FINAL PROGRAMATIC REPORT (FISHERIES)
Blackwater River Wetland, Fisheries, and Watershed Restoration #2005-0001-042
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NATIONAL FISH AND WILDLIFE FOUNDATION
FINAL PROGRAMMMATIC REPORT

Project Name and Number: Blackwater River Wetland, Fisheries, and Watershed Restoration #2005-0001-042

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1) Summary: Fish assemblages were sampled from an historically freshwater section of the upper Blackwater River (UB) which has seen increases in salinity levels due to a connection to the Little Choptank River provided by a canal constructed in the 1800's. Blackwater National Wildlife Refuge (NWR) recently, with partners, constructed a weir to block saltwater being conveyed from the Little Choptank River via the canal. Sampling occurred pre and post weir construction, although due to the lateness of the weir construction, post monitoring was of a much shorter duration than hoped for (e.g. little time had passed for the system to freshen, only three months). As a control, the hydrologically unimpacted Little Blackwater River (LB), which has salinity levels in the upper stretches presumed to mimic the UB prior to construction of the canal, was also sampled. During the study, average salinity in the UB ranged from 9-12 ppt., while average salinity in the upper LB ranged from 0-5 ppt. Salinity differences explain the strong fish assemblage differences documented between UB and the LB. At present, the UB is not suitable to support anadromous , fresh water spawning species such as herring (*Alosa* spp.). In addition, wetland vegetation in the UB was sampled, and that report is included as a addendum to this final report. Wetland sampling was all pre weir construction, and documented a salt tolerant dominant wetland plant community. Both studies provide excellent baseline information for future assessment of weir success relative to restoring a freshwater system.

2) Introduction: Humans have accelerated the rate of global climate change (Sahagian *et al. 1994*) and consequences to wetland habitats, and the fish and wildlife species dependant on those habitats, may be dire (Benson 1981; Titus 1988; Carpenter *et al*. 1992; Michener *et al*. 1997). Wetlands support productive fisheries by contributing to recruitment success for species, and buffer coastal systems from nutrient loading and pollution. Tidal wetlands, through detrital production and export, also provide much of the energetic engine driving estuaries such as the Chesapeake Bay. As salinity levels increase in wetlands, marine species may become proportionately abundant (Garcia *et al.* 2001; Love *et al.*, in review), which may affect predator/prey interactions, or possibly recruitment for freshwater spawning species (Van Den Avyle and Maynard 1994; Hare and Able 2007)

Sea level rise has been recognized as an important contributor to wetland loss in the Blackwater River drainage. Surprisingly, the headwaters of the Blackwater River, the section of the river most removed from the rising sea levels of Chesapeake Bay, is also changing to a saltier environment, and the upper and middle sections of the river are exhibiting the most severe wetland losses. It appears human alterations to the hydrology of the system is also playing a role, and may be the bigger culprit in the upper section of the river. In order to test this theory, the Little Blackwater River (which has relatively unaltered hydrology) was used as a control in this study for comparison purposes to the Blackwater River.

The headwaters of the Blackwater River, part of Blackwater NWR, was historically freshwater; supporting spawning habitat for migratory fish and vast expanses of emergent threesquare (*Schoenoplectus* americanus) wetlands. Stewarts Canal, dug in the 1800's, connected the salt waters of the Little Choptank River via Parsons Creek, to these headwaters, eliminating migratory fish habitat (changing water quality by increasing salinity to up to 12 ppt). This has also resulted in the conversion of hundreds of acres of freshwater threesquare marsh into saline open water and mud flat, changing the habitat value throughout the watershed. Blackwater Refuge, working with a host of partners, intended to repair the breach associated with Stewarts Canal by constructing a hydrologic barricade, thus returning the watershed to an ecological continuum comprised of freshwater headwaters, tidal freshwater associated expansive threesquare wetlands, and brackish water tidal wetlands in the lower portion of the river. In so doing, spawning migratory fish, as well as other fish and wildlife species associated with tidal freshwater marsh,

were targeted to be restored. Weir construction did occur, however much later than planned relative to pre and post construction monitoring. Most sampling occurred before the structure was functioning as designed, with post construction monitoring only occurring for a three month period.

In order to monitor the efficacy of the weir, the Friends of Blackwater NWR, through monies associated with this grant, funded the U.S.Fish and Wildlife Service's (FWS) Maryland Fisheries Resource Office (MFRO) to lead a study to document fish and wetland resource response. Contributing partners in the study included University of Maryland Eastern Shore, the FWS Chesapeake Bay Field Office (lead for the wetland work), and Blackwater NWR. It was hoped that this short term monitoring effort would evaluate barricade success, and determine future actions required (if any) for migratory fish spawning habitat and tidal wetland habitat restoration. Due to the relative small number of post construction sampling days, as compared to preconstruction, this study has provided the first report of spatiotemporal patterns of fish and wetland distribution in the UB, and highlighted the importance of saltwater intrusion on fish assemblage structure. Both fisheries and wetland studies provide an excellent baseline for future comparison of existing and planned restoration activities undertaken by the refuge and its many partners, including the long term effects of the weir and other saltwater intrusion projects yet to be undertaken. Future management activities on the UB can be compared to sea level rise effects (if any) on the upper LB where refuge management does not occur

3) Methods: Three sites were selected on the UB river and three sites were selected on the LB river in order to compare habitats, fish diversity and fish community structure between the two systems (Figure 1). All sampling locations on the UB river were upriver from the Route 235 bridge, and encompassed the upper one third of the total length of the Blackwater River. On the LB river, the three nets covered all salinity regimes occurring throughout the length of the river (e.g. head of tide, middle section of river, and lower section of river). Sampling locations were designated by river and upstream, middle, or downstream location, with the number 1 designating upstream (UB1), number 2 designating middle (UB2), and number 3 designating the downstream sampling location (UB3). Sites were sampled monthly from December 2005 until July 2007. Due to weather conditions (primarily ice) and logistic issues (primarily boat engine

problems) sampling upstream sites of UB did not occur for December 2005, February 2006, or any sites in UB for August 2006. Sampling frequency increased to weekly from March – May in order to evaluate potential spawning use of the river by anadromous fish species such as alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*). Other resident species of local angling interest included yellow perch (*Perca flavescens*) and largemouth bass (*Micropterus salmoides*)

Environmental Conditions

During each sampling event, water temperature (^{0}C), salinity (ppt), specific conductivity (µS), and dissolved oxygen (mg/L) were recorded using a YSI (Yellow Springs Instruments, Inc) at each sampling location. Water clarity was measured using a Secchi disk (mm). Patterns of environmental variability among sites were identified. To determine if average dissolved oxygen and salinity differed among sites, an analysis of variance test was used. Post-hoc tests (Bonferroni corrected post-hoc tests) were used to make pairwise comparisons among sites. Prior to analysis, all data was normalized using logarithmic transformations.

Species Diversity

Fish, and non-targeted macroinvertebrates and herpetofauna, were collected using fyke nets (2.5 cm mesh, 15.2 m lead line), which were set for approximately 24 hours. Nets were deployed with the lead line staked to an existing shoreline, oriented perpendicular to the shoreline, with the cod end of the net staked channelward in deeper water. Prior to nets being deployed, a bullet float was placed in the cod end of each net to provide an air pocket. The air pocket prevented the inadvertent killing of non-targeted species, such as turtles. Fishing depths averaged 0.3 m to 1.2 m. When retrieving the net, each fish, crab, or turtle was identified to species, counted, and released. For each fish species encountered, 10 individuals were measured for total length (mm).

