Ohio Environmental Protection Agency

Biological and Water Quality Study of the Tiffin River and Select Tributaries, 2012-2014.

Defiance, Fulton, Williams, and Henry Counties

Division of Surface Water
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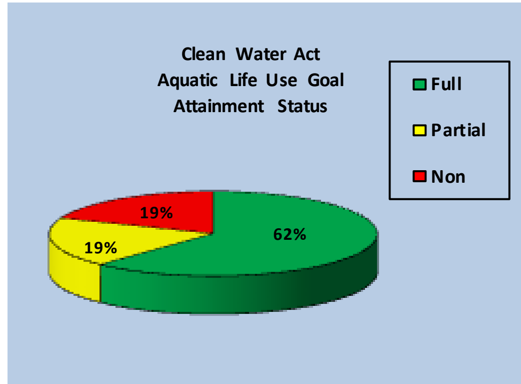
EXECUTIVE SUMMARY



Rivers and streams in Ohio support a variety of beneficial uses such as recreation, water supply, and aquatic life. Ohio EPA evaluates streams throughout the state to determine appropriate use designations and also to determine if the use is meeting the goals of the federal Clean Water Act. In 2012 and 2013, 22 streams in the Tiffin River watershed, located in Defiance, Fulton, Williams, and Henry counties, were evaluated for aquatic life and recreation use potential. The majority of data presented throughout this report were collected in 2013. Additional surface water chemistry data were collected during the 2014 sampling season for locations displaying biological impairment in 2013. Limited sampling occurred in 2012 at four locations on the lower Tiffin River mainstem. Sampling locations and corresponding narrative biological evaluations are displayed in Figure 1 and Table 1.

Biological samples were collected from 52 sampling locations. The majority of streams sampled are designated Warmwater Habitat (WWH) aquatic life use. One stream, Old Bean Creek, is designated Modified Warmwater Habitat (MWH). Of the 52 sampling locations, 33 locations (63.5%) were fully meeting the designated or recommended aquatic life use (ALU), 10 locations (19.2%) were in partial attainment, and 9 locations (17.3%) were in non-attainment.

All 10 (100%) of the locations evaluated on the Tiffin River mainstem were found to be in full attainment of the existing or recommended aquatic life use designations. This is a significant improvement from 1992, when only one of seven (14.3%) sites were in full attainment, one of seven (14.3%) sites were in non-attainment, and five of seven (71.4%) sites were in partial attainment of the designated aquatic life use. Results for tributaries were variable; 23 of 42 (54.8%) sites were in full attainment, 10 (23.8%) were in partial attainment, and 9 (21.4%) were in non-attainment of existing or recommended aquatic life use designations. The majority (74%) of impaired tributaries were under 20 mi^2 drainage area.

Negative impacts associated with nutrient and organic enrichment, such as large diel (daily) dissolved oxygen (DO) concentration swings or chronically low diel DO concentrations, were pervasive throughout the basin and were a likely driver of biological impairment at multiple locations. Excessive siltation smothering natural substrates and/or low base streamflow were also commonly associated with impairment in many of the smaller tributaries. Row crop agriculture, manure application to agricultural fields, and historical channelization activities were the most widespread sources of nonpoint source pollution. Underperforming wastewater treatment plants (WWTPs), unsewered areas, and potentially faulty home sewage treatment systems (HSTS) were also likely causing impairment in more localized areas. A complete list of sampling locations, attainment status, and associated causes and sources of impairment are found in Table 2. More in depth discussion of impaired areas can be found throughout the body of this document.

Surface water chemistry grab sample results indicated multiple minimum Water Quality Standards (WQS) DO violations throughout the study area including: Mill Creek (3), Bates Creek (1), Owl Creek (1), Brush Creek (1), Doty Run (1), Miller Creek (1), Little Lick Creek (4), Lick Creek (2), Dry Creek (2), Buckskin Creek (2), and Webb Run (1). Additionally, continuous water quality sonde recorders indicated multiple minimum and 24-hour average DO violations and exceedances, respectively, throughout the study area, indicative of both nutrient and organic enrichment (Table 13-Table 16, Appendices F and H). Likely sources include agricultural land use practices, poor performing WWTPs, and unsewered communities. Total phosphorus (TP) and nitrate-nitrite concentrations were above target levels at numerous locations throughout the study area (Table 17). Even so, it appears that there have been slight decreases in nutrient concentrations observed in the Tiffin River mainstem since 1992 (Figure 28 and Figure 29). Numerous iron exceedances and a single copper exceedance were observed and are likely a result of high background soil concentrations from the underlying geology of the area.

Macrohabitat quality in the Tiffin River mainstem has improved substantially since 1992. Qualitative Habitat Evaluation Index (QHEI) scores from 2012-13 (x̄=59.1, n=9) clearly indicate improvement since 1992 (x̄=45.3, n=7) (Figure 13). Substrate quality, a component of the QHEI which evaluates substrate type and degree of siltation/embeddedness, was found to be substantially better in 2013 (x̄=8.5, n=9) than in 1992 (x̄=3.9, n=7). Substrates were comprised largely of pea-gravel and sand; the presence and pervasiveness of excessive silts and flocculent clays that smother natural substrates has decreased since 1992. Several recent studies have investigated trends in suspended sediment discharge reductions and sediment load reduction to streams in the Maumee River basin and assert that these reductions appear to reflect the success agricultural management programs have had in reducing erosion and sediment export to streams (Myers, et al. 2000, and Richards, et al. 2009). Water quality benefits and improved aquatic biology resulting from agricultural BMPs in Ohio are further quantified by Miltner (2015). Improvements in substrate quality, and reductions in the amounts of silts and flocculent clays in the Tiffin River can likely be attributed to conservation tillage, various agricultural best management practices (BMPs), and other agricultural management programs. These BMPs and other agricultural management programs may have contributed, at least in part, to the slight decreases in nutrient concentrations observed as well.

Biological communities were evaluated at 52 locations throughout the watershed. Fish community performance in the mainstem has improved substantially since 1992. Mean Index of Biotic Integrity (IBI) and Modified Index of well-being (MIwb) scores for the Tiffin River mainstem were substantially higher in 2012-13 (40.8, 9.45, n=9) than in 1992 (34.3, 7.7, n=7) (Figure 6). The relative abundance (#/km) of pollution sensitive fish species in the mainstem more than doubled since 1992; additionally, four more sensitive species were collected during the latest survey that weren't collected in 1992 (Figure 8). Most notably of these is the state listed eastern sand darter, a species of concern in Ohio (Ohio DNR 2015). The eastern sand darter is exceptionally sensitive to excess silts and flocculent clays that can blanket clean sandy substrates required for feeding and reproduction. These are the first Ohio EPA records of eastern sand darters in the Tiffin River basin. Historically, the eastern sand darter was widespread throughout the Maumee River and the lower portions of its tributaries, but was nearly eliminated by the early 1900s due to habitat degradation and changes in land use practices that accelerated delivery of silts and clays to river systems (Trautman 1981). Only recently has there been documented recovery of eastern sand darter populations in the Maumee River drainage system (Tessler et al. 2012).The relative abundance and biomass of common carp, a highly tolerant fish species, decreased from 1992 to 2013, while corresponding increases were observed in round body suckers and other native species (Figure 8 and Figure 9). Macroinvertebrate community performance in the mainstem as indicated by the Invertebrate Community Index (ICI) was generally similar in 2013 compared to previous years; however, pollution sensitive taxa diversity was on average nine taxa higher in 2013 compared to 1992. The state endangered caddisfly *Brachycentrus numerosus* was collected at two sampling locations on the Tiffin River mainstem (RMs 47.9 and 40.7) and one location on Bean Creek (RM 2.2). Fish community performance in tributaries to the Tiffin River was variable; however, IBI and MIwb scores were unequivocally higher in 2013 compared to historical values at nearly all locations sampled. ICI scores and qualitative evaluations in tributaries were generally similar to previous years. Improved biological performance, especially regarding substrate sensitive species such as the eastern sand darter, is likely a result of improved macrohabitat and substrate quality.

Thirty-seven locations in the Tiffin River watershed were tested for bacteria indicators (*Escherichia coli*) to determine recreation use attainment status in 2012 and 2013. Evaluation of *E. coli* results revealed that only 4 of 37 (11%) locations attained the applicable geometric mean criterion, and thus were in full attainment of the designated recreation use. Plausible sources of *E. coli* contamination at locations not attaining the recreation use criteria are unsanitary conditions from agricultural manure runoff, underperforming wastewater treatment plants, failing HSTS, and unsewered communities.

A total of 31 National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water, and/or industrial storm water into the Tiffin River watershed (Table 20). The city of Bryan and village of Archbold WWTPs are considered major dischargers in the watershed; both were found to have substantial impacts on biological communities and were likely causing impairment downstream from their respective facilities. The village of West Unity WWTP had several permit limit violations for *E. coli* and ammonia during the summer of 2013. Substantial discussion regarding these areas is contained in multiple sections throughout this document.

Sediment chemistry sampling was conducted at six locations: four in the Tiffin River mainstem between RMs 47.54 and 7.09, one in Brush Creek downstream from the Archbold WWTP (RM 13.28), and one in Prairie Creek downstream from the Bryan WWTP (RM 9.8). Several s-VOC (PAH) concentrations were detected downstream from the Bryan WWTP in Prairie Creek. All s-VOC concentrations were above the threshold effect concentration (TEC), but below the probable effect concentration (PEC) and are unlikely to cause any harmful effects (Appendix G). The s-VOC compounds detected above TEC include benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, fluoranthene, indeno[1,2,3-cd]pyrene, 3 & 4 methylphenol, phenanthrene, and pyrene.

Fish tissue data were sufficient to support one meal per month advisories on northern pike over 25", all flathead catfish, and channel catfish over 20", all due to mercury. Northern pike had previously been on a one meal per month advisory for all sizes, denoting an improvement in this species. Flathead catfish had not been previously collected in the Tiffin River. All other statewide advisories still apply.

Public water supply (PWS) beneficial uses were evaluated for the village of Archbold which serves approximately 6,000 people. The Village stores drinking water in two upground reservoirs. The raw water intake is located on the Tiffin River at RM 47.54. Both nitrate and atrazine were below the respective WQS criterion at the intakes. A two year Inland Lake Assessment was done on Reservoir #2 and the results are presented on page 137. Samples for evidence of harmful algae blooms were collected in 2013 and 2014. Six samples (one in 2013, five in 2014) were collected and analyzed for microcystin. All results were below detection.

Table 1. Tiffin River watershed sampling locations, 2012 & 2013. The color of the site number corresponds to the narrative biological score of the lowest scoring organism group, either fish or macroinvertebrates. Blue is exceptional to very good (meets Exceptional Warmwater Habitat), green is good to marginally good (meets WWH), yellow is fair, orange is poor, and red is very poor. Typically fair, poor, and very poor do not meet the goals of WWH, except in certain circumstances in the Huron-Erie Lake Plain (HELP) ecoregion with regard to fish biocriteria. In these limited circumstances a fair narrative would be considered meeting WWH goals.

Site Number	Stream Name/Location	River Mile	Drainage Area (mi^2)	Longitude	Latitude
1	Tiffin River/Northwest of Archbold @ County Rd. G	47.54	337	41.572800	-84.337200
2	Tiffin River/At Lockport @ County Rd. 22-75/ County Rd. I-25	41.12	374	41.546853	-84.391036
3	Tiffin River/At Stryker @ State Route 191	35.28	407	41.509878	-84.428745
4	Tiffin River/West of Stryker @ County Rd. F (Curtis St.)	33.95	412	41.500000	-84.430100
5	Tiffin River/Dst. Stryker @ Oak Grove Church Rd.	26.17	418	41.456400	-84.420800
6	Tiffin River/Near Evansport @ County Rd. 22/A	19.72	421	41.431436	-84.401222
7	Tiffin River/At Evansport @ State Route 191	18.73	476	41.427200	-84.389400
8	Tiffin River/ South of Evansport @ Stever Rd.	14.00	562	41.388100	-84.396100
9	Tiffin River/ Northeast of Defiance Airport @ Evansport Rd.	7.09	736	41.346400	-84.418900
10	Tiffin River/Near Defiance @ Dey Rd.	0.89	775	41.290300	-84.385600
11	Old Bean Creek/Near Thelma @ County Rd. 19	6.22	14.0	41.635864	-84.229314
12	Old Bean Creek/ Southeast of Fayette @ Old Angola Rd.	1.85	25.0	41.623300	-84.290300
13	Deer Creek/Dst. Fayette @ County Rd. 23	4.56	9.9	41.670000	-84.307500
14	Bean Creek/East of Powers @ US Route 20	7.55	206	41.677867	-84.231875
15	Bean Creek/Southeast of Fayette @ Old Angola Rd.	2.20	246	41.623100	-84.296100
16	Mill Creek/Ust. Alvordton trib. @ County Rd. S	14.49	12.9	41.680600	-84.395600
17	Mill Creek/Southeast of Alvordton @ County Rd. P	11.90	23.4	41.651400	-84.411900
18	Mill Creek/Southeast of Alvordton @ County Rd. 28	7.92	32.8	41.641700	-84.399200
19	Mill Creek/South of Fayette @ Old Angola Rd.	1.85	39.0	41.622800	-84.323600
20	Bates Creek/East of West Unity @ County Rd. 25-2	1.65	11.8	41.583900	-84.351400
21	Flat Run/Northeast of Stryker @County Rd. 22-75	0.40	10.2	41.538600	-84.382800

22	Leatherwood Creek/North of Stryker @ County Rd. H	1.15	9.8	41.528100	-84.421400
23	Beaver Creek/Southwest of West Unity @ County Rd. K	17.12	14.9	41.572200	-84.497500
24	Beaver Creek/At Beaver Ck. Wildlife Area @ County Rd. 16	12.66	29.5	41.537800	-84.515300
25	Beaver Creek/South of Pulaski @ US Route 127	7.52	36	41.491100	-84.514700
26	Beaver Creek/At County Rd. D	2.90	41	41.469700	-84.463600
27	Beaver Creek/Northwest of Evansport @ County Rd. 20	0.61	44.8	41.458900	-84.438300
28	Owl Creek/Southwest of Archbold @ County Rd. 25	0.07	10.3	41.466400	-84.342200
29	Brush Creek/Ust. Archbold @ Archbold-Lutz Rd. (County Rd. D)	19.06	19.7	41.543300	-84.264400
30	Brush Creek/Dst. Archbold @ County Rd. 24	13.28	34.6	41.498300	-84.325600
31	Brush Creek/Southwest of Archbold @ County Rd. 24-25	9.11	54.0	41.467200	-84.356700
32	Brush Creek/Northeast of Evansport @County Rd. C	5.76	62.0	41.456400	-84.374700
33	Brush Creek/Near Evansport @ County Rd. 22-60	1.05	65.0	41.433300	-84.390000
34	Coon Creek/East of Evansport @ County Rd. 23	0.62	9.3	41.429200	-84.379200
35	Doty Run/Southwest of Evansport near mouth @ Evansport Rd.	0.63	5.3	41.381325	-84.417186
36	Miller Creek/West of Bryan adj. County Rd. 309/D	0.50	20.9	41.471400	-84.586400
37	Little Lick Creek/Northwest of Ney @ Behnfeldt Rd.	4.97	7.5	41.408300	-84.573600
38	Little Lick Creek/Ust. Ney ust. railroad	0.80	23.3	41.378300	-84.526700
39	Prairie Creek/Dst. Bryan WWTP adj. County Rd. C	9.80	9.8	41.456100	-84.508600
40	Prairie Creek/Northeast of Ney @ Flickinger Rd. (lower crossing)	3.40	26.0	41.398800	-84.478300
41	Lick Creek/Northwest of Bryan @ County Rd. 13	21.77	6.2	41.486534	-84.573998
42	Lick Creek/Southwest of Bryan @ County Rd. 13	17.66	30	41.445300	-84.572800
43	Lick Creek/At Ney @ The Bend Rd.	10.05	58.5	41.380800	-84.516400
44	Lick Creek/North of Oxbow Lake @ Trinity Rd.	1.23	105	41.368900	-84.438300
45	Dry Creek/Southeast of Farmer @ County Rd. 124 (Openlander Rd.)	3.76	11	41.355075	-84.592292

46	Lost Creek/Northeast of Hicksville @ Seevers Rd.	8.97	14.4	41.368600	-84.684200
47	Lost Creek/North of Sherwood @ Behnfeldt Rd.	1.41	25.6	41.334200	-84.575800
48	Mud Creek/North of Sherwood @ Coy Rd.	10.10	47.3	41.334200	-84.544400
49	Mud Creek/Northwest of Brunersburg @ Trinity Rd.	1.50	58.0	41.350300	-84.438100
50	Buckskin Creek/Northwest of Brunersburg @ State Route 15	1.20	6.1	41.324610	-84.418459
51	Webb Run/Northwest of Defiance @ Flory Rd.	2.99	9.3	41.340589	-84.394536
52	Webb Run/North of Brunersburg, near mouth, dst. Tanby Ditch	0.40	20.0	41.317800	-84.390800

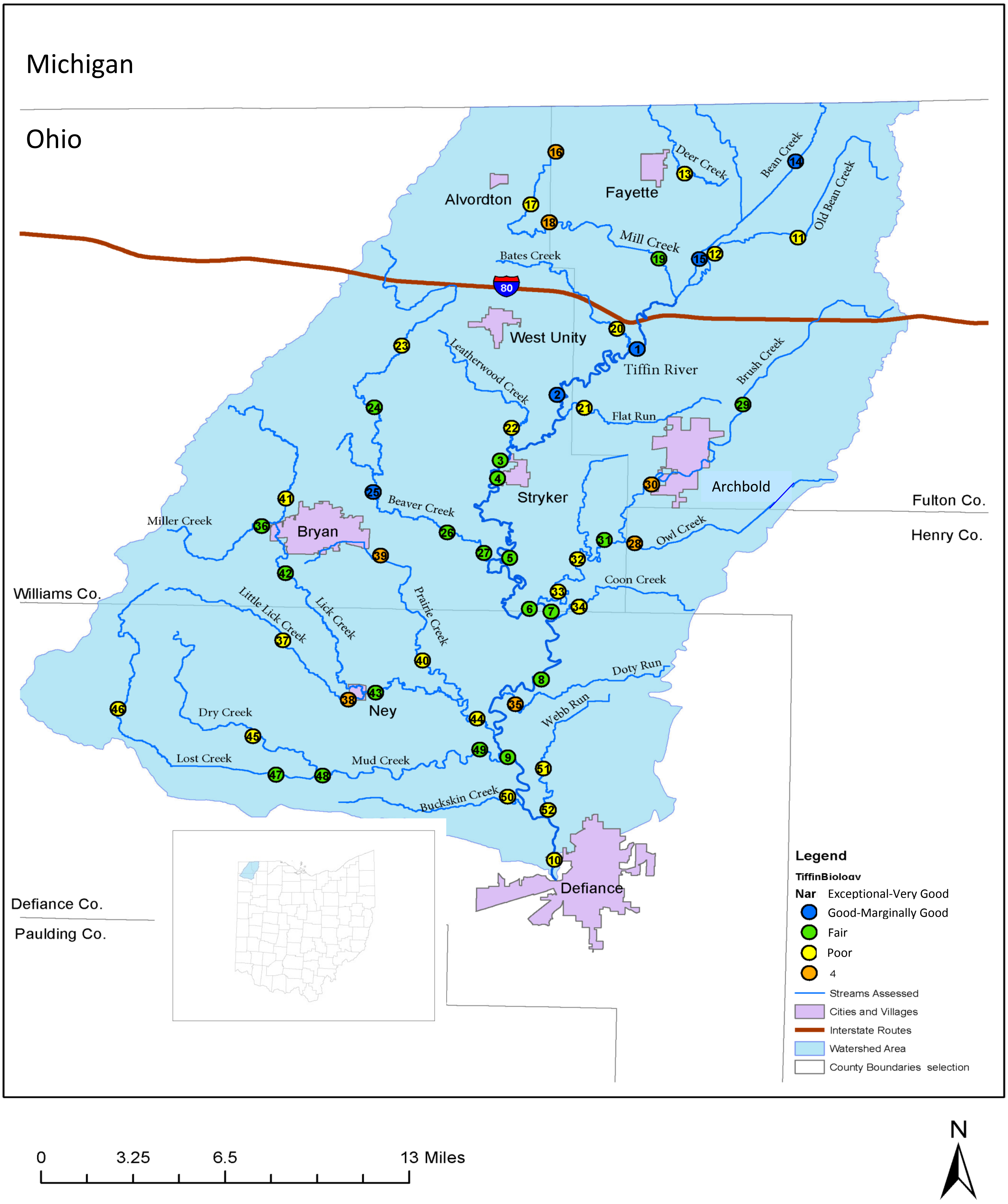


Figure 1. Tiffin River basin sampling locations and biological community performance, 2012-13. Site numbers correspond to Table 1.

Table 2. Aquatic life use attainment status for stations sampled in the Tiffin River study area based on data collected June-October, 2013. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat of the stream to support a biotic community. The Tiffin River study area lies within the Huron-Erie Lake Plain (HELP) and Eastern Corn Belt Plains (ECBP) ecoregions and is noted on the table as such. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted. Data from several locations in the lower Tiffin River were also collected in 2012 and are denoted by [brackets]; only most recent data were used to determine attainment status. N/A = not applicable.

Location	STORET (RM)[a]	DRAIN. (MI²)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Tiffin River (04-600)	*WWH Existing (ECBP & HELP)*								
ECBP Ecoregion									
Northwest of Archbold @ County Rd. G	P07K06 (47.54)	337[B]	48	9.46	50	61.25	**FULL**		
Lockport @ County Road 22-75/ County Rd. I-25	302205 (41.12)	374[B]	46	9.51	50	66.75	**FULL**		
HELP Ecoregion									
Stryker @ State Route 191	P07K03 (35.28)	407[B]	41	9.26	32[NS]	41.0	**FULL**		
West of Stryker @ County Rd. F (Curtis St.)	300020 (33.95)	412[B]	43	9.78	MG[NS]	49.75	**FULL**		
Dst. Stryker @ Oak Grove Church Rd.	P07S07 (26.17)	418[B]	42	9.94	32[NS]	64.75	**FULL**		
Near Evansport @ County Road 22/A	302206 (19.72)	421[B]	38	9.31	42	57.5	**FULL**		
[Evansport @ State Route 191]	500300 (18.73)	476[W]	[36]	[7.77]	[44]	[56.0]	**FULL**		
South of Evansport @ Stever Rd.	P07K01 (14.00)	562[B[W]]	35[41]	9.33[9.08]	46[50]	65.0[70.5]	**FULL**		
Northeast of Defiance Airport @ Evansport Rd.	P07S05 (7.09)	736[B[W]]	40[33]	10.05[8.54]	48[54]	76.0[75.25]	**FULL**		
Tiffin River (04-600)	*WWH Existing – MWH-I Recommended (HELP)*								
[Near Defiance @ Dey Rd.]	500160 (0.89)	775[B]	[35]	[8.41]	[18]	[49.75]	**FULL**		

Location	STORET (RM)[a]	DRAIN. (MI²)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Old Bean Creek (04-632)	*MWH-C Existing (HELP & ECBP)*								
HELP Ecoregion									
Near Thelma @ County Rd. 19	302203 (6.22)	14.0[H]	36	N/A	F	31.5	**FULL**		
ECBP Ecoregion									
Southeast of Fayette @ Old Angola Rd.	P07S34 (1.85)	25.0[W]	41	7.50	F	36.0	**FULL**		
Deer Creek (04-628)	*WWH Existing (ECBP)*								
Dst. Fayette @ County Rd. 23	P07W24 (4.56)	9.9[H]	36[NS]	N/A	LF*	61.0	**PARTIA**L	Nutrient Enrichment	Row Crop Agriculture
Bean Creek (04-626)	*WWH Existing (ECBP)*								
East of Powers @ US Route 20	500330 (7.55)	206[W]	51	9.98	50	71.75	**FULL**		
Southeast of Fayette @ Old Angola Rd.	P07S33 (2.20)	246[W]	50	9.81	52	51.0	**FULL**		
Mill Creek (04-624)	*WWH Existing – MWH-C Recommended (ECBP)*								
Ust. Alvordton trib. @ County Rd. S	P07W25 (14.49)	12.9[H]	24	N/A	MG[NS]	30.25	**FULL**		
Mill Creek (04-624)	*WWH Existing (ECBP)*								
Southeast of Alvordton @ County Rd. P	P07W26 (11.90)	23.4[W]	28*	7.65*	MG[NS]	61.0	**PARTIAL**	Organic Enrichment, Fish Passage Barrier	Unsewered Areas, Downstream Impoundment
Southeast of Alvordton @ County Rd. 28	P07S32 (7.92)	32.8[W]	<u>26*</u>	6.53*	G	58.5	**NON**	Nutrient Enrichment, Fish Passage Barrier	Row Crop Agriculture, Downstream Impoundment
South of Fayette @ Old Angola Rd.	P07S31 (1.85)	39.0[W]	38[NS]	8.91	52	63.0	**FULL**		
Bates Creek (04-622)	*WWH Existing (ECBP)*								
East of West Unity @ County Rd. 25-2	P07K30 (1.65)	11.8[H]	34*	N/A	F*	51.25	**NON**	Siltation	Channelization, Row Crop Agriculture

Location	STORET (RM)[a]	DRAIN. (MI²)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Flat Run (04-620)	*Unverified/WWH Confirmed (ECBP)*								
Northeast of Stryker @ County Rd. 22-75	P07K28 (0.40)	10.2[H]	34*	N/A	LF*	40.0	**NON**	Siltation	Channelization, Row Crop Agriculture
Leatherwood Creek (04-619)	*WWH Existing (ECBP)*								
North of Stryker @ County Rd. H	P07K27 (1.15)	9.8[H]	34*	N/A	F*	57.5	**NON**	Siltation	Channelization, Row Crop Agriculture
Beaver Creek (04-617)	*WWH Existing (ECBP & HELP)*								
ECBP Ecoregion									
Southwest of West Unity @ County Rd. K	P07P17 (17.12)	14.9[H]	34*	N/A	G	54.5	**PARTIAL**	Siltation	Channelization, Row Crop Agriculture
Beaver Ck. Wildlife Area @ County Rd. 16	P07K25 (12.66)	29.5[W]	41	9.49	48	70.5	**FULL**		
South of Pulaski @ US Route 127	P07P14 (7.52)	36[W]	48	9.21	46	66.5	**FULL**		
HELP Ecoregion									
@ County Rd. D	P07S01 (2.90)	41[W]	36	7.97	48	59.25	**FULL**		
Northwest of Evansport @ County Rd. 20	P07P11 (0.61)	44.8[W]	38	9.18	38	56.25	**FULL**		
Owl Creek (04-615)	*Unverified/WWH Confirmed (HELP)*								
Southwest of Archbold @ County Rd. 25	P07S03 (0.07)	10.3[H]	26[NS]	N/A	LF*	26.0	**PARTIAL**	Organic Enrichment, Siltation, Low Flow	Unrestricted Livestock Access, Channelization
Brush Creek (04-614)	*WWH Existing (HELP)*								
Ust. Archbold @ Archbold-Lutz Rd. (County Rd. D)	P07S22 (19.06)	19.7[H]	36	N/A	G	31.25	**FULL**		
Dst. Archbold @ County Rd. 24	P07S20 (13.28)	34.6[W]	29[NS]	6.20*	<u>12*</u>	47.5	**NON**	Organic Enrichment	Archbold WWTP
Southwest of Archbold @ County Rd. 24-25	P07W29 (9.11)	54.0[W]	36	8.14	44	25.5	**FULL**		

Location	STORET (RM)[a]	DRAIN. (MI^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Northeast of Evansport @County Rd. C	P07K19 (5.76)	62.0[W]	30[NS]	8.26	36	40.0	**FULL**		
Near Evansport @ County Rd. 22-60	P07W15 (1.05)	65.0[W]	32	8.10	36	42.0	**FULL**		
Coon Creek (04-616)	*WWH Existing (HELP)*								
East of Evansport @ County Rd. 23	P07K24 (0.62)	9.3[H]	28	N/A	LF*	46.25	**PARTIAL**	Natural Low Flow	Natural
Doty Run (04-613)	*Unverified/WWH Confirmed (HELP)*								
Southwest of Evansport near mouth @ Evansport Rd.	302201 (0.63)	5.3[H]	26[NS]	N/A	P*	42.75	**NON**	Natural Low Flow	Natural
Miller Creek (04-612)	*WWH Existing (ECBP)*								
West of Bryan adj. County Rd. 309/D	P07K17 (0.50)	20.9[W]	39	8.12[NS]	46	71.5	**FULL**		
Little Lick Creek (04-611)	*WWH Existing (ECBP & HELP)*								
ECBP Ecoregion									
Northwest of Ney @ Behnfeldt Rd.	P07W22 (4.97)	7.5[H]	40	N/A	F*	50.5	**PARTIAL**	Nutrient Enrichment	Row Crop Agriculture
HELP Ecoregion									
Ust. Ney ust. railroad	P07S41 (0.80)	23.3[W]	35	8.21	P*	57.25	**NON**	Organic Enrichment	Manure Application
Prairie Creek (04-609-001)	*WWH Existing (ECBP & HELP)*								
ECBP Ecoregion									
Dst. Bryan WWTP adj. County Rd. C	P07S13 (9.80)	9.8[H]	28*	N/A	P*	35.75	**NON**	Nutrient Enrichment, Flocculent Bottom Deposits	Bryan WWTP
HELP Ecoregion									
Northeast of Ney @ Flickinger Rd. (lower crossing)	P07W12 (3.40)	26.0[W]	29[NS]	8.36	38	64.0	**FULL**		

Location	STORET (RM)[a]	DRAIN. (MI²)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Lick Creek (04-609)	*WWH Existing (ECBP & HELP)*								
ECBP Ecoregion									
Northwest of Bryan @ County Rd. 13	P07W20 (21.77)	6.2[H]	36[NS]	N/A	F*	61.5	**PARTIAL**	Nutrient Enrichment	Row Crop Agriculture
Southwest of Bryan @ County Rd. 13	P07K13 (17.66)	30.0[W]	37[NS]	9.36	36	67.25	**FULL**		
HELP Ecoregion									
Ney @ The Bend Rd.	P07S36 (10.05)	58.5[W]	42	8.50	32[NS]	56.5	**FULL**		
North of Oxbow Lake @ Trinity Rd.	500310 (1.23)	105[W]	31[NS]	7.72	48	52.75	**FULL**		
Dry Creek (04-608)	*Unverified/WWH Confirmed (HELP)*								
Southeast of Farmer @ County Rd. 124 (Openlander Rd.)	302202 (3.76)	11[H]	32	N/A	F*	36.25	**PARTIAL**	Low Flow, Siltation, Nutrient Enrichment, Organic Enrichment	Channelization, Row Crop Agriculture, Manure Application
Lost Creek (04-606)	*Unverified/WWH Confirmed (ECBP & HELP)*								
ECBP Ecoregion									
Northeast of Hicksville @ Seevers Rd.	P07W19 (8.97)	14.4[H]	32*	N/A	F*	71.5	**NON**	Unknown	Unknown
HELP Ecoregion									
North of Sherwood @ Behnfeldt Rd.	P07W18 (1.41)	25.6[W]	35	7.84	44	64.0	**FULL**		
Mud Creek (04-605)	*WWH Existing (HELP)*								
North of Sherwood @ Coy Rd.	P07W17 (10.10)	47.3[W]	34	7.48	G	60.0	**FULL**		
Northwest of Brunersburg @ Trinity Rd.	P07S04 (1.50)	58.0[W]	42	7.89	44	50.0	**FULL**		

Location	STORET (RM)[a]	DRAIN. (MI²)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Buckskin Creek (04-604)	*WWH Existing (HELP)*								
Northwest of Brunersburg @ State Route 15	P07K11 (1.20)	6.1[H]	32	N/A	F*	42.0	**PARTIAL**	Natural Low Flow	Natural
Webb Run (04-602)	*WWH Existing (HELP)*								
Northwest of Defiance @ Flory Rd.	302204 (2.99)	9.3[H]	36	N/A	LF*	40.75	**PARTIAL**	Natural Low Flow	Natural
North of Brunersburg, near mouth, dst. Tanby Ditch	P07K09 (0.40)	20.0[H]	28	N/A	MG[NS]	51.25	**FULL**		

a - River Mile (RM) represents the Point of Record (POR) for the station, not the actual sampling RM.
b - MIwb is not applicable to headwater streams with drainage areas $\leq$ 20 mi^2.
c - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
d - Attainment is given for the proposed status when a change is recommended.
ns - Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
B - Boat site.
H - Headwater site.
W - Wading site.

Biological Criteria								
	Huron-Erie Lake Plain (HELP)				Eastern Corn Belt Plains (ECBP)			
Index – Site Type	EWH	WWH	MWH-I	MWH-C	EWH	WWH	MWH-I	MWH-C
IBI – Headwaters	50	28	N/A	20	50	40	N/A	24
IBI – Wading	50	32	N/A	22	50	40	N/A	24
IBI – Boat	48	34	22	20	48	42	30	24
MIwb – Wading	9.4	7.3	N/A	5.6	9.4	8.3	N/A	6.2
MIwb - Boat	9.6	8.6	5.7	5.7	9.6	8.5	6.6	5.8

RECOMMENDATIONS

Streams in the Tiffin River watershed currently listed in the Ohio Water Quality Standards (WQS) are assigned one of the following aquatic life use designations: Warmwater Habitat (WWH) or Modified Warmwater Habitat (MWH). MWH aquatic life use designations are grouped into three disturbance type categories and include channelized (MWH-C), impounded conditions (MWH-I), and mine affected. The aquatic life use designations for the streams in this survey have been previously verified using biological data with the exception of Buckskin Creek, Dry Creek, Doty Run, Owl Creek, Lost Creek, and Flat Run. These streams were originally designated for aquatic life use in the 1978 Ohio WQS but the techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. This study used biological data to evaluate and establish aquatic life uses for streams in the Tiffin River study area.

Twenty-two streams in the Tiffin River study area were evaluated for aquatic life and recreational use potential in 2013, with limited sampling occurring in 2012 on the lower Tiffin River mainstem (Table 3). Significant findings include the following.

- The Tiffin River mainstem should retain the existing WWH use designation for all segments except the lower stretch extending from US Route 15 (RM 1.3) to the mouth. This lower segment is perennially impounded by pooled conditions in the Maumee River due to the Independence lowhead dam. Thus, it is recommended that the aquatic life use for the lower 1.3 miles of the Tiffin River be re-designated MWH-Impounded.

- Biological performance in the upper portions of the Tiffin River situated in the ECBP currently exceed expected WWH assemblages; the IBI score at RM 47.54 and ICI scores at RM 47.54 and 41.12 currently meet EWH expectations, while the IBI score at RM 41.12 and MIwb scores at RM 47.54 and 41.12 are currently in non-significant departure from EWH criteria. If applicable biocriteria from this segment of the Tiffin River improves above the EWH non-significant departure range, it may have the potential to support EWH communities and thereby could be considered for the EWH aquatic life use designation in the future.

- Bean Creek has an existing WWH designation and is being recommended EWH from its confluence with the Tiffin River to the Ohio border. Biological community performance has displayed a consistently positive trajectory through time and was found to fully support EWH assemblages where assessed. Fourteen sensitive fish species were collected in Bean Creek, including several rare and pollution intolerant American brook lamprey; sensitive fish species comprised nearly 60% of the biomass in Bean Creek. Bean Creek was also found to support the highest number (34) of sensitive macroinvertebrate taxa for the entire survey. Most notably, the state listed caddisfly *Brachycentrus numerosus* (endangered) was collected at RM 2.2. Seven species of freshwater mussels were also documented in Bean Creek, including the state listed creek heelsplitter (species of concern) at U.S. 20 (RM 7.55). As discussed in the *Study Area Description*, the Tiffin River and Bean Creek are functionally the same stream, essentially different only in name. Thus, taking into account the information in the above bullet point regarding the upper reaches of the Tiffin River, it is not surprising to observe biological communities performing in the exceptional range in Bean Creek. Despite fully supporting expected EWH assemblages and the presence of sensitive and rare taxa, habitat scores are slightly lower than would be expected to support such assemblages. Bean Creek has a history of significant channel modification in the approximately 10 miles residing in Ohio. However, the approximately 40 miles located in Michigan maintain much of their functional sinuosity and still have large swaths of intact riparian corridor. The Tiffin River in Ohio also maintains much of this functional sinuosity and a relatively intact riparian corridor. Given its glacial history, Bean Creek has substantial groundwater connectivity throughout with a relatively high stream gradient compared to other streams in the basin. Within the small portion of the historic "ditch-like" channel residing in Ohio, sufficient gradient has afforded this stream enough power to regain many natural stream attributes over the past 100 years. Active vertical and lateral erosion and deposition within the historical channel has allowed the stream to regain some functional sinuosity. Connectivity to the groundwater table ameliorates habitat deficiencies. It would be beneficial to establish more substantial riparian cover in areas lacking along the Ohio portion of Bean Creek. It should also be noted that Bean Creek is being recommended EWH because of a specific set of circumstances occurring within this stream system; not all streams with as significant a history of channelization would be expected to meet EWH criteria. Under most circumstances, channelization, stream maintenance activities, and associated impacts have negative influences that are reflected in the biological performance, but substantial groundwater input and sufficient gradient enable biological communities in Bean Creek to overcome these habitat deficiencies and fully support EWH assemblages.

