

**Eighteenmile Creek
Great Lakes Area of Concern (AOC)
Niagara County, New York**

FINAL

Bioaccumulation Modeling and Ecological Risk Assessment

Prepared for

US Army Corps of Engineers Buffalo District and
Niagara County Soil & Water Conservation District

Prepared by

E Risk Sciences, LLP

12 Holton Street

Allston, MA 02134

Katherine von Stackelberg

and

US Army Corps of Engineers
Karl Gustavson

January 2012

Table of Contents

Executive Summary	5
1.0 Introduction.....	6
1.1 Components of Modeling Effort	7
2.0 Field Sampling Summary and Data Results	8
2.1 Description of Fish Sampling and Analysis.....	9
2.2 Description of Sediment Sampling and Analysis.....	10
2.3 Description of Fish Stomach Content and Aging Analyses.....	12
2.4 Results from Analyses of Sediments and Fish.....	12
3.0 <i>TrophicTrace</i> Model Development and Results	19
3.1 Modeling Area.....	19
3.2 Assessment and Measurement Endpoints	20
3.3 Model Parameterization	20
3.3.1 Environmental Inputs.....	22
3.3.2 Food Web Composition and Exposures.....	24
3.4 Effects Assessment.....	28
3.4.1 TRVs.....	29
3.5 Results and Ecological Risk Characterization	34
3.5.1 Predicted Tissue Concentrations.....	34
3.5.2 Discussion on Model Performance and Implications	36
3.5.3 Ecological Effects Risk Characterization	36
3.5.4 Discussion of Ecological Effects Results	41
4.0 Discussion of Uncertainty.....	42
4.1 Surface Water Dissolved-phase Contaminant Concentrations.....	42
4.3 Fish Foraging Strategies and Dietary Exposure.....	42
4.4 Terrestrial Receptor Foraging Strategies and Dietary Exposures	43
4.5 Toxicity Reference Values	43
5.0 References.....	44

List of Tables

Table 1. Characteristics of Collected Fish

Table 2. Numbers of Fish (or Composites) Collected in Each Reach of Sections 1 and 2

Table 3. Sediment Sampling Locations in Section 1

Table 4. PCB and TOC Summary Statistics for Sediment Data at Eighteenmile Creek

- Table 5. Summary of Total PCB Concentrations Based on Sum of Congeners (mg/kg wet weight) from Whole Fish Collected in Each Section of Eighteenmile Creek
- Table 6. Summary of Lipid Data (Percent) from Eighteenmile Creek Fish
- Table 7. Composition of the Diets of Largemouth Bass and Brown Bullhead from Eighteenmile Creek
- Table 8. Numbers of Largemouth Bass and Brown Bullhead from Eighteenmile Creek for Each Age Group
- Table 9. Data Sources for Exposure Input Concentrations
- Table 10. Dietary Preferences (% of Diet) for the Modeled Species
- Table 11. Input Data for the *TrophicTrace* Model
- Table 12. Relative Percent Difference between Modeled and Predicted Fish Tissue Concentrations
- Table 13. Matrix of Interpretation of LOAEL- and NOAEL-based Exceedances for the Probable (Conclusion of Potential Risk) and Possible (Uncertainty) Ranges
- Table 14. Results of the Ecological Risk Assessment

List of Figures

- Figure 1. Map of Modeling Area and Sections
- Figure 2: Section 1 PCB Concentrations in Sediment
- Figure 3: Relationship Between Fish Age Group and Lipid-normalized PCB Concentration
- Figure 4. Example of the Calculation to Estimate the Probable Range for Toxicity Quotients
- Figure 5. Aquatic Conceptual Site Model for Eighteenmile Creek
- Figure 6. Terrestrial Conceptual Site Model for Eighteenmile Creek
- Figure 7. Predicted Fish Tissue versus Observed Fish Tissue Concentrations
- Figure 8. Predicted Toxicity Quotients at Eighteenmile Creek

Appendices

- Appendix 1. Field Sampling Plan – Fish Collection
- Appendix 2. Fish Sampling Field Collection Log
- Appendix 3. Fish Sample Locations
- Appendix 4. Chain of Custody Forms – Fish Collection
- Appendix 5. Field Sampling Plan – Sediment Collection
- Appendix 6. Sediment Sampling Field Collection Log

Appendix 7. Chain of Custody Forms – Sediment Collection

Appendix 8. Diet and Age of Largemouth Bass and Brown Bullhead from Eighteenmile Creek,
New York

Appendix 9. Individual Fish and Sediment Samples Used in Modeling for Eighteenmile Creek

Appendix 10. Species Profiles for the Receptors of Concern

EXECUTIVE SUMMARY

This report presents the results of the bioaccumulation modeling and associated field sampling efforts at the Eighteenmile Creek Area of Concern (AOC) in response to a request from the USACE Buffalo District. We developed a bioaccumulation model describing the movement of PCB congeners from sediment and water exposure sources through the aquatic food web. The model does not address PCB fate and transport or the relationship between sediment and water. In addition, the model evaluates potential impacts to several ecological receptors.

We used the *TrophicTrace* model based on an aquatic food web model originally developed by Dr. Frank Gobas and colleagues at Simon Frasier University together with ecological risk equations. The *TrophicTrace* model predicts fish tissue concentrations, ecological receptor daily doses, and toxicity quotients for fish and higher order ecological receptors. The *TrophicTrace* model allows users a range of up to four input values to describe uncertainty using interval mathematics. The model generates a “probable” range (based on a median and/or mean) and a “possible” range (based on lower and upper confidence limits).

Sediment and fish tissue were collected to parameterize and calibrate the food web model. Surface sediments (approximately top 6 inches) were collected from below Burt Dam (sediment samples from above Burt Dam were available from recent EPA sampling). Three fish species were collected from above and below Burt Dam and analyzed for PCBs and lipid contents. The ages and stomach contents of these fish were also analyzed to support the food web modeling. We compared modeled fish tissue concentrations to observed tissue concentrations for the two sections of Eighteenmile Creek above and below Burt Dam. The model shows good agreement with measured fish tissue PCB concentrations to within a factor of two or less across the modeled species (pumpkinseed, brown bullhead, largemouth bass) in both River sections.

The comparison of fish body burdens to toxicity reference values from the literature indicate that it is likely that fish in the study area experience exposures that exceed no-effect threshold levels. Although it is less likely that fish body burdens exceed actual effect levels, that cannot be ruled out. We predict toxicity quotients for avian and mammalian ecological receptors based on a comparison of predicted average daily doses to literature-based toxicity reference values. The results for the heron show predicted toxicity quotients that fall below one. Predicted toxicity quotients for the kingfisher show a low potential for exposures to exceed a no-effect threshold level, but it is unlikely that the kingfisher will experience exposures that exceed effect levels. Predicted toxicity quotients for the mink suggest there is a low potential for mink to exceed no-effect threshold levels, and while it is less likely that these exposures exceed actual effect levels, potential exceedances cannot be ruled out.

We conclude that the *TrophicTrace* model adequately predicts fish tissue concentrations in the study area (based on the available data), and that these tissue concentrations are associated with the potential for exposure to PCBs for several receptors (e.g., fish, mink) to exceed no-effect levels, but are less likely to exceed effect levels. Predicted toxicity quotients are slightly higher for Section 2 above Burt Dam than for Section 1 below Burt Dam.

1.0 INTRODUCTION

Eighteenmile Creek is one of forty-three areas of concern (AOCs) established within the Great Lakes due to loss of “beneficial uses” from degraded water quality. The AOC encompasses Eighteenmile Creek from its entry into Lake Ontario, upstream to the Burt Dam (approximately 2 miles). The AOC has three identified use impairments linked to sediment contamination: (1) restrictions on fish and wildlife consumption; (2) degradation of benthos; and (3) restrictions on dredging activities.

Studies since the 1970s have indicated elevated levels of polychlorinated biphenyls (PCBs), chlorinated pesticides, and metals in surficial sediments throughout most of the AOC (for a Summary, see Chapter 4 of the Remedial Action Plan [NYSDEC 1997]). Several studies have documented potential risk to human, aquatic organism, and terrestrial wildlife receptors. New York State Department of Health (NYSDOH) has designated Eighteenmile Creek with its most stringent “Do Not Eat” fish advisory on the basis of PCB contamination. Lake Ontario is subject to other less stringent, species-specific fish advisories related to the presence of PCBs, Mirex, and dioxins/furans (NYSDOH, 2009). The U.S. Army Corps of Engineers (USACE) Buffalo District conducted an evaluation of the toxicity and bioaccumulation of persistent organics in samples from the lower reach collected in 2003 (USACE Buffalo District, 2008); this study indicated that Dichlorodiphenyltrichloroethane (DDE) likely presented a chronic toxicity risk relative to selected freshwater toxicity threshold values and was bioaccumulating at higher than anticipated levels. PCBs were also found to be bioaccumulating. Dioxins were detected in sediment samples and predicted to cause potential wildlife bioaccumulation risks based on an equilibrium partitioning approach used by the New York State Department of Environmental Conservation (NYSDEC).

Invertebrate bioaccumulation testing also suggests that organic contaminants moving through the food web are creating environmental risks (Karn et al., 2004). Specific contamination sources to the creek have not been fully delineated. However, recent investigations by NYSDEC have focused on a contamination source in Lockport, NY, near the upper reach at the Erie Canal (approximately 12 miles upstream of Burt Dam). During investigations in the 1980s and early-1990s, elevated levels of PCBs were detected in sediments near this facility and fish tissue contaminant levels were also elevated (samples above 2 mg/kg total PCBs wet weight) in the creek reach above the Burt Dam (NYSDEC, 1997).

In 2008, a study on the Beneficial Use Impairments of Eighteenmile Creek (Ecology and Environment, 2008) concluded that the impairment was largely due to PCB contamination. This study evaluated contaminant levels in brown bullhead collected below the Burt Dam and at a reference station (Oak Orchard Creek). It showed elevated tissue residues in Eighteenmile Creek fish compared to Oak Orchard Creek, with PCBs exceeding literature-based critical tissue concentrations for PCBs while dioxins/furans did not exceed critical levels (Ecology and Environment, 2008). That report concluded, “Overall, these results suggest that bullhead from Eighteenmile Creek may be at risk from elevated tissue residues of PCBs but not from dioxins/furans” (p. 3-29). A risk evaluation for fish-eating wildlife from PCBs and dioxins/furans was conducted as part of the investigation. The results indicate small excess risk from dioxins/furans to mink with much greater risk from PCBs. Slightly elevated risk to fish-

eating birds was indicated for PCBs, but not dioxins/furans (p. 3-36). Risks from chlorinated pesticides were not evaluated in this study.

To date, there have been several data collection efforts in and upstream of the AOC to define PCB levels in sediments, surface water, and biota. However, they have been limited in scope and have not focused on understanding PCB bioaccumulation, movement in the aquatic food web, and consequent environmental risks. Developing such an understanding will assist site managers as they move toward greater resolution on the nature of impairments at the site, develop remedial actions, and ultimately delist the area.

The US Army Engineer Research and Development Center (USAERDC) has completed the bioaccumulation modeling effort presented here in response to a request from the USACE Buffalo District. This is the Final Report of the food web bioaccumulation modeling effort, focusing specifically on PCB contamination in the AOC.

1.1 Components of Modeling Effort

This final report is supported by two interim memoranda:

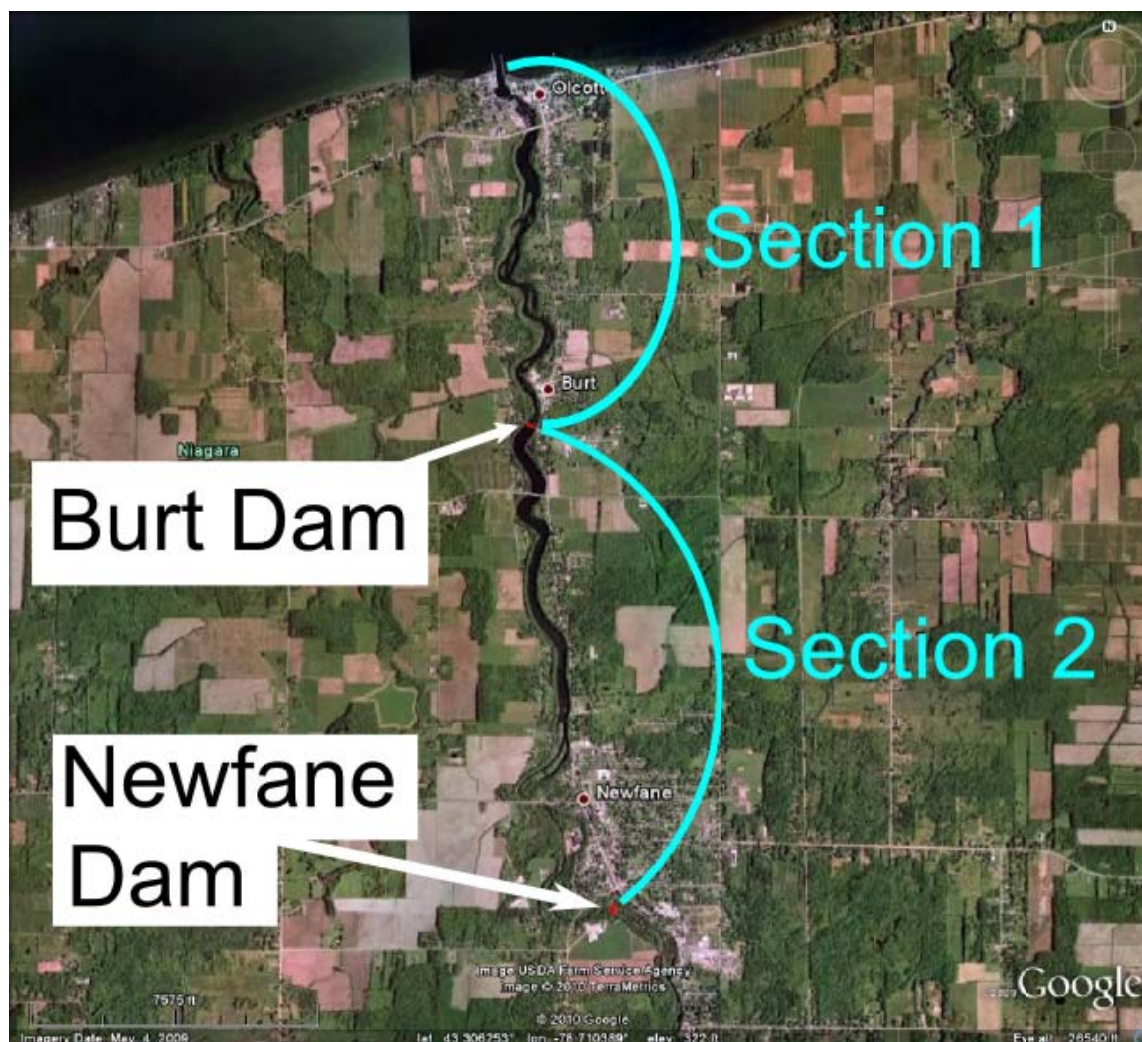
1) Final Data Gaps Memorandum, dated August 3, 2010. This memo provided a description of the food web bioaccumulation modeling to be performed and an associated review of existing contaminant data for Eighteenmile Creek to identify data gaps with respect to spatial resolution, contaminants, and types of organisms used to inform the bioaccumulation modeling effort. This memo recommended sampling/analysis efforts to support development of the modeling effort.

2) Final Conceptual Site Model (CSM) Memorandum, dated January 21, 2011. This memorandum describes the CSM, providing an overview of the physical, chemical, and biological aspects of the system that are modeled, including site-specific assumptions used to establish modeling conditions.

In this Final Report, we summarize the field sampling effort and resulting analytical data, describe the *TrophicTrace* model and its parameterization, and present model output, including risk estimates to terrestrial aquatic and terrestrial wildlife receptors. As appropriate, critical components of the earlier memoranda are summarized.

2.0 FIELD SAMPLING SUMMARY AND DATA RESULTS

As described in greater detail below, the area below Burt Dam is designated as Section 1 and the area above Burt Dam as Section 2 (See Figure 1). Based on sampling needs identified in the August 3, 2010 Final Data Gaps Memorandum, sediment and fish tissue sampling was conducted in the Eighteenmile Creek AOC, above and below Burt Dam. The sediment data from these and other efforts are used to represent exposure concentrations in the *TrophicTrace* model, and the fish tissue concentrations are used as the empirical basis for model calibration and validation.



d as
n of

PCB contamination is depicted using the sum of detected congeners (rather than individual or sum of Aroclors). It is well known that Aroclors represent the mixture of congeners released to the environment originally, but over time the congener composition changes due to weathering, selective dechlorination, and magnification of particular congeners resistant to dechlorination. Thus, congener-based analyses were selected to depict PCB contamination (see Section 3.3 for a more detailed explanation of PCB toxicity as it relates to congeners versus Aroclors).

2.1 Description of Fish Sampling and Analysis

Fish sampling took place in the Eighteenmile Creek AOC, above and below Burt Dam, on six days between September 13 and 30, 2010. Fish were collected by the U.S. Fish and Wildlife Service (USFWS), Lower Great Lakes Fish and Wildlife Conservation Office in Amherst, NY. Boat mounted electrofishing gear or minnow traps were used for collection. Per the CSM (See the Final CSM Memorandum), largemouth bass, brown bullhead, and pumpkinseed were targeted. These fish species represent different trophic levels, have different feeding strategies, and their tissue concentrations can be simulated in the *TrophicTrace* Model (see Section 3).

Sampling was performed according the Fish Tissue Field Sampling Plan included in Appendix 1. The field sampling plan describes targeted species, size ranges, and numbers of fish along with sampling contingencies. A summary of the collected fish is included in Table 1.

Table 1. Characteristics of Collected Fish

	Number Collected		Size (inches) (min-max, geometric mean)		Weight (grams) (min-max, geometric mean)	
	Section 1	Section 2	Section 1	Section 2	Section 1	Section 2
Largemouth Bass	10	10	11.2 - 15.0, 12.9	12.6 - 15.0, 13.6	364 - 956, 547	492 - 884, 607
Brown Bullhead	9	10	8.9 - 11.1, 10.5	9.5 - 11.9, 10.7	146 - 312, 244	188 - 450 284
Pumpkinseed (5-fish composite)	10	11	NA	NA	NA	NA

NA: Not applicable. Weight and length measurements were not taken on the pumpkinseed to be composited. Composites were 5 fish of <4 inches in length (A2R2PKN5 was a composite of 4 fish, see Appendix 2).

Target Species, Size, and Number

For all three species, the targeted number of fish was collected. While the bullhead were slightly larger than those targeted, this does not affect the overall basis for their inclusion which was a close association with sediments and sediment derived food sources (see stomach content analysis). The largemouth bass were within the targeted (contingency) size range. For pumpkinseed, the contingency to expand to alternate *Lepomis* spp. was used. The collection included a mixture of bluegill, green sunfish, and pumpkinseed, all below 4 inches in length. At that size range, *Lepomis* spp. share a similar trophic level and feeding preference. Overall, the size of fish sampled from Sections 1 and 2 was quite similar. Appendix 2, the fish sampling field collection log, contains descriptions of each fish and composite.

Targeted Sampling Areas

Sampling occurred in the creek sections above and below Burt Dam. Each section was divided into 3 equal reaches in an effort to collect fish equally throughout the section (see Figures 1 through 3 of Appendix 1). This was intended to permit an evaluation of the relationship between sediment and fish contaminants in a per-reach basis. However, fish could not be equally

sampled from each reach, either because they were not equally distributed or collection techniques were not equally effective in all reaches. Thus, the sampling plan's contingency to collect fish throughout the whole section was used. Table 2 summarizes the distribution of sampled fish within the designated reaches of each section. Appendix 3 to this report presents locations of the electroshocking runs or traps along with the fish collected at those locations.

Table 2: Numbers of Fish (or Composites) Collected in Individual Reaches of Sections 1 and 2

		Reach 1	Reach 2	Reach 3
Section 1	Largemouth Bass	3	4	3
	Brown Bullhead	4	0	5
	Pumpkinseed	3	3	4
Section 2	Largemouth Bass	3	7	0
	Brown Bullhead	0	10	0
	Pumpkinseed	0	8	3

Fish Processing and Shipping

Several field days were required to achieve targeted numbers and species in the two river sections. Fish were processed according to procedures documented in Appendix 1. Following each day's sampling, fish were bagged and labeled. Fish were then frozen at the USFWS, Lower Great Lakes Fish and Wildlife Conservation Office until shipping. Chain of custody forms are provided in Appendix 4.

Fish Lipid and Contaminant Analyses

Whole fish were submitted to the Environmental Chemistry Laboratory at USAERDC for analysis of PCB congeners and lipid. Fish samples were thawed, contents of stomach removed (see Section 2.3), and the entire fish (or composite for the pumpkinseed samples) was ground using a meat grinder. Approximately 5g of fish were weighed into vials and extracted overnight with 10% acetone in hexane in a sonic bath. Extracts were filtered followed by cleanup using florisil (SW846 3620 modified) and sulfuric acid (SW846 3665). Extracts were concentrated to 2mL and analyzed by Gas Chromatography/Electron Capture Detector (GC/ECD) using dual columns (SW846 8082).

2.2 Description of Sediment Sampling and Analysis


Sediment sampling took place on October 26, 2010. Sediment surface grab samples were collected by the USACE Buffalo District at 16 locations throughout Section 1 (See Table 3). Field duplicate samples were also collected at two locations (EMC-4 and EMC-12). Sediment samples were analyzed for PCBs to represent sediment exposure concentrations. The Section 1 sampling and analysis will be further described below.

Sediments in Section 2 in the Burt Dam reservoir were collected for PCB analysis in May 2010 by the Great Lakes National Program Office (GLNPO). In addition to an extensive vibracoring effort in the Burt Dam reservoir, surface sediment samples were collected using a petite ponar

grab (that device was also used in Reach 1 sampling). Section 2 sediment sampling and analyses are described in Eighteenmile Creek Site Characterization Data Summary Report (CH2MHill 2011)¹. Briefly, ponar grab samples were collected at 27 locations and analyzed for TOC and PCB congeners, among other analytes (See Table 2-1b in CH2MHill 2011). The location of sediment sampling is depicted in Figures 2-1 and 2-2 of the Data Summary Report. The ponar sampling data will be used in this report to represent sediment PCB exposure concentrations in Section 2 (see Section 3.2.1 for further discussion).

Table 3. Sediment Sampling Locations in Section 1

Sample	Latitude	Longitude
EMC-1	43 20.316	78 43.127
EMC-2	43 20.222	78 42.999
EMC-3	43 20.146	78 42.931
EMC-4	43 20.043	78 42.978
EMC-5	43 19.936	78 42.958
EMC-6	43 19.825	78 42.929
EMC-7	43 19.745	78 42.942
EMC-8	43 19.619	78 43.016
EMC-9	43 19.519	78 43.073
EMC-10	43 19.437	78 43.038
EMC-11	43 19.352	78 42.969
EMC-12	43 19.279	78 42.876
EMC-13	43 19.177	78 42.859
EMC-14	43 19.115	78 42.953
EMC-15	43 19.059	78 43.022
EMC-16	43 18.912	78 42.907



Section 1 Sediment Sampling and Analysis

Section 1 sediment sampling was performed according to the Sediment Field Sampling Collection Plan included in Appendix 5. Field notes from that effort are included in Appendix 6. Collection was typically by petite ponar. Sediment samples were collected in 8 ounce jars for contaminant analysis and 4 ounce jars for analysis of total organic carbon (TOC). At site EMC-16 near the Fisherman's Park area, the sediment was predominantly gravel (with some minor sand mixed in), so sampling was accomplished by scoop. Field personnel stated that sampling using the ponar sampler was to a depth of approximately 3-6 inches. When poor recoveries of sediment occurred (typically due to hard or gravelly substrate), the location was moved to achieve appropriate sample volume. Actual sampling locations varied slightly (20-30 feet) from the locations designated in the sampling plan. Actual sampling locations are presented in Table 3.

¹In CH2MHill (2011), the area between Burt and Newfane Dam is designated as sections 2 and 3

Sediment samples were processed according to procedures documented in Appendix 5. Sediments were collected, processed, and shipped on the same day. Samples were packed on ice and shipped via overnight delivery to the USAERDC chemistry laboratory for contaminant and TOC analyses. Chain of custody forms are provided in Appendix 7.

Sediments were analyzed for PCB congeners. Approximately 15g of sediment were extracted by Accelerated Solvent Extraction (SW846 3545) followed by clean up with acid (SW846 3665). Extract volume was adjusted to 2mL and extracts were analyzed using GC/ECD with dual columns (SW846 8082).

2.3 Description of Fish Stomach Content and Aging Analyses

Prior to grinding fish for contaminant extraction, stomach contents (not the stomach itself) were removed and examined at 160x magnification to determine prey items and establish their percent volume or mass of the entire gut contents. Individual bullhead and largemouth bass were aged using either scales or pectoral spines. See Appendix 8 for a complete description of methods and results.

2.4 Results from Analyses of Sediments and Fish

Sediment Chemical Analysis Results

Table 4 provides a summary of the PCB and TOC analytical data for Section 1 and 2 of Eighteenmile Creek. Total PCB and TOC data from individual samples collected from Section 1 are presented in Appendix 9 (Section 2 data, not collected as part of this effort, are included here for ease in comparison). Figure 2 presents these results graphically, interpolating PCB results between data points. Data files from the USAERDC chemistry laboratory with the full suite of congeners, Aroclors, and quality control samples and information have been provided electronically to the sponsor. For the purposes of data analysis and modeling, non-detect values were assigned ½ the detection limit.

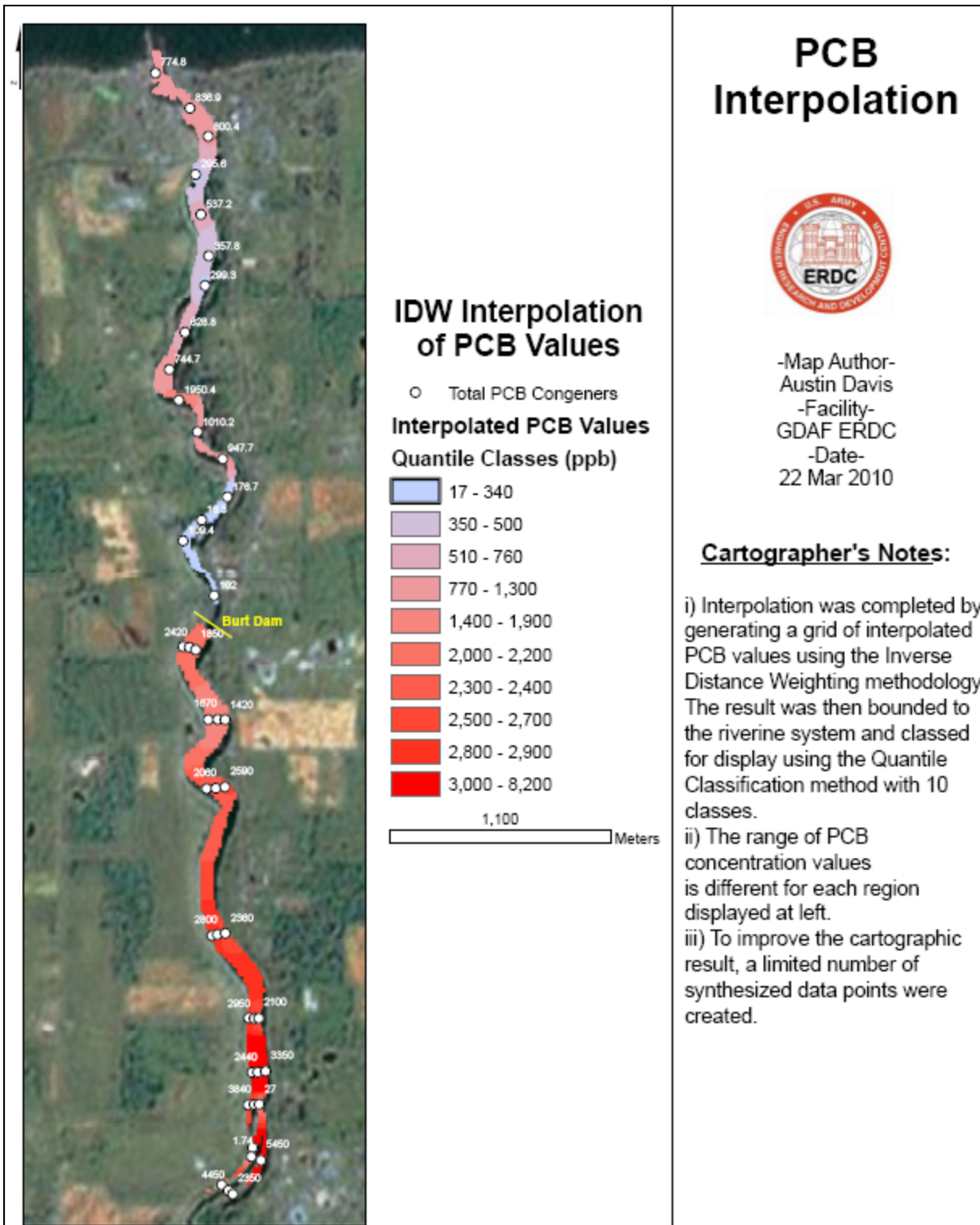


Figure 2: PCB Concentrations in Sediment. Figure depicts total PCB concentrations interpolated across the section (shown as colors) and as individual sampling points (white circles). See Appendix 9 for individual sample values.

Table 4: Summary Statistics for Sediment at Eighteenmile Creek.

PCB Concentration							
Section	n	Average	Standard Deviation	5% LCL	95% UCL	Min	Max
		ug/kg dry weight					
1	16	601	484	343	859	16.3	1950
2	27	2640	1691	1971	3309	1.7	8300

TOC-normalized PCB Concentration					
Section	n	Average TOC-norm	Standard Deviation TOC-norm	Min TOC-norm	Max TOC-norm
		mg/kg TOC-normalized			
1	16	33.5	17.5	1.3	55.8
2	27	60.3	40.6	0.07	203

Total Organic Carbon (TOC)						
Section	n	Average TOC	Min TOC	Max TOC	5%LCL	95% UCL
		Percent				
1	16	1.6	0.69	3.8	1.2	1.9
2	27	4.5	0.34	9.3	3.8	5.2

Fish Tissue Chemical Analysis Results

Table 5 provides summary statistics for the fish tissue data, and Table 6 provides a summary of the lipid data. Total PCB and lipid data from individual samples are presented in Appendix 9. Data files from the USAERDC chemistry laboratory with the full suite of congeners, Aroclors, and quality control samples and information have been provided electronically to the sponsor.

Table 5: Summary of Total PCB Concentrations Based on Sum of Congeners (mg/kg wet weight) from Whole Fish Collected in Each Section of Eighteenmile Creek

Section	Number of fish	Arithmetic Mean	Standard Deviation	Minimum	Maximum	Geometric Mean
Largemouth Bass (LMB)						
1	10	2.5	1.8	0.7	6.3	1.9
2	10	8.6	9.4	1.8	34.6	6.2
Brown Bullhead (BB)						
1	9	1.2	0.5	0.4	2.1	1.1
2	10	2.7	1.4	1.1	6.3	2.4
Pumpkinseed (PKSD)¹						
1	10	2.4	1.2	1.2	5.1	2.2
2	10 ²	2.4	1.1	0.8	4.3	2.2

¹Pumpkinseed represent a composite of individual *Lepomis* spp. See section 2.1. Eleven pumpkinseed composites were collected from Reach 2. PKN11 was collected just below the Newfane Dam, well above the reservoir and area with sediment chemistry. Therefore PKN11 chemistry was not included.

Table 6. Summary of Lipid Data (Percent) from Eighteenmile Creek Fish

Species	Number of fish	Average	Standard Deviation	Minimum	Maximum	5% LCL	95% UCL
LMB	20	2.9	1.2	1.2	5.1	2.3	3.4
BB	19	3.1	1.3	0.6	5.5	2.4	3.7
PKSD	20	2.4	0.9	1.0	3.9	2.0	2.8

Fish Stomach Content and Aging Analysis Results

Table 7 provides a summary of the composition of the diets of largemouth bass and brown bullhead from the site. Table 8 summarizes the ages of the collected largemouth bass and bullhead. The relationship between the age group of the fish and lipid normalized PCB total PCB concentrations is presented in Figure 4. A discernible relationship of PCB concentration with age is noted only for largemouth bass in Section 2 (however, only two age groups were collected in that Section). This observation is mostly driven by the anomalously high PCB concentration in the single fish. Overall, fish tissue PCB concentrations do not appear to vary as a function of age in the sampled population.