Because sample size differed among sites, diversity of fishes was calculated using rarefaction curves that standardize diversity measures for differences in abundance among sampling efforts. Rarefaction is an interpolative method that randomly subsamples the original dataset for *a priori* abundance levels set by the

user, and calculates diversity for the subsample. For each set abundance the subsampling procedure was iterated for 1000 times to generate for each abundance level a mean, standard deviation, and 95% confidence interval (CI). All data for each site was included, and limited comparisons of diversity to among sites. Diversity was calculated as both species richness and dominance, with the fraction of the sample represented by the most abundant species. To compare diversity values, rarefaction curves were generated and compared to 95% CI among sites at the greatest abundance shared by sites. For rarefaction, Ecosim (Version 7.0; Gotelli and Entsminger 2001) was used.

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4) Results:

Environmental Conditions

Habitat conditions differed between UB and LB, and among sites within LB. The LB had a lower salinity, on average, than UB ($F_{5,96} = 107.079$; $P < 0.001$; Table 1). Within LB, salinity was lower upstream than downstream. Intraseasonal variability in salinity was high at UB3 and LB3, generally during the summer (Table 1). Dissolved oxygen levels were lower at the upstream LB sites (LB1 and LB2) than downstream LB3 ($F_{5,96} = 3.246$; $P = 0.009$; Table 1). The LB has fresh headwaters that experienced lower dissolved oxygen than mesohaline downstream habitats during the hot summer months. The UB did not differ significantly in salinity or dissolved oxygen among sites. Although not statistically analyzed, water clarity in the UB appeared better, comparatively, than the LB (Table 1). Seasonal water temperature, dissolved oxygen and salinity variations in both river systems are presented in Figures 2, 3, and 4, respectively.

Species Diversity

Study period sampling included 102 fyke net sets and retrievals, with each net set covering a 24 hour sampling period (Table 4). During the sampling period, 43,812 individual fish were collected; 28,945 and 14,867 at LB and UB, respectively (Table2).

Fish collections encompassed 27 species (Table 2). White perch (*Morone americana*) was abundant at all sites, and accounted for 46% of the total catch (Figures 5 and 6). Brown bullhead (*amerius nebulosus*) and

pumpkinseed (*Lepomis gibbosus*) were the second most abundant and widespread, accounting for 15% and 12% of the catch, respectively (Figures 5 and 6). More smaller, euryhaline fishes such as banded killifish (*Fundulus diaphanous*) and Atlantic silverside (*Menidia menidia*) were collected in the upper portion of the UB (Table 2). In the upper end of the LB, which is predominately freshwater, brown bullhead was the second most abundant species collected and black crappie (*Pomoxis nigromaculatus*) was the third most abundant (Table 2). River herring, both alewife and blueback herring, were caught in small relatively equal numbers in both river systems, and represented a minute portion of the total catch (Table 2). In addition to fishes, macroinvertebrate and herpetological fauna was collected, which included crabs, crayfish, tadpoles, and turtles. Blue crabs (*Callinectes sapidus*) and the brackish water associated diamondback terrapin (*Malaclemys terrapin*) were more abundant in the UB, while freshwater turtles were more abundant in the LB (Table 3). Proportional analysis of abundance for crustaceans and turtles are presented in Figures 7 and 8.

For baseline data considerations, length frequency distribution graphs were created for five abundant species on the UB and LB, which included black crappie, bluegill, brown bullhead catfish, pumpkinseed, and white perch. This information is presented in Figures 9 and 11. As species of special interest, and also for baseline consideration relative to future collections, length frequency distribution graphs were also created for largemouth bass, river herring, and yellow perch. This information for both river systems is presented in Figures 10 and 12. Given the small number of yellow perch encountered on the UB, graphs were not developed for this species (Table 2 and Figure 12).

Fish species diversity was higher at UB than LB for a randomly drawn 961 individuals (Richness: UB, 95% CI: $19 < x < 19$; LB, 95% CI: 9 , x , 14; Dominance: UB, 95% CI: $0.05 < x < 0.05$; LB 95% CI: $0.39 < x < 0.47$). While species richness (diversity) was higher at UB, species evenness (the measure of how similar the abundance of different species are) was lower. Species richness seasonally varied more at LB (CV = 10%) than UB (CV = 4%), possibly due to collections of infrequently caught species at LB (e.g. eastern mudminnow, *Umbra pygmae*) rather than seasonal migrations of fishes such as herring; American eel (*Anguilla rostrata)*, or striped bass (*Morone saxatilis*), which occurred in both systems (Table 2). At upstream sites of the UB and LB, seasonal variability in species dominance was greater at UB (CV = 39%)

as compared to LB (CV = 26%). Therefore, the number of species at UB was more consistent seasonally than for LB, but the relative proportions of species varied more.

5. DISCUSSION: Saltwater intrusion, whether attributed to rising sea levels or human alterations to the hydrology of the landscape, is influencing species diversity and assemblage structure for fishes inhabiting historically freshwater wetlands of the Blackwater River. While historical data on fish assemblages in these wetlands is lacking, anecdotal evidence suggests historically greater use by freshwater dependent species (e.g. largemouth bass and yellow perch) in currently mesohaline environments (pers. comm.., B. Giese, U.S. Fish and Wildlife Service). In the absence of historical data, this study demonstrates spatial turnover of fish assemblage structure, which appears to be attributable to salinity gradients in the drainage.

The weir at Stewarts canal was only functioning for the last three months of the study period, and as such, the UB did not show signs of decreasing salinity. In addition, there are at least two other sources of saltwater intrusion in UB; those being a culvert on Smithville Road allowing for saltwater inputs from Slaughter Creek, and a defunct tide gate along Route 16 in the vicinity of the town of Church Creek allowing saltwater inputs from Church Creek.

Both species diversity and assemblage structure for fishes change as a result of population declines, with causes that can be difficult to indentify, and which can include invasive species (Fairchild *et al.* 1998), habitat degradation (Haines and Baker 1986; Haro *et al.* 2000), and stream barriers (Haro *et al.* 2000). Increasing salinity seems to contribute to assemblage differences between UB and LB by causing declines in freshwater dependent species. In highly brackish habitats of UB both euryhaline and freshwater dependant fish assemblages were found, suggesting that there may be a time lag in the response of freshwater dependant assemblages to increasing salinities. Anecdotal evidence (pers. comm.., B Giese, U.S. Fish and Wildlife Service) suggests that salinities have been increasing over time in the last 40 years in the UB. Whether the construction of the weir can reverse this process will not likely be known for some time. Additionally, at present the contribution of saltwater by the Smithville Road and Church Creek connections are unknown. Changes in fish assemblages due to saltwater intrusion may take decades to develop if assemblages are robust and resilient (Chesney *et al*. 2000). Alternatively, species assemblages

may not change if species are locally adapted and tolerant to seemingly harsh environmental conditions (Deker and Magoulick 2007). However, for anadromous species such as river herring which require freshwater for spawning, the UB, at present, does not provide spawning habitat. During sampling, neither the UB or LB supported large numbers of herring

Species richness was higher for the UB, which harbored a fish fauna comprised of species typical of freshwater wetlands, as well as those from euryhaline salt marshes. The UB may represent an ecotone, which is a boundary between two adjacent ecologically different habitats. In this case remnant freshwater marshes characterized by threesquare, as compared to marshes converting to saltmarsh characterized by smooth cordgrass (*Spartina* alterniflora). Fish assemblages of the UB were represented by the ubiquitous white perch, euryhaline species such as hogchoker (*Trinectes maculates*), killifish, and silverside, as well as freshwater dependent fishes, such as largemouth bass and river herring. Ecotones may harbor greater diversity than the surrounding landscape (Traut 2005), and the combination of fauna from euryhaline and oligohaline wetlands likely contribute to greater diversity at UB. Species richness may also be lower for the LB because of the dominance (by abundance) of freshwater species. The Little Blackwater River may be a nursery habitat for species such as the brown bullhead and white perch. Nursery habitats are those that disproportionately contribute a greater number of juveniles to the adult population (Beck *et al.* 2001).