- Mill Creek is currently designated WWH throughout and should maintain this designation except from its headwaters to RM 14.0 (at confluence with the unnamed tributary just downstream from County Road S). This segment is being recommended MWH-C. A QHEI score of 30.25 at this location is below the benchmark value of what would be considered sufficient to support typical WWH assemblages. This particular location, while not on active ditch maintenance from county engineers, appears to be maintained to an extent and had been recently dipped at the time of sampling. The segment immediately upstream flows adjacent to a railroad which may be the source of local maintenance. Additionally, segments of Mill Creek upstream from the sampling location at RM 14.49 and several tributaries that drain into Mill Creek in the vicinity are on active ditch maintenance by their respective county engineers. Fish community performance at the RM 14.49 location has been consistently far below ecoregional expectations and has even declined slightly since 1997. Fish community performance at this location has likely plateaued; the Harrison Lake State Park dam at RM 5.0 functions as a fish passage barrier, effectively limiting upstream movement and recolonization, and will likely preclude full attainment of fish biocriteria even with complete remediation of all identified causes and sources of impairment in Mill Creek.

- Additionally, the 2013 survey confirmed the WWH use designation is appropriate for six streams that had previously been unverified; these streams have now been assessed using standardized approaches to the collection of instream biological data and numerical biological criteria. These streams include Buckskin Creek, Dry Creek, Doty Run, Owl Creek, Lost Creek, and Flat Run. IBI scores at nearly all of these locations are meeting, or are nearly meeting, WWH expectations. Macroinvertebrate community performance is lagging behind fish community performance. Habitat quality may be suboptimal at several of these locations; however, given the positive trajectory of the watershed as a whole, it is not unfathomable that biological performance in these streams could meet WWH expectations given another reporting cycle, if identified stressors are addressed.

- The previously verified WWH use designation was confirmed for 15 streams and this use should be retained. These streams include Webb Run, Mud Creek, Lost Creek, Lick Creek, Prairie Creek, Little Lick Creek, Miller Creek, Brush Creek, Coon Creek, Beaver Creek, Leatherwood Creek, Bates Creek, and Deer Creek.

- Old Bean Creek has an existing MWH-C use designation that should be retained. Improvements in both fish and macroinvertebrate community performance were observed. IBI scores met expected WWH assemblages, but macroinvertebrate community performance, while improved, still did not meet WWH expectations. Old Bean Creek could be considered for WWH recommendation next reporting cycle if biological community performance continues to improve.

- All streams should retain their respective Primary Contact Recreation (PCR) or Secondary Contact Recreation (SCR) use designation, along with the Agricultural Water Supply (AWS), Public Water Supply (PWS) and Industrial Water Supply (IWS) use designations.

Impacts from historical channelization activities, agriculture and row crop production, and manure application were the most prevalent nonpoint sources of impairment throughout the study area. Several localized areas were impacted by unsewered communities and/or underperforming WWTPs. Excessive siltation and substrate embeddedness, nutrient and organic enrichment, and low flow conditions were the most common causes of impairment throughout the study area.

Substantial improvements in macrohabitat quality, particularly instream sediment quality, were observed at sites on the Tiffin River mainstem. Biological community performance improved over the same time period throughout the entire basin. Improved instream macrohabitat and sediment quality and subsequent improvements in biological performance, especially regarding substrate sensitive fish species, can likely be attributed, at least in part, to the reduction of erosion and sediment loads to the Tiffin River and its tributaries as a result of conservation tillage, various BMPs, and other agricultural management programs that were implemented beginning in the late 1980s and early 1990s. Several studies observed sediment load reductions to streams in the Maumee River basin and attributed these observed improvements to conservation tillage and other BMPs (Myers, et al. 2000, and Richards et al. 2009). Water quality benefits and improved aquatic biology resulting from agricultural BMPs in Ohio are further quantified by Miltner (2015). It is important to highlight the apparent success conservation tillage and other agricultural BMPs have had in reducing soil erosion and sediment loading to streams and rivers, not only because of improved environmental conditions, but because of the significant amounts of money invested in these programs. The following quote from Myers, Metzker, and Davis (2000) states the importance of documenting these improvements: *"Without direct evidence of improving water quality, farmers and others may become indifferent to the voluntary use of these practices and programs. This, in turn, could negate the apparent success of these programs and the investments made by federal, state, and local natural-resource managers."* It is critical not to compromise substantial environmental improvements gained through conservation tillage, BMPs, and other agricultural management programs discussed above.

Table 3. Waterbody use designation recommendations for the Tiffin River watershed, including those streams not sampled in 2012-13. Streams highlighted in yellow were those evaluated during this survey. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a confirmation of an existing use and a triangle (▲) denotes a new recommended use based on the findings of this report. A (o) indicates a designated use based on justification other than results of a biological field assessment performed by the Ohio Environmental Protection Agency. Symbols separated by a / indicate confirmation of the existing beneficial use.

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Tiffin river - at RM 47.54		+						o	+	+		+		PWS intake - Archbold
-all other segments		+							+	+		+		
-RM 1.3 to mouth				▲					+	+		+		Impounded by Maumee River at Independence lowhead dam
Dowe ditch		*							*	*		*		
Webb run (Tiffin river RM 2.9)		+							+	+		+		
Tanby ditch		*							*	*		*		
Mattock ditch		*							*	*		*		
Buckskin creek		*/+							*/+	*/+		*/+		
Mud creek		+							+	+		+		
Lost creek		+							+	+		+		
Crooked creek		*							*	*		*		
Dry creek		*/+							*/+	*/+		*/+		
Lick creek		+							+	+		+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Prairie creek		+							+	+		+		
Pigeon run (Prairie creek RM 11.0)				+					+	+		+		HELP ecoregion - channel modification
Black creek		*							*	*		*		
Little Lick creek		+							+	+		+		
Miller creek		+							+	+		+		
Dotty Creek (A.K.A. Doty Run)		*/+							*/+	*/+		*/+		
Brush creek - at RM 17.64		+						o	+	+		+		PWS intake - Archbold
- all other segments		+							+	+		+		
Owl creek		*/+							*/+	*/+		*/+		
Coon creek		+							+	+		+		
Beaver creek		+							+	+		+		
Lost creek		*/+							*/+	*/+		*/+		
Leatherwood creek		+							+	+			+	
Flat run		*/+							*/+	*/+		*/+		
Walnut run		+							+	+		+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Bates creek		+							+	+		+		
Clear creek		+							+	+		+		
Mill creek – All other segments		+							+	+		+		
– RM 14.0 to headwaters				▲										HELP Ecoregion – channel modification
West fork		*							*	*		*		
Bean creek			▲						+	+		+		
Stag run		*							*	*		*		
Deer creek		+							+	+		+		
Spring brook		*							*	*		*		
Spring creek		*							*	*		*		
Iron creek		*							*	*		*		
Old Bean creek				+					+	+			+	HELP ecoregion - channel modification

INTRODUCTION

Fifty-two stream sampling locations were evaluated in the Tiffin River watershed in Defiance, Fulton, Henry, and Williams counties in 2013. Additional surface water chemistry data were collected during the 2014 sampling season at or near locations displaying biological impairment in 2013. Limited sampling occurred in 2012 at four locations on the lower Tiffin River mainstem. In 2013, ten locations on the Tiffin River mainstem were sampled along with 42 locations on tributaries including Old Bean Creek, Deer Creek, Bean Creek, Mill Creek, Bates Creek, Flat Run, Leatherwood Creek, Beaver Creek, Owl Creek, Brush Creek, Coon Creek, Doty Run, Miller Creek, Little Lick Creek, Prairie Creek, Lick Creek, Dry Creek, Lost Creek, Mud Creek, Buckskin Creek, and Webb Run.

A total of 31 National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water, and/or industrial storm water into streams situated in the Tiffin River watershed. A complete list of NPDES permitted facilities can be found in Table 20.

From 2012-2014, Ohio EPA conducted a water resource assessment of 22 streams in the Tiffin River watershed (Figure 2) using standard Ohio EPA protocols as described in Appendix A. Included in this study were assessments of the biological, surface water and recreation (bacterial) condition. A total of 52 biological, 59 water chemistry, 36 water quality sonde, and 37 bacteriological stations were sampled in the Tiffin River watershed. Physical habitat was assessed at each biological sampling location. Fish tissue was also collected in the Tiffin River, Mud Creek, and Lick Creek.

Specific objectives of the evaluation were to:

- systematically sample and assess the principal drainage network of the Tiffin River in support of both the TMDL process and NPDES permits program;
- ascertain the present biological conditions in the Tiffin River watershed by evaluating fish and macroinvertebrate communities;
- assess physical habitat influences on biotic integrity;
- identify ambient levels of organic, inorganic, and nutrient parameters in the water column and sediments;
- verify the appropriateness of existing Beneficial Use designations (e.q., aquatic life, recreational, and water supply);
- assign Beneficial Use designations to undesignated waters;
- determine recreational water quality;
- determine the attainment status and recommend changes to Beneficial Use designations if deemed appropriate; and
- document any changes in the biological, chemical, and physical conditions within the study area where historical information exists.

The findings of this evaluation may factor into regulatory actions taken by the Ohio EPA (e.g. NPDES permits, Director's Orders, or the Ohio Water Quality Standards [OAC 3745-1]), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, Total Maximum Daily Loads (TMDLs) and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

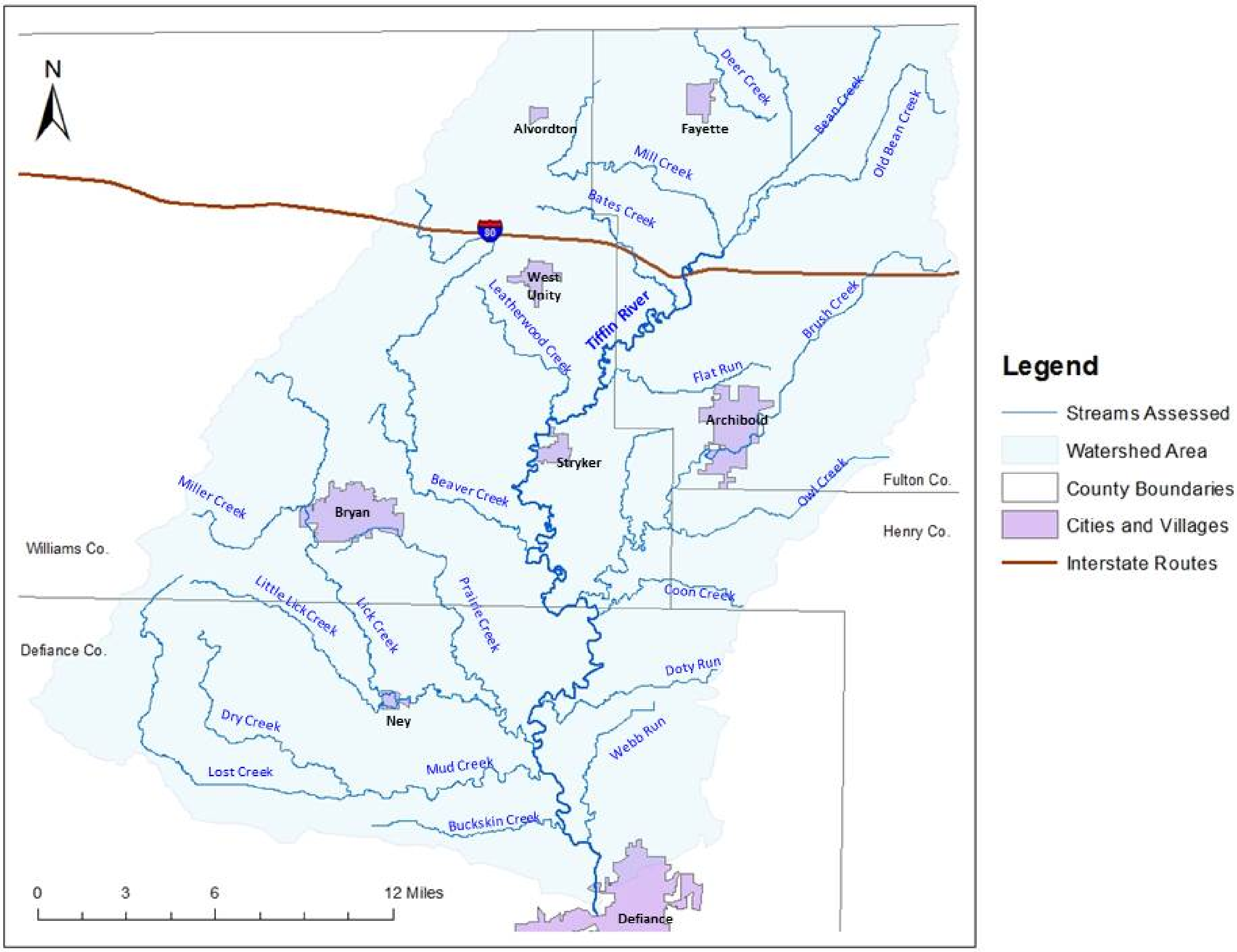


Figure 2. Streams within the Tiffin River watershed assessed 2012-14.

STUDY AREA DESCRIPTION

Location, Scope, and Demographics

The Tiffin River watershed is one of four principal drainage networks that comprise the Maumee River basin. It represents approximately 11.7% of the Maumee watershed. The Tiffin River watershed originates in southern Michigan near the town of Hudson and flows southward through glaciated topography, eventually draining into the Maumee River near Defiance, Ohio. The Tiffin River is officially formed in Ohio by the "confluence" of two tributaries, Bean Creek and Mill Creek, which join together in Fulton County, approximately 51 miles upstream from the Maumee River. However, Bean Creek and the Tiffin River can be functionally regarded as one continuous stream; they are different only in name. Early French settlers originally termed this stream various names including *Anse des Fèves* and *Crique Fèves* (Cove/Creek of the Beans, Bean Creek) (Slocum 1905). In Ohio it was renamed the Tiffin River in the early 1820s after then Surveyor General of the West and Ohio's first governor Edward Tiffin, M.D. in 1822 (Slocum 1905). In the early 1960s, the U.S. Board on Geographic Names settled on two separate names for this system, with the majority of the Ohio portion termed Tiffin River and the Michigan portion named Bean Creek (USGS Geographic Names Information System).

Including the upper reaches in Michigan referred to as Bean Creek, the total length of the Tiffin River stretches approximately 110 miles. The headwaters of the Tiffin River are formed by several glacial lakes and portions of the system the flow through once glaciated areas have substantial groundwater connectivity. Approximately 70% of the watershed area is located within Ohio, with the remaining 30% situated in Michigan. Major tributaries to the Tiffin River in Ohio include Bean Creek (285 mi^2), Mill Creek (40.5 mi^2), Beaver Creek (45 mi^2), Brush Creek (65.5 mi^2), Lick Creek (106 mi^2), and Mud Creek (59 mi^2).

In Ohio, the Tiffin River watershed is located in Defiance, Fulton, Henry, and Williams counties in northwestern Ohio. The watershed encompasses five 10-digit Hydrologic Unit Codes (HUCs): Mill and Bean Creek sub-basin (0410000602), Upper Tiffin River sub-basin (0410000603), Middle Tiffin River sub-basin (0410000605), Lick Creek sub-basin (0410000604), and Lower Tiffin River sub-basin (0410000606). The watershed drains approximately 778 mi^2.

The largest urban areas in the Tiffin River watershed include (population in parentheses) Bryan (8,545), Archbold (4,346), West Unity (1,671), and Stryker (1,335) (US Census Bureau, 2010). The 2010 census data, including census blocks wholly or partially in the watershed, specifies that the Tiffin River watershed in Ohio supports a resident population of approximately 62,368 (US Census Bureau, 2010).

Land Use

Agriculture accounts for the majority of the land use within the watershed. Because the watershed consists of such poorly drained soils, an extensive tile drainage network is necessary to maintain crop production. Many small streams in the watershed have been extensively channelized to support tile and drainage systems (ODNR 2008). Aggregated land use across the Tiffin River watershed is approximately 81.82% agricultural and 8.70% developed for urban or residential use. Other land uses included 5.0% forest, 0.29% open water, 0.12% grassland, 4.0% wetland, and 0.07% other (USFSA 2012). Corn and soybeans are the overwhelmingly dominant crop types, with lesser amounts of other crops occurring within the basin (Figure 3). Agriculture and associated physical habitat modifications due to channelization are the predominant sources of nonpoint source (NPS) pollution in the watershed.

Ecoregions, Geology, and Soils

The Tiffin watershed is located within the Huron-Erie Lake Plain (HELP) and Eastern Corn Belt Plains (ECBP) ecoregions as described in Omernik (1987). A map detailing ecoregion boundaries can be viewed in Figure 2-1 at http://www.epa.ohio.gov/Portals/35/documents/Vol2.pdf. Approximately 50% of the Tiffin River watershed is located within the ECBP ecoregion, including the upper mainstem and tributaries in the western portion of the basin; several tributaries originate in the ECBP and flow into the HELP before joining the Tiffin River. The ECBP consists of rolling glacial end moraines deposited on Devonian limestone. About two-thirds of the lower mainstem is located within the HELP ecoregion. The HELP is characterized by a broad, almost level, lake plain crossed by low moraines and beach ridges. This area is largely a remnant of the Great Black Swamp, a deforested and extensively drained historical wetland. The HELP has historically had the most widespread and severe agricultural impacts of any of the five Ohio ecoregions. This is primarily related to channelization, excessive export of silts and flocculent clays to receiving streams, a lack of woody riparian vegetation, and low stream gradients, all of which can often preclude full recovery of natural stream habitat features.

Most of the region was channelized and drained for cropland by the turn of the 20th century. Stream gradients are typically very low, with most less than 1-2 feet/mile. Local relief is generally only a few feet and soils are poorly to very poorly drained. Soil hydric groups present in the watershed include approximately 50% group D (poorly to very poorly drained), 40% group C (moderately poor to poorly drained), and 10% group B (moderately well drained) (U.S. Army Corps of Engineers 2009). The dominant soil types within the Tiffin River watershed are depicted in Figure 4. The Pewamo-Glynwood-Blount, Latty-Fulton, Roselms-Paulding, Lenawee-Del Rey, Nappanee-Hoytville, and Millgrove-Mermill soil types compose 82.4% of the dominant soil types for this area. All of the soils except the Pewamo-Glynwood-Blount (Somewhat Poorly Drained) above are considered very poorly draining or poorly draining soils.

Protected Lands

The Tiffin River watershed includes approximately 1,941 acres of protected lands contained within 22 sites. These lands are divided into two main categories, recreation land and conservation land. Recreation lands in this watershed include one state park and several local parks. Conservation lands include a park, wildlife areas, a nature preserve, and a conservation club. Of the 1,941 acres of protected lands, approximately 1,378 acres (71%) are in the conservation land categories and are most protected from development and human impact. The other 563 acres (29%) are recreation lands. A complete list of protected areas is listed in Table 4.

Of the conservation lands that make-up 71% of the total protected areas, three Ohio DNR managed sites account for 77.7% of this area. These three sites are the Oxbow Lake Wildlife Area, the Tiffin River Wildlife Area, and the Goll Woods State Nature Preserve.

The Oxbow Lake Wildlife Area is located in northwestern Ohio near the city of Defiance. The area is situated in the glaciated lake plain of Ohio and has a slightly rolling topography. Some steep land lies adjacent to Mud Creek, which bisects the area. Substantial amounts of brush land and meadow are maintained by the Division of Wildlife for upland game habitat. Oxbow Lake and Little Oxbow Lake provide habitat for fish, furbearers, waterfowl, and other birds. Originally, the entire area was forested. During the latter part of the last century, the virgin woods were cut down to utilize the moderately fertile soil for agriculture. The wildlife area was purchased by the state of Ohio in 1948. The 38-acre Oxbow Lake was constructed in 1953. A smaller, 4.5-acre impoundment, called Little Oxbow Lake, was constructed in 1958 (ODNR 2014b).

The Tiffin River State Wildlife Area is a joint venture between the Ohio DNR Division of Wildlife, the National Wild Turkey Federation and Pheasants Forever. Located north of Archbold, the area is comprised of three separate wooded and wetland habitats and will provide additional outdoor recreational opportunities for Ohioans. Portions of Bean Creek, Old Bean Creek, Mill Creek and the Tiffin River intersect the three sections of the wildlife areas (ODNR 2014c).

Located northwest of Archbold, Goll Woods State Nature Preserve is the least disturbed woodland known to remain in extreme northwestern Ohio. This preserve features some of the largest trees remaining in the state. Goll Woods exemplifies the "Black Swamp" forest which once covered a vast area of the flat post-glacial lake plains southwest of Lake Erie. An outstanding feature of this preserve is the abundance of giant bur oaks and exceptionally large white oaks, chinquapin oaks and cottonwoods. Many of these magnificent trees are 200-400 years old and measure four feet in diameter. A rich variety of native shrubs and wildflowers occur in the woods including spotted coral-root and three-birds-orchid. The preserve is best visited in the spring before mosquitoes emerge (ODNR 2014a).

Table 4. Protected lands in the Tiffin River watershed as documented in the Ohio EPA, Geographic Information System Recreation and Conservation Areas (CARL) Layer, 2007. Table created January, 2014.

Protected Lands in the Tiffin River Watershed					
SITE_NAME	**Owner**	**Managed By**	**Description**	**Type**	**Acres**
Oxbow Lake WA	State	Ohio DNR	Wildlife Area	Conservation	411.47
Tiffin River WA	State	Ohio DNR	Wildlife Area	Conservation	351.27
Goll Woods SNP	State	Ohio DNR	Nature Preserve	Conservation	307.70
Harrison Lake SP	State	Ohio DNR	Park	Recreation	238.38
Parkersburg WA	State	Ohio DNR	Wildlife Area	Conservation	157.58
Goldie Newman WA	Local		Wildlife Area	Conservation	80.39
Recreation Park	Local		Park	Recreation	73.98
Willams Co. Conserv. League	County	Williams Co. Conserv. League	Sportsman's Club	Conservation	68.96
Opdycke Park	Local		Park	Recreation	64.53
George Bible Park	Local		Park	Recreation	60.31
Diehl Park	Local		Park	Recreation	41.64
Moore Park	Local		Park	Recreation	13.01
Garver Park	Local		Park	Recreation	12.01
Springfield Township Park	Local		Park	Recreation	11.64
West Unity Memorial Park	Local		Park	Recreation	11.15
Ney Community Park	Local		Park	Recreation	9.65
East End Park	Local		Park	Recreation	8.06
Roseland Park	Local		Park	Recreation	7.08
Fountain City Park	Local		Park	Recreation	6.87
Maple Grove Park	Local		Park	Recreation	3.52
Butterfly Park	Local		Park	Recreation	1.63
Mattie Marsh Park	Local		Park	Conservation	0.63

Nonpoint Source Issues

The most common nonpoint sources negatively affecting water quality throughout the study area included excess siltation from agricultural crop production and historical channelization activities, excess nutrients from fertilizer and land applied manure runoff, failing home sewage treatment systems or unsewered areas, and urban runoff. Agricultural practices including historical systematic channelization, routine drainage maintenance activities in streams and ditches, and drainage from farm fields through subsurface tiles can often cause habitat and flow alterations in receiving streams and can preclude full recovery of natural stream habitats.

Drainage alterations were also found where floodplains and wetlands were crossed by numerous highways and railroads, as well as in urban areas where development has encroached or filled in natural wetlands and floodplains. All of the counties in the study area have programs for drainage maintenance (ODNR 2008). Unsewered communities in the watershed can potentially contribute to recreational use impairment due to the lack of centralized wastewater collection and treatment.

Watershed Groups

The Conservation Action Project (CAP) of Ohio is a water quality effort aimed at improving the water quality of Lake Erie by increasing the number of acres of conservation tillage on the farms in seven counties bordering or draining into the Maumee River. The CAP program is planned and conducted by a Board of Trustees made up of one agricultural chemical, equipment, or seed dealer, one county soil and water conservation district (SWCD) person, and one farmer from each of the seven counties (Conservation Action Project, 2014).

The Maumee River Basin Partnership of Local Governments (MRBPLG) is a consortium of cities, towns, villages, townships, counties, watershed management groups, and the regional community, which was founded in March 2001 by the city of Fort Wayne, Indiana and the city of Toledo, Ohio. This Partnership stretches across three state boundaries and focuses on a watershed based approach to water quality management in the Maumee River Basin (Maumee River Basin Partnership of Local Governments, 2014).

Beneficial Uses

Beneficial use designations within the Tiffin River watershed include those for aquatic life, recreation, and public, agricultural, and industrial water supply. The vast majority of streams within the watershed have the WWH ALU designation. Several streams have the MWH-C ALU designation. A small segment of the lower Tiffin River is being recommended MWH-I because of impounded conditions from the Maumee River at the Independence lowhead dam. Bean Creek currently is designated WWH and is being recommended EWH based on observed biological performance. All streams in the watershed are classified as General High Quality Waters under Ohio anti-degradation rules. The Tiffin River mainstem is a PCR Class A recreation stream from RM 47.54 to the mouth. Old Bean Creek and Leatherwood Creek are SCR streams and all other assessed streams are PCR Class B recreation streams. All streams in the basin are designated Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Two public water supply (PWS) intakes are located in the Tiffin River. Water also is withdrawn from Brush Creek and conveyed to Archbold Reservoir #2 for PWS purposes.

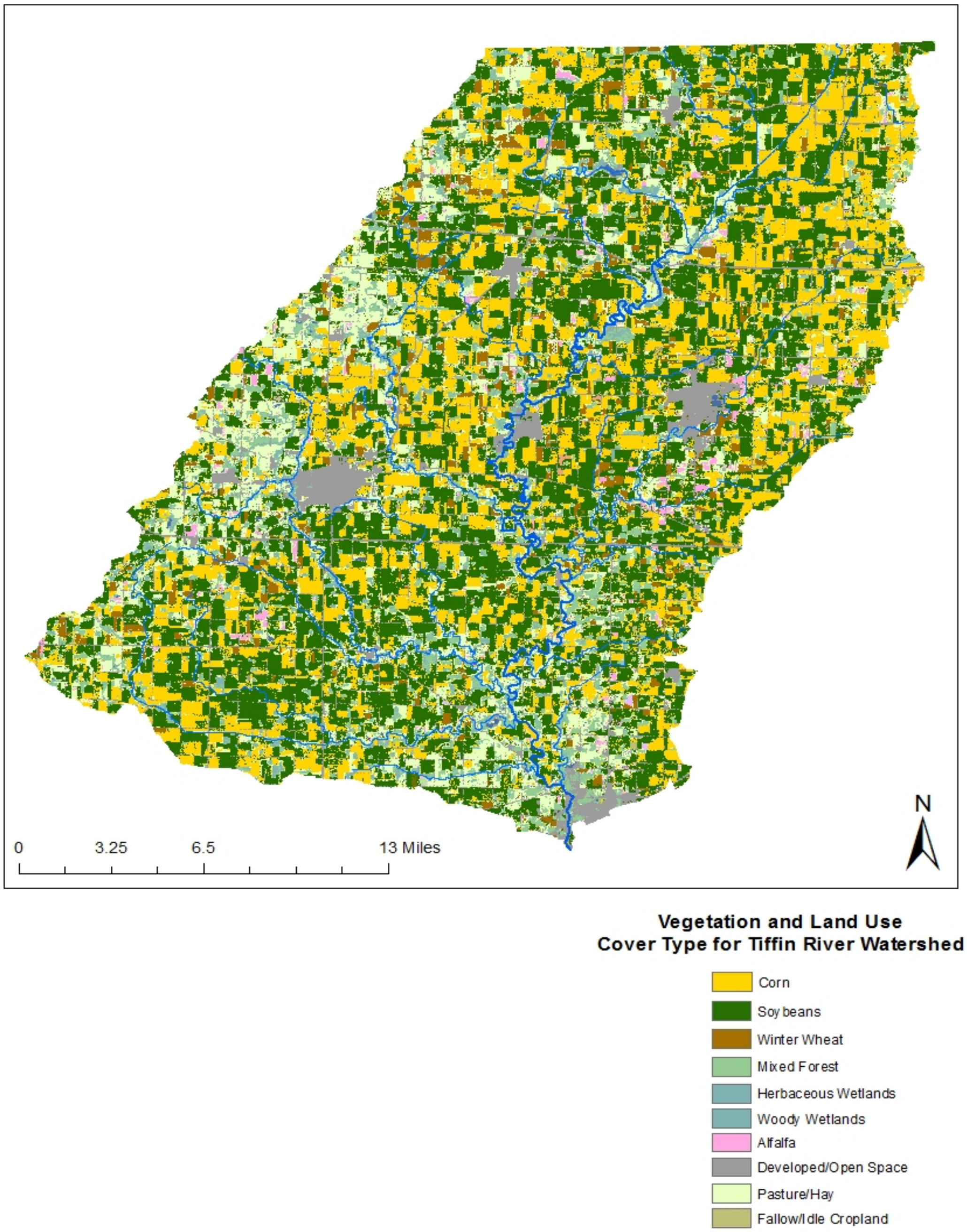


Figure 3. Vegetation and land use cover types for the Tiffin River watershed, Ohio, 2012.

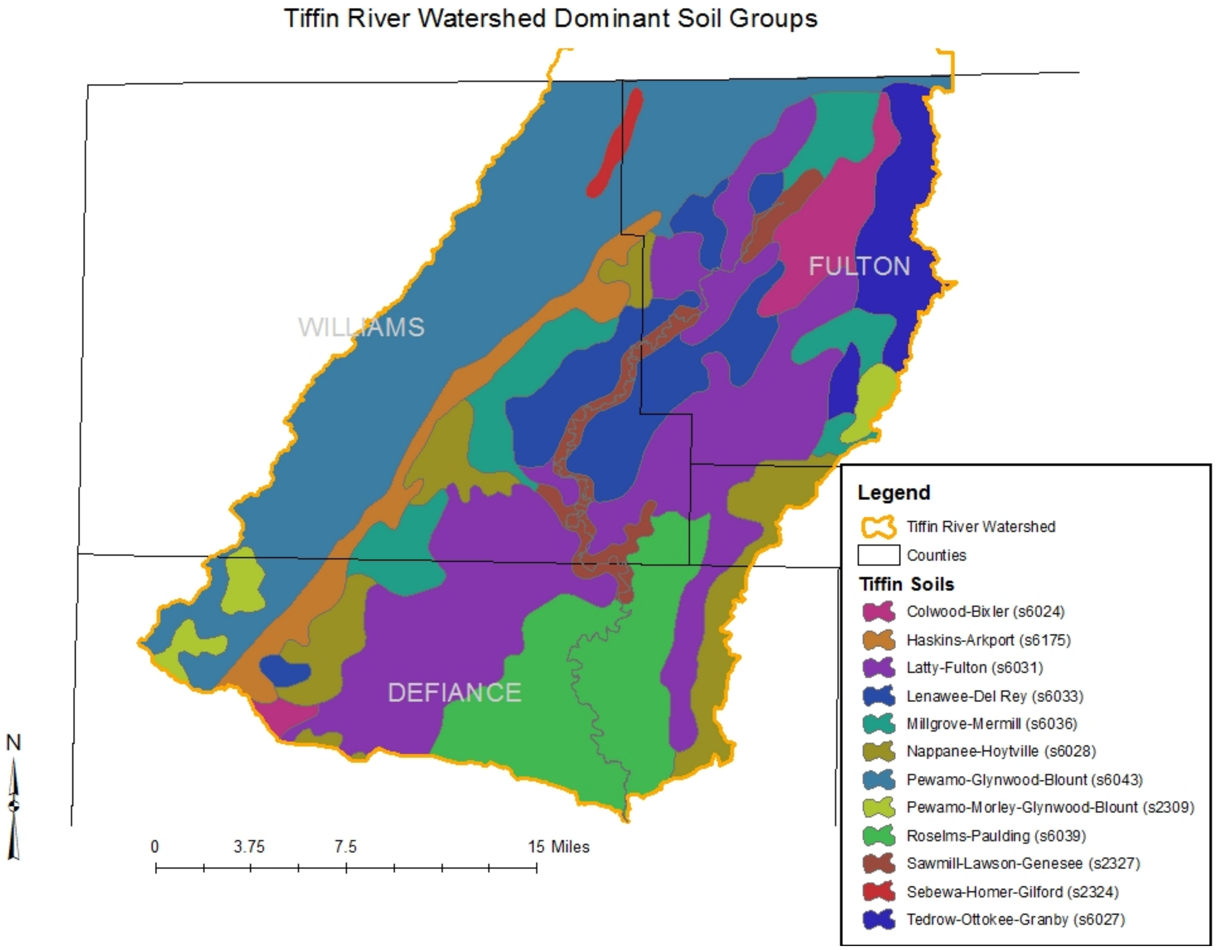


Figure 4. STATSGO general soil groups in the Tiffin River watershed, 2012.

NPDES Permitted Facilities

A total of 31 National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water, and/or industrial storm water into streams situated in the Tiffin River watershed. The city of Bryan and the village of Archbold are considered major dischargers based on the volume (>1 MGD) and type of waste they discharge. All other individual NPDES permitted facilities in the watershed are considered minor dischargers. Minor dischargers include two concentrated animal feeding operations (CAFOs), eight activated sludge sewage treatment plants, four sewage lagoons, four package plants, and two industrial storm water discharges. A complete list of NPDES permitted facilities can be found in Table 20.

Public Drinking Water Supplies

Many rural residents in Ohio depend on ground water wells as their source of drinking water. Outside of the service area of municipal public water systems, residents and businesses rely on wells for potable water. Many municipalities and communities in the Tiffin River watershed use ground water for the source of their public drinking water supply (Table 5).

The status of the public drinking water supply use is summarized in the Ohio 2012 Integrated Water Quality Monitoring and Assessment Report which can be located at the following website http://www.epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx. The only surface water intake in the Tiffin River watershed is for the village of Archbold and is located on the Tiffin River at RM 47.54; there is another intake for the village of Archbold located on Brush Creek, but this intake is not currently in use and hasn't been so for quite some time. Drinking water is ultimately conveyed to both Archbold upground reservoirs #1 and #2 for storage before use. Sampling conducted in 2013 and 2014 at the Archbold water intake is discussed in detail in the *Public Drinking Water Supply* section of this report. Additional information on drinking water sources can be found in the Drinking Water Source Assessments for the municipalities located in the watershed at the following website http://epa.ohio.gov/ddagw/swap.aspx .

Table 5. Community ground water treatment plants.

WTP Name	PWSID	COUNTY
Ney WTP	OH2000512	Defiance
Bryan Municipal Light And Water Utilities	OH8600012	Williams
Northland Senior Community	OH8601112	Williams
Aqua Ohio - Norlick	OH8601012	Williams
North Pine Estates	OH8600812	Williams
Oakwood MHP	OH8601212	Williams
Stryker Village	OH8601712	Williams
Williams Co/Hillside Country Living	OH8601912	Williams
West Unity WTP	OH8601812	Williams
Fayette Village	OH2600412	Fulton

FISH COMMUNITY OVERVIEW

A total of 60,443 fish representing 70 different species and 7 hybrids were collected from 52 locations in the Tiffin River study area from June to October in 2012 and 2013. Four sites in the lower Tiffin River were monitored in 2012 in conjunction with the Maumee River mainstem study. Only the most recent data are used for aquatic life use attainment status in this report. Relative numbers, biomass, and species collected per location are presented in Appendix C and IBI and MIwb scores are presented in Appendix D. Fish numbers and biomass are standardized to a distance of 0.3 km for headwater and wading sites and 1 km for boat sites. Sampling locations were evaluated using the assigned or recommended ALU including WWH, MWH-I or MWH-C criteria within each site's respective ecoregion, HELP or ECBP. A summary of the fish community data is presented in Table 7. Longitudinal graphs displaying fish community performance including both current and historical data are displayed in Figure 6, Figure 10, Figure 11, and Figure 12.

Tiffin River mainstem

Ten Tiffin River mainstem sites evaluating approximately 47 river miles were sampled intensively during 2012 and 2013. All ten mainstem sites were found to fully meet applicable fish biocriteria in both years. The nine most upstream sites were previously designated WWH and fully achieved applicable WWH biocriteria. The two uppermost locations (RMs 47.54 and 41.12) exceeded WWH expectations and IBI scores are either meeting or are within non-significant departure from EWH biocriteria. The most downstream site (RM 0.80) is perennially impounded by the Maumee River due to the Independence lowhead dam; thus, this site has been recommended MWH-I and was evaluated using those biocriteria. Longitudinal performance of fish biocriteria is displayed in Figure 6.

Table 6 . Average IBI and MIwb scores for the Tiffin River mainstem, 2012, 2013, and 1992.

Year	IBI	MIwb
2013, n=8	41.6	9.58
2012, n=4	36.3*	8.45*
1992, n=7	34.3	7.7

*Due to extremely low flows in 2012, 3 of 4 locations were sampled using wading methods. See Table 7.

Average IBI (41.6) and MIwb (9.58) scores from 2013 correspond to a good to very good narrative evaluation (Table 6). Overall, fish assemblages throughout the Tiffin River mainstem ranged from fair to exceptional (Table 7). Aggregate catch statistics from 2013 indicate the six most numerically abundant fish species (#/km) included spotfin shiner (18.57%), bluntnose minnow (17.03%), golden redhorse (8.83%), channel catfish (7.74%), emerald shiner (5.48%), and silver redhorse (5.24%). In terms of relative biomass (kg/km), common carp (28.05%), freshwater drum (18.01%), silver redhorse (17.29%), channel catfish (10.69%), golden redhorse (6.81%), and flathead catfish (5.11%) were the most abundant.

