

Tables

Table 1. Population in Cuyahoga County, Ohio, 1796-2003 (*from Whittlesey, 1867 and U.S. Bureau of Census*).

Year	Population (Number of Individuals)	Census
1796	4	NA
1797	15	NA
1800	7	NA
1810	57	NA
1820	50	NA
1825	500	NA
1830	1075	U.S. Bureau of Census
1832	1500	NA
1833	1900	NA
1834	3323	City of Cleveland
1835	5080	City of Cleveland
1840	6071	City of Cleveland
1845	9573	City of Cleveland
1846	10,135	City of Cleveland
1850	17,034	U.S. Bureau of Census
1851	21,140	City of Cleveland
1852	25,670	City of Cleveland
1860	43,838	U.S. Bureau of Census
1866	67,500	City of Cleveland
1900	439,120	U.S. Bureau of Census
1950	1,389,532	U.S. Bureau of Census
1990	1,412,140	U.S. Bureau of Census
2000	1,393,978	U.S. Bureau of Census
2003	1,363,888	U.S. Bureau of Census

Table 2. United States Geological Survey (USGS) water gage stations located in the Cuyahoga River. Sites in bold represent those from which we used data for this study.

Site Number	Site Name	From	To
04202000	Cuyahoga River at Hiram Rapids OH	1927	2003
04202500	Cuyahoga River near Kent OH-	1933	1935
04203900	Cuyahoga River at Cuyahoga Falls Oh	1999	2000
04204000	Little Cuyahoga River at Mogadore OH	1945	1978
04204500	Little Cuyahoga River at Massilon Rd Akron OH	1945	1974
04206488	Chippewa Creek in Chippewa Met Pk	2001	2002
04206500	Cuyahoga River at Brecksville OH	1923	1924
04208000 ✓	Cuyahoga River at Independence OH	1921	2003
04208460	Mill Creek at Garfield Hts OH	2001	2003
04208501	West Creek at Independence OH	2001	2002
04208502	Big Creek at Cleveland OH	1972	2003
04208504 ✓	Cuyahoga River near Newburg Heights OH	1991	2003

Table 3. Water quality concerns (by parameter) for the Cuyahoga River.

Location	Study Period	Parameters	Level Recorded
Downstream from Akron	1999	Zinc	slightly higher than 100 ug/l
West Third St (RM 3.26)	1993	DO	above 1.5 mg/l
West Third St (RM 3.26)	1995-1996	DO	sometimes below 1.5 mg/l
Munroe Falls dam pool	Before 1998	DO	below 5 mg/l
Between Akron and Cleveland	1993	Fecal Coliform	exceeding 1000/100 ml criterion
Between Lake Rockwell and Munroe Falls	NA	Phosphorus	median 0.08-0.1 mg/l
Small river reference sites in the Lake Plain	NA	Phosphorus	median 0.06 mg/l

Table 4. Heavy metal concentrations (mg/kg-dry weight) from sediments collected at Kingsbury Run, located within the Cuyahoga River basin. Percent sands is the percentage (weight to weight) of particles in the sample greater than 60 μ (settling time <0.5 minutes). (From Ohio EPA, 1999)

Sampling Site	River Mile	As	Cd	Cr	Cu	Fe	Pb	Hg	Zn	% Sands
At Mouth	0.1	13.9	2.17	79	91	35,100	107	0.123	435	56
Near Mouth	0.2									
At Mouth	0		1.5	23.4	248.8	127,806	49.4	0.106	1365	56

Values in **bold** - highly elevated concentrations.

Values in **bold** and underlined - extremely elevated concentrations.

Table 5. Biological quality data for river miles 3.3 – 5.0 of the Cuyahoga River including biological indices, fish community, and macroinvertebrate community, and habitat statistics. Data were collected between 1984 and 2002.