6. Conclusions: This study, and the attached companion wetland study, was designed to assess weir construction effects on fish diversity, fish assemblages, and wetlands in the UB, as compared to diversity and assemblage structure in the hydrologically unimpacted LB. Given the short duration of sampling after weir construction, and the lack of any changes (pre as compared to post weir construction) to salinity gradients in the UB, no conclusions regarding weir effects can be developed. In addition, the present salinity inputs at Smithville Road and Church Creek are unknown relative to salinity observed in the UB during the study period. The lack of conclusions would apply to both fisheries and wetland data collection. Both fisheries and wetland studies do provide, for the first time in the UB and LB, baseline numbers for future comparison of existing and planned restoration activities undertaken by the refuge.

The Chesapeake Marshlands NWR Complex, of which Blackwater NWR is a part, is presently assessing future refuge management needs relative to observed changes to historic habitats and living resources. Potential effects of sea level rise is of major consideration. Some changes associated with sea level rise are probably inevitable, with no recourse available to the refuge outside of major dam and dike construction. Such an approach would likely have significant non-targeted effects to hydrology and habitats. However, where human alterations allow for saltwater intrusions (e.g. Stewarts canal, and culverts and tide gates constructed originally for purposes of improved drainage), manipulation of the landscape to return the watershed to historic conditions may be economically and ecologically justified. Baseline information collected as part of this study can be used to assess the efficacy of such an approach.

Lastly, the fisheries and wetland information collected can be used as a barometer on the effects of changes in the landscape. The LB receives runoff from adjacent, predominately agricultural uses, as well as expanding urban development in the headwaters. In comparison, the UB watershed is predominately forested, with expansive emergent wetland complexes between the river and higher forested ground. If the UB, through refuge and partner activities, is returned to a predominately freshwater system, it can be compared to the agricultural and changing urban landscape in the LB.

7. Acknowledgements: Michael MacKinnon, numerous assistants from Blackwater NWR, and the Friends of Blackwater NWR (FOB) helped in the field sampling effort. Dr. Dixie Birch (Supervisory Biologist at Blackwater NWR) and Glenn Carowan (Project Leader of Blackwater NWR during the study period) were instrumental in organizing logistic and planning support. Bill Giese (Fire Officer at Blackwater NWR) provided historical information and knowledge of the waterways in and around Blackwater NWR. Tom Hook, Ron Tillier, and all the members of the FOB supported this study through grant development and concept support.

8. Dissemination: This study will be featured on the FOB wet site: www.friendsofblackwater.org . Other disseminations which will be used by the FOB include displays at the refuge visitors center, and articles in the FOB newsletter. A portion of this study was presented at the American Fisheries Science

National meeting in September of 2007. In addition, parts of this study have been submitted for publication in the " Southeast Naturalist". This study will also be presented at the March 2008 Blackwater NWR Science Conference.

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I hereby certify that the Final Phase described above has been completed and that the above information is accurate and complete.

Friends of Blackwater National Wildlife Refuge, Inc.

Approved:_____ Date:_____

Signature

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Print name and title

FISHERIES

TABLES, FIGURES, and GRAPHS

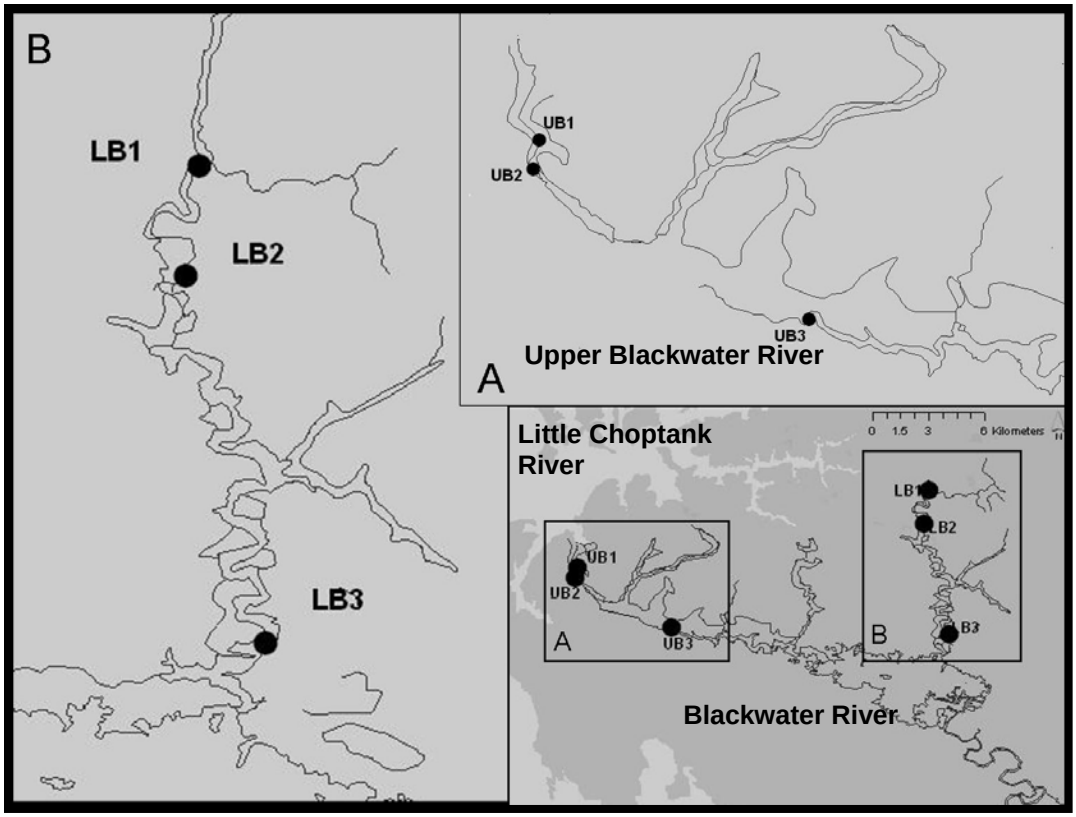

Figure 1. Map of Blackwater River drainage (Cambridge, MD)(lower right quadrant) depicting two areas under study, upper Blackwater River (A) and Little Blackwater River (B). Three sites were surveyed in the upper Blackwater River (UB1 – UB3) and three sites were surveyed in the Little Blackwater River (LB1 – LB3).