Fish taxa sensitive to various environmental disturbances were well represented throughout the Tiffin River. About 23.2% of all fish and 27.2% of fish biomass in the Tiffin River mainstem in 2013 was comprised of species that are intolerant or moderately intolerant to various types of water pollution and habitat alteration; these fish taxa are collectively referred to as pollution sensitive species. Pollution sensitive species collected in 2013 included brindled madtom, dusky darter, golden redhorse, greenside darter, hornyhead chub, logperch darter, northern hog sucker, river chub, rosyface shiner, sand shiner, shorthead redhorse, silver redhorse, smallmouth bass, and stonecat madtom. Additionally, two other pollution sensitive species, namely the brook silverside and eastern sand darter, were also collected in the Tiffin River mainstem in 2012. Several of the aforementioned pollution sensitive species were not collected during the previous mainstem survey in 1992, including the logperch darter, river chub, hornyhead chub, and eastern sand darter. The eastern sand darter is considered a species of concern in Ohio because of a significant reduction in its historical range and intolerance to excessive silt and muck substrates that can blanket clean sandy substrates required for feeding and reproduction (Ohio DNR 2015, Tessler et al. 2012). The logperch darter is also considered a substrate sensitive species, though not as sensitive as the eastern sand darter. More discussion of the above point is contained within the mainstem trends portion of this section.

Sport fishes were well represented throughout the Tiffin River mainstem. Channel catfish were the most abundant and were collected at each sampling location. Flathead catfish were also collected at nearly all locations, with the largest individual weighing approximately 33 lbs. collected at RM 14.0 (right). The presence of flathead catfish in the Tiffin River basin is a relatively new phenomenon, as they had not been previously collected in the Tiffin River basin in 1992 or 1997. Northern pike and other popular pan fishes such as bluegill sunfish, rock bass, and crappie were also present throughout the mainstem.

Tributaries

Fish communities in 21 tributaries to the Tiffin River were fully assessed during the 2013 sampling season. Of the 42 sites sampled, IBI and/or MIwb scores at 32 (76.2%) fully met, one (2.4%) partially met, and nine (21.4%) failed to meet applicable fish biocriteria; narrative scores ranged from poor to exceptional (Table 7).

Mill & Bean Creek sub-basin - HUC 10 (04100006 02) Old Bean Creek, Bean Creek, Mill Creek, and Deer Creek

Old Bean Creek originates in the HELP ecoregion and flows southwest through the ECBP before joining the Tiffin River near the Tiffin River Wildlife Area. The fish community in Old Bean Creek was assessed at County Rd 19 (RM 6.22) and at Old Angola Rd. (RM 1.85), and at both locations was found to meet applicable fish biocriteria. Despite this, the fish community was dominated by species that are tolerant of pollution and omnivorous, such as the bluntnose minnow. The fish community was influenced by poor overall habitat conditions including poor channel development, extensive siltation, and high levels of embeddedness.

The fish community in Deer Creek was assessed at County Rd. 23 (RM 4.56), and was found to be just meeting expectations of an ECBP ecoregion WWH fish assemblage. Tolerant species such as creek chubs, white suckers, and bluntnose minnows comprised about 76% of the catch numerically and 87% of the biomass. The fish community also exhibited a relatively high proportion of generalist (50.4%) and omnivorous (25.2%) fish species and a relatively low proportion of insectivores (17.6%). A high proportion of tolerant, generalist, and omnivorous fishes can be reflective of nutrient enrichment. The percentage of pioneering fish taxa (68.0%) was also relatively high; pioneering fish taxa are tolerant of a wide range of environmental disturbance and can predominate in unstable environments impacted by temporal desiccation or other anthropogenic stresses. Although the fish community was just attaining the applicable IBI biocriterion, macroinvertebrate communities were not. Biological performance at this location indicated negative impacts from nutrient enrichment. Total phosphorus (0.26 mg/l) and nitrate-nitrite (1.11 mg/l) concentrations were above target levels. Aside from nutrient enrichment influences, the upstream village of Fayette has historically had issues with combined sewer overflows (CSOs) that may have also been a factor limiting biological performance. However, Fayette's Long Term Control Plan was approved in October 2012 to address this issue, and separation of their sewers is expected by April 2015 per their NPDES permit. After separation, 18 months of post-construction monitoring will be conducted to determine the effectiveness of these projects.

Bean Creek was found to exceed expected WWH fish assemblages at US Route 20 (RM 7.55) and Old Angola Rd. (RM 2.20), with numeric scores being exceptional throughout. IBI and MIwb scores performed in the EWH range and were among the highest in the entire basin. Pollution sensitive fish species, such as the river chub, northern hog sucker, and golden redhorse comprised about 48% numerically and 58% of the biomass for Bean Creek. Other pollution sensitive species collected included brindled and stonecat madtoms, rosyface and sand shiners, dusky darter, and shorthead and silver redhorse suckers. Several rare, pollution intolerant American brook lampreys were also collected in 2013. Negative effects from several habitat limited areas and the overall history of channel modification were ameliorated by sufficient gradient and significant connection to the water table.

Fish communities in Mill Creek were assessed at County Rd. S (RM 14.49), County Rd. P (RM 11.90), County Rd. 28 (RM 7.92), and Old Angola Rd. (RM 1.85). Fish communities were only found to meet applicable fish biocriteria at RM 1.85 (Table 7). Harrison Lake separates this lowermost site from the upper three and functionally acts as a barrier to upstream fish movement. Pollution sensitive fishes such as darters and redhorse suckers were completely absent from the fish community upstream from this impoundment; 19 fish species were absent from these upstream reaches that were present at RM 1.85. Tolerant and pioneering species were an overwhelmingly dominant component of the fish community at all three impaired sites. Fish communities appeared negatively influenced by multiple DO exceedances, as well as several large diel DO swings stemming from nutrient enrichment influences at RMs 14.49 and 7.92. Excessive siltation is also negatively impacting biological performance at RM 14.49. Sonde data revealed several diel DO sags at RM 11.9, with values as low as 1.07 mg/l; these are likely caused by excess organic enrichment emanating from the unsewered village of Alvordton. A diel sag in DO is typically associated with various sources of organic enrichment, in which microbes consume much of the stream's DO in an effort to process excess organic pollution in a stream ultimately resulting in chronically low DO values over a 24-hour period. Conversely, a large diel DO swing is typically associated with excess algal production in an enriched stream, where instream DO concentrations are very high in daylight hours during periods of algal photosynthesis and very low at night during periods of algal respiration. The negative influences impacting the fish community discussed above are exacerbated by the inability of fishes to migrate past the Harrison Lake dam, effectively limiting the amount and types of fish species that can be present and limiting the ability of fishes to avoid impacted areas. Even if all other sources of identified stress were addressed, the presence of the Harrison Lake dam, though beneficial for aesthetic and recreational functions, may ultimately preclude full attainment of fish biocriteria in the upstream reaches of Mill Creek.

Upper Tiffin River sub-basin - HUC 10 (04100006 03) Bates Creek, Flat Run, and Leatherwood Creek

Bates Creek, Flat Run, and Leatherwood Creek are all direct tributaries to the Tiffin River and are situated in the ECBP ecoregion. Each stream was evaluated at one location using the applicable headwater IBI biocriterion. Fish community performance in all three streams failed to meet the biocriterion. Tolerant fish species overwhelmingly dominated fish assemblages, comprising 78.4%, 68.9%, and 68.3% of the fish collected in Bates Creek, Flat Run, and Leatherwood Creek, respectively.

Pollution sensitive fish species were nearly absent in these streams, comprising less than 1% of the fish community where present. Fish community performance was negatively influenced by pervasive siltation and embeddedness. Additionally, excess siltation in both Bates Creek and Flat Run appeared to be causing a high sediment oxygen demand (SOD) and was likely contributing to the DO sags observed at these locations. A SOD can occur when biological activity in a stream consumes oxygen through chemical oxidation of reduced elements such as Fe^{2+} contained in soils and silts that enter a stream during erosion and run-off events. Excess siltation in a stream or large amounts of organic material contained within soils can exacerbate this process.

<u>Middle Tiffin River sub-basin – HUC 10 (04100006 05) Beaver Creek, Brush Creek, Owl Creek, Coon Creek, and Doty Run</u>

Beaver Creek originates in the ECBP ecoregion and flows southwest into the HELP ecoregion before joining the Tiffin River south of Stryker. Fish communities were assessed at County Rd. K (RM 17.12), County Rd. 16 (RM 12.66), US Route 127 (RM 7.52), County Rd. D (RM 2.90), and County Rd. 25 (RM 0.61). All locations except the most upstream (RM 17.12) fully attained applicable fish biocriteria. Fish community performance was generally higher in the upper reaches situated in the ECBP and declined slightly into the marginally good range as Beaver Creek transitioned into the HELP ecoregion. Pollution sensitive species were present throughout Beaver Creek and comprised about 8% numerically and 12% of biomass. Excessive siltation and embeddedness, along with other negative influences related to historical channelization activities likely limited fish community performance at the uppermost site in Beaver Creek.

Brush Creek is situated entirely in the HELP ecoregion. Fish communities were assessed at County Rd. D (RM 19.06), County Rd. 24 (RM 13.28), County Rd. 24-25 (RM 9.11), County Rd. C (RM 5.76), and County Rd. 22-60 (RM 1.05). Fish communities fully met applicable fish biocriteria at four locations (Table 7). The fish community at RM 13.28 failed to achieve the MIwb criterion. Out of all locations sampled on Brush Creek, this particular location had the highest relative percentages (78.4%) and relative biomass (91.2%) of tolerant and moderately tolerant fish species (Figure 5). Pollution sensitive fish taxa were completely absent from the two most upstream locations. The relative number of fishes (excluding tolerant fishes) at RM 13.28 was also anomalously low, the second lowest of the entire survey (Table 7). Anomalously low relative numbers can indicate impacts from organic enrichment. Sonde and surface water chemistry data also indicated several minimum DO exceedances at this location. Sonde data from RM 13.28 indicated DO sags as low as 1.23 mg/L and 24-hour averages as low as 3.25 mg/L, both of which are well below the 4.0 mg/L minimum Water Quality Standards criterion. Brush Creek at RM 19.06 exhibited large diel DO swings indicative of high amounts of algal growth over the same time period; in contrast, DO sags at RM 13.28

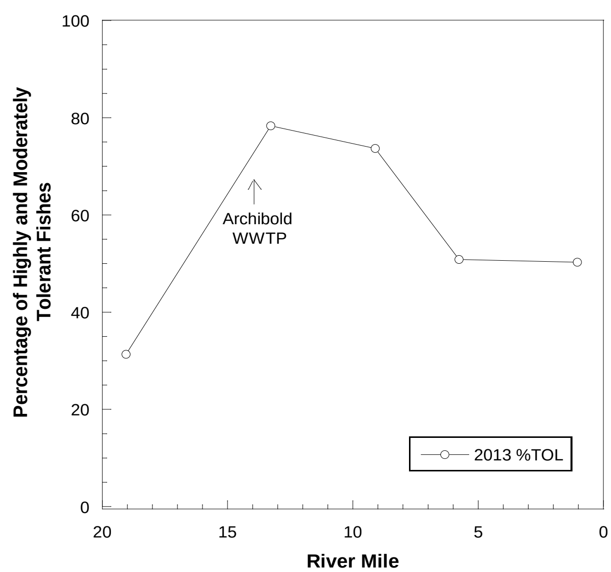


Figure 5 . Relative percent (#/0.3 km) of tolerant fish composition of total catch by river mile for Brush Creek sampling locations, 2013.

were consistently below criterion values and did not exhibit the large diel DO or related pH swings associated with nutrient enrichment. The latter type of DO sag is typically associated with sources of oxygen demanding organic waste, such as that emanating from a WWTP, CSOs, or excess manure. Biological performance was most likely limited primarily by excess organic wastes emanating from the Archbold WWTP. Poor habitat conditions are likely exacerbating the effects from the Archbold WWTP and precluding more significant recovery throughout Brush Creek. A mean QHEI score of 37.3 for Brush Creek is substantially lower than the benchmark QHEI score of 60 where one would typically expect fish communities to meet the WWH aquatic life use.

Owl Creek, Coon Creek, and Doty Run are situated in the HELP ecoregion. Fish communities were evaluated at one location each and either fully met or were in non-significant departure of the applicable fish IBI biocriterion; narrative scores ranged from poor to fair (Table 7). However, tolerant fish taxa comprised 81%, 82% and 89% of the fish communities in Owl Creek, Coon Creek, and Doty Run, respectively. Low flow conditions in all three streams and excessive siltation and organic enrichment in Owl Creek has likely limited fish community performance in these streams.

Lick Creek sub-basin – HUC 10 (04100006 04) Lick Creek, Miller Creek, Little Lick Creek, Prairie Creek

Lick Creek originates in the ECBP ecoregion and flows in a southeast direction through the HELP ecoregion before joining the Tiffin River just north of the Oxbow Lake Wildlife Area. Fish communities were assessed at County Rd. 13 north of Bryan (RM 21.77), County Rd. 13 south of Bryan (RM 17.66), The Bend Rd. (RM 10.05), and at Trinity Rd (RM 1.23). Fish communities at all these locations fully met or were in non-significant departure from applicable fish biocriteria (Table 7). Fish species tolerant of pollution comprised about 52% of the overall fish community in Lick Creek. An eastern sand darter, classified as a species of concern in Ohio, was collected at RM 1.2.

Miller Creek and Little Lick Creek are both tributaries to Lick Creek. Both streams originate in the ECBP ecoregion; however, Little Lick Creek transitions through the HELP ecoregion before joining Lick Creek. Fish communities were assessed at County Rd 309/D (RM 0.50) in Miller Creek and Behnfeldt Rd (RM 4.97) and upstream from Ney (RM 0.80) in Little Lick Creek. IBI and MIwb scores at all three sites fully met the applicable biocriteria. Multiple DO exceedances were observed at both locations sampled on Little Lick Creek. Despite achieving applicable biocriteria, the fish community exhibited signs of stress from low DO conditions, as pioneering, tolerant, and omnivorous fish species comprised the majority of the fish community. Phosphorus concentrations were elevated at both RM 4.97 (0.09 mg/L) and RM 0.8 (0.13 mg/L) in Little Lick Creek. Additionally, sonde data revealed modest diel DO swings at RM 4.97 and diel DO sags at RM 0.8. Nutrient enrichment is likely precluding more significant recovery at the upper site, while data suggests organic enrichment is a larger contributing factor than excess nutrients at RM 0.8.

Prairie Creek originates in the ECBP ecoregion and flows southeast through the HELP ecoregion before joining Lick Creek east of Ney. Fish communities in Prairie Creek were assessed at County Rd. C (RM 9.80) and the lower crossing on Flickinger Rd (RM 3.40), both of which were downstream from the Bryan WWTP. The IBI score did not meet the WWH biocriterion at RM 9.8, 1.2 miles below the WWTP. The fish community at RM 9.8 was comprised of over 86% tolerant and 61% pioneering fish taxa, with pollution sensitive taxa comprising less than 1% of the fish community. Benthic chlorophyll-a concentrations of 334 mg/m^2 indicate over-enriched conditions which are reflected in the biological communities. Total phosphorus (0.15 mg/L) and nitrate-nitrite (5.96 mg/L) concentrations were also above target levels at this location and provided further evidence of the over-enriched conditions at this location. Sonde data revealed diel DO swings as large as 11 mg/L, indicative of nutrient enrichment.

Pervasive siltation and embeddedness, and more generally poor overall habitat quality, also negatively impacted aquatic communities here and likely exacerbated nutrient issues. Flocculent solids and a milky-white color in the water column immediately downstream from the Bryan WWTP outfall were observed during follow-up sampling in the summer of 2014. The flocculent solids have the potential to smother natural substrates and can also negatively influence biological performance. The Bryan WWTP is a likely source contributing to the observed over-enrichment and flocculent bottom deposits observed at RM 9.8.

Lower Tiffin River sub-basin – HUC 10 (04100006 06) Lost Creek, Mud Creek, Dry Creek, Buckskin Creek, and Webb Run

Lost Creek originates in the ECBP ecoregion before transitioning through the HELP ecoregion prior to joining Mud Creek north of Defiance. Fish communities were assessed at Seevers Rd. (RM 8.97) and Behnfeldt Rd. (RM 1.41) and only achieved applicable WWH biocriteria at the lowermost site at RM 1.41 (Table 7). The fish community at RM 8.97 displayed a higher percentage of tolerant (84.9%), generalist feeding (67%) fish taxa, with fewer pollution sensitive (<1%) and insectivorous (13.7%) fish taxa than were present at the downstream site. Nutrient levels were below target levels and the QHEI score (71.5) indicated excellent overall habitat attributes. It was noted on the QHEI that there may be a possible impoundment such as a beaver dam or log jam located downstream, evidenced by little observed flow in the stream channel; however, water quality modeling staff indicated good instream flow and an overall aesthetically pleasing stream during follow-up sampling at the same location in the summer of 2014. Fish community sampling in 2013 indicated 10 fish species absent from RM 8.97 that were present at RM 1.41, a decline which could be realized due to impounded conditions at that time. However, the ultimate cause(s) and source(s) of biological community impairment at RM 8.97 cannot be definitively identified and are being treated as unknown.

Dry Creek is a tributary to Mud Creek and was evaluated at County Rd. 124 (RM 3.76). Fish community performance met the applicable WWH IBI biocriterion at the one location sampled. The fish community was comprised of a relatively high percentage of tolerant (64%), omnivorous (37%), and pioneering (55%) fish taxa. Biological performance, particularly with regard to macroinvertebrates which did not meet WWH expectations, appeared to be negatively influenced by both nutrient and organic enrichment originating from row crop agriculture and manure applications. Low flow conditions and excessive siltation were also having negative influences on biological performance.

Mud Creek is a direct tributary to the Tiffin River and is situated within the HELP ecoregion. Fish community performance in Mud Creek was observed to be marginally good to good (Table 7). Pollution sensitive fish species comprised nearly 17% of the overall fish community. Additionally, two eastern sand darters were collected at RM 1.5.

Fish communities in Buckskin Creek and Webb Run fully met the applicable WWH IBI biocriterion. Low stream flows due to natural conditions may have limited fish community performance, though not significant enough to cause impairment.

Table 7. Fish community summaries based on pulsed D.C. electrofishing sampling conducted by Ohio EPA in the Tiffin River watershed during the 2012 and 2013 sampling seasons. Relative numbers and weights are per 0.3 km for wading and headwater sites, and per 1.0 km for boat sites. NA= not applicable. Data from locations in the lower Tiffin River collected in 2012 are denoted by [brackets]. Mainstem sites noted with an *asterisk* would typically be sampled using boat sampling methods; however, exceptionally low flows in 2012 warranted the use of wading sampling methods.

Stream	River Mile	Sampling Method	Eco-region	Fish Species (Total)	Relative Number	Relative Weight (kg)	QHEI (Habitat)	**IBI**	**MIwb**	Narrative Evaluation (IBI/MIwb)
Tiffin River	47.54	Boat	ECBP	27	832.0	75.4	61.3	**48**	**9.46**	Exceptional/Very Good
Tiffin River	41.12	Boat	ECBP	33	712.0	52.7	66.8	**46**	**9.51**	Very Good/Exceptional
Tiffin River	35.20	Boat	HELP	30	669.0	106.2	41.0	**41**	**9.26**	Good/Very Good
Tiffin River	33.95	Boat	HELP	27	416.0	108.5	49.8	**43**	**9.78**	Good/Exceptional
Tiffin River	26.17	Boat	HELP	29	618.0	133.5	64.8	**42**	**9.94**	Good/Exceptional
Tiffin River	19.72	Boat	HELP	27	492.0	60.9	57.5	**38**	**9.31**	Good/Very Good
[Tiffin River]	18.73	*Wading*	HELP	26	271.0	38.9	56.0	**36**	**7.77**	Marg. Good/Marg. Good
Tiffin River	14.00	Boat	HELP	36	765.0	93.4	65.0	**35**	**9.33**	Good/Very Good
[Tiffin River]	14.00	*Wading*	HELP	33	1121.0	15.16	70.5	**41**	**9.09**	Good/Very Good
Tiffin River	7.09	Boat	HELP	37	1387.0	114.3	76.0	**40**	**10.05**	Marg. Good/Good
[Tiffin River]	7.09	*Wading*	HELP	38	1465.0	14.57	75.25	**33**	**8.54**	Fair/ Good
[Tiffin River]	0.89	Boat	HELP	24	495.0	90.9	49.8	**35**	**8.41**	Marg. Good/Marg. Good
Old Bean Creek	6.22	Headwater	HELP	21	1282.0	N/A	31.5	**36**	**N/A**	Marg. Good
Old Bean Creek	1.90	Wading	ECBP	26	603.0	14.6	36.0	**41**	**7.50**	Good/Fair

Stream	River Mile	Sampling Method	Eco-region	Fish Species (Total)	Relative Number	Relative Weight (kg)	QHEI (Habitat)	**IBI**	**MIwb**	Narrative Evaluation (IBI/MIwb)
Deer Creek	4.56	Headwater	ECBP	18	2349.0	N/A	61.0	**36**^{NS}	**N/A**	Marg. Good
Bean Creek	7.55	Wading	ECBP	40	1435.5	47.1	71.8	**51**	**9.98**	Exceptional/ Exceptional
Bean Creek	2.20	Wading	ECBP	38	781.5	20.6	51.0	**50**	**9.81**	Exceptional/ Exceptional
Mill Creek	14.49	Headwater	ECBP	15	1044.0	N/A	30.3	**24***	**N/A**	Poor
Mill Creek	11.90	Wading	ECBP	21	1637.1	15.2	61.0	**28***	**7.65***	Fair/Fair
Mill Creek	7.92	Wading	ECBP	15	2158.3	22.1	58.5	**26***	**6.53***	Poor/Fair
Mill Creek	1.85	Wading	ECBP	35	1473.6	20.8	63.0	**38**^{NS}	**8.91**	Marg. Good/Very Good
Bates Creek	1.65	Headwater	ECBP	17	972.0	N/A	51.3	**34***	**N/A**	Fair
Flat Run	0.40	Headwater	ECBP	22	850.0	N/A	40.0	**34***	**N/A**	Fair
Leatherwood Creek	1.15	Headwater	ECBP	26	1016.0	N/A	57.5	**34***	**N/A**	Fair
Beaver Creek	17.12	Headwater	ECBP	16	1512.0	N/A	54.5	**34***	**N/A**	Fair
Beaver Creek	12.66	Wading	ECBP	29	1617.0	22.5	70.5	**41**	**9.49**	Good/Very Good
Beaver Creek	7.52	Wading	ECBP	31	1558.0	27.2	66.5	**48**	**9.21**	Very Good/Very Good
Beaver Creek	2.90	Wading	HELP	28	500.4	14.6	59.3	**36**	**7.97**	Marg. Good/Good
Beaver Creek	0.61	Wading	HELP	36	860.3	7.5	56.3	**38**	**9.18**	Good/Very Good
Owl Creek	0.07	Headwater	HELP	11	272.0	N/A	26.0	**26**^{NS}	**N/A**	Poor
Brush Creek	19.06	Headwater	HELP	14	6418.5	N/A	46.3	**36**	**N/A**	Marg. Good
Brush Creek	13.28	Wading	HELP	22	277.4	10.0	31.3	**29**^{NS}	**6.20***	Fair/Poor
Brush Creek	9.11	Wading	HELP	22	450.0	32.6	47.5	**36**	**8.14**	Marg. Good/Good

Stream	River Mile	Sampling Method	Eco-region	Fish Species (Total)	Relative Number	Relative Weight (kg)	QHEI (Habitat)	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
Brush Creek	5.76	Wading	HELP	24	2008.7	12.9	25.5	**30^{NS}**	**8.26**	Fair/Good
Brush Creek	1.05	Wading	HELP	31	777.5	15.1	40.0	**32**	**8.10**	Fair/Good
Coon Creek	0.62	Headwater	HELP	24	558.0	N/A	42.0	**28**	**N/A**	Fair
Doty Run	0.63	Headwater	HELP	17	474.0	N/A	42.8	**26^{NS}**	**N/A**	Poor
Miller Creek	0.50	Wading	ECBP	27	1527.0	44.9	71.5	**39**	**8.12^{NS}**	Good/Marg. Good
Little Lick Creek	4.97	Headwater	ECBP	16	1992.0	N/A	50.5	**40**	**N/A**	Good
Little Lick Creek	0.80	Wading	HELP	28	2335.2	18.9	57.3	**35**	**8.21**	Marg. Good/Good
Prairie Creek	9.80	Headwater	ECBP	19	804.0	N/A	35.8	**28***	**N/A**	Fair
Prairie Creek	3.40	Wading	HELP	32	1567.1	25.2	64.0	**29^{NS}**	**8.36**	Fair/Good
Lick Creek	21.77	Headwater	ECBP	12	976.0	N/A	61.5	**36^{NS}**	**N/A**	Marg. Good
Lick Creek	17.66	Wading	ECBP	25	3053.3	23.9	67.3	**37^{NS}**	**9.36**	Marg. Good/Very Good
Lick Creek	10.05	Wading	HELP	33	668.0	5.9	56.5	**42**	**8.50**	Good/Good
Lick Creek	1.23	Wading	HELP	37	721.6	13.7	52.8	**31^{NS}**	**7.72**	Fair/Marg. Good
Dry Creek	3.76	Headwater	HELP	19	1980.0	N/A	36.3	**32**	**N/A**	Fair
Lost Creek	8.97	Headwater	ECBP	17	1042.2	N/A	71.5	**32***	**N/A**	Fair
Lost Creek	1.41	Wading	HELP	26	907.8	16.3	64.0	**35**	**7.84**	Marg. Good/Marg. Good
Mud Creek	10.10	Wading	HELP	31	925.8	12.4	60.0	**34**	**7.48**	Marg. Good/Marg. Good
Mud Creek	1.50	Wading	HELP	30	662.8	3.5	50.0	**42**	**7.89**	Good/Marg. Good
Buckskin Creek	1.20	Headwater	HELP	23	2062.0	N/A	42.0	**32**	**N/A**	Fair
Webb Run	2.99	Headwater	HELP	20	838.0	N/A	40.8	**36**	**N/A**	Marg. Good
Webb Run	0.40	Headwater	HELP	16	861.0	N/A	51.3	**28**	**N/A**	Fair

ns Nonsignificant departure from biocriterion (≤4 IBI units; ≤0.5 MIwb units).

*Significant departure from biocriterion (>4 IBI units; >0.5 MIwb units). Poor and very poor results are underlined.

Biological Criteria								
	Huron-Erie Lake Plain (HELP)				Eastern Corn Belt Plains (ECBP)			
Index – Site Type	EWH	WWH	MWH-I	MWH-C	EWH	WWH	MWH-I	MWH-C
IBI – Headwaters	50	28	N/A	20	50	40	N/A	24
IBI – Wading	50	32	N/A	22	50	40	N/A	24
IBI – Boat	48	34	22	20	48	42	30	24
MIwb – Wading	9.4	7.3	N/A	5.6	9.4	8.3	N/A	6.2
MIwb - Boat	9.6	8.6	5.7	5.7	9.6	8.5	6.6	

FISH COMMUNITY TRENDS

Tiffin River Mainstem

The fish community in the Tiffin River mainstem was sampled extensively in 1984, 1992, and 2013; while limited sampling occurred at four sites in 2012 on the lower mainstem. For the purposes of evaluating the fish community trends in the mainstem over time, an analysis of fish community performance between 1992 and 2013 will be the primary historical trend period provided, with 2012 and 1984 data incorporated where applicable.

Fish community indices for the Tiffin River mainstem showed substantial improvement compared to 1992. IBI and MIwb scores were higher at nearly all locations sampled; aggregate performance was also substantially higher (Figure 6). From 1992 to 2012-13, MIwb scores improved from not achieving WWH criteria at nearly all sites, to meeting WWH ALU goals at all locations. Figure 7 highlights improvements of fish community performance at three selected locations through time and exemplifies the generally positive trajectory of fish community performance observed throughout the watershed. Increases in both the IBI and MIwb over time suggest improved structural and functional aspects of the fish community in the Tiffin River mainstem.

In addition to the primary fish community indices, other various groups of indicator species can be useful for examining trends in environmental condition over time. Several of these indicator groups are depicted in Figure 8 and Figure 9. One such indicator of stream integrity is the overall number and relative abundance of pollution sensitive fish species. A total of 16 pollution sensitive fish species were collected from the Tiffin River mainstem during the latest survey, four more than were collected in 1992. These species include hornyhead and river chubs, and logperch and eastern sand darters. The relative abundance of sensitive fish species more than doubled since 1992 (Figure 8). Sensitive fish species also comprised a larger relative percentage and percent of relative biomass of the overall fish community in 2013 (23.1%, 27.2%) than in 1992 (10.8%, 20.3%).

Darters may generally be considered sensitive to a range of environmental disturbance. The abundance of darters in a stream is often reflective of ambient water quality and habitat conditions due to life history characteristics that make them intolerant to physical and chemical environmental disturbances (Ohio EPA 1987). The relative number of darters (#/km) increased nearly fourfold from 1992 (3.9/km) to 2013 (16.7/km) (Figure 8). Three eastern sand darters, a species of concern in Ohio, were collected in the Tiffin River mainstem in 2012 (2 at RM 7.09, 1 at RM 14.00); additionally, three other eastern sand darters were collected near the mouths of Lick Creek (1 at RM 1.2) and Mud Creek (2 at RM 1.5) in 2013. These are the first Ohio EPA records of eastern sand darters in the Tiffin River basin. The eastern sand darter is exceptionally sensitive to excessive silt and muck substrates that can blanket clean sandy substrates required for feeding and reproduction and will quickly become extirpated from areas affected by such impacts (Tessler et al. 2012, Trautman 1981). Historically, the eastern sand darter was widespread throughout the Maumee River and the lower portions of its tributaries, but was nearly eliminated by the early 1900s due to habitat degradation and changes in land use practices that accelerated delivery of silts and clays to river systems (Trautman 1981). Only recently has there been documented recovery of eastern sand darter populations in the Maumee River drainage system (Tessler et al. 2012). Logperch darters are also sensitive to substrate quality, though not to the degree of the eastern sand darter. Nonetheless, no logperch darter specimens were collected in either the 1992 mainstem or 1997 tributaries surveys; however, they were found to be widely distributed throughout the mainstem and tributaries during this most recent survey. The increased abundance of darters observed in the Tiffin River watershed, particularly the recovery of eastern sand darter populations and the ubiquitous presence of logperch darters, appears to be related to improvements of instream substrate quality.

Several other groups of fish species collected in the Tiffin River mainstem are displayed in Figure 9. Common carp are a classic generalist species that is highly tolerant of degraded environmental conditions and are often quite abundant in such conditions (Trautman 1981). Percent biomass (% kg/km) of common carp decreased drastically from 1992 to 2013 (Figure 9). Conversely, the relative abundance and percent biomass of sensitive species such as round-bodied suckers increased over the same time period (Figure 9). The antithesis to common carp, round-bodied suckers (excluding the highly tolerant white sucker) are sensitive to a wide range of environmental disturbance, particularly excessive amounts of siltation, poor quality substrates, modified flow regimes, and other types of habitat alteration; round-bodied suckers are an important component of Midwestern streams and their increased abundance is a good indicator of overall water and habitat quality (Ohio EPA 1987). Many other native fish species increased in abundance and biomass as well over the same time period (Figure 9). Reductions in common carp biomass in conjunction with increases in sensitive and native fish species through time may be an emerging trend in Ohio. Where observed here and elsewhere, this trend does not appear random or otherwise stochastic given the consistent patterns observed across multiple study areas and reporting cycles (Ohio EPA 2013a). These trends are likely a result of a combination of improved ambient water quality and improvements in macrohabitat, especially substrate quality. A possible explanatory mechanism is that under improved water quality and macrohabitat conditions, such as that observed in the Tiffin River, native and/or pollution sensitive fish species may become ecologically superior competitors and occupy a greater portion of available niche space that might otherwise be occupied by non-native or tolerant fish species under degraded conditions. More simply stated, degraded habitat and water quality conditions may favor the persistence of highly tolerant and invasive fish species such as carp, whereas native and sensitive species may outcompete highly tolerant species given better overall habitat and water quality. Regardless of ultimate mechanisms driving this observation, the reduction of highly tolerant and exotic species, such as the common carp, and increases in the abundance of native and sensitive fish species is viewed as a positive trend, an observation supported by Kennard et al. (2005).

Many of the positive trends discussed above involve fish species referred to as simple lithophilic spawners which are considered to be among the more environmentally sensitive of fish spawning guilds. These types of fish species broadcast their eggs in the water column, which then sink and come into contact with bottom substrates. Eggs then develop in the interstitial spaces between sand, gravel, and cobble sized substrate particles. Excessive amounts of silts or flocculent clays in streams can smother natural substrates and render eggs inviable (Ohio EPA 1987).

Improvements in fish community performance in the Tiffin River mainstem and its tributaries, especially an increased abundance of species intolerant to poor substrate quality and excessive silts, can be attributed at least in part to improvements observed in macrohabitat quality, particularly with regard to instream substrate quality. Continued participation in conservation tillage and BMPs that reduce soil erosion and the amount of sediment entering streams are critical to improving and maintaining the high quality habitat and clean, sandy substrates critical to the life history of the eastern sand darter and other species with similar life history requirements. More in depth discussion of the improvements observed in the macrohabitat quality is contained in the *Stream Physical Habitat* section of this document.

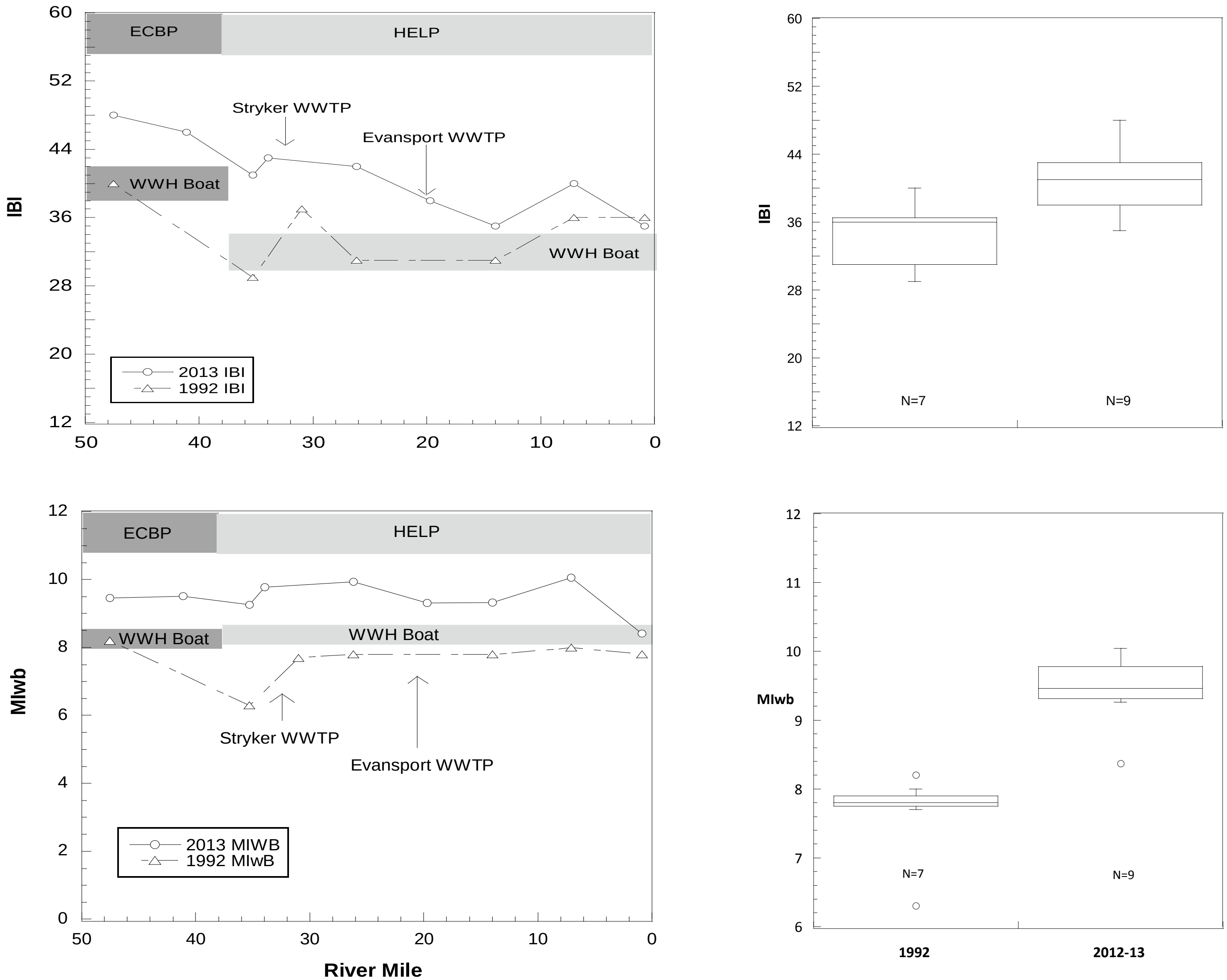
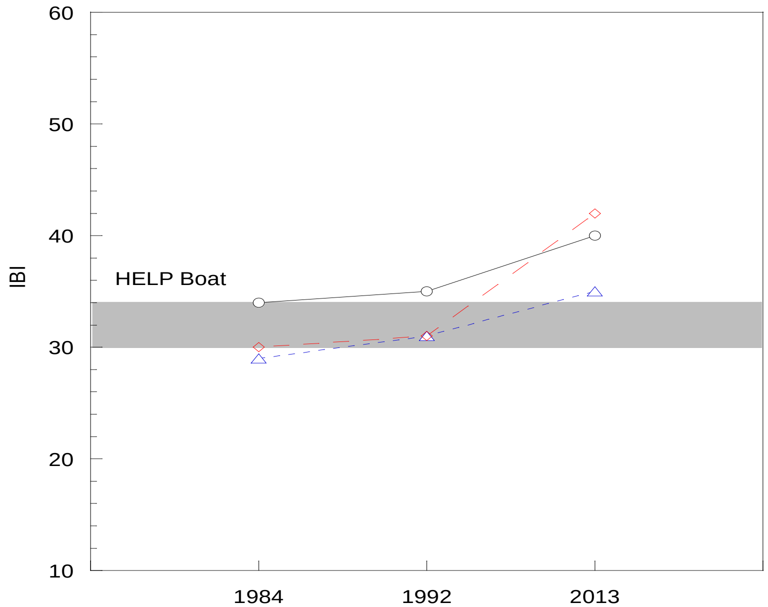


Figure 6. Longitudinal (left) and aggregate (right) performance of IBI and MIwb scores for the Tiffin River mainstem, 1992 and 2012-13. The shaded portions represent applicable biocriteria and areas of non-significant departure from said values. Only data collected using boat methods are displayed.