Year	Indices			Fish Community			Macroinvertebrate Community		Habitat
	IBI	IWB	ICI	Rel Num	Rel Wght	Mean Spp	Total Taxa	Qual Taxa	QHEI
1984		2.3		24	8.6	3.7			22.0
1985		5.6		422	13.0	4.0			
1987		1.6		61	15.8	2.7	23	3	20.0
1988		4.7	10	184	55.6	5.7	24	3	
1991		5.2	10	253	19.7	6.0	28	19	27.0
1994		5.5		260	42.3	7.3	41	10	31.0
1996	33	5.7	8	156	2.0	9.0	20	12	33.0
2002		5.5		356	26.9	7.0			

- G Generalist
- H Herbivore
- C Carnivore

3. BRD GLD (Breeding Guild) Column:

- N Complex, non parental care
- C Complex with parental care
- M Simple, miscellaneous
- S Simple lithophils

4. TOL (Pollution Tolerance) Column:

- R Rare Intolerant
- S Special Intolerant
- I Common Intolerant
- M Moderately Intolerant
- T Highly Tolerant
- P Moderately Tolerant

5. RIV SIZ (River Size) Column:

- L Large River Species
- H Headwaters Species
- P Pioneering Species

6. HAB PRF (Habitat Pref.) Column:

- P Prefers pools
- R Prefers riffles
- B Prefers both

Details of keys from:

http://www.epa.state.oh.us/dsw/documents/BioCrit88_Vol2ApxB.pdf

Table 7. 1991 fish survey for mile 5.0 in the Cuyahoga River (from OEPA Division of Surface by email from OPEA Water Ecological Assessment Unit, 02/28/2005)..

Abbreviations are defined in Table 6.

River Mile 5.0		Study Period		7/18/91 through 8/15/91						
Species Name	IBI Grp	Feed Breed Guild Tol			# of Fish	Relative number	% by number	Relative Weight	% by weight	Ave(g m)
		d	M	T						
Gizzard Shad		O	M		231	231	91.3	46.28	46.28	39.47
Common Carp	G	O	M	T	8	8	3.16	38.28	38.28	942.81
Goldfish	G	O	M	T	1	1	0.40	3.55	3.55	700.00
Emerald Shiner	N	I	S		2	2	0.79	0.04	0.04	4.00
Common Carp										1700.0
X Goldfish	G	O		T	1	1	0.40	8.63	8.63	0
White Bass	F	P	M		5	5	1.98	1.26	1.26	49.60
White Perch	E		M		1	1	0.40	0.08	0.08	15.00
Largemouth Bass	F	C	C		1	1	0.40	1.06	1.06	208.00
Pumpkinseed sunfish	S	I	C	P	1	1	0.40	0.30	0.30	60.00
Green SF X Hybrid					2	2	0.79	0.52	0.52	51.00
Mile Total					253	253		19.70		
Number of Species					8					
Number of Hybrids					2					

Table 8. 1993 fish survey for mile 5.0 in the Cuyahoga River (*from* OEPA Division of Surface by email from OPEA Water Ecological Assessment Unit, 02/28/2005).

Abbreviations are defined in Table 6.

River Mile	11/05/93 to										
5.0	12/14/93										
Species Name	IBI Grp	Feed Guild	Breed Guild	# of Tol	Relative % by number	Relative % by number	Relative % by Weight	Relative % by weight	Ave(gm) Weight		
Gizzard											
Shad		O	M		471	168.21	99.37	1.87	69.93	11.09	
Common											
Carp	G	O	M	T	1	0.36	0.21	0.78	29.05	2171.00	
Largemouth											
Bass	F	C	C		1	0.36	0.21	0.01	0.40	30.00	
Bluegill											
Sunfish	S	I	C	P	1	0.36	0.21	0.02	0.60	45.00	
	Mile Total				474						
	Number of Species				4						
	Number of Hybrids				0						

Table 9. 1994 fish survey for mile 4.8 in the Cuyahoga River (*from* OEPA Division of Surface by email from OPEA Water Ecological Assessment Unit, 02/28/2005).