Table 1. Averages and ranges for salinity (ppt), dissolved oxygen (%), and water clarity (measured with a Secchi Disk in mm) for Little Blackwater River (LB) and Blackwater River (UB)

Site	***Average***	***Range***	***Average***	***Range***	***Average***	***Range***
LB1	0.2	0.1-1.2	63.6%	20-120%	379.6	175-750
LB2	0.45	0.1-2.9	66.9%	22-117%	300.3	140-500
LB3	3.74	0.1-10.2	93.9%	67-120%	290.0	170-498
UB1	9.35	2.5-14.3	69.6%	19-108%	622.4	192-1110
UB2	8.14	2.6-14.3	73.6%	6-107%	416.2	230-685
UB3	5.96	0.8-14.7	63.6%	0.6-110%	534.3	250-850

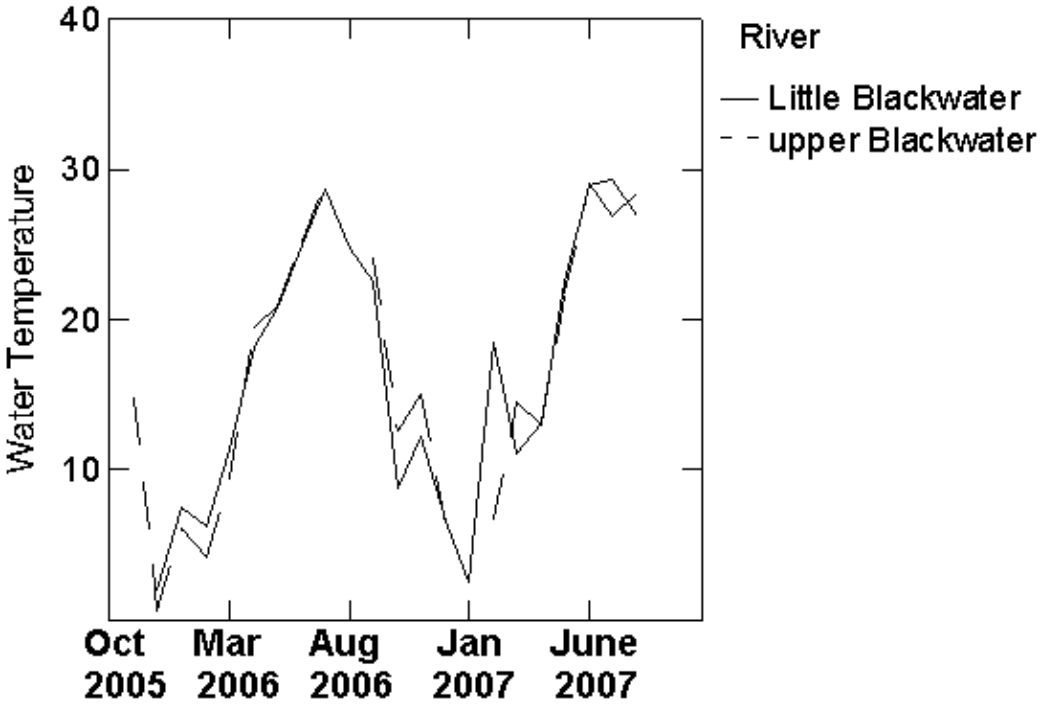

Figure 2. Variation in average, monthly water temperature (º C) over time (October 2005 – July 2007) in the Little Blackwater River (solid line) and upper Blackwater River (dashed line).

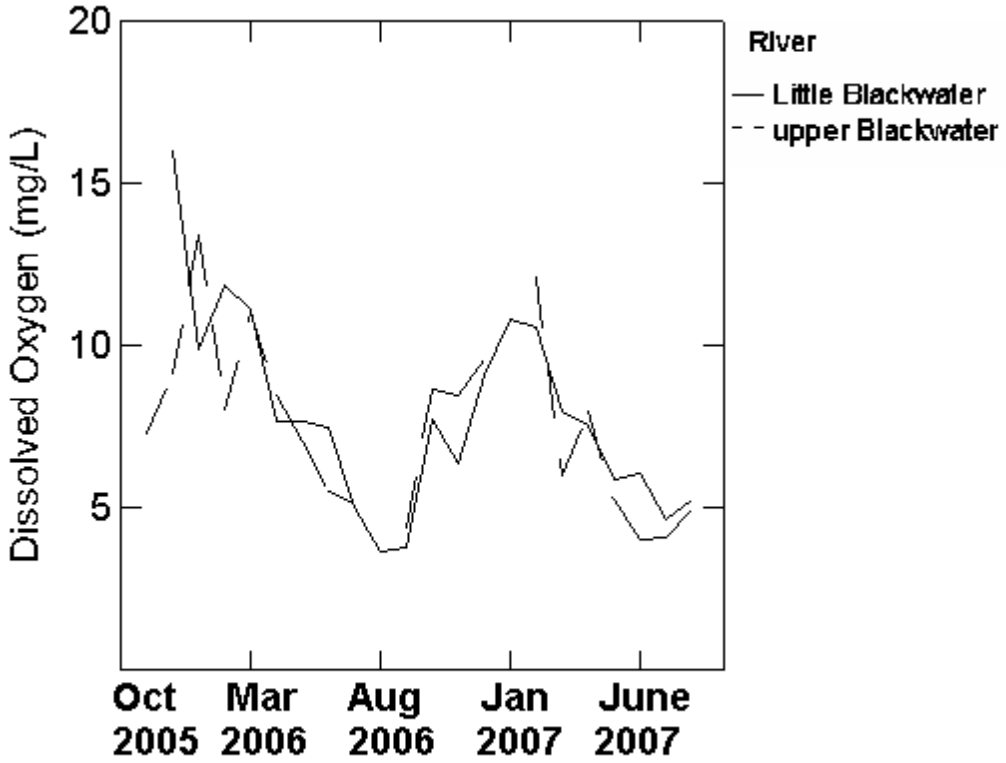

Figure 3. Variation in average, monthly dissolved oxygen (mg/L) over time (October 2005 – July 2007) in the Little Blackwater River (solid line) and upper Blackwater River (dashed line).

