Evaluation of Newbury Weirs (Rock Riffles) for Improving Habitat Quality and Biotic Diversity in Illinois Streams.

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Introduction

In predominately agricultural watersheds, such as those in Illinois, remediation techniques have been used for reducing nonpoint source pollution (see Gale et al. 1993). In 1998, the Illinois Natural History Survey in conjunction with the Illinois Department of Natural Resources (IDNR) began collecting baseline data on four Illinois watersheds that were targeted for extensive remediation practices. One watershed in the Spoon River basin has completed the implementation phase. As part of our study on the effects of watershed-wide remediation, we also began assessing the effects of two sets of Newbury weirs (rock riffle structures installed in summer 2001 and a second set in spring 2003) on abiotic and biotic parameters of stream quality. From a scientific and management perspective, there is still a great deal to be learned about the relative effectiveness of individual practices in particular environmental settings and how fish and invertebrate assemblages respond to these practices under various environmental conditions. By assessing individual practices, we can inform watershed planning committees which types of practices will have the greatest impact on stream quality, thus, aiding their decisions in watershed remediation planning.

The goal of this study was to increase our understanding of riffle structures for improving stream quality in Illinois watersheds. Our specific objectives were to assess changes in physical habitat due to installation of Newbury weirs and assess the response of macroinvertebrate and fish assemblages to this particular type of remediation practice.

Study Site and Methods

For our study on rock riffle structures, sites were located in the Court Creek Watershed, a tributary to the Spoon River basin (Figure 1). In 2001 and 2003, Newbury weirs (rock riffle structures) were installed in two separate stream reaches on North Creek (tributary to Court Creek), Knox County, IL. We monitored these two weir sites and a reference site before and after weir installation. At the site where Newbury weirs were installed in 2001 (NW1), we monitored habitat, fish, and invertebrates twice before (fall 2000 and spring 2001) and seven times after (late summer and spring 2001-2004) weir placement. At the second set of weirs installed in 2003 (NW2), we collected habitat, fish, and invertebrate data twice before (fall 2002 and spring 2003) and four times after (late summer and spring 2003-2004 and spring 2006) weir implementation. The "control" or reference site on North Creek was also sampled at approximately the same time as the two treated sites. Length of both treated and reference sites were approximately 20 times mean bankfull width (Gough 1997) to ensure that at least one riffle-run-pool sequence was sampled. At all three sites, physical habitat and bank/riparian cover was measured using a quantitative point/transect method (Stanfield et al.1998). Fish were collected using IDNR's standard protocol of a single pass with an AC electric seine using block nets to enclose the stream reach (Bayley et al. 1989). Macroinvertebrates were quantitatively sampled using a stratified random sampling design whereby habitats were sampled in proportion to their availability. We used a coring device in pool areas and a Hess sampler in riffles. At both weir sites, changes in abiotic and biotic parameters were assessed by comparing these characteristics of stream quality before and after implementation. Analysis of Variance was used to determine significant differences in habitat and biota between before and after time periods. An alpha value of 0.05 was used to determine significant changes in habitat and biotic communities.

Results

We found significant changes in habitat and biotic communities at these Newbury weir sites on North Creek. Several habitat variables showed a significant change between pre- and post-weir periods; however, the biotic community showed less of a change after implementation.

Newbury Weir Site 1

At the first set of weirs installed in 2001 (NW1 site), we found that both point substrate and maximum substrate sizes significantly increased after weir installation due to placement of large rock in the stream to simulate natural riffles ($p_{point\ sub.} = 0.04$, $p_{max\ sub.} = 0.02$, Table 1). Although depth did not significantly increase in the post-weir period, we found that width and width/depth ratio was marginally significantly different ($p < 0.10$, Table 1) with average width increasing and width/depth ratio decreasing after weir installation. Average surface area sampled increased significantly ($p = 0.04$) following weir construction, possibly due to readjustment and shifting of the stream bed and banks, creating a wider channel.