Abbreviations are defined in Table 6.

River Mile										
4.8										
7/26/94 to 9/28/94										
Species Name	IBI Grp	Feed Guild	Breed Guild	# of Tol	Relative % by number	Relative % by Weight	Ave(gm) weight	Weight	Weight	Weight
Gizzard Shad Common		O	M		149 231	38.11	3.19	7.54	32.08	
Carp	G	O	M	T	46 8	11.76	26.73	63.24	871.74	
Emerald Shiner	N	I	S		14 2	3.58	0.02	0.04	1.97	
Spotfin Shiner	N	I	M		3	0.77	0.00	0.00	1.00	
Common Carp X										
Goldfish	G	O		T	18 1	4.60	9.40	22.24	783.33	
Yellow Bullhead		I	C	T	1	0.26	0.08	0.19	120.00	
White Bass	F	P	M		100 5	25.58	1.21	2.86	18.16	
White Perch	E		M		24 1	6.14	0.72	1.71	45.17	
Largemouth Bass	F	C	C		10 1	2.56	0.35	0.82	52.10	
Warmouth Sunfish	S	C	C		1	0.26	0.01	0.03	20.00	
Bluegill Sunfish	S	I	C	P	8	2.05	0.18	0.42	33.25	
Pumpkinseed sunfish	S	I	C	P	16 1	4.09	0.38	0.89	35.38	
Grren SF X Pumpkinseed					1 2	0.26	0.01	0.02	10.00	
		Mile Total			391	260.67		42.28		
		Number of Species			11					
		Number of Hybrids			2					

Table 10. 1996 fish survey for mile 4.8 in the Cuyahoga River (from OEPA Division of Surface by email from OPEA Water Ecological Assessment Unit, 02/28/2005).

Abbreviations are defined in Table 6.

River Mile										
4.8										
7/31/96 to 9/12/96										
Species Name	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish		Relative % by number		Ave(gm) Weight	
Gizzard Shad Common		O	M		131	131	83.97	0.92	45.64	6.99
Carp	G	O	M	T	2	2	1.28	0.46	23.12	232.00
Goldfish	G	O	M	T	1	1	0.64	0.03	1.59	32.00
Creek Chub	N	G	N	T	1	1	0.64	0.01	0.30	6.00
Emerald Shiner	N	I	S		1	1	0.64	0.01	0.30	6.00
Bluntnose Minnow	N	O	C	T	1	1	0.64	0.00	0.20	4.00
Yellow Bullhead		I	C	T	1	1	0.64	0.01	0.30	6.00
White Bass	F	P	M		3	3	1.92	0.20	9.72	65.00
White Perch	E		M		8	8	5.13	0.27	13.25	33.25
White Crappie	S	I	C		1	1	0.64	0.01	0.30	6.00
Largemouth Bass	F	C	C		1	1	0.64	0.01	0.40	8.00
Green Sunfish	S	I	C	T	1	1	0.64	0.06	2.99	60.00
Bluegill Sunfish	S	I	C	P	2	2	1.28	0.00	0.10	1.00
Pumpkinseed sunfish	S	I	C	P	1	1	0.64	0.01	0.50	10.00
Freshwater Drum			M	P	1	1	0.64	0.03	1.30	26.00
		Mile Total			156			2.01		
		Number of Species			15					
		Number of Hybrids			0					

Table 11. 1996 fish survey for mile 4.2 in the Cuyahoga River (from OEPA Division of Surface by email from OPEA Water Ecological Assessment Unit, 02/28/2005).

Abbreviations are defined in Table 6.