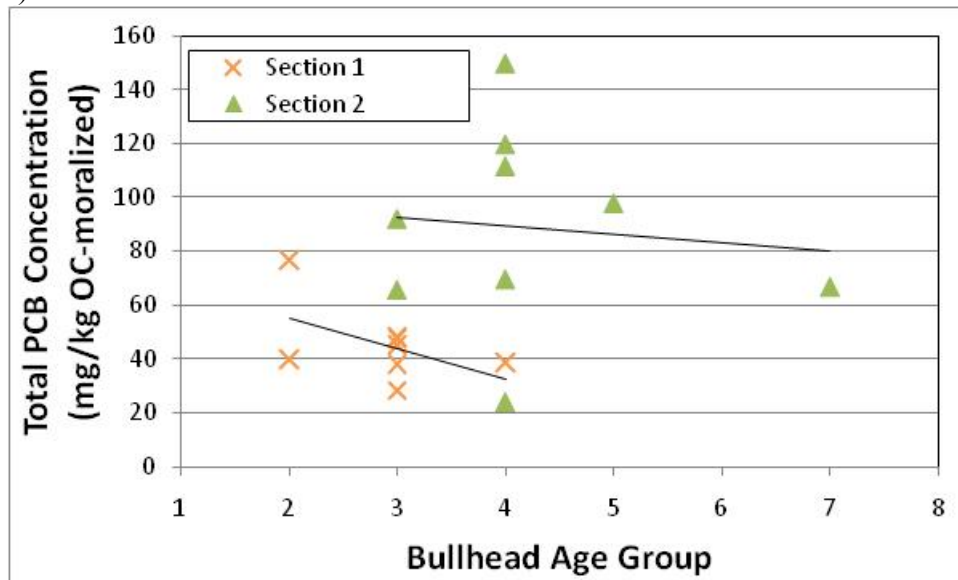
Table 7: Composition of the Diets of Largemouth Bass and Brown Bullhead from Eighteenmile Creek. Overall prey number, food volume, and food weight are means (and standard deviations). Prey frequency (Freq), number, weight (bass), and estimated volume (bullhead) are percentages of total value. See Appendix 8 for details.

% With Food Prey Number Food Volume (mm ³) Food Weight (g)	Largemouth Bass N = 20				Brown Bullhead N = 19			
	60				89			
	0.90 (0.19)				4.16 (0.95)			
	1.92 (0.58)				1.80 (0.43)			
Prey	1.77 (0.52)				2.02 (0.47)			
	Freq	Number	Weight	RI	Freq	Number	Volume	RI
Algae & Detritus	-	-	-	-	5	16.35	64.13	51.78
Vascular Plant	5	5.5	0.4	0.01	32	7.69	11.56	28.09
Seed	-	-	-	-	16	3.85	0.41	0.25
Bryozoa	-	-	-	-	5	11.30	0.03	0.02
Physidae	-	-	-	-	21	17.79	2.44	9.00
Ancylidae	-	-	-	-	5	1.20	0.03	T
Planorbidae	-	-	-	-	5	1.20	0.03	T
Gastropoda (UNID)	-	-	-	-	5	1.20	0.06	T
Sphaeriidae	-	-	-	-	10	2.40	0.03	0.01
Dreissenidae	5	5.5	0.2	0.01	5	1.20	0.01	T
Invertebrate (UNID)	-	-	-		5	8.65	0.06	0.03
Cambaridae	30	38.9	70.0	92.16	16	6.25	10.20	10.07
Aranea	5	5.5	2.2	0.07	-	-	-	-
Anisoptera	-	-	-	-	5	1.20	0.06	T
Gyrinidae	5	5.5	0.2	0.01	-	-	-	-
Coleoptera (UNID)	5	5.5	1.8	0.06	5	1.20	0.06	T
Hydroptilidae	-	-	-	-	5	1.20	0.03	T
Trichoptera (UNID)	-	-	-	-	16	3.85	0.12	0.07
Chironomidae	-	-	-	-	16	3.85	0.09	0.05
Diptera (pupae)	-	-	-	-	5	1.20	0.03	T
Insecta (UNID)	-	-	-	-	5	1.20	0.03	T
Cyprinidae	5	5.5	6.6	0.20	-	-	-	-
Centrarchidae	5	5.5	3.8	0.12	5	1.20	2.35	0.14
Percidae	-	-	-	-	5	1.20	2.94	0.17
Perciform (UNID)	-	-	-	-	5	1.20	0.23	0.01
Fish (UNID)	20	22.2	14.7	7.36	5	1.20	0.03	T
Vertebrate (UNID)	-	-	-		5	1.20	5.00	0.30
Total	n/a	99.6	99.9	100	n/a	98.8	99.96	99.99

Table 8: Numbers of Largemouth Bass and Brown Bullhead from Eighteenmile Creek for Each Age Group

Age Group	Largemouth Bass	Brown Bullhead
II	-	2
III	-	7
IV	9	6
V	9	1
VI	1	-
VII	-	1

a)



b)

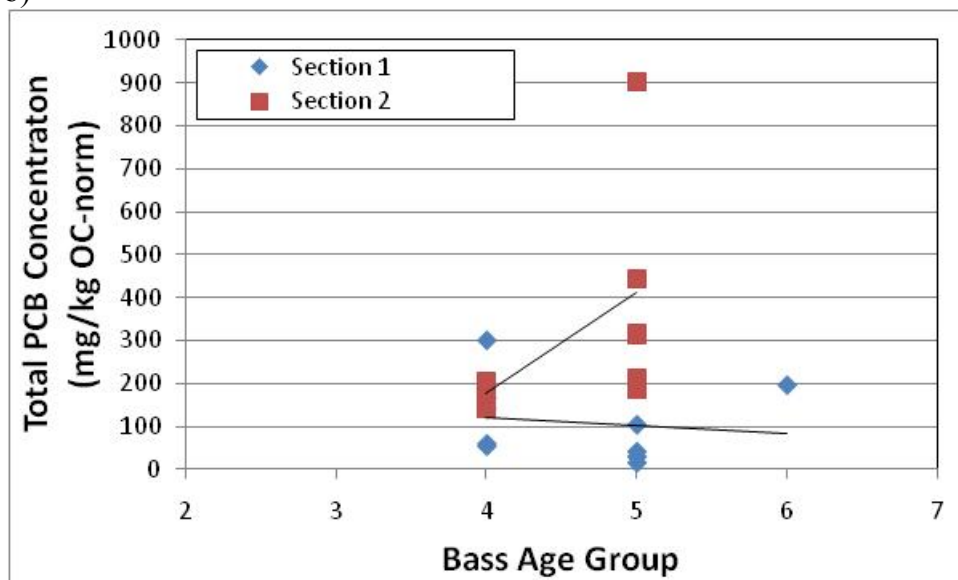


Figure 3: Relationship Between Fish Age Group and Lipid-normalized PCB Concentration. Individual data points are presented for a) bullhead and b) largemouth bass in both sections of the Eighteenmile Creek study area. Linear trend lines for each section are also included.

3.0 *TrophicTrace* MODEL DEVELOPMENT AND RESULTS

We developed a bioaccumulation and ecological risk model using the *TrophicTrace* food web bioaccumulation model. The *TrophicTrace* model is a steady-state model that predicts the expected body burden in fish and then uses these results as inputs to the ecological risk model to predict average daily doses to ecological receptors. Finally, the model estimates toxicity quotients (TQs) by dividing the receptor's average daily dose by the toxicity reference values from the literature. TQs are estimated for ecological receptors exposed to expected (e.g., average) conditions and also develops uncertainty bounds around predicted central estimates. The bioaccumulation modeling portion of *TrophicTrace* and its underlying mathematical structure (Gobas 1993) are well-accepted and have been used in a number of regulatory applications (Gustavson et al. 2011). Appendix B of the Data Gaps Memorandum provides more detailed background information regarding the *TrophicTrace* Bioaccumulation Model.

Ecological risk can be evaluated in different ways. Evaluating potential adverse effects across a population of receptors requires evaluating multiple lines of evidence. There are assessment endpoints -- the ecological endpoints that we are interested in protecting (e.g., growth, reproduction and sustainability of fish and wildlife populations) -- and measurement endpoints (e.g., those aspects of ecosystem function that we measure to evaluate the assessment endpoints - the lines of evidence). Evidence ranges from the type of modeling presented here (e.g., comparisons of predicted body burdens and/or doses to no- and lowest-observed effect levels from the literature) to various kinds of field studies. If the modeling results presented here suggest the potential for receptors to experience exposures in the field that are likely to exceed no- or lowest observed effect levels from the literature, then that would provide an indication that additional field studies may be warranted in order to draw stronger conclusions concerning the potential for adverse effects to occur as a result of exposures in the study area.

3.1 Modeling Area

The model is run separately for each of the two creek sections described earlier: Eighteenmile Creek from Lake Ontario to Burt Dam (Section 1) and an upper reach from Burt Dam to the Newfane Dam (Section 2) (Figure 1). The definition of the two sections assumes that fish populations will not interact and only be exposed to conditions in those sections.

The AOC (Section 1) and the Burt Dam reservoir area (Section 2) are the closest in environmental conditions, habitat, and fishery, so they are appropriate conditions to fulfill the SOW objective "to evaluate organic contaminant bioaccumulation, trophic transfer and consequent risks in creek sections above and below Burt Dam of the Eighteenmile Creek." The Burt Dam Reservoir extends approximately 2 miles before more typical stream morphology continues for another mile to the Newfane Dam. The Newfane Dam along with the relatively swift shallower bedrock and gravel channel below the Newfane dam are hydraulically significant features and serve as impediments to fish movement. Fish and sediment in Section 2 were collected from the reservoir (Figure 2), not all the way up to Newfane dam. Modeling results are most applicable to the area encompassed by sampling. Conditions are more complex upstream of Newfane Dam with more typical stream reach/run morphology; these areas will possess fewer fine-grained sediments, support a different fishery, and exhibit a different dynamic of

contaminant exposure between modeled organisms, sediments, dietary constituents, and water. However, as described earlier, contamination source areas and impacted receptors extend further upstream of the modeled sections to the city of Lockport at the Erie Canal.

3.2 Assessment and Measurement Endpoints

Assessment endpoints are selected to represent those aspects of the study area ecosystem that are to be protected and potentially at risk from exposures to PCBs. In general, ecological risk assessment endpoints relate to populations rather than individuals, and should reflect ecosystem structure and function at higher levels. The assessment endpoints selected for this study area include:

- maintenance and sustainability of fish that serve as a prey base for other fish and wildlife (as represented by forage fish as described in Section 3.3.2); and,
- maintenance and sustainability of wildlife (as represented by specific receptors as described in Section 3.3.2).

Measurement endpoints are those aspects of the ecosystem that can be measured. For this study area, the primary concern is potential exposures of ecological receptors to PCB concentrations in sediment. Available measurements include PCB concentrations in sediment and fish. Using the *TrophicTrace* bioaccumulation model, we first predict expected PCB concentrations in fish (and compare the results to data), and then predict expected average daily doses to higher-order receptors and compare those to no- and lowest-observed effect levels from the literature.

3.3 Model Parameterization

To the extent possible, development and parameterization of the *TrophicTrace* model relied on site-specific data. This section describes the modeling assumptions and data used to parameterize the *TrophicTrace* model.

The *TrophicTrace* model predicts the mean expected fish tissue contaminant concentration and this is the basis of all model prediction-data comparisons. However, the mean observed fish tissue contaminant concentration is uncertain as reflected by the standard error on the mean from the data. The model is designed to capture the uncertainty in the mean by allowing model inputs for each module (e.g., bioaccumulation, ecological risk) to be specified as a range, representing the uncertainty in the mean estimate of that input. Fuzzy set theory or interval analysis (Zadeh, 1965; Zimmerman, 1985) can be used to propagate uncertainty in a mathematical model when there is insufficient information to use a more sophisticated framework (e.g., probabilistic approaches) or when the equations are too complex to allow for analytical approaches (Hammonds et al., 1994). Fuzzy set approaches have been used for risk assessment applications (Guyonnet et al., 1999; Huang et al., 1999; Lee et al., 1994) and for fate and transport studies (Dou et al., 1995; Bardossy et al., 1995).

When possible, each model input value is defined by three (in some cases, four) numbers. These values represent two ranges: a probable range (the likeliest range based on average input values) and a possible range, analogous to an upper and lower 95% confidence limit. In terms of

predictions, the probable range represents the best estimate of predicted fish body burdens, average daily doses, and resulting TQs based on using central tendency estimates for each input value in the model. The possible range represents the lowest and highest possible predicted risks based on using a 5% lower confidence and 95% upper confidence interval of the mean, respectively, for each input value. We use the probable TQ range to make a determination of potential risk, and use the possible range to describe our confidence in those conclusions.

Figure 4 provides a graphical representation of how the final TQ ranges are calculated. The highest possible TQ value (and prior to that, average daily dose, and prior to that, predicted fish body burden) is derived by simultaneously combining the series of all upper bound input estimates. Note that it is unlikely that all input values would simultaneously occur at the 95% upper confidence limit value in a steady-state fashion (that is, ecological receptors would consume fish exposed to a 95% upper confidence sediment concentration consistently over time and so on). In the same manner, the lowest possible predicted value represents a lower bound on the risk estimate, derived by simultaneously combining all 5% lower confidence level values for model inputs. The possible range is calculated for the purpose of uncertainty analysis to provide perspective on how high (or low) predicted TQs could be given our uncertainty in the input values.

For this analysis, the probable input range is represented by a single value (the mean value of the input variable) for most of the inputs except for temperature, Log K_{ow} , dissolved water concentration, and the Toxicity Reference Values (TRVs). The possible range reflects the uncertainty in the central tendency input value as reflected by a 95% confidence interval on either side of the mean. The exception to this is the input values for the TRVs. As described in Section 3.3.1, there is more than one mean TRV available based on individual studies from the literature, so these inputs are based on at most four values (low, medium, medium-high-and high), but in some cases only two. For the dissolved water concentration, the data do not support development of more than one value (and PCB uptake from water is expected to have minimal influence on fish tissue concentration), so a single value was used.

The specific inputs selected to represent environmental conditions, contaminant exposures, and the food webs are described in the rest of this section. Table 11 at the end of this section provides an overall summary of all inputs to the model.

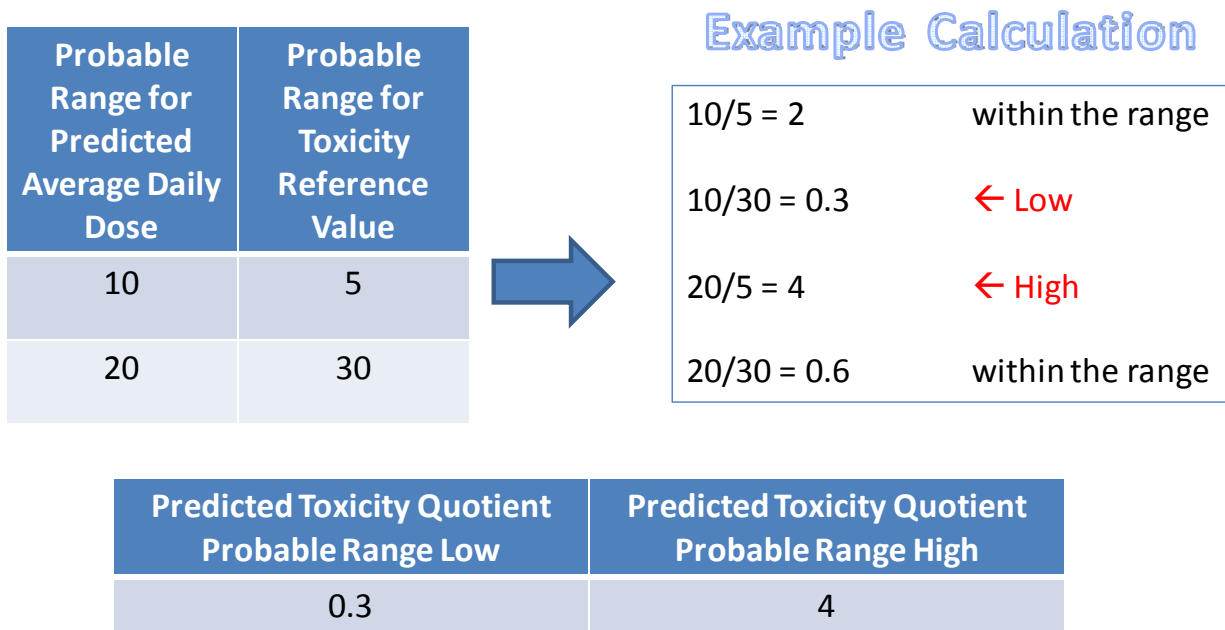


Figure 2: Example of the Calculation to Estimate the Probable Range of Predicted Toxicity Quotients. Probable and possible ranges for outputs (e.g., fish tissue concentrations, average daily doses for ecological receptors and toxicity quotients across fish and ecological receptors) are generated through combinations of inputs in the food web equations based on interval mathematics. For example, since ecological risk (measured as a toxicity quotient [TQ]) is described mathematically by dividing a predicted average daily dose (for ecological receptors) or a fish tissue body burden (for fish) by a toxicity reference value (TRV), the lowest probable TQ is obtained by dividing the lowest predicted average daily dose by the highest TRV; the highest probable TQ is obtained by dividing the highest predicted average daily dose by the lowest TRV. The same is true for the possible range.

3.3.1 Environmental Inputs

Sediment and Water Exposure Concentrations

Sediment PCB and TOC concentrations were derived from sampling conducted in May (Section 2) and October 2010 (Section 1), which correspond closely to the September 2010 fish sampling that occurred in both Sections. Water concentrations were derived from site literature. Only a single freely dissolved water concentration data point of 80 ng/L was available; this datum was obtained in 1998 at a location just below Burt Dam in Section 1 (Garabedian et al., 2001).² This value was used as the input concentration for dissolved water in Section 1, and proportionally increased to 100 ng/L. The 25% increase in concentration for Section 2 was a simple estimate derived considering the higher surface sediment PCB concentrations in Section 2, the location of the single sample (at the base of the dam, water could realistically be considered either Section 1 or 2 water), and the small role that direct water uptake plays with respect to bioaccumulation through the food web. The need for additional water data is examined further in Section 4,

² Since 2002, the U.S. Environmental Protection Agency (EPA) has collected Eighteenmile Creek surface water samples for analysis of PCBs and other pollutants (e.g. Zevin 2011). However, these analyses are of “whole water” samples, and do not represent the freely dissolved PCB fraction which is needed for food web modeling.

Discussion of Uncertainty. Table 9 summarizes the sources of exposure concentration data for each Section. Sediment concentrations are represented in the model by three values: we selected the mean value from the data to represent the probable input range, and the lower and upper 95% confidence limits of the mean to represent the possible range.

Table 9: Summary of Data Sources for Exposure Input Concentrations

	Sediment	Water
Section 1	USAERDC and USACE Buffalo District October 2010 PCB congener analysis of surface sediments.	Garabedian et al., 2001; sample collected by NYSDEC in November 1998.
Section 2	GLNPO May 2010 PCB congener analysis of surface sediments (CH2MHill 2011); data received electronically in October 2010 from Ecology and Environment.	Extrapolated from single measurement from Section 1.

Temperature

Several parameters within the food web model are temperature dependent, including feeding rate and growth rate. Temperature inputs were derived from a number of sampling programs at Eighteenmile Creek and reflect an April to October average, which is the most active foraging time for fish. Historical temperature data for the site were compiled in the Data Gaps Analysis (see 18miCk_water.xlsx, submitted August 2010) from sampling conducted by US EPA in 2004, 2005, 2006; NYSDEC and U.S. Geological Survey (USGS) in 1990; and USGS back to the mid-1970's. Four input values are used to represent the range in expected temperatures in Eighteenmile Creek over the period from April to October. The probable range for temperature is based on the median and mean of the available data; the possible range is represented by the lower and upper 95% confidence limits on the mean.

Log K_{ow}

The octanol-water partitioning coefficient (Log K_{ow}) is an indicator of the hydrophobicity of a compound and its partitioning between water and organic phases (e.g., organic carbon and lipid). The term is used to derive several rate constants in the model. We used four input values to represent the range of expected Log K_{ow} values. The probable -- likeliest -- range for Log K_{ow} is 6 to 6.2. Aroclor 1248 (Log K_{ow} approximately 6) is the primary Aroclor at the site; a mixture of 20% Aroclor 1260 and 80% Aroclor 1248 has an approximate Low K_{ow} of 6.2.³ The possible range is represented by a low of 5.8 and a high of 6.4. Those values represent the uncertainty in the mean (e.g., the best estimate for the mean value of Log K_{ow} is 6 to 6.2, but that mean could be as high as 6.4 or as low as 5.8, given specific, but unknown, conditions in Eighteenmile Creek).

³ Aroclor 1260 was found in fewer than half of the samples analyzed between the Burt Dam and Newfane Dam by in the May 2010 sediment sampling effort (CH2MHill 2011). When Aroclor 1260 was found in surface sediments (top 1 foot), it was approximately 20% of the total Aroclor present.

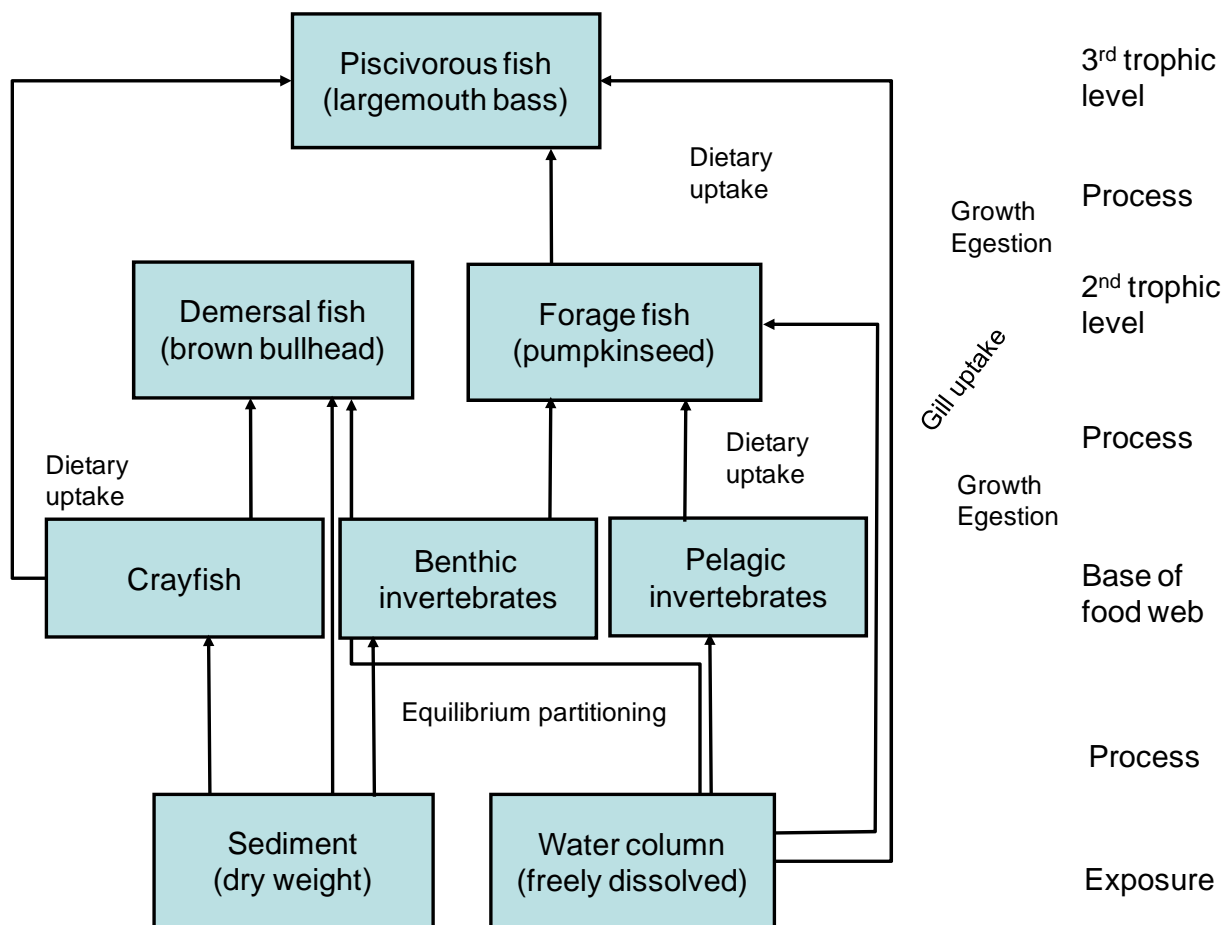
Benthos-Sediment Accumulation Factor (BSAF)

The BSAF assumed in the modeling is based on a site-specific laboratory study using sediments obtained from Section 1 in Eighteenmile Creek. This laboratory study exposed *Lumbriculus variegatus* to site sediments and developed ratios of lipid-normalized benthic invertebrate concentrations to TOC-normalized sediment concentrations (USACE Buffalo District 2008). That study recommends a BSAF of 1.7 for total PCBs. We therefore represented both the probable and possible ranges for BSAF using 1 as the lower bound and 1.7 as the upper bound for the crayfish and benthic invertebrate food web compartments. A BSAF = 1 was maintained for the sediment compartment which, based on gut contents analyses, was a significant dietary component of the brown bullhead.

3.3.2 Food Web Composition and Exposures

The CSM memorandum introduced the proposed food web and provided qualitative information on food web composition. Since that time, the foodweb model was modified based on input from the sponsor and stakeholders (e.g., upper level terrestrial receptors were modified to include known inhabitants of the area) and from stomach content analyses of collected fish. More quantitative details regarding the modeling framework are provided in this section.

Figure 5: Conceptual Site Model for the Aquatic Food Web at Eighteenmile Creek



Aquatic Food Web

Figure 5 presents a simplified CSM for the aquatic food web in Eighteenmile Creek, and Table 11 provides a summary of all the input data to the *TrophicTrace* model (except for dietary preferences, found in Table 10). The goal is to develop a modeling framework that captures exposures to PCBs in sediment. Because PCBs are known to bioaccumulate, it is also important to include fish species that consume other fish, and to focus on permanent residents of Eighteenmile Creek rather than transient species.⁴ The proposed food web starts with invertebrates that serve as a prey base for forage, demersal, and piscivorous fish.

Benthic Invertebrates

Contaminant concentrations in benthic invertebrates are assumed to be in equilibrium with those in local sediments. We model two kinds of benthic invertebrates and a detrital sediment compartment as food sources. The first benthic invertebrate compartment (benthos) represents the range of infaunal and epifaunal organisms typically found in riverine systems. Lipid content for the benthos is based on a large database of lipid across sieved organisms from the Hudson River sampling program (US EPA 2000). As mentioned, a site-specific benthic BSAF of 1.7 was applied to the equilibrium partitioning equation to estimate concentrations in this compartment.

The second compartment for benthic invertebrates is represented by crayfish, based on the stomach contents analysis (see Table 7) that showed that largemouth bass, in particular, consume a large amount of crayfish. Crayfish lipid content was obtained from Gewurtz et al. (2000) and Lin et al. (2000). Across the two studies, data from 43 crayfish was available for parameterizing the *TrophicTrace* model. The BSAF of 1.7 was also applied to crayfish. There were not site-specific data on crayfish contaminant or lipid concentration.

The third “invertebrate” compartment (sediment) is represented by detrital matter and vegetation found on the surface of sediment. The stomach contents analysis (Table 7) of brown bullhead collected from the site showed a very high dietary portion of detritus and vegetation (an observation similar to other studies on bullhead diets [e.g., Eddy and Surber, 1947]). A BSAF was not applied to this compartment as consuming these items is analogous to direct sediment consumption. Equilibrium partitioning from sediment was used to estimate concentrations in this compartment, together with an assumption of lipid content equivalent to that found in the benthos compartment.

Pelagic Invertebrates

Pelagic invertebrates are assumed to be in equilibrium with dissolved-phase water concentrations.

⁴ Eighteenmile Creek is an important recreational salmonid fishery. The salmonids spend the majority of their life cycle in the open water of Lake Ontario, returning to Eighteenmile Creek to spawn. Because they are primarily open water residents, they are not appropriate to include in food web modeling that focuses on Eighteenmile Creek sediment. In addition, salmonid species are routinely stocked; the resident warm-water species analyzed in this study are not (Niagara County Soil and Water Conservation District 2007).

Forage Fish

The forage fish sampling program focused on small forage fish (*Lepomis spp.*) less than 4 inches in size. In this size range, the primary food source is zooplankton with some epibenthic invertebrates, depending on the species (Mittelbach 1984).

Brown Bullhead (Ameiurus nebulosus)

The next feeding guild that is important to capture is the demersal fish, such as brown bullhead. Collected fish ranged from approximately 9 to 12 inches (Table 1). In this size range, bullhead consume primarily benthic food sources and a small percentage of pelagic invertebrates. Stomach content analysis of the collected fish (Table 7) shows that bullhead consumed primarily sediment-associated detrital matter, with approximately 10% pelagic invertebrates (e.g., snails [Physidae] and other pelagic invertebrates) and 10% crayfish (e.g., Cambaridae).

Largemouth Bass (Micropterus salmoides)

The piscivorous feeding guild is represented by largemouth bass. Collected fish ranged from 11 to 15 inches (Table 1), which is the size range that would be attractive to anglers and larger ecological receptors. In this size range, bass consume primarily smaller forage fish and benthic invertebrates, including crayfish. As shown in Table 7, largemouth bass from the site consume greater than 90% of their diet as crayfish.

Table 10: Dietary Preferences (% of Diet) for the Modeled Species

Species	Pelagic	Sediment	Benthos	Crayfish	PKSD	Notes
PKSD	80		20			BSAF probable and possible ranges = 1 to 1.7
BB	10	80		10		BSAF = 1
LMB				92	8	BSAF probable and possible ranges = 1 to 1.7
Kingfisher			12	10	78	46% -100%fish; 5% - 41% invertebrates
Heron					100	100% fish
Mink				16.5	34	18.8% - 34% fish; 13.9% - 16.5% inverts; large proportion of small mammals

Terrestrial Food Web

Fish and invertebrates that may have accumulated contaminants from sediments in Eighteenmile Creek also serve as a prey base for ecological receptors, including fish eating birds and mammals. Figure 6 presents a simplified conceptual model for terrestrial receptors that consume fish. The selected species were chosen based on the following criteria:

- Observed in the study area or could occur in the study area
- Fish consumers
- Life histories and foraging strategies that lead to potential exposures from Eighteenmile Creek
- Modeling parameters are readily available (e.g., knowledge of quantitative foraging preferences, etc.)

We evaluate potential exposures and hazards to two avian receptors known to inhabit Eighteenmile Creek: the belted kingfisher (*Ceryle alcyon*) and the great blue heron (*Ardea herodias*). One mammalian receptor is selected: the mink (*Mustela vison*). The primary reference for body weight, ingestion rate, and dietary preferences, the three key inputs, is obtained from the US EPA's Wildlife Exposure Factors Handbook and data provided therein (US EPA, 1993a and 1993b). A summary of dietary preferences is found in Table 10, and Table 11 provides a summary of all inputs to the *TrophicTrace* model.

Belted Kingfisher

The belted kingfisher is a medium-sized bird, measuring about 13 in (33 cm) (Peterson 1980). It is blue-gray with a ragged bushy crest and broad gray breastband. It generally feeds on fish that swim near the surface or in shallow water. The kingfisher may also feed on crayfish, and in times of food shortages it can feed on a variety of invertebrates and vertebrates. Kingfishers nest in burrows that they excavate in embankments. Kingfishers are found throughout the study area (Ecology and Environment, 2007, p 7-33,7-47; also as documented on the Atlas 2000 website for block 1980C; <http://www.dec.ny.gov/cfm/xtapps/bba/>). Body weight, ingestion rates, and dietary preferences for the kingfisher were obtained from the US EPA Wildlife Exposure Factors Handbook (US EPA, 1993a and 1993b) and references contained therein.