Overall, in-stream fish cover increased after implementation as indicated by the percentage of no fish cover decreasing after implementation ($p_{no\ cover} < 0.001$, Table 2). We did find that the percent of unembedded wood cover decreased ($p < 0.001$); however, the percentage of embedded flat rock increased ($p = 0.044$). Percent habitat composition and in-stream vegetation changed more with season than between time periods (Tables 1 and 2). In late summer/early fall, habitat consisted primarily of pools with smaller amounts of run and slow riffle habitat. On the dates sampled in late spring, habitat composition was more diverse with larger percent run, slow riffle, and fast riffle habitat. Conversely, the amount of in-stream vegetation showed an opposite trend with higher percentage and more diverse types of vegetation in late summer/early fall than in late spring samples with the exception of the spring 2004 date. These trends in habitat composition and vegetation are probably due to higher water levels in the spring creating riffle and run habitat and preventing in-stream vegetation from becoming established; while, in the late summer, water levels are lower creating more slow flowing pooled areas and allowing vegetation to grow in the stream. As a result of these seasonal trends, we found no significant differences in habitat composition and only a marginally significant difference ($p < 0.10$, Table 2) in filamentous algae between pre- and post-weir dates.

Fish species richness and catch per unit effort (CPUE) did not significantly change after weir installation (Table 3). However, we observed a dramatic decline in CPUE a year following weir placement followed by a steady increase through time to numbers more similar to pre-weir conditions. We also found a shift in community composition after the weirs were installed. Percent composition of catostomids and centrarchids were marginally significantly higher after weir placement ($p_{catostomids} = 0.07$, $p_{centrarchids} = 0.08$), and percentage of smallmouth bass increased immediately after weir placement followed by a decline to pre-weir conditions four years after implementation. Since installation of these weirs, three new ictalurid species have been found at NW1 (black bullhead, channel catfish, and stonecat). This increase in catostomids and centrarchids and the appearance of black bullhead and channel catfish is potentially due to the creation of deeper scour pools located downstream of the riffle structures.

At the first set of weirs, invertebrate taxa richness within riffles significantly increased after weir placement ($p_{riffle\ richness} = 0.04$, Table 4). Although no other invertebrate parameters we analyzed changed significantly between the two time periods, we did observe a few shifts in community composition. Total taxa richness and the more sensitive insect taxa in the Ephemeroptera, Plecoptera, and Trichoptea (%EPT) families also increased after implementation. Relative abundance (catch per area, CPA) did not show a significant change after weir placement, but CPA in glide habitats did show a seasonal trend with higher numbers in the fall with the exception of the spring 2004 sampling date (Table 4).

Newbury Weir Site 2

At the second set of weirs installed in 2003 (NW2), we found evidence that the structures affected physical habitat and the biota. However, fewer parameters significantly changed as a result of implementation compared to the changes at the NW1 site. After weir placement, the width/depth ratio significantly decreased ($p = 0.002$) due to the marginally significant increase in depth ($p = 0.07$, Table 5). Unlike the NW1 site, substrate did not significantly change, but average maximum substrate was marginally significantly larger after implementation ($p = 0.08$).

As with the NW1 site, we observed an increase in amount of fish cover at the NW2 site following weir placement as evidenced by the marginally significant decline in amount of streambed with no cover ($p = 0.07$, Table 6). A seasonal trend in habitat composition and in-stream vegetation was also apparent at this weir site (Tables 5 and 6). Percentage of riffle and run habitats were greater in spring when flows are presumably higher due to spring rains. Late summer/fall sample dates tended to have higher percent of vegetation when flows are low and stable, allowing them to establish in the stream. Although percent vegetation showed a seasonal trend, we did find a significant decrease in filamentous algae after weir implementation ($p = 0.003$, Table6).

We found no significant changes in our fish assemblage parameters after weir installment at the NW2 site and observed no dramatic decline in CPUE as we did at the NW1 site (Table 7). However, we did find similar shifts in assemblage composition as seen at the NW1 site. We found a marginally significant increase in percent centrarchids ($p = 0.08$) and percent smallmouth bass ($p = 0.09$) in the post-weir sample dates. We also found an increase in average number of darters which was not observed at the NW1 site.

Invertebrate taxa richness within glide habitats significantly decreased after implementation ($p_{glide\ richness} = 0.03$, Table 8), unlike at the NW1 site which showed an increase in richness in riffle habitats. No other invertebrate parameters significantly changed between the pre- and post-weir periods, but we did detect shifts in the community that oppose those shifts seen at the NW1 site. We observed %EPT decreased on average after implementation as opposed to NW1 where %EPT increased (Table 4). We also found a marginally significant increase in the Family Biotic Index (FBI) during the post-weir period ($p = 0.08$). Based on tolerance of the invertebrates present at NW2 site, water quality changed from fairly poor (average FBI = 6.1) in the pre-weir period to poor (7.0) in the post-weir period. This decrease in the sensitive EPT taxa and increase in FBI score suggests that some change in physical or chemical habitat quality may be impacting the invertebrate community at this site.

