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). Since 1998, the Illinois Natural History Survey in conjunction with the Illinois Department of Natural Resources (IDNR) has been collecting baseline data on four Illinois watersheds which will have extensive remediation practices implemented. 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

Our study 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 in which 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 three times after (late summer and spring 2003-2004) 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 the NW1 site, changes in physical habitat and fish assemblages were assessed by comparing habitat and fish assemblage characteristics before and after implementation. At the NW2 site, shifts in habitat and fish assemblages were assessed through comparisons before and after implementation between the treated and reference sites (BACIP, Stewart-Oaten et al.1986). Changes in macroinvertebrate communities at both weir sites were assessed

through comparisons of composition, abundance, and biotic indices using the BACIP design. Analysis of Variance was used to determine significant differences in habitat and biota between before and after time periods.

Results

We found significant changes in habitat and biotic communities at these Newbury weir sites on North Creek. 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 ($p < 0.10$) 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 readjusting and shifting of the stream bed and banks, creating a wider and deeper channel. Percent habitat composition and in-stream vegetation changed more with season than between time periods (Table 1). 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 establish in the stream. As a result of these seasonal trends, we found no significant differences in habitat composition and only a marginally significant difference ($p < 0.10$) in filamentous algae between pre- and post-weir dates.

At the NW1 site, fish species richness, CPUE, and Index of Biotic Integrity (IBI) did not significantly change after weir installation (Table 2). However, we observed a dramatic decline in CPUE a year following weir placement and then 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 ($p_{catostomids} = 0.07$, $p_{centrarchids} = 0.08$). Since installation of these weirs, three new ictalurid species have been found at NW1 (black bullhead, channel catfish, and stonecat).

At the first set of weirs and the reference site, we analyzed macroinvertebrate samples from two pre-weir dates (Fall 2000 and Spring 2001) and four post-weir dates (Fall 2001, Summer 2002, Spring 2004 and Fall 2004) to determine initial and long-term impacts of these structures on invertebrate communities. Total taxa richness and taxa richness within riffles significantly increased after weir placement compared to the reference site ($p_{tot\ richness} = 0.01$, $p_{riffle\ richness} = 0.02$, Table 3). Although no other invertebrate parameters significantly changed between the two time periods, we did see some shifts in community composition and abundance. Before weir placement, abundance in the reference site was twice as high as the NW1 site, but immediately after weir installation, total abundance became similar to the reference site. Abundance was

also greater at NW1 compared to the reference site three years after weir installation. In the pre-weir period, percent Ephemeroptera, Plecoptera, and Trichoptera taxa (%EPT) and Family Biotic Index (FBI) values were similar between the two sites with water quality rated as poor to fairly poor at both sites. However, one year following weir installation, %EPT increased substantially compared to the reference and water quality was rated as fair at NW1 site After three years post-weir, we found percent EPT and FBI scores at the NW1 site became more similar to the reference site.

At the second set of weirs installed in 2003 (NW2), we found significant changes in channel morphology characteristics when compared to the reference site (Table 4). After weir placement, both average width and depth significantly increased compared to the reference ($p_{width} = 0.02$, $p_{depth} = 0.01$). Average sample area also significantly increased at NW2 compared to the reference site ($p = 0.01$) due to the increases in width and depth. We found no significant changes in fish assemblage parameters after weir installment at the NW2 site (Table 5). However, we did find similar shifts in assemblage composition as seen at the NW1 site. We found a substantial increase in numbers of catostomids and centrarchids in the post-weir sample dates. We also found an increase in numbers of darters which was not observed at the NW1 site. Although we did not find significant changes 15 months after weir implementation at the NW2 site, continued shifts in channel morphology, substrate, and bank stability are likely to occur, potentially affecting fish assemblages 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 by increasing the amount of stable substrate and creating wider and deeper pool areas. In addition to changes in habitat, we found shifts and trends in fish and invertebrate community composition following weir placement at NW1 and the beginning stages of fish community shifts at NW2 indicating that these structures do create important habitat and improve the quality of the stream for sensitive taxa (smallmouth bass, darters, mayflies, etc.). We found similar changes in channel morphology and fish composition at both weir sites and expect that over time the channel will continue to adjust and shift the habitat and fish composition, particularly at the NW2 site in which weirs were placed most recently. When comparing the two weir sites, we did find some differences in their effects on stream fish 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 number of ictalurids; whereas at the NW3, the number of darters increased after weir placement. 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. To thoroughly examine the effects of these structures at smaller drainage areas, continued evaluation of the NW2 site is needed due to the few samples collected during the post-weir phase. Additional habitat, fish, and invertebrate sampling/processing will give us a clearer understanding of shifts and trends initially found at the NW2 site. 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