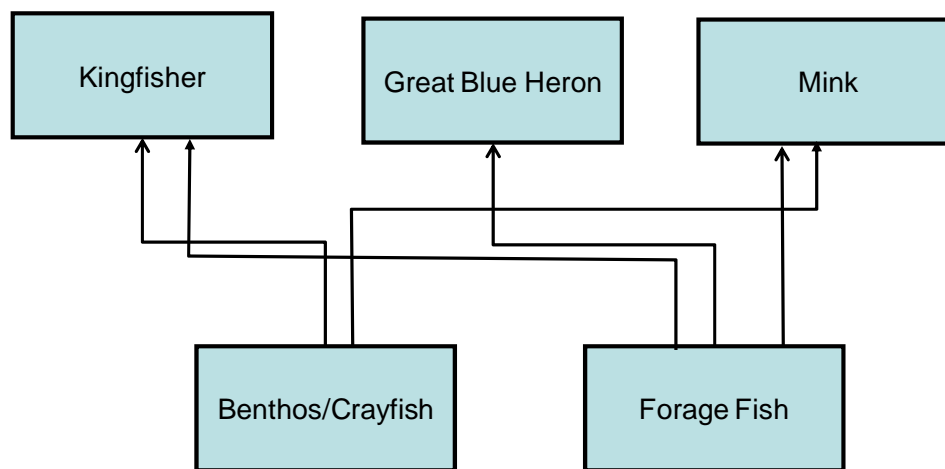
Great Blue Heron

The great blue heron is one of the largest wading birds found in upper New York State. It can stand over 4 ft high (average 42 to 52 in) with a wing span of 6 to 7 ft. It has a blue-gray color and adults are white about the head. Their long legs, necks, and bills are adapted for wading in the shallow water and stabbing prey. Fish are the preferred prey of great blue herons, but they also eat amphibians, reptiles, crustaceans, insects, birds, and mammals. Great blue herons have been observed throughout New York State, and have been observed in the study area (<http://www.guides.nynhp.org/guide.php?id=6752&part=3>; Ecology and Environment, 2007, p 7-47; Atlas 2000 website <http://www.dec.ny.gov/cfm/xtapps/bba/>). Body weight, ingestion rates, and dietary preferences for the heron were obtained from the US EPA Wildlife Exposure Factors Handbook (US EPA, 1993a and 1993b) and references contained therein.

Mink

The proposed mammalian receptor is the mink. The mink is a small carnivore that is widely distributed throughout New York State (<http://nyfalls.com/wildlife/Wildlife-mammals-weasel-like.html>) and is found throughout the study area as well (Ecology and Environment, 2007, p 7-47). Generally, mink are opportunistic in their feeding habits and prey varies according to seasonal abundance of prey and habitat. They feed on a variety of prey including fish, aquatic invertebrates, and small mammals. Their sensitivity to PCBs is well understood.

Figure 6: Conceptual Site Model for Eighteenmile Creek Terrestrial Foodweb



Further information on the feeding strategies and life histories of the selected species is provided in Appendix 10. The values used in the modeling are provided in Table 11.

3.4 Effects Assessment

This section provides a general overview of the toxicology of PCBs and describes the methods used to characterize particular toxicological effects of PCBs on aquatic and terrestrial organisms. TRVs are levels of exposure associated with either Lowest Observed Adverse Effects Levels (LOAELs) or No Observed Adverse Effects Levels (NOAELs). They provide a basis for judging the potential effects of measured or predicted exposures that are above or below these levels.

The toxicity of PCBs has been shown to manifest itself in many different ways, among various species of animals. Typical responses to PCB exposure in animals include wasting syndrome, hepatotoxicity, immunotoxicity, neurotoxicity, reproductive and developmental effects, gastrointestinal effects, respiratory effects, dermal toxicity, and mutagenic and carcinogenic effects. Some of these effects are manifested through endocrine disruption.

PCBs are typically present in the environment as complex mixtures. These mixtures consist of discrete PCB molecules that are individually referred to as PCB congeners. PCB congeners are often introduced into the environment as commercial mixtures known as Aroclors. PCB toxicity varies significantly among different congeners and is dependent on a number of factors. Two significant factors relate to the chemical structure of the PCB congener, including the degree of chlorination and the position of the chlorines on the biphenyl structure (Safe et al., 1985). In general, higher chlorine content typically results in higher toxicity, and PCB congeners that are chlorinated in the ortho position are typically less toxic than congeners chlorinated in the meta and para positions. Furthermore, metabolic activation is believed to be the major process contributing to PCB toxicity.

This ecological risk assessment focuses on effects that relate to the survival, growth, and reproduction of individuals within the local populations of fish and wildlife species. Reproductive effects are defined broadly herein to include egg maturation, spawning, egg hatchability, survival of fish larvae, and offspring survival.

Reproductive effects tend to be the most sensitive endpoint for animals exposed to PCBs. Indeed, toxicity studies in vertebrates indicate a relationship between PCB exposure, as demonstrated by aryl hydrocarbon hydroxylase (AHH) induction, and functions that are mediated by the endocrine system, such as reproductive success. A possible explanation for the relationship between AHH activity and reproductive success may be due to a potential interference from the P450-dependent MFO with the ability of this class of P450 proteins to regulate sex steroids. In fact, the induction of cytochrome P450 isozymes from PCB exposure has been shown to alter patterns of steroid metabolism (Spies et al., 1990). As another example, the maternal hepatic AHH activity of the flatfish, *Paralichthys stellatus*, at the time of spawning, was found to be inversely related to three reproductive functions: egg viability, fertilization success, and successful development from fertilization through hatching (Long and Buchman, 1990).

Historically, the most common approach for assessing the ecological impact of PCBs has involved estimating exposure and effects in terms of totals or Aroclor mixtures. It is important to note that, since different PCB congeners may be metabolized at different rates through various enzymatic mechanisms, when subjected to processes of environmental degradation and mixing, the identity of Aroclor mixtures is altered (McFarland and Clarke, 1989). Therefore, depending on the extent of breakdown, the environmental composition of PCBs may differ significantly from the original Aroclor mixture released into the environment. Furthermore, commercial Aroclor mixtures used in laboratory toxicity studies may not represent true environmental exposures. Thus, there are some unquantifiable uncertainties associated with estimating the ecological effects of PCBs using a combination of congener-based exposure data and Aroclor or “total PCB” based effects data (See Discussion in Section 4).

3.4.1 TRVs

TRVs can be developed on the basis of no-observed adverse effect levels (NOAELs) and lowest observed effect levels (LOAELs). These two alternative TRV values reflect the range of uncertainty that exists between the presence and absence of an adverse effect. If the HQ based on the NOAEL does not exceed a value of one, it is concluded that the chemical does not pose a hazard. If the HQ based on the LOAEL exceeds a value of one, it is expected that the chemical could pose a significant hazard. If the HQ based on the LOAEL is less than one but the HQ based on the NOAEL is greater than one, the chemical is probably close to a level that could cause adverse effects, but whether or not significant effects would actually occur cannot be judged with certainty. TRVs for the present risk assessments are developed on the basis of NOAELs and LOAELs to provide perspective on the range of potential effects relative to modeled exposures. TRVs used in this analysis are shown in Table 11.

Differences in the feeding behavior of aquatic and terrestrial organisms determine the type of toxicity endpoints used to assess risk. For example, the dose consumed in food is more easily measured for terrestrial animals than for aquatic organisms. For aquatic organisms, toxicity

endpoints are often expressed as concentrations in external media (e.g., water) or as accumulated concentrations in the tissue of the exposed organism (also called a “body burden”). In some studies, doses are administered via gavage, intraperitoneal injection into an adult, or injection into a fish or bird egg. If appropriate studies are available, TRVs for the present risk assessment are selected on the basis of the most likely route of exposure, as described below:

- TRVs for fish are expressed as critical body residues (e.g., mg/kg whole body weight and mg/kg lipid in eggs).
- TRVs for terrestrial receptors (e.g., birds and mammals) are expressed as daily dietary doses (e.g., mg/kg whole body wt/d).

TRVs for Fish

No laboratory studies were identified that examined toxicity of PCBs to the selected fish species. A low and high NOAEL and LOAEL were selected to provide perspective on the range of potential toxicity quotients based on three studies. A study by Bengtsson (1980) on the minnow is selected as the lowest appropriate NOAEL for development of the TRV. In this study, fish were exposed to Clophen 50 (a commercial mixture with a chlorine content of 50%) in food for 45 days. Hatchability was significantly reduced in fish with an average total PCB concentration of 170 mg/kg (measured on day 171 of the experiment), but not in fish with an average concentration of 15 mg/kg. Because the experimental study measured the actual concentration in fish tissue, rather than estimating the dose on the basis of the concentration in external media (e.g., food, water, or sediment, or injected dose), a subchronic-to-chronic uncertainty factor is not applied. Because results of studies of dioxin-like PCBs on fish eggs have shown another species of minnow to be of intermediate sensitivity compared to all other fish species tested, an interspecies uncertainty factor of 10 is applied to the LOAEL (170 mg/kg) and NOAEL (15 mg/kg) from this study to develop TRVs for fish.

A second study (Hansen et al., 1974) that exposed sheepshead minnow to Aroclor 1254 for 28 days developed a NOAEL of 1.9 mg/kg wet weight and a LOAEL of 9.3 mg/kg wet weight based on significantly reduced fry hatchability. This study is used to develop TRVs for the current assessment.

A study by the USACE (1988) was also selected for TRV development. In that study, spawning and fecundity was significantly reduced in fathead minnow (*Pimephales promelas*) exposed in the laboratory to sediments from Sheboygan Harbor in Wisconsin (exact mixture of PCBs unknown but an environmental mixture rather than a pure Aroclor). Because the experimental study measured the actual concentration in fish tissue, rather than estimating the dose on the basis of the concentration in external media (e.g., food, water, or sediment), a subchronic-to-chronic uncertainty factor is not applied. Effects were observed at 13.7 mg/kg wet weight (LOAEL), but not at 5.3 mg/kg wet weight (NOAEL) for total PCBs.

Finally, we developed TRVs using several field studies by Adams et al. (1989, 1990 and 1992) who evaluated the redbreast sunfish (*Lepomis auritus*), a species in the same family as the pumpkinseed and largemouth bass. The NOAEL for growth was reported as being significantly different from a one downstream location, but no comparison to the reference sites was provided.

Growth is a relevant endpoint, and the NOAEL for growth, 0.3 mg/kg, and the LOAEL for growth, 0.4 mg/kg, was used in this assessment based on total PCBs. A subchronic-to-chronic uncertainty factor is not applied because the experimental study measured the actual concentration in fish tissue, rather than estimating the dose on the basis of the concentration in external media.

Avian Receptors

No laboratory studies were identified that examined the toxicity of PCBs in the diet of either the kingfisher or the great blue heron or a bird in the same order. Following the methodology established by The Great Lakes Water Quality Initiative to develop wildlife criteria among studies that are similar (e.g., in exposure duration, etc.), preference is given to laboratory studies with wildlife species (USEPA, 1995). A study by Dahlgren et al. (1972) on the ring-necked pheasant is selected for development of TRVs since this study reports TRVs for a wildlife species and provides both a NOAEL and a LOAEL. In this study, egg production was significantly reduced in birds fed a dietary dose of 7.1 mg PCBs/kg/day, but was not reduced at a dose of 1.8 mg/kg/day over the course of 16 weeks. Egg production by hens fed PCBs at the LOAEL was 32-97% that of control hens. Because gallinaceous birds, such as the pheasant, are among the most sensitive of avian species to the effects of PCBs, an interspecies uncertainty factor is not applied. Because a hatching period is a short-term event by nature, a subchronic-to-chronic uncertainty factor is not applied.

Chapman (2003) developed recommended avian TRVs on behalf of US EPA Region 5 and these are within the range of the values selected here.

Mink

The TRVs for mink are based primarily on a study by Aulerich and Ringer (1977) which has been used as the basis for TRV development at numerous sites and for many studies (Hope 1999; Blankenship et al., 2008; Chapman 2003). In this study, mink were exposed by diet to several doses of Aroclor 1254 (0, 1, 5, 15 mg/kg in feed) for up to 130 d and a dose of 2 mg/kg for up to 298 d through a critical reproductive life stage. Conversions of concentrations in the diet to a daily dose were based on a normalized ingestion rate of 0.15 kg/kg/d (based on assumptions of a food consumption rate of 0.15 kg/d and a body weight of 1.0 kg). No adverse effects were observed on the number of kits per female at a dose level of 1 mg/kg in feed (or 0.15 mg PCB/kg/d). At this dose, the number of kits per female was 4.3, which was not a statistically significant difference compared to three different sets of controls in which the number of kits ranged from 4.1 to 6.0. At a dose of 2 mg/kg of Aroclor 1254 in feed (or 0.3mg PCB/kg/d), adverse effects were observed including a reduction in the number of kits per female. However, when Aroclors 1221, 1242, and 1016 (41 percent chlorine) were tested at dietary concentrations of 2 mg/kg (or 0.3 mg PCB/kg/d), no effects were observed on reproduction. Thus, since Aroclor 1254 was found to be more toxic than other Aroclors tested, the NOAEL and LOAEL values of 1 and 2mg PCB/kg (or 0.15 and 0.3 mg PCB/kg/d) of Aroclor 1254 in feed should be considered a conservative estimate of the NOAEL and LOAEL, respectively (Blankenship et al., 2008), and these values are appropriate for Aroclor 1248, as well, as studies have shown that Aroclor 1248 is just as toxic as Aroclor 1254 in an *in vitro* bioassay (Chapman 2003 citing Tillitt et al., 1992). Since the study considered dietary exposure during the sensitive and ecologically

relevant time period of reproduction, the 0.15 and 0.30 mg PCB/kg/d doses were considered to be chronic dietary-based NOAELs and LOAELs, respectively.

Chapman (2003) developed recommended mink TRVs on behalf of US EPA Region 5 based on a meta-analysis of several studies. He developed a recommended NOAEL of 0.5 mg/kg-d and a LOAEL of 0.6 mg/kg-d for environmental mixtures of PCB congeners based on total PCBs.

Table 11: Summary of Input Data to the *TrophicTrace* Model (dietary preference data found in Table 10)

Environmental	Units	Possible Low	Probable Low	Probable High	Possible High	Reference(s)
Total PCB Congeners Section 1	mg/kg dw	341	599	599	857	Data
TOC Section 1	%	1.23	1.61	1.61	1.98	Data
Dissolved Water Section 1	ng/L	80	80	80	80	Data
Total PCB Congeners Section 2	mg/kg dw	1971	2640	2640	3309	Data
TOC Section 2	%	3.79	4.51	4.51	5.23	Data
Dissolved Water Section 2	ng/L	100	100	100	100	Data
Temperature (both sections)	Deg C	15	18	20	22	Data
Log K _{ow}	L/kg	5.8	6	6.2	6.4	PCB Congeners
Benthic BSAF	unitless	1.0	1.0	1.7	1.7	USACE, 2008
Biota						
Benthic lipid	%	1.8	2.2	2.2	2.6	US EPA, 2000
Crayfish lipid	%	2.41	2.83	2.83	3.25	Lin et al. 2004; Gewurtz et al. 2000
Pelagic lipid	%	0.01	0.2	0.2	0.8	US EPA, 2000

PKSD lipid	%	2.0	2.4	2.4	2.8	Data
PKSD weight	gr	4.0	5.8	5.8	7.6	Data
PKSD TRV NOAEL	mg/kg ww	0.3	1.5	1.9	5.3	Adams et al. 1992; Bengtsson, 1980; Hansen et al. 1974; USACE, 1988
PKSD TRV LOAEL	mg/kg ww	0.4	9.3	13.7	17.0	Adams et al. 1992; Hansen et al. 1974; Bengtsson, 1980; USACE, 1988
BB lipid	%	2.4	3.1	3.1	3.7	Data
BB weight	gr	237	274	274	312	Data
BB TRV NOAEL	mg/kg ww	0.3	1.5	1.9	5.3	Adams et al. 1992; Bengtsson, 1980; Hansen et al. 1974; USACE, 1988
BB TRV LOAEL	mg/kg ww	0.4	9.3	13.7	17.0	Adams et al. 1992; Hansen et al. 1974; Bengtsson, 1980; USACE, 1988
LMB lipid	%	2.3	2.9	2.9	3.4	Data
LMB weight	Gr	515	601	601	686	Data
LMB TRV NOAEL	mg/kg ww	0.3	1.5	1.9	5.3	Adams et al. 1992; Bengtsson, 1980; Hansen et al. 1974; USACE, 1988
LMB TRV LOAEL	mg/kg ww	0.4	9.3	13.7	17.0	Adams et al. 1992; Hansen et al. 1974; Bengtsson, 1980; USACE, 1988
<i>Kingfisher</i>						
Weight	kg	0.14	0.15	0.15	0.16	US EPA 1993a; 1993b
Ingestion rate	kg/day	0.055	0.058	0.058	0.06	US EPA 1993a; 1993b
TRV (NOAEL)	mg/kg-d	0.6	0.6	1.8	1.8	Chapman 2003; Dahlgren et al. 1972
TRV(LOAEL)	mg/kg-d	1.2	1.2	7.1	7.1	Chapman, 2003; Dahlgren et al. 1972
<i>Great Blue Heron</i>						
Weight	kg	2.04	2.29	2.29	2.57	US EPA 1993a; 1993b
Ingestion rate	kg/day	0.28	0.35	0.35	0.43	US EPA 1993a; 1993b

TRV (NOAEL)	mg/kg-d	0.6	0.6	1.8	1.8	Chapman, 2003; Dahlgren et al. 1972
TRV (LOAEL)	mg/kg-d	1.2	1.2	7.1	7.1	Chapman, 2003; Dahlgren et al. 1972
<i>Mink</i>						
Weight	kg	0.55	0.83	1.02	1.36	US EPA 1993a; 1993b
Ingestion rate	kg/day	0.12	0.13	0.13	0.15	US EPA 1993a; 1993b
TRV (NOAEL)	mg/kg-d	0.04	0.15	0.15	0.5	Blankenship et al. 2008
TRV(LOAEL)	mg/kg-d	0.3	0.3	0.6	0.6	Hope, 1999; Blankenship et al. 2008; Chapman, 2003

3.5 Results and Ecological Risk Characterization

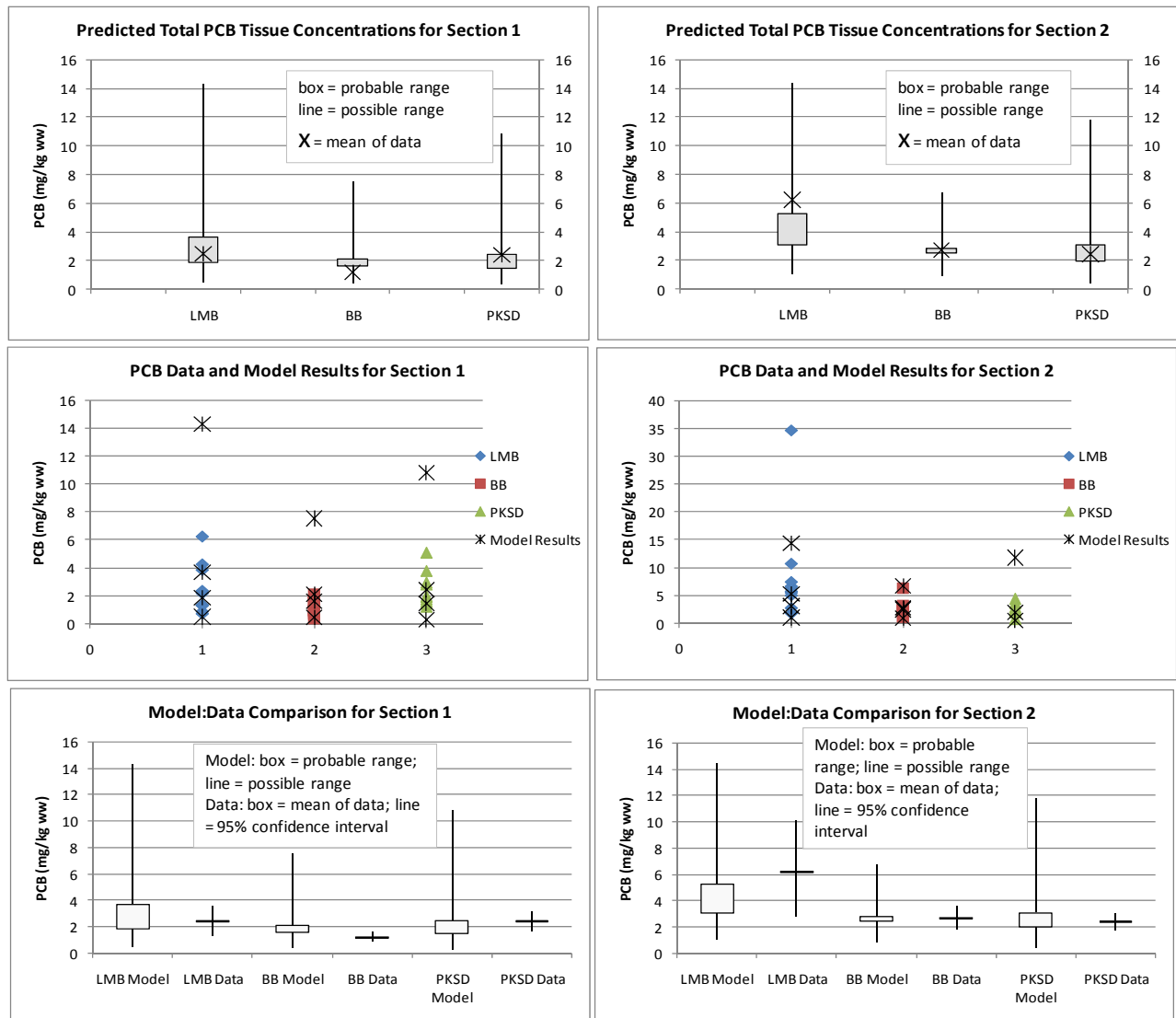
This section provides the results of the *TrophicTrace* modeling. The summary statistics for the contaminant concentrations of collected fish (Table 4) are used as the basis for comparing tissue concentrations predicted by the model. Below, we present the modeled tissue concentrations and comparisons to the empirical data. Finally, we present the predicted toxicity quotients resulting from comparisons of predicted doses (or body burdens) to receptors as compared to TRVs from the literature.

3.5.1 Predicted Tissue Concentrations

Figure 7 shows the results for the *TrophicTrace* bioaccumulation modeling using three different graphical formats for the same results. The top row of graphs shows the predicted tissue concentrations as compared to the mean of the data. The box represents the range of probable predicted concentrations; while the lines depict the range of possible (incorporating uncertainty) predicted concentrations. The possible and probable ranges are estimated by using ranges for input values. The second row of graphs shows the same results, but this time compared to individual data points. This graph shows that for Section 2, there is one LMB sample that is significantly higher than the remaining data set. The asterisks in this set of graphs represent the range of model output (the top and bottom asterisks represent the possible range, while the two center asterisks represent the probable range). Finally, the bottom row of graphs shows the model predictions as compared to the data using the same box format. In this set of graphs, the data are represented by the mean (center line) and the 95% confidence interval (lines).

These graphs show that the model predictions are well within the range of data, particularly for the most probable predicted range. As noted previously, the model predicts the expected average fish tissue contaminant concentration with associated uncertainty. Thus, the possible range reflects the uncertainty in the predicted mean, and is greater than the 95% confidence interval of the data itself. This is because the model reflects the underlying uncertainty in the model inputs rather than just the variability of the data.

Figure 7: Predicted Fish Tissue versus Observed Fish Tissue Concentrations. Top row: graphs show the predicted tissue concentration as compared to the mean of the data. The box represents the range of probable predicted concentrations, while the lines depict the range of possible predicted concentrations. The asterisk is the mean of the data. Second row: graphs show the same results, but individual data points are compared. Bottom row: model predictions are compared to empirical data using the same box format as the top row, but empirical fish data are represented by the mean (center line/box) and the 95% confidence interval of the mean (vertical lines).



3.5.2. Discussion on Model Performance and Implications

The *TrophicTrace* model was parameterized, run, and the results compared to the available data without going through an explicit calibration process. That is, we parameterized the model and compared the results to data, and having found an acceptable agreement between the predictions and data, we then used the predicted fish body burdens to estimate ecological TQs. Table 12 below shows the relative percent difference for the probable predicted range from the *TrophicTrace* model as compared to the mean value from the data. This table shows that for Section 1, *TrophicTrace* probable range (expected value) predicted body burdens were within less than 25% to greater than 1% of the data, a very close prediction. For brown bullhead, the model somewhat overpredicted observed tissue concentrations by between 15 and 27%, while for largemouth bass, the model predicted to within 13% less and 20% more than the mean value from the data.

In Section 2, the model predicted to within 10% less and 12% more than the data for pumpkinseed, while brown bullhead model performance was slightly better, predicting to within less than 5% and greater than 1% relative to the mean. The largemouth bass model somewhat underpredicted body burdens, but achieved a prediction within 8% of the mean value. Note that there is one largemouth bass sample that is considered, statistically, an outlier (although, of course, all data were included in the derivation of mean concentrations at the site). Overall, these results demonstrate excellent agreement with the data. In general, this is considered excellent performance for a food web model that required no explicit calibration to site data.

There are no known substantive differences in potential food web bioaccumulation dynamics between Sections 1 and 2; i.e., both areas are equally well predicted by the bioaccumulation model. This suggests that the environmental conditions that varied between sections (contaminant and TOC concentrations) accounted for the differences seen in fish tissue concentrations. Still, there are uncertainties associated with model parameterization (see Section 4). Reducing these uncertainties would provide confidence that model performance results from a refined relationship between sediments and fish, rather than an inspired selection of model parameters. Optimally, a further verification data set would be collected to verify the model's performance.

Table 12: Relative Percent Difference between Actual and Predicted Fish Tissue Concentrations

Relative Percent Difference	PKSD	BB	LMB
Section 1	-25% to 1%	15% to 27%	-13% to 20%
Section 2	-10% to 12%	-5% to 1%	-34% to -8%

3.5.3 Ecological Effects Risk Characterization

A toxicity quotient (TQ) is estimated as the ratio between the predicted contaminant concentration in an organism (for fish) and dose (for birds and mammals) and the literature-derived TRV. A predicted TQ is not an actual measure of risk, but simply a convenient method for indicating exceedance of a TRV (Hope 1999). TRVs can be based on NOAELs and/or

LOAELs. These alternative TRV values reflect the range of uncertainty that exists in the actual threshold between the presence and absence of an adverse effect. If the TQ based on the NOAEL does not exceed a value of one, it is concluded that the chemical does not pose a hazard (a conclusion of no significant risk [NSR]). If a TQ based on the LOAEL exceeds a value of one, it is expected that exposure could pose a hazard, that is, adverse effects cannot be ruled out. If the TQ based on the LOAEL is less than one but the TQ based on the NOAEL is greater than one, predicted exposures are probably close to levels that could cause adverse effects, but whether or not significant effects would actually occur cannot be judged with certainty. Therefore, the conclusion is that there is a low potential for risk.

The LOAEL-based comparison, by definition, reflects an exceedance of an effect level; therefore, potential risk of adverse effects is presumed to be directly proportional to the degree of exceedance of the LOAEL for the probable range with the following conclusions: no significant risk (NSR) for $TQ \leq 1$, low potential risk for $1 < TQ \leq 10$, moderate for $10 < TQ \leq 100$, and high for $TQ > 100$.

The probable range (box) of predicted TQs is used to determine the potential for adverse effects, while the possible range (line) is used to determine our confidence in that result. That is, a probable range less than one but a possible range greater than one indicates a lower degree of confidence in the results than if both the possible and probable ranges fall below one. TQs are estimated as the average expected TQ across the population -- for example, if we were to sample a random fish and measure the body burden, we would expect the result to fall in the probable range, but the result for any random fish could fall in the possible range as that reflects our uncertainty. Table 13 below provides the interpretation of the risk characterization results.

Table 13: Matrix of Interpretation of LOAEL- and NOAEL-based Exceedances for the Probable (Conclusion of Potential Risk) and Possible (Uncertainty) Ranges

Probable Range	Conclusion	<-- Confidence in Conclusion -->		
		Possible range upper $N \leq 1$	Possible range upper $1 < N \leq 10$	Possible range upper $10 < N \leq 100$
$N \leq 1$	No potential for exposures to exceed a NOAEL	High	Moderate	Low
$1 < N \leq 10$	Low potential for exposures to exceed a NOAEL	-----	High	Moderate
$10 < N \leq 100$	Moderate potential for exposures to exceed a NOAEL	-----	-----	High
$N > 100$	High potential for exposures to exceed a NOAEL	-----	-----	-----

Probable Range	Conclusion	Possible range upper $L \leq 1$	Possible range upper $1 < L \leq 10$	Possible range upper $10 < L \leq 100$
$L \leq 1$	NSR	High	Moderate	Low
$L \leq 1; N > 1$	Low potential risk	High	Moderate	Low
$1 < L \leq 10$	Low potential risk	-----	High	Moderate
$10 < L \leq 100$	Moderate potential risk	-----	-----	High
$L > 100$	High potential risk	-----	-----	-----

Figure 8 shows the results of the comparison of predicted daily doses and/or body burdens for the ecological receptors as compared to literature-derived TRVs. As for Figure 7, the box represents the probable range, while the lines represent the possible range incorporating uncertainty around the mean estimate (although the line does not, strictly speaking, represent a 95% confidence interval in statistical terms, it is analogous to that). The red line is the threshold value of one: results above this line indicate a potential for exposures (NOAEL-based comparison) and/or effects (LOAEL-based comparison). Table 13 presents these results in a tabular format.

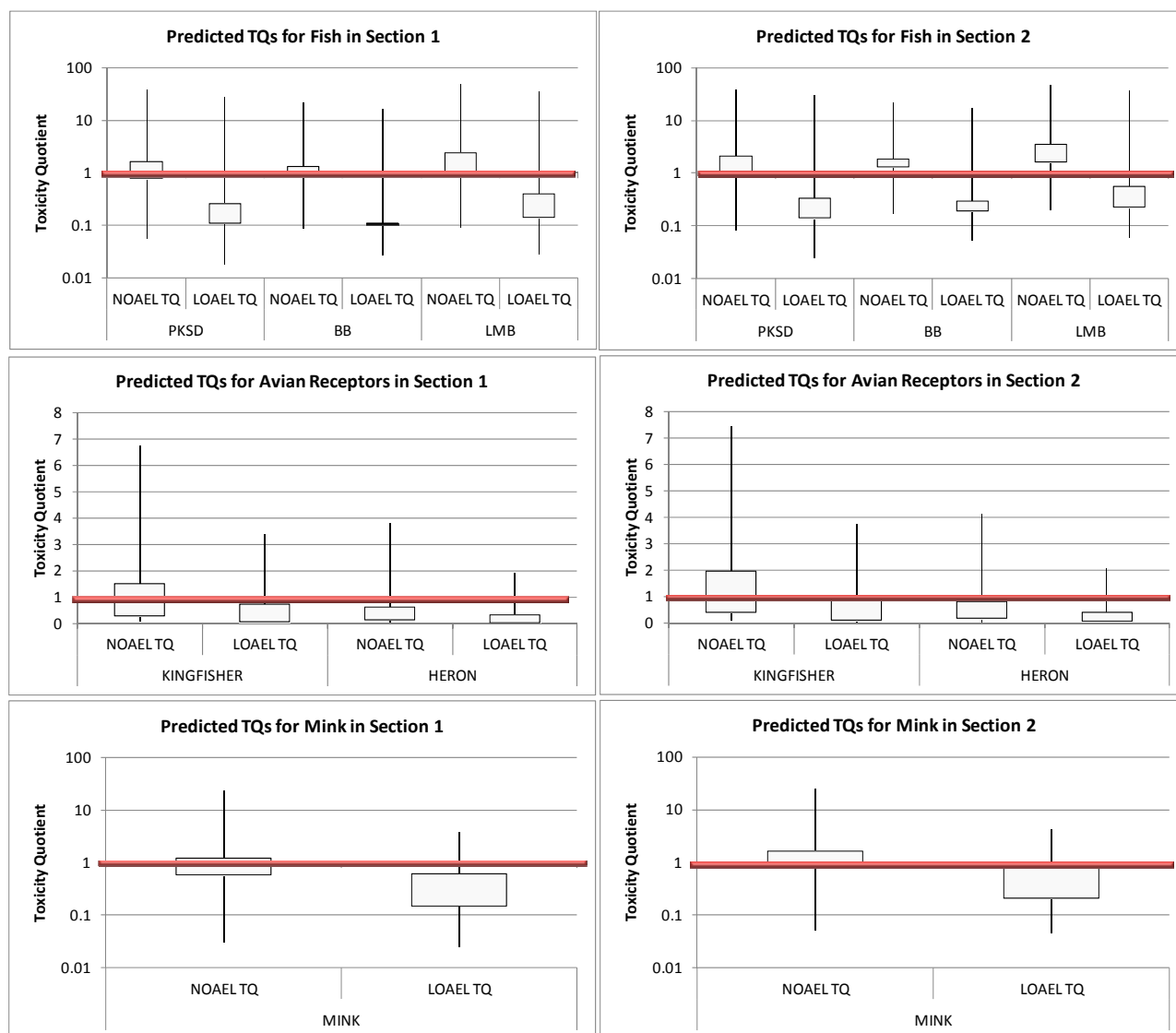
Results for Fish in Section 1

The probable range results for pumpkinseed, a forage fish that serves as a prey base for piscivorous fish, and largemouth bass, a top-level predator, show NOAEL-based comparisons between one and ten, but the LOAEL-based comparisons are all below one. Because the true effect level could theoretically occur at any exposure between the NOAEL and LOAEL, we conclude there is a low potential for risk. The possible upper bound for both the NOAEL- and LOAEL-based comparisons are greater than ten but less than 100, indicating moderate confidence in the results (i.e., there is moderate confidence in the conclusion of low potential for risk). For the brown bullhead, a demersal fish, both the LOAEL- and NOAEL-based comparisons for the probable range fall below one, indicating no potential for exposures to exceed a no-effect level and a conclusion of no significant risk. However, since the possible upper bound for both is greater than ten, we have low confidence in the conclusion of no significant risk (e.g., the body burden of a randomly selected fish could easily exceed either a NOAEL- or a LOAEL, and the potential for adverse effects cannot be ruled out).