Discussion and Summary

Results from monitoring of Newbury weirs supports the idea that these structures change channel morphology characteristics of the stream. We found similar changes in channel morphology at both sites; implementation of rock riffle structures increased the amount of larger, stable substrate, created wider and deeper pool areas, and increased fish cover. In addition to changes in habitat, we found some similarities in the shifts and trends of fish community composition following weir placement. Percentage of centrachid species (which typically prefer pools with moderate to slow flows) increased following implementation, indicating that these structures do create new habitats important for several fish species.

Comparing the two weir sites, we did find differences in their effects on stream fish and invertebrates when these structures are located at different drainage areas. At the NW1 site (located at a larger drainage area), shifts in fish assemblages included increased abundance of ictalurids and three new ictalurid species. Two of these new ictalurid species are larger bodied species (channel catfish and black bullhead) and typically prefer deeper pools. At the NW2 site, the number of darters (which are smaller species that typically prefer faster riffles) increased after weir placement. The difference in how the fish communities reacted to the weir implementation at the two sites is likely due to the downstream site (NW1) being closer in proximity to larger water (Court Creek) and, therefore, allowing colonization by bigger species in the newly created scour pools. Changes in invertebrate communities showed very different patterns between the two weir sites. At the downstream weir site, invertebrates showed an improvement in number of taxa present in riffles and percentage of sensitive EPT taxa; whereas, the upstream weir site (NW2) showed a decline in percentage of EPT taxa and an increase in tolerant taxa (i.e., FBI score increased) following implementation. One explanation for this difference in response could be due to local land use and water quality issues at the upstream weir site.

Through assessment of these riffle structures at two different drainage areas within a watershed, we can obtain a more comprehensive examination of how these structures affect stream ecosystems in different environmental settings. By gaining a fuller understanding of the effects of rock riffles in streams, managers will be better able to predict the effectiveness of these structures in other Illinois watersheds of similar size.

Literature Cited

Bayley, P. B., R. W. Larimore, and D. C. Dowling. 1989. Electric seine as fish sampling gear in streams. Transactions of the American Fisheries Society 118:447-453.

Gale, J. A., D. E. Line, D. L. Osmond, S. W. Coffey, J. Spooner, J. A. Arnold, T. J. Hoban, and R. C. Wimberly. 1993. Evaluation of the experimental rural clean water program. National Water Quality Evaluation Project, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC, USA.

Gough, S. C. 1997. Stream classification and assessment. The Nature Conservancy, Peoria, Illinois Field Office, Peoria, Illinois, USA.

Hilsenhoff, W.L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of North American Benthological Society 7:65-68.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. benthic macroinvertebrates and fish. EPA/444/4-89/0001. Office of Water Regulations and Standards, United States Environmental Protection Agency, Washington, DC.

Stanfield, L., M. Jones, M. Stoneman, B. Kilgour, J. Parish, G. Wichert. 1998. Stream assessment protocol for Ontario. v. 2.1.

Stewart-Oaten, A., W. W. Murdoch, and K. R. Parker. 1986. Environmental impact assessment: "pseudoreplication" in time? Ecology 67:929-940.

Figure 1. Location of Court Creek watershed and Newbury weir sites on North Creek. *Map modified from IDNR Technical Support Section.