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

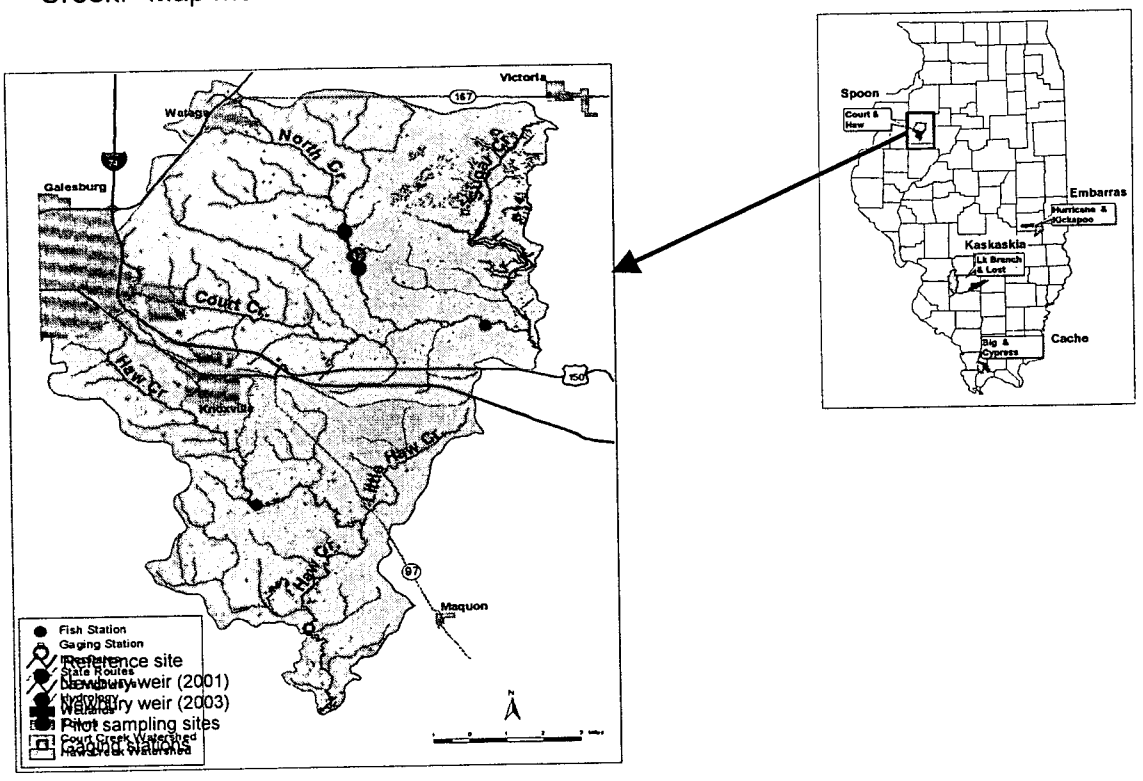

Table 1. Mean and standard errors (in parentheses) of channel morphology features and habitat composition at the Newbury Weir site (NW1) in the Court Creek watershed located 300m downstream of our upper Court Creek pilot site. Weirs were installed in June 2001. An alpha value of 0.05 was used to detect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