Results for Fish in Section 2

In Section 2, there is a low potential for risk for all fish species given that the NOAEL-based comparisons for the probable range exceed one, but the LOAEL-based comparisons do not (indicating that effects could occur within that spectrum). The possible upper bounds exceed ten across species and endpoints, indicating moderate confidence in the conclusion that there is a low potential for risk.

Figure 8: Predicted Toxicity Quotients at Eighteenmile Creek



Results for Avian Receptors in Section 1

Kingfisher in Section 1 show a low potential for risk, since the NOAEL-based comparison for the probable range slightly exceeds one but the LOAEL-based comparison does not. The possible upper bound for both the NOAEL- and LOAEL-based comparisons are greater than one but less than ten, indicating a high confidence in this conclusion (i.e., the potential for risk across the population is low given that even the upper bound is less than ten although greater than one).

For the heron, both the NOAEL- and LOAEL-based comparisons for the probable range fall below one, indicating no potential for exposures to exceed no-effect levels and a conclusion of no significant risk. The possible range comparisons for both endpoints are greater than one but less than ten, indicating moderate confidence in the conclusion (i.e., exceedances cannot be ruled out).

Results for Avian Receptors in Section 2

Kingfisher in Section 2 show a low potential for risk, since the NOAEL-based comparison for the probable range exceeds one but the LOAEL-based comparison does not. The possible upper bound for both the NOAEL- and LOAEL-based comparisons are greater than one but less than ten, indicating a high confidence in this conclusion (i.e., the potential for risk across the population is low given that even the upper bound is less than ten although greater than one).

Table 14: Results of the Ecological Risk Assessment

<<---- Results for Section 1 ----->>										
	Low Possible Predicted TQ		Low Probable Predicted TQ		High Probable Predicted TQ		High Possible Predicted TQ		Conclusion	Confidence
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL		
PKSD	0.1	0.02	0.8	0.1	2	0.3	36	27	Low potential risk	Moderate
BB	0.1	0.03	0.8	0.1	1.3	0.1	21	16	Low potential risk	Moderate
LMB	0.1	0.03	0.99	0.1	2	0.4	48	36	Low potential risk	Moderate
Kingfisher	0.1	0.02	0.3	0.1	1.5	0.7	7	3	Low potential risk	Moderate
Heron	0.02	0.005	0.1	0.03	0.6	0.3	4	2	No potential for exposures to exceed NOAELs; NSR	Moderate
Mink	0.03	0.03	0.6	0.2	1.2	0.6	23	4	Low potential risk	Moderate to High
<<---- Results for Section 2 ----->>										
	Low Possible Predicted TQ		Low Probable Predicted TQ		High Probable Predicted TQ		High Possible Predicted TQ		Conclusion	Confidence
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL		
PKSD	0.1	0.03	1.0	0.1	2	0.3	39	30	Low potential risk	Moderate
BB	0.2	0.1	1.3	0.2	2	0.3	22	17	Low potential risk	Moderate
LMB	0.2	0.1	2	0.2	4	0.6	48	36	Low potential risk	Moderate
Kingfisher	0.1	0.03	0.4	0.1	2	1.0	7	4	Low potential risk	High
Heron	0.03	0.01	0.2	0.04	0.8	0.4	4	2	No potential for exposures to exceed NOAELs; NSR	Moderate
Mink	0.05	0.04	0.8	0.2	2	0.8	26	4	Low potential risk	Moderate to High

For the heron, both the NOAEL- and LOAEL-based comparisons for the probable range fall below one, indicating no potential for exposures to exceed no-effect levels and a conclusion of no significant risk. The possible range comparisons for both endpoints are greater than one but less than ten, indicating moderate confidence in the conclusion (i.e., exceedances cannot be ruled out).

Results for Mink in Section 1

The results for mink in Section 1 indicate a low potential for risk, since the NOAEL-based comparison for the probable range exceeds one but the LOAEL-based comparison does not. The possible upper bound for the NOAEL-based comparison is greater than ten, indicating high confidence that the NOAEL-based comparison is likely greater than one. The possible upper bound for the LOAEL-based comparison is greater than one but less than ten, indicating moderate confidence in the conclusion of low potential risk.

Results for Mink in Section 2

The results for mink in Section 2 indicate a low potential for risk, since the NOAEL-based comparison for the probable range exceeds one but the LOAEL-based comparison does not. The possible upper bound for the NOAEL-based comparison is greater than ten, indicating high confidence that the NOAEL-based comparison is likely greater than one. The possible upper

bound for the LOAEL-based comparison is greater than one but less than ten, indicating moderate confidence in the conclusion of low potential risk.

3.5.4 Discussion of Ecological Effects Results

For fish, the NOAEL- and LOAEL-based comparisons across the probable and possible ranges indicate that the body burdens of fish from either creek section could exceed a NOAEL or a LOAEL. Although the probable range for the LOAEL-based comparisons all fall below one, the NOAEL-based comparisons for pumpkinseed and largemouth bass are greater than one, and the possible ranges are not only greater than one, but greater than ten. Indeed, looking at the data collected for this study, we did observe one largemouth bass sample of approximately 35 mg/kg, twice the highest observed LOAEL for this species (17 mg/kg), and over two orders of magnitude higher than the lowest observed LOAEL (0.4 mg/kg), confirming that it is possible for a randomly collected fish to have a predicted LOAEL-based TQ greater than ten.

Avian receptors show less of a range in the results. Even the highest predicted TQs for the possible range are less than ten. The probable range only exceeds one for the kingfisher and is less than one for the heron. Taken together, we conclude there is a low potential for risk to kingfisher and a negligible potential for risk to the heron.

For mink, there is a wide range in NOAEL-based TRVs. When predicted doses are compared to these TRVs, the result is that for the most part, comparisons fall below one or are between one and ten, except for the highest possible NOAEL-based comparison, which is greater than ten across both Sections of the study area. We therefore conclude there is a low potential for risk to mink foraging across the study area. This conclusion also includes a consideration of the actual TRVs, which, as shown in Table 11, show an overlap between LOAELs and NOAELs. That is, the highest NOAEL (0.5 mg/kg-d) is higher than the lowest LOAEL of 0.3 mg/kg-d. Both studies are reasonable, well-conducted, and explored endpoints relevant to reproduction.

The modeling approach developed here is termed a “bottom-up” study. Another approach, termed “top-down,” involves collecting field observations that may indicate impacts from exposures within the study area, and these studies could be used as additional lines of evidence with which to evaluate the conclusions of the modeling study. These include efforts such as wildlife studies, benthic invertebrate community studies and population analyses.

The 2008 bioaccumulation study on Eighteenmile Creek AOC sediments (USACE Buffalo District 2008) found that PCBs are accumulating in invertebrates. That report also indicated that several samples exceeded the probable effect level (PEL) in sediments developed by Environment Canada (2003) of 277 µg/kg Total PCBs. The current dataset indicate that sediment concentrations on a mean basis, including the lower 5% confidence limit on the mean, all exceed this value as well. Further, based on empirical data from laboratory bioaccumulation experiments on field collected sediments, USACE Buffalo District (2008) indicated that PCBs in surficial sediments throughout most of the AOC (Section 1 below Burt Dam) PCBs in surface sediments are “bioaccumulating in benthic invertebrates, and are likely to bioaccumulate in predator fish and higher trophic levels”. The results of this study are generally in concert with that finding.

4.0 DISCUSSION OF UNCERTAINTY

The modeling presented here is based on the best available information and data collected up to this point. The model reflects our understanding of the relationship between sediment (and nominally water) contaminant exposure concentrations and fish body burdens on the basis of one sampling event. Consequently, uncertainties remain that are briefly described in this section.

4.1 Surface Water Dissolved-phase Contaminant Concentrations

There is only one dissolved phase water PCB concentration available within the study area to support the model's depiction of freely dissolved PCBs in surface water. Soluble contaminants are an important pathway for contaminant uptake and bioaccumulation in aquatic organisms. One option to estimate this parameter is to predict water concentrations from sediment concentrations based on equilibrium partitioning theory. Alternatively, synoptic water sampling can be conducted to empirically derive an average exposure concentration over a relevant timeframe. In our case, only a single empirical data point was available. This is suboptimal and creates uncertainty in the depiction of soluble contaminants and estimation of fish tissue contaminant concentrations.

4.2 Contaminant Concentrations at the Base of the Food Web

The stomach contents analyses conducted as part of this effort revealed that largemouth bass, in particular, consume a higher than anticipated amount of crayfish. Site-specific contaminant data do not exist for crayfish, so this part of the model utilized literature values for lipid content, and predicted crayfish concentrations were never verified by field data. Similarly, benthic and pelagic invertebrate inputs were all based on literature values. Such information could be relatively easily obtained from a collection and analysis effort.

4.3 Fish Foraging Strategies and Dietary Exposure

The two primary factors influencing contaminant uptake into fish tissue are exposure concentrations and fish foraging strategies. Fish body burdens reflect both what fish consume (which will vary seasonally according to prey and bioamass availability) and may vary spatially depending on their movements and exposure history. Fish integrate exposures over particular spatial and temporal scales, and these are assumed rather than known. For example, the model assumes essentially equal exposures within each section as reflected by the mean and 95% confidence limit on the mean used as inputs to the model. If there was evidence of preferential foraging within a section, these exposure estimates could be refined. This uncertainty is not readily informed without, for example, fish tracking studies. However, those studies are resource intensive and still may not provide information capable of refining the understanding of bioaccumulation from contaminated sediments.

Similarly, dietary preferences of the fish also represent an uncertainty. Although stomach content analysis was conducted on the fish sampled during Fall 2010, that represents one snapshot in time and does not address seasonality in feeding and potential spatial differences in

feeding. A more refined understanding of diet (and hence dietary exposures of contaminants) during the course of the year could be developed from additional sampling during the spring and summer periods. Such information could be relatively easily obtained from a collection and analysis effort.

4.4 Terrestrial Receptor Foraging Strategies and Dietary Exposures

All exposure parameters used for terrestrial receptors in this analysis (e.g., kingfisher, great blue heron, and mink body weight, ingestion rate, and dietary preferences) were obtained from the literature as referenced in the US EPA Wildlife Exposure Factors Handbook (US EPA 1993a; 1993b). Although the uncertainty in these estimates was captured to some extent through the use of ranges as inputs rather than deterministic values, there is still uncertainty as to the composition of these diets.

4.5 Toxicity Reference Values

There is significant uncertainty inherent in the TRVs that are used in the analysis to predict risk. This is due to several factors, including:

- *Use of laboratory versus field studies.* In general, TRVs developed from laboratory studies are used because the exposure of concern can be isolated in the species of concern. However, this introduces uncertainty given that environmental conditions and contaminant exposures differ significantly between the laboratory and field environments.
- *Use of Aroclor TRVs.* As mentioned above, PCB congener composition differed across commercial mixtures of aroclors. Then these aroclors were released into the environment and underwent environmental processes that differed from site to site. Consequently, PCB mixtures in the laboratory used to develop TRVs can vary greatly from those found in the environment.
- *Attribution of effects related to cooccurring contaminants (and/or other stressors) in field studies.* While field studies better represent exposure to environmentally weathered PCBs, there may or may not be cooccurring unmeasured contaminants responsible for observed effects. One way to reduce this uncertainty is to use field-collected sediments in a laboratory setting, although it is difficult to measure all possible contaminants and to develop statistically robust models based on large numbers of potential predictors.
- *Species differences in effects studies (e.g., pheasant, chicken, etc.).* Often, TRV studies are conducted on reference species (e.g., chicken, pheasant) or TRVs are based on field studies that of necessity focus on the key receptors at those locations (e.g., falcon) that may or may not adequately represent species at other areas.

TRVs can reflect no- observed adverse effect levels or lowest-observed adverse effect levels, and both are used in this report. However, it is possible, particularly when values are taken from across the published literature and are not from the same study, for NOAELs to exceed LOAELs, and this is the case here. This reflects the very real and true uncertainty in those values -- a NOAEL from one study could exceed a LOAEL from another study, yet both are from well-designed studies and reflect endpoints relevant to the population.

5.0 REFERENCES

- Adams SM, Crumby WD, Greeley Jr MS, Ryon MG and EM Schilling. 1992. Relationships between physiological and fish population responses in a contaminated stream. *Env Tox Chem* 11:1549-1557.
- Adams SM, Shepard KL, Greeley Jr MS, Jimenez BD, Ryon MG, Shugart LR and JF McCarthy. 1989. The use of bioindicators for assessing the effects of pollutant stress on fish. *Marine Env Res* 28:459-464.
- Adams SM, Shugart LR, Southworth GR and DE Hinton. 1990. Application of bioindicators in assessing the health of fish populations experiencing contaminant stress. In: J.F. McCarthy and L.R. Shugart, eds., *Biomarkers of Environmental Contamination*. Lewis Publishers, Boca Raton, FL. Pp. 333-353.
- Aulerich RJ and R Ringer. 1977. Current status of PCB toxicity in mink and effect on their reproduction. *Arch. Environ. Contam. Toxicol.* 6:279-292.
- Bardossy A and Duckstein L. 1995. Fuzzy rule-based modeling in geophysical, economic, biological, and engineering systems. Boca Raton, FL: CRC Press.
- Bengtsson BE. 1980. Long-term effects of PCB (Clophen A50) on growth, reproduction and swimming performance in the minnow, *Phoxinus phoxinus*. *Water Research*, Vol. 1, pp. 681-687.
- Blankenship AL, Kaya DP, Zwiernik MJ, Holem RR, Newsted JL, Hecker M and JP Giesy. 2008. Toxicity reference values for mink exposed to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) equivalents (TEQs). *Ecotox Env Saf* 69:325-349.
- Chapman, J. 2003. EPA Region 5 recommended mink and avian toxicity reference values. Memorandum and Appendix D. March 6, 2003.
- CH2MHill. 2011. Data Summary Report. Site Characterization. Eighteenmile Creek Area of Concern. Niagara County, New York. March 2011.
- Dahlgren RB, Linder RL and Carlson CW. 1972. Polychlorinated biphenyls: Their effects on penned pheasants. *Env Health Perspect* 1:89-101.
- Dou C, Woldt W, Bogardi I and Dahab M. 1995. Steady-state groundwater flow simulation with imprecise parameters. *Water Resources Research* 31(11):2709-2719.
- Ecology and Environment, Inc. 2007. Eighteenmile Creek State of the Basin Report.
- Ecology and Environment, Inc. 2008. Draft Beneficial Use Impairment Investigation for Eighteenmile Creek, Niagara County, New York.

Eddy S and Surber T. 1947. Northern Fishes: With Special Reference to the Upper Mississippi Valley. The University of Minnesota Press. Minneapolis, MN.

Environment Canada. 2003. Canadian Environmental Quality Guidelines.
http://www.ccme.ca/assets/pdf/e1_062.pdf

Garabedian B, Estabrooks F, Swart J, Bopp RF. 2001. Final Report, Eighteenmile Creek Sediment Study: Summary of August 17-20 and November 3, 1998 Results. NYSDEC, Division of Water, December 2001.

Gewurtz SB, Lazar R and Haffner D. 2000. Comparison of polycyclic aromatic hydrocarbon and polychlorinated biphenyl dynamics in benthic invertebrates of Lake Erie, USA. *Env Tox Chem* 19(12):2943–2950.

Gobas F. 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: Application to Lake Ontario. *Ecological Modeling* 69(1-2):1-17.

Gustavson KE, von Stackelberg T, Linkov I, Bridges, T. 2011. *Bioaccumulation models: State of the application at large Superfund sites*. DOER Technical Notes Collection. ERDC TN-DOER-R17. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Guyonnet D, Côme B, Perrochet P and Parriaux A. 1999. Comparing two methods for addressing uncertainty in risk assessments. *Journal of Environmental Engineering* 7:660-666.

Hammonds JS, Hoffman FO and Bartell SM. 1994. An introductory guide to uncertainty analysis in environmental and health risk assessment. Environmental Restoration Program, Oak Ridge National Laboratory. ES/ER/TM-35/RI.

Hansen DJ, Schimmel SC and E Matthews. 1974. Avoidance of Aroclor 1254 by shrimp and fishes. *Bull Environ Contam Toxicol* 12(2):253-293.

Hope BK. 1999. Assessment of risk to terrestrial receptors using uncertain analysis—A case Study. *Hum. Ecol. Risk Assess.* 5(1):145-170.

Huang GH, Chen Z, Tontiwachwuthikul P, Chakma A. 1999. Environmental risk assessment for underground storage tanks through an interval parameter fuzzy relation analysis approach. *Energy Sources*, 21(1-2):75-96.

Karn R, Escalon L, Lotufo G. 2004. Sediment Sampling, Biological Analyses, and Chemical Analyses for Eighteenmile Creek AOC, Olcott, New York. Vol I-II. US Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory, March.

Lee YW, Dahab MF, Bogardi I. 1994. Nitrate risk assessment using fuzzy set approach. *Journal of Environmental Engineering* 121(3):245-256.

Lin H-I, Berzins DW, Myers L, George WJ, Abdfelghani A and Watanabe KH. 2000. Bayesian approach to parameter estimation for a crayfish (*Procambarus Spp.*) bioaccumulation model. *Env Tox Chem* 23(9):2259-2266.

Long ER and Buchman MF. 1990. A comparative evaluation of selected measures of biological effects of exposure of marine organisms to toxic chemicals. In: *Biomarkers of Environmental Contamination*. Pp 355-394. J.F. McCarthy, and L.R. Shugart, Editros. Lewis Publishers. Boca Raton, FL.

McFarland VA and Clarke JU. 1989. Environmental occurrence, abundance and potential toxicity of polychlorinated biphenyl congeners: considerations for a congener-specific analysis. *Environ Health Perspect* 81:225-239.

Mittelbach GG. 1984. Predation and resource partitioning in two sunfishes (Centrarchidae). *Ecology* 65(2):499-513.

Niagara County Soil and Water Conservation District. 2007. Eighteenmile Creek Remedial Action Plan (RAP) 2006 Status Report. March 2007. Available at: <http://www.eighteenmilerap.com/2006%20Status%20Report%20%28Final%29.pdf>.

New York State Department of Environmental Conservation (NYSDEC). 1997. Eighteenmile Creek Remedial Action Plan. August 1997.

NYSDOH. 2009. Chemicals in Sportfish and Game: 2009-2010 Health Advisories. <http://www.health.state.ny.us/environmental/outdoors/fish/docs/fish.pdf>

Peterson, R.T. 1980. *A Field Guide to the Birds East of the Rockies*. Fourth Edition. Houghton Mifflin Company. Boston, MA. 384 pp.

Safe S, Bandiera S, Sawyer T, Robertson L, Safe L, Parkinson A, Thomas PE, Ryan DE, Reik LM, Levin W, Denomme MA and Fujita T. 1985. PCBs: structure – function relationships and mechanisms of action. *Env Health Perspect* 60: 47-56.

Spies RB, Stegeman JJ, Rice DW, Woodlin B, Thomas P, Hose JE, Cross JN and Prieto M. 1990. Sublethal responses of *Platichthys stellatus* to organic contamination in San Francisco Bay with emphasis on reproduction in biomarkers of environmental contamination. pp. 87-121. J.F. McCarthy and L.R. Shugart, Editors. Lewis Publishers. Boca Raton, FL.

Tillitt D, Ankley G, Giesy J, Ludwig J, Kurita-Matsuba H, Weseloh D, Ross P, Bishop C, Sileo L, Stromborg K, Larson J and Kubiak T. 1992. Polychlorinated biphenyl residues and egg mortality in doublecrested cormorants from the Great Lakes. *Environ Toxicol Chem* 11:1281-1288.

US Army Corps of Engineers (ACE) Waterways Experiment Station. 1988. Environmental Effects of Dredging Technical Notes. No. EEDP-01-13. Relationship Between PCB Tissue Residues and Reproductive Success of Fathead Minnows. April 1988.

US Army Corps of Engineers, Buffalo District. 2008. Concentrations, Bioaccumulation and Bioavailability of Contaminants in Surface Sediment. Eighteenmile Creek, Great Lakes Area of Concern (AOC), Niagara County, New York, June.

United States Environmental Protection Agency (USEPA). 1995. Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife. Office of Water, Washington, DC. EPA/820/B-95/008. March, 1995.

United States Environmental Protection Agency (USEPA). 2000. Phase 2 Report: Further Site Characterization and Analysis, Volume 2D – Revised Baseline Modeling Report, Hudson River PCBs Reassessment RI/FS. Prepared by TAMS Consultants, Inc., Limno-Tech, Inc., Menzie-Cura, Inc. and Tetra Tech, Inc. Available from www.epa.gov/hudson click on “reassessment reports.”

United States Environmental Protection Agency (USEPA). 1993a. Wildlife Exposure Factors Handbook. Volume I of II. USEPA Office of Research and Development. Washington, D.C. EPA/600/R-93/187a.

United States Environmental Protection Agency (USEPA). 1993b. Wildlife Exposure Factors Handbook. Volume II of II. USEPA Office of Research and Development. Washington, D.C. EPA/600/R-93/187b.

United States Geological Survey (USGS). 1971-2008. Online electronic data. URLs (accessed 22 Jan 2010):

http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=04219767

http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=04219765

Zadeh LA. 1965. Fuzzy Sets. *Inform. and Control*, 8:338-353.

Zevin. P. 2011. Field Data Report Lake Ontario Tributaries 2009-2010. Dated March 28, 2011.

Zimmermann HJ. 1991. Fuzzy Set Theory and its Application. Boston: 2nd Edition, Kluwer Academic Publisher.

APPENDIX 1
FIELD SAMPLING PLAN
FISH COLLECTION

FIELD PROCEDURES: FISH COLLECTION

Field Sampling Plan: Eighteen Mile Creek Fish Collection for Tissue Contaminant Analysis

Introduction. Fish and Wildlife Service (FWS) Lower Great Lakes Fish & Wildlife Conservation Office will be collecting fish from Eighteenmile Creek between Olcott and Newfane, NY for analysis polychlorinated biphenyls at the Army Engineer Research and Development Center (ERDC) Environmental Chemistry Branch. Contaminant levels in fish tissue will be used to calibrate a foodweb bioaccumulation model being developed on Eighteenmile Creek.

Location. Fish will be sampled from two areas in Eighteenmile Creek: below Burt Dam to Olcott Harbor at Lake Ontario and above Burt Dam to the Newfane Dam. The objective will be to collect fish from each of the three reaches of each area (See Figure 1) to achieve fish collection targets (Table 1) for the collection area.

Fish Collection Targets. Three species of fish are targeted for collection: largemouth bass, brown bullhead, and pumpkinseed. The size ranges of the fish are intended to narrow the year class of fish that will be included in the data sets, with those species/sizes being representative of a trophic niche (largemouth bass, piscivores; brown bullhead, bottom feeding; and pumpkinseeds, planktivores). Table 1 describes the targeted species, number of fish, and size ranges.

Table 1. Summary of fish collection targets for fish collection areas 1 and 2.

Fish species	Targeted number of individuals per area (contingency)	Acceptable size range (contingency)	Comments
Largemouth Bass	10 per area with 3 or 4 fish in each of the reaches (min 8)	11-14 inches (10-15 inches)	Size range represents approximately 3 yr classes of adult fish at a size where fish are a major dietary component [1].
Brown Bullhead	10 per area with 3 or 4 fish in each of the reaches (min 8)	6-10 inches (include black or yellow bullhead, all spp. 5-11 inches)	Size range represents bottom feeding fish with a diet of benthic invertebrates. a similar age with primary macroinvertebrates [2].
Pumpkinseed	10 composites of 5 per area with 3 or 4 composites in each of the reaches (5 composites of 5)	<4inches (Include other <i>Lepomis</i> spp.)	Size range represents young-of-the-year or Year 1 fish that would be feeding primarily on zooplankton and serve as food for higher predators [3].

Fish Collection Contingencies. If targeted numbers and sizes of fish can't be achieved, the following contingencies, in this order, are acceptable (shown in parentheses).

- 1) Collect target number of fish from fewer reaches (i.e., if no fish are captured in one reach, collect the entire target number from the other reaches).
- 2) Expand acceptable size range or, for pumpkinseed, expand to similar species
- 3) Decreased target sample number

FIELD PROCEDURES: FISH COLLECTION

4) Expansion to alternate species and size ranges (Table 2). If this contingency is pursued, any sampled primary species will be retained and secondary species and sizes will be sampled to achieve the targeted number.

Table 2. Summary of alternate fish collection targets.

Fish species	Targeted number of individuals per area (contingency)	Acceptable size range (contingency)
<i>Alternate:</i> Smallmouth Bass	10 (min 8)	11-14 inches (10-15 inches)
<i>Alternate:</i> Carp	10 (min 8)	6-10 inches (5-11 inches)
<i>Alternate:</i> Year-round resident minnow species	5 composite samples of 10 g tissue (5composites of 5)	None specified

Collection equipment. Fish will be collected using a 12 ft. jon boat equipped with a gas powered generator and a Smith-Root GPP Portable Electrofishing unit. Electrofishing will be conducted along one shore or divided between both shores within a reach until the desired number of targeted fish are collected. Fish will be measured for total length and processed for shipping as described below.

Fish Collection Record. The sampling date, time, and coordinates of the starting point, ending point, and turning points of each fishing run will be recorded in the Fish Collection Record form (Appendix A). Fish collected during each sampling run should be recorded in that form. If possible, the coordinates of the location of each fish should be recorded.

Fish Processing and Packaging. Collected fish should be processed to determine species, length, and weight and recorded in the Fish Collection Record (Appendix A). Each fish should be individually wrapped in extra heavy duty aluminum foil; pumpkinseed collected within a reach of an area can be wrapped together. Spines on fish should be sheared to minimize punctures in the aluminum foil packaging. The sample identification label shown below should be taped to the outside of each aluminum foil package, each individual fish should be placed into a waterproof plastic bag and sealed. All of the packaged individual specimens in a composite sample should be kept together (if possible) in one large waterproof plastic bag in the same shipping container (ice chest) for transport. Once packaged, samples should be cooled on ice or blue ice immediately. Following each day of collection, fish will be brought back to the US Fish and Wildlife Service, Lower Great Lakes Fish & Wildlife Conservation Office and frozen in preparation for shipping.

Labeling. Jaw tags will be attached to individual fish. The following convention will be used for labeling.

Site-	Area	Reach-	Species	# of that species collected in the area
18	A1/A2	R1/R2/R3	LMB/BB/PKN	e.g., 1-10

For example, 18-A1R1-LMB3, would be the third largemouth bass collected in reach 1 of area 1 of Eighteenmile Creek.

FIELD PROCEDURES: FISH COLLECTION

Species		Sampling Site (Area and Reach)	
# of individuals, if composite		Collection Point Coordinates (if avail.)	
Length (list individuals if composite)		Weight (list individuals if composite)	
Specimen ID _ _ _ _ _		Sampling Date (MMDDYYYY)	
		Time (24h clock)	

Shipping

Fish packages will be shipped on gel-pack ice or double bagged water ice via overnight carrier to the ERDC analytical lab using the following information: FedEx account number: 239971342; Internal Reference number (PRC number): 00820280. Both the account number and the internal reference number will need to go on the shipping form.

The ship to address is:

USACE ERDC EP-C
ATTN: Patty Tuminello
3909 Halls Ferry Road
Vicksburg, MS 39180
601-634-4826

Chain of custody will be documented per Appendix B.

Notes on fish size rationale:

[1] Ontario avg: 3 yr, 11.3 in; 4 yr, 12.6 in; 5 yr, 13.7 in; 6 yr, 15.4 in. "Ontario [growth] does not fall behind that of the northern United States". Above 3 yrs, 50-90% of diet is fish; 10-40% is crayfish. (Scott and Crossman 1973).

[2] First year of growth, up to 4.8 in; 2 yr, 6 in; 3 yr, 7.6 in; 4 yr, 9.5 in; 5 yr, 10.5 in (Little Lake Butte des Morts, WI; Priegel, 1969 in Scott and Crossman 1973). Diet seems to be dictated by availability, benthic macroinvertebrates are a major portion. Pearse (1918) found aquatic insects to consist primarily of aquatic macroinvertebrates, but small fish (<3 in ave) were examined. However, 5 in (ave) black bullheads were also primarily fed on benthic macroinvertebrates.

FIELD PROCEDURES: FISH COLLECTION

[3] Young-of-year and Year 1 fish were less than 4.2 inches in various Ontario Lakes (Scott and Crossman 1973).

References:

Scott WB, Crossman EJ. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin.

Pearse AS. 1918. The Food of the Shore Fishes of Certain Wisconsin Lakes. Bulletin of the Bureau of Fisheries Volume XXXV, Document No. 856. Pp. 249-292.