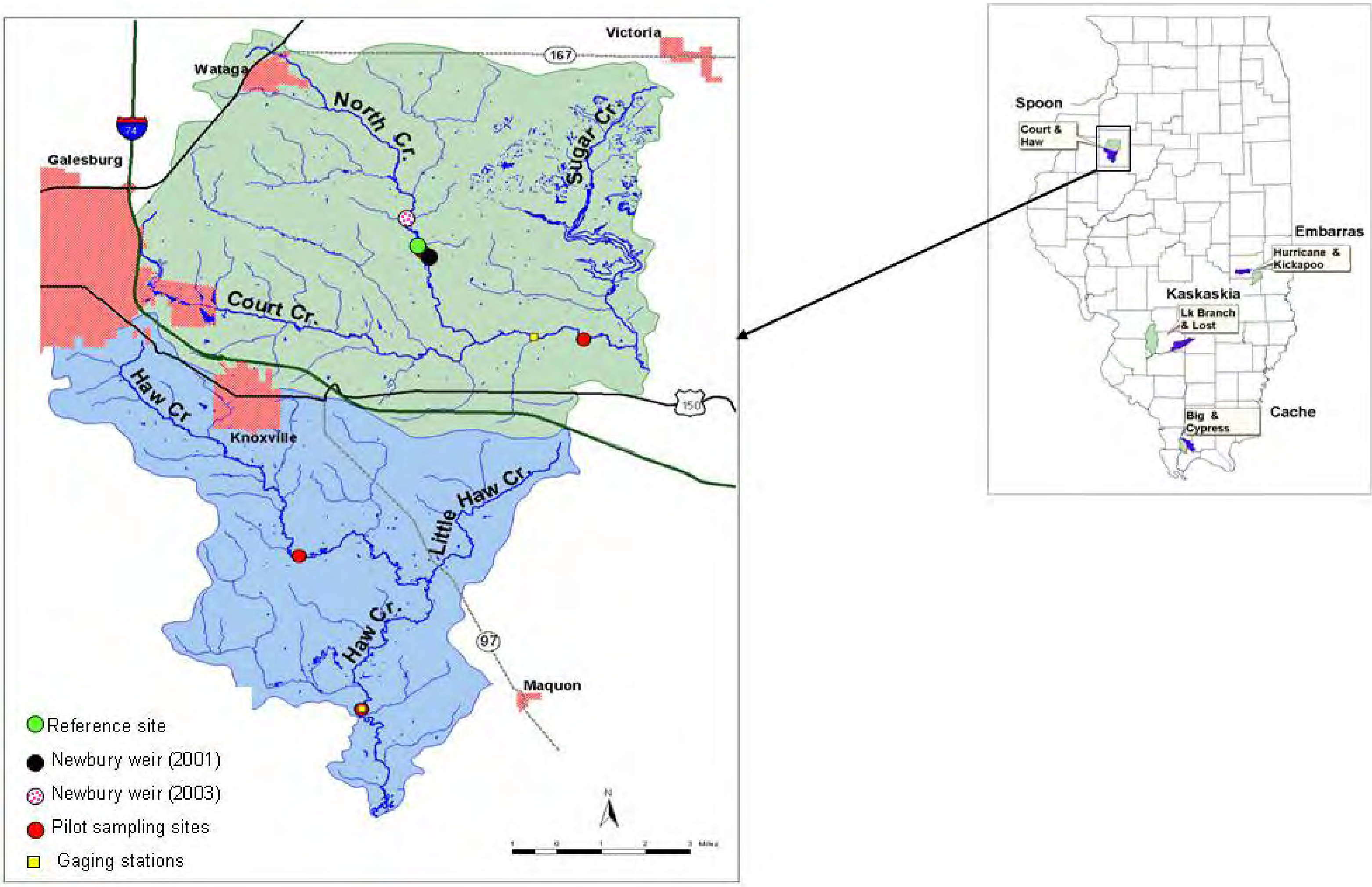

Table 1. Mean and standard errors (in parentheses) of channel morphology features and habitat composition at the Newbury Weir site (NW1) in the Court Creek watershed located 300m downstream of our upper North Creek pilot site (reference). Weirs were installed in June 2001. An alpha value of 0.05 was used to detect significant difference in pre- and post-weir dates.

	Pre-weir			Post-weir								
	10/00	5/01	Mean (SE)	8/01	6/02	9/02	5/03	8/03	6/04	9/04	Mean (SE)	P-value
Ave. Sample Area	1226	1663	1444.5 (218.5)	2733	3114	2906	3010	2422	1820	1687	2527.4 (217.1)	0.04
Ave. Width (m)	5.6	7.7	6.7 (1.1)	7.9	9.0	8.4	8.7	7.0	8.2	7.6	8.1 (0.3)	0.07
Ave. Depth (mm)	229.5	346.2	287.9 (58.4)	369.1	674.9	416.8	478.2	345.7	529.3	352.9	452.4 (45.1)	0.12
Width/Depth Ratio	24.3	22.4	23.4 (1.0)	21.5	13.3	20.1	18.2	20.2	15.4	21.5	18.6 (1.2)	0.09
Ave. Pt. Substrate (mm)	6.5	9.3	7.9 (1.4)	16.9	43.5	92.6	88.7	49.4	54.6	79.4	60.7 (10.4)	0.04
Ave. Max Substrate (mm)	20.8	25.0	22.9 (2.1)	86.1	92.0	152.5	122.5	85.4	109.4	212.6	122.9 (17.5)	0.02
Ave. Velocity (m/s)	0.03	0.28	0.16 (0.13)	0.01	0.35	0.05	0.21	0.00	0.16	0.01	0.11 (0.05)	0.72
% Pool	83	20	51.7 (31.7)	93	35	88	68	100	63	92	77.0 (8.7)	0.31
% Run	7	28	17.5 (10.5)	5	30	5	15	0	13	5	10.4 (3.8)	0.44
% Slow Riffle	7	33	20.0 (13.0)	0	24	5	5	0	9	0	6.1 (3.2)	0.14
% Fast Riffle	2	17	9.5 (7.5)	2	11	2	12	0	11	0	5.4 (2.1)	0.46
% Island	2	2	2 (0.0)	0	0	0	0	0	4	3	1.0 (0.7)	0.46