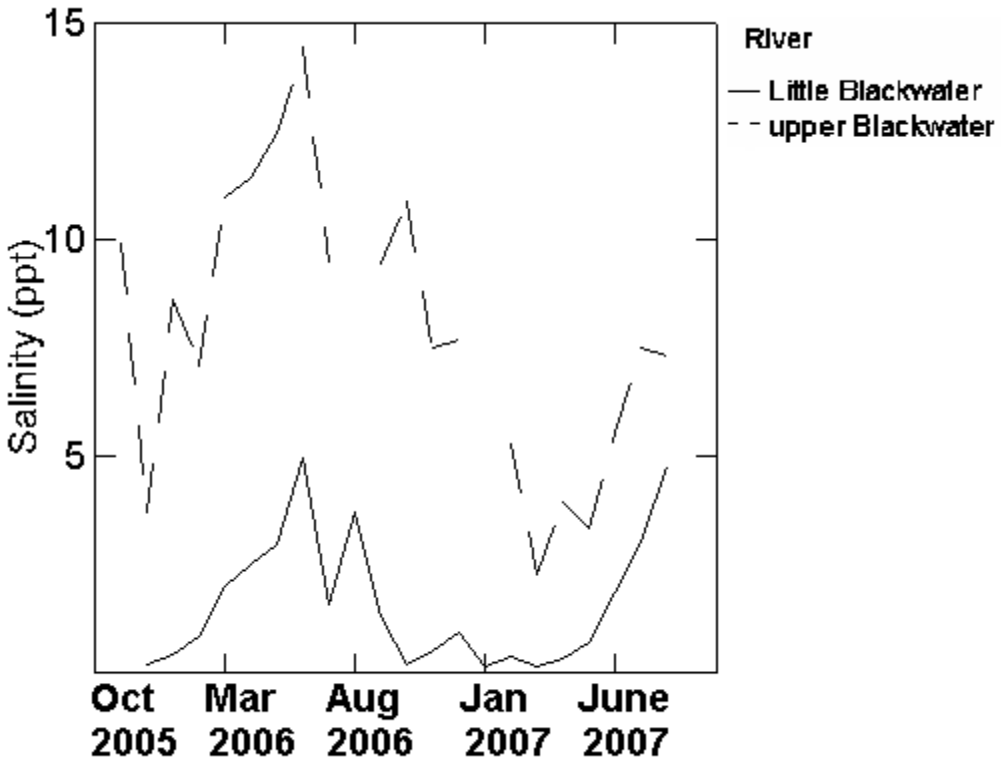

Figure 4. Variation in average, monthly salinity (ppt) over time (October 2005 – July 2007) in the Little Blackwater River (solid line) and upper Blackwater River (dashed line).

Table 2. Fish species and their abundance collected using fyke nets from October 2005 to July 2007 summed across sites within the Little Blackwater (LB) and upper Blackwater (UB) Rivers.

Species	*LB*	*UB*
American Eel	87	8
Atlantic Menhaden	0	15
Atlantic Silverside	1	131
Banded Killifish	4	173
Black Crappie	4007	510
Bluegill	2682	360
Brown Bullhead	5732	739
Chain Pickerel	0	1
Channel Catfish	52	5
Common Carp	991	49
Eastern Mudminnow	2	0
Gizzard Shad	1723	66
Golden Shiner	5	10
Hogchoker	2	89
Inland Silverside	1	11
Largemouth Bass	18	11
Longear (or Redbreast?) Sunfish	10	11
Mummichog	0	75
Pumpkinseed	1210	2896
Redfin Pickerel	9	6
River Herring (Alewife and Blueback)	8	3
Sheepshead Minnow	0	2
Spot	4	7
Striped Bass	3	6
Striped Killifish	0	12
White Catfish	40	4
White Perch	12312	9665
Yellow Perch	42	2
Total s	28,945	14,867
Total for LB and UB	43,812	

Table 3. Abundance of macroinvertebrates and herpetological fauna collected using fyke nets from October 2005 to July 2007 at sites within the Little Blackwater (LB) and upper Blackwater (UB) Rivers.

Macroinvertebrates	**LB**	**UB**
Blue crab	277	487
crayfish	10	0
Herpetofauna	**LB**	**UB**
Eastern Painted Turtle	109	2
Red Bellied Cooter	15	1
Eastern Snapping Turtle	87	9
Diamondback Turtle	25	45
Eastern Mud Turtle	14	0
Tadpole	5	0

Table 4. Frequency of fyke net sampling at three sites within the Little Blackwater (LB) and upper Blackwater (UB) Rivers. The "X" denotes days when fyke net sampling was accomplished.

	LB1	LB2	LB3	UB1	UB2	UB3
OCT				X	X	X
DEC			X			X
JAN	X		X		X	X
FEB	X		X			X
MAR	X		X		X	X
APR	X	X	X	X	X	X
MAY	X	X	X	X	X	X
JUN	X		X	X	X	X
JUL	X	X	X	X		X
AUG	X	X	X			
SEP	X	X	X	X	X	X
OCT	X	X	X	X		X
NOV	X	X	X	X	X	X
DEC	X	X	X	X		X
JAN						
FEB	X	X	X		X	X
MAR	X	X	X	X		X
APR	X	X	X	X	X	X
MAY	X	X	X	X	X	X
JUN	X	X	X	X	X	X
JUL	X	X	X	X	X	X
AUG	X	X	X		X	X

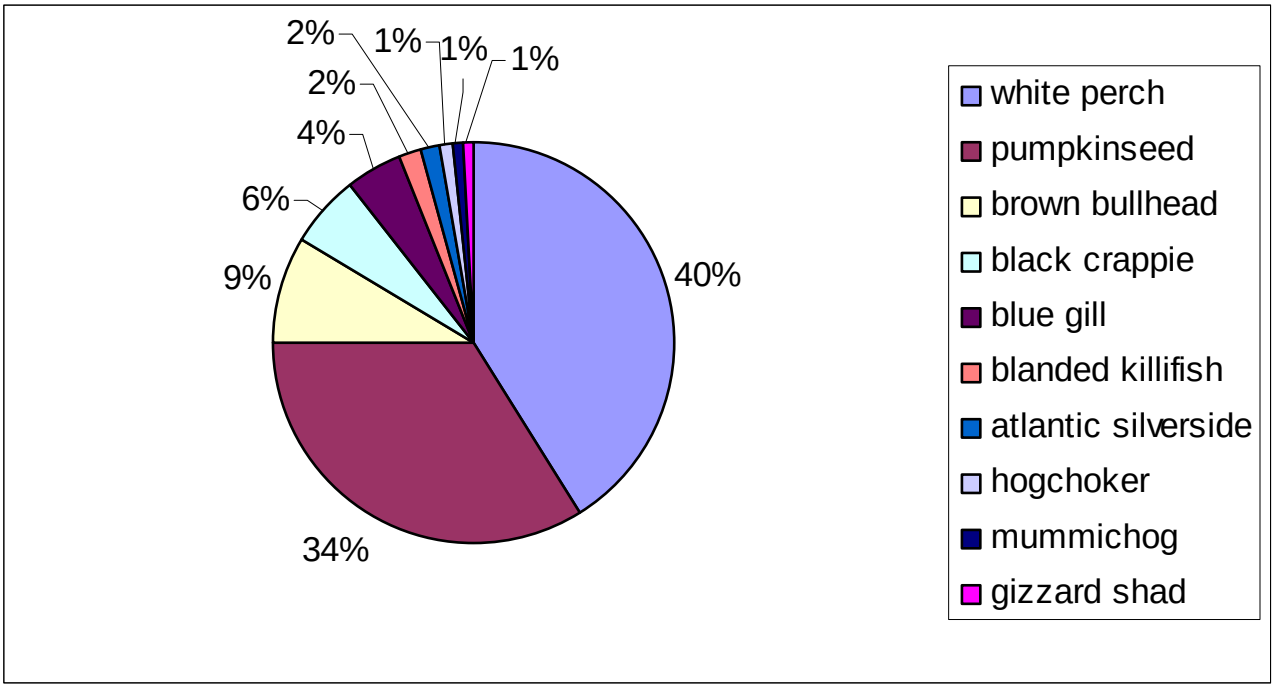

Figure 5. Proportion of fishes collected in the upper Blackwater River using fyke nets from October 2005 to July 2007.