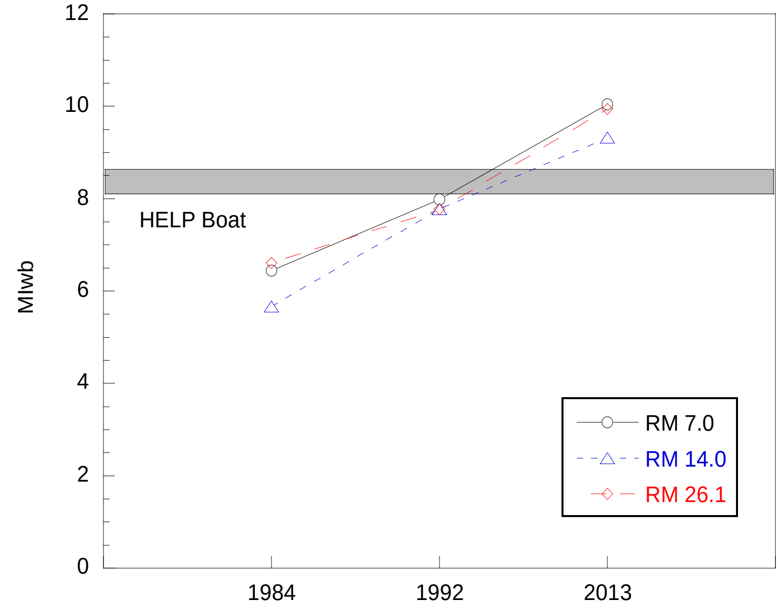


Figure 7. Performance of IBI (left) and MIwb (right) scores at selected locations in the Tiffin River mainstem through time, 1984, 1992, and 2013. The shaded portions represent applicable biocriteria and areas of non-significant departure from said values.

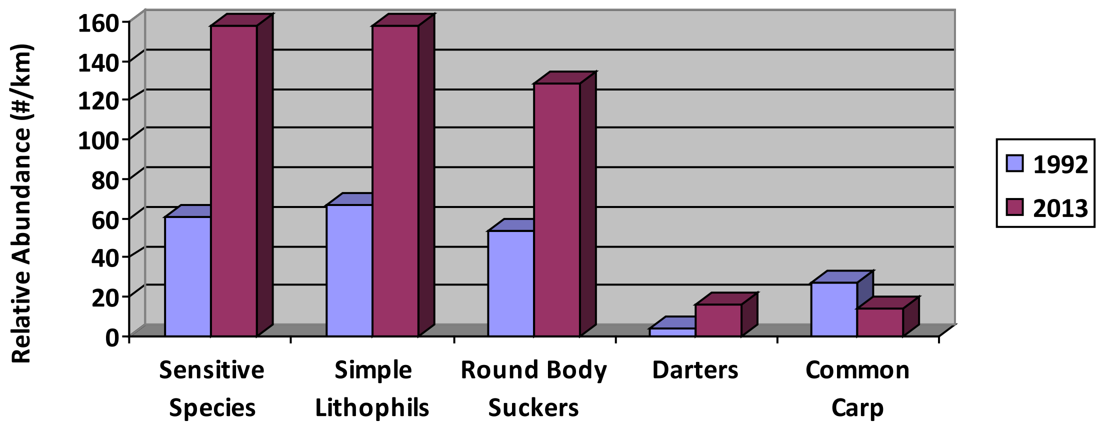


Figure 8. Relative Abundance (#/km) for selected characteristic fish groups and common carp from the Tiffin River mainstem, 1992 and 2013.

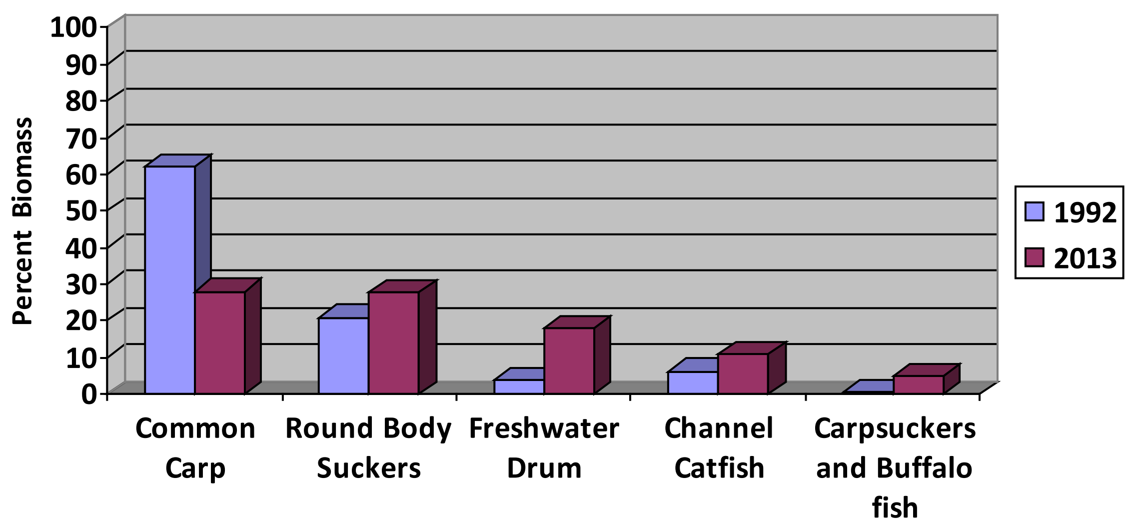


Figure 9. Percent biomass (%kg/km) of common carp compared to round-bodied suckers, freshwater drum, channel catfish, and carpsuckers and bufflalo fish species from Tiffin River mainstem, 1992 and 2013.

Tributaries

Limited sampling on selected Tiffin River tributaries was conducted in 1992 and 2002, with more extensive, basin wide tributary sampling conducted in 1997 and 2013. For trends purposes, analyses of fish communities from selected Tiffin River tributaries will focus primarily on data collected in 1997 and 2013, with 1992 and 2002 data incorporated where available.

Mill & Bean Creek sub-basin - HUC 10 (04100006 02)

Stable to slightly improved fish community performance was observed in Old Bean Creek and Deer Creek as indicated by similar or increasing MIwb and IBI scores in 2013 as compared to scores in 1997 and 1992.

In Mill Creek, three of four sites were found to consistently underachieve applicable fish biocriteria over time. These sites correspond to the three locations upstream from Harrison Lake. Relatively substantial improvements in the fish community were observed downstream from Harrison Lake (RM 1.85) (Figure 10). The Harrison Lake dam will likely preclude full recovery of the fish community upstream from this impoundment by impeding upstream recruitment of species, effectively limiting the number and types of species present, especially pollution sensitive species.

Fish community performance in Bean Creek was found to be improved in 2013 compared to 1992 and 1997. The IBI and MIwb showed a consistently positive trajectory over time. The relative percentage of sensitive taxa displayed an increasing trend over time, while the relative percentage of highly and moderately pollution tolerant taxa generally decreased over the same time period.

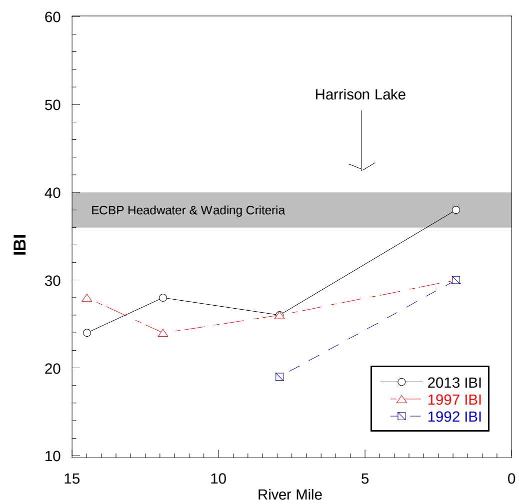


Figure 10. Longitudinal performance of IBI scores for Mill Creek, 2013, 1997, and 1992. The shaded portions represent applicable biocriteria and areas of non-significant departure from said values.

Upper Tiffin River sub-basin - HUC 10 (04100006 03)

Although the applicable fish community index still fails to achieve its biocriterion in Bates Creek and Leatherwood Creek, slight improvements have occurred. IBI scores for these streams remain in the fair range; average IBI scores increased from 28 and 32, respectively, in 1997 to 34 at each location in 2013. The fish community in Flat Run had not been previously assessed and, therefore, no historical trends can be made.

Middle Tiffin River sub-basin – HUC 10 (04100006 05)

Fish community performance in Beaver and Brush creeks exhibited substantial improvements since 1997, as evidenced by higher IBI and MIwb scores at all locations (Figure 11). Several pollution sensitive species found in Beaver Creek in 2013, namely the brindled madtom, stonecat madtom, and hornyhead chub, were absent in 1997. Also, pollution sensitive species comprised a greater portion of the fish community, while pollution tolerant fish species saw their relative abundance and biomass decrease in 2013 compared to 1997. Brush Creek experienced similar decreases in the relative abundance and biomass of pollution tolerant species; however, pollution sensitive species were not as well represented.

Increased fish community performance was observed in Coon Creek as the IBI performance at the only location sampled increased from 20 to 28 between 1997 and 2013. Fish communities in Owl Creek and Doty Run had not previously been assessed and, therefore, no historical trends can be provided.

Lick Creek sub-basin – HUC 10 (04100006 04)
Fish community performance in Lick Creek saw substantial improvements since 1997, with both IBI and MIwb scores improved at all locations (Figure 11). Pollution sensitive species comprised a greater proportion and pollution tolerant species comprised a lesser proportion of the fish community in 2013 than in 1997. Several pollution sensitive species collected in 2013, namely the brindled madtom, hornyhead and river chubs, greenside and logperch daters, and the shorthead redhorse were not present in Lick Creek in 1997. Additionally, a single eastern sand darter, a species of concern in Ohio whose importance is discussed more thoroughly in the Tiffin River mainstem trends section, was collected near the mouth of Lick Creek at RM 1.2 (Ohio DNR 2015). Improvements in basin wide macrohabitat quality are likely positively influencing the fish community in Lick Creek, as evidenced by the presence of several fish species intolerant of excessive sedimentation in 2013.

Fish community performance in Miller Creek, Little Lick Creek, and Prairie Creek were observed to be stable to slightly improving from 1997 to 2013, as evidenced by similar to slightly increased IBI and MIwb scores.

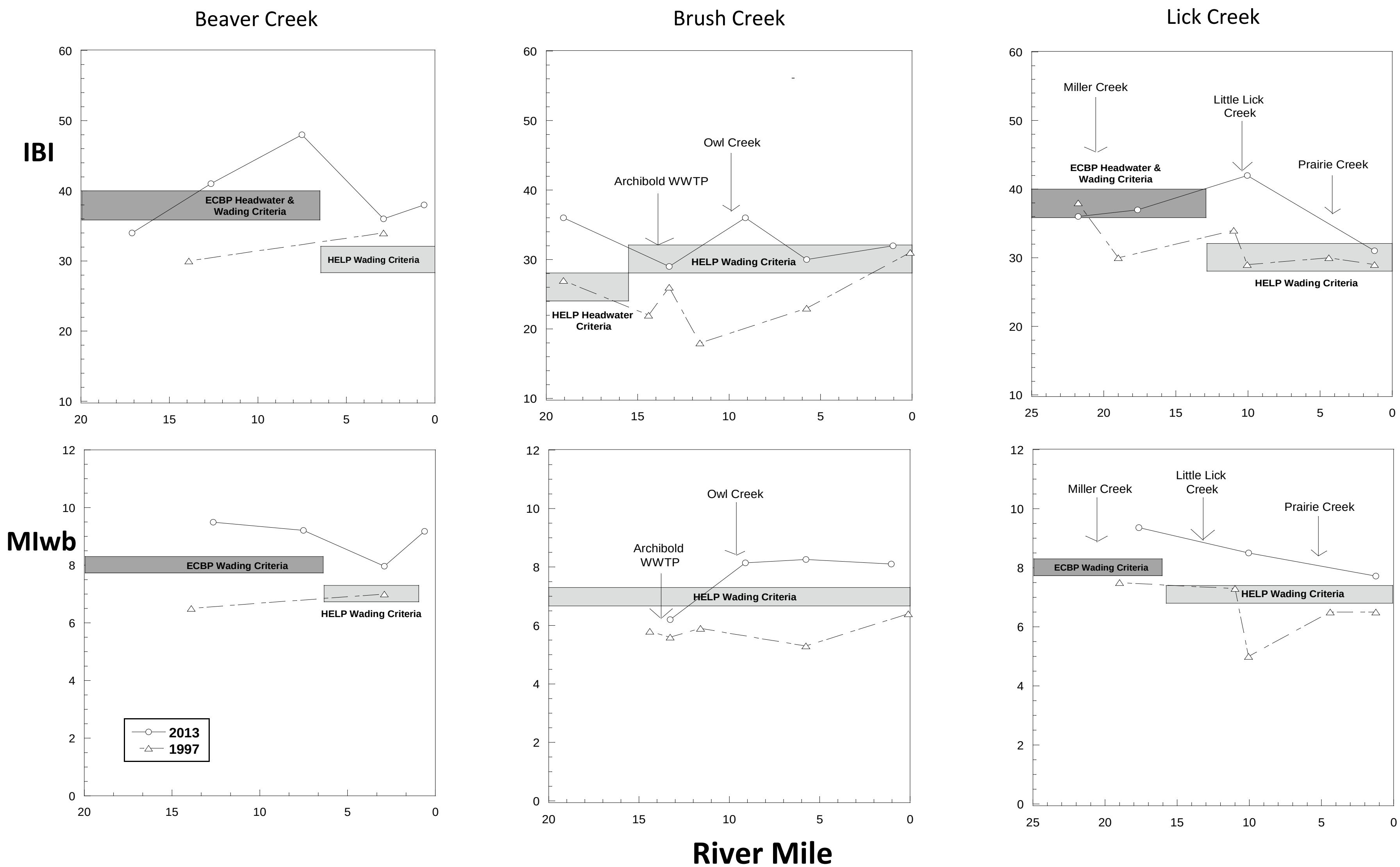


Figure 11. Longitudinal performance of IBI and MIwb scores for Beaver Creek (left), Brush Creek (middle), and Lick Creek (right), 2013 and 1997. The shaded portions represent applicable biocriteria and areas of non-significant departure from said values.

Lower Tiffin River sub-basin – HUC 10 (04100006 06)

Fish community performance in Mud Creek improved substantially in 2013 compared to 1997. Both the IBI and MIwb were higher at all locations sampled in 2013 than in 1997 (Figure 12). Pollution sensitive fish species comprised a larger percent abundance of the fish community in 2013; pollution sensitive species collected in 2013 but not 1997 include the eastern sand darter, river chub, greenside darter, and logperch darter. The percent abundance of pollution tolerant fishes also decreased over the same time period.

Fish community performance in Webb Run appeared to be relatively stable, as limited sampling at two stations indicated IBI scores similar to that of historical conditions. Fish community performance improved in Lost Creek and Buckskin Creek with an average increase of seven IBI points over historical values at the three locations assessed. The fish community was not previously assessed in Dry Creek and, therefore, no historical trend assessment can be made.

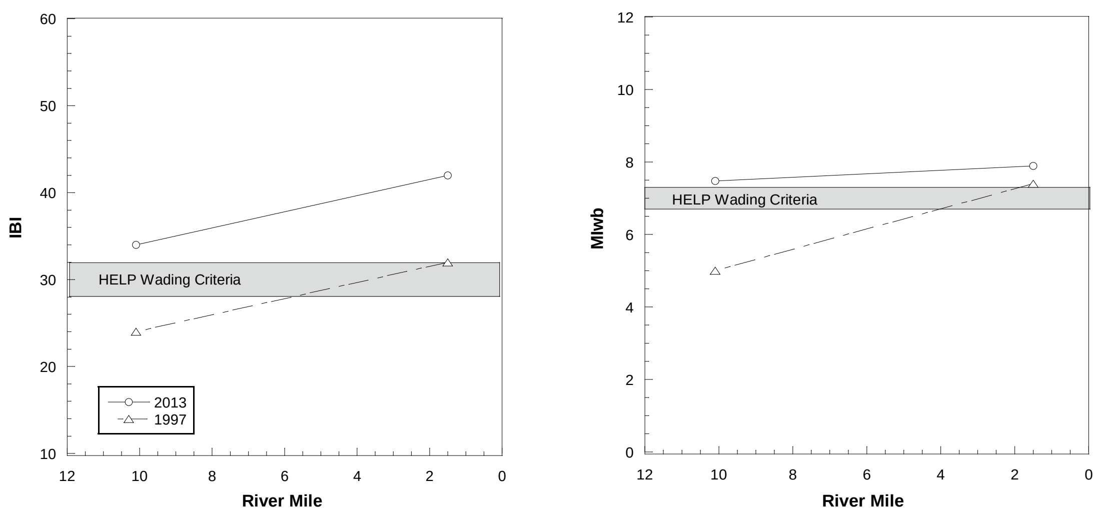


Figure 12. Longitudinal performance of IBI and MIwb scores for Mud Creek, 1997 and 2013. Shaded areas represent respective applicable biocriteria and areas of non-significant departure from biocriteria.

STREAM PHYSICAL HABITAT

Tiffin River at RM 14.0 south of Evansport at Stever Rd.

Stream physical habitat is evaluated using the Qualitative Habitat Evaluation Index (QHEI), which is a qualitative, visual habitat assessment method correlated with fish community condition (Ohio EPA 2006, Rankin 1989). Stream segments with mean QHEI values of at least 60 typically indicate a level of macrohabitat quality sufficient to support an assemblage of aquatic organisms fully consistent with the WWH aquatic life use designation; reach averages with values greater than 75 are generally considered adequate to fully support EWH (Rankin 1989, 1995). Reach averages with values between 45 and 55 indicate limiting components of habitat are present and may be negatively influencing biological performance. However, due to the potential for compensatory stream features (e.g. strong groundwater connectivity) or other watershed attributes, average QHEI scores below 60 do not necessarily preclude these streams from fully supporting WWH or even EWH assemblages. Conversely, QHEI scores over 60 do not necessarily guarantee a stream will support WWH assemblages if there are other factors limiting biological performance (e.g. organic enrichment from a WWTP, excess nutrients in a system). Stream physical habitat was evaluated at 52 biological sampling locations in the Tiffin River watershed study area during the 2012-13 sampling seasons (Table 9, Appendix E).

<u>*Tiffin River mainstem*</u>

Habitat was evaluated at ten biological sampling locations on the mainstem of the Tiffin River (Table 9). Overall habitat quality ranged from poor to excellent. The mean QHEI score for Tiffin River mainstem sites in 2012-13 was 59.1 (n=9), which is indicative of generally fair to nearly good overall habitat conditions. Both longitudinal and aggregated QHEI scores clearly indicate improvements in macrohabitat quality from 1992 to 2012-13 (Figure 13).

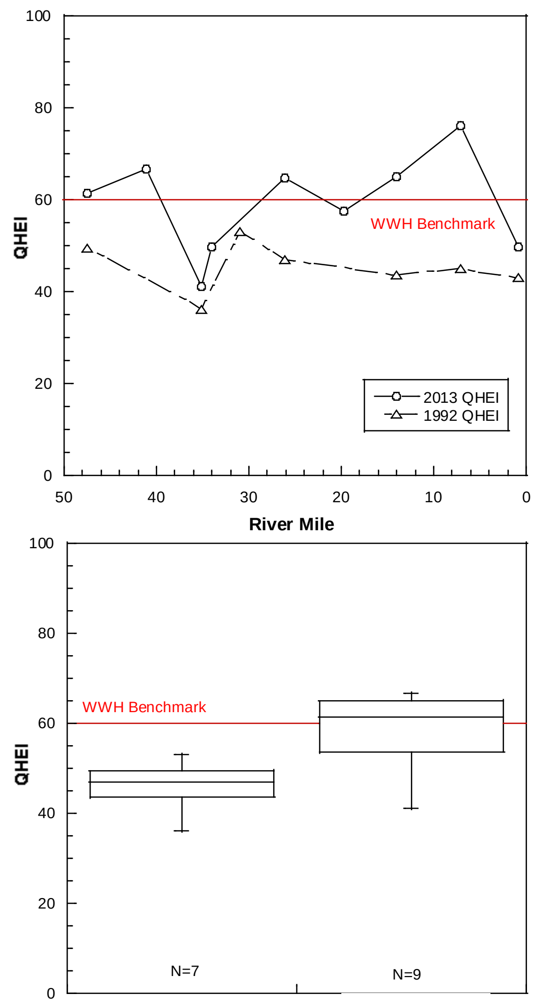


Figure 13. Longitudinal and aggregated QHEI performance for the Tiffin River mainstem, 1992 and 2012-13. Only QHEI scores collected in conjunction with boat fish sampling methods are displayed.

The Tiffin River mainstem had historically been subject to significant channel and riparian area modification. During the late 19th and early 20th centuries, the mainstem and many of the tributaries were systematically modified. Channel modifications may have included removal of natural meanders, relocation of the active channel, dredging activities, and removal of riparian vegetation. Though systematic, basin wide channel modifications have not been conducted for over ninety years, many of these drainage modifications have been maintained to some extent since the mid-1960s (Ohio EPA 1993). The activities described above have had substantial influences upon macrohabitat quality and biological communities in the Tiffin River. Pervasive siltation and embeddedness along with monotonous channel development have historically plagued the Tiffin River; however, noticeable recovery has occurred in overall macrohabitat quality since 1992 (Figure 13). The natural recovery process has been generally slow because of a low overall stream gradient, which averages about 1.2 ft/mile with local gradients as low as 0.47 ft/mile. Low stream gradient reduces stream power and increases the retention time of suspended and bedload sediment that can smother natural substrates; streams with sufficient gradient have more stream power allowing them to more readily export excess sediment and reestablish natural habitat features. Nonetheless, habitat quality has improved in the Tiffin River mainstem and should continue to do so over time.

Substrate type and quality is a component of the QHEI that can account for up to 20 of the 100 total points. Several factors can influence substrate scores such as the presence and abundance of “best types” like boulders, cobbles, gravel, and sand, the substrate origin, degree of embeddedness, and how extensively substrates are covered by silt. Substrate quality and type can have a significant influence on biological community performance and taxa richness. Substrates in the Tiffin River mainstem consisted primarily of sand and gravel, with lesser amounts of silt and detritus in localized areas. As a whole, substrate quality has improved immensely throughout the Tiffin River since 1992. Average substrate metric scores increased from 3.9 in 1992 to 8.5 in 2013 (Figure 14). The 1992 survey indicated that pervasive siltation was considered one of the most significant factors affecting the basin (Ohio EPA 1993). QHEI results from 1992 indicate that silts were the most common substrate type throughout the Tiffin River mainstem, and were present as a dominant substrate type at every sampling location. In contrast, sand was the most common substrate type in 2013. The average score for dominant substrate types, a component of the substrate metric of the QHEI, was substantially higher in 2013 (10.2) than in 1992 (6.7). Substrate quality in 1992 was also negatively affected by a greater degree of embeddedness and siltation than in 2013. Embeddedness is the degree that cobble, gravel, and boulder substrates are surrounded, impacted in, or covered by fine sand and silt. Extensive amount of embeddedness and siltation are detrimental to aquatic communities.

In addition to improved substrate quality, the amounts and types of instream cover that can be used by the stream biota also improved from 1992 (10.6) to 2013 (15.4). Different types of instream cover (large logs, deep pools, root mats, etc.) can offer instream refuge for fish and macroinvertebrates. Stable deadwood snags and other woody debris were the dominant cover types throughout the mainstem and were present at every site. This improvement is likely a result of fewer deadwood snag removal and stream “maintenance” activities. Woody debris and stable deadwood snags in streams, particularly in low gradient streams such as the Tiffin River, can be important in “creating” riffles by constricting flow and developing areas of faster moving current which can be beneficial to aquatic biota that favor these faster flowing habitats, such as redhorse suckers and darter species. This is a likely explanation for the slight improvements in riffle quality observed. Improvements in bank erosion and riparian cover were also observed. Intact, functional riparian areas adjacent to streams are an important component to a healthy stream ecosystem.

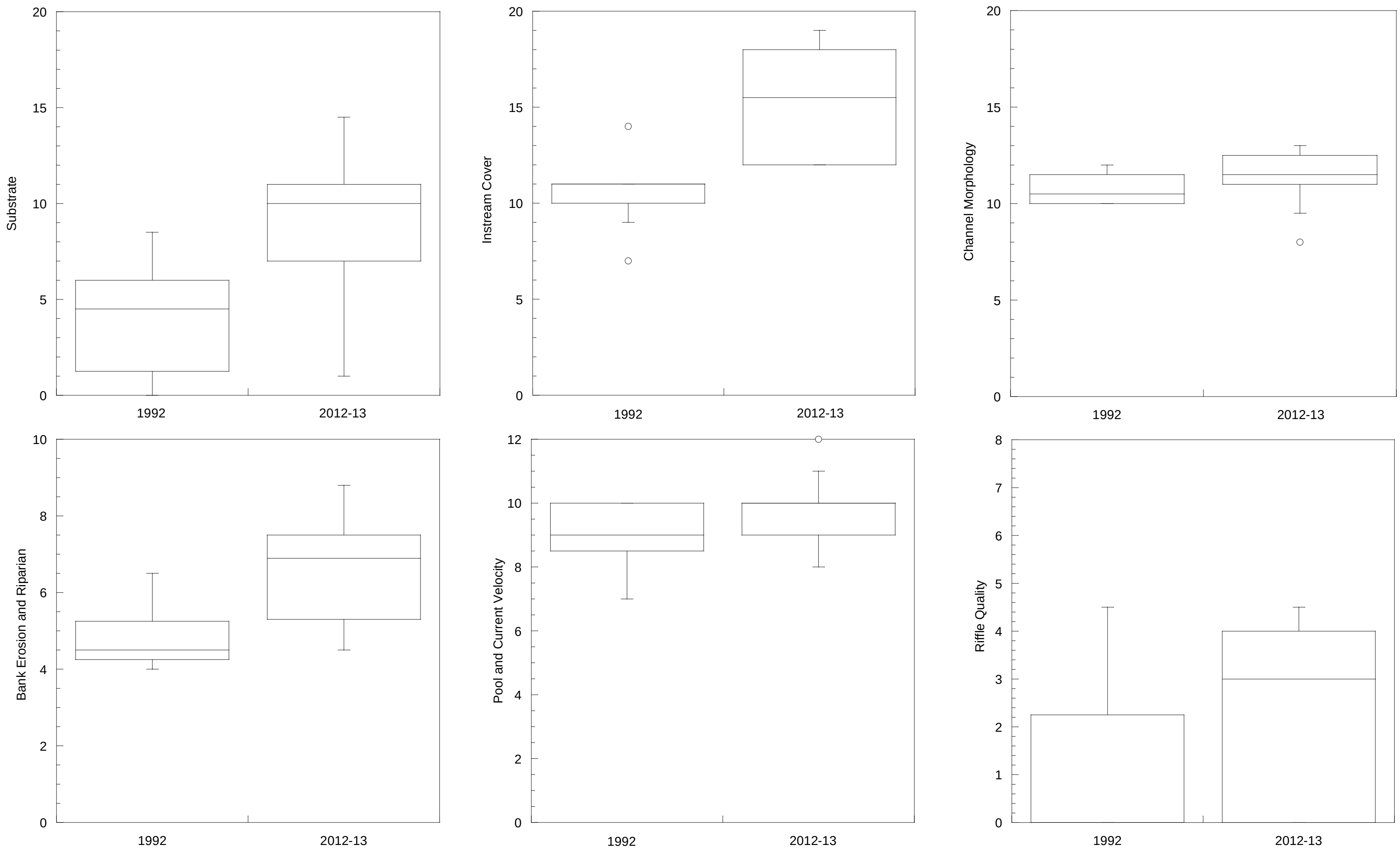


Figure 14. Individual QHEI metric distributions for the Tiffin River mainstem, 1992 and 2012-13. Only QHEI scores collected in conjunction with boat sampling methods are displayed.

Table 8.Summary statistics for Figure 20.

		1992	2012-13		1992	2012-13		1992	2012-13
Substrate	Minimum	0	1	Instream Cover	7	12	Channel Morphology	10	8
	Maximum	8.5	14.5		14	19		12	13
	Sum	27.5	84.5		74	154		76	113
	Points	7	10		7	10		7	10
	Mean	3.928571	8.45		10.57143	15.4		10.85714	11.3
	Median	4.5	10		11	15.5		10.5	11.5
	RMS	4.946139	9.424702		10.75706	15.6269		10.88249	11.39517
	Std Deviation	3.245877	4.399811		2.149197	2.796824		0.801784	1.549193
	Variance	10.53571	19.35833		4.619048	7.822222		0.642857	2.4
	Std Error	1.226826	1.391342		0.81232	0.884433		0.303046	0.489898
	Skewness	-0.03988	-0.75835		-0.15988	-0.11307		0.235217	-0.99889
	Kurtosis	-1.3057	-0.48186		-0.20114	-1.56754		-1.51337	0.079604

		1992	2012-13		1992	2012-13		1992	2012-13
Bank Erosion and Riparian	Minimum	4	4.5	Pool and Current Velocity	7	8	Riffle Quality	0	0
	Maximum	6.5	8.8		10	12		4.5	4.5
	Sum	34	66		63	98.5		9	25
	Points	7	10		7	10		7	10
	Mean	4.857143	6.6		9	9.85		1.285714	2.5
	Median	4.5	6.9		9	10		0	3
	RMS	4.928054	6.732013		9.06327	9.905806		2.405351	3.082207
	Std Deviation	0.899735	1.398412		1.154701	1.106797		2.195775	1.900292
	Variance	0.809524	1.955556		1.333333	1.225		4.821429	3.611111
	Std Error	0.340068	0.442217		0.436436	0.35		0.829925	0.600925
	Skewness	0.828489	-0.06553		-0.70156	0.334305		0.948683	-0.39682
	Kurtosis	-0.45783	-1.14508		-0.8125	-0.04723		-1.1	-1.48166

Improvements in substrate quality and reductions in the amounts of silts, flocculent clays, and substrate embeddedness observed in the Tiffin River can likely be attributed to conservation tillage and other various BMPs that were implemented beginning in the early 1980s. Within Defiance, Fulton, and Williams counties, the use of conservation tillage increased drastically during the mid-1980s through the early 1990s and by 1992, approximately 50% of corn and soybeans were being produced using conservation tillage practices (Ohio EPA 1993). Data from 1996-98 indicate that the Tiffin River basin had one of the higher percentages of fields in conservation tillage in the Maumee River basin (Figure 15). From 2006 to 2010, the percentage of cultivated crop acres (corn, soybeans, and wheat) in conservation tillage ranged from approximately 52% to 58% (USDA 2010). The 1993 Tiffin River TSD asserted that *"...these activities (referring to conservation tillage, reduction in tillage intensity, and the establishment of riparian buffer and grass filter strips) should reduce agricultural nonpoint loadings to the Tiffin River and improve physical habitat characteristics."* It is likely that the observed improvements in the substrate quality metric of the QHEI, and macro-habitat quality in general, can be attributed to the increased use of conservation tillage and other various agricultural BMPs.

Several recent studies have investigated trends in suspended sediment discharge reductions and sediment load reduction to streams in the Maumee River basin, and what effect conservation tillage practices and other agricultural BMPs have had on observed reductions (Myers et al. 2000, and Richards et al. 2009). As part of a USGS study, Myers et al. (2000) demonstrated that decreases in suspended sediment discharge from several major streams in the Maumee River basin can likely be attributed to increased use of conservation tillage and subsequent reductions in soil erosion. Similarly, Richards et al. (2009) analyzed a 30 year dataset from the National Center for Water Quality Research (NCWQR) at Heidelberg College to identify and interpret trends between suspended sediment loads and agricultural BMPs designed to reduce sediment loss and soil erosion in the Maumee and Sandusky rivers. They observed sustained decreases in sediment loads which appear to reflect the success of agricultural management programs in reducing erosion and sediment export to streams in these basins (Richards et al. 2009). Miltner (2015) further quantifies water quality benefits and improved aquatic biology resulting from agricultural BMPs in Ohio. These external lines of evidence seem to support the notion that conservation tillage, BMPs, and other agricultural management programs have played an important role in reducing erosion and the export of excess silts and clays to streams in the Tiffin River and elsewhere in the Maumee River basin.

It is important to highlight the apparent success conservation tillage and other agricultural BMPs have had in reducing soil erosion and sediment loading to streams and rivers, not only because of improved environmental conditions, but because of the significant amounts of money invested in these programs. The following quote from Myers et al. (2000) characterizes the situation well: *"Without direct evidence of improving water quality, farmers and others may become indifferent to the voluntary use of these practices and programs. This, in turn, could negate the apparent success of these programs and the investments made by federal, state, and local natural-resource managers."* Improved habitat conditions observed in the Tiffin River, along with improved biological community performance, are pieces of evidence that can be used to help highlight the apparent successes these agricultural management programs have had in reducing erosion and subsequent sediment delivery to streams. It is also important to note that many of these programs were originally designed and intended to reduce erosion and excess sediments in local area streams and waterways and not necessarily to target the fate and downstream transport of all forms of nutrients specifically.

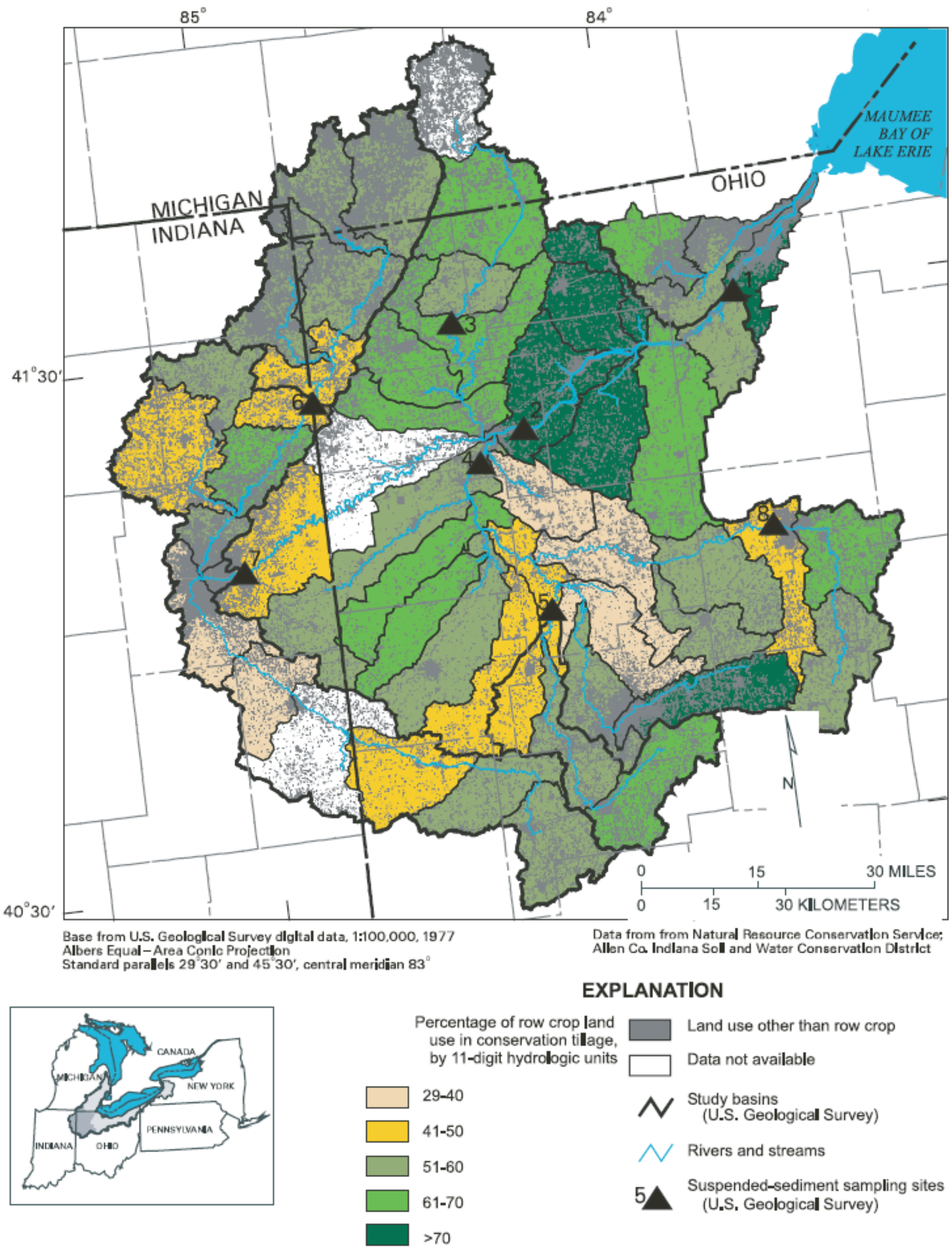


Figure 15. Percentage of agricultural area in conservation tillage in the Maumee River basin by hydrologic unit, 1996-98, from Myers et al. 2000.