River Mile											
4.2		8/21/96 to 9/24/96									
Species Name	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish		Relative % by number		Relative % by Weight		Ave(gm) Weight
Gizzard Shad Common		O	M		445	448	57.94	0.57	1.22	1.23	
Carp	G	O	M	T	25	25	3.49	35.15	74.99	1300	
Goldfish	G	O	M	T	2	2	0.27	2.12	4.52	1000	
Golden Shiner	N	I	M	T	2	2	0.27	0.02	0.04	10.	
Emerald Shiner	N	I	S		177	177	25.41	0.26	0.55	1.33	
Spotfin Shiner	N	I	M		1	1	0.14	0.00	0.00	1.00	
Bluntnose Minnow	N	O	C	T	1	1	0.14	0.00	0.00	2.00	
Yellow Bullhead		I	C	T	5	5	0.72	1.07	2.28	193	
Brown Bullhead		I	C	T	8	8	1.15	4.67	9.95	525	
Brook Silverside		I	M	M	1	1	0.13	0.00	0.00	2.00	
White Bass	F	P	M		1	1	0.14	0.20	0.43	180	
White Perch	E		M		19	19	2.60	0.11	0.23	5.37	
Rock Bass	S	C	C		3	3	0.40	0.28	0.59	92.	
Smallmouth Bass	F	C	C	M	1	1	0.14	0.01	0.01	6.0	
Largemouth Bass	F	C	C		3	3	0.43	0.25	0.54	75.67	
Warmouth Sunfish	S	C	C		3	3	0.42	0.07	0.14	20.67	
Green Sunfish	S	I	C	T	7	7	0.96	0.17	0.36	22.29	
Bluegill Sunfish	S	I	C	P	8	8	1.11	0.30	0.63	34.25	
Pumpkinseed sunfish	S	I	C	P	21	21	2.89	1.27	2.70	56.48	
Bluegill x Pumpkinseed					2	2	0.27	0.20	0.43	93.	

Green SF x										
Bluegill SF					4	4	0.55	0.15	0.32	35.
Yellow Perch			M		1	1	0.14	0.01	0.01	6.00
Logperch	D	I	S	M	1	1	0.14	0.01	0.01	6.00
Freshwater										
Drum			M	P	1	1	0.13	0.01	0.02	10.
			Mile Total		742	773.22		46.88		
			Number of							
			Species		22					
			Number of							
			Hybrids		2					

Table 12. Summary of fish community data from Tables 6 - 11.

Year	River Mile	Total Individuals	Relative Individuals	Number of Species	Dominating Species (<i>in order of most common to less common</i>)
1987	5.0	102	71.5	8	Common Carp, Gizzard Shad, Emerald Shiner, White Bass
1991	5.0	253	253	8	Gizzard Shad, Common Carp, White Bass
1993	5.0	474		4	Gizzard Shad
1994	4.8	391	260.6	11	Gizzard Shad, White Bass, Common Carp, White Perch
1996	4.8	156		15	Gizzard Shad
1996	4.2	742	773.2	22	Gizzard Shad, Emerald Shiner, Common Carp

Table 13. Cuyahoga River Valley restoration options & metrics

	Oxbow wetlands ^a	Kingsbury Run restoration ^b	Pocket wetlands in Cuyahoga River ^c	Reduce dredging depth to 12 feet ^d	Stop dredging ^d
Area directly affected, acres	70 (oxbow) +44 (river) = 114 acres	2	44	154	154
Stream distance affected, mi	5.6	0.5 (run only)	5.6	5.6	5.6
1. Cost [per entire ship channel]	\$4.8 - 8.1 million	\$0.6 - \$1.6 million	\$ 11.35 million	\$0	\$0
Cost (\$1000) per ecosystem acre	\$42 - \$71	\$308 - \$915	\$516		
Cost (\$1,000,000) per stream mile	\$0.9 - \$1.4	\$1.1 - \$3.3	\$ 2		
2. Non-point runoff mitigation					
Potential quantity of rainfall retained during 1" storm event (acre-ft)	6	0.2	3.7	N/A	N/A
Maximum water retention, acre-ft	140	8	N/A		
Potential quantity of water retained from non-point sources (acre-ft/year)	4600	2700	2900	storage reduced	storage reduced
Sediments retained, metric tons/year	206	33	50	94,000	0
Phosphorus retained, metric tons/year	1.1	0.20	0.14	268	0
3. Wetlands Expected					
Wetland type	marsh/forest	Riparian vegetation	marsh possible	none	none
Water source and level	Nonpoint source/Cuyahoga River	Kingsbury Run watershed	Cuyahoga River	N/A	N/A
Wetland soil type	river alluvium	cobble/rock	river alluvium	N/A	N/A
Vegetation (mix of cover and open water, and the height, arrangement, and density of wetland plants)	high density of plants; 50% open water	little vegetation except for trees and shrubs on edges	Low density of macrophytes; stressed by river flow and currents	N/A	N/A
<i>Time-lag until effect complete</i>	2 years	3 years	3 years	immediate effect	immediate effect

