparian zone types is interesting. Larval aquatic insects colonized the mesocosms via oviposition, but specific mechanisms of zooplankton colonization are less understood (Bilton et al. 2001; Bohonak and Jenkins 2003). Anecdotal evidence suggests that zooplankton dispersal occurs passively via animals (waterfowl, amphibians, reptiles, mammals, and insects), wind, rain, and flooding (Bilton et al. 2001; Bohonak and Jenkins 2003). Some zooplankton taxa are capable of colonizing new aquatic habitats and mesocosms quickly (Caceres and Soluk 2002; Vanschoenwinkel et al. 2008). Introduction of water from outside sources (i.e. flooding or agricultural runoff) containing zooplankton was not possible. The small size of our mesocosms makes it unlikely that zooplankton were introduced via waterfowl or aquatic mammals. Amphibians and reptiles were not observed in our mesocosms, but it is possible that zooplankton colonized via insects. Zooplankton colonization via wind or rain is also possible especially since our mesocosms were short distances (<7 m) from headwater streams that periodically dry up in the summer. Ephemeral aquatic habitats are a source of zooplankton propagules capable of short distance wind dispersal (Caceres and Soluk 2002; Vanschoenwinkel et al. 2008). Our unchannelized streams dry up more frequently in the summer and experience overbank flooding more often in the winter than our channelized streams (King et al. 2009). We suspect the greater relative abundance of Copepoda and zooplankton within unchannelized riparian zones may be a function of a greater availability of zooplankton propagules for wind dispersion within unchannelized riparian zones. Future research is needed to confirm this prediction.

In conclusion, our results suggest that riparian habitat modifications as a result of channelization has impacted the community structure of aquatic macroinvertebrates within riparian habitats adjacent to channelized headwater streams in central Ohio. Management practices leading to the development of forested riparian zones adjacent to channelized headwater streams should provide ecological benefits for aquatic macroinvertebrates within riparian and instream habitats.

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