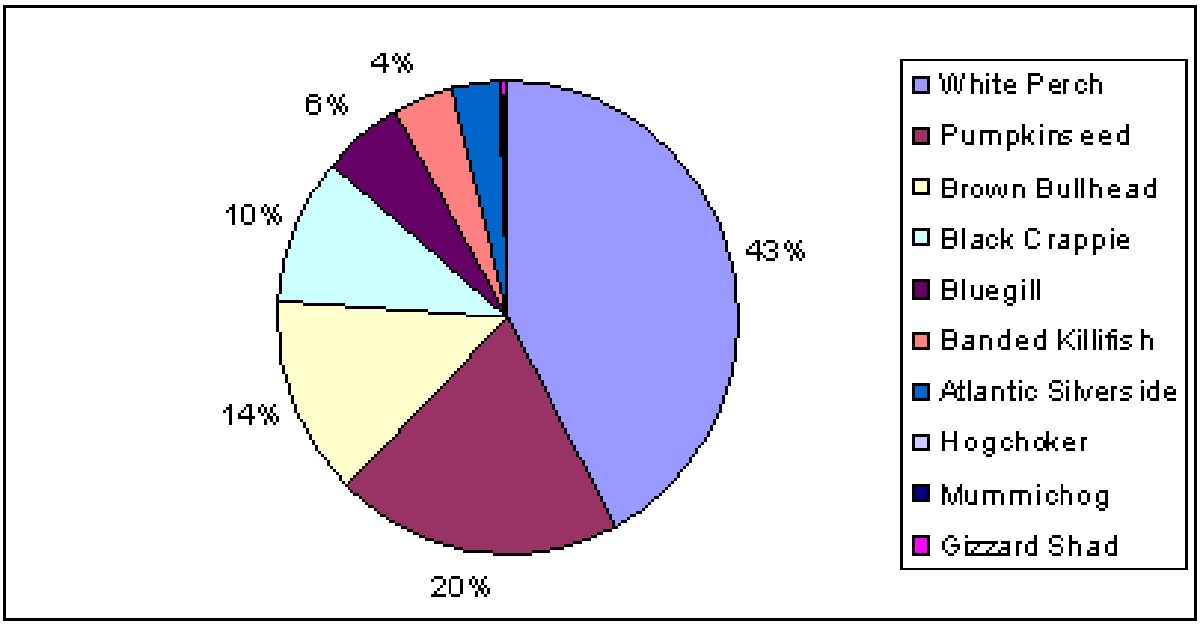

Figure 6. Proportion of fishes collected in the Little Blackwater River using fyke nets from December 2005 to July 2007.

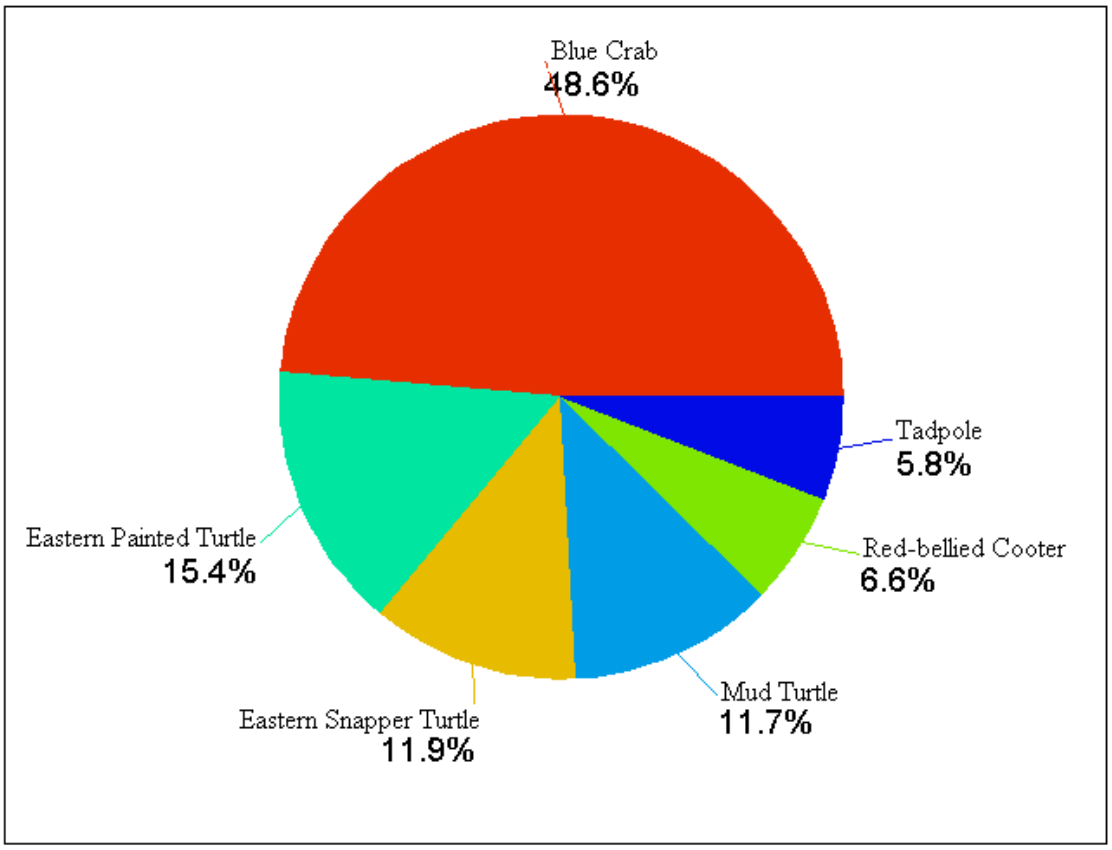

Figure 7. Proportion of crustaceans and turtles collected in the Little Blackwater River using fyke nets from December 2005 to July 2007.