Tributaries

Physical habitat was assessed for 21 tributaries to the Tiffin River at 42 different sampling locations during the 2013 sampling index period, corresponding to respective biological sampling locations. Narrative evaluations ranged from very poor to good.

Mill & Bean Creek sub-basin - HUC 10 (04100006 02)

Habitat quality in Old Bean Creek was assessed at two locations and had a mean QHEI score of 33.8, corresponding to poor overall habitat quality. High and moderate influence negative habitat attributes such as silt and muck substrates, fair to poor channel development, and high to moderate embeddedness were pervasive and have the potential to limit biological performance. As these negative habitat attributes begin to accumulate, both at a site and throughout a stream reach, the potential to limit biological performance increases; the probability of fully attaining WWH decreases substantially when the ratio of negative to positive habitat attributes becomes greater than 2:1. The full list of negative and positive influence habitat attributes can be found in Appendix E. The upper reaches of Old Bean Creek (headwaters to near County Road 21) and several smaller tributaries draining into Old Bean Creek are on active ditch maintenance (Fulton Co. Engineer Drainage Map 2013); active ditch maintenance in the upper reaches of Old Bean Creek will continue to influence biological performance in the more downstream portion. In addition, much of this stream's base flow has been diverted to Bean Creek as part of a relocation of the active channel in 1906 (Ohio EPA 1993). This flow diversion coupled with low local stream gradient will further hamper recovery of natural habitat features.

Overall habitat quality in Bean Creek, assessed at two locations, can be characterized as good, with an average QHEI of 61.4. Despite having a history of significant channel modification, Bean Creek has reacquired many free-flowing habitat characteristics. Significant groundwater connectivity and sufficient gradient act to ameliorate negative influences the habitat quality may be having on stream biota. Components of high quality stream habitat include, but are not limited to, moderate to high sinuosity, moderate to extensive instream cover, and substrates relatively free of silt deposition.

Habitat was assessed at four locations in Mill Creek. Mean QHEI values of 53.2 reflect fair overall habitat quality. Sand substrates predominated, with lesser amounts of gravel, cobble, and silts present. Habitat quality upstream from Harrison Lake (RMs 7.92-14.49) showed an abundance of moderate influence negative habitat characteristics such as fair to poor channel development and moderate to high amounts of embeddedness (Appendix E). These upstream reaches also had low sinuosity with a riparian zone consisting mainly of row crops. Downstream from Harrison Lake, habitat quality improved, regaining functional WWH characteristics such as lower overall embeddedness, higher sinuosity, and improved instream cover quality. Negative habitat attributes have the potential to limit biological performance in the upper reaches of Mill Creek.

Overall habitat quality in Deer Creek can be characterized as good. Cobble and gravel substrates were dominant, with lesser amounts of sand, silt, and detritus present. Macrohabitat quality in Deer Creek, in and of itself, should not preclude full attainment of biological indices.

Upper Tiffin River sub-basin - HUC 10 (04100006 03)

Bates Creek, Flat Run, and Leatherwood Creek are all small, headwater streams that are direct tributaries to the Tiffin River and all have similar habitat characteristics. The average habitat scores at the three locations assessed was 49.6, corresponding to fair overall habitat quality. Sand was the dominant substrate type, with lesser amounts of hardpan and silt present. Flat Run had the lowest quality habitat of the three; heavy silt cover, no sinuosity, poor channel development, and channelization activities have negatively impacted habitat quality at this location. Bates Creek and Leatherwood Creek showed slightly better habitat quality; however, moderate influence negative habitat attributes were still pervasive (Appendix E). Relatively low QHEI scores and an overwhelming presence of moderate and high influence negative habitat attributes suggest that habitat, especially excessive siltation, may be a factor limiting biological performance in these streams.

Middle Tiffin River sub-basin – HUC 10 (04100006 05)

Habitat quality throughout Beaver Creek ranged from fair to good at the five locations assessed; mean QHEI values of 61.4 indicate good overall habitat quality. Sand was the most dominant substrate type followed by gravel; lesser amounts of cobbles, hardpan, and silt were also present. Normal to moderate silt cover and embeddedness occurred throughout Beaver Creek. Sparse to moderate instream cover was also present throughout.

QHEI scores for Brush Creek ranged from very poor to fair at the five locations assessed, with a mean QHEI value of 37.3 indicating poor overall habitat quality. Moderate influence negative habitat attributes predominated; these include, but are not limited to, moderate to heavy silt cover and substrate embeddedness, hardpan substrate origin, poor to fair channel development, and low sinuosity (Appendix E). Silt substrates were the most common, with lesser amounts of sand, gravel, hardpan, and muck. However, applicable biocriteria were in full attainment at four of five locations despite the pervasiveness of negative influence habitat attributes.

Brush Creek at RM 19.06 upstream from Archbold at County Road D.

Owl Creek, a tributary to Brush Creek, is characterized as having very poor habitat quality. Owl Creek shares many of the same characteristics as Brush Creek, which may be a factor limiting biological performance here. Coon Creek and Doty Run are both direct tributaries to the Tiffin River and also display many of the same modified attributes as Brush and Owl Creek. QHEI scores for Coon Creek and Doty Run are reflective of fair habitat quality. Intermittent flows were observed in all three of the aforementioned tributaries, suggesting they may go dry periodically, further limiting biological potential.

Lick Creek sub-basin – HUC 10 (04100006 04)

QHEI scores in Lick Creek ranged from fair to good, with a mean habitat score of 59.5 at four locations. Sand and gravel were the dominant substrate types, with lesser amounts of hardpan, cobbles, boulders, and silt present. Amounts of instream habitat cover ranged from sparse to moderate. Channel development ranged from poor to fair.

Miller Creek, Little Lick Creek, and Prairie Creek are all tributaries to Lick Creek. Overall habitat quality was found to be good in Miller Creek. Dominant substrate types were sand and gravel, with lesser amounts of cobble and boulders present. Sufficient stream gradient has allowed this stream to retain many positive influence habitat attributes (Appendix E). QHEI scores from Little Lick Creek indicate fair overall habitat quality, with an average score of 53.5 at two locations sampled. Dominant substrate types were sand and gravel, with lesser amounts of hardpan, and silt present. QHEI scores for Prairie Creek indicate habitat ranging from poor in the headwaters to good further downstream (Table 9). Several segments of Prairie Creek are on active ditch maintenance which can limit biological performance (Defiance Co. SWCD, 2010); however, this did not preclude full attainment of applicable biocriteria at RM 3.4. Dominant substrate types present were sand and gravel, with lesser amounts of cobbles and hardpan. Areas of active erosion were evident on both stream banks. Functional instream cover was sparse to nearly absent at RM 9.8 and moderate to high influence negative habitat attributes were pervasive at this upstream site. Though municipal sources appeared to be the primary factor limiting biological performance, habitat issues likely exacerbate other identified stressors.

<u>*Lower Tiffin River sub-basin – HUC 10 (04100006 06)*</u>

Mud Creek is a direct tributary to the Tiffin River. Overall habitat quality in Mud Creek can be characterized as fair, with an average QHEI score of 55.0 at both locations assessed. Sand was the dominant substrate type, with lesser amounts of gravel and detritus. Instream cover was moderate to sparse. Little to moderate amounts of bank erosion were evident at both sampling locations; the stream appeared to be recovering from past channelization activities.

Mud Creek at RM 10.1 north of Sherwood at Coy Rd.

Lost Creek and Dry Creek converge at their mouths to form Mud Creek. An average QHEI score of 67.8 suggests good overall habitat quality in Lost Creek. Dominant substrate types were sand and gravel, with lesser amounts of cobbles, boulders, and hardpan. Sinuosity was found to be low to moderate in the areas sampled, with fair to poor channel development, and deep (>1.0m) pools were also present. Habitat quality in Dry Creek can be characterized as poor in the one location sampled. Dominant substrate types were sand and silt, with extensive amounts of embeddedness and moderate to heavy silt cover that negatively affect substrate quality. A combination of low flows observed later in the year and a fish community dominated by "pioneering" species suggests that portions of Dry Creek may go dry periodically. Moderate and high influence negative habitat attributes that could limit biological performance were pervasive (Appendix E).

Both Webb Run and Buckskin Creek are direct tributaries to the Tiffin River. Habitat quality can be characterized as poor at the one location sampled in Buckskin Creek. Upstream from the RM 1.2 sampling location, Buckskin Creek receives channel maintenance activities, which may negatively influence habitat quality at RM 1.2. Moderate and high influence negative habitat attributes were pervasive (Appendix E). A combination of low flows and a primarily "pioneering" fish species community suggests that portions of Buckskin Creek may periodically go dry. Habitat quality in Webb Run can be characterized as fair, with an average QHEI score of 46.1 for both locations sampled. Intermittent flow was observed at the most upstream site at RM 2.98 and may be having a negative influence on biological performance. Sparse instream cover observed at both locations, and along with other negative influence habitat attributes present at both locations, may also be impacting biological performance.

Table 9. Stream physical habitat (QHEI) summarized results for the Tiffin River basin 2012-2013. Data denoted by [brackets] were collected in 2012.

STREAM	RIVER MILE	DRAIN. AREA (Mi^2)	LOCATION	QHEI	COMMENTS
Tiffin River	47.54	337	Northwest of Archbold @ County Rd. G	61.25	Sand substrates dominant, less silt cover than previous survey
Tiffin River	41.12	374	At Lockport @ County Road 22.75/ County Rd. I.25	66.75	Sand substrates dominant, extensive woody debris cover
Tiffin River	35.20	407	At Stryker @ State Route 191	41.0	Heavy silt cover, moderate/sparse instream cover
Tiffin River	33.95	412	West of Stryker @ County Rd. F (Curtis St.)	49.75	Heavy silt cover, pools and woody debris dominant cover type
Tiffin River	26.17	418	Dst. Stryker @ Oak Grove Church Rd.	64.75	Sand/gravel substrates, less silt cover than previous survey
Tiffin River	19.72	421	Near Evansport @ County Road 22/A	57.5	Sand/gravel substrates dominant, log jams creating riffle habitat
[Tiffin River]	[18.73]	[476]	[At Evansport @ State Route 191]	[56.0]	Significant woody debris cover throughout zone
Tiffin River	14.00	562	South of Evansport @ Stever Rd.	65.0 [70.5]	Sand/gravel substrates dominant, Less silt cover than previous survey
Tiffin River	7.09	736	Northeast of Defiance Airport @ Evansport Rd.	76.0 [75.25]	Sand/gravel substrates dominant, moderate/extensive instream cover
[Tiffin River]	[0.89]	[775]	[Near Defiance @ Dey Rd.]	[49.75]	Impounded by pooled conditions In Maumee River @ Independence Dam
Old Bean Creek	6.22	14.0	Near Thelma @ County Rd. 19	31.5	Silt/hardpan substrates dominant, highly modified, groundwater influence
Old Bean Creek	1.90	25.0	Southeast of Fayette @ Old Angola Rd.	36.0	Silt/muck substrates dominant, extensive and deep silt deposits
Deer Creek	4.56	9.9	Dst. Fayette @ County Rd. 23	61.0	Sand/cobble substrates dominant, moderate/sparse instream cover
Bean Creek	7.55	206	East of Powers @ US Route 20	71.75	Sand/gravel substrates dominant, moderate/sparse instream cover, strong groundwater influence
Bean Creek	2.20	246	Southeast of Fayette @ Old Angola Rd.	51.0	Sand substrates dominant, moderate/sparse instream cover, strong groundwater influence
Mill Creek	14.49	12.9	Ust. Alvordton trib. @ County Rd. S	30.25	Silt substrates dominant, no sinuosity, channelized
Mill Creek	11.90	23.4	Southeast of Alvordton @ County Rd. P	61.0	Sand substrates dominant, grass buffer strips evident

Mill Creek	7.92	32.8	Southeast of Alvordton @ County Rd. 28	58.5	Sand/cobble substrates dominant, sparse instream cover, surrounded by row crop
Mill Creek	1.85	39.0	South of Fayette @ Old Angola Rd.	63.0	Sand substrates dominant, moderate instream cover
Bates Creek	1.65	11.8	East of West Unity @ County Rd. 25-2	51.25	Sand/hardpan substrates dominant, moderate instream cover, poor channel development
Flat Run	0.40	10.2	Northeast of Stryker @County Rd. 22.75	40.0	Sand/silt substrates dominant, heavy silt cover, no sinuosity, poor channel development, channelized
Leatherwood Creek	1.15	9.8	North of Stryker @ County Rd. H	57.5	Sand/hardpan substrates dominant, moderate silt cover, sparse instream cover
Beaver Creek	17.12	14.9	Southwest of West Unity @ County Rd. K	54.5	Sand substrates dominant, sparse instream cover, poor channel development
Beaver Creek	12.66	29.5	At Beaver Ck. Wildlife Area @ County Rd. 16	70.5	Sand/gravel substrates dominant, high sinuosity, moderate/sparse instream cover
Beaver Creek	7.52	36	South of Pulaski @ US Route 127	66.5	Gravel substrates dominant, moderate/sparse instream cover
Beaver Creek	2.90	41	@ County Rd. D	59.25	Sand substrates dominant, good/fair channel development
Beaver Creek	0.61	44.8	Northwest of Evansport @ County Rd. 20	56.25	Sand substrates dominant, moderate/sparse instream cover
Owl Creek	0.070	10.3	Southwest of Archbold @ County Rd. 25	26.0	Silt/muck substrates dominant, sparse instream cover, intermittent flow
Brush Creek	19.06	19.7	Ust. Archbold @ Archbold-Lutz Rd. (County Rd. D)	31.25	Sand/much substrates dominant, instream cover nearly absent, riparian width none
Brush Creek	13.28	34.6	Dst. Archbold @ County Rd. 24	47.5	Silt substrates dominant, heavy silt cover, substrates extensively embedded
Brush Creek	9.11	54.0	Southwest of Archbold @ County Rd. 24.25	25.5	Silt/muck substrates dominant, poor channel development, heavy silt cover
Brush Creek	5.76	62.0	Northeast of Evansport @County Rd. C	40.0	Silt substrates dominant, fair/poor channel development, heavy silt cover
Brush Creek	1.05	65.0	Near Evansport @ County Rd. 22-60	42.0	Silt substrates dominant, poor channel development, heavy silt cover
Coon Creek	0.62	9.3	East of Evansport @ County Rd. 23	46.25	Gravel/hardpan substrates dominant, sparse instream cover, intermittent flow
Doty Run	0.63	5.3	SW of Evansport near mouth @ Evansport Rd.	42.75	Sand/gravel substrates dominant, instream cover nearly absent, intermittent flows

Miller Creek	0.50	20.9	West of Bryan adj. County Rd. 309/D	71.5	Sand/gravel substrates dominant, good/fair channel development
Little Lick Creek	4.97	7.5	Northwest of Ney @ Behnfeldt Rd.	50.5	Sand/gravel substrates dominant, poor channel development, surrounded by row crop
Little Lick Creek	0.80	23.3	Ust. Ney ust. railroad	57.25	Sand/gravel substrates dominant, moderate silt cover, riparian width narrow/none
Prairie Creek	9.80	9.8	Dst. Bryan WWTP adj. County Rd. C	35.75	Sand/gravel substrates dominant, moderate/extensive substrate embeddedness, no riparian cover
Prairie Creek	3.40	26.0	NE of Ney @ Flickinger Rd. (lower crossing)	64.0	Sand substrates dominant, erosion evident, moderate instream cover
Lick Creek	21.77	6.2	Northwest of Bryan @ County Rd. 13	61.5	Sand/gravel substrates dominant, moderate/sparse instream cover
Lick Creek	17.66	30.0	Southwest of Bryan @ County Rd. 13	67.25	Sand/gravel substrates dominant, moderate/sparse instream cover
Lick Creek	10.05	58.5	At Ney @ The Bend Rd.	56.5	Gravel/hardpan substrates dominant, little/moderate bank erosion
Lick Creek	1.23	105	North of Oxbow Lake @ Trinity Rd.	52.75	Sand substrates dominant, sparse/absent instream cover, poor channel development
Dry Creek	3.76	11	SE of Farmer @ County Rd. 124 (Openlander Rd.)	36.25	Sand/silt substrates dominant, surrounded by row crop, sinuosity low/none, poor channel development
Lost Creek	8.97	14.4	Northeast of Hicksville @ Seevers Rd.	71.5	Sand/gravel substrates dominant, moderate/sparse instream cover
Lost Creek	1.41	25.6	North of Sherwood @ Behnfeldt Rd.	64.0	Sand substrates dominant, bank erosion evident
Mud Creek	10.10	47.3	North of Sherwood @ Coy Rd.	60.0	Sand substrates dominant, bank erosion evident, poor channel development
Mud Creek	1.50	58.0	NW of Brunersburg @ Trinity Rd.	50.0	Sand substrates dominant, sparse instream cover
Buckskin Creek	1.20	6.1	NW of Brunersburg @ State Route 15	42.0	Sand/hardpan substrates dominant, riffle extensively embedded, poor channel development
Webb Run	2.99	9.3	Northwest of Defiance @ Flory Rd.	40.75	Sand substrates dominant, intermittent flows, instream cover nearly absent
Webb Run	0.40	20.0	N of Brunersburg, dst. Tanby Ditch	51.25	Cobble/gravel substrates dominant, interstitial flows, instream cover nearly absent

General narrative ranges assigned to QHEI scores.				
Narrative Rating		QHEI Range		
		Headwaters (≤20 mi^2)	Larger Streams	Lacustuary
Excellent		≥70	≥75	≥80
Good		55 to 69	60 to 74	60 to 80
Fair		43 to 54	45 to 59	45 to 59
Poor		30 to 42	30 to 44	30 to 44
Very Poor		<30	<30	<30

MACROINVERTEBRATE COMMUNITY OVERVIEW

Macroinvertebrate communities were evaluated at 52 sampling locations in the Tiffin River study area (Table 10, Appendices A and B). The community performance was evaluated as exceptional at 12 sampling locations, very good at four, good at nine, marginally good at seven, fair at nine, low fair at five, and poor at four sampling locations. The sampling location with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness, collectively referred to as EPT, was on Bean Creek at US 20 (RM 7.55) with 30 taxa. The sampling location with the highest number of total sensitive taxa was on Bean Creek at US 20 (RM 7.55) with 34 taxa. Eight uncommonly collected sensitive taxa (excluding the freshwater mussels) were collected during this study and their collection locations are listed in Table 10. The state listed caddisfly *Brachycentrus numerosus* (endangered) was collected at two sampling locations on the Tiffin River (RMs 47.9 and 40.7) and one on Bean Creek (RM 2.2). The study area had a relatively low number of uncommonly collected sensitive taxa which is an indication of the moderate to high impact to the aquatic resource quality in the Tiffin River basin from agricultural activities in conjunction with the overall lower gradient and smaller substrate particle sizes associated with the HELP ecoregion. Seventeen species of freshwater mussels were collected during this study (Table 11). Four of these were state listed as species of concern - purple wartyback, creek heelsplitter, round pigtoe and deertoe. The sampling locations with the highest number of mussel species (10) were the Tiffin River at Stever Road (RM 13.7), Beaver Creek at CR 20 (RM 0.61) and Lick Creek at Trinity Road (RM 1.23).

Tiffin River mainstem

Macroinvertebrate communities were evaluated at eight locations in 2013 (Figure 16, Table 12.). The two most upstream sampling locations (RMs 47.9 and 40.9) performed in the exceptional range. High qualitative sample EPT (22, 29) and sensitive taxa (ST) (22, 19) diversity were present at both sampling locations, including the state listed caddisfly *Brachycentrus numerosus* (endangered). The remaining sampling locations were achieving or marginally achieving the WWH macroinvertebrate biocriterion. The Stryker WWTP (RM 32.65) and Evansport WWTP (RM 20.04) were not having a noticeable negative impact on the macroinvertebrate communities. Twelve freshwater mussel species were documented in the Tiffin River mainstem, including the purple wartyback at two sampling locations and the deertoe at five sampling locations; both are state listed as species of concern.

Tributaries

Mill & Bean Creek sub-basin - HUC 10 (04100006 02) Old Bean Creek, Bean Creek, Mill Creek and, Deer Creek

Four Tiffin River tributaries were sampled at nine locations in this segment. The macroinvertebrate communities in Bean Creek were performing in the exceptional range with high EPT (26, 23) and sensitive taxa (29, 22) diversity. The state listed caddisfly *Brachycentrus numerosus* (endangered) was collected from Bean Creek at County Road L (RM 2.2). Seven species of freshwater mussels were documented in Bean Creek including the state listed creek heelsplitter (species of concern) at US 20 (RM 7.55). The macroinvertebrate communities evaluated in Deer Creek and Old Bean Creek were not meeting WWH expectations. The Deer Creek community at RM 4.56 was predominated by tolerant and facultative taxa with low to very low diversity of EPT (5) and sensitive taxa (0). This sampling location may have been impacted by nutrient enrichment from the surrounding agricultural activities or potentially CSOs in the village of Fayette. Fayette's Long Term Control Plan was approved in October 2012 to address this issue, and separation of their sewers is expected by April 2015 per their NPDES permit. After separation, 18 months of post-construction monitoring will be conducted to determine the effectiveness of these projects. The communities in Old Bean Creek appear to be limited by poor habitat. The stream bed contained thick silt deposits as the result of old channel modifications and low gradient. The four sampling locations evaluated on Mill Creek all had macroinvertebrate communities that were meeting or marginally meeting the WWH biocriterion (Figure 17). The headwaters were mildly impacted by siltation as the result of channelization and agricultural activities. The remaining sampling locations improved into the very good to exceptional range near the mouth (RM 1.85).

Upper Tiffin River sub-basin - HUC 10 (04100006 03) Bates Creek, Flat Run and, Leatherwood Creek

Three Tiffin River tributaries were sampled at three sampling locations in this portion of the study area. The macroinvertebrate communities evaluated in Bates Creek, Flat Run and Leatherwood Creek were not meeting WWH expectations. The communities were predominated by facultative and tolerant taxa with low to very low diversity of EPT (4-8) and sensitive taxa (0-1). These sampling locations were impacted by siltation from past channel modifications and agricultural activities.

Middle Tiffin River sub-basin – HUC 10 (04100006 05) Beaver Creek, Brush Creek, Owl Creek, Coon Creek and, Doty Run

Five Tiffin River tributaries were sampled at 13 sampling locations in this segment. The macroinvertebrate communities evaluated at all five sampling locations on Beaver Creek (Figure 18) were performing at the good to exceptional range with moderate to high EPT (11-23) and sensitive taxa (6-20) diversity. Twelve species of freshwater mussels were documented in Beaver Creek including the state listed creek heelsplitter and round pigtoe (species of concern). The macroinvertebrate communities evaluated in Brush Creek (Figure 19) were negatively impacted by the Archbold WWTP (RM 13.95). The community declined from good upstream from the WWTP at RM 19.06 (EPT=14, ST=7) to poor downstream from the WWTP at RM 13.28 (ICI=12, EPT=3, ST=0). The downstream community was predominated by tolerant and facultative taxa of midges. Communities further downstream improved into the good range based on the ICI (36-44); however, the EPT (5-8) and sensitive taxa (0-10) diversity failed to recover to WWH expectations. Seven species of freshwater mussels were documented at the most downstream sampling location (RM 1.05). The macroinvertebrate communities evaluated in Owl Creek, Coon Creek and Doty Run were not meeting WWH expectations. The communities were predominated by facultative and tolerant taxa with low to very low diversity of EPT (2-4) and sensitive taxa (0). Owl Creek, Doty Run and potentially Coon Creek were primarily limited by low flow. Owl Creek appeared to also be impacted by siltation and organic enrichment.

Lick Creek Sub-basin – HUC 10 (04100006 04) Lick Creek, Miller Creek, Little Lick Creek, and Prairie Creek

Four Tiffin River tributaries were sampled at nine sampling locations in this segment. The macroinvertebrate community evaluated at the upstream sampling location on Lick Creek (RM 21.77) was not meeting WWH expectations (Figure 20). The community was predominated by facultative taxa with low diversity of EPT (5) and sensitive taxa (2). This sampling location appeared to be impacted by siltation from past channel modifications and excess nutrients. The remaining sampling locations were achieving or marginally achieving the WWH macroinvertebrate biocriterion. The sampling location downstream from the Ney WWTP at RM 10.5 had a community that declined in biotic integrity measures (ICI from 36 to 32, EPT from 13 to 5, ST from 7 to 4), possibly due to a mild impact from the WWTP and/or reduced habitat quality, though not severe enough to cause biological impairment. The farthest downstream sampling location (RM 1.23) improved substantially (ICI=48, EPT=16, ST=19). Ten species of freshwater mussels were documented at the downstream most sampling location on Lick Creek including the state listed creek heelsplitter and deertoe (species of concern). The macroinvertebrate community evaluated on Miller Creek was performing at the good to exceptional range with an ICI of 46 and moderate EPT (16) and sensitive taxa (13) diversity. The macroinvertebrate communities evaluated in Little Lick Creek were not meeting WWH expectations. The upstream sampling location at RM 4.97 was evaluated as fair with low-moderate EPT (9) and very low sensitive taxa (1) diversity. This site was impacted by nutrient enrichment, as evidenced by elevated nutrients and modest diel DO swings. The downstream sampling location at RM 0.8 was predominated by tolerant and facultative taxa with very low EPT (2) and sensitive taxa (0) diversity. This location was limited by low flow and organic enrichment. Prairie Creek (Figure 21) receives the effluent from the Bryan WWTP (RM 11.0). The sampling location downstream from the WWTP (RM 9.8) had a poor macroinvertebrate community which was predominated by tolerant and facultative taxa with very low EPT (2) and sensitive taxa (0) diversity. The most abundant organism was the toxic tolerant midge *Polypedilum (P.) illinoense*, which, together with the low diversity, are indications of a toxic impact from the WWTP. The downstream sampling location (RM 3.4) improved to the fair to good range with an ICI of 38 and low-moderate EPT (8) and sensitive taxa (7) diversity. Six species of freshwater mussels were documented at the downstream sampling location on Prairie Creek including the state listed creek heelsplitter (species of concern).

Lower Tiffin River sub-basin – HUC 10 (04100006 06) Lost Creek, Mud Creek, Dry Creek, Buckskin Creek, and Webb Run

Five Tiffin River tributaries were sampled at eight sampling locations in this segment. The macroinvertebrate communities evaluated on Mud Creek were performing at the good to very good range with an ICI value of 44, EPT of 18 and 15, and sensitive taxa diversity of 15 and 13. The macroinvertebrate communities evaluated in Dry Creek, Buckskin Creek and the upstream sampling location on Webb Run (RM 2.99) were not meeting WWH expectations. The communities were predominated by facultative and tolerant taxa with low EPT (4-7) and very low diversity of sensitive taxa (0-2). Buckskin Creek, Dry Creek, and Webb Run may have primarily been limited by low stream flow. The downstream sampling location on Webb Run (RM 0.4) improved into the marginally good range with 11 EPT and 4 sensitive taxa. This sampling location may also be somewhat limited by low flow. The macroinvertebrate community evaluated at the upstream sampling location on Lost Creek (RM 8.97) was not meeting WWH expectations. The community was predominated by facultative taxa with low to moderate EPT (8) and sensitive taxa (8) diversity. This sampling location may be mildly impacted by siltation and enrichment. The downstream sampling location on Lost Creek (RM 1.41) improved into the good to very good range with an ICI of 44, 16 EPT, and 11 sensitive taxa.

Macroinvertebrate Community Trends

The Tiffin River macroinvertebrate community trend was generally similar in 2013 to previous years (Figure 16). However, the sensitive taxa diversity was on average nine taxa higher in 2013 compared to 1992. This may be an indication of a general water quality or habitat improvement in the Tiffin River. The Mill Creek macroinvertebrate community trend was similar in 2013 to previous years except that the sampling location downstream from Harrison Lake (RM 1.85) had substantially higher EPT (9 taxa increase) and sensitive taxa (11 taxa increase) diversity in 2013 (Figure 17). The Beaver Creek ICI was similar in 2013 to previous years at the one sampling location (RM 2.9) where historical ICI data exists (Figure 18). Qualitative sampling data in Beaver Creek from 2013 indicated substantially higher EPT and sensitive taxa diversity at the two sampling locations (RM 2.9 and RM 12.66) where historical qualitative data exists. This indicated improved biotic integrity in Beaver creek. The Brush Creek macroinvertebrate community trend was generally similar in 2013 to previous years (Figure 19). The community was impacted downstream from the Archbold WWTP, with improvements downstream (especially in 2013 and 1997). The Lick Creek macroinvertebrate community trend was generally similar in 2013 to previous years (Figure 20). Community performance was depressed in the headwaters (RM 21.77) and around the community of Ney (RM 10.05). The most downstream sampling location (RM 1.23), however, did show improved biotic integrity in 2013 compared to previous years with increased EPT and sensitive taxa diversity. The Prairie Creek macroinvertebrate community trend was generally similar in 2013 to previous years (Figure 21). The community was impacted downstream from the Archbold WWTP, with improvements downstream, especially in 2013 and 1997.

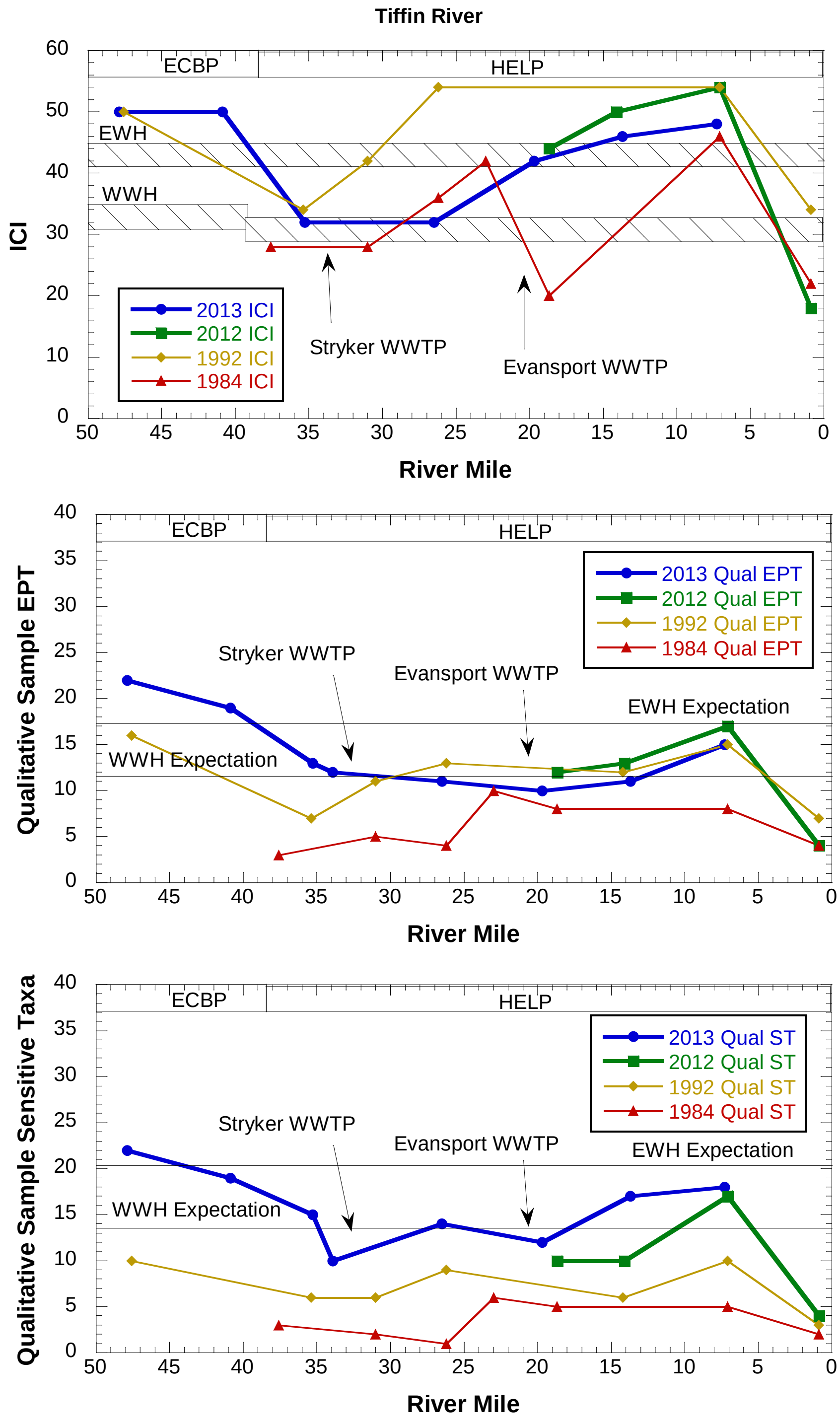
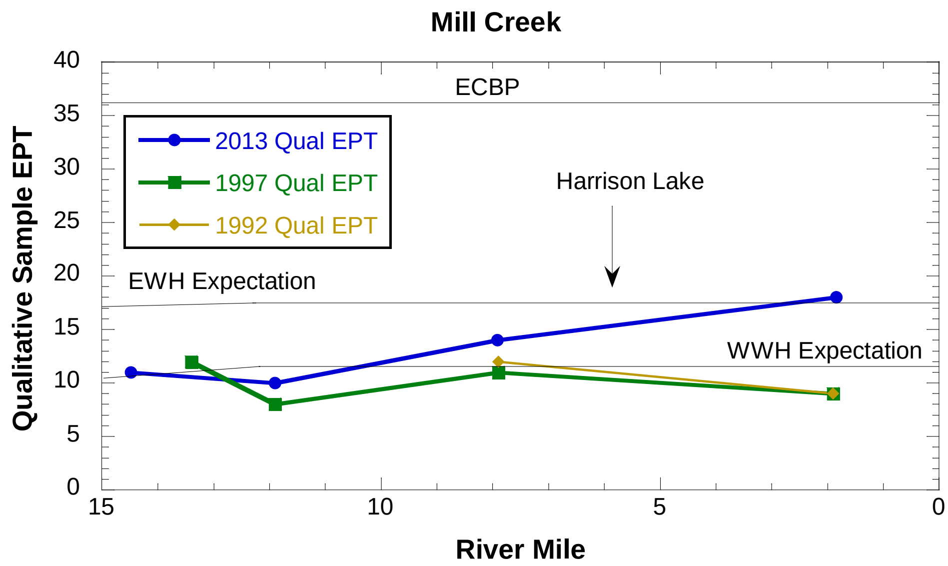


Figure 16. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in the Tiffin River, 1984-2013.



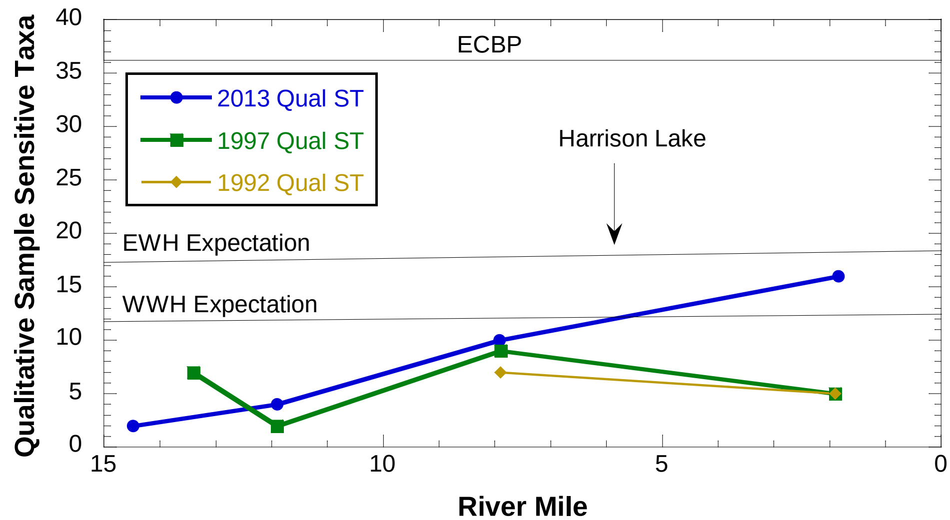


Figure 17. Longitudinal trend of the number of EPT taxa (EPT) in the qualitative sample and number of sensitive taxa (ST) in the qualitative sample in Mill Creek, 1992-2013.