	Pre-Weir			Post-Weir								P-value
	10/10/00	5/30/01	Mean (SE)	8/30/01	6/6/02	9/3/02	5/28/03	8/27/03	6/9/04	9/22/04	Mean (SE)	
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. List of fish species, numbers collected, species richness, and Index of Biotic Integrity (IBI) in pre- and post-weir construction periods at the Newbury weir site (NW1) located 300m downstream of the upper Court Creek site. Weirs were installed in June 2001.

Species	Scientific Name	Pre-weir 10/11/00	Pre-weir 5/31/01	Post-weir 8/30/01	Post-weir 6/6/02	Post-weir 9/4/02	Post-weir 5/28/03	Post-weir 8/27/03	Post-weir 6/22/04	Post-weir 9/17/04
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 2. 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
Index of Biotic Integrity		39	42	37	35	39	35	47	41	47
% cyprinids		49.1	45.8	39.8	43.0	38.5	42.6	41.0	86.5	80.5
% catostomids		0.7	7.1	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
% Smallmouth bass		0.3	0.4	6.2	5.5	4.1	0.9	2.8	0.9	1.3

Table 3. Macroinvertebrate abundance (numbers per m^2), taxa richness, Family Biotic Index (FBI), percent EPT, and percent Oligocheates within each site/date and habitat type in the Newbury Weir (treated, NW1) site located 300m downstream of our upper Court Creek site (reference). Weirs were installed in June 2001. Habitat types which were not found at that site are designated as N/C (not collected). Similarity is based on FBI values.

	Pre-weir	Fall 00	Pre-weir	Spr 01	Post-weir	Fall 01	Post-weir	Sum 02	Post-weir	Spr 04	Post-weir	Fall 04
	Court Newbury	Court Upper	Court Newbury	Court Upper	Court Newbury	Court Upper	Court Newbury	Court Upper	Court Newbury	Court Upper	Court Newbury	Court Upper
Total CPA ($no./m^2$)	193764	405561	101833	172999	157237	156289	58781	116815	418789.9	72530	105500	93679
CPA: Glides	120468	201977	40848	90762	148391	105947	31296	50880	380443.5	45470	67443	69665
CPA: Riffles	7617	10756	11305	44289	8847	43046	27486	1941	38346	27060	38057	24014
CPA: Runs	65679	192827	49680	37948	N/C	7296	N/C	63995	N/C	N/C	N/C	N/C
Total Richness	35	43	36	42	46	45	36	27	47	44	51	44
Richness: Glides	25	18	14	18	22	16	15	15	19	20	21	13
Richness: Riffles	26	38	31	39	39	39	32	21	40	39	48	41
Runs	14	19	9	13	N/C	29	N/C	11	N/C	N/C	N/C	N/C
%EPT	12.2	7.5	11.0	12.3	9.4	10.0	39.1	24.3	16.7	9.7	20.7	17.9
% Oligocheates	30.2	6.8	27.7	55.5	14.4	12.8	23.8	10.9	45.9	43.4	13.3	13.8
FBI	6.7	6.7	6.5	6.9	7.2	6.4	5.6	6.0	6.6	6.7	6.1	6.2
% Similarity	100		94		113		94		98		99	

FBI Score	Water Quality
0.00 - 3.75	Excellant
3.76 - 4.25	Very Good
4.26- 5.00	Good
5.01 - 5.75	Fair

% Similarity	Condition
>= 85%	Very Similar
70-84%	Moderately Similar
50-69%	Slightly Similar
<50%	Different