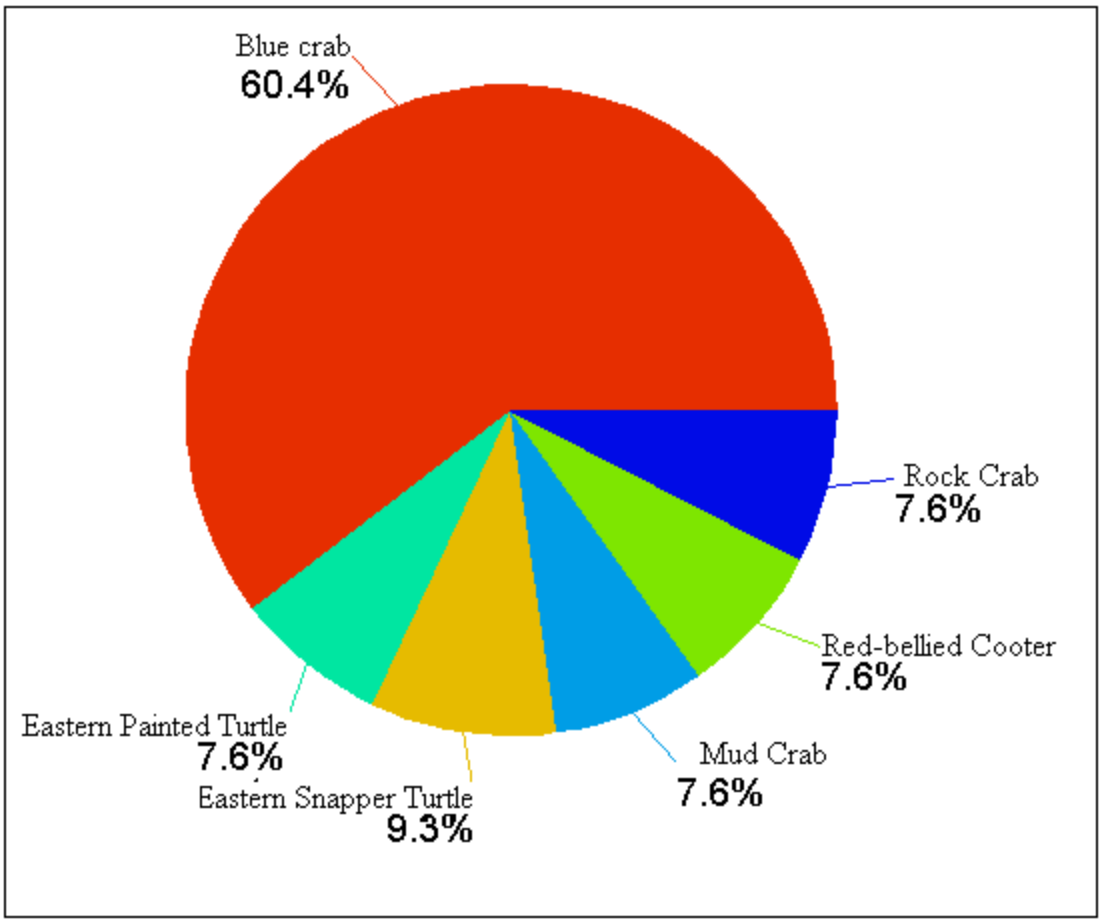

Figure 8. Proportion of crustaceans and turtles collected in the upper Blackwater River using fyke nets from October 2005 to July 2007.

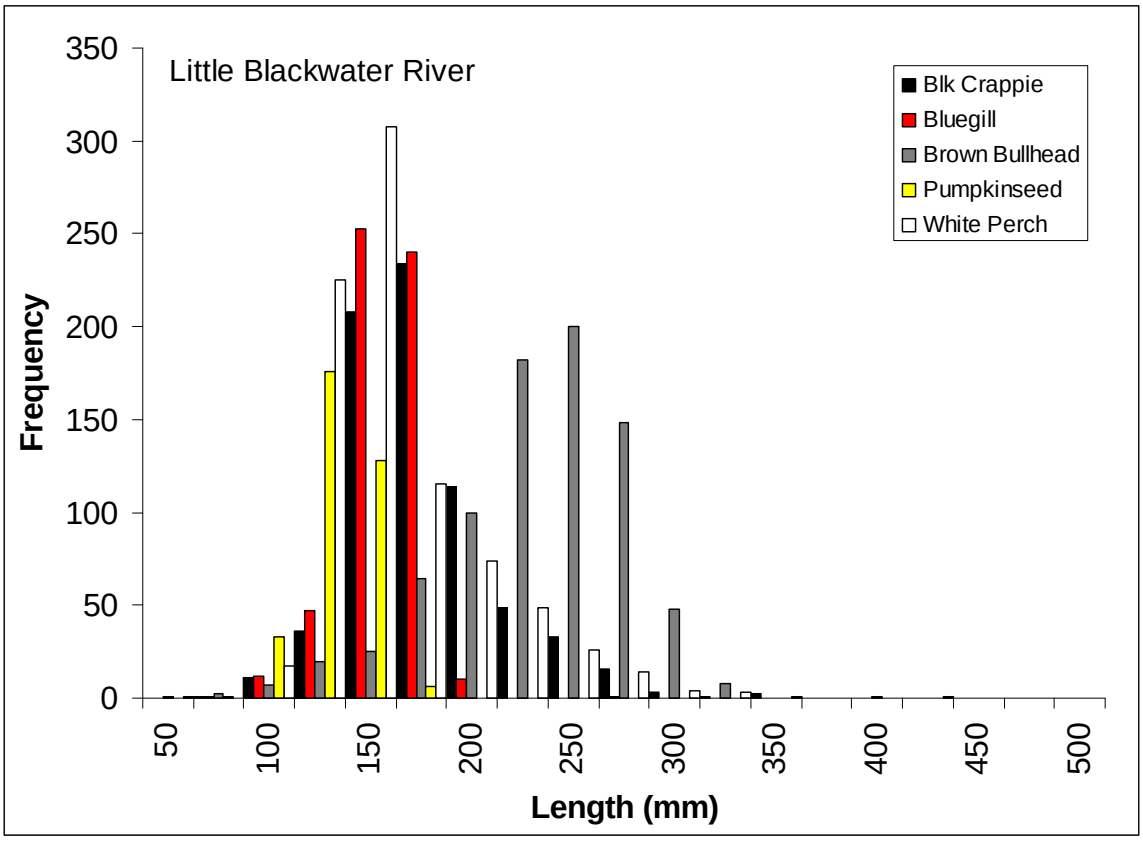

Figure 9. Length frequency distribution of five abundant fish species collected using fyke nets from December 2005 to July 2007 in the Little Blackwater River.

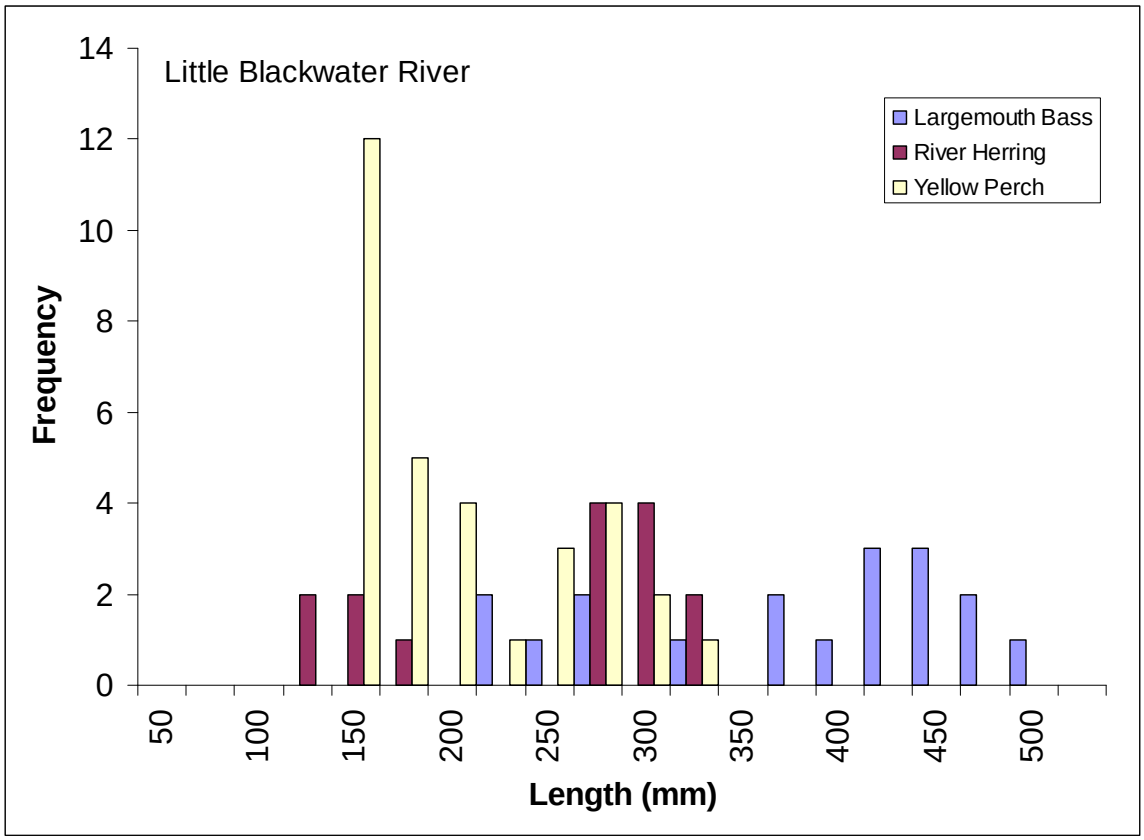

Figure 10. Length frequency distribution of largemouth bass (*Micropterus salmoides*), river herring (*Alosa* spp.), and yellow perch (*Perca flavescens*) collected using fyke nets from December 2005 to July 2007 in the Little Blackwater River.