Table 2. Mean and standard errors (in parentheses) of percent in-stream cover and vegetation at the Newbury Weir site in the Court Creek watershed located 300m downstream of our upper North Creek pilot site (reference). Weirs were installed in June 2001. An alpha value of 0.05 was used to detect significant difference in pre- and post-weir dates.

	Pre-weir			Post-weir								
	10/00	5/01	Mean (SE)	8/01	6/02	9/02	5/03	8/03	6/04	9/04	Mean (SE)	P-value
Cover												
U. Flat Rock	0	0	0.0 (0.0)	0	2	2	13	0	4	9	4.3 (1.9)	0.280
U. Round Rock	0	0	0.0 (0.0)	5	28	10	8	32	20	21	17.7 (3.9)	0.056
U. Wood	10	7	8.5 (1.5)	2	2	2	2	0	2	0	1.4 (0.4)	0.000
E. Flat Rock	0	0	0.0 (0.0)	7	2	8	2	2	2	3	3.7 (1.0)	0.099
E. Round Rock	0	0	0.0 (0.0)	12	6	12	2	5	6	5	6.9 (1.4)	0.044
No Cover	90	93	91.5 (1.5)	75	61	67	73	62	67	62	66.7 (2.1)	0.000
Vegetation												
Macrophytes	2	0	1.0 (1.0)	2	0	0	0	0	11	40	7.6 (5.6)	0.571
Filamentous Algae	12	2	7.0 95.0)	27	2	27	27	25	30	36	24.9 (4.0)	0.066
Terrestrial	17	8	12.5 (4.5)	10	9	0	2	2	13	12	9.0 (3.5)	0.646
No Vegetation	70	90	80.0 (10.0)	62	89	73	72	73	46	12	61.0 (9.5)	0.317

Table 3. List of fish species, numbers collected, species richness, and percent cyprinids, catastomids, centrachids, and smallmouth bass (SMB) in pre- and post-weir construction at the Newbury weir site (NW1) located 300m downstream of the upper North Creek pilot site (reference). Weirs were installed in June 2001.

		Pre-weir		Post-weir						
Species	Scientific Name	10/00	5/01	8/01	6/02	9/02	5/03	8/03	6/04	9/04
Catostomidae										
Golden redhorse	*Moxostoma erythrurum*	5	10	7	3	6	3	126	67	164
Northern hog sucker	*Hypentelium nigricans*	1	1	0	0	0	0	1	1	2
Quillback	*Carpiodes cyprinus*	0	2	4	4	6	25	5	16	16
White sucker	*Catostomus commersoni*	25	44	104	0	24	16	30	6	17
Centrarchidae										
Bluegill	*Lepomis macrochirus*	3	1	5	0	46	15	78	5	25
Bluegill x Green sunfish hybrid	*Lepomis macrochirus x L. cyanellus*	0	0	0	0	0	1	0	0	0
Green sunfish	*Lepomis cyanellus*	0	0	0	0	29	34	45	20	48
Largemouth bass	*Micropterus salmoides*	6	3	7	0	1	0	0	0	2
Smallmouth bass	*Micropterus dolomieu*	12	3	52	7	18	5	45	10	24
Cyprinidae										
Bigmouth shiner	*Notropis dorsalis*	289	25	26	0	11	1	0	0	0
Blacknose dace	*Rhinichthys atratulus*	36	17	0	0	1	1	0	0	0
Bluntnose minnow	*Pimephales notatus*	2207	261	392	7	100	296	755	600	851
Carp	*Cyprinus carpio*	0	0	0	1	0	0	1	0	0
Central stoneroller	*Campostoma anomalum*	199	113	65	25	41	4	58	47	237
Creek chub	*Semotilus atromaculatus*	151	26	35	10	2	2	48	7	18
Golden shiner	*Notemigonus crysoleucas*	0	0	0	1	0	0	2	0	0
Hornyhead chub	*Nocomis biguttatus*	13	1	0	0	14	5	8	10	10
Red shiner	*Cyprinella lutrensis*	419	41	29	15	55	16	88	187	177
Redfin shiner	*Lythrurus umbratilus*	1	0	1	12	14	26	20	38	96
Sand shiner	*Notropis ludibundus*	1181	196	80	25	50	86	225	112	68
Southern redbelly dace	*Phoxinus erythrogaster*	0	0	0	0	0	0	4	0	0
Striped shiner	*Luxilus chrysocephalus*	21	2	0	5	9	8	32	16	28