FIELD PROCEDURES: FISH COLLECTION

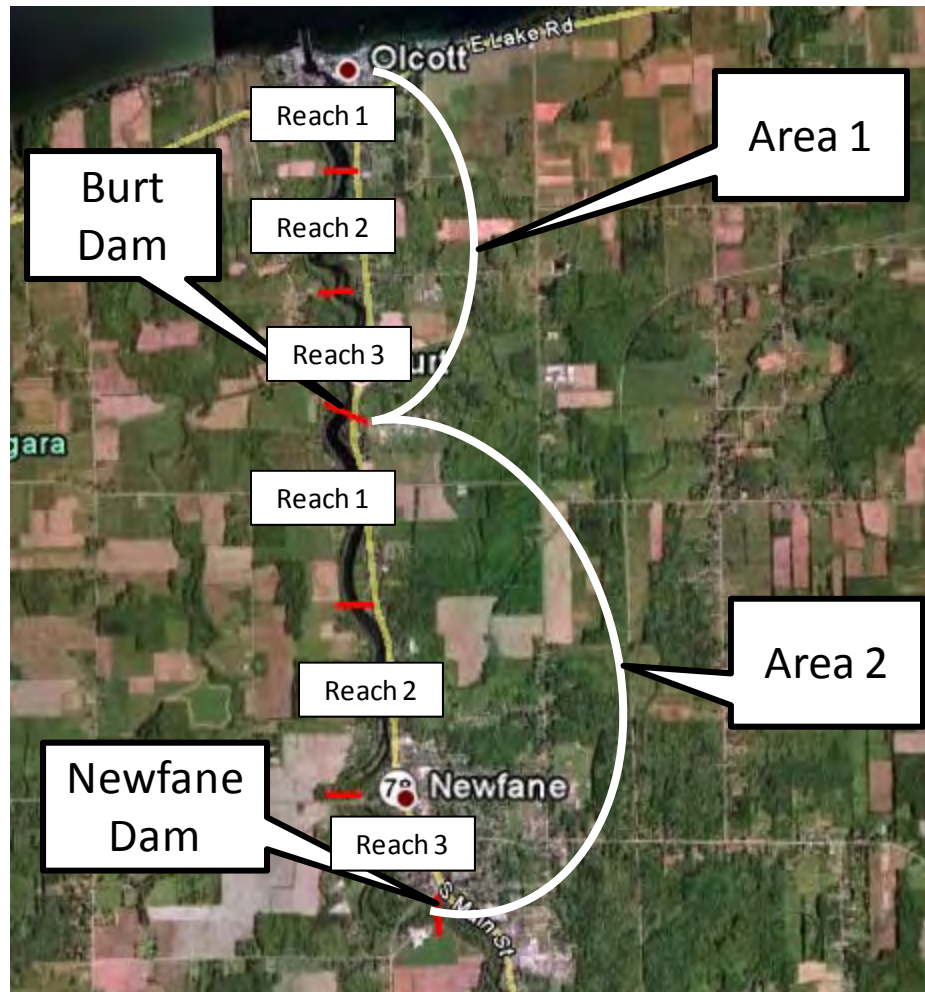


Figure 1: Eighteenmile Creek Sampling Area Overview

FIELD PROCEDURES: FISH COLLECTION

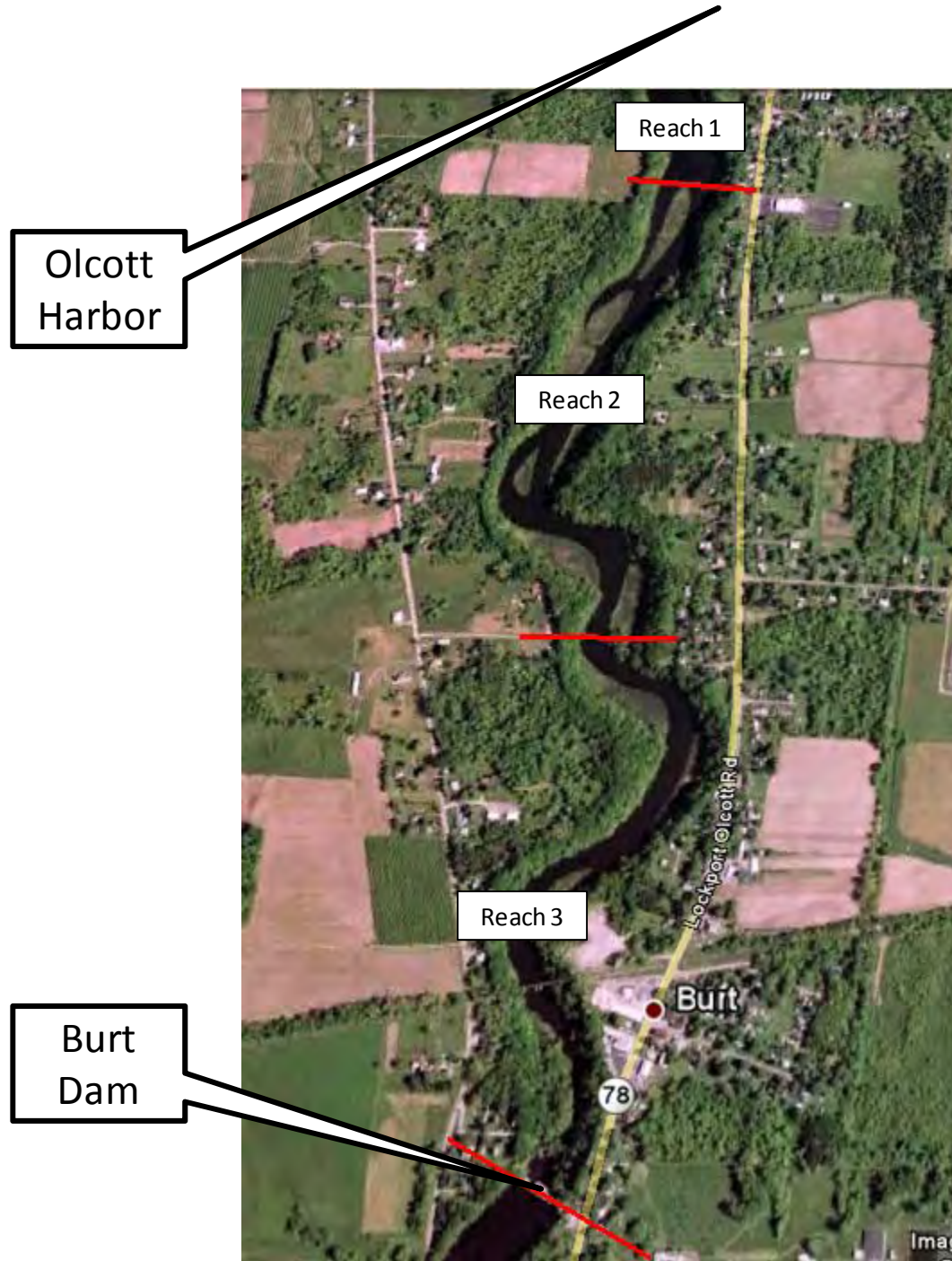


Figure 2: Area 1 with Reach Designations

FIELD PROCEDURES: FISH COLLECTION

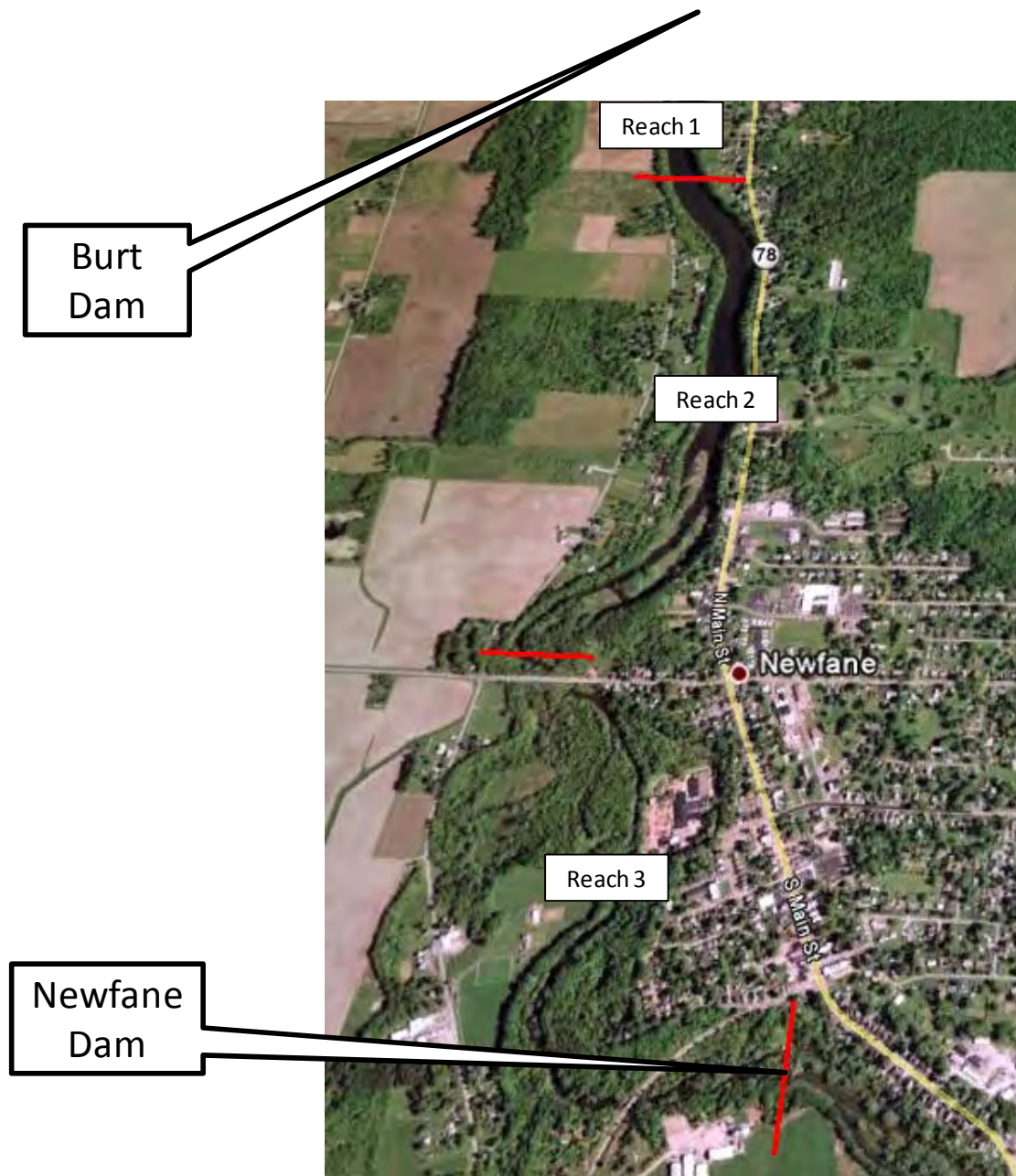


Figure 3: Area 2 with Reach Designations

APPENDIX A FISH COLLECTION RECORD

DATE _____ TIME _____

BY COLLECTOR(S) _____ USING _____ COLLECTION METHOD _____

EIGHTEENMILE CREEK SAMPLING AREA _____

COORDINATE INFORMATION (START; END; TURNS): _____

[illegible]

APPENDIX 2

FISH SAMPLING FIELD COLLECTION LOG

APPENDIX A: FISH COLLECTION RECORD

DATE 9/13/10 TIME 11:18 - 15:05

BY COLLECTOR(S) Betsy Trometer, Katherine McElhearn USING boat electrofishing COLLECTION METHOD

EIGHTEENMILE CREEK SAMPLING AREA Area 2 Reach 1 - start 43°18'39.0", 78°42'56.0" finish 43°18'10.8", 78°42'54.6"

COORDINATE INFORMATION (START; END; TURNS): Area 2 Reach 2-start 43°18'02.3" 78°42'55.7" finish 43°17'42.9" 78°42'46.4"

[illegible]

APPENDIX A: FISH COLLECTION RECORD

DATE 9/14/10 TIME 10:10-13:00

BY COLLECTOR(S) Betsy Trometer, Jerry Kraina, Carolyn Lock USING boat electrofishing COLLECTION METHOD

EIGHTEENMILE CREEK SAMPLING AREA Areal - Reach 1 start: $43^{\circ}20'04.5''$ $78^{\circ}42'58.1''$ finish: $43^{\circ}19'37.9''$ $78^{\circ}43'01.7''$

COORDINATE INFORMATION (START; END; TURNS): Area 1 - Reach 2 start: 43°19'33.7" 78°43'04.6" finish: 43°19'19.6" 78°42'59.1"

[illegible]

FIELD PROCEDURES: FISH COLLECTION

APPENDIX A: FISH COLLECTION RECORD

EIGHTEENMILE CREEK FISH COLLECTION RECORD

DATE 9/15/10 TIME 10:15 - 11:30

BY COLLECTOR(S) Betsy Trometer, Jerry Krajina USING boat electrofisher COLLECTION METHOD

EIGHTEENMILE CREEK SAMPLING AREA Area 1 Reach 3

COORDINATE INFORMATION (START; END; TURNS): Start: 43°19'17.5", 78°42'55.8" Finish: 43°19'06.3" 78°42'59.4"

COLLECTION OR TAG NO.	SPECIES	DATE TAKEN	LOCATION (AREA/REACH AND COORDINATES, IF POSSIBLE)	LENGTH (in)	WEIGHT (g)	REMARKS
-33 18-AIR3-LMB6	LMB	9/15/10	Area 1 Reach 3	15	956	
-25 18-AIR3-LMB7	LMB			12.8	488	
-10 18-AIR3-BB1	BB			10	216	
-09 18-AIR3-BB2	BB			11.1	302	
-10 18-AIR3-BB3	BB			10.6	304	
-04 18-AIR3-BB4	BB			11.1	312	
-26 18-AIR3-LMB8	LMB			14.5	790	
-03 18-AIR3-BB5	BB			11	278	
-22 18-AIR3-PKN4	PKN			—	42	all bluegills
-11 18-AIR3-PKN5	PKN			—	26	1 pumpkinseed, 4 bluegills
-23 18-AIR3-PKN6	PKN			—	16	all bluegills
-13 18-AIR3-PKN7	PKN			—	12	all bluegills

APPENDIX A: FISH COLLECTION RECORD

DATE 9/15/10 TIME 13:30 - 15:00

EIGHTEENMILE CREEK SAMPLING AREA Area 1, Reach 1 through Reach 2

COORDINATE INFORMATION (START; END; TURNS): start 43°20'04.5", 78°42'58.3" finish: 43°19'28.5", 78°43'06.9"

[illegible]

APPENDIX A: FISH COLLECTION RECORD

DATE 9/20 - 9/21/10

TIME

BY COLLECTOR(S) Betsy Trometer, Carolyn Lock

USING baited minnow traps COLLECTION METHOD

EIGHTEENMILE CREEK SAMPLING AREA Area 2 Reach 2 43° 17' 12.65" 78° 42' 57.03" 15:00 - 9:30

COORDINATE INFORMATION (START; END; TURNS): Area 2 Reach 3 43° 16' 43.38" 78° 42' 30.47" 15:30 - 10:50

[illegible]

APPENDIX A: FISH COLLECTION RECORD

DATE 9/29/10 TIME 10:40

EIGHTEENMILE CREEK SAMPLING AREA Area 2 Reach 2

COORDINATE INFORMATION (START; END; TURNS): start: $43^{\circ} 17' 16.4''$, $78^{\circ} 42' 59.3''$ finish $43^{\circ} 17' 21.7''$, $78^{\circ} 42' 48.9''$

[illegible]

FIELD PROCEDURES: FISH COLLECTION

APPENDIX A: FISH COLLECTION RECORD

EIGHTEENMILE CREEK FISH COLLECTION RECORD

DATE 9/29/10

TIME 11:25

BY COLLECTOR(S) Betsy Trometer, Eric Snyder, Katherine McElhearn USING boat electrofish COLLECTION METHOD (2)

EIGHTEENMILE CREEK SAMPLING AREA Area 2 Reach 2

COORDINATE INFORMATION (START; END; TURNS): start: 43°17'23.2", 78°42'47.2" finish: 43°17'36.2" 78°42'44.9"

COLLECTION OR TAG NO.	SPECIES	DATE TAKEN	LOCATION (AREA/REACH AND COORDINATES, IF POSSIBLE)	LENGTH (in)	WEIGHT (g)	REMARKS
-49 18-A2R2-PKN8	PKN8	9/29	Area 2 Reach 2	—	40	2 bluegill + 3 pumpkinseed
-56 18-A2R2-PKN9	PKN9			—	8	all bluegill
-58 18-A2R2-LMB7	LMB7			13.4	570	
-43 18-A2R2-BB5	BB5			11.9	426	
-46 18-A2R2-LMB8	LMB8			12.6	496	
-53 18-A2R2-LMB9	LMB9			14.0	732	
-42 18-A2R2-LMB10	LMB10			14.5	828	
-54 18-A2R2-BB6	BB			9.7	210	
-50 18-A2R2-PKN10	PKN			—	48	3 bluegill + 3 pumpkinseed

APPENDIX A: FISH COLLECTION RECORD

DATE 9/29/10 TIME 13:30

EIGHTEENMILE CREEK SAMPLING AREA Area 2 Reach 2

COORDINATE INFORMATION (START; END; TURNS): start: 43°17'19.1", 78°42'54.3" finish 43°17'37.7" 78°42'45.2"

[illegible]

APPENDIX A: FISH COLLECTION RECORD

DATE 9/30/10 TIME 10:45-12:30

BY COLLECTOR(S) Betsy Trometer USING minnow trap COLLECTION METHOD

EIGHTEENMILE CREEK SAMPLING AREA Area 2 Reach 3

COORDINATE INFORMATION (START; END; TURNS): 43° 16' 43.38" 78° 42' 30.47"

[illegible]

APPENDIX 3
FISH SAMPLE LOCATIONS

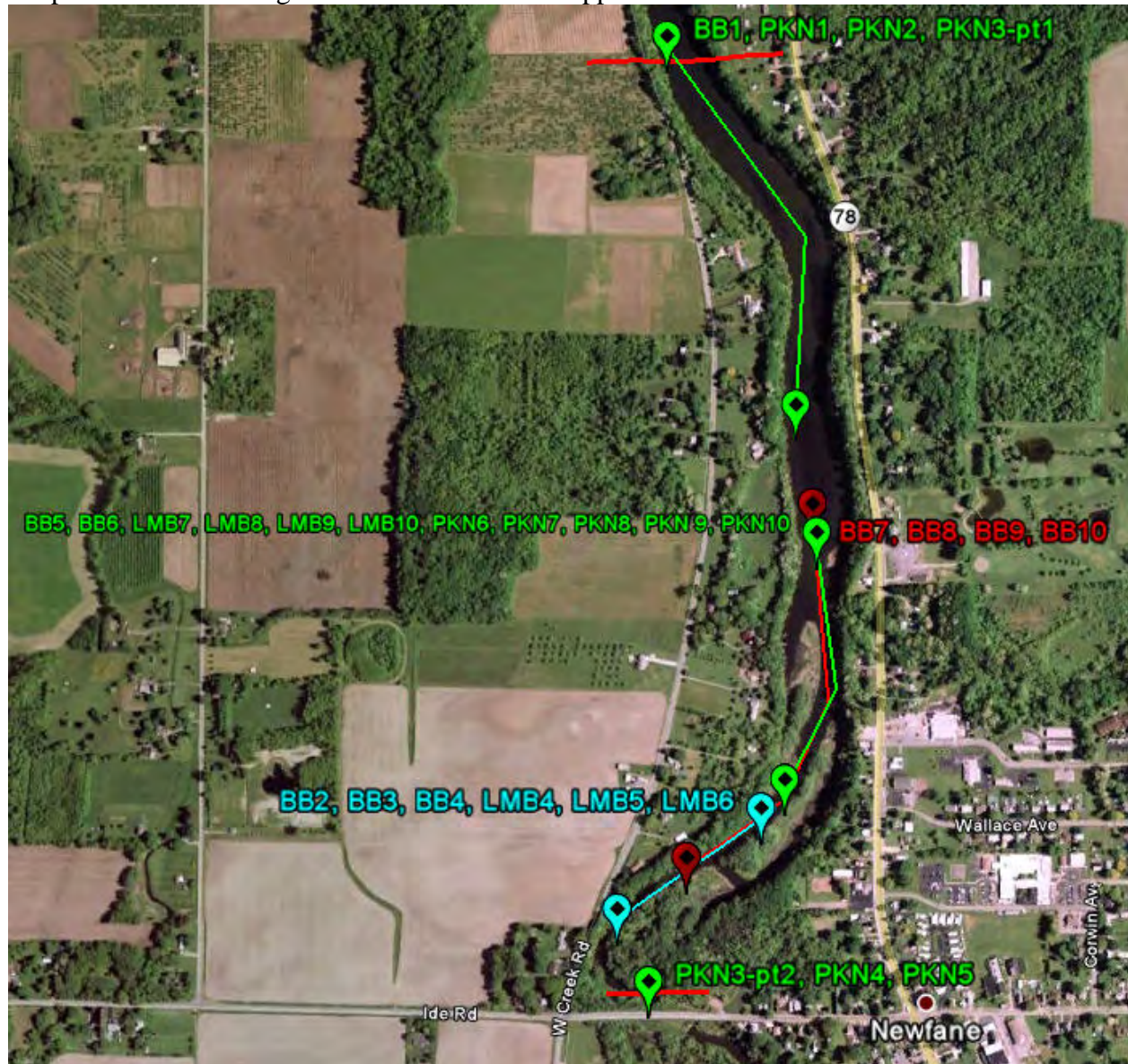
Figure 1. Reach 1 Fish Sampling Runs. Icons are coordinates of the start and end of electroshocking runs. Fish samples collected during the run are indicated at upper icon of the run.



Figure 2. Reach 2 Fish Sampling Runs. Icons are coordinates of the start and end of electroshocking runs. Fish samples collected during the run are indicated at upper icon of the run. Colors are used to differentiate sampling runs. Single icons indicate minnow traps used for sampling.



Figure 3. Area 2, Reach 2, Fish Sampling Runs (Inset from Figure 2). Icons are coordinates of the start and end of electroshocking runs. Colors are used to differentiate sampling runs. Fish samples collected during the run are indicated at upper icon of the run.



APPENDIX 4
CHAIN OF CUSTODY FORMS
FISH COLLECTION

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name <i>Eighteenmile Creek, Niagara Co, NY</i>				Number of Containers										
Sampler : (Signature) <i>Betsy Tromer</i>																
Date	Time	Pres.	Grab	Comp	Site Code/Sample Number											
<i>9/27/10</i>		<i>Freeze</i>			<i>18-A2R2-BB1</i>	<i>3</i>										<i>-01</i>
					<i>18-A1R1-BB8</i>											<i>-02</i>
					<i>18-A1R3-BB5</i>											<i>-03</i>
					<i>18-A1R3-BB4</i>											<i>-04</i>
					<i>18-A1R1-BB9</i>											<i>-05</i>
					<i>18-A1R3-BB1</i>											<i>-06</i>
					<i>18-A1R1-BB6</i>											<i>-07</i>
					<i>18-A1R1-BB7</i>											<i>-08 ✓</i>
					<i>18-A1R3-BB2</i>											<i>-09</i>
					<i>18-A1R3-BB3</i>											<i>-10</i>
Sampler Relinquished by: <i>Betsy Tromer</i>		Date/Time: <i>9/27</i>		Received by: (Sig.)			Date/Time		Hazards Associated with Samples							
Relinquished by: (Sig.) <i>Betsy Tromer</i>		Date/Time		Received by: (Sig.)			Date/Time									
Relinquished by: (Sig.)		Date/Time		Received for Laboratory by: (Sig.) <i>[Signature]</i>			Date/Time: <i>9/28/10</i>									
Custody Seal No.				Lab case No.: <i>wo: 0092802</i>				Remarks at time of receipt:								

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name <i>Eighteenmile Cr., Niagara Co., NY</i>				Number of Containers										
Sampler : (Signature) <i>Betsy Tromer</i>																
Date	Time	Pres.	Grab	COMB	Site Code/Sample Number											
<i>9/27/10</i>		<i>Freeze</i>			<i>18-AIR3-PKN5</i>	<i>3</i>										<i>-11'</i>
					<i>18-A2R2-PKN2</i>											<i>-12-</i>
					<i>18-AIR3-PKN7</i>											<i>-13</i>
					<i>18-AIR2-PKN2</i>											<i>-14-</i>
					<i>18-AIR1-PKN10</i>											<i>-15</i>
					<i>18-AIR2-PKN3</i>											<i>-16-</i>
					<i>18-AIR1-PKN8</i>											<i>-17</i>
					<i>18-A2R3-PKN4</i>											<i>-18-</i>
					<i>18-A2R2-PKN1</i>											<i>-19-</i>
					<i>18-AIR2-PKN1</i>											<i>-20-</i>
Sampler Relinquished by: <i>Betsy Tromer</i>		Date/Time <i>9/27</i>		Received by: (Sig.)			Date/Time		Hazards Associated with Samples							
Relinquished by: (Sig.) <i>Betsy Tromer</i>		Date/Time <i>9/27</i>		Received by: (Sig.)			Date/Time									
Relinquished by: (Sig.)		Date/Time		Received for Laboratory by: (Sig.) <i>[Signature]</i>			Date/Time <i>9/28/10</i>									
Custody Seal No.				Lab case No.: <i>0092802</i>				Remarks at time of receipt:								

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name <i>Eighteenmile Creek, Niagara Co., NY</i>				Number of Containers											
Sampler : (Signature) <i>Betsy Truitt</i>																	
Date	Time	Pres.	Grab	Comp	Site Code/Sample Number												
<i>9/27</i>		<i>Freeze</i>			<i>18-A2R2-PKN3</i>	<i>3</i>											-21-
					<i>18-A1R3-PKN4</i>												-22-
					<i>18-A1R3-PKN6</i>												-23-
					<i>18-A1R1-PKN9</i>												-24
					<i>18-A1R3-LMB7</i>												-25✓
					<i>18-A1R3-LMB8</i>												-26✓
					<i>18-A2R1-LMB2</i>												-27✓
					<i>18-A1R2-LMB4</i>												-28✓
Sampler Relinquished by: <i>Betsy Truitt</i>		Date/Time <i>9/27</i>		Received by: (Sig.)			Date/Time		Hazards Associated with Samples								
Relinquished by: (Sig.) <i>Betsy Truitt</i>		Date/Time <i>9/27</i>		Received by: (Sig.)			Date/Time										
Relinquished by: (Sig.)		Date/Time		Received for Laboratory by: (Sig.) <i>[Signature]</i>			Date/Time <i>9/28/10</i>										
Custody Seal No.				Lab case No.: <i>0092802</i>				Remarks at time of receipt:									

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name <i>Eighteenmile Creek, Niagara Co., NY</i>			Number of Containers											
Sampler: (Signature) <i>Betsy Troneter</i>																
Date	Time	Pres.	Grab	Comp												Site Code/Sample Number
<i>9/27</i>		<i>Freeze</i>			<i>18-AIR2-LMB5</i>	<i>3</i>										<i>-29 ✓</i>
					<i>18-AIR1-LMB9</i>											<i>-30 ✓</i>
					<i>18-AIR1-LMB10</i>											<i>-31 ✓</i>
					<i>18-A2R1-LMB3</i>											<i>-32 -</i>
					<i>18-AIR3-LMB6</i>											<i>-33 ✓</i>
					<i>18-A2R1-LMB1</i>											<i>-34 ✓</i>
					<i>18-AIR2-LMB3</i>											<i>-35</i>
					<i>18-AIR2-LMB2</i>											<i>-36 ✓</i>
<i>✓</i>		<i>✓</i>			<i>18-AIR1-LMB1</i>											<i>-37 ✓</i>
					<i>Field collection sheets</i>											
Sampler Relinquished by: <i>Betsy Troneter</i>		Date/Time <i>9/27</i>		Received by: (Sig.)			Date/Time		Hazards Associated with Samples							
Relinquished by: (Sig.) <i>Betsy Troneter</i>		Date/Time		Received by: (Sig.)			Date/Time									
Relinquished by: (Sig.)		Date/Time		Received for Laboratory by: (Sig.) <i>[Signature]</i>			Date/Time <i>9/28/10</i>		Remarks at time of receipt:							
Custody Seal No.		Lab case No.: <i>0092802</i>														

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name <i>Eighteenmile Cr., Niagara Co., NY</i>				Number of Containers											Remarks:
Sampler: (Signature) <i>Betsy Trotter</i>																	
Date	Time	Pres.	Grab	Comp	Site Code/Sample Number												
<i>9/30/10</i>		<i>Freeze</i>			<i>18-A2R2-BB9</i> ✓											<i>0092802-38</i>	
					<i>18-A2R2-BB2</i> ✓											<i>-39</i>	
					<i>18-A2R2-BB3</i> ✓											<i>-40</i>	
					<i>18-A2R2-PKN6</i> ✓											<i>-41</i>	
					<i>18-A2R2-LMB10</i> ✓											<i>-42</i>	
					<i>18-A2R2-BB5</i> ✓											<i>-43</i>	
					<i>18-A2R2-BB8</i> ✓											<i>-44</i>	
					<i>18-A2R2-BB4</i> ✓											<i>-45</i>	
					<i>18-A2R2-LMB8</i>											<i>-46</i>	
<i>✓</i>					<i>18-A2R2-LMB6</i> ✓											<i>-47</i>	
Sampler Relinquished by:		<i>Betsy Trotter</i>		Date/Time	<i>9/30/10</i>	Received by: (Sig.)				Date/Time	Hazards Associated with Samples						
Relinquished by: (Sig.)		<i>Betsy Trotter</i>		Date/Time	<i>9/30/10</i>	Received by: (Sig.)				Date/Time							
Relinquished by: (Sig.)				Date/Time		Received for Laboratory by: (Sig.)				Date/Time							Remarks at time of receipt:
Custody Seal No.						Lab case No.: <i>0092802</i>											

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name <i>Eighteenmile Creek, Niagara Co., NY</i>				Number of Containers											
Sampler: (Signature) <i>Betsy Tromer</i>																	
Date	Time	Pres.	Grab	Comp	Site Code/Sample Number												Remarks:
<i>9/30/10</i>		<i>Freeze</i>			<i>18-A2R2-BB10 ✓</i>												<i>- 48</i>
					<i>18-A2R2-PKN8 ✓</i>												<i>- 49</i>
					<i>18-A2R2-PKN10 ✓</i>												<i>- 50</i>
Sampler Relinquished by: <i>Betsy Tromer</i>		Date/Time <i>9/30/10</i>		Received by: (Sig.)			Date/Time		Hazards Associated with Samples								
Relinquished by: (Sig.) <i>Betsy Tromer</i>		Date/Time <i>9/30/10</i>		Received by: (Sig.)			Date/Time										
Relinquished by: (Sig.)		Date/Time		Received for Laboratory by: (Sig.) <i>[Signature]</i>			Date/Time <i>10/1/10</i>		Remarks at time of receipt:								
Custody Seal No.				Lab case No.: <i>0092802</i>													

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name <i>Eighteenmile Cr., Niagara Co., NY</i>				Number of Containers										
Sampler: (Signature) <i>Betsy Trout</i>																
Date	Time	Pres.	Grab	Comp	Site Code/Sample Number											
<i>9/30/10</i>		<i>Freeze</i>			<i>18-A2R2-BB6 ✓</i>											<i>009 2802-S1</i>
					<i>18-A2R2-LMB4 ✓</i>											<i>-S2</i>
					<i>18-A2R2-LMB9 ✓</i>											<i>-S3</i>
					<i>18-A2R2-LMB5 ✓</i>											<i>-S4</i>
					<i>18-A2R2-PKN7 ✓</i>											<i>-S5</i>
					<i>18-A2R2-PKN9 ✓</i>											<i>-S6</i>
					<i>18-A2R2-BB7 ✓</i>											<i>-S7</i>
					<i>18-A2R2-LMB7 ✓</i>											<i>-S8</i>
					<i>18-A2R3-PKN5 ✓</i>											<i>-S9</i>
					<i>18-A2R3-PKN11 ✓</i>											<i>-60</i>
Sampler Relinquished by: <i>Betsy Trout</i>		Date/Time <i>9/30</i>		Received by: (Sig.)			Date/Time		Hazards Associated with Samples							
Relinquished by: (Sig.) <i>Betsy Trout</i>		Date/Time <i>9/30</i>		Received by: (Sig.)			Date/Time									
Relinquished by: (Sig.)		Date/Time		Received for Laboratory by: (Sig.) <i>R. J. L.</i>			Date/Time <i>10/1/10</i>									
Custody Seal No.				Lab case No.: <i>0092802</i>				Remarks at time of receipt:								

APPENDIX 5
FIELD SAMPLING PLAN
SEDIMENT COLLECTION

FIELD PROCEDURES: SEDIMENT COLLECTION

Work Plan. Sediment Sampling for Contaminant Analysis in the Eighteenmile Creek AOC.

1. Introduction. The Engineering Research and Development Center Environmental Laboratory (ERDC-EL) will work with the Army Corps of Engineers (USACE) Buffalo District to conduct sediment sampling for contaminant analysis in the Eighteenmile Creek Area of Concern (AOC). ERDC will provide general oversight, sample containers, shipping materials, and laboratory facilities and personnel to perform chemical testing on collected samples. USACE Buffalo District will provide the personnel, labor, and equipment for sediment sampling. Specific activities are as described in this work plan.

2. Responsibility. ERDC-EL is responsible for providing the sample containers, shipping coolers, and the laboratory facilities for chemical testing. The Buffalo District Corps of Engineers is responsible for personnel, equipment, and boat facilities for obtaining surface sediment grab samples from the Eighteenmile Creek AOC and for shipping the samples to ERDC-EL for testing.

3. Sediment Sampling

3a. Location. Sediment sampling will take place in the Eighteenmile Creek, below Burt Dam to Olcott Harbor at Lake Ontario. Sampling will take place at 16 locations along Eighteenmile Creek as designated in Figure 1 and the coordinates in Table 1. Sample locations are located approximately in the center of the channel, approximately 600 ft apart along the length of the river below Burt Dam to Olcott Harbor at Lake Ontario.

3b. Sampling Procedures. At each location, discrete grab samples will be collected with a standard Ponar grab sampler with a 9" bucket using methods described USACE (2001, Section C.5.4.5). It is anticipated that this device will sample approximately the top 6 inches of sediment. Upon retrieval, samples will be placed into separate, pre-cleaned stainless steel pans and homogenized with a stainless spatula. A subsample of the retrieved sediment will be taken from each location except that a field duplicate samples will also be taken at EMC-4 and EMC-12. Sub-samples will be taken for both contaminant analysis and for Total Organic Carbon (TOC) analysis; 18 sediment samples for each analysis (36 in total). Sediment and TOC samples will be placed into pre-cleaned amber glass jars provided by the ERDC Environmental Chemistry Branch. Jars will be sealed and labeled with the sample ID (location), date, and initials of individual conducting the sampling with permanent marker and immediately placed on ice. A variety of parameters on site conditions, location, and sample description will be collected at each sampling location per the sampling log (Appendix A).

3c. Packaging and shipping.

Containers will be placed in a cooler with ice or gel-pack ice to maintain temperatures of 4°C during transit. Sample containers will be packaged to prevent breakage during shipping. A chain of custody report (attachment B) will be filled by the sampling team. Coolers will be shipped to the ERDC Chemistry lab via overnight courier. Shipping airbills will be retained for inclusion in the results report.