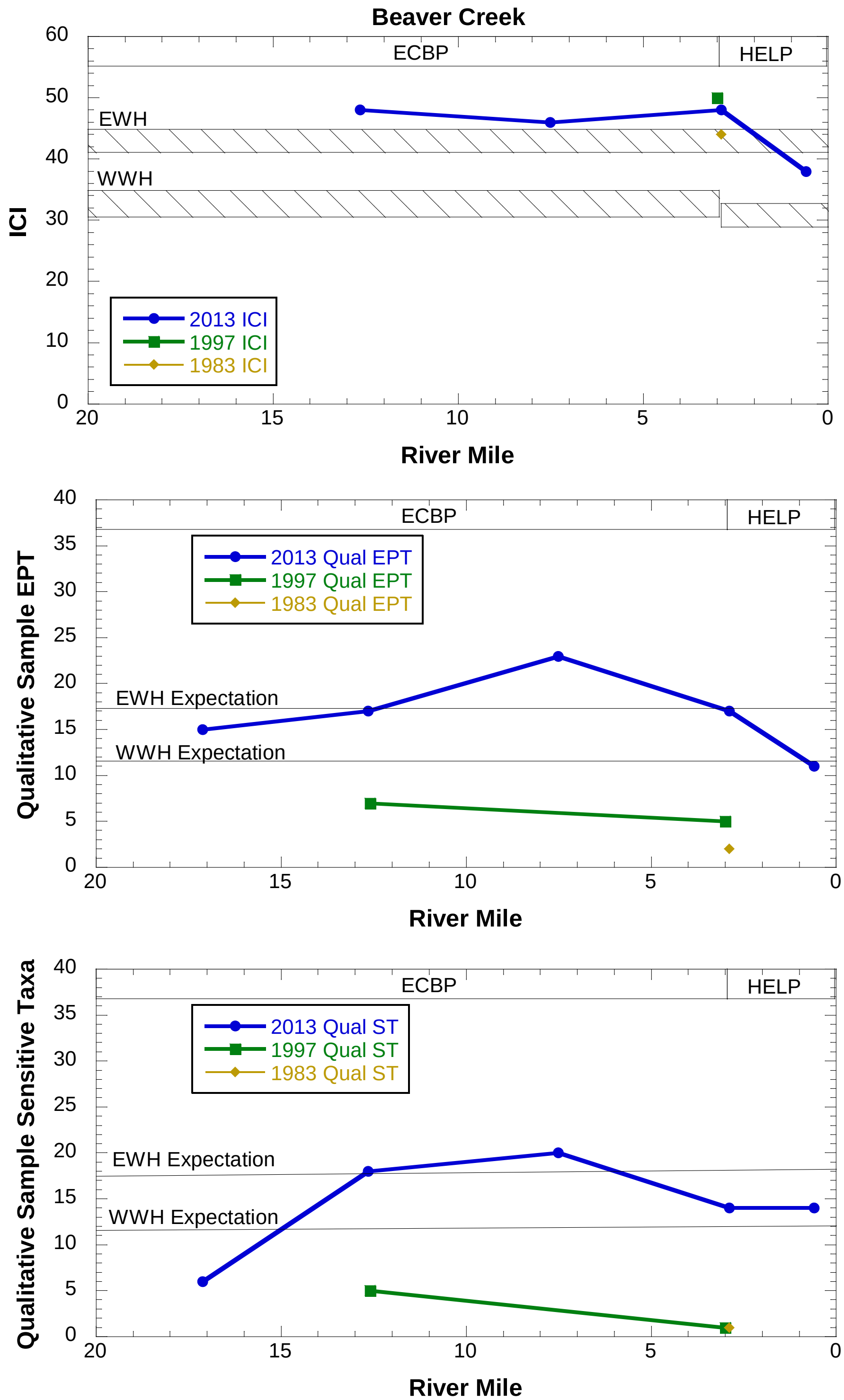


Figure 18. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in Beaver Creek, 1983-2013.

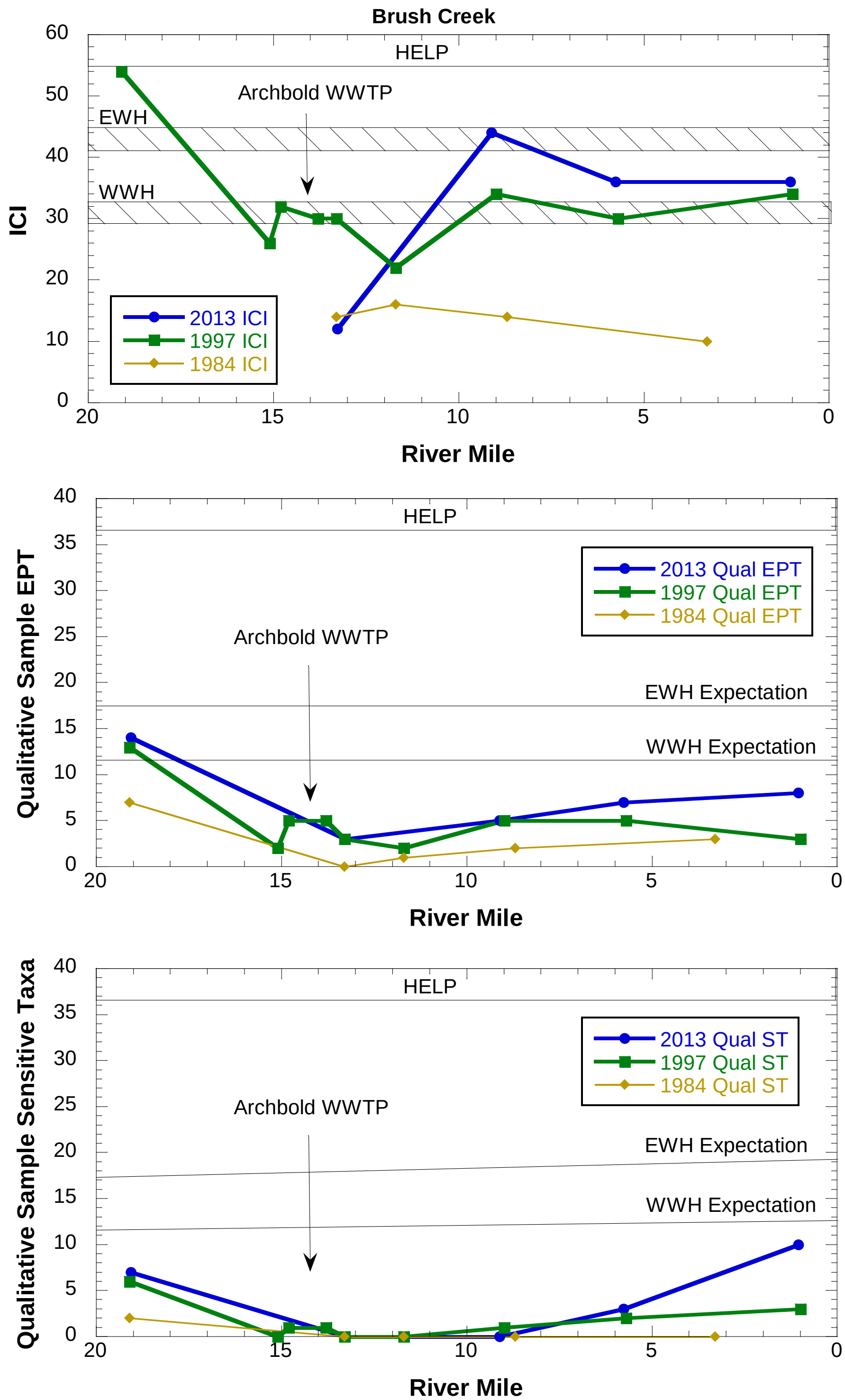


Figure 19. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in Brush Creek, 1984-2013.

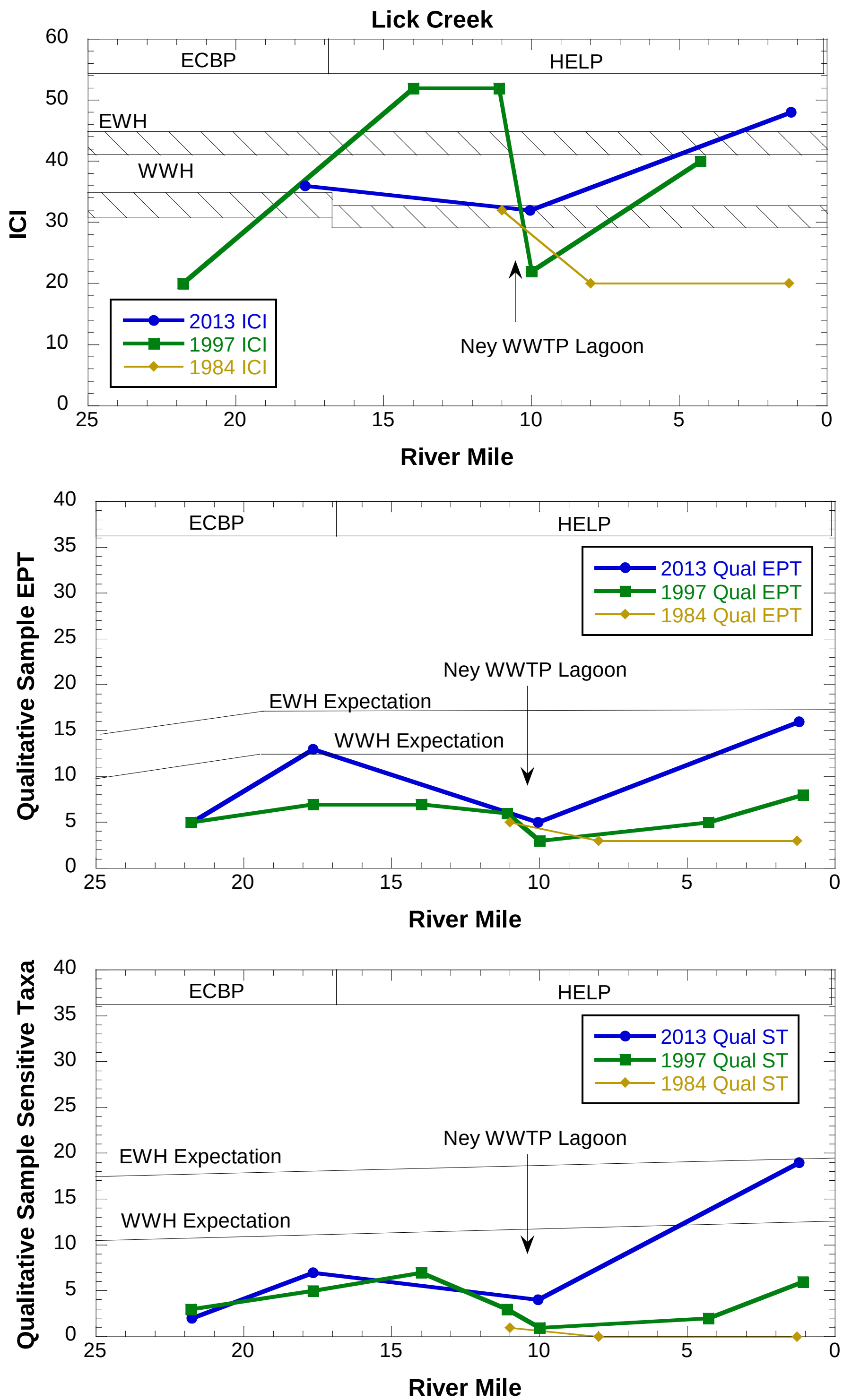


Figure 20. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in Lick Creek, 1984-2013.

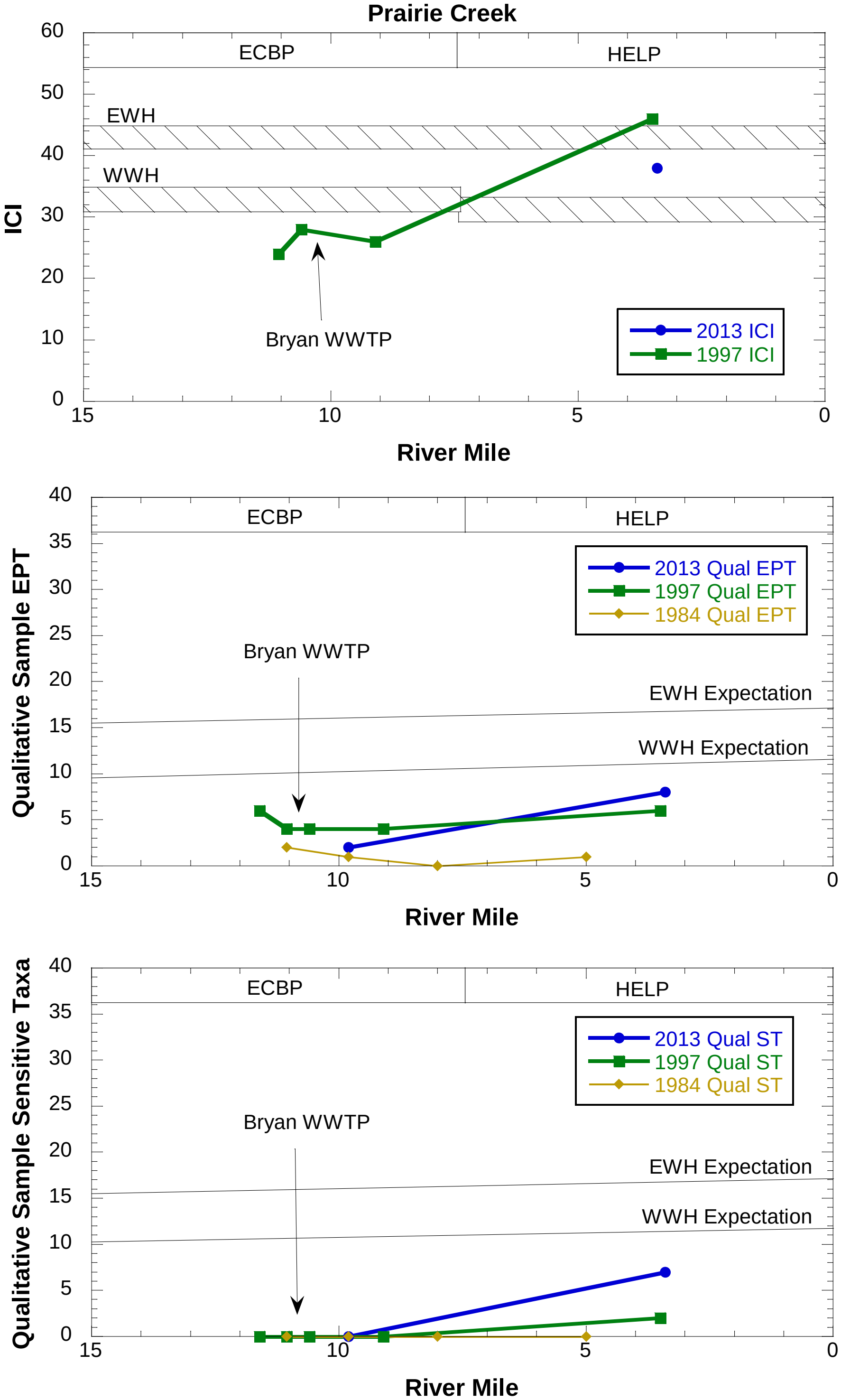


Figure 21. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in Prairie Creek, 1984-2013.

Table 10. Uncommon sensitive macroinvertebrate taxa collection locations in the Tiffin River basin, 2013. State listed species are designated with E for Endangered Species.

Taxa	**Collection Location by River Mile**
Mayflies	
Paracloeodes fleeki	Tiffin R. 47.9, 40.9; Bean Cr. 7.55; Lick Cr. 1.23; Mud Cr. 1.5
Paracloeodes minutus	Tiffin R. 40.9; Bean Cr. 2.2; Mud Cr. 10.1, 1.5
Ephoron album	Bean Cr. 7.55
Stoneflies	
Acroneuria abnormis	Bean Cr. 2.2
Caddisflies	
Brachycentrus numerosus (**E**)	Tiffin R. 47.9, 40.9; Bean Cr. 2.2
Midges	
Polypedilum (Cerobregma) ontario	Beaver Cr. 12.66
Cladotanytarsus vanderwulpi group sp. 4	Mill Cr. 1.85; Beaver Cr. 2.9
Stempellina sp. 2	Miller Cr. 0.5; Buckskin Cr. 1.2

Table 11. Freshwater mussel species (Unionidae) collected live or fresh-dead in the Tiffin River study area, 2013. State listed species are designated with SC for Species of Concern.

Stream River Mile	***Amblema plicata* (Threeridge)**	***Anodontoides ferussacianus* (Cylindrical Papershell)**	***Cyclonaias tuberculata* (SC) (Purple Wartyback)**	***Fusconaia flava* (Wabash Pigtoe)**	***Lampsilis radiata luteola* (Fatmucket)**	***Lasmigona complanata* (White Heelsplitter)**	***Lasmigona compressa* (SC) (Creek Heelsplitter)**	***Leptodea fragilis* (Fragile Papershell)**	***Pleurobema sintoxia* (SC) (Round Pigtoe)**	***Potamilus alatus* (Pink Heelsplitter)**	***Pyganodon grandis* (Giant Floater)**	***Quadrula pustulosa* (Pimpleback)**	***Quadrula quadrula* (Mapleleaf)**	***Strophitus undulatus* (Creeper)**	***Toxolasma parvum* (Lilliput Shell)**	***Truncilla truncata* (SC) (Deertoe)**	***Utterbackia imbecillis* (Paper Pondshell)**	**Total Species per Site**
Tiffin River (04-600-000)																		
47.9					X			X		X				X				4
40.7					X			X		X							X	4
35.28				X				X		X	X	X	X			X		7
33.95					X			X		X	X							4
26.5			X		X			X		X		X	X			X		7
19.72								X		X		X	X			X		5
13.7	X		X	X	X			X		X	X	X	X			X		10
7.3				X				X		X		X				X		5
Bean Creek (04-626-000)																		
7.55	X			X	X		X			X	X							6
2.2				X	X			X		X								4

Stream River Mile	***Amblema plicata* (Threeridge)**	***Anodontoides ferussacianus* (Cylindrical Papershell)**	***Cyclonaias tuberculata* (SC) (Purple Wartyback)**	***Fusconaia flava* (Wabash Pigtoe)**	***Lampsilis radiata luteola* (Fatmucket)**	***Lasmigona complanata* (White Heelsplitter)**	***Lasmigona compressa* (SC) (Creek Heelsplitter)**	***Leptodea fragilis* (Fragile Papershell)**	***Pleurobema sintoxia* (SC) (Round Pigtoe)**	***Potamilus alatus* (Pink Heelsplitter)**	***Pyganodon grandis* (Giant Floater)**	***Quadrula pustulosa* (Pimpleback)**	***Quadrula quadrula* (Mapleleaf)**	***Strophitus undulatus* (Creeper)**	***Toxolasma parvum* (Lilliput Shell)**	***Truncilla truncata* (SC) (Deertoe)**	***Utterbackia imbecillis* (Paper Pondshell)**	**Total Species per Site**
Old Bean Creek (04-632-000)																		
6.22		X				X					X							3
Mill Creek (04-624-000)																		
1.85	X	X				X					X							4
Flat Run (04-620-000)																		
0.4											X							1
Beaver Creek (04-617-000)																		
17.12		X													X			2
12.66											X			X				2
7.52					X	X					X							3
2.9	X	X			X	X	X				X			X				7
0.61	X	X		X	X	X		X	X	X	X			X				10
Brush Creek (04-614-000)																		
1.05		X			X	X		X		X		X	X					7
Owl Creek (04-615-000)																		
1.3											X							1

Stream River Mile	*Amblema plicata* (Threeridge)	*Anodontoides ferussacianus* (Cylindrical Papershell)	*Cyclonaias tuberculata* (SC) (Purple Wartyback)	*Fusconaia flava* (Wabash Pigtoe)	*Lampsilis radiata luteola* (Fatmucket)	*Lasmigona complanata* (White Heelsplitter)	*Lasmigona compressa* (SC) (Creek Heelsplitter)	*Leptodea fragilis* (Fragile Papershell)	*Pleurobema sintoxia* (SC) (Round Pigtoe)	*Potamilus alatus* (Pink Heelsplitter)	*Pyganodon grandis* (Giant Floater)	*Quadrula pustulosa* (Pimpleback)	*Quadrula quadrula* (Mapleleaf)	*Strophitus undulatus* (Creeper)	*Toxolasma parvum* (Lilliput Shell)	*Truncilla truncata* (SC) (Deertoe)	*Utterbackia imbecillis* (Paper Pondshell)	Total Species per Site
Coon Creek (04-616-000)																		
0.62											X							1
Lick Creek (04-609-000)																		
10.05						X					X							2
1.23		X		X		X	X	X		X		X	X		X	X		10
Miller Creek (04-612-000)																		
0.5					X													1
Prairie Creek (04-609-001)																		
9.8		X									X							2
3.4		X				X	X				X		X		X			6
Mud Creek (04-605-000)																		
10.1		X																1
1.5		X						X		X	X			X				5
Dry Creek (04-608-000)																		
3.76		X									X							2

Stream River Mile	***Amblema plicata* (Threeridge)**	***Anodontoides ferussacianus* (Cylindrical Papershell)**	***Cyclonaias tuberculata* (SC) (Purple Wartyback)**	***Fusconaia flava* (Wabash Pigtoe)**	***Lampsilis radiata luteola* (Fatmucket)**	***Lasmigona complanata* (White Heelsplitter)**	***Lasmigona compressa* (SC) (Creek Heelsplitter)**	***Leptodea fragilis* (Fragile Papershell)**	***Pleurobema sintoxia* (SC) (Round Pigtoe)**	***Potamilus alatus* (Pink Heelsplitter)**	***Pyganodon grandis* (Giant Floater)**	***Quadrula pustulosa* (Pimpleback)**	***Quadrula quadrula* (Mapleleaf)**	***Strophitus undulatus* (Creeper)**	***Toxolasma parvum* (Lilliput Shell)**	***Truncilla truncata* (SC) (Deertoe)**	***Utterbackia imbecillis* (Paper Pondshell)**	**Total Species per Site**
Lost Creek (04-606-000)																		
8.97		X									X							2
Buckskin Creek (04-604-000)																		
1.2											X							1

Table 12. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Tiffin River study area, June to September, 2013. Data from locations in the lower Tiffin River collected in 2012 are denoted by [brackets].

Stream RM	Dr. Ar. (mi^2)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
Tiffin River (04-600-000)										
47.9	336	-	53	22 / 24	22 / 23	M / 1130	0	Hydropsychid caddisflies (MI,F), midges (F)	50	
40.9	374	-	46	19 / 21	19 / 22	M / 462	0	Hydropsychid caddisflies (F,MI), mayflies (MI,F), midges (F,T)	50	
35.28	407	-	42	13 / 15	15 / 16	L-M / 439	0	Hydropsychid caddisflies (MI,F), baetid mayflies (F), midges (T,F)	32	
33.95	412	-	44	12	10	L-M	0	Hydropsychid caddisflies (MI,F), baetid mayflies (F), midges (T,F)	-	Marg. Good
26.5	422	15	38	11 / 13	14 / 15	L / 225	0	Caddisflies (MI,F), mayflies (F), midges (F,T)	32	
19.72	476	-	40	10 / 12	12 / 14	M / 297	0	Hydropsychids (MI,F), mayflies (F,MI), midges (F,MT)	42	
[18.7]	541	-	[32]	[12/14]	[10/13]	[M/333]	[0]	Hydropsychid caddisflies (MI,F)	[44]	
[14.1]	562	-	[30]	[13/16]	[10/15]	[L-M/273]	[0]	Riffle beetles (F), heptageniid mayflies (MI,F), Hydropsychid caddisflies (MI,F)	[50]	
13.7	563	-	49	11 / 14	17 / 21	L-M / 371	0	Mayflies (F,MI), hydropsychids (F,MI)	46	
7.3	737	-	48	15 / 17	18 / 21	L / 426	0	Hydropsychid caddisflies (F,MI), mayflies (F,MI)	48	
[7.2]	737	-	[49]	[17/21]	[17/23]	[M/996]	[0]	Hydropsychid caddisflies (MI,F), baetid mayflies (F), riffle beetles (F)	[54]	

Stream RM	Dr. Ar. (mi^2)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
[0.9]	775	8	[33]	[4/7]	[4/6]	[L/2431]	[0]	Water mites (F), midges (F,MT)	[18]	
Bean Creek (04-626-000)										
7.55	206	-	89	26 / 30	29 / 34	M / 2527	0	Mayflies (MI,F), hydropsychid caddisflies (F,MI), midges (F)	50	
2.2	246	-	58	23 / 28	22 / 26	M / 941	0	Mayflies (MI,F), hydropsychid caddisflies (F,MI), midges (F,T)	52	
Deer Creek (04-628-000)										
4.56	9.9	-	40	5	0	M-H	1	Midges (T,F), blackflies (F), baetid mayflies (F)	-	Low Fair
Old Bean Creek (04-632-000)										
6.22	14.6	-	39	6	2	M	1	Midges (T,F), water boatmen (MT)	-	Fair
2.2	22.4	-	32	9	5	L	0	Hydropsychid caddisflies (F), mayflies (F), midges (F)	-	Fair
Mill Creek (04-624-000)										
14.49	12.9	-	40	11	2	L-M	0	Hydropsychid caddisflies (F), midges (MT,F,T)	-	Marg. Good
11.9	23.4	-	55	10	4	L-M	0	Hydropsychid caddisflies (F), baetid mayflies (F), midges (F,MT)	-	Marg. Good
7.92	32.8	-	43	14	10	M	0	Flatworms (F), hydropsychid caddisflies (F), baetid mayflies (F)	-	Good
1.85	39	15	64	18 / 22	16 / 20	M / 653	0	Hydropsychid caddisflies (F), midges (F,T), baetid mayflies (F)	52	

Stream RM	Dr. Ar. (mi^2)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
Bates Creek (04-622-000)										
1.65	11.8	-	30	8	0	M	0	Midges (F), sowbugs (MT), hydropsychid caddisflies (F)	-	Fair
Flat Run (04-620-000)										
0.4	10.2	-	37	4	0	L	0	Midges (T,MT,F)	-	Low Fair
Leatherwood Creek (04-619-000)										
1.15	9.8	-	47	8	1	L	0	Midges (F), baetid mayflies (F), hydropsychid caddisflies (F)	-	Fair
Beaver Creek (04-617-000)										
17.12	14.9	-	57	15	6	M-H	0	Hydropsychid caddisflies (F), baetid mayflies (F), midges (F,T)	-	Good
12.66	29.5	-	69	17 / 19	18 / 22	M / 2199	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (MI,F)	48	
7.52	36	-	68	23 / 27	20 / 27	M-H / 1153	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (F)	46	
2.9	41	15	65	17 / 18	14 / 19	L / 363	0	Hydropsychid caddisflies (F), baetid mayflies (F), midges (F)	48	
0.61	44.8	-	54	11 / 15	14 / 17	L-M / 345	0	Hydropsychid caddisflies (F), baetid mayflies (F,MI), midges (F)	38	
Brush Creek (04-614-000)										
19.06	19.7	-	59	14	7	M	0	Midges (F), hydropsychid caddisflies (F), baetid mayflies (MI)	-	Good
13.28	34.6	15	39	3 / 3	0 / 0	L-M / 679	0	Midges (MT,T,F)	12	

Stream RM	Dr. Ar. (mi²)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
9.11	54	-	33	5 / 6	0 / 1	L / 552	0	Hydropsychid caddisflies (F), baetid mayflies (F), midges (T,F)	44	
5.76	62	15	39	7 / 9	3 / 4	L-M	0	Midges (F)	36	
1.05	65	-	50	8 / 8	10 / 11	L / 256	0	Hydropsychid caddisflies (F), mayflies (F), midges (F,MT)	36	
Owl Creek (04-615-000)										
1.3	9.6	-	32	4	0	L	0	Flatworms (F)	-	Low Fair
Coon Creek (04-616-000)										
0.62	9.3	-	33	3	0	L	1	Midges (T,F), hydropsychid caddisflies (F)	-	Low Fair
Doty Run (04-613-000)										
0.63	5.3	9	29	2	0	L	1	Midges (F,T) mosquitos (F), damselflies (T,F)	-	Poor
Lick Creek (04-609-000)										
21.77	6.2	-	42	5	2	M	2	Baetid mayflies (F), midges (F), blackflies (F)	-	Fair
17.66	30	-	65	13 / 14	7 / 8	M / 642	0	Hydropsychid caddisflies (F), baetid mayflies (F), flatworms (F)	36	
10.05	58.5	15	45	5 / 6	4 / 5	M / 1044	0	Hydropsychid caddisflies (F), baetid mayflies (F), midges (F,T)	32	
1.23	105	-	71	16 / 16	19 / 20	M / 2121	0	Hydropsychid caddisflies (F), baetid mayflies (F,MI), midges (F,MT)	48	
Miller Creek (04-612-000)										
0.5	20.9	15	52	16 / 18	13 / 19	M / 478	1	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (F)	46	

Stream RM	Dr. Ar. (mi²)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
Little Lick Creek (04-611-000)										
4.97	7.5	-	38	9	1	M	0	Baetid mayflies (F), hydropsychid caddisflies (F), midges (F)	-	Fair
0.8	23.3	9	31	2	0	M-H	0	Midges (MT,T,F)	-	Poor
Prairie Creek (04-609-001)										
9.8	9.8	-	41	2	0	M	0	Midges (T,F), flatworms (F), fingernail clams (F)	-	Poor
3.4	26.0	-	42	8 / 10	7 / 8	M / 659	0	Midges (F), flatworms (F)	38	
Mud Creek (04-605-000)										
10.1	47.3	-	53	18	15	M	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (F)	-	Good
1.5	58	15	57	15 / 19	13 / 16	L / 310	0	Baetid mayflies (F)	44	
Dry Creek (04-608-000)										
3.76	11.0	-	43	7	0	M	0	Baetid mayflies (F), snails (T,F), midges (F,T,MT)	-	Fair
Lost Creek (04-606-000)										
8.97	14.4	-	36	8	8	M	0	Midges (F), baetid mayflies (F), hydropsychid caddisflies (F)	-	Fair
1.41	25.6	15	68	16 / 17	11 / 13	L-M / 946	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (F)	44	
Buckskin Creek (04-604-000)										
1.2	6.1	9	29	5	2	-	0	Sowbugs (MT), Physella snails (T), hydropsychid caddisflies (F)	-	Fair

Stream RM	Dr. Ar. (mi^2)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
Webb Run (04-602-000)										
2.99	9.3	-	28	4	0	L	0	Blackflies (F), Midges (T,F)	-	Low Fair
0.4	20.0	-	53	11	4	M	0	Baetid mayflies (F), hydropsychid caddisflies (F), midges (F)	-	Marg. Good

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 8=Non-Detectable Current, 9=Intermittent or Near-Intermittent Conditions, 12=Suspected High Water Influence, 13=Suspected Disturbance by Vandalism, 15=Current >0.0 fps but<0.3 fps, 27=Wetland Stream Sample.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
CW: Cold Water.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant

SURFACE WATER CHEMISTRY

Surface water chemistry samples were collected in the Tiffin River study area from June 2012 through October 2014, including water column chemistry, benthic chlorophyll-a, bacteriological, and continuous water quality sondes. Primary chemistry sampling occurred between December 2012 and September 2013, covering 52 locations (Appendix G). Four sites in the Tiffin River Large River Assessment Unit (LRAU) portion were monitored in 2012 in conjunction with the Maumee River mainstem study. The LRAU includes the Tiffin River mainstem from Brush Creek (RM 19.7) to the mouth. Additional surface water chemistry data were collected during the 2014 sampling season at or near locations displaying biological impairment in 2013.

Chemistry sites were established in free-flowing sections of the streams and were sampled directly from the streams or at bridge crossings. Water column samples were dispensed into appropriate containers, preserved, and delivered to Ohio EPA's Environmental Services laboratory for analysis of a variety of parameters including nutrients and metals. Monthly water samples were also collected from 8 sentinel locations from December 2012 through September 2013. Collected water was preserved using appropriate methods, as outlined in the Ohio EPA Surface Water Field Sampling Manual, January 31, 2013 (Ohio EPA 2012a, 2013b).

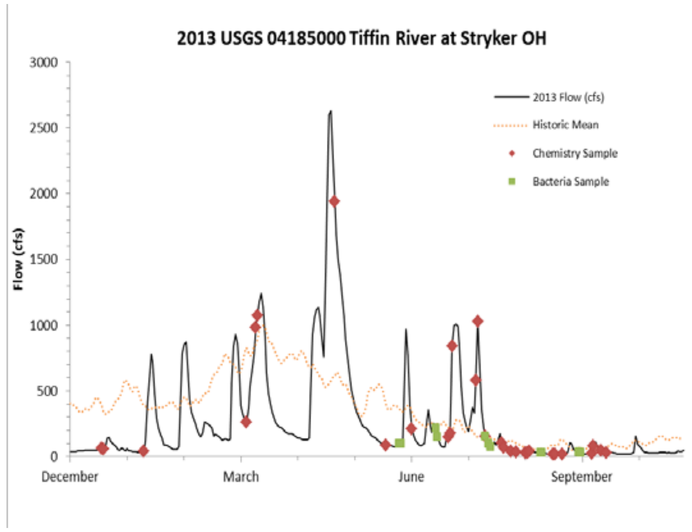


Figure 22. Mean flow conditions in the Tiffin River at the USGS gage at Stryker at CR F from December 2012 to November 2013. USGS Provisional Data.

USGS gage data from the Tiffin River at the Village of Stryker on Curtis Street (County Road F) was used to show flow trends in the Tiffin River watershed during 2013 chemistry sampling. Water and bacteria sample collection dates are noted in Figure 22. Flow conditions during the sampling index period were typically lower than the historic mean but exceeded the historic mean regularly due to intense precipitation events. Water chemistry samples were collected over a variety of flow conditions in the study area during the field season. Bacteria was collected during the recreation use season (May 1 through October 31) and was typically collected during lower flows. Samples collected during 2012 in the LRAU (04100006 90 01 - Brush Creek to the Mouth) occurred at low flow conditions in an exceptionally dry sampling season.

Surface water samples were analyzed for metals, nutrients, semi-volatile organic compounds, herbicides, bacteria, pH, temperature, conductivity, dissolved oxygen (DO), percent DO saturation, and suspended and dissolved solids (Appendix G). Parameters which were in exceedance of the Ohio WQS criteria are reported in Table 13-Table 16. Nutrient results are presented in Table 17 and will be discussed later in this section along with additional trophic status parameters (chlorophyll-*a* and DO). Bacteriological samples were collected from 33 locations in 2013 and four locations in 2012; these results are reported in the *Recreation Use* section of this document

Multi-parameter water quality sondes were deployed within the study area to collect continuous physical parameter data. These sondes monitored temperature, DO, pH, and specific conductance (conductivity). Temperature, DO, and pH are influenced by diel, or daily, patterns. These diel patterns have the greatest impact for streams during certain critical conditions that include stable, low streamflow. Specific conductance is not influenced by the same diel triggers but is monitored because it is a strong indicator of changes in streamflow. The water quality sondes collect readings hourly to monitor parameters throughout the diel cycle. Grab readings differ because they only represent one point on the diel curve. While they are effective at characterizing water quality parameters that change based on hydrologic regime or season, they can miss or not fully characterize parameters that exhibit diel patterns. When the diel fluctuations are of concern, continuous monitoring at regular intervals throughout the diel cycle is needed.

Diel patterns in temperature reflect air temperature, solar radiation, base flow (groundwater), discharge, and shading. In general, diel fluctuations in temperature increase as base flow, discharge, and shading decrease. The inverse is also true.

DO responds in a similar diel pattern to temperature, as they are affected by similar factors. In addition, DO trends are directly dependent on temperature. At high temperatures the solubility of oxygen in water decreases, resulting in an inverse relationship. Without the influence of other environmental conditions this would cause the two parameters to follow opposite trends. However, the DO produced by photosynthesis can be enough to overwhelm the inverse relationship causing the trends to follow similar trajectories.

Large diel DO fluctuations are typically associated with excess algal production in an enriched stream, where in-stream DO concentrations are very high in daylight hours during periods of algal photosynthesis and very low at night during periods of algal respiration. The result is a diel trend that typically reaches a maximum in the early evening and a minimum preceding sunrise. In some cases dissolved oxygen does not exhibit strong diel trends in low flow, warm conditions. Either primary productivity is limited or decomposition of organic matter in the stream is controlling the DO concentrations. A diel sag in DO concentration is typically associated with various sources of excess instream organic material, in which microbes consume much of the stream's DO in an effort to process excess organic materials in a stream, ultimately resulting in chronically low DO values over a 24-hour period. Sonde monitoring contributes to the body of evidence used to identify DO trends that are influenced by primary productivity or decomposition that may be causing biological impairment.

Diel patterns in pH are also reflective of primary productivity. Carbon dioxide, which dissolves in water to form carbonic acid, is consumed during photosynthesis, raising the pH of the stream. The result is a maximum pH value observed at a similar time to the maximum dissolved oxygen

During each deployment in the Tiffin River watershed, the sondes took measurements every hour for a period of three to five days. These continuous measurements were taken at 4 sites in 2012, 11 in 2013, 18 in 2014, and 8 in both 2013 and 2014 (Figure 23). In 2012 and 2013, sonde sites were a subset of chemistry sites, located at USGS stream gage locations, the outlets of all major tributaries, regular intervals along the mainstem of the Tiffin River, and bracketing particular areas of concern. The targeted areas of concern within the Tiffin basin were primarily wastewater treatment plants (WWTPs), including those for the cities of Archbold (Ohio EPA Permit # 2PD00017) and Bryan (Ohio EPA Permit # 2PD00018). In 2014, sondes were deployed in locations not previously monitored for biology or chemistry to clarify pollutant sources.