Table 3. Continued

Ictaluridae										
Black bullhead	*Ameiurus melas*	0	0	0	0	0	0	1	0	0
Channel catfish	*Ictalurus punctatus*	0	0	0	0	0	2	2	0	0
Slender madtom	*Noturus exilis*	1	0	0	0	0	0	0	0	0
Stonecat	*Noturus flavus*	0	0	10	1	1	2	5	5	1
Yellow bullhead	*Ameiurus natalis*	2	0	1	11	8	3	8	4	8
Percidae										
Johnny darter	*Etheostoma nigrum*	47	0	15	0	2	1	33	12	31
Orangethroat darter	*Etheostoma spectabile*	25	5	2	0	0	3	3	13	22
Total Catch		4644	751	835	127	438	555	1623	1176	1845
Species Richness		20	17	17	14	20	22	24	19	20
Catch per hour of electroshocking		2953	547	743	72	355	473	1211	1249	1728
% cyprinids		49.1	45.8	39.8	43.0	38.5	42.6	41.0	86.5	80.5
% catostomids		0.7	7.6	12.1	5.2	7.6	7.3	9.1	7.7	10.8
% centrachids		0.5	0.9	7.1	5.2	17.7	9.0	9.4	3	5.4
%SMB		0.3	0.4	6.2	5.5	4.1	0.9	2.8	0.9	1.3

Table 4. Macroinvertebrate abundance (numbers per m^2), taxa richness, Family Biotic Index (FBI), percent Ephemeroptera, Plecoptera, Trichoptera (EPT), and percent Oligocheates for each date and habitat type sampled at the Newbury Weir (treated, NW1) site located 300m downstream of our upper North Creek site (reference). Weirs were installed in June 2001.

	Pre-weir			Post-weir							
	10/00	5/01	Mean (SE)	10/01	7/02	10/02	5/03	8/03	6/04	9/04	Mean (SE)
Total CPA (no./m^2)	193764	101833	147799 (45966)	157238	58781	111506	49583	158557	418790	105500	151422 (47365)
CPA: Glides	120468	40848	80658 (39810)	148391	31296	64977	35366	100016	380444	67443	118276 (46249)
CPA: Riffles	7617	11305	9461 (1844)	8847	27486	46528	14217	58541	38346	38057	33146 (6647)
Total Richness	35	36	35.5 (0.5)	54	42	42	40	34	45	50	43.9 (2.5)
Richness: Glides	25	14	19.5 (5.5)	22	15	23	18	16	19	21	19.1 (1.1)
Richness: Riffles	26	31	28.5 (2.5)	48	38	36	36	34	40	48	40.0 (2.2)
%EPT	12.2	11.0	11.6 (0.6)	9.4	39.0	56	17.9	9	16.7	20.7	24.1 (6.5)
% Oligocheates	30.2	27.7	29.0 (1.3)	14.4	23.8	4.6	23.4	18.5	45.9	13.3	20.6 (4.90
FBI	6.7	6.5	6.6 (0.1)	7.2	5.6	5.1	6.1	7.5	6.6	6.1	6.3 (0.3)

FBI	Water Quality
0.00 - 3.75	Excellent
3.76 - 4.25	Very Good
4.26- 5.00	Good
5.01 - 5.75	Fair
5.76 - 6.50	Fairly Poor
6.51 - 7.25	Poor
7.26 - 10.00	Very Poor

* from Hilsenhoff (1988)

Table 5. Mean and standard errors (in parentheses) of channel morphology features and habitat composition at the Newbury Weir site (NW2) in the Court Creek watershed located approximately 2 miles upstream of our upper North Creek pilot site (reference). Weirs were installed in June 2003. An alpha value of 0.05 was used to detect significant difference in pre- and post-weir dates.