4. References.

USACE (U.S. Army Corps of Engineers). 2001. Requirements for the Preparation of Sampling and Analysis Plans. Engineer Manual 200-1-3. February 1, 2001.

FIELD PROCEDURES: SEDIMENT COLLECTION

TABLE 1: Eighteenmile Creek Sample Location Coordinates

	Latitude	Longitude
EMC-1	43° 20.303'	78° 43.110'
EMC-2	43° 20.234'	78° 42.995'
EMC-3	43° 20.149'	78° 42.929'
EMC-4	43° 20.043'	78° 42.978'
EMC-5	43° 19.937'	78° 42.963'
EMC-6	43° 19.831'	78° 42.928'
EMC-7	43° 19.726'	78° 42.967'
EMC-8	43° 19.623'	78° 43.019'
EMC-9	43° 19.522'	78° 43.073'
EMC-10	43° 19.441'	78° 43.017'
EMC-11	43° 19.356'	78° 42.965'
EMC-12	43° 19.284'	78° 42.873'
EMC-13	43° 19.187'	78° 42.847'
EMC-14	43° 19.110'	78° 42.946'
EMC-15	43° 19.006'	78° 42.981'
EMC-16	43° 18.912'	78° 42.907'

FIELD PROCEDURES: SEDIMENT COLLECTION

Figure 1: Sample Locations and Names.



FIELD PROCEDURES: SEDIMENT COLLECTION



US Army Corps
of Engineers®
Buffalo District

APPENDIX A: SAMPLE LOG

Project Area: _____

Sampling Site ID: _____

Sample Matrix: ☐ Soil ☐ Sediment ☐ Water

Weather: _____

Date: _____ Site Water Depth: _____

Time: _____ Site Water Temperature: _____

Sampling Crew: _____

Site Coordinates

Waypoint: _____

Latitude: _____ Longitude: _____

Sediment/Soil Sample Description:

Number of Grabs: _____ Sampling Equipment Used: _____

Substrate Color/Characteristics: _____

Additional Comments: _____

Sample Photo ID #(s): _____

APPENDIX B: CHAIN OF CUSTODY FORM

[illegible]

APPENDIX 6

SEDIMENT SAMPLING FIELD COLLECTION LOG



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-1

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 13 ft

Time: 1005

Site Water Temperature: 53°F

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 588

Latitude: 43° 20.316' N

Longitude: 078° 43.127' W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BROWN SILTY CLAY WITH
SOME FINE SAND AND ORGANICS

Additional Comments: MOVED FROM PROPOSED LOCATION DUE TO
LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0149; 100-0150; 100-0151; 100-0152
UPSTREAM DOWNSTREAM
(LAKE)



US Army Corps
of Engineers®
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-2

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 4'

Time: 1045

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 591

Latitude: 43° 20.222'N Longitude: 078° 42.999'W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BROWN SILTY CLAY W FINE
SAND + LOTS OF ORGANICS (MACROPHYTE BED)

Additional Comments: MOVED FROM PROPOSED LOCATION DUE TO
LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0153



US Army Corps
of Engineers®
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-3

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 8'

Time: 1055

Site Water Temperature: 57°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 592

Latitude: 43° 20.46' N

Longitude: 078° 42.931' W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BROWN SANDY SILT

Additional Comments: MOVED FROM PROPOSED LOCATION DUE
TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0154 ; 100-0155 ;
UPSTREAM



US Army Corps
of Engineers®
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-4

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 12

Time: 1100

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: NA

Latitude: _____ Longitude: _____

Sediment/Soil Sample Description:

Number of Grabs: 1 Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BROWN SILTY CLAY - VERY
LITTLE SAND

Additional Comments: DUPLICATE SAMPLE TAKEN
HERE (1102)

Sample Photo ID #(s): 100-0156; 100-0157; 100-0158
UPSTREAM DOWNSTREAM



US Army Corps
of Engineers®
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-S

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 4'

Time: 1107

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 593

Latitude: 43° 19.936' N

Longitude: 078° 42.958' W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BROWN silty CLAY VERY little SAND

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0161



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-6

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 9'

Time: 1115

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 594

Latitude: 43° 19.825' N

Longitude: 078° 42.929' W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: LIGHT BROWN SILTY CLAY

W/ SOME SAND + MACROPHYTES

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0162



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-7

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 6'

Time: 1125

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 599

Latitude: 43° 19.745' N

Longitude: 079° 42.942' W

Sediment/Soil Sample Description:

Number of Grabs: 2

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: HARD CHUNKS OF CLAY
WITH SOME SILT + MACROPHYTES

Additional Comments: SITE MOVED FROM PROPOSED DUE TO LACK
OF RETRIEVAL

Sample Photo ID #(s): 100-0163 ; 100-0164
UPSTREAM



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-8

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 4'

Time: 1135

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 600

Latitude: 43° 19.619' N Longitude: 078° 43.016' W

Sediment/Soil Sample Description:

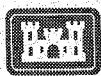
Number of Grabs: 2

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: ~~BLK~~ BLACK SILT w/very
little CLAY, NO SAND

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0165



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-9

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 3'

Time: 1143

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 602

Latitude: 43° 19.519' N Longitude: 078° 43.073' W

Sediment/Soil Sample Description:

Number of Grabs: 1 Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: SANDY SILT WITH SOME
CLAY AND BROKEN THICK MACROPHYTES

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0167



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-10

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 3'

Time: 1148

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 604

Latitude: 43° 19.437' N

Longitude: 078° 43.038' W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BLACK SILT - LOADED WITH ORGANICS

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0168



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-11

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 3'

Time: 1155

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 605

Latitude: 43° 19.352' N

Longitude: 078° 42.969' W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BLACK SILT W/ SOME
CLAY, LOTS OF ORGANICS

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0169; 100-0170
UPSTREAM



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-12

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 3'

Time: 1103

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 606

Latitude: 43° 19.279' N

Longitude: 078° 42.876' W

Sediment/Soil Sample Description:

Number of Grabs: 2

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BLACK SILT W/ LOTS OF ORGANICS
SOME SAND

Additional Comments: DUPLICATE SAMPLE TAKEN
HORN (1105); SITE MOVED DUE TO
LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0171; 100-0172
UPSTREAM



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-13

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 3'

Time: 1208

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 610

Latitude: 43° 19.177' N

Longitude: 078° 42.859' W

Sediment/Soil Sample Description:

Number of Grabs: 2

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: LIGHT BROWN / RED CLAY WITH
SOME SILT

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0174



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-14

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 2'

Time: 1220

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 011

Latitude: 43° 19.115' N

Longitude: 078° 42.953' W

Sediment/Soil Sample Description:

Number of Grabs: 1

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: BROWN/RED CLAY

Additional Comments: SITE MOVED DUE TO LACK OF RETRIEVAL

Sample Photo ID #(s): 100-0175



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-15

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: < 2'

Time: 1227

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: 612

Latitude: 43° 19.059' N

Longitude: 078° 43.022' W

Sediment/Soil Sample Description:

Number of Grabs: 2

Sampling Equipment Used: Standard Ponar

Substrate Color/Characteristics: ALL GRAVEL, SOME COARSE SAND

Additional Comments: DS FROM BRIDGE, VERY SHALLOW

SITE MOVED DUE TO ACCESS

Sample Photo ID #(s): 100-0176



US Army Corps
of Engineers
Buffalo District

SAMPLE LOG

Project Area: Eighteen Mile Creek Area of Concern (EMC)

Sampling Site ID: EMC-16

Sample Matrix: ☐ Soil ☒ Sediment ☐ Water

Weather: Partly cloudy, breezy, mid-70s

Date: October 26, 2010

Site Water Depth: 0.2'

Time: 1320

Site Water Temperature: 53°

Sampling Crew: Miller, Rimer, Ruby, A. Hannes

Site Coordinates

Waypoint: NA

Latitude: _____ Longitude: _____

Sediment/Soil Sample Description:

Number of Grabs: NA Sampling Equipment Used: SCOOP
~~Standard Ponar~~

Substrate Color/Characteristics: GRAVEL w/SOME SAND

Additional Comments: COULD NOT GET BOAT UP THIS
FAR, SAMPLE TAKEN BY HAND

Sample Photo ID #(s): 100-0177; ~~100-0182~~ 100-0183; 100-0184

APPENDIX 7



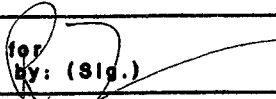
CHAIN OF CUSTODY FORMS

SEDIMENT COLLECTION

U.S. Army Corps of Engineers

Chain of Custody Record


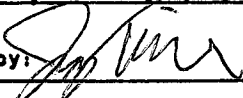
(ER 1110-1-263)

Proj. No.		Project Name 18-MILE CREEK			Number of Containers	PCBs - AROCLORS	PCBs - CONGENERS	TOC					Remarks:	
Sampler: (Signature) 														
Date	Time	Pres.	Grab	COM										Site Code/Sample Number
10/26	1005	ICE	X		EMC-1	2	X	X	X					-01
	1045		X		EMC-2	2	X	X	X					-02
	1055		X		EMC-3	2	X	X	X					-03
	1100		X		EMC-4	2	X	X	X					-04
	1102		X		EMC-4 DUP	2	X	X	X					-05
	1107		X		EMC-5	2	X	X	X					-06
	1115		X		EMC-6	2	X	X	X					-07
	1125		X		EMC-7	2	X	X	X					-08
	1135		X		EMC-8	2	X	X	X					-09
	1143		X		EMC-9	2	X	X	X					-10
Sampler Relinquished by: JAY MILLER					Date/Time	Received by: (Sig.)		Date/Time		Hazards Associated with Samples NA				
Relinquished by: (Sig.) 					Date/Time	Received by: (Sig.)		Date/Time						
Relinquished by: (Sig.)					Date/Time	Received for Laboratory By: (Sig.) 		Date/Time 10/27/10		Remarks at time of receipt: NA				
Custody Seal No.					Lab case No.: 0 10 2702									

U.S. Army Corps of Engineers

Chain of Custody Record

(ER 1110-1-263)

Proj. No.		Project Name 18-MILE CREEK			Number of Containers	<div style="display: flex; justify-content: space-around;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">PCB ANALOGS</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">PCB CONCENTRATIONS</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">TOC</div> </div>										
Sampler: (Signature) 																
Date	Time	Pres.	Grab	COMB												Site Code/Sample Number
10/26	1148	ICE	X		EMC-10	2	X	X	X							-11
	1155		X		EMC-11	2	X	X	X							-12
	1203		X		EMC-12	2	X	X	X							-13
	1205		X		EMC-12 DUP	2	X	X	X							-14
	1208		X		EMC-13	2	X	X	X							-15
	1220		X		EMC-14	2	X	X	X							-16
	1227		X		EMC-15	2	X	X	X							ALL GRAVEL -17
	1320		X		EMC-16	2	X	X	X							ALL GRAVEL -18
Sampler Relinquished by: 					Date/Time: 10/26/1600		Received by: (Sig.)			Date/Time		Hazards Associated with Samples N/A				
Relinquished by: (Sig.) JAY MILLER					Date/Time		Received by: (Sig.)			Date/Time						
Relinquished by: (Sig.)					Date/Time		Received for Laboratory by: (Sig.)			Date/Time		Remarks at time of receipt: N/A				
Custody Seal No.							Lab case No.: 0 10 2702									

APPENDIX 8

DIET AND AGE OF COLLECTED FISH

Diet and Age of Largemouth Bass and Black Bullhead From Eighteenmile Creek, New York

Steven G. George and Jan Jeffrey Hoover

**U.S. Army Engineer Research and Development Center
Waterways Experiment Station, Environmental Laboratory
Vicksburg, Mississippi 39180**

Abstract

Diet and age were evaluated for two species of fish from a small stream in New York as part of a field study of environmental contaminants. Largemouth bass (*Micropterus salmoides*), 284-381 mm total length, were specialized carnivores feeding primarily on crayfish and secondarily on fishes. Black bullhead (*Ameiurus melas*), 226-302 mm total length, were generalized omnivores feeding principally on algae and detritus, vascular plants, crayfish, and snails. Bass examined were Age IV to Age VI, bullhead Age III to Age VII. Results suggest that models of contaminant pathways for this system should address uptake by plants, mollusks, and crayfish and substantial size overlap among age classes of both species of fish.

Introduction

Largemouth bass (*Micropterus salmoides*) and black bullhead (*Ameiurus melas*) are long-lived (> 4 years) aquatic predators (Carlander, 1969, Carlander, 1977) that are exploited (and consumed) by anglers (La Monte, 1958), and are broadly distributed throughout North America (Lee, 1980; Glodek, 1980). The two species are often syntopic but have different feeding behaviors. Bass, like other sunfishes, are crepuscular, feed by sight, sometimes ambushing their animal prey; bullheads, like other catfishes, are nocturnal, feed by touch and taste, grabbing vegetable and animal foods as they encounter them (Pflieger, 1975). Because individual fish collectively spend years feeding on sediment-associated organisms (benthos) and multiple trophic levels (plants, invertebrates, fishes), they are useful model organisms for studies of contaminants in aquatic environments.

Both species are well-documented in the scientific literature. There have been numerous life history studies of largemouth bass dating from the mid to late 1800's (Eoff, 1855; citations in Reighard, 1906) to the present (Parkos and Wahl, 2010). Life history aspects (e.g., diet and age) of largemouth bass have been summarized by Mraz et al. (1961), Heidinger (1975), and Carlander (1977). In contrast, life history studies of black bullhead are limited. Forney (1955) conducted a thorough life history study of black bullhead in Clear Lake, Iowa, and Kutkuhn (1955) reports the diet of black bullhead in North Twins Lake, Iowa. Other life history studies of black bullhead have been conducted in Arkansas (Applegate and Mullan, 1967), South Dakota (Repsys et al., 1976) and Kentucky (Campbell and Branson, 1978).

Information on food habits and age structure of fishes can provide insight into sources of contaminant-based risk. There is evidence to suggest that contaminants in aquatic systems are affecting the health of aquatic organisms as well as humans through the consumption of contaminated fish (Black and Baumann, 1991; Baumann, 1984). Contaminants are an important issue in the Great Lakes region, especially in lake harbors and tributary mouths (DeVault, 1995; Black and Baumann, 1991). Baumann (1984) reports an increase in tumors in wild freshwater fish population from the Great Lakes. Several authors that report tumors as related to contaminants in black bullhead (Blazer and Schrank 1995, Black and Baumann, 1991). Because of increased concern over contaminants in aquatic systems, we described the diet and age of largemouth bass and black bullhead from Eighteen Mile Creek a tributary of the Great Lakes. These data will supplement those from field study of contaminants being conducted by the Environmental Protection Agency and ERDC Chemistry Lab.

Materials and Methods

Study Site and Field Protocol

Eighteen Mile Creek is located in western New York between Olcott and Newfane, New York. It is a small tributary that drains into Lake Ontario along its southern shores. Fishes were collected between or in the vicinity of Olcott, NY and Newfane, NY, by electro-fishing, 13-29 Sep 2010, between 1000-1500 hours. Total length (TL) of all individuals was measured to the nearest millimeter and weight measured to the nearest gram. Fishes were put on ice and then frozen.

Laboratory Protocol

Stomach contents were removed and refrozen until processed. Stomach contents were examined under a dissecting microscope at 160x magnification, sorted, identified to the lowest practical taxon, counted, and, when possible, dimensions measured to the nearest 0.01 mm using a digital caliper. Plant tissues, algae and detritus were assigned a count of '1' for any sample in which they occurred, because it was impossible to count and know how many plant fibers or algae were consumed. After being identified, food contents were blotted dry and weighed on a top-loading balance to the nearest 0.01g. The sample was then placed in a graduated cylinder (100 ml or smaller) with a known volume of water and the volume displacement recorded to the nearest 0.1 ml. Stomach contents were then preserved in 70% Ethyl Alcohol.

Different structures were used to estimate age for each species. For largemouth bass, sagittal otoliths were removed and stored in 100% glycerin. Whole otoliths were read using the distal surface still immersed in glycerin and examined on a black background with a dissecting microscope under reflected light. Each bass otolith was aged using methods reported by Maraldo and MacCrimmon (1979). For black bullhead, the right pectoral spine was removed from each fish, and then air dried. Proximal end of the spine was cut perpendicularly on a low-speed Buehler Isomet saw into a 0.65-0.75 mm section: two sections were cut from each spine. Sections were mounted on a microscope slide using Flo-Texx mounting medium then aged using a dissecting microscope. Each section was examined and the numbers of annuli were counted

following methodology described by Mayhew (1969) and Sneed (1951). All estimates of age were obtained independently and objectively by two readers. Each structure was aged separately by each reader and without reference to the length of the fish. Disagreements in counts between readers for any structure were resolved by mutual examination of the structure in question. Representative photographs were taken of bullhead spines and bass otoliths.

Data Summary and Analyses

To describe diets, we created a matrix in which sample units (stomachs) were rows, and taxonomic units (prey categories) were columns. For each prey category observed (total of 27), number and quantity (measured weight in bass, estimated percent total food volume in bullhead) were recorded for each sample. Because “number” cannot be assigned to plant prey (algae and detritus, vascular plant fragments), number was assumed to be one. Seeds, however, were counted individually since they are large and distinct, with discrete surfaces. Metrics calculated for each prey category included frequency of occurrence (percentage of stomachs in which that category occurred), mean number of individuals, and mean quantity of prey. These provide estimates for each prey category of the likelihood of being eaten (i.e., frequency), the intensity on which it is fed (i.e., number), and an indirect estimate of its contribution to the energy requirements of the fish (i.e., weight or volume).

Zero values (nonoccurrence of prey) predominate in descriptive studies of fish diets due to the low number of prey eaten by an individual and the high number of prey categories consumed by a population. Consequently, traditional parametric statistics are problematic and of limited applicability. To provide data reduction and to objectively identify principal foods for each species, we calculated an index of Relative Importance (RI) according to George and Hadley (1979):

$$RI_i = 100 \left[\frac{\% \text{ Frequency} \times \% \text{ Number} \times \% \text{ Quantity}}{\sum_{i=1}^n \% \text{ Frequency} \times \% \text{ Number} \times \% \text{ Quantity}} \right]$$

in which, i = a prey category,

% Frequency = percentage of samples in which that prey category was observed

% Number = percentage that category comprised of all individual prey

% Quantity = percentage that category comprised of total food weight or volume

n = number of prey categories

Values range from near 0.00 when that prey is rarely eaten, and then, only in low numbers and quantities, to near 100 when that prey is eaten almost to the exclusion of any other prey. Indices of dietary importance have been criticized for confounding multiple sources of error and variation and for a lack of comparability with other studies in which they are not used and cannot be calculated from reported data (Hyslop, 1980). They provide, however, a way of making commonly eaten small prey more equitable in value to rarely eaten large prey. As such, they have been identified as a useful means of making interspecific comparisons among fish with different feeding behaviors and they are amenable to non-parametric statistical tests (Hyslop, 1980).

To describe size and age structure of the samples, data were compiled and analyzed using SAS (Statistical Analysis Systems, Carey, NC). For each fish, TL and weight were used to calculate an index of individual fish robustness or “condition factor,” designated K_{TL} and defined by Carlander (1969) as

$$K_{TL} = (\text{Weight} \times 10^5) / (\text{TL})^3$$

Values for index approximate unity, with greater values representing fish that are more massive for their length. Size metrics (TL, weight, K_{TL}) for all age classes were reported as means, standard deviations, and ranges. Significant differences were tested using analysis of variance (ANOVA) using a significance level of $p = 0.10$. Higher p value (than traditional $p = 0.05$) was used to reduce likelihood of a Type I error (i.e., rejecting the hypothesis that there were no differences in size) because demographic data for larger, long-lived fish are naturally high in variation, and because sample sizes were small (< 30) and non-random (specimens selected for uniformity of size) for population-based inferences. Significant differences among groups were identified using the Student-Newman-Kuels test.

Results

For both fish species, size was moderate (226-391 mm TL) and uniform ($CV < 10\%$). Largemouth bass ($N = 20$) measured 284-391 mm TL ($\bar{x} = 337.8 \pm 31.6$ std) and black bullhead ($N = 19$) measured 226-302 mm TL ($\bar{x} = 269.8 \pm 18.3$ std).

Most fish had food in their stomachs (Table 1). Empty stomachs occurred in eight largemouth bass and two black bullheads. Majority of prey in bass stomachs were large and intact enabling gravimetric quantification. Most food items in black bullhead stomachs were small and many were amorphous, so estimated percentages of total food volume were used for quantification. Total food volume (approximately $2 \text{ mm}^3/\text{fish}$) and total weight of food (approximately $2 \text{ g}/\text{fish}$) were comparable for the two species. Number of prey was low in bass ($< 1/\text{fish}$) than in bullhead ($> 4/\text{fish}$), indicating that bass fed on fewer, larger prey, and that bullhead fed on more, smaller prey.

Largemouth bass consumed 9 taxa and were specialized carnivores (Table 1). Diet was dominated primarily by crayfish ($RI = 92.0$), secondarily by fishes (combined $RI = 7.7$). Other taxa were unimportant components of the diet ($RI < 0.1$), occurring infrequently (5 % fish), in low numbers (< 6 % prey), and in small amounts (< 3 % of food weight). Crayfish eaten were uniform in size: 45-66 mm from tip of rostrum to tip of telson.

Black bullheads consumed more than 16 taxa and were generalized omnivores (Table 1). Diet was dominated by four principal plant and animal prey: algae and detritus ($RI = 51.8$), vascular plants ($RI = 28.1$), crayfish ($RI = 10.1$), and pouch snails ($RI = 9.0$). Fishes were eaten but were minor components of the diet ($RI = 0.6$). Other taxa were not high in importance ($RI < 0.3$), but some (seeds, larval midges in the family Chironomidae, larval caddisflies in the order Trichoptera) were eaten as frequently as some principal foods (i.e., each by 16% of the fish). Their low numbers (each $< 4\%$ of prey) and small size (each $< 1\%$ of estimate food volume)

made them minor dietary components. Other rare and unusual prey items included bivalve mollusks and bryozoan statoblasts (multiple types).

Annuli were distinct and easily counted on bass otoliths (Fig. 1 and 2) and on bullhead spines (Fig. 3 and 4). Bass were comprised of three age classes: Ages IV (N=9), V (N=9), and VI (N=1) which ranged in mean TL from 325 to 368 mm (Table 2). Variation in TL within Ages IV and V were low ($CV < 10\%$), but weights were more variable ($CV > 25\%$) presumably due to natural sources of variation (e.g., allometry, gender, etc.). Mean condition was high for all size classes ($K_{TL} > 1.50$) and variation low ($CV < 10\%$). There were no significant differences in TL, weight, or K_{TL} among the three size classes ($F < 1.70$, $p > 0.22$, d.f. = 2/16). Bullheads were comprised of four age classes: Ages II (N=1), III (N=7), IV (N=6), V (N=1), and VII (N=1) which ranged in mean TL from 246 mm to 282 mm. Variation in TL within Ages III and IV were low ($CV < 12\%$), but weights were more variable ($CV = 15$ and 32% , respectively). Weight for the single Age VII fish was unusually high (450 g). Correspondingly, mean K_{TL} was moderate for Ages II through V ($K_{TL} = 1.20$ - 1.41), but extremely high for the Age VII fish ($K_{TL} = 2.01$). As a result, differences among age classes were non-significant for TL ($F = 0.83$, $p = 0.53$, d.f. = 4/12), and significant for weight and condition ($F > 2.70$, $p < 0.09$, d.f. = 4/12). This outcome was outlier driven, however. When the Age VII fish was excluded, differences among age classes for all three metrics were non-significant ($F < 1.70$, $p > 0.20$, d.f. = 3/12).

Discussion

Food habits and sizes of largemouth bass and black bullhead in Eighteen Mile Creek are comparable to those of populations elsewhere. Numerous diet studies have demonstrated that largemouth bass are specialized predators on crayfish and small fishes (Bennett, 1950; Lewis and Helms 1964; Heidinger 1975; Hodgson and Kitchell 1987) and that black bullhead are omnivorous on a wide variety of plants and animals (Forney 1955; Kutkuhn 1955; Applegate and Mullan 1967). Age and growth studies indicate that bass Age IV to VI are often 300-400 mm TL (Carlander, 1977) and bullheads Ages II to V are often 200-300 mm (Carlander, 1969)(Table 3). Largemouth bass and black bullhead in Eighteen Mile Creek, then, appear typical for their species, and represent, respectively, a large, carnivore and a smaller, omnivore, presumably at higher and lower respective risk for bioaccumulation of contaminants. Respective risks become more disparate when longevity of the two species is considered: 15-23 years for largemouth bass (Green and Heidinger, 1994; Buckmeier and Howells, 2003) and approximately 6-10 years for black bullhead (Forney, 1955; Pflieger, 1975).

In Eighteen Mile Creek, and elsewhere, size ranges overlap substantially among age classes in both species (Table 3). This overlap may be influenced by techniques of determining ages. In this study, for largemouth bass, we used whole otoliths in glycerin following methods of Maraldo and MacCrimmon (1979). Other researchers (e.g., Hoyer et. al. 1985; Long and Fisher 2001) suggest that sectioned otoliths provide more precise readings and that ages of older fish can be underestimated when reading whole otoliths (Hoyer et. al., 1985; Besler, 1999). If so, our overlap in sizes may be partly attributed to our technique and underestimates of age in older fish. Comparative age determinations using multiple techniques (e.g., whole otoliths and sectioned otoliths for bass, spines and otoliths for bullheads) would be required to evaluate this influence.

Overlap in size ranges, however, could also result from natural variation in growth rates of individual fish. This is supported by published data from other populations for the two species which are comparable in size and variability in size for the same age classes (Table 3). Minimizing risk for contaminant transfer to humans becomes problematic since simple management techniques (e.g., advisories that provide limits on maximum size of fish consumed) may underestimate fish exposure time by underestimating age associated with a particular sized fish. Site-specific demographic data and/or population models could be coupled with contaminant burden data to provide definitive sizes below which contaminant exposure would be low.

Acknowledgments

William T. Slack reviewed an earlier draft of this report. Larry Southern and Bradley Lewis assisted with processing otoliths and pectoral spines and confirmed ages of fish. Karl Gustavson sponsored the study and provided specimens and information. Our thanks to all of the above. This study was funded by the United State Environmental Protection Agency. Permission to publish was provided by the Chief of Engineers.

Literature Cited

- Applegate, R. L. and J. W. Mullan 1967. Food of the black bullhead (*Ictalurus melas*) in a new reservoir. Proc. S.E. Assoc. Game Fish Comm. 20:288-292.
- Baumann, P. C. 1984. Cancer in wild freshwater fish populations with emphasis on the Great Lakes. J. Great Lakes Res. 10(3):251-253.
- Bennett, G. W. 1950. Experimental largemouth bass management in Illinois. Trans. Am. Fish Soc., 80: 231-239.
- Besler, D. A. 1999. Utility of scales and whole otoliths for aging largemouth bass in North Carolina. Proc. Annu. Conf. Southeast. Assoc. Fish & Wildl. Agencies 53:119-129.
- Black, J. J. and Baumann, P. C. 1991. Carcinogens and cancers in freshwater fishes. Environmental Health Perspectives 90: 27-33.
- Blazer, V. S, C. S. Schrank 1995. Malignant lymphoma in black bullhead from Allouez Bay, Superior, Wisconsin, USA. Dis. Aquat. Org. 23:229-234.
- Buckmeier, D. L. and R. G. Howells, 2003. Validation of otoliths for estimating ages of largemouth bass to 16 years. North American Journal of Fisheries Management 23:590-593

- Campbell R. D. and B. A. Branson 1978. Ecology and population dynamics of the black bullhead, *Ictalurus melas* (Rafinesques), in central Kentucky. Tulane Stud. Zool. Bot. 20(3-4):99-136.
- Carlander, K. D. 1969. Handbook of freshwater fishery biology. Vol.1. Life history data on freshwater fishes of the United States and Canada, exclusive of the Perciformes. Iowa St. Univ. Press. Ames. 752 p.
- Carlander, K. D. 1977. Handbook of freshwater fishery biology. Vol.2. Life history data on centrarchid fishes of the United States and Canada. Iowa St. Univ. Press. Ames. 431 p.
- De Vault, D. S 1985. Contaminants in fish from Great Lakes harbors and tributary mouths. Arch. Environ. Contam. Toxicol. 14:587-594.
- Eoff, J. 1855. On the habits o the black bass of the Ohio. IXth Annual Report of the Board of Regents of the Smithsonian Institution, 289-290.
- Forney, J. L. 1955. Life history of the Black bullhead, *Ameiurus melas* of Clear Lake Iowa. Iowa State Journal of science 30:145-162.
- George, E. L. and W. F. Hadley 1979. Food and habitat partitioning between rock bass (*Ambloplites rupestris*) and smallmouth bass (*Micropterus dolomieu*) young of the year. Trans. Am. Fish. Soc. 108: 253-261.
- Glodek, G.S. 1980. *Ictalurus melas* (Rafinesque), Black Bullhead, pp. 441 in Lee, et al. Atlas of North American Freswater Fishes. N.C. State Mus. Nat. His., Raleigh. i-r + 854 pp.
- Green, D.M. and R.C. Heidinger. 1994. Longevity record for largemouth bass. Trans. Am. Fish Soc. 14(2): 464-465.
- Heidinger, R. C. 1975. Life history of the largemouth bass, p 11-20, In: HR.H. Stroud and H. Cleppers, eds. Black bass biology and management. Sport Fisheries Inst., Washington DC.
- Hodgson, J. R. and J. F. Kitchell 1987. Opportunistic foraging by largemouth bass (*Micropterus salmoides*). Amer. Mid. Natur. Vol 118 No.2 323-336.
- Hoyer, M. V., J. V. Shireman, and M. J. Maceina. 1985. Use of otoliths to determine age and growth of largemouth bass in Florida. Trans. Amer. Fish. Soc. 114:307-309.
- Hyslop, E.J. 1980. Stomach contents analysis-a review of methods and their Application. J. Fish Biol. 17: 411-429
- Kutkuhn, J. K. 1955. Food and feeding habits of some fishes in a dredged Iowa Lake. Proc. Iowa Acad. Sci 62:576-588.

- La Monte, F. 1958. North American Game Fishes. Doubleday and Company, Garden City, NY, 206 pp.
- Lee, D.S., 1980. *Micropterus salmoides* (Lacepede) Largemouth bass, pp. 608 in Lee, et al. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History, Raleigh. x+854 pp.
- Lewis, W. M., and D. R. Helms. 1964. Vulnerability of forage organisms to largemouth bass. Trans. Amer. Fish. Soc. 93:315-318
- Long, J. M., and W. L. Fisher. 2001 Precision and bias of largemouth, smallmouth, and spotted bass ages estimated from scales, whole otoliths, and sectioned otoliths. North Am. J. Fish. Manage. 3:636-645
- Maraldo, D. C. and H. R. MacCrimmon 1979. Comparison of aging methods and growth rates on largemouth bass, *Micropterus salmoides* Lacepede, from northern latitudes. Environ. Biol. Fish. 3:263-271
- Mayhew, J. K. 1969. Age and growth of flathead catfish in the Des Moines River, Iowa. Trans. Am. Fish. Soc. 98:118-120.
- Mraz, D., S. Kmiotek, and L. Frankenberger. 1961. The Largemouth bass, its life history, ecology and management. Wisc. Conserv. Dep. Publ. 232. 15 pp.
- Parkos J. J. and D. H. Wahl. 2010. Intra- and intersystem variation in largemouth bass recruitment: reproduction, prey availability, and the timing of year-class establishment. Trans. Amer. Fish. Soc. 139:1372-1385.
- Pflieger, W.F. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, 343 pp.
- Reighard, J. 1906. The breeding habits, development and propagation of the black bass *Micropterus dolomieu* Lacepede and *Micropterus salmoides* (Lacepede). Bull. Michigan Fish. Comm. 7, 73 pp., figs. A-K, 1-29.
- Repsys, A. J., L. Applegate, and D. C. Hales. 1976. Food and food selectivity of the black bullhead, *Ictalurus melas*, in Lake Poinsett, South Dakota. J. Fish. Res. Bd. Can. 33(4):768-775.
- Sneed, K. E. 1951. A method for calculating the growth of channel catfish, *Ictalurus lacustris punctatus*. Trans. Amer. Fish. Soc. 80:174-183.

Table 1. Composition of the diets of largemouth bass and black bullhead from Eighteen Mile Creek, New York. Overall prey number, food volume, and food weight are means (and standard deviations). Prey frequency, number, weight (bass), and estimated volume (bullhead) are percentages of total value.