4. Ecosystem indicators					
IBI estimate for habitat	45-50 in wetland	35 in run	25 in river	25 in river	35-40 in river
Dissolved oxygen (mg/L ave.)	8.0 in wetland	5.0 in run	6.0-7.0 in river	6.0 in river	6.5 in river
CDI (community diversity index) ^e	>2.0	0.5	>1.0	0.0	0.0

^a Oxbow wetland

1. Costs

assume 70 acres plus 44 acres of river enhancement (see pocket wetlands footnote c); cost for 2004; calculation based on 1994 cost for created wetlands from King and Bohlen (1994): Forested wetland \$77,900/acre; Emergent wetland \$46,700/acre

Forested wetland cost = 70 acres x \$77,900/acre x (1.04)¹⁰ = \$8.1 million

Emergent marsh cost = 70 acres x \$46,700/acre x (1.04)¹⁰ = \$4.8 million

Cost/acre = \$4.8 to 8.1 million/114 acres = \$42,000 to \$71,000 /acre

Cost/mile = \$4.8 to 8.1 million /5.6 miles = \$860,000 to \$1,400,000/mile

2. Non-point runoff mitigation

Rainfall retained during one-inch storm

(1"/12"/ft) x 70 acres = 6 acre-ft

Maximum water retention (assume average = 2 ft deep)

2 ft x 70 acres = 140 acre-ft

Potential water retained per year (66 ft/yr total inflow, based on ORW studies in Columbus by authors

66ft/yr x 70 acres = 4600 acre-ft/yr

Inflow assumed to be 70% urban runoff, streamflow and 30% Cuyahoga River

Sediments in river = 70 mg/L (USEPA data); total phosphorus = 0.2 mg/L

(Figure 13). Sediments in urban runoff = 100 mg/L; total phosphorus = 0.6 mg/L

(Brezonik and Stadelmann, 2002) Assume 40% retention of sediments and

phosphorus

40% x ((70% x 4600 acre-ft x 100 mg/L) + (30% x 4600 acre-ft x 70 mg/L)) = 206 metric tons/yr sediment retention

40% x ((70% x 4600 acre-ft x 0.6 mg/L) + (30% x 4600 acre-ft x 0.2 mg/L)) = 1.1 metric tons/yr P retention

^b Kingsbury Run restoration

1. Cost

range of restoration costs \$106 to \$315 per foot (North Carolina, 2004)

River length to be restored = 0.5 miles based on map contours

Watershed = circle with radius of 0.5 mile = 1004 acres

Stream area – 30 ft wide x 0.5 mile long = 2 acres

2. *Non-point runoff mitigation*

Rainfall retained during one-inch storm

$(1\frac{1}{2}\text{"/ft}) \times 2 \text{ acres} = 0.2 \text{ acre-ft}$

Maximum water retention (assume average = 4 ft deep)

$4 \text{ ft} \times 2 \text{ acres} = 8 \text{ acre-ft}$

Potential water retained per year (assume 80% of precipitation becomes runoff)

$3.3\text{ft/yr precipitation} \times 1006 \text{ acres} \times 80\% = 2700 \text{ acre-ft/yr}$