	Pre-weir			Post-weir					
	10/02	4/03	Mean (SE)	9/03	6/04	9/04	5/06	Mean (SE)	P-value
Ave. Sample Area	1050	1152	1101 (51.0)	1060	1303	1267	1638	1317 (119.6)	0.3
Ave. Width (m)	5.6	6.0	5.8 (0.2)	5.3	7.2	7.0	8.6	7 (0.7)	0.3
Ave. Depth (mm)	265.1	306.0	285.6 (20.5)	337.4	497.2	429.7	545.1	452.3 (45.0)	0.07
Width/Depth Ratio	21.12	19.6	20.36 (0.8)	15.7	14.5	16.2	15.8	15.6 (0.4)	0.002
Ave. Pt. Substrate (mm)	17.8	5.7	11.8 (6.1)	17.7	43.3	14.1	20.6	23.9 (6.6)	0.313
Ave. Max Substrate (mm)	35.5	30.4	33.0 (2.5)	63.4	72.9	39.9	81.6	64.5 (9.0)	0.081
Ave. Velocity (m/s)	0.00	0.09	0.05 (0.04)	0.00	0.05	0.00	0.11	0.04 (0.03)	0.922
% Pool	100	73	86.7 (13.4)	100	92	97	52	85.3 (11.2)	0.922
% Run	0	12	6 (6)	0	3	0	30	8.3 (7.3)	0.85
% Slow Riffle	0	2	1 (1)	0	0	0	17	4.3 (4.3)	0.638
% Fast Riffle	0	13	6.5 (6.5)	0	5	0	2	1.8 (1.2)	0.336
% Island	0	0	0 (0)	0	0	3	0	0.8 (0.8)	0.542

Table 6. Mean and standard errors (in parentheses) of percent in-stream cover and vegetation at the Newbury Weir site in the Court Creek watershed located approximately 2 miles upstream of our upper North Creek pilot site (reference). Weirs were installed in June 2003. An alpha value of 0.05 was used to detect significant difference in pre- and post-weir dates.

	Pre-weir			Post-weir					
	10/02	4/03	Mean (SE)	9/03	6/04	9/04	5/06	Mean (SE)	P-value
Cover									
U. Flat Rock	2	0	1.0 (1.0)	0	0	0	3	0.8 (0.8)	0.855
U. Round Rock	0	0	0.0 (0.0)	13	13	5	3	8.5 (2.6)	0.98
U. Wood	3	0	1.5 (1.5)	0	2	2	0	1.0 (0.6)	0.712
E. Flat Rock	0	3	1.5 (1.5)	3	2	0	3	2.0 (0.7)	0.74
E. Round Rock	0	0	0.0 (0.0)	2	3	3	0	2.0 (0.7)	0.132
E. Wood	0	2	1.0 (1.0)	2	2	0	0	1.0 (0.6)	1
No Cover	95	95	95.0 (0.0)	80	78	90	91	84.8 (3.6)	0.074
Vegetation									
Macrophytes	0	12	6.0 (6.0)	0	15	17	50	20.5 (10.5)	0.425
Filamentous Algae	28	30	29.0 (1.0)	18	17	12	15	15.5 (1.3)	0.003
Moss	0	0	0.0 (0.0)	0	0	0	2	0.5 (0.5)	0.542
Terrestrial	3	3	3.0 (0.0)	7	23	24	2	14 (5.6)	0.26
No Vegetation	68	55	60.0 (8.0)	75	45	47	31	49.5 (9.2)	0.487

Table 7. List of fish species, numbers collected, species richness, and percent cyprinids, catostomids, centrachids, and smallmouth bass (SMB) in pre-weir and post-weir construction periods at the Newbury weir site (NW2) located two miles upstream of the upper Court Creek site (reference). Weirs were installed in June 2003.