	Largemouth Bass N = 20				Black Bullhead N = 19			
% With Food	60				89			
Prey Number	0.90 (0.19)				4.16 (0.95)			
Food Volume (mm ³)	1.92 (0.58)				1.80 (0.43)			
Food Weight (g)	1.77 (0.52)				2.02 (0.47)			
Prey	Frequency	Number	Weight	RI	Frequency	Number	Volume	RI
Algae & Detritus	-	-	-	-	5	16.35	64.13	51.78
Vascular Plant	5	5.5	0.4	0.01	32	7.69	11.56	28.09
Seed	-	-	-	-	16	3.85	0.41	0.25
Bryozoa	-	-	-	-	5	11.30	0.03	0.02
Physidae	-	-	-	-	21	17.79	2.44	9.00
Ancylidae	-	-	-	-	5	1.20	0.03	T
Planorbidae	-	-	-	-	5	1.20	0.03	T
Gastropoda (UNID)	-	-	-	-	5	1.20	0.06	T
Sphaeriidae	-	-	-	-	10	2.40	0.03	0.01
Dreissenidae	5	5.5	0.2	0.01	5	1.20	0.01	T
Invertebrate (UNID)	-	-	-	-	5	8.65	0.06	0.03
Cambaridae	30	38.9	70.0	92.16	16	6.25	10.20	10.07
Aranea	5	5.5	2.2	0.07	-	-	-	-
Anisoptera	-	-	-	-	5	1.20	0.06	T
Gyrinidae	5	5.5	0.2	0.01	-	-	-	-
Coleoptera (UNID)	5	5.5	1.8	0.06	5	1.20	0.06	T
Hydroptilidae	-	-	-	-	5	1.20	0.03	T
Trichoptera (UNID)	-	-	-	-	16	3.85	0.12	0.07
Chironomidae	-	-	-	-	16	3.85	0.09	0.05
Diptera (pupae)	-	-	-	-	5	1.20	0.03	T
Insecta (UNID)	-	-	-	-	5	1.20	0.03	T
Cyprinidae	5	5.5	6.6	0.20	-	-	-	-
Centrarchidae	5	5.5	3.8	0.12	5	1.20	2.35	0.14
Percidae	-	-	-	-	5	1.20	2.94	0.17
Perciform (UNID)	-	-	-	-	5	1.20	0.23	0.01
Fish (UNID)	20	22.2	14.7	7.36	5	1.20	0.03	T
Vertebrate (UNID)	-	-	-	-	5	1.20	5.00	0.30
Total	n/a	99.6	99.9	100	n/a	98.8	99.96	99.99

Table 2. Ages and corresponding sizes of largemouth bass and black bullhead from Eighteen Mile Creek, New York. Values reported are means (and standard deviations).

Age	Largemouth Bass				Black bullhead			
	N	TL mm	Weight g	K	N	TL mm	Weight g	K
II	-	-	-	-	2	246.3 (28.8)	180.0 (48.0)	1.20 (0.10)
III	-	-	-	-	7	269.7 (10.9)	260.6 (40.4)	1.32 (0.12)
IV	9	325.3 (26.4)	537.8 (139.2)	1.54 (0.09)	6	271.2 (23.9)	289.7 (93.8)	1.41 (0.12)
V	9	347.1 (34.1)	648.4 (216.1)	1.50 (0.14)	1	272	264	1.31
VI	1	368	790	1.58	-	-	-	-
VII	-	-	-	-	1	282	450	2.01

Table 3. Total lengths of largemouth bass and black bullhead from Eighteen Mile Creek compared with previous studies of populations in the north United States. Ranges are minimum and maximum size observed. Numbers in parentheses are central 50% of observations.

Age	Largemouth bass		Black bullhead		
	This study	Carlander, 1977 NY, NJ, PA	This study	Forney, 1955 IA	Carlander, 1969 WI
II	-	-	226, 267	122-218	157-216
III	-	-	254-282	178-267	150-267
IV	284-368	190-457 (297-353)	241-302	157-246	239-295
V	287-381	226-480 (309-395)	272	203-310	-
VI	368	221-493 (340-450)	-	-	-
VII	-	-	282		

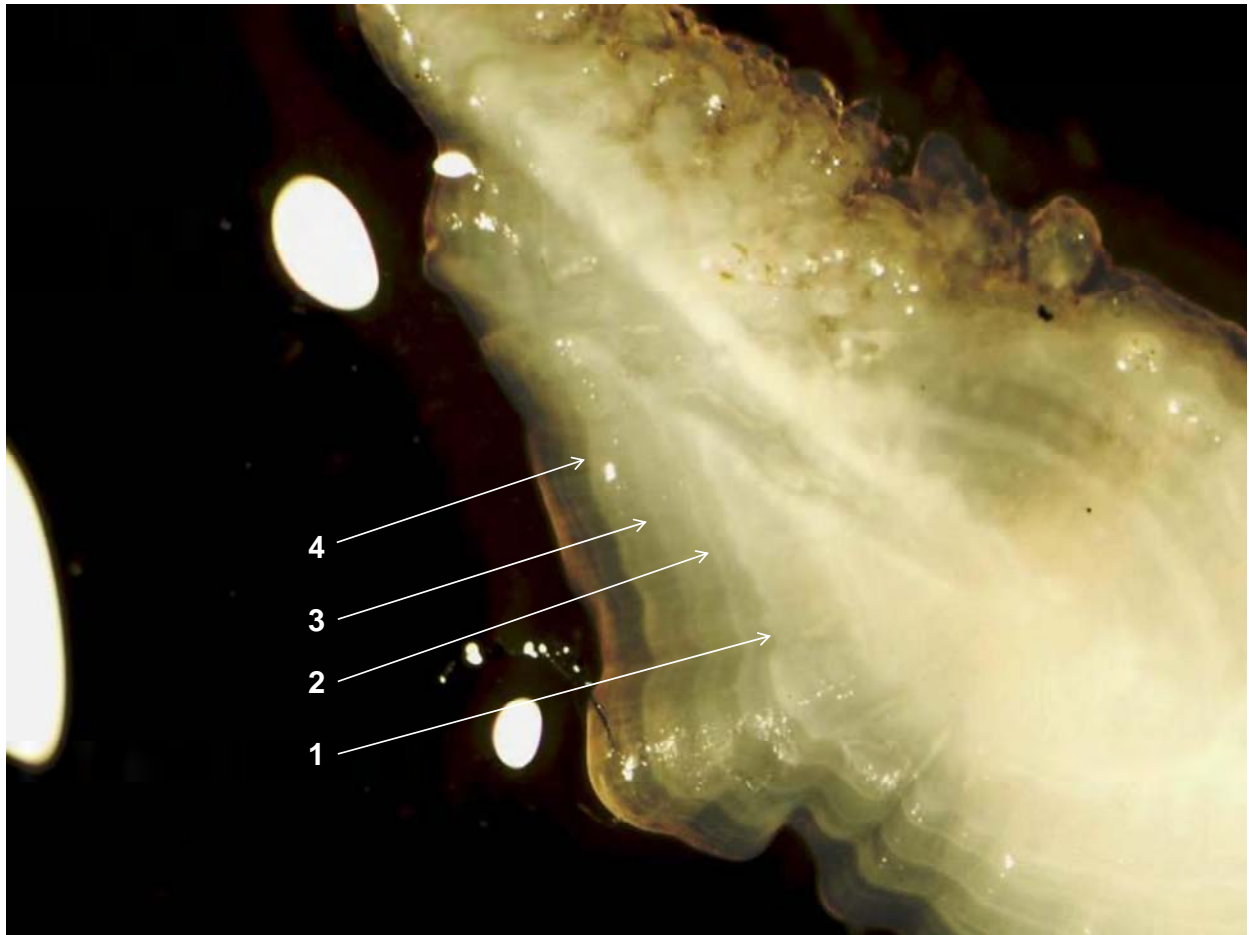


Figure 1. Whole otolith of an Age IV largemouth bass from Eighteen Mile Creek.

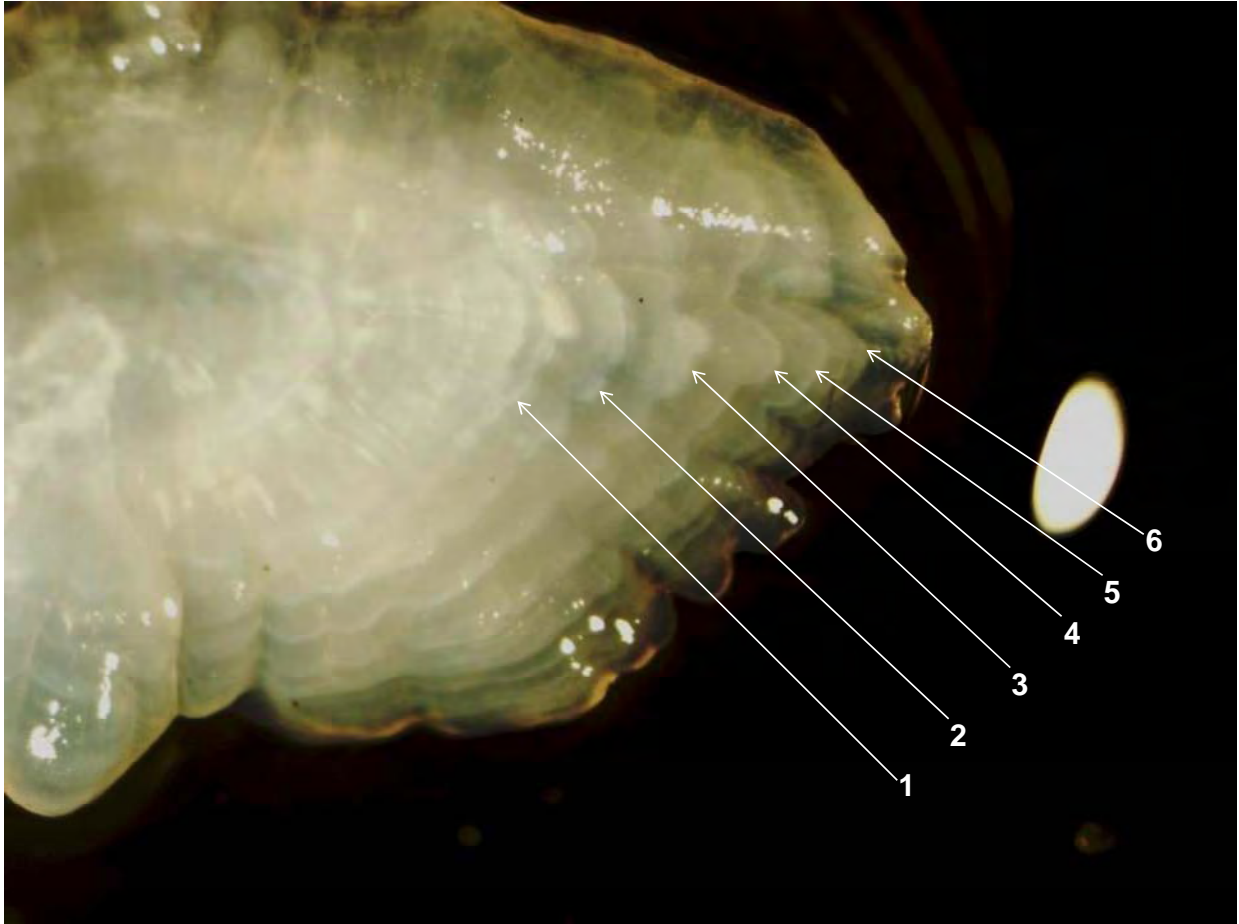


Figure 2. Whole otolith of an Age VI largemouth bass from Eighteen Mile Creek.

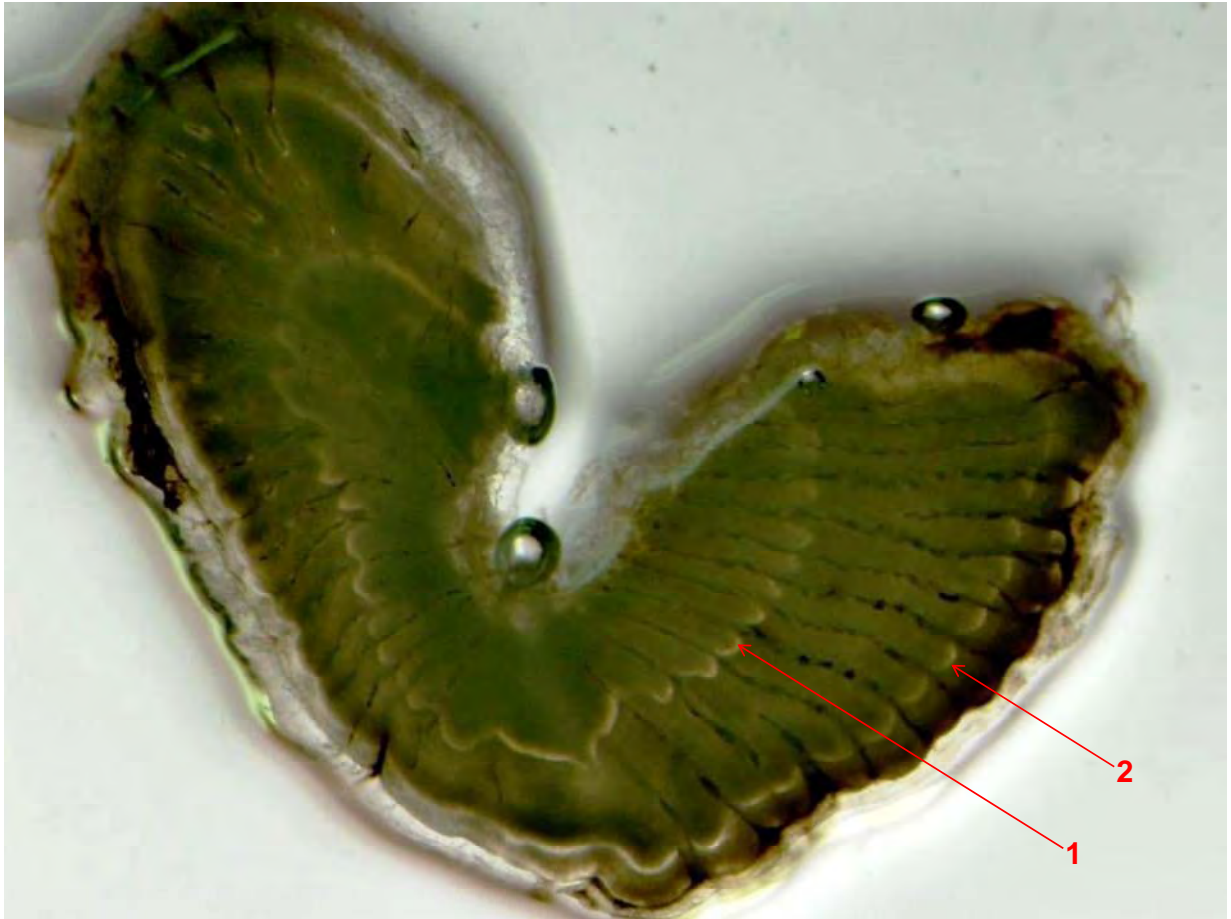


Figure 3. Cross section of a pectoral spine from an Age II black bullhead from Eighteen Mile Creek.

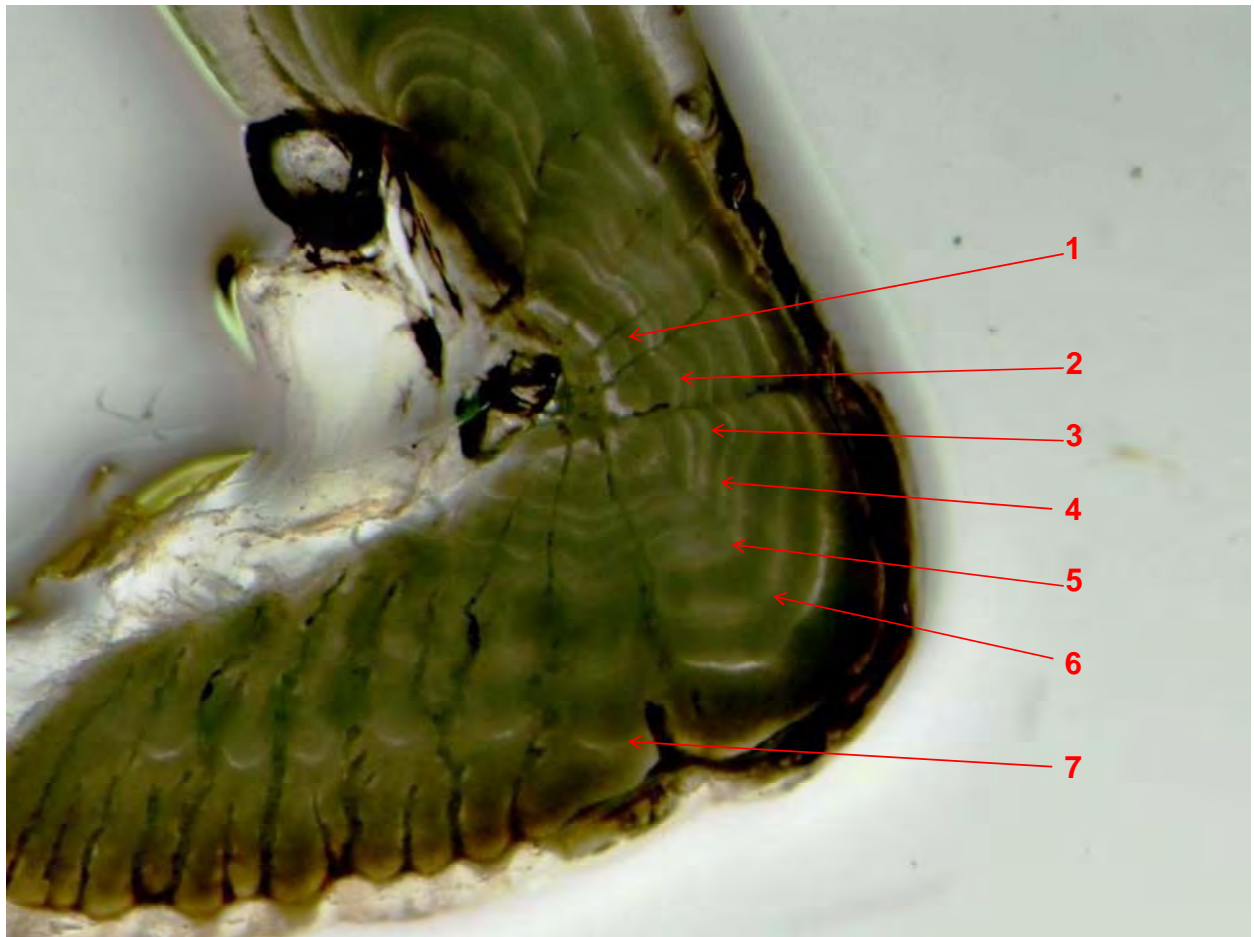


Figure 4. Cross section of a pectoral spine of an Age VII black bullhead from Eighteen Mile Creek.

APPENDIX 9

INDIVIDUAL FISH AND SEDIMENT SAMPLES USED IN MODELING FOR EIGHTEENMILE CREEK

SEDIMENT DATA FOR EIGHTEENMILE CREEK

Sum of Congeners

Sample ID	Section	Reach	ug/kg dw	TOC %	ug/kg TOC norm
EMC - 1	1		773	1.9	40681
EMC - 2	1		833	1.5	55551
EMC - 3	1		794	1.5	52926
EMC - 4	1		296	1.6	18499
EMC - 5	1		537	1.45	37028
EMC - 6	1		357	1.3	27446
EMC - 7	1		301	1.4	21486
EMC - 8	1		628	1.4	44862
EMC - 9	1		746	1.5	49716
EMC - 10	1		1955	3.8	51452
EMC - 11	1		1026	2.3	44615
EMC - 12	1		950	1.95	48707
EMC - 13	1		178	1.4	12739
EMC - 14	1		21	1.3	1587
EMC - 15	1		113	0.69	16446
EMC - 16	1		106	0.74	14335
R2-001-V-Z1P2	2	R2	1950	4.46	43722
R2-002-V-Z1P	2	R2	2420	4.62	52381
R2-003-V-Z1P2	2	R2	1850	4.38	42237
R2-004-V-Z1P2	2	R2	1760	4.23	41608
R2-005-V-Z1P	2	R2	1670	9.31	17938
R2-006-V-Z1P2	2	R2	1420	4.65	30538
R2-007-V-Z1P2	2	R2	2400	5.11	46967
R2-008-V-Z1P	2	R2	2060	4.55	45275
R2-009-V-Z1P2	2	R2	2590	3.72	69624
R2-010-V-Z1	2	R2	2980	5.52	53986
R2-011-V-Z1	2	R2	2800	3.2	87500
R2-012-V-Z1	2	R2	2360	4.89	48262
R2-013-V-Z1	2	R2	2770	5.3	52264
R2-014-V-Z1	2	R2	2950	6	49167
R2-015-V-Z1	2	R2	2100	3.17	66246
R3-016-V-Z1	2	R3	8300	7.09	117066
R3-017-V-Z1	2	R3	2440	3.4	71765
R3-018-V-Z1	2	R3	3350	5.74	58362
R3-019-V-Z1	2	R3	2500	6.14	40717
R3-020-V-Z1	2	R3	3840	4.73	81184
R3-021-V-Z1	2	R3	27	0.971	2781
R3-022-V-Z1	2	R3	4440	2.16	205556
R3-023-V-Z1	2	R3	2	2.46	71
R3-024-V-Z1	2	R3	5450	6.25	87200
R3-025-V-Z1	2	R3	53	0.34	15618
R3-026-V-Z1	2	R3	4450	4.74	93882

R3-027-V-Z1	2	R3	2350	4.71	49894
-------------	---	----	------	------	-------

FISH DATA FOR EIGHTEENMILE CREEK

Sample ID	Section	Reach	Species	Percent Lipid	Sum of Congeners	
					mg/kg ww	mg/kg LipNorm
18 - A1R1 - BB8	1	1	BB	1.54	0.73	47.62
18 - A1R1 - BB9	1	1	BB	2.01	0.97	48.30
18 - A1R1 - BB6	1	1	BB	4.05	1.61	39.67
18 - A1R1 - BB7	1	1	BB	0.55	0.42	76.62
18 - A1R3 - BB5	1	3	BB	3.34	2.11	63.07
18 - A1R3 - BB4	1	3	BB	2.44	0.94	38.56
18 - A1R3 - BB1	1	3	BB	1.97	0.89	45.10
18 - A1R3 - BB2	1	3	BB	4.39	1.67	38.04
18 - A1R3 - BB3	1	3	BB	5.45	1.54	28.20
18 - A2R2 - BB1	2	2	BB	1.49	1.11	74.20
18 - A2R2 - BB9	2	2	BB	4.22	6.32	149.69
18 - A2R2 - BB2	2	2	BB	2.17	2.60	119.68
18 - A2R2 - BB3	2	2	BB	4.8	1.16	24.11
18 - A2R2 - BB5	2	2	BB	4.54	3.16	69.67
18 - A2R2 - BB8	2	2	BB	4.07	2.68	65.75
18 - A2R2 - BB4	2	2	BB	2.46	2.41	97.85
18 - A2R2 - BB10	2	2	BB	3.39	2.26	66.79
18 - A2R2 - BB6	2	2	BB	2.36	2.63	111.60
18 - A2R2 - BB7	2	2	BB	3.45	3.17	92.02
18 - A1R1 - LMB9	1	1	LMB	4.9	0.74	15.00
18 - A1R1 - LMB10	1	1	LMB	2.17	0.89	41.05
18 - A1R1 - LMB1	1	1	LMB	2.56	4.27	166.84
18 - A1R2 - LMB4	1	2	LMB	3.71	2.20	59.36
18 - A1R2 - LMB5	1	2	LMB	2.08	6.26	301.08
18 - A1R2 - LMB3	1	2	LMB	2.51	1.34	53.42
18 - A1R2 - LMB2	1	2	LMB	1.28	1.33	103.63
18 - A1R3 - LMB7	1	3	LMB	2.74	3.87	141.08
18 - A1R3 - LMB8	1	3	LMB	1.21	2.37	196.20
18 - A1R3 - LMB6	1	3	LMB	4.65	1.35	29.12
18 - A2R1 - LMB2	2	1	LMB	5.1	10.70	209.78
18 - A2R1 - LMB3	2	1	LMB	2.53	1.80	71.05
18 - A2R1 - LMB1	2	1	LMB	3.83	34.59	903.03
18 - A2R2 - LMB10	2	2	LMB	1.91	2.75	143.80
18 - A2R2 - LMB8	2	2	LMB	3.34	6.28	187.95
18 - A2R2 - LMB6	2	2	LMB	3.23	5.74	177.60
18 - A2R2 - LMB4	2	2	LMB	2.92	5.48	187.50
18 - A2R2 - LMB9	2	2	LMB	3.24	6.63	204.52
18 - A2R2 - LMB5	2	2	LMB	1.58	5.00	316.32
18 - A2R2 - LMB7	2	2	LMB	1.67	7.42	444.46
18 - A1R1 - PKN10	1	1	PKSD	2.22	1.57	70.56
18 - A1R1 - PKN8	1	1	PKSD	3.17	1.19	37.41
18 - A1R1 - PKN9	1	1	PKSD	3.44	2.78	80.92
18 - A1R2 - PKN2	1	2	PKSD	3.62	1.41	39.06

18 - A1R2 - PKN3	1	2	PKSD	2.21	1.94	87.70
18 - A1R2 - PKN1	1	2	PKSD	3.82	3.76	98.35
18 - A1R3 - PKN5	1	3	PKSD	3.85	1.90	49.27
18 - A1R3 - PKN7	1	3	PKSD	2.78	1.73	62.35
18 - A1R3 - PKN4	1	3	PKSD	2.84	2.94	103.37
18 - A1R3 - PKN6	1	3	PKSD	3.32	5.07	152.67
18 - A2R2 - PKN2	2	2	PKSD	2.36	2.01	85.33
18 - A2R2 - PKN1	2	2	PKSD	2.24	0.88	39.07
18 - A2R2 - PKN3	2	2	PKSD	2.04	4.35	213.35
18 - A2R2 - PKN6	2	2	PKSD	1.18	2.92	247.73
18 - A2R2 - PKN8	2	2	PKSD	2.09	2.52	120.75
18 - A2R2 - PKN10	2	2	PKSD	1.02	2.35	230.63
18 - A2R2 - PKN7	2	2	PKSD	1.66	3.62	218.26
18 - A2R2 - PKN9	2	2	PKSD	2.02	2.28	112.73
18 - A2R3 - PKN4	2	3	PKSD	1.4	0.83	59.25
18 - A2R3 - PKN5	2	3	PKSD	1.18	2.55	216.40

APPENDIX 10

SPECIES PROFILES FOR THE RECEPTORS OF CONCERN

LARGEMOUTH BASS

The largemouth bass, *Micropterus salmoides*, is a relatively large, robust fish that has a tolerance for high temperatures and slight turbidity (Scott and Crossman 1973). It occupies waters with abundant aquatic vegetation. Largemouth bass show a low tolerance for low oxygen conditions. The largemouth bass represents a top predator in the aquatic food web, consuming primarily fish but also benthic invertebrates.

Foraging

Young largemouth bass feed on algae, zooplankton, insect larvae, and microcrustaceans (Boreman 1981). Largemouth bass can grow to 136 grams on a diet consisting of insects and plankton. Larger prey is needed to continue growth after reaching a total length of 20 mm. Young largemouth bass compete for food with a variety of other warmwater and bottom-feeding fishes.

Johnson (1983) found that the diets of juvenile fish foraging in the St. Lawrence River varied somewhat by location and length of the fish. Fish, insects including corixids, and other invertebrates made up the diets in varying proportions.

Largemouth bass longer than 50 mm total length usually forage exclusively on fish. Observed prey species include gizzard shad, carp, bluntnose minnow, silvery minnow, golden shiner, yellow perch, pumpkinseed, bluegill, largemouth bass, and silversides. (Scott and Crossman 1973). Cannibalism is more prevalent among largemouth bass than among many species. Ten percent of the food of largemouth bass 203 mm and longer is made up of their own fry (Scott and Crossman 1973).

Largemouth bass take their food at the surface during morning and evening, in the water column during the day, and from the bottom at night. They feed by sight, often in schools, near shore, and almost always close to vegetation. Feeding is restricted at water temperatures below 10°C and decreases in winter and during spawning. Largemouth bass do not feed during spawning.

Information on feeding habits of largemouth bass in the upper Hudson River was obtained for 73 juvenile and adult fish collected in Spring 1997 by the New York Department of Environmental Conservation and analyzed by Menzie-Cura & Associates. Thirty-one of the bass (42%) had fish remains in their digestive system and represented the most common food item for adult bass. Crayfish were eaten occasionally at most river locations. However, six of twenty bass collected at Catskill Creek had eaten crayfish. Primarily benthic invertebrates were observed in the diet of juvenile bass. On the basis of the available data it is estimated that fish comprise between 75 and 90% of the diet. The spring 1997 data indicate that the balance of the diet is made up of benthic invertebrates.

Further gut content analyses of 32 adult largemouth bass from the Hudson River in Fall 1997 and 21 bass collected from in Spring 1998 show similar results. Thirty-one of the bass (58%) had fish in their digestive systems and crayfish were occasionally eaten. Smaller invertebrates (insects and crustaceans) were commonly present. Frogs were also occasionally eaten.

Largemouth bass feed on a variety of invertebrates that inhabit sediments, live on plants, or are part of the zooplankton. Predominant invertebrate species observed in the gut contents of bass include amphipods (both *Hyallorella* and *Gammarus*), isopods (*Caecidotea*), cladocerans (*Bosmina*, *Chydorus*, *Eurycercus*, and *Simocephalus*), cyclopoid copepods, ostracods (e.g., *Podocopa*), and some chironomid larvae. The crustacea observed include a number of species that inhabit the water column (e.g., *Bosmina*), occupy the littoral area and also open water (e.g., *Chydorus sphaericus*), and live in close association with surface sediments (e.g., *Gammarus* and *Caecidotea*). The amphipod *Gammarus* spp. also occur in the plankton of the river and are likely influenced by both water and surficial sediment exposures. The isopod is probably a surface deposit feeder and is also likely influenced by surface water as well as surficial sediment exposure.

On the basis of the available data, we estimate that fish comprise between 75 and 90% of the average adult largemouth bass diet. The balance of the diet is made up primarily of invertebrates including crayfish. Our estimates consider the relative size of the prey organisms as well as the frequency of prey animals in the diet. Terrestrial animals are also occasionally eaten. A qualitative assessment of data from the Hudson River suggests that 54% and 68% of the invertebrates are associated with sediments and 34 to 46% are associated with water. Invertebrates associated with sediments such as amphipods and isopods are also likely influenced by water exposures. The extent to which water or sediment affect the body burdens of surface deposit feeders and meroplanktonic animals such as *Gammarus* is not known.

Range, Movement and Habitat

Largemouth bass have distinct home ranges and are generally found between 8 and 9 kilometers of their preferred range (Kramer and Smith 1960). Kramer and Smith found that 96 percent of the fish remained within 91 meters of their nesting range. Fish and Savitz (1983) found that bass in Cedar Lake, Illinois, have home ranges from 1,800 to 20,700 square meters. The average home range was 9,245 square meters and the average primary occupation area, defined as that area within the home range in which the fish spends the majority of its time, including foraging, was 6,800 square meters.

Largemouth bass are almost universally associated with soft bottoms, stumps, and extensive growths of a variety of emergent and submerged vegetation, particularly water lilies, cattails, and various species of pond weed. It is unusual to find largemouth bass in rocky areas. Largemouth bass are rarely caught at depths over 20 feet, although they often move closer to the bottom of the river during the winter.

Mobility of largemouth bass also varies seasonally. Daily movements increase with temperature from March through June, but decrease sharply during the hottest months (Mesing and Wicker 1986). Activity during warmer seasons occurs primarily near dawn and dusk, while cool-water activity is most extensive in the afternoon.

Largemouth bass prefer to establish habitats near dense vegetation not just during winter, primarily near milfoil (*Myriophyllum verticillatum*) (Carlson 1992). A study of largemouth bass in two freshwater lakes in central Florida found a positive correlation between the use of specific habitats in proportion to the availability of those habitats to the fish (Mesing and Wicker 1986).

Vegetative habitat covers included *Panicum* spp., cattails (*Typha* spp.), and water lilies (*Nuphar* spp.).