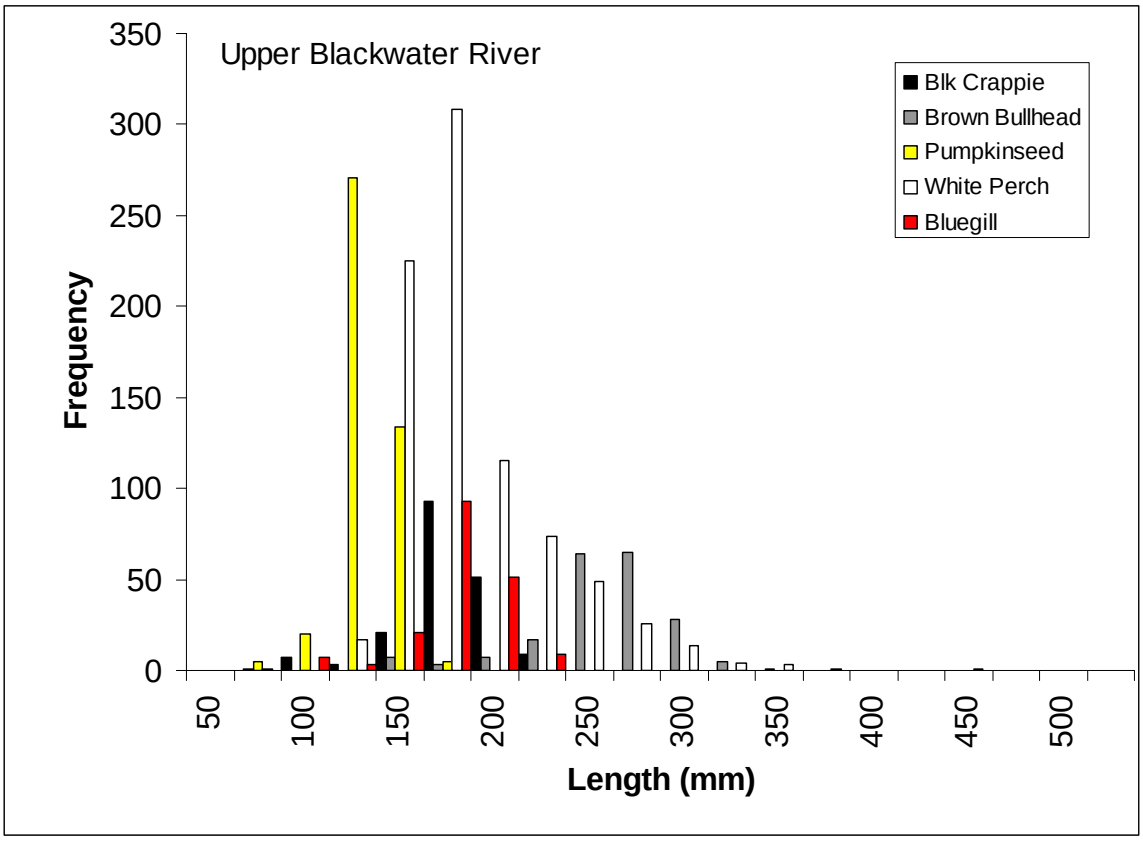

Figure 11. Length frequency distribution of five abundant fish species collected using fyke nets from October 2005 to July 2007 in the upper Blackwater River.

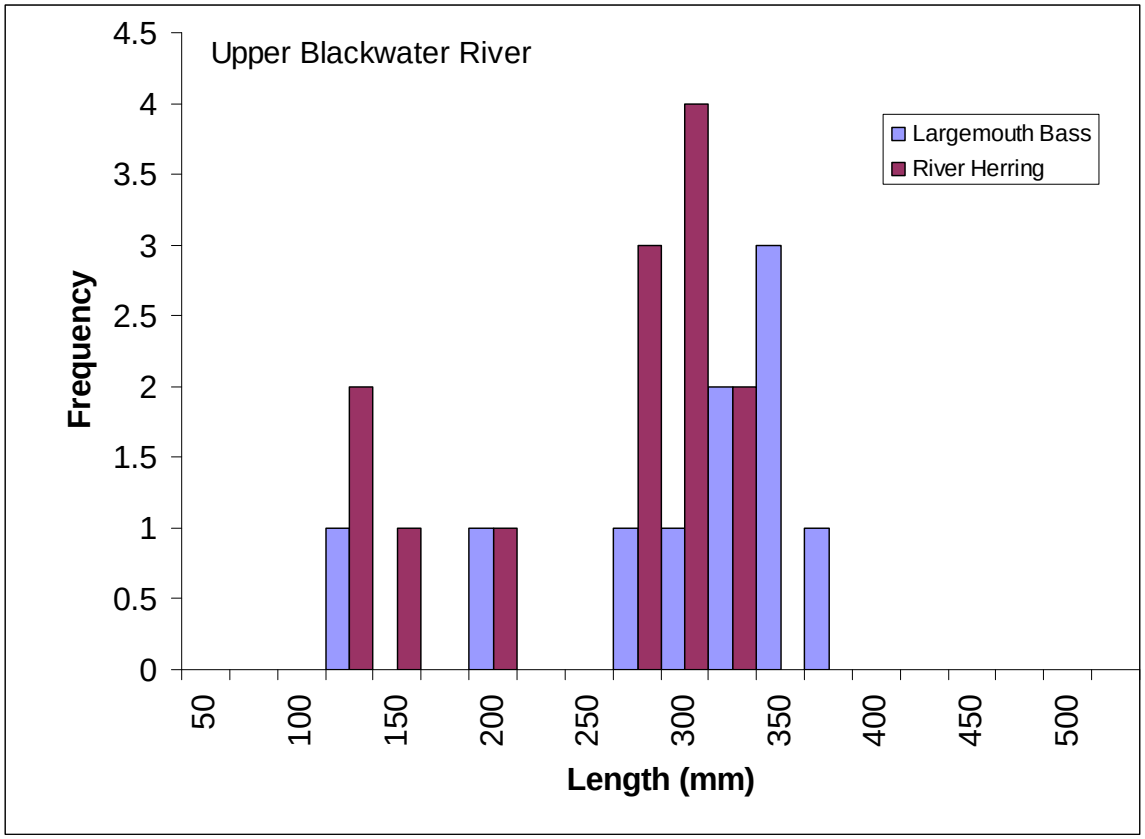

Figure 12. Length frequency distribution of largemouth bass (*Micropterus salmoides*) and river herring (*Alosa* spp.) collected using fyke nets from October 2005 to July 2007 in the upper Blackwater River.

FISHERIES

PHOTOS

ADDENDUM REPORT (WETLANDS)

Blackwater River Wetland, Fisheries, and Watershed Restoration #2005-0001-042

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