		Pre-weir		Post-weir			
Species	Scientific Name	10/02	4/03	9/03	6/04	9/04	5/06
Catostomidae							
Golden redhorse	*Moxostoma erythrurum*	3	2	97	22	246	47
Northern hog sucker	*Hypentelium nigricans*	1	0	0	0	0	0
Quillback	*Carpiodes cyprinus*	0	0	9	4	38	3
River carpsucker	*Carpiodes carpio*	0	0	0	0	4	15
Shorthead redhorse	*Moxostoma macrolepidotum*	0	0	0	0	1	0
White sucker	*Catostomus commersoni*	48	75	153	4	45	56
Centrarchidae							
Bluegill	*Lepomis macrochirus*	39	1	190	19	89	139
Bluegill x Green sunfish hybrid	*Lepomis macrochirus x L. cyanellus*	0	0	0	1	0	0
Green sunfish	*Lepomis cyanellus*	17	6	58	12	78	40
Largemouth bass	*Micropterus salmoides*	5	0	0	0	0	0
Smallmouth bass	*Micropterus dolomieu*	16	2	20	13	28	19
Cyprinidae							
Bigmouth shiner	*Notropis dorsalis*	48	34	0	0	0	0
Blacknose dace	*Rhinichthys atratulus*	4	1	1	0	0	0
Bluntnose minnow	*Pimephales notatus*	913	236	1049	217	135	278
Central stoneroller	*Campostoma anomalum*	11	94	87	52	91	17
Common shiner	*Luxilius cornutus*	1	0	1	0	0	0
Creek chub	*Semotilus atromaculatus*	12	35	30	23	12	2
Fathead minnow	*Pimephales promelas*	0	0	0	0	0	3
Hornyhead chub	*Nocomis biguttatus*	3	8	11	2	11	0
Red shiner	*Cyprinella lutrensis*	88	34	65	124	75	47
Redfin shiner	*Lythrurus umbratilus*	12	28	54	51	80	68
Sand shiner	*Notropis ludibundus*	187	155	65	21	3	38
Southern redbelly dace	*Phoxinus erythrogaster*	0	6	0	0	0	0
Spotfin shiner	Cyprinella spiloptera				1	0	0
Striped shiner	*Luxilus chrysocephalus*	0	6	10	11	9	0

Table 7. continued.

Ictaluridae							
Black bullhead	*Ameiurus melas*	0	0	16	0	0	0
Stonecat	*Noturus flavus*	2	5	2	3	2	0
Yellow bullhead	*Ameiurus natalis*	3	1	13	3	5	4
Percidae							
Johnny darter	*Etheostoma nigrum*	6	9	25	8	25	14
Orangethroat darter	*Etheostoma spectabile*	3	4	11	3	19	4
Total Catch		1422	742	1967	594	996	794
Species Richness		21	20	21	20	20	17
Catch per hour of electrofishing		1530	788	1457	825	972	533
% cyprinids		89.9	85.8	69.8	84.5	41.8	57.1
% catostomids		3.7	10.4	13.2	5.1	33.5	15.2
% centrachids		5.4	1.2	13.6	7.6	19.6	24.9
%SMB		1.1	0.3	1	2.2	2.8	2.4

Table 8. Macroinvertebrate abundance (numbers per m^2), taxa richness, Family Biotic Index (FBI), percent Ephemeroptera, Plecoptera, Trichoptera (EPT), and percent Oligocheates for each date and habitat type sampled at the Newbury Weir (treated, NW2) site located approximately 2 miles upstream of our upper North Creek pilot site (reference). Weirs were installed in June 2003.

	Pre-weir			Post-weir				
	10/02	4/03	Mean (SE)	9/03	6/04	9/04	5/06	Mean (SE)
Total CPA (no./m^2)	115689	347989	231839 (116150)	147467	346462	100847	20012	153697 (69439)
CPA: Glides	98238	290009	194123.5 (95886)	94308	272821	60423	12163	109929 (56853)
CPA: Riffles	17451	57980	37715.5 (20265)	53159	73641	40424	7849	43768 (13790)
Total Richness	32	37	34.5 (2.5)	28	39	38	30	33.8 (2.8)
Richness: Glides	18	21	19.5 (1.5)	16	15	14	12	14.3 (0.9)
Richness: Riffles	29	31	30.0 (1.0)	24	38	36	29	31.8 (3.3)
%EPT	41.1	8.1	24.6 (16.50	12.7	12.3	15.3	5.7	11.5 (2.0)
% Oligocheates	8.2	26.8	17.5 (9.3)	19.4	38.5	42.4	61.7	40.5 (8.7)
FBI	5.7	6.4	6.1 (0.4)	7.7	6.8	6.6	7.0	7.0 (0.2)

FBI	Water Quality
0.00 - 3.75	Excellent
3.76 - 4.25	Very Good
4.26- 5.00	Good
5.01 - 5.75	Fair
5.76 - 6.50	Fairly Poor
6.51 - 7.25	Poor
7.26 - 10.00	Very Poor

* from Hilsenhoff (1988)

Pictures of the 2001 Newbury weir site before weirs (a), 3 months after weirs (b), 3 years after weirs installed (c) and picture of reference site (d).

a. b.

c. d.

Pictures depicting gaging station on North Creek (e), invertebrate sampling (f), habitat sampling (g), and fish sampling (h).

e.

f.

g.

h.