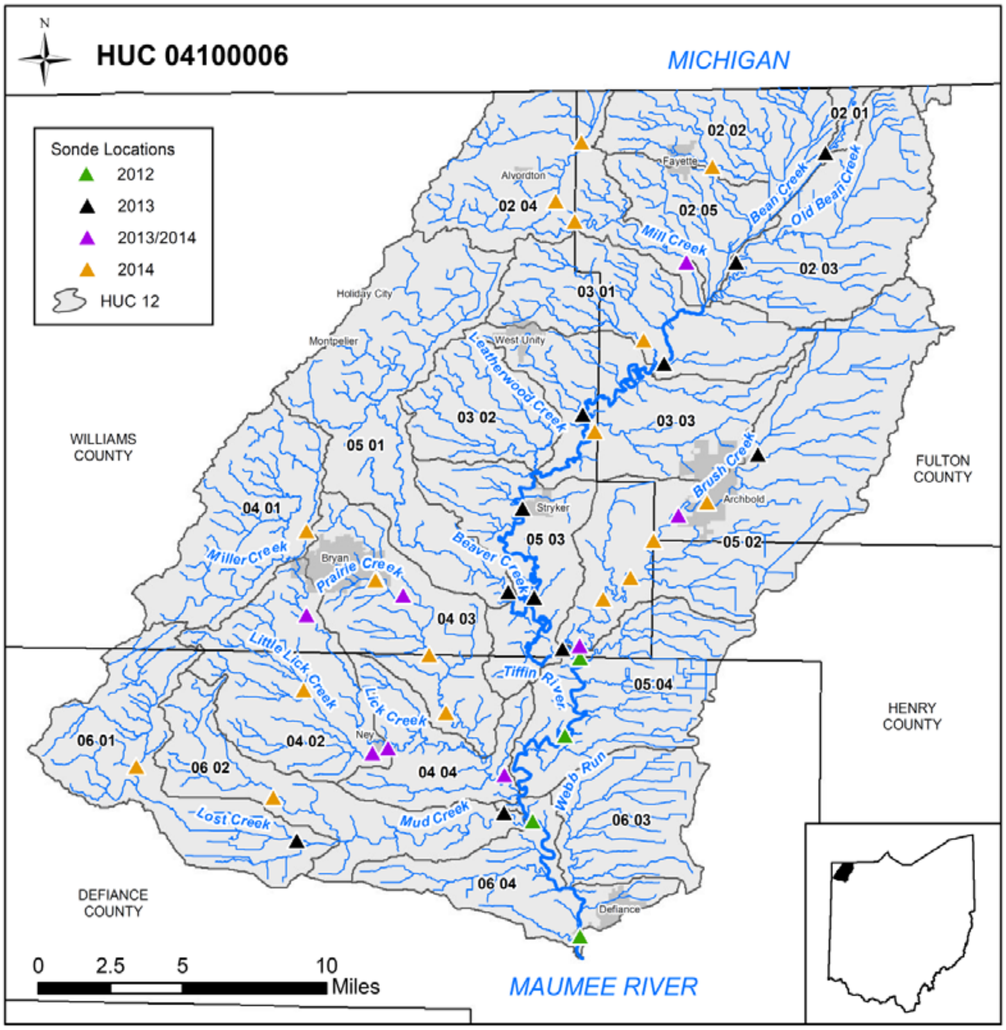


Figure 23. Map of deployment locations for sondes in the Tiffin River watershed during the 2012, 2013, and 2014 survey seasons.

Sondes were deployed July 17-19 and August 7-9 in 2012, July 30-August 1 and August 20-22 in 2013, and July 15-17 and August 15-19 in 2014. Critical conditions for the parameters monitored with sondes are times when flows are low, temperatures are high, and daylight is long; these conditions are typical of the summer sampling period. When compared to the 80-year normal flow at the Tiffin River USGS gage at Stryker, flows during 2012 were well below a typical year. On the other hand, heavy rain events in the early summers of 2013 and 2014 led to elevated flow that continued until mid- to late-July those years. All three years were below the 80-year normal once August arrived (Figure 24).

In 2012, the critical conditions were exacerbated due to drought conditions in the area and temperatures consistently above the daily normal (Figure 25). The first deployment period (July 17-19) covered the ideal condition, with temperatures as high as 38°C and flows as low as 3.3 cfs at the gage. There was a storm during the August deployment; therefore, its data was not as representative of critical conditions as the first, although still helpful in assessment.

The summer of 2013 was generally wetter than an average summer and capturing an effective critical condition was difficult due to the wet weather (Figure 26). Although flow was decreasing prior to the July survey, temperatures were relatively low compared to a typical summer. The second deployment (August 20-22) better represents critical conditions because it was preceded by continuously lower flows and slightly warmer weather. By this survey, Tiffin River flows had dropped below the 80-year normal.

Follow-up sampling in 2014 saw weather patterns similar to 2013, with high flows in the early summer and temperatures generally under 25°C (Figure 27). While flows had decreased leading up to the mid-July survey, temperatures dropped sharply and made conditions slightly less favorable. By the second deployment, temperatures were rising well above the normal for that time of year and flows were becoming consistently lower. The longer deployment period during the August survey (five days as opposed to three) showed a range of conditions not normally captured, with cloudy, rainy days at the beginning and more critical conditions toward the end.

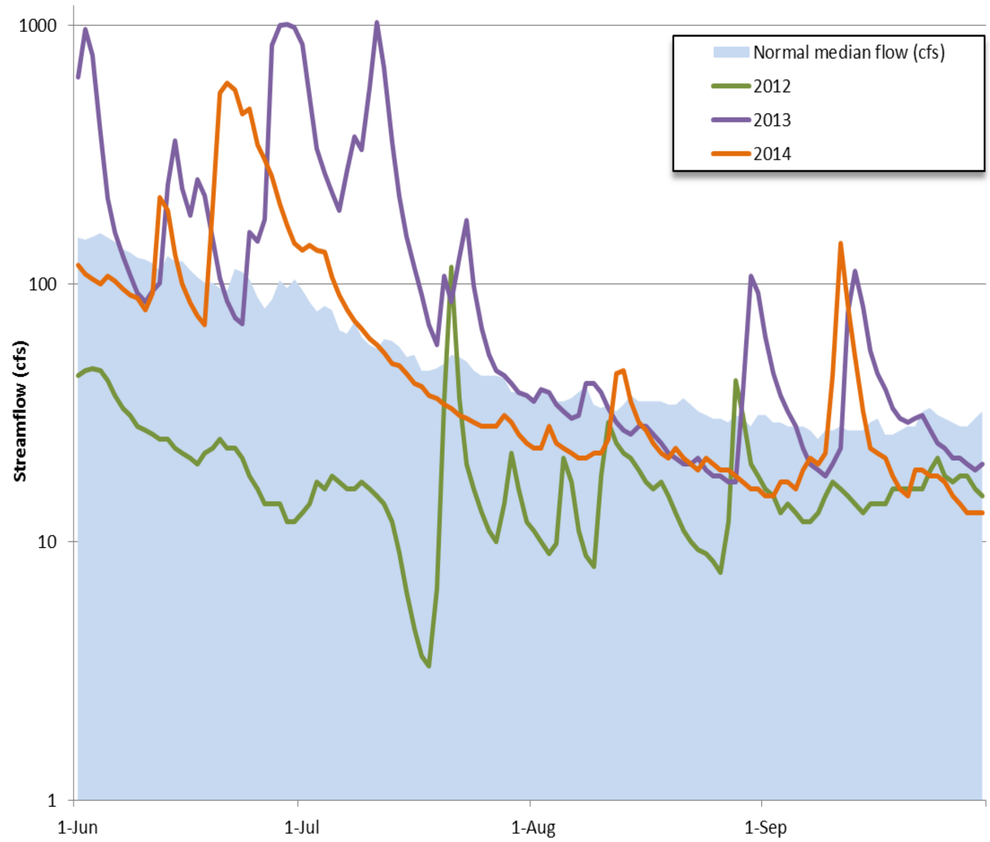


Figure 24. Summer flow comparison (2012-2014) at USGS gage 04185000 (Tiffin River at Stryker Ohio)

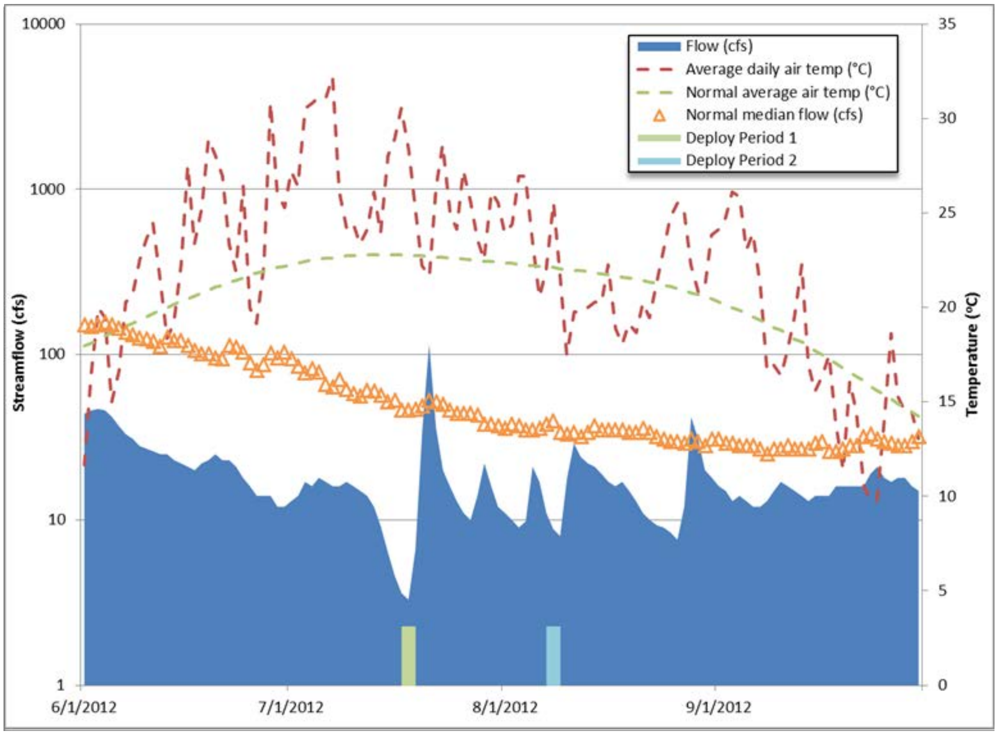


Figure 25. Graph of average daily streamflow relative to the daily median streamflow (USGS 04185000 Tiffin River at Stryker OH) including the average daily air temperature (NOAA -GHCND:USW00004851) for the 2012 sonde sampling season.

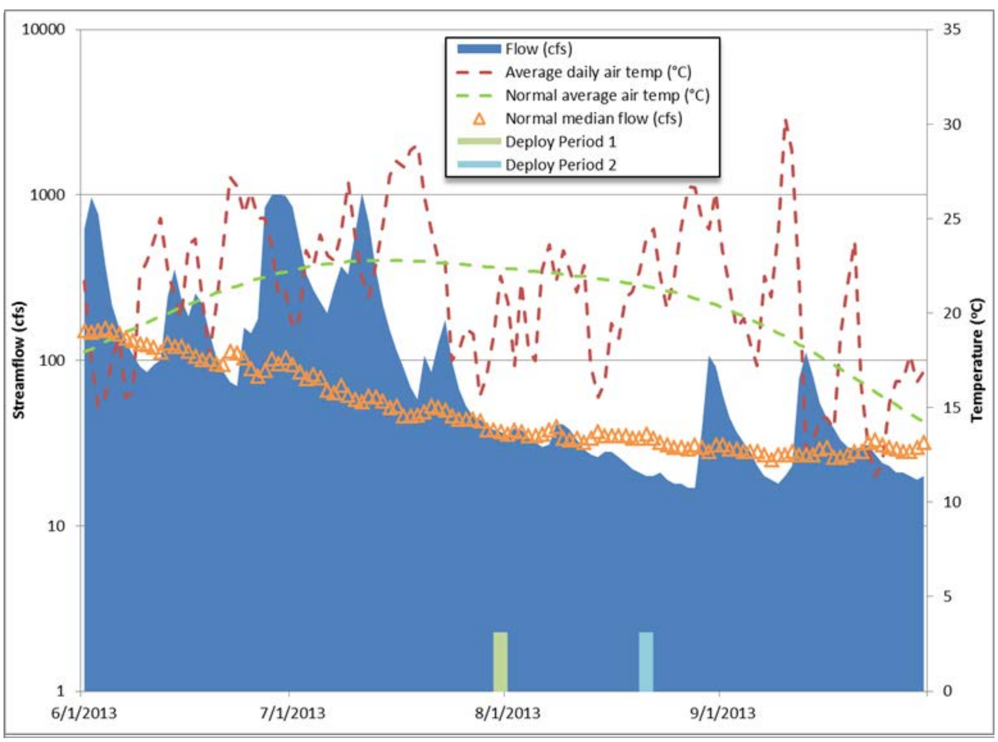


Figure 26. Graph of average daily streamflow relative to the daily median streamflow (USGS 04185000 Tiffin River at Stryker OH) including the average daily air temperature (NOAA -GHCND:USW00004851) for the 2013 sonde sampling season.

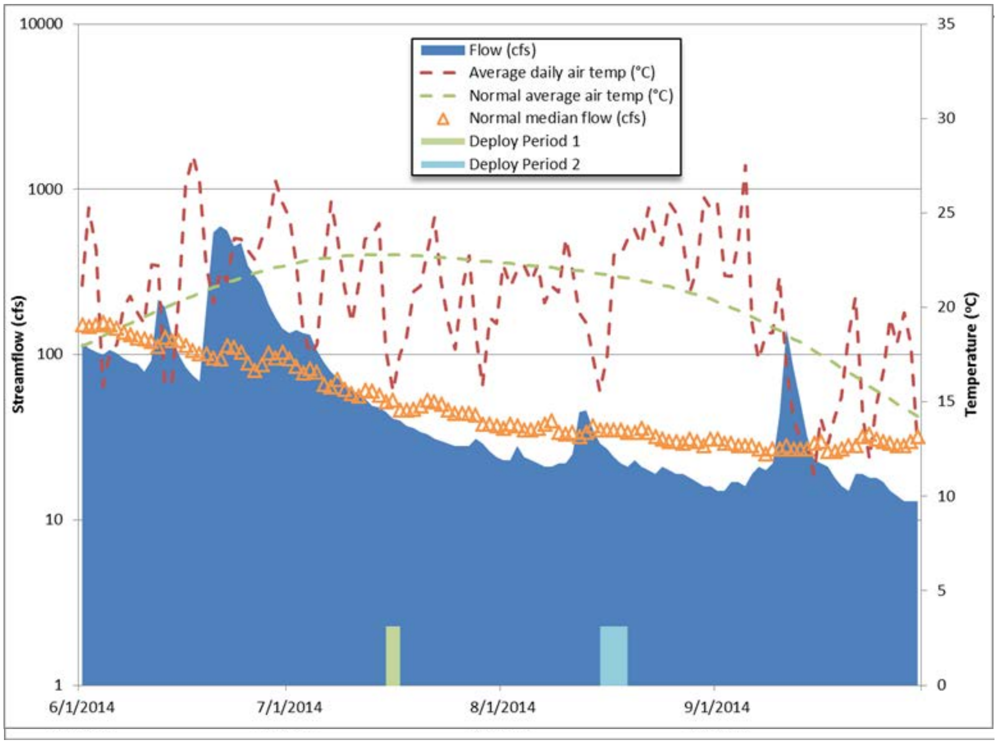


Figure 27. Graph of average daily streamflow relative to the daily median streamflow (USGS 04185000 Tiffin River at Stryker OH) including the average daily air temperature (NOAA -GHCND:USW00004851) for the 2014 sonde sampling season.

Ohio promulgates water quality standards through Ohio Administrative Code Chapter 3745-1. The data collected during the sonde deployments are sufficient to evaluate exceedances of the standards for the protection of aquatic life for: maximum daily temperature, minimum DO, 24-hour average DO, pH, and specific conductivity. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. 24-hour average DO criteria exceedances are compared to 24-hour rolling averages. An exceedance of the water quality criteria does not represent stream impairment; rather if biological impairment is present, the exceedances help develop a body of evidence that identifies the conditions that are stressing aquatic life. Exceedance summaries are presented by year in Table 14-Table 16. The tables include descriptions of exceedances based on Ohio EPA staff's knowledge of specific sites.

Table 13. Exceedances of Ohio Water Quality Standards criteria (OAC3745-1) for chemical/physical parameters measured in the Tiffin River watershed, 2012 and 2013. Exceedances from the 2012 data are in bold. Bacteria exceedances are presented in the Recreation Use section of this document.

Stream/RM	**Location**	**Parameter (value – mg/l unless noted)**
Tiffin River WWH Existing (ECBP & HELP)		
ECBP Ecoregion		
47.54	CR G at Archbold water intake	Iron: 5,140 µg/l[c,d]
41.14	CR I-25 (Lockport)	None
HELP Ecoregion		
35.28	UPST Stryker at SR 191	Iron: 11,600 µg/l[c]
33.95	Stryker at County Road F (Curtis St.)	Iron: 12,300 µg/l[c], 13,300 µg/l[c]
26.17	DST Stryker at County Road C	Iron: 19,100 µg/l[c]
19.72	DST Evansport WWTP at CR 22-A	None
18.7	Evansport at SR 191	None
14.00	Stever Rd.	None
7.09	Evansport Rd. (lower crossing)	None
Tiffin River WWH Existing/MWH-I Recommended (HELP)		
0.9	**Dey Rd.**	**Iron: 12,200 µg/l[c]; Temperature: 16.12° C[c]**
Old Bean Creek MWH-C Existing (HELP & ECBP)		
HELP Ecoregion		
6.22	CR 19	None
ECBP Ecoregion		
1.85	Old Angola Rd. (CR L)	None
Deer Creek WWH Existing (ECBP)		
4.56	DST Fayette, CR 23	None
Bean Creek WWH Existing/EWH Recommended (ECBP)		
7.55	CR 20	Iron: 6,320 µg/l[c]
2.20	Old Angola Rd. (CR L)	None
Mill Creek WWH Existing/MWH-C Recommended (ECBP)		
14.49	CR S	Dissolved Oxygen: 3.60[a], 3.65[a]
Mill Creek WWH Existing (ECBP)		
11.90	DST Alvordton, CR P	None
7.92	CR 28	Dissolved Oxygen: 3.89[a]
1.85	Old Angola Rd. (CR L)	Iron: 6,350 µg/l[c], 8,810 µg/l[c]
Bates Creek WWH Existing (ECBP)		
1.65	CR 25.2	Dissolved Oxygen: 2.80[a]
Flat Run WWH Confirmed (ECBP)		
0.40	CR 22.75	None
Leatherwood Creek WWH Existing (ECBP)		
1.15	CR H	None
Beaver Creek WWH Existing (ECBP & HELP)		
ECBP Ecoregion		
17.12	CR K	None
12.66	CR 16	None
7.52	DST Pulaski, SR 127	None
HELP Ecoregion		
2.90	CR D	None
0.61	CR 20	Iron: 5,900 µg/l[c], 6,310 µg/l[c], 7,480 µg/l[c]
Owl Creek WWH Confirmed (HELP)		
0.07	CR 25	Dissolved Oxygen: 2.54[a]

Brush Creek	*WWH Existing (HELP)*	
19.06	Archbold Lutz Rd. (CR D)	None
13.28	DST Archbold WWTP, at CR 24	Iron: 10,700 µg/l[c]; Dissolved Oxygen: 2.44[a]
9.11	CR 24.25	None
5.76	CR C	None
1.05	CR 22.60	Iron: 8,850 µg/l[c]
Coon Creek	*WWH Existing (HELP)*	
0.62	CR 23	None
Doty Run	*WWH Confirmed (HELP)*	
0.63	Evansport Rd.	Dissolved Oxygen: 3.37[a]
Miller Creek	*WWH Existing (ECBP)*	
1.00	CR 12	Dissolved Oxygen: 1.27[a]
Little Lick Creek	*WWH Existing (ECBP & HELP)*	
ECBP Ecoregion		
4.97	Behnfeldt Rd.	Dissolved Oxygen: 1.47[a]
HELP Ecoregion		
0.80	UPST Ney at Old RR crossing	Dissolved Oxygen: 2.70[a], 3.60[a], 3.69[a]
Prairie Creek	*WWH Existing (ECBP & HELP)*	
ECBP Ecoregion		
9.80	DST Bryan WWTP adj. CR C	None
HELP Ecoregion		
3.40	Flickinger Rd. (Lower Crossing)	None
Lick Creek	*WWH Existing (ECBP & HELP)*	
ECBP Ecoregion		
21.77	NW of Bryan at CR 13	Dissolved Oxygen: 3.29[a]
17.66	SW of Bryan at CR 13	None
HELP Ecoregion		
10.05	DST Ney at The Bend Rd. (CR 134)	Dissolved Oxygen: 3.9[a]
1.23	Trinity Rd.	Iron: 8,610 µg/l[c], 18,100 µg/l[c], 6,600 µg/l[c]
Dry Creek	*WWH Confirmed (HELP)*	
3.75	DST dairy farm at Openlander Rd.	Dissolved Oxygen: 1.07[a], 3.96[a]
Lost Creek	*WWH Confirmed (ECBP & HELP)*	
ECBP Ecoregion		
8.97	Seevers Rd.	None
HELP Ecoregion		
1.41	Behnfeldt Rd.	None
Mud Creek	*WWH Existing (HELP)*	
10.10	Coy Rd.	None
1.5	Trinity Rd.	Iron: 9,220 µg/l[c], 18,800 µg/l[c], 8,450 µg/l[c]; Copper: 16.8 µg/l
Buckskin Creek	*WWH Existing (HELP)*	
1.20	SR 15	Dissolved Oxygen: 3.59[a], 3.62[a]
Webb Run	*WWH Existing (HELP)*	
2.98	Flory Rd.	Dissolved Oxygen: 3.34[a]
0.40	Near Mouth, east of Deerfield Dr.	None

[a] Exceedance of the aquatic life Outside Mixing Zone Minimum water quality criterion.
[b] Exceedance of the daily maximum temperature criterion
[c] Exceedance of the statewide water quality criteria for the protection of agricultural uses.
[d] Exceedance of the human health drinking water criteria for the Lake Erie drainage basin with intake within 500 yards.

Table 14. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring, 2012. Sondes were deployed at 4 sites in 2012, with all sites sampled twice. The first deployment was 7/17-7/19/12 and the second was 8/7-8/9/12, with approximately 48 hours of data at each site during each visit. Sites that were sampled on both deployments are indicated in **bold** in the table. All exceedances in this table occurred during the first (7/17-7/19) survey.

RM	Location	Parameter (D.O. in mg/L, Temp in °C)	Comments
Tiffin River		*WWH Existing (HELP)*	
18.7	**At Evansport @ SR 191**	**DO min: 42(1.9)**	**Low flow; drought conditions**
		DO avg: 23(2.4)	
14.1	**S of Evansport @ Stever Rd**	**DO min: 36(0.7)**	**Low flow; drought conditions**
		DO ave: 24(1.9)	
7.0	**NE of Defiance Airport @ Evansport Rd**	**DO min: 2(3.98)**	**Low flow; drought conditions**
		DO avg: 20(4.6)	
Tiffin River		*MWH Recommended (HELP)*	
0.9	**Near Defiance @ Dey Rd**	**Temperature: 1(29.4), 4(30.0), 1(29.5)**	**Wide channel with narrow riparian shading; drought conditions**

Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average criteria. The duration is the count of consecutive hours that exceeded the criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria and is presented in parenthesis after the duration. Applicable water quality criteria include: minimum dissolved oxygen (DO)[a], average DO[b], maximum temperature[c], pH[d] and specific conductance[e].

Notes:

a The General Lake Erie basin daily maximum temperature criteria apply; See OAC 3745-1-07, Table 7-14(G).

b Applicable minimum 24-hour average D.O. criteria – EWH: 6.0 mg/L, WWH: 5.0 mg/L, MWH: 4.0 mg/L.

c Applicable minimum D.O. criteria – EWH: 5.0 mg/L, WWH: 4.0 mg/L, MWH (HELP): 2.5 mg/L.

d The criterion for pH is 6.5-9.0 S.U.

e The criterion for specific conductivity is 2400 µS/cm.

Table 15. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring, 2013. Sondes were deployed at 19 sites in 2013, with 8 of those sites sampled twice. The first deployment was 7/30-8/1/13 and the second was 8/20-8/22/13, with approximately 48 hours of data at each site during each visit. Sites that were sampled on both deployments are indicated in **bold** in the table.

RM	Location	Parameter (D.O. in mg/L, Temp in °C)	Comments
Tiffin River		*WWH Existing (ECBP)*	
47.54	**NW of Archbold @CR G**	**None**	
41.14	At Lockport @ CR 22.75/CR I.25	None	
Tiffin River		*WWH Existing (HELP)*	
33.95	**W of Stryker @ CR F (Curtis St)**	**None**	
26.17	Dst. Stryker @ Oak Grove Church Rd	None	
19.72	Near Evansport @ CR 22/A	None	
Old Bean Creek		*MWH Existing (ECBP)*	
1.85	SE of Fayette @ Old Angola Rd	None	
Bean Creek		*EWH Recommended (ECBP)*	
7.55	**E of Powers @ US 20**	**None**	
Mill Creek		*WWH Existing (ECBP)*	
1.85	S of Fayette @ Old Angola Rd	None	
Beaver Creek		*WWH Existing (HELP)*	
0.61	**NW of Evansport @ CR 20**	**None**	
Brush Creek		*WWH Existing (HELP)*	
19.06	Ust Archbold @ Archbold-Lutz Rd	Temp. max.: 4(30.5)	No riparian shading
		D.O. min.: 6(3.7), 11(3.3)	Typical of excess primary production
13.28	**Dst Archbold @ CR 24**	**D. O. min.: 7(3.7), 16(2.8), 14(3.3), 18(2.7)**	**Organic enrichment**
		D. O. avg.: 29(3.8), 15(3.6)	
1.05	**Near Evansport @ CR 22-60**	**None**	

RM	Location	Parameter (D.O. in mg/L, Temp in °C)	Comments
Little Lick Creek		*WWH Existing (HELP)*	
0.8	Ust Ney ust railroad	None	
Prairie Creek		*WWH Existing (ECBP)*	
9.8	Dst Bryan WWTP adj CR C	None	
Lick Creek		*WWH Existing (ECBP)*	
17.66	SW of Bryan @ CR 13	None	
Lick Creek		*WWH Existing (HELP)*	
10.05	**At Ney @ The Bend Rd**	**None**	
1.23	**N of Oxbow Lake @ Trinity Rd**	**None**	
Lost Creek		*WWH Confirmed (HELP)*	
1.41	At Ney @ The Bend Rd	None	
Mud Creek		*WWH Existing (HELP)*	
1.5	NW of Brunersburg @ Trinity Rd	None	

Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average criteria. The duration is the count of consecutive hours that exceeded the criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria and is presented in parenthesis after the duration. Applicable water quality criteria include: minimum dissolved oxygen (D.O.)[a], average D.O.[b], maximum temperature[c], pH[d] and specific conductance[e].

Notes:

a The General Lake Erie basin daily maximum temperature criteria apply; See OAC 3745-1-07, Table 7-14(G).

b Applicable minimum 24-hour average D.O. criteria – EWH: 6.0 mg/L, WWH: 5.0 mg/L, MWH: 4.0 mg/L.

c Applicable minimum D.O. criteria – EWH: 5.0 mg/L, WWH: 4.0 mg/L, MWH (HELP): 2.5 mg/L.

d The criterion for pH is 6.5-9.0 S.U.

e The criterion for specific conductivity is 2400 µS/cm.

Table 16. Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring, 2014. Sondes were deployed at 26 sites in 2014, with 11 of those sites sampled twice. The first deployment was 7/15-7/17/14 and the second was 8/15-8/19/14, with approximately 48 hours of data at each site during the first visit and 96 hours of data at each site during the second visit. Sites that were sampled on both deployments are indicated in **bold** in the table.

RM	Location	Parameter (D.O. in mg/L, Temp in °C)	Comments
Deer Creek		*WWH Existing (ECBP)*	
4.56	Dst Fayette @ CR 23	D.O. min.: 8(3.4), 11(2.9) D.O. avg.: 9(4.8)	Typical of excess primary production
Mill Creek		*MWH Recommended (ECBP)*	
14.49	**Ust Alvordton trib @ CR S**	**D.O. min.: 6(2.1), 4(2.6), 2(2.0), 8(2.2)**	**Typical of excess primary production**
Mill Creek		*WWH Existing (ECBP)*	
11.9	**SE of Alvordton @ CR P**	**D.O. min.: 1(2.6), 60(1.1)** **D.O. avg.: 56(1.7)**	**Organic enrichment**
7.92	**SE of Alvordton @ CR 28**	**None**	
1.85	S of Fayette @ Old Angola Rd	None	
Bates Creek		*WWH Existing (ECBP)*	
1.65	E of West Unity @ CR 25-2	D.O. min.: 3(3.9) D.O. avg.: 16(4.8)	Organic enrichment
Flat Run		*WWH Confirmed (ECBP)*	
0.4	**NE of Stryker @ CR 22.75**	**D.O. min.: 7(2.9), 1(3.9), 2(2.4), 2(3.6), 1(3.7), 5(3.3), 1(3.8), 17(1.9)** **D.O. avg.: 40(3.5)**	**Organic enrichment**
Brush Creek		*WWH Existing (HELP)*	
15.25	**At Archbold @ SR 66**	**D.O. min.: 9(2.8), 7(3.4), 4(3.19)** **D.O. avg.: 6(4.7)**	**Signatures of both excess primary production (7/15/14) and organic enrichment (8/18/14)**
13.28	**Dst Archbold @ CR 24**	**D.O. min.: 10(3.5), 13(3.1), 18(1.2)** **D.O. avg.: 53(2.7)**	**Organic enrichment**
11.66	SW of Archbold @ County Line Rd	None	
9.11	SW of Archbold @ CR 24.25	D.O. min.: 2(3.7), 3(3.8) D.O. avg.: 41(4.5)	Organic enrichment
5.76	NE of Evansport @ CR C	None	

RM	Location	Parameter (D.O. in mg/L, Temp in °C)	Comments
1.05	**Near Evansport @ CR 22-60**	**None**	
Little Lick Creek		*WWH Existing (ECBP)*	
4.97	**NW of Ney @ Behnfeldt Rd**	**D.O. min.: 6(3.6), 8(3.0)**	**Typical of excess primary production**
Little Lick Creek		*WWH Existing (HELP)*	
0.8	**Ust Ney ust railroad**	**D.O. min.: 3(2.9), 15(3.5), 2(3.9), 7(3.4), 1(3.9), 1(3.9), 2(3.9), 11(2.6), 6(3.1), 2(3.9), 1(3.7), 3(3.9), 13(2.0)** **D.O. avg.: 24(3.8), 66(3.8)**	**Organic enrichment**
Pigeon Run		*MWH Existing (ECBP)*	
0.06	Just upst Bryan WWTP	None	
Prairie Creek		*WWH Existing (ECBP)*	
11.2	Upst Bryan WWTP, upst Pigeon Run	Temperature: 2(31.1), 1(30.2), 2(30.9), 3(30.3)	Shallow stream; no riparian shading
9.8	**Dst Bryan WWTP adj CR C**	**None**	
Prairie Creek		*WWH Existing (HELP)*	
6.62	SE of Bryan @ County Line Rd	None	
3.4	NE of Ney @ Flickinger Rd (lower crossing)	None	
Lick Creek		*WWH Existing (ECBP)*	
21.77	NW of Bryan @ CR 13	None	
17.66	SW of Bryan @ CR 13	None	
Lick Creek		*WWH Existing (HELP)*	
10.05	At Ney @ The Bend Rd	None	
1.23	N of Oxbow Lake @ Trinity Rd	None	

RM	Location	Parameter (D.O. in mg/L, Temp in ^{o}C)	Comments
Dry Creek		*WWH Confirmed (HELP)*	
3.76	**SE of Farmer @ CR 124 (Openlander Rd)**	**D.O. min.: 12(3.6), 8(3.4), 10(3.0), 12(0.9), 12(1.7)**	**Signatures of both excess primary production (8/17/14) and organic enrichment (7/15/14)**
		D.O. avg.: 20(4.5), 3(4.9), 34(4.0)	
Lost Creek		*WWH Confirmed (ECBP)*	
8.97	NE of Hicksville @ Seevers Rd	None	

Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average criteria. The duration is the count of consecutive hours that exceeded the criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria and is presented in parenthesis after the duration. Applicable water quality criteria include: minimum dissolved oxygen (D.O.)[a], average D.O.[b], maximum temperature[c], pH[d] and specific conductance[e].

Notes: HELP - Huron Erie Lake Plain, ECBP – Eastern Corn Belt Plains
[a] The General Lake Erie basin daily maximum temperature criteria apply; See OAC 3745-1-07, Table 7-14(G).
[b] Applicable minimum 24-hour average D.O. criteria – EWH: 6.0 mg/L, WWH: 5.0 mg/L, MWH: 4.0 mg/L.
[c] Applicable minimum D.O. criteria – EWH: 5.0 mg/L, WWH: 4.0 mg/L, MWH (HELP): 2.5 mg/L.
[d] The criterion for pH is 6.5-9.0 S.U.
[e] The criterion for specific conductivity is 2400 µS/cm.

Table 17 . Seasonal geometric mean values (mg/l) for nutrients calculated from grab samples collected in the Tiffin River WAU. Target levels for total phosphorus (TP) are 0.08 mg/l (WWH) and 0.34 mg/l (MWH) for headwaters, 0.10 mg/l (WWH) and 0.28 mg/l (MWH) for wadeable streams, and 0.17 mg/l (WWH) for small rivers. Target levels for nitrate-nitrite ($NO_{3/2}$) are 1.0 mg/l (WWH & MWH) for headwaters, 1.0 mg/l (WWH) and 1.6 mg/l (MWH) for wadeable streams, and 1.5 mg/l (WWH) for small rivers. Highlighted results are above statewide recommended targets (Ohio EPA 1999).