Inflow assumed to be 100% urban runoff

Sediments in urban runoff = 100 mg/L; total phosphorus = 0.6 mg/L

(Brezonik and Stadelmann, 2002) Assume 10% retention of sediments and phosphorus

$10\% \times 2700 \text{ acre-ft} \times 100 \text{ mg/L} =$

3.3 metric tons/yr sediment retention

$10\% \times 2700 \text{ acre-ft} \times 0.6 \text{ mg/L} =$

0.2 metric tons/yr P retention

^c Pocket wetlands

1. *Cost*

Pocket wetland cost (from U.S. Army Corps of Engineers, 2004) = \$9600 per 50 ft of shoreline = \$192/ft

Assume 32.5 ft width of impacted area per shoreline per illustration

Area affected = 32.5 ft wide x 5.6 miles x 5380 ft/mi/43560 ft²/acre x 2 shorelines = 44 acres

Pocket wetland cost = \$192/ft x 5.6 mi x 5280 ft/mi x 2 shorelines = \$11.35 million

Cost/acre = \$11.35 million/44 acres = \$516,000/acre

Cost/mile = \$11.35 million/5.6 miles = \$2 million/mi

2. *Non-point runoff mitigation*

Assume 5.6 miles of shoreline x 2 shorelines = 44 acres of pocket wetlands

Sediments in river = 70 mg/L (USEPA data); total phosphorus = 0.2 mg/L (Figure 13).

Assume 20% retention of sediments and phosphorus and 66 ft/yr inflow to pocket wetlands (same as oxbow)

$66\text{ft/yr} \times 44 \text{ acres} = 2900 \text{ acre-ft/yr}$

$20\% \times 2900 \text{ acre-ft/yr} \times 70 \text{ mg/L} =$

50 metric tons/yr sediment retention

$20\% \times 2900 \text{ acre-ft/yr} \times 0.2 \text{ mg/L} =$

0.14 metric tons/yr P retention

^d Dredging

Assumes impact on 5.6 miles of streams with average width of 228 feet = 154 acres

Sediments in river = 70 mg/L (USEPA data); total phosphorus = 0.2 mg/L (Figure 13).

Ratio = $0.2/70 = 0.0029$ ton P/ton sediments

Current dredging in lower Cuyahoga River = 250,000 cubic yd/each year (R.W. Waxmonsky, Buffalo USACOE report, March 2003) = 250,000 m³/yr

Therefore current sediment retention = 250,000 m³/yr x 0.75 ton/m³ density (from OSU data for unconsolidated recent sedimentation) = 187,500 ton sed/year

Current phosphorus retention = 187,500 tons sed/yr x 0.0029 ton P/ton sed
= 536 ton P/yr

Assumes 50% retention of sediments and phosphorus from entire river flow for dredging to 12 feet:

Sediment retention = 187,500 x 0.5 = 94,000 ton/yr

P retention = 536 x 0.5 = 268 ton P/yr

Assume steady state and no sediment or phosphorus retention in the river itself if dredging stops

^e Community diversity index (CDI)—wetland community diversity index developed by Mitsch et al. (2005)

Table 14. Average costs per unit for stream restoration work (from Kelly 2001).

Practice	Component	Units	Unit average cost
Filter Strip	Site prep and seedling	foot	\$5
Riparian Forest Buffer	Site preparation	foot	\$1
	Tree planting	foot	\$8
	Tree shelters	each	\$3
	Seeding	foot	\$4
Fish Habitat Improvement	Stream boulder placement	each	\$50
	Log/wood frames	linear foot	\$3
	Rock riprap	cubic yard	\$50
Streambank Stabilization	Brush matting	linear foot	\$6
	Plant cuttings	each	\$0.50
	Fiber rolls	linear foot	\$12
	Live stakes	each	\$2
	Erosion control blanket	square yard	\$2
	Herbaceous plants	each	\$2