Reproduction

Largemouth bass mature at age five and spawn from late spring to mid-summer, in some cases as late as August. Male largemouth bass construct nests in sand and/or gravel substrates in areas of nonflowing clear water containing aquatic vegetation (Nack and Cook 1986). This aquatic vegetation generally consists of water chestnut (*Trapa natans*), milfoil (*Myriophyllum verticillatum*), and water celery (*Valisneria americana*).

Females produce 2,000 to 7,000 eggs per pound of body weight (Smith 1985) and leave the nest after spawning.

BROWN BULLHEAD

The brown bullhead, *Ictalurus nebulosus*, is a demersal omnivorous species occurring near or on the bottom in shallow, warmwater situations with abundant aquatic vegetation and sand to mud bottoms. Brown bullhead are sometimes found as deep as 40 feet, and are very tolerant of conditions of temperature, oxygen, and pollution (Scott and Crossman 1973).

Foraging

The brown bullhead feeds on or near the bottom, mainly at night. Adult brown bullhead are truly omnivorous, consuming offal, waste, molluscs, immature insects, terrestrial insects, leeches, crustaceans including crayfish and plankton, worms, algae, plant material, fishes, and fish eggs. Raney and Webster (1940) found that young bullheads in Cayuga Lake near Ithaca, New York fed upon crustaceans, primarily ostracods and cladocerans, and dipterans, mostly chironomids. For brown bullhead in the Ottawa River, algae have also been noted as a significant food source (Gunn et al. 1977).

Another study conducted in the Hudson River near Newburgh (LMS 1975) showed that brown bullhead displayed a varied and seemingly opportunistic feeding behavior. Smaller bullheads (size interval I) ate primarily chironomid insect larvae, amphipods., odonata, and oligochaete worms. Larger bullheads displayed a similar feeding behavior but also ate young-of-the-year fish. Observations made on gut contents of brown bullheads collected in the Kingston area indicated that oligochaete worms were a major part of the diet.

Further Hudson River brown bullhead stomach contents analyses indicate that the diet reflects a large benthic invertebrate component. Only one fish was observed in a gut of one bullhead. The data indicate that predominant prey items for bullheads included small clams, amphipods (*Gammarus*), isopods (*Caecidotea*), a few of the cladoceran species, and chironomid insect larvae that are typically considered to burrow into sediments (e.g., *Procladius*). It was also observed that the diet of brown bullhead frequently contain oligochaete setae (worms are usually quickly digested or unidentifiable).

Data for the Hudson River show that 71 to 83% of the invertebrates found in brown bullhead stomachs were associated with sediments and 17 to 29% were associated with water. Because

oligochaete worms may be a major food item, the benthic percentage is probably even higher and estimated to be as high as 95%. Data for the lower Hudson reported by LMS (1974) also support a high component of the diet as benthic in nature in that a large component was comprised of oligochaete worms. These organisms are digested more quickly than insects and crustaceans and are probably underrepresented in typical stomach content analyses. Fish are considered to be a minor component of the diet (less than 5%).

Range, Movement and Habitat

Brown bullhead, a freshwater demersal fish, resides in water conditions that are shallow, calm and warm. In the summer, bullheads can be found in coves with ooze bottoms and lush vegetation, especially water clover, spatterdock and several species of pond weed (Raney 1967). Carlson (1986) found that the vegetated backwaters and offshore areas are the most common habitats for brown bullheads. McBride (1985) found bullhead abundant in river canal pools. Brown bullheads prefer wetlands, embayments, and shallow habitats. Carlson (1986) found bullheads most frequently in backwaters, but also in other, deeper areas such as the channel border. This species prefers silty bottoms, slow currents, and deeper waters.

Reproduction

Brown bullheads reach maturity at two years and spawn for two weeks in the late spring and early summer. Smith (1985) noted that in New York, brown bullheads spawn when water temperatures reach 27°C in May and June.

They prefer to spawn among roots of aquatic vegetation, usually near the protection of a stump, rock or tree, near shores or creek mouths. Males, sometimes aided by females, build nests under overhangs or obstructions (Smith 1985). Eggs are guarded.

BELTED KINGFISHER (*Ceryle alcyon*)

The belted kingfisher is distinguished by a blue-gray dorsal plumage and mostly white underparts, a large, heavy bill, and a double peaked crest of feathers on the crown. It has a white throat and a broad white and blue-gray collar around the neck, a small white spot near the eye, and is spotted on the ventral portion of the wings and tail. The ventral side of the tail feathers remains distinctly barred with gray and white banding. The sole distinctive plumage characteristic between the sexes is the presence of a distinct rufous band crossing the chest in the female. Kingfishers have broad wing areas relative to their body size and fly with a wing beat characteristic of a deep and rapid irregular pace (Farrand 1983). Across their North American range adults are 31.0 to 36.0 cm total length (Farrand 1983), and weigh 136.0 to 155.0 gms (Brooks and Davis 1987; Dunning 1993; Poole 1938).

Habitat, Home Range, and Migration

Belted kingfishers are found along the shoreline of rivers, streams, ponds, and lakes, including both freshwater and brackish areas. The kingfisher diet is almost exclusively aquatic prey items and nesting usually occurs in close proximity to feeding areas. Preferred riparian areas include areas with mature woody vegetation with numerous overhangs above the water surface. The overhangs are critical for use as perching posts from which aquatic prey may be observed. Clear

water conditions assist in prey capture (Bent 1940). Artificial perches for feeding include overhead wires above the water surface and bridges.

Typically the streams and rivers selected for feeding areas are larger (4 to >16 m) permanent lotic environments with a diverse assemblage of microhabitats (i.e., riffles, pools, runs etc.) of varying depths (0.17-0.50 m) (Brooks and Davis 1987). Banks can be steep or gradual in inclination and remain well vegetated. Feeding can occur in aquatic microhabitats with higher water velocities (i.e., riffles and runs) or more quiescent conditions (i.e., pools and runs). Generally feeding occurs in both lentic and lotic habitats, although lotic environments appear to be favored (Brooks and Davis 1987). Nesting always occurs in a cavity in close proximity to the feeding area. Nesting occurs in cavities that have been excavated in the steep, exposed banks of the shoreline or in riparian areas associated with the feeding habitat. Use of abandoned woodpecker holes and wood duck nests has been documented but are uncommon relative to earthen cavity sites (Andrle and Carroll 1988). The vertical inclination and height of the embankment slope appears to be a critical factor and may act as a deterrent to predators, allow for easy excavation, and prevent the nest from flooding during high flows. Brooks and Davis (1987) observed an average inclination of 55 to 89% and a height of one to two meters above the ground in nest embankments in Ohio and Pennsylvania populations. Eroded tracks at the base of the hole from the adults dragging their feet in flight when entering the nest cavity are characteristic of kingfisher nests. Embankments subject to severe erosion and rock outcrops are characteristics that may limit nest site selection. Suitable nest sites appear to be a limiting factor in the distribution of mating pairs (Brooks and Davis 1987). Home range is typically defined by length of shoreline defended by mated pairs (breeding territory) and feeding areas defended by solitary adults (non-breeding). Generally, breeding pairs defend a larger habitat than solitary individuals, although considerable overlap in size occurs. Davis (1982) reported that non-breeding individuals occupied an average home range of 0.39 km of shoreline and that breeding pairs defend an average home range of 1.03 km of shoreline in Pennsylvania and Ohio populations. NYS populations are expected to occupy similar home ranges.

The kingfisher is native throughout North America. In NYS, the kingfisher can be both a seasonal migrant or a resident species throughout the year. Migrations in the northeast are dependent upon the severity of the winter season, in particular the degree of ice cover on feeding waters. During severe conditions (i.e., persistent cold and continuous ice cover) northeast populations will migrate as far south as portions of the Carolinas and Virginia. Fall migration in NYS occurs from September through October and spring migration occurs from April through June (Bent 1940). During milder winters, the kingfisher can remain in NYS as long as a steady food supply is available and aquatic habitats remain free of ice (USEPA 1993b). Annual residence time of this species in NYS ranges from 245 days/year (migrants) to 365 days/year (full time resident).

Feeding Habits and Diet

Throughout their North American range belted kingfishers are opportunistic piscivores with smaller fish species dominating the diet and larger aquatic invertebrates like crayfish supplementing the diet. While amphibians, reptiles, and small mammals have been documented as occurring in the diet, wholly aquatic prey (fish and crayfish) are the principal diet components in northeast populations (USEPA 1993b).

Kingfishers locate aquatic prey by perching above the water surface and visually detecting the prey. All feeding occurs by sight with detection of prey being based upon movement. Capture of aquatic prey consists of the kingfisher diving from its perch into the water and physically seizing the prey with its bill. Prey detection and capture occurs within a few inches of the water surface (Davis 1982). Water turbidity is thought to contribute to feeding success. A reduction in feeding duration during peak or storm flow periods has been observed (Brooks and Davis, 1987). Diet studies of northeast and central North American populations (Michigan, New York, Pennsylvania, and Ohio) indicate that the typical diet of belted kingfishers ranges from 46-100% fish, 5-41% crayfish and other aquatic invertebrates, and 0-6% amphibians, reptiles or small mammals (USEPA 1993b). Stomach content analyses from 25 individuals from south-central NYS revealed an average diet of 72% fish, 22% crayfish/invertebrates, and 6% amphibian/reptiles (Gould, unpublished data cited in USEPA 1993b). Comparison of these data to the observed North American range shows the diets to be comparable. Fish consumed from NYS waters include salmonids, cyprinids, percids, ichthyocids and centrarchids (USEPA, 1993b). Prey species selectivity appears to be based upon local abundance within the aquatic community rather than species specificity. Davis (1982) observed that all fish captured by belted kingfishers in Ohio and Pennsylvania populations ranged from 4.0 to 14.0 cm in length. It is anticipated that NYS kingfisher populations would have similar size selectivity.

Reproduction

Males typically arrive prior to females and select and defend a breeding territory. Kingfishers are highly territorial and do not congregate in large numbers (Davis 1982). Because of limitations of suitable excavation/nest sites breeding pairs may nest some distance away from the foraging area (Andrle and Carroll 1988). The male and female excavate a cavity in an earthen tunnel for nesting. Tunnels are circular 8.9 to 10.0 cm wide and 7.6 to 8.9 cm high and can be excavated into the embankment up to 4.6 meters. Established breeding pairs often return to the same excavated nest cavities year after year. Excavations are often associated with other species that use earthen cavities to nest, including bank swallows (*Riparia riparia*) and rough winged swallows (*Stelgidopteryx serripenniss*). Nests are devoid of nest lining material and eggs are laid on the earthen floor (Andrle and Carroll 1988). Although belted kingfishers prefer areas with as little disturbance as possible for nest site locations, they will tolerate human incursion and have been found nesting in roadway cuts and gravel and sand quarries (Hamas 1974). Eggs in NYS populations are laid from April to June and a single brood is common (Andrle and Carroll 1988). Five to eight eggs are generally laid in North American kingfishers (Peterson 1980). Incubation lasts approximately 17 to 24 days in NYS. Both male and female feed the nestlings. At hatching, nestlings typically weigh 10.0 to 12.0 gms and grow at a rate of five to six grams per day. At fledgling, generally occurring from July through August, individuals weigh 149 to 169 gms (Brooks and Davis 1987). The diet of nestlings and fledglings is comparable to the adult diet.

GREAT BLUE HERON (*Ardea herodias*)

The great blue heron is the largest heron species (order Ciconiiformes) indigenous to NYS. It is a common wading bird that inhabits both freshwater and estuarine portions of rivers throughout

the state. The USFWS considers it a migratory, non-game avian species. NYS populations are monitored by the NYSDEC Non-game Species Program.

The sexes are similar in body size, wing span and coloration, although males are slightly larger in body mass and wing span than females (Peterson 1980). Body size ranges 104.0 to 132.0 cm with a wing span of 1.8 to 2.2 m and a height of 1.2 to 1.5 m (Farrand 1983). Dunning (1993) lists average body masses as 2,576 gms for males and 2,204 gms for females. Plumage in both sexes is identical. Adults have a white head with the sides of the crown and nape being black with short plumes projected to the rear; the neck is light gray, with a whitish ventral stripe; the bill is large and yellowish; the body is blue gray; and the legs are dark brown to black in coloration (Farrand 1983).

Habitat, Home Range, and Migration

Preferred habitats for feeding and breeding are riparian habitats along the shoreline of rivers, streams, lakes, and wetlands. These include both non-tidal and tidal portions of rivers and estuaries. When feeding along the shoreline of aquatic habitats, the great blue heron diet is composed almost exclusively of aquatic prey. It is semi-tolerant of human disturbance and is common along drainage ditches and river banks associated with human development, but will readily flush when approached on foot (Eckert and Karalus 1983). Heronries are typically located in standing trees and dead snags in secluded areas with minimal human disturbance (Andrle and Carroll 1988). Home range can be considered in terms of both distance traveled to feeding grounds from heronries and defended foraging areas used for feeding. USEPA (1993a) gives mean ranges of 3.1 to 8.0 km linear distance (max. 24.4 km). Unit areas for foraging varied by habitats with an average area of 0.6 ha in a Oregon freshwater marsh to 8.4 ha in an Oregon estuary (USEPA 1993a). No NYS home range data were available, but values are expected to be similar to those observed in other areas of the continental US.

In NYS, the great blue heron can be both a seasonal migrant or a resident species throughout the year as long as open water persists (Bull, 1998). Results of the Audubon Christmas Bird Count show that the great blue heron is an uncommon winter resident (CBC, 1999). Migrations in the northeast are highly dependent upon the severity of the winter season, primarily the degree of ice cover on feeding waters. During severe conditions (i.e., persistent cold and continuous ice cover) northeast populations will migrate south to portions of the Carolinas and Virginia. Fall migration in NYS populations remains unclear given the tendency of this species to linger or reside in summer grounds during the winter period. Fall migration may begin as early as mid-July. Spring migrants typically return to NYS habitats from late-March through early April (Bull 1998). Annual residence of this species in NYS can range up to 365 days/year for year-round residents.

Feeding Habits and Diet

The feeding behavior in great blue herons can be characterized as a stalking and ambush approach to prey capture (Eckert and Karalus 1983). Great blue herons are typically solitary hunters along shorelines of aquatic habitats. However, when prey is abundant (e.g., baitfish stranded in tidal mudflat shallows) great blue herons will congregate in large numbers to feed (Krebs 1974). Feeding typically occurs throughout the day with greatest activity occurring during dawn and dusk. Solitary feeding behaviors consists of a slow and deliberate pace in

shallow water with prey being detected based upon visible movement. Maximum depth in which feeding occurs is approximately 1.5 to 1.6 m with firm bottom substrates (USEPA 1993a).

Stomach contents of adults and nestlings from a southwestern Lake Erie population were found to consist of 100% fish with most fish eaten being less than 20 cm total length (Hoffman 1978). Fish species indigenous to the Hudson River which were found in the Lake Erie study include: carp and minnows (Cyprinidae) 50% to 53%, perch (Percidae) 10% to 28%, sunfish and bass (Centrarchidae) 7% to 10%, drum (Sciaenidae) 4% to 10%, catfish (Ictaluridae) 0% to 5%, herrings and shad (Clupeidae) 0% to 5%, and aquatic invertebrates (crayfish, aquatic insects) 5% to 31% (USEPA 1993a). While herons prefer to feed on fish, amphibians/reptiles, small mammals and insects are taken on occasion (USEPA 1993a; Eckert and Karalus 1983).

Herons capture fish by impaling them with their bill. They realign fish in the beak and then swallow them whole. Fish up to 0.6 m long and up to one kilogram can be captured and swallowed (Eckert and Karalus 1983). Krebs (1974) found that smaller prey were selected more frequently because of greater abundance and less handling time. Through field observations, Krebs categorized fish size based upon comparative size of the fish captured to the length of the herons bill (assuming a 12.7 cm bill length) using the categories of small fish (< ½ bill length), medium fish (>½ to 1 bill length), and large fish (> 1 bill length). Results of the field investigation revealed a distribution in prey size of 73.4% small fish (<6.0 cm total length [TL]); 19.4 % medium fish (approximately 6.0-13 cm TL) and 7.4 % large fish (> 13.0 cm TL).

Reproduction

Great blue herons are colonial nesters and form heronries that in NYS range from less than 50 nests to up to 1,000 nests, given optimal nesting habitats (Bull 1998; Andrle and Carroll 1988). Confirmed heronries have been found throughout NYS (Andrle and Carroll 1988). Selection of nesting sites remains highly selective with the availability of densely distributed large trees or standing snags or dense scrub, a local foraging habitat and minimal human disturbance being three of the most critical characteristics for location of heronries (Eckert and Karalus 1983). Nests vary greatly in their dimensions from flimsy new platforms of sticks 0.5 m across to bulky older structures 0.9-1.2 m across. Nests are usually 7.6 to 30.5 m above the ground (Andrle and Carroll 1988). Mating occurs from late March through early April and eggs are laid between April 15 and June 9. The nestling stage extends for approximately 60 days after hatching and fledglings leave the nest by July in NYS (Andrle and Carroll 1988).

MINK (*Mustela vison*)

The mink is a small, opportunistic, carnivore found throughout the U.S. and Canada. It is indigenous to New York State where it is considered a furbearer species and its take is regulated by NYSDEC Division of Fish, Wildlife and Marine Resources. They are semi-aquatic in habit and frequent the shoreline and shallows of rivers, lakes, streams and wetlands. Mink are dark brown in color with a white chin patch and their fur is rich in guard hairs. Mink are sexually dimorphic in body size with males being larger than females. Males range from 33 - 43 cm total body length, 18 - 23 cm tail length. Females range from 30 - 36 cm body length; 13 - 20 cm in tail length (Burt and Grossenheider 1976). Body mass in adult mink from wild populations (from across the N.A. range) by sex range: 681 - 1,233 g. males; and 567 - 586 g. females (Burt and

Grossenheider 1976, Mitchell 1961). Mitchell found adult male and female Montana mink to weigh an annual average of 1,150 g. for males and 600 g. for females. A total of twenty historical skins of this species from portions of the Hudson River Valley (Saratoga, Albany, Rensselaer, Greene, Columbia, Ulster and Dutchess Counties) are curated at the New York State Museum (NYSM) in Albany, New York. Unfortunately, morphological data recorded at the time of collection is only available for a single specimen. An adult, male mink collected from the Hudson River Valley weighed 1.1 Kg in body mass and was 59.0 cm in total length. Domestically raised mink are slightly larger in body mass for both sexes than individuals from wild populations. Hornshaw et al. (1983) reported body weights of 1,734 g. for male and 974 g. for female captive mink. The observed difference in body mass between wild and domestic populations appears related to nutritional enhancement in diets fed to captive individuals (Hornshaw et al. 1983).

Habitats and Home Range

Mink are found around stream banks, lake shores, and marshes. They tend to prefer areas where there is extensive cover and they defend large territories. In general, mink prefer wetlands and riparian habitat with irregular and diverse shorelines. They are reasonably tolerant of human disturbance but are sensitive to prey abundance which may drop in conjunction with human development (Allen 1986). Mink may also be limited by the availability of suitable den sites. In general, the upper New York State mink population size depends on the availability of wetlands and riparian habitats that are surrounded by dense woods and shrubs to provide adequate cover. Bulkheaded and channelized shorelines devoid of adequate cover are not considered significant mink habitat (Allen 1986). Regardless of the type of habitat utilized, mink dens are always associated with water and typically remain no more than 5-100 meters from a water body.

Depending upon the nature of habitat, (i.e., wetland vs. riverine), home range has been expressed either as per unit area of wetland or per length of river shoreline. Home range also varies by sex as male mink appear to defend a larger territory than females (Eagle and Whitman 1987). Gerell (1970) reported home range in lotic environments to be 1.0 to 2.8 river Km for adult males and 1.0 to 2.8 river Km for adult females. Mitchell (1961) reported a home range for adult female mink from a Montana riverine population of 7.8 Ha in heavy riparian vegetation and 20.4 Ha in sparse riparian vegetation.

Habits and Diet

Mink are nocturnal in habit, and entirely carnivorous in diet. Like other members of the weasel family, they are solitary (with exception of mating and courtship), aggressive predators and actively seek prey within their home range. They are active year round and do not hibernate. Generally, mink are opportunistic in selection of prey in their feeding habits and will exploit select prey species during periods of abundance. Mink feed primarily on small aquatic and terrestrial animals, although feeding upon prey items larger than themselves (such as waterfowl and muskrats) has been documented (Sealander 1943). Principal prey items identified from various feeding studies include muskrats, voles, rabbits, fish, frogs, crayfish, salamanders, clams, and insects (DeGraaf and Rudis, 1987, Sealander 1963). Ingestion of vegetation/soil appears incidental to feeding behaviors on other organisms (Waller 1962; Sealander 1943). Diet composition appears to be linked to both habitat and prey abundance. Hunting in aquatic

habitats occurs in shallow, near shore areas where aquatic prey is captured and then moved to the shore prior to consumption (Allen 1986, Douth et al. 1977).

Riverine populations appear to have a greater aquatic prey fraction in the diet than wetland populations. In riverine populations sampled from Michigan rivers, diets were comprised of 85% fish, 4% crayfish, 3% amphibians, 6 % birds/mammals and 2% other matter/vegetation (Alexander 1977). Hamilton (1936) in a stomach content analysis study of a sample of seventy mink trapped from throughout New York State found the winter diet of NYS mink to consist in order of frequency: 54.1% mammals; 18.8 % fish; 16.5 % crayfish; 2.4% amphibians and 7.0 % insects. Hamilton (1940) reported that the summer diet for mink in Montezuma Marsh, New York on a percentage by bulk basis consisted of 42.7% mammals; 27.3% fish; 13.9% aquatic invertebrates; 9.1% birds and 4.5% reptiles/amphibians.

Based on field observations and scat analysis, Hamilton (1940) reported that the mink fed upon fish 7.6-10.5 cm TL. The dominant species fed upon was the most abundant forage fish in Montezuma Marsh, the golden shiner (*Notemigonus crysoleucas*) and the aquatic invertebrate fraction consisted almost entirely of adult forms of aquatic beetles belonging to the Family Dytiscidae. The apparent size selectivity for smaller fish species and food web niche (i.e., an abundant forage fish) of preferred fish prey species in the mink diet observed by Hamilton is supported by the study of Gilbert and Nancekivell (1982). Gilbert and Nancekivell found that the dominant fish prey species consumed by a Montana river mink population is the brook stickleback (*Culaea inconstans*) which is an abundant, small (3.8 - 6.4 cm TL) forage fish species in the drainages studied. Both Hamilton (1940) and Gilbert and Nancekivell (1982) suggest that prey selectiveness for fish species in the mink diet are based upon abundance and size of forage species. Arnold and Fritzell (1987) found that in wetlands managed for waterfowl populations, waterfowl and muskrats appear to be the most important prey items for mink.

Mink capture aquatic prey and return to the shoreline to feed provides a mechanism for incidental ingestion of abiotic material. Ingestion of vegetation/soil appears incidental to feeding on other organisms by mink (Waller 1962; Sealander 1943). No quantitative dietary data regarding abiotic media ingestion by mink are available. Hamilton (1940) recorded minor quantities of sand (reported only as "trace") in mink scat samples collected from Montezuma Marsh, NY. On average, the frequency of occurrence of sand in the samples is 1.33%. Hamilton (1936) found grasses to occur at a relative frequency of 1.18 % in mink stomachs from NYS and Alexander (1977) speculated that such finds are incidental material ingested during consumption of animal prey. Based upon the documented presence of sand and vegetation in mink diets, and the similarity in the diets of mink and raccoons, it is assumed that incidental ingestion by mink of non-prey related material approximates 9.4%.

Hibernation/Aestivation

Mink are active during all four seasons and do not aestivate nor hibernate (Douth. et al. 1977; Alexander 1977). Populations within the study area will be active throughout the year.

Seasonal and Long Distance Migrations

Mink do not migrate on a seasonal basis, but occupy and defend a resident territory throughout the year. This excludes local movements for purposes of territoriality by adults and dispersal of

sub-adults from resident populations (Allen 1986). Populations within the study area of the Hudson River Valley are year round residents.

Reproduction

Mink build their dens below ground under fallen trees or stumps, in hollow logs, muskrat lodges or other abandoned animal dens (Allen 1986, Doult et al. 1977). They breed in the early Spring and have a gestation period of about 50 days but delay implantation of the embryos in order to give birth during the period of April to June across their range (Eagle and Whittman 1987). The kits are born naked and blind and An average litter contains an average of 3 or 4 kits (Burt and Grossenhieler 1976). Sexual maturity is typically reached by one year, although mating may occur as early as 10 months in captive populations (Burt and Grossenhieler 1976, Enders 1952). Mink have been shown to suffer reproductive failure at relatively low exposures to PCBs (Aulerich and Ringer 1977). Mink may also be limited by the availability of suitable den sites.

REFERENCES

- Alexander, G. 1977. Food of vertebrate predators on trout waters in north central lower Michigan. *Michigan Academician* 10: 181-195. In. EPA 1993a. *Wildlife Exposure Factors Handbook*. Vol. I. Office of Research and Development, Washington, D.C. EPA/600/R-93/187a.
- Allen, A.W. 1986. Habitat suitability index models: mink. *U.S. Fish Wildl. Serv. Biol. Rep.* 82 (10.127).
- Andrle, R.F. and J.R. Carroll (Editors). 1988. *The Atlas of Breeding Birds in New York State*. Cornell University Press. Ithaca, New York. 551 pp.
- Arnold, T.W. and Fitzell, E.K. 1987. Food habits of prairie mink during the waterfowl breeding season. *Can. J. Zool.* 65: 2322-2324.
- Aulerich, R.J. and R. Ringer. 1977. Current status of PCB toxicity in mink and effect on their reproduction. *Arch. Environ. Contam. Toxicol.* 6:279-292.
- Bent, A.C. 1940. Life histories of North American cuckoos, goatsuckers, hummingbirds, and their allies. *U.S. Natl. Mus. Bull.* 176. 506p.
- Beyer, W.N., E. Conner, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. *J. Wildl. Manage.* 58: 375-382.
- Brooks, R.P., and W.J. Davis. 1987. Habitat selection by breeding Belted Kingfishers (*Ceryle alcyon*). *Amer. Midl. Nat.* 117:6370.
- Boreman, J. 1981. Life histories of seven fish species that inhabit the Hudson River Estuary. National Marine Fisheries Service, Woods Hole Laboratory, No. 81-34, October.

Carlson, D.M. 1986. Fish and their habitats in the Upper Hudson Estuary. Region 4 Fisheries, Stamford, New York. November.

Carlson, D.M. 1992. Importance of wintering refugia to the largemouth bass fishery in the Hudson River Estuary. *Journal of Freshwater Ecology* 7:173-180.

Davis, W.J. 1982. Territory size in *Megaceryle alcyon* along a stream habitat. *Auk* 99:353-362.

Doutt, J.K., C.A. Heppenstall and J.E. Guilday. 1977. Mammals of Pennsylvania. The Pennsylvania Game Commission. Harrisburg, PA. 285 p.

Dunning, J.B. Jr. 1993. CRC Handbook of Avian Body Masses. CRC Press. Ann Arbor Michigan. 371 pp.

Eagle, T.C. and J.S. Whitman. 1987. Mink. In: Novak, M., Baker, J.A., Obbarel, M.E., et al., Eds. Wild furbearer management and conservation. Pittsburgh, PA. University of Pittsburgh Press. pp. 615-624.

Enders, R.K. 1952. Reproduction of the mink (*Mustela vison*). Proc. Am. Philos. Soc. 96: 691-755. In. USEPA 1993. Wildlife Exposure Factors Handbook. Vol. I. Office of Research and Development, Washington, D.C. EPA/600/R-93/187a.

Farrand, Jr., John. (Editor). 1983. The Audubon Society Master Guide to Birding. Vol. I. Loons to Sandpipers. Alfred A. Knopf. New York, New York. 447 pp.

Fish, P.A. and J. Savitz. 1983. Variations in home ranges of largemouth bass, yellow perch, bluegills, and pumpkinseeds in an Illinois lake. *Trans. Am. Fish. Soc.* 112:147-153.

Foley, R.E., S.J. Jackling, R.L. Sloan and M.K. Brown. 1988. Organochlorine and mercury residues in wild mink and otter: Comparison with fish. *Environ. Tox. Chem.* 7:363-374.

Gerell, R. 1970. Home ranges and movements of the mink (*Mustela vison Schreber*) in southern Sweden. *Oikos* 20:451-460.

Gilbert, F.F. and E.G. Nancekivell. 1982. Food habits of mink (*Mustela vison*) and otter (*Lutra canadensis*) in northeastern Alberta. *Can. J. Zool.* 60: 1282-1288.

Greer, K.R. 1955. Yearly food habits of the river otter in the Thompson Lakes region, Northwestern Montana, as indicated by scat analysis. *Am. Mid. Nat.* 54: 299-313.

Gunn, J.M., S.U. Quadri and D.C. Mortimer. 1977. Filamentous algae as a food source for the brown bullhead (*Ictalurus nebulosus*). *J. Fish Res. Board Can.* 34:396-401.

Hamas, M.J. 1974. Human incursion and nesting sites of the Belted Kingfisher. *Auk* 91:835-836.

- Hamilton, W. J. 1936. Food habits of the mink in New York. *Journ. Wild. Manag.* 17(2): 169.
- Hamilton, W.J. 1940. The summer food of minks and raccoons on the Montezuma Marsh, New York. *Journ. Wild. Manag.* 4(1): 80-84.
- Horshaw, T.C., R. J. Aulerich and H.E. Johnson. 1983. Feeding Great Lakes fish to mink: effects on mink and accumulation and elimination of PCBs by mink. *J. Toxicol. Environ. Health.* 11:933-946.
- Johnson, J.H. 1983. Summer diet of juvenile fish in the St. Lawrence River. *New York Fish and Game Journal* 30(1).
- Kramer, R.H. and L.L. Smith, Jr. 1960. Utilization of nests of largemouth bass, *Micropterus salmoides*, by golden shiners, *Notemigonus crysoleucas*. *Copeia* (1):73-74.
- Lawler, Matusky & Skelly Engineers. 1974. 1973 Hudson River aquatic ecology studies at Roseton and Danskammer Point. Volume III: Fish. Prepared for Central Hudson Gas & Electric Corporation, October.
- McBride, N.D. 1985. Distribution and relative abundance of fish in the Lower Mohawk River. New York State Department of Environmental Conservation. Stony Brook, New York.
- Mesing, C.L. and A.M. Wicker. 1986. Home range, spawning migrations, and homing of radio-tagged Florida largemouth bass in two central Florida lakes. *Trans. Am. Fish. Soc.* 115:286-295.
- Mitchell, J. L. 1961. Mink movements and populations on a Montana river. *J. Wildl. Manage.* 25:48-54.
- Nack, S. and W. Cook. 1986. Characterization of spawning and nursery habitats of largemouth bass (*Micropterus salmoides*) in the Stockport component of the Hudson River National Estuarine Research Reserve. In Polgar Fellowship Reports of the Hudson River National Estuarine Research Reserve Program (Eds: E.A. Blair and J.C. Cooper) New York State Department of Environmental Conservation, The Hudson River Foundation, and The U.S. Department of Commerce.
- Peterson, R.T. 1980. A Field Guide to the Birds East of the Rockies. Fourth Edition. Houghton Mifflin Company. Boston, MA. 384 pp.
- Poole, E.L. 1938. Weights and wing areas in North American birds. *Auk* 55: 511-517.
- Raney, E.C. 1967. Some catfishes of New York. *Conservationist* 21(6):20-25.
- Raney, E.C. and D.A. Webster. 1940. The food and growth of the young common bullhead, *Americurus nebulosus* (LeSueur) in Cayuga Lake, New York. *Trans. Am. Fish. Soc.* 69:205-209.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin 184. Fisheries Board of Canada, Ottawa.

Sealand, J.A. 1943. Winter food habits of mink in southern Michigan. *J. Wildl. Manage.* 7:411-417.

USEPA, 1993a. Wildlife Exposure Factors Handbook. Volume I of II. USEPA Office of Research and Development. Washington, D.C. EPA/600/R-93/187a.

USEPA, 1993b. Wildlife Exposure Factors Handbook. Volume II of II. USEPA Office of Research and Development. Washington, D.C. EPA/600/R-93/187b.

Waller, D. 1962. Feeding behavior of mink in some Iowa marshes. M.S. Thesis. Iowa State Univ. 90 pp. In: Newell, A.J., D.W. Johnson, and L.K. Allen. 1987. Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife. NYSDEC. Division of Fish and Wildlife. Technical Rpt. 87-3. 182 pp.

White, H.C. 1953. The eastern belted kingfisher in the Maritime provinces. *Bull. Fish. Res. Board Can.* 97. 44p.