Table 4. 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 two miles upstream of our upper Court 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				
	10/1/02	4/21/03	Mean (SE)	9/19/03	6/9/04	9/22/04	Mean (SE)	P-value
Ave. Sample Area	1050	1152	1101 (51.0)	1060	1303	1267	1210 (75.7)	0.375
Ave. Width (m)	5.6	6.0	5.8 (0.2)	5.3	7.2	7.0	6.5 (0.6)	0.442
Ave. Depth (mm)	265.1	306.0	285.6 (20.5)	337.4	497.2	429.7	421.4 (46.3)	0.115
Width/Depth Ratio	21.12	19.6	20.36 (0.8)	15.7	14.5	16.2	15.5 (0.5)	0.011
Ave. Pt. Substrate (mm)	17.8	5.7	11.8 (6.1)	17.7	43.3	14.1	25.0 (9.2)	0.372
Ave. Max Substrate (mm)	35.5	30.4	33.0 (2.5)	63.4	72.9	39.9	58.7 (9.9)	0.138
Ave. Velocity (m/s)	0.00	0.09	0.05 (0.04)	0.00	0.05	0.00	0.02 (0.02)	0.528
% Pool	100	73	86.7 (13.4)	100	92	97	96.1 (2.4)	0.667
% Run	0	12	6 (6)	0	3	0	1 (1)	0.361
% Slow Riffle	0	2	1 (1)	0	0	0	0 (0)	0.272
% Fast Riffle	0	13	6.5 (6.5)	0	5	0	1.7 (1.7)	0.429
% Island	0	0	0 (0)	0	0	3	1 (1)	0.495

Table 5. List of fish species, numbers collected, species richness, and Index of Biotic Integrity (IBI) 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 2002.

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

Table 5 continued.

Ictaluridae						
Black bullhead	*Ameiurus melas*	0	0	16	0	0
Stonecat	*Noturus flavus*	2	5	2	3	2
Yellow bullhead	*Ameiurus natalis*	3	1	13	3	5
Percidae						
Johnny darter	*Etheostoma nigrum*	6	9	25	8	25
Orangethroat darter	*Etheostoma spectabile*	3	4	11	3	19
Total Catch		1422	742	1967	594	996
Species Richness		21	20	21	20	20
Catch per hour of electrofishing		1530	788	1457	825	972
Index of Biotic Integrity		37	40	40	41	47
% cyprinids		89.9	85.8	69.8	84.5	41.8
% catostomids		3.7	10.4	13.2	5.1	33.5
% centrachids		5.4	1.2	13.6	7.6	19.6
%SMB		1.1	0.3	1	2.2	2.8

05-026W

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

ILLINOIS NATURAL HISTORY SURVEY

August 11, 2005

Todd Bittner
Illinois Department of Natural Resources
IVCCE Campus Bldg. 11
815 N. Orlando Smith Road
Oslesby, IL 61348

Dear Mr. Bittner:

Enclosed are three hard copies (and a CD) of the Final Report for the project entitled "Evaluation of Newbury Weirs (Rock Riffles) for improving habitat quality and biotic diversity in Illinois streams" Also enclosed are nine digital images on the CD. Following is a description of the pictures.

Newbury weir site - Pre-weir.jpg is the NW1 site (weirs installed in 2001) in Oct. before weirs installed
Newbury weir site- 3mo post weir.jpg is the NW1 site 3 months after weirs installed (the picture is of the same exact location as the pre-weir)
Newbury weir site - 3 yr post weir.jpg is the NW1 site 3 yrs (2004) after weirs installed (the picture is of same location as the pre-weir)
Newbury weir site - 3yr post weir scour hole.jpg shows a large pool created below the riffles
North Creek Reference site.jpg is a picture of a natural riffle at the reference
The other pictures are of invert, habitat, and fish sampling/processing

Also enclosed is a copy of the news report that the university has submitted to the newspaper. They will send you a copy of the paper when the article appears.

The university has previously sent you the report of expenditures made under the grant agreement.

Please let me know if you need anything else.

Sincerely,
David H Wahl
David H. Wahl
Professor

DHW/rw

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