Headwaters (drainage area < 20 mi²)

04100006-02-03: Old Bean Creek
6.22 * (Old Bean Creek) - TP (0.04), $NO_{3/2}$ (3.54)

04100006-02-02: Deer Creek-Bean Creek
4.56 (Deer Creek) - TP (0.26), $NO_{3/2}$ (1.11)

04100006-02-04: Mill Creek
14.49 (Mill Creek) - TP (0.16), $NO_{3/2}$ (0.89)

04100006-03-01: Bates Creek – Tiffin River
1.65 (Bates Creek) - TP (0.14), $NO_{3/2}$ (2.25)

04100006-03-03: Flat Run – Tiffin River
0.4 (Flat Run) - TP (0.12), $NO_{3/2}$ (0.82)

04100006-03-02: Leatherwood Creek
1.15 (Leatherwood Creek) - TP (0.07), $NO_{3/2}$ (0.91)

04100006-05-01: Beaver Creek
17.12 (Beaver Creek) - TP (0.05), $NO_{3/2}$ (0.36)

04100006-05-02: Brush Creek
0.07 (Owl Creek) - TP (0.13), $NO_{3/2}$ (0.75)
19.06 (Brush Creek) - TP (0.05), $NO_{3/2}$ (0.87)

04100006-05-04: Coon Creek – Tiffin River
0.62 (Coon Creek) - TP (0.05), $NO_{3/2}$ (0.32)
0.63 (Doty Run) - TP (0.11), $NO_{3/2}$ (0.55)

04100006-04-02: Upper Lick Creek
4.97 (L. Lick Creek) - TP (0.09), $NO_{3/2}$ (0.86)

04100006-04-03: Prairie Creek
9.8 (Prairie Creek) - TP (0.15), $NO_{3/2}$ (5.96)

04100006-04-01: Upper Lick Creek
21.77 (Lick Creek) - TP (0.18), $NO_{3/2}$ (2.43)

04100006-06-02: Mud Creek
3.76 (Dry Creek) - TP (0.22), $NO_{3/2}$ (0.59)

04100006-06-01: Lost Creek
8.97 (Lost Creek) - TP (0.06), $NO_{3/2}$ (0.90)

04100006-06-04: Buckskin Creek – Tiffin River
1.2 (Buckskin Creek) - TP (0.14), $NO_{3/2}$ (0.24)

04100006-06-03: Webb Run
3.0 (Webb Run) - TP (0.18), $NO_{3/2}$ (0.80)

Wadeable Stream (drainage area ≥20 mi² to < 200 mi²)

04100006-02-03: Old Bean Creek
1.85 * (Old Bean Creek) - TP (0.06), $NO_{3/2}$ (2.87)

04100006-02-04: Mill Creek
11.9 (Mill Creek) - TP (0.13), $NO_{3/2}$ (0.95)
7.92 (Mill Creek) - TP (0.12), $NO_{3/2}$ (0.74)
1.85 (Mill Creek) - TP (0.06), $NO_{3/2}$ (1.36)

04100006-05-01: Beaver Creek
12.66 (Beaver Creek) - TP (0.09), $NO_{3/2}$ (0.87)
7.52 (Beaver Creek) - TP (0.09), $NO_{3/2}$ (0.62)
2.9 (Beaver Creek) - TP (0.12), $NO_{3/2}$ (0.83)
0.61 (Beaver Creek) - TP (0.11), $NO_{3/2}$ (0.67)

04100006-05-02: Brush Creek
13.28 (Brush Creek) - TP (0.26), $NO_{3/2}$ (2.41)
9.11 (Brush Creek) - TP (0.26), $NO_{3/2}$ (1.04)
5.76 (Brush Creek) - TP (0.22), $NO_{3/2}$ (1.48)
1.05 (Brush Creek) - TP (0.18), $NO_{3/2}$ (1.66)

04100006-04-01: Upper Lick Creek
1.0 (Miller Creek) - TP (0.13), $NO_{3/2}$ (0.47)

04100006-04-02: Upper Lick Creek
0.8 (L. Lick Creek) - TP (0.13), $NO_{3/2}$ (0.90)
17.66 (Lick Creek) - TP (0.08), $NO_{3/2}$ (0.34)

04100006-04-03: Prairie Creek
3.4 (Prairie Creek) - TP (0.11), $NO_{3/2}$ (4.34)

04100006-04-04: Lower Lick Creek
10.05 (Lick Creek) - TP (0.13), $NO_{3/2}$ (0.59)
1.23 (Lick Creek) - TP (0.08), $NO_{3/2}$ (2.38)

04100006-06-01: Lost Creek
1.41 (Lost Creek) - TP (0.07), $NO_{3/2}$ (0.60)

04100006-06-02: Mud Creek
10.1 (Mud Creek) - TP (0.09), $NO_{3/2}$ (0.63)
1.5 (Mud Creek) - TP (0.08), $NO_{3/2}$ (0.36)

04100006-06-03: Webb Run
0.4 (Webb Run) - TP (0.05), $NO_{3/2}$ (0.32)

Small River (drainage area ≥ 200 mi^2 to <1000 mi^2)

04100006-02-02: Deer Creek-Bean Creek
6.0 (Bean Creek) - TP (0.03), $NO_{3/2}$ (0.98)

04100006-02-05: Stag Run – Bean Creek
2.2 (Bean Creek) - TP (0.07), $NO_{3/2}$ (1.01)

04100006-03-01: Bates Creek – Tiffin River
47.54 (Tiffin River) - TP (0.07), $NO_{3/2}$ (1.10)

04100006-03-03: Flat Run – Tiffin River
41.1 (Tiffin River) - TP (0.10), $NO_{3/2}$ (1.05)

04100006-05-03: Village of Stryker – Tiffin River
35.28 (Tiffin River) - TP (0.13), $NO_{3/2}$ (1.04)
33.95 (Tiffin River) - TP (0.12), $NO_{3/2}$ (1.23)
26.17 (Tiffin River) - TP (0.14), $NO_{3/2}$ (0.99)
19.7 (Tiffin River) - TP (0.14), $NO_{3/2}$ (1.04)

04100006-05-04: Coon Creek – Tiffin River
18.7[12] (Tiffin River) – TP (0.174), $NO_{3/2}$ (0.64)
14.0[12] (Tiffin River) – TP (0.18), $NO_{3/2}$ (0.50)
14.0 (Tiffin River) - TP (0.14), $NO_{3/2}$ (1.27)

04100006-06-04: Buckskin Creek – Tiffin River
7.09[12] (Tiffin River) – TP (0.15), $NO_{3/2}$ (0.68)
7.09 (Tiffin River) - TP (0.11), $NO_{3/2}$ (1.19)
0.9[12] (Tiffin River) – TP (0.13), $NO_{3/2}$ (0.65)

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[*] Modified Warmwater Habitat
[12] Data from 2012 sampling season

Results and Discussion

Single sample DO concentrations were found below the minimum water quality criteria at 13 locations, with a total of 19 exceedances during the 2013 sampling period.

Nutrients collected at each sampling location include ammonia, nitrate+nitrite, total Kjeldahl nitrogen (TKN), total phosphorus (TP), and orthophosphate. Thirty of the 52 locations sampled in 2012 and 2013 yielded geometric means that exceeded regional reference conditions for nitrate + nitrite and/or total phosphorus. The geometric means for nitrate + nitrite and total phosphorus measured in the Tiffin River watershed that exceeded nutrient target concentrations are detailed in Table 17.

Numerous iron exceedances were also observed throughout the study area; however, this is likely a result of high background concentration. Iron is abundant in the soils and rock in the area and routinely results in elevated iron levels existing in many ground water and surface water sources in northwest Ohio.

Tiffin River Mainstem

Ten locations on the Tiffin River mainstem were sampled and evaluated for surface water chemistry, which were collected in conjunction with biological monitoring locations throughout the summers of 2012 and 2013. Surface water quality conditions were generally good. A single temperature exceedance occurred at RM 0.9 during the summer of 2012.

TP and nitrate-nitrite concentrations were in large part below statewide target values, except for two instances of slightly elevated TP at RMs 18.7 and 14.0; both of these instances occurred during the 2012 sampling season and elevated concentrations may have been exacerbated by anomalously low flows that summer. Geometric means for TP in the Tiffin River gradually increase in a downstream progression and then begin to decline approximately 10 miles upstream from the confluence with the Maumee River (Figure 28). Nitrate + nitrite geometric means display a relatively similar to very slight increasing downstream trend (Figure 29). TKN geometric means display a very slight decreasing downstream trend (Figure 30). Ammonia levels throughout the entire watershed did not exceed the WQS criteria at the locations sampled and gradually decreased in a downstream progression with a slight increase about 10 miles upstream from the confluence with the Maumee River (Figure 31).

Nutrient concentrations observed during the 1992 Tiffin River survey were compared to nutrient concentrations in the 2013 assessment. Overall, there have been slight decreases in TP, nitrate-nitrite, and ammonia concentrations. Comparisons made between 2012-13 and 1992 nutrient concentrations using a chi-square test indicate there was not a significant difference between years. However, it can be readily observed that TP, nitrate-nitrite, and ammonia concentrations within the Tiffin River have decreased slightly since 1992 (Figure 28-Figure 31).

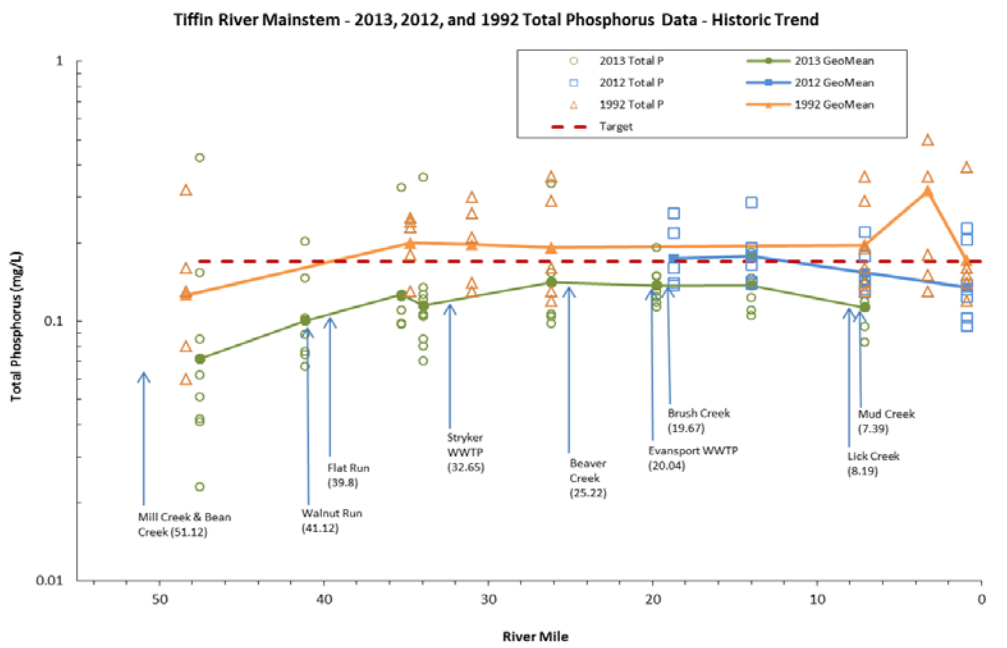

Figure 28. TP concentration results for the Tiffin River mainstem with geometric mean and specified target concentration, 2013, 2012, and 1992.

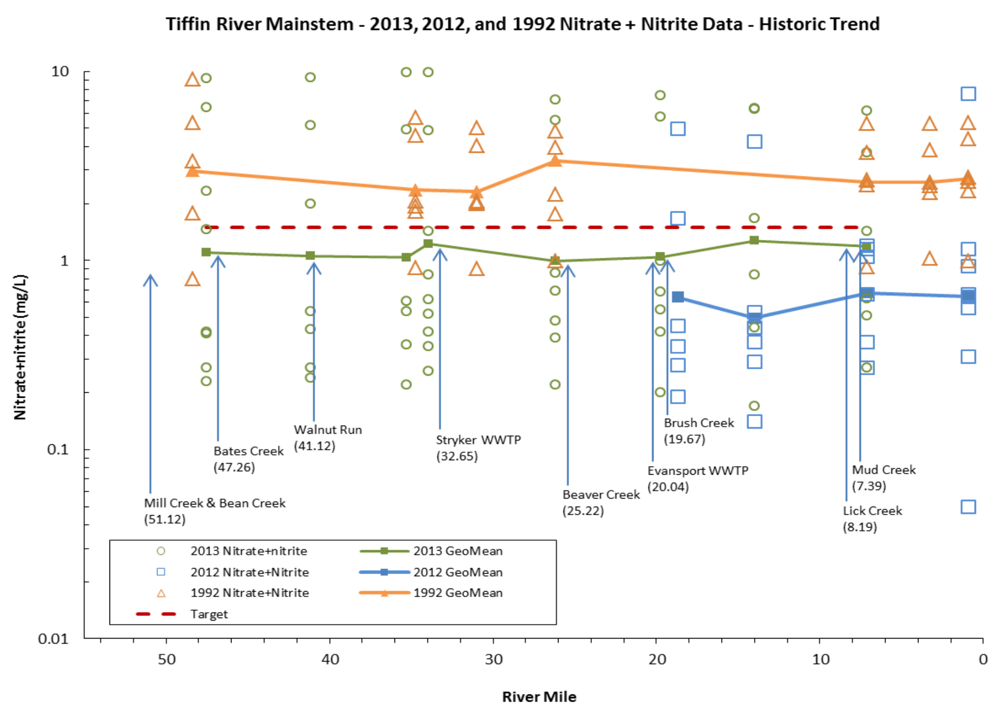

Figure 29. Nitrate-nitrite concentration results for the Tiffin River mainstem with geometric mean and specified target concentration, 2013, 2012, and 1992.

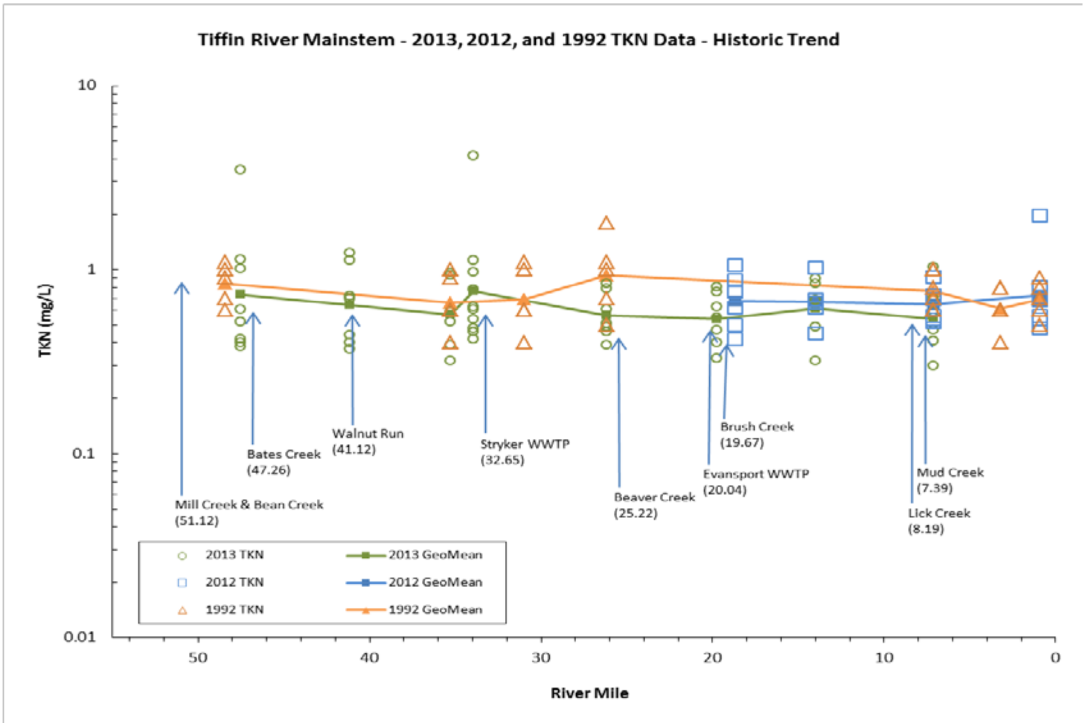

Figure 30. TKN concentration results for the Tiffin River mainstem with geometric mean, 2013, 2012, and 1992.

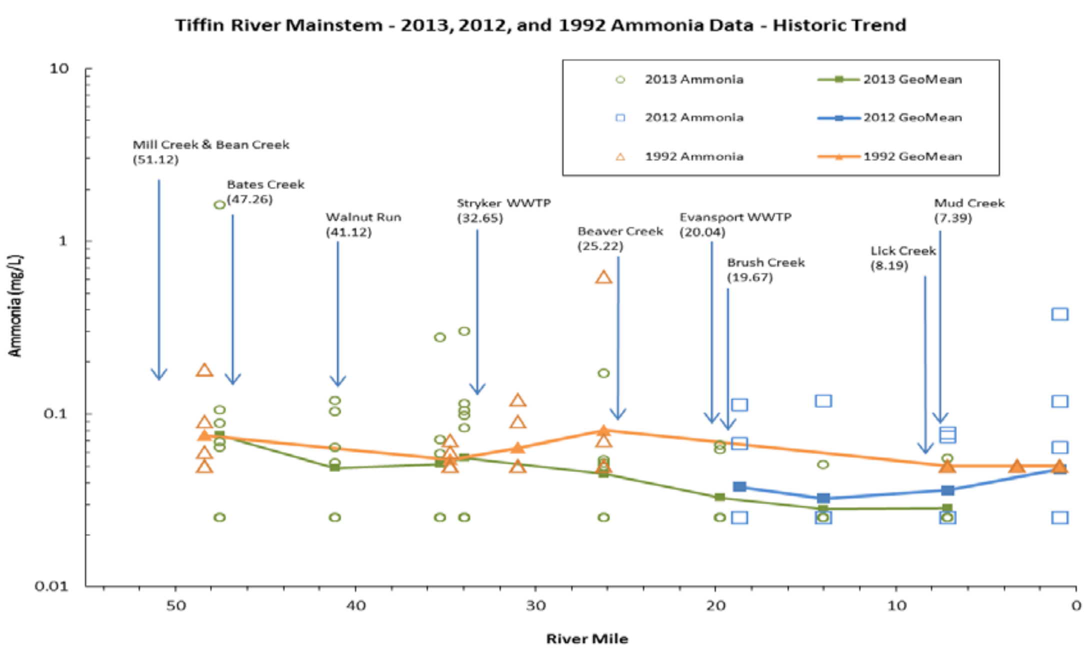

Figure 31. Ammonia concentration results for the Tiffin River mainstem with geometric mean, 2013, 2012, and 1992.

Tributaries

Overall, surface water chemistry results for tributaries were variable. The most common exceedances from WQS criteria were DO and iron concentrations. Nitrate-nitrite and TP were also commonly above target values. The significance of iron exceedances is discussed above. Several temperature exceedances were also observed throughout the study area and are not surprising given the altered riparian and instream habitat of many northwest Ohio streams. Detailed discussion for selected streams is contained below and presented by HUC 10 watershed units.

An overview of nitrate-nitrite and TP input to the Tiffin River mainstem from its tributaries is displayed in Figure 32. The tributaries with the most nutrient impact to the Tiffin River based on the geometric mean of the nutrient levels from the sampling locations nearest the confluence of the tributaries to the Tiffin River are Bean Creek, Lick Creek, and Brush Creek. Because nutrient loadings are a product of discharge and concentration, it is not surprising to see that tributaries having the largest weighted contributions are those that have the largest drainage areas.

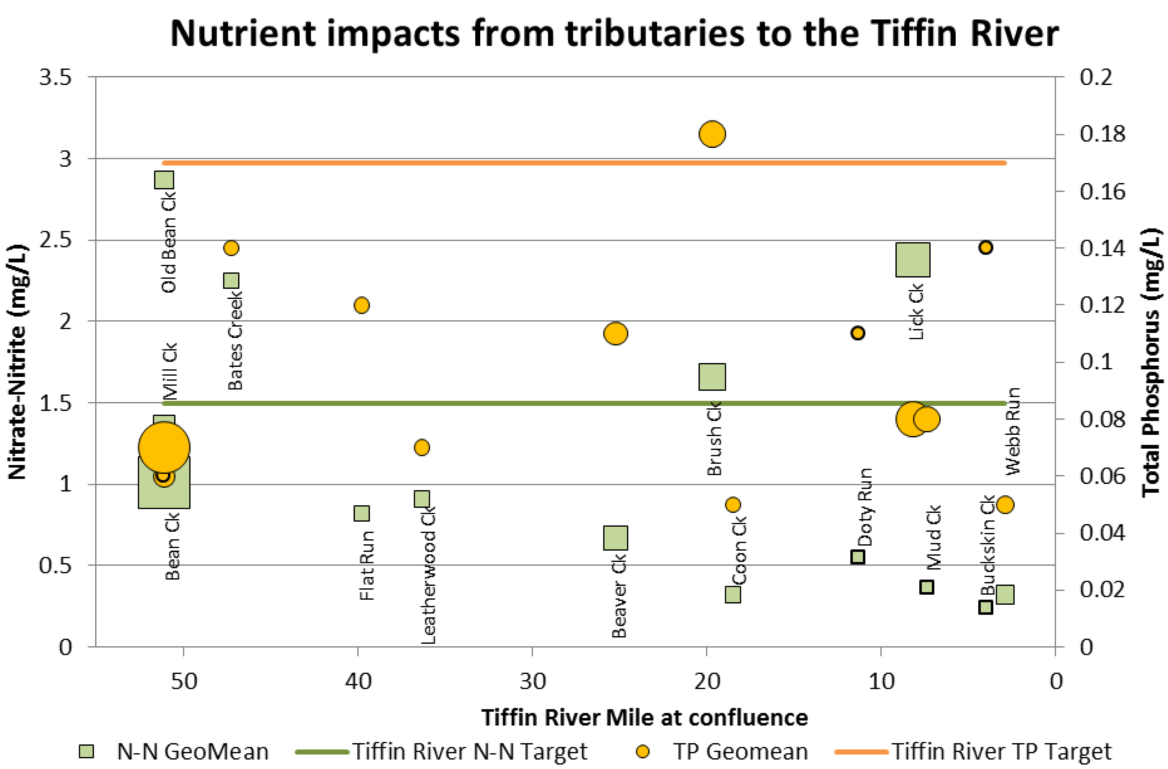

Figure 32. Nitrate-nitrite and total phosphorus loads from tributaries to the Tiffin River. The data points are calculated geometric means of the most downstream sampling location of the individual tributaries. The data points are weighted based on the total drainage area of the individual stream.

Mill & Bean Creek sub-basin - HUC 10 (04100006 02) Old Bean Creek, Bean Creek, Mill Creek, Deer Creek

The most upstream sampling location on Mill Creek (RM 14.49) lacked both a riparian buffer and observable flow later in the summer. Results for TP concentrations at this location revealed a geometric mean higher than the statewide target of 0.08 mg/L for WWH, though less than the 0.34 mg/L target for MWH streams for which this segment is recommended. High TP concentrations have the potential to cause excess algal production that may exacerbate both the low DO values and large DO swings observed at this location. Several large diel DO swings were also recorded at Mill Creek RM 7.92 which suggests nutrient enrichment impacts. Conversely, sonde data from Mill Creek RM 11.90 revealed multiple diel DO sags below the 24-hour average WQS criterion of 5 mg/L from August 15th-19th 2014, with 24-hour averages as low as 1.85 mg/L. This type of diel DO sag is more often associated with organic, rather than nutrient, enrichment. A small tributary draining the unsewered village of Alvordton joins Mill Creek just upstream from RM 11.90 and is a suspected source contributing to the organic enrichment observed at this location.

Both TP and nitrate-nitrite concentrations in Deer Creek were well above statewide target concentrations. Nutrient enrichment is a likely factor limiting biological performance at this location.

No major water quality exceedances were observed in Bean Creek and Old Bean Creek, though nitrate-nitrite concentrations were observed to be above the target value in Old Bean Creek.

Upper Tiffin River sub-basin - HUC 10 (04100006 03) Bates Creek, Flat Run, Leatherwood Creek

A single DO exceedance occurred in Bates Creek. Additionally, two diel DO sags that were just below the 24-hour average WQS criterion were recorded in Bates Creek over July 15th-17th 2014. Similar DO sags, though slightly greater in magnitude, were recorded in Flat Run over August 15th-19th 2014. TP was elevated in both Flat Run and Bates Creek, while nitrate-nitrite was elevated only in the latter. Sediment oxygen demand was relatively high in all three streams assessed within this HUC 10 and is likely contributing to the observed diel DO sags. A sediment oxygen demand can occur when biological activity in a stream consumes oxygen through chemical oxidation of reduced elements such as Fe^{2+} contained in soils and silts that enter a stream during erosion and run-off events. Excess siltation in a stream or large amounts of organic material contained within soils can exacerbate this process.

Middle Tiffin River sub-basin – HUC 10 (04100006 05) Beaver Creek, Brush Creek, Owl Creek, Coon Creek, Doty Run

Brush Creek is 28 miles long and drains an area of 65.7 mi^2. The upper 13 miles (33 mi^2 drainage) largely lack riparian buffer areas, are surrounded by row crop agriculture, and are influenced by a small unsewered area at the headwaters (Tedrow) and the village of Pettisville WWTP discharge (RM 18.9 from an unnamed tributary). The village of Archbold WWTP discharges to Brush Creek at RM 13.94.

The sampling location at County Road D (RM 19.06) is downstream from the unsewered community of Tedrow and predominantly row crop agriculture, but upstream of the Pettisville and Archbold WWTP discharges. Ammonia, nitrate-nitrite, and TP concentrations at RM 13.28 were all quite high compared to the other sampling locations on Brush Creek. The Pettisville WWTP discharge is a controlled discharge lagoon and the only time effluent was discharged from the lagoon was in March 2013 and, therefore, would not be a contributor to the elevated levels observed during sampling. Nutrient concentrations found upstream from Archbold at RM 19.06 were the lowest for the monitoring period for nitrate-nitrite and TP, and the second lowest observed for ammonia. A single DO exceedance was observed at RM 13.28, while sonde data at RM 13.28 revealed diel DO sags from August 15th-19th 2014, with concentrations as low as 1.23 mg/L and 24-hr averages as low as 3.25 mg/L, both of which exceed the minimum and 24-hr average WQS criteria. The data from RM 13.28 is suggestive of organic enrichment. In contrast, Brush Creek at RM 19.06 displayed diel DO swings as large as 10.61 mg/L from August 20-22nd, 2013 which are more indicative of excess primary productivity. Though no biological impairment occurred at RM 19.06, sonde data provide excellent examples of the contrasting influences of organic and nutrient enrichment on a stream's diel DO regime and provide further evidence suggesting organic enrichment is the main factor limiting biological performance at RM 13.28. The Archbold WWTP is the largest point source contributor of nutrients to Brush Creek and is likely the source of organic enrichment observed at RM 13.28 (Figure 33). Low overall habitat scores in Brush Creek are likely exacerbating many of these observed water chemistry issues, though not enough to cause biological impairment at other sampling locations on Brush Creek with similar habitat attributes.

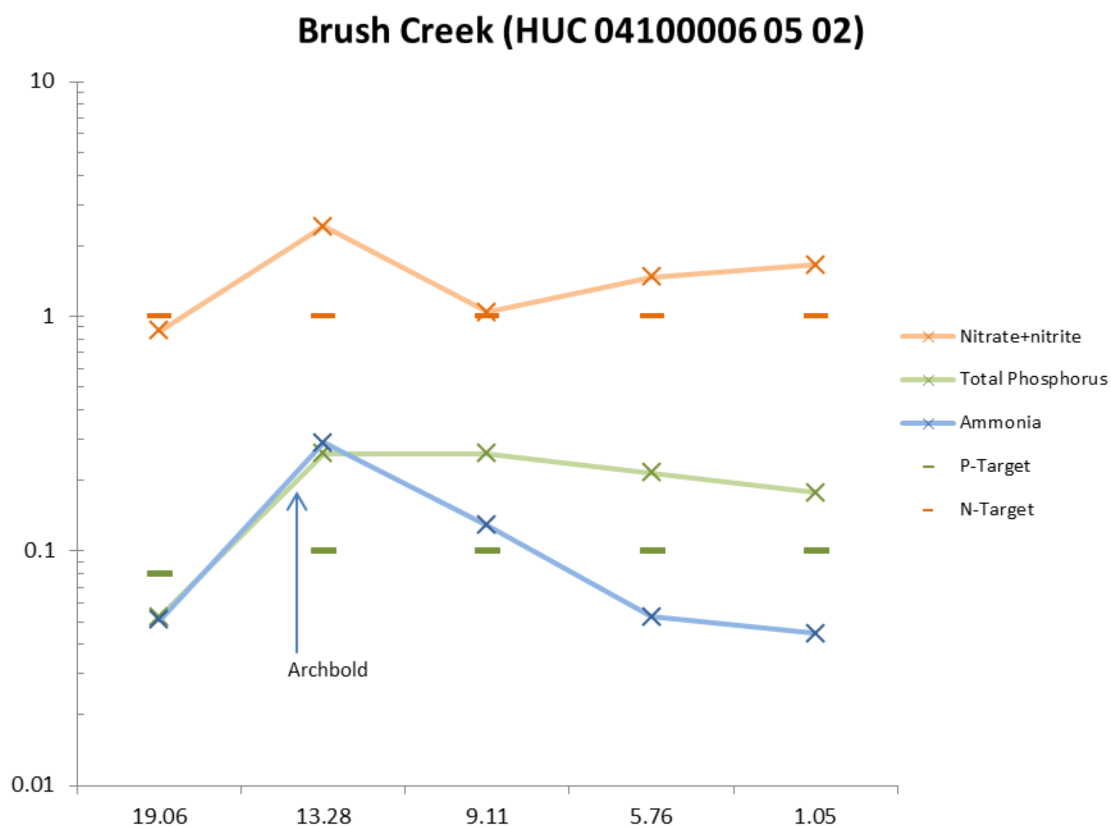

Figure 33. Ammonia, nitrate-nitrite, and total phosphorus geometric means for Brush Creek, 2013.

One slight temperature exceedance occurred in Brush Creek. One DO grab sample had concentrations below the 24-hour average criterion, but not the minimum criterion value. TP concentrations were above target values at the two lowermost sampling locations.

Several DO exceedances were recorded in Owl Creek and Doty Run. TP was above target concentrations in Owl Creek and Doty Run. Flow conditions at sampling conditions for each of these streams were observed to be extremely low during late summer and are likely exacerbating issues observed in these streams. Additionally, unrestricted livestock access in Owl Creek is likely contributing to excessive siltation and organic enrichment at this location.

Lick Creek sub-basin – HUC 10 (04100006 04) Lick Creek, Miller Creek, Little Lick Creek, Prairie Creek

Lick Creek is 28 miles long and drains an area of 106 mi^2. The length of the stream has an average to good riparian corridor, has a predominantly row crop agriculture land use, has wastewater discharges from Norlick Place (RM 21.76) and the village of Ney (RM 10.5), and has a confluence with Miller Creek, Little Lick Creek, Prairie Creek, and other smaller tributaries. The Miller Creek confluence with Lick Creek is at RM 20.54 and has a wastewater discharge from the Williams County South Central Sewer District entering the stream at RM 1.8. The Little Lick Creek confluence with Lick Creek is at RM 10.24 and has small wastewater discharges from TruFast Corporation (RM 2.2) and the village of Ney Water Treatment Plant (RM 2.99). The Prairie Creek confluence with Lick Creek is at RM 4.1 and has a direct discharge from the city of Bryan at RM 11.0 and Springfield Dairy is located in the watershed downstream from the Bryan WWTP.

The most upstream portions of Lick Creek are predominantly surrounded by agricultural land and showed elevated TP and nitrate-nitrite concentrations above statewide targets at the most upstream sampling location (RM 21.77). The Norlick Place WWTP potentially could have contributed to the elevated concentrations observed at this location, though given the small scale of the facility, nonpoint source agricultural runoff is likely the greatest contributor. TP and nitrate-nitrite concentrations from Little Lick Creek appear to influence increasing concentrations of these nutrients in Lick Creek. Prairie Creek has the largest influence on the nitrate-nitrite concentrations in Lick Creek. Nitrate-nitrite concentrations at the sampling location downstream from the Bryan WWTP (RM 9.8) are the highest geometric mean levels observed in the entire watershed during the assessment and only slightly decrease at the downstream site on Prairie Creek at RM 3.4.

Overall, the nonpoint source agricultural impacts in the headwaters of Lick Creek RM 21.77 are already evident in the stream prior to the addition of nutrients from other downstream influences. Miller Creek does not appear to contribute to the nutrient issues at an observable scale. However, Little Lick Creek has an increasing influence on TP and nitrate-nitrite concentrations in Lick Creek. The two smaller discharges to Little Lick Creek could potentially contribute to nutrients in the stream; however, nonpoint source run-off during rain events from agriculture would be a more likely source of nutrients due to it being the overwhelmingly predominant land use. The largest nitrate-nitrite input appears to be from the city of Bryan WWTP (observed in annual MOR data) and contributes to increases of nitrate-nitrite to Prairie Creek and receiving streams (Figure 34). Sonde data revealed diel DO swings as large as 11.02 mg/L from July 15th-17th 2014 immediately downstream from the Bryan WWTP at RM 9.8. Benthic chlorophyll-a concentrations of 334 mg/m^2, considered over-enriched, lend further evidence of the nutrient enrichment issues observed downstream from this WWTP. Field observations from the summer of 2014 noted flocculent bottom deposits immediately downstream from the WWTP outfall that are smothering natural substrates and may be contributing to biological impairment observed at RM 9.8. Poor habitat conditions at RM 9.8 are likely exacerbating nutrient issues observed here.

Three surface water grab samples collected from Little Lick Creek RM 0.8 exceeded the minimum DO WQS criterion of 4.0 mg/L, with individual grab samples as low as 2.7 mg/L. Additionally, sonde data from this location revealed several diel DO sags, with individual concentrations as low as 2.0 mg/L and 24-hour averages as low as 3.78 mg/L between August 15th-19th, 2014, both exceeding their respective criterion. Geometric mean results for TP also demonstrated levels higher than the statewide target at RM 0.8. Low DO concentrations from multiple grab samples coupled with diel DO sags and elevated TP suggest organic enrichment, with excess manure application a likely source. One surface water grab sample from Little Lick Creek RM 4.97 exceeded the minimum DO criterion; furthermore, sonde data from this location revealed several DO exceedances as well as modest DO swings. Benthic chlorophyll was also observed to be elevated at RM 4.97. Data suggests nutrient enrichment impacts at Little Lick Creek RM 4.97 are likely resulting in biological impairment.

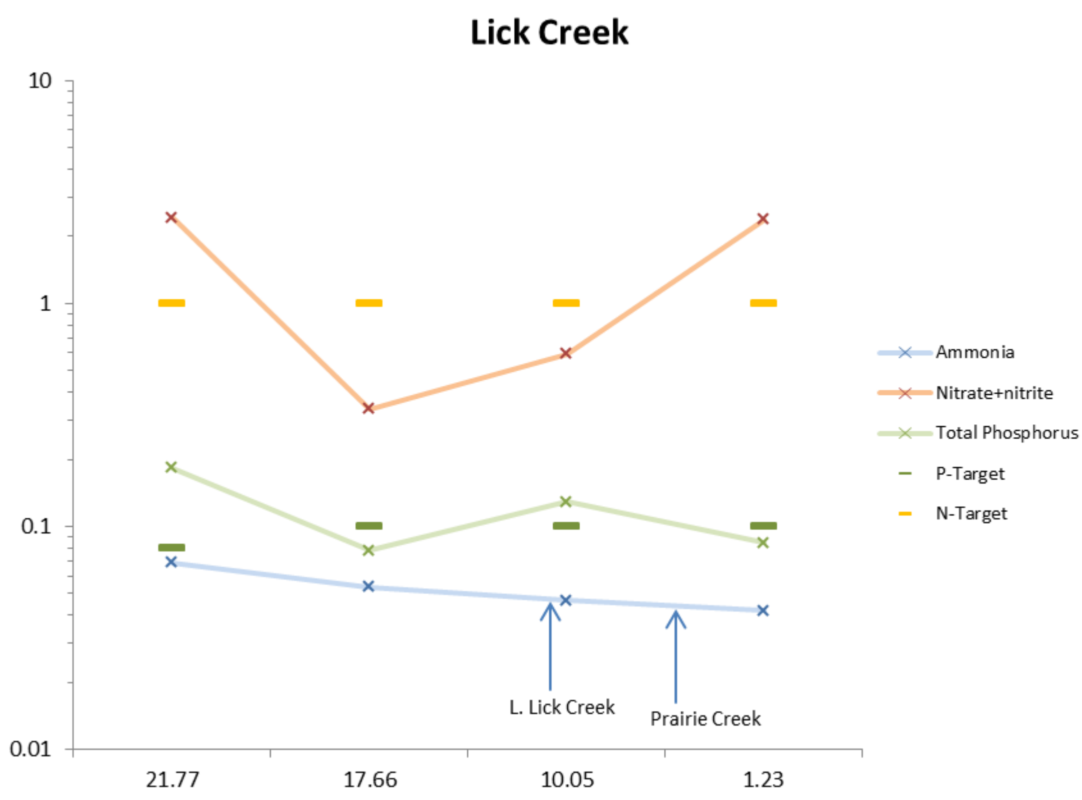

Figure 34. Ammonia, nitrate-nitrite, and total phosphorus geometric means from the 2013 summer sampling season.

Lower Tiffin River sub-basin – HUC 10 (04100006 06) Lost Creek, Mud Creek, Dry Creek, Buckskin Creek, Webb Run

The Buckskin Creek RM 1.2 and Webb Run RM 2.99 sites were observed to be nearly dry with minimal interstitial flow between small pools during late summer. Low flows and hot summer temperatures likely resulted in the low DO concentrations routinely observed.

A single copper exceedance occurred in Mud Creek and may be from runoff associated with high flows observed in the stream during sample collection.

Multiple DO exceedances were observed in Dry Creek RM 3.76 and TP concentrations were also well above target levels. Sonde data revealed DO sags indicative of organic enrichment at this sampling location with exceedances of both the 24-hr. average and minimum WQS criteria. Despite no large diel DO swings recorded, single grab sample DO concentrations were found to be as high as 11.47 mg/L, with supersaturation also occurring; this sample was collected in the afternoon which coincides with periods of greatest photosynthesis associated with excessive algal production. It is reasonable to infer that nutrient enrichment is also occurring here because of both the high DO concentrations observed during the afternoon and low DO concentration observed in the mornings, after periods of greatest algal respiration. Manure applications and row crop agriculture are likely contributors to the organic and nutrient enrichment issues. The small unsewered village of Farmer may contribute to the observed organic enrichment issues. However, given the small size of this village compared to the predominantly agricultural land use surrounding this small stream, nonpoint source agricultural runoff is likely the greatest contributor to the observed nutrient and organic enrichment issues. Deficient habitat and low flows present in Dry Creek likely exacerbated the effects of the nutrient and organic enrichment.

No water quality exceedances were recorded in Lost Creek. Sonde data displayed no large diel DO swings or sags. Despite this, benthic chlorophyll-a concentrations collected in 2014 at RM 8.97 were high enough to be considered enriched. The sampling location at RM 8.97 has excellent overall habitat quality and good riparian cover. It is unknown whether or not nutrient enrichment is contributing to biological impairment observed at this location.

Water Quality Sonde Summary and Discussion

The Tiffin River mainstem is a generally deep, entrenched stream with significant canopy cover and little potential for temperature variations. When the lower mainstem was sampled in 2012, the area was experiencing a drought with temperatures well above historical averages. The temperature exceedance at the most downstream Tiffin River site (with a maximum of 30°C) occurred in a stream reach greatly impacted by the Maumee River. In this reach, the channel widens significantly, lessening the shade of the existing riparian corridor, making it anomalous.

The tributaries within the basin vary in canopy and depth, thus demonstrating a variety of temperature patterns. Sonde data from the first 2013 survey showed no temperature exceedances on the mainstem or tributaries, mainly due to the higher than average flow and lower than average air temperatures in the week prior to deployment. The second 2013 survey captured data more demonstrative of the critical condition, with average maximum temperature around 25°C (as opposed to 21°C in late July). During this survey, a temperature exceedance was measured on Brush Creek at RM 19.06, where the temperature was above the criterion for four hours, reaching a maximum of 30.5°C. Brush Creek, upstream from Archbold, has a shallow channel with fairly low flow, draining less than 20 mi^2.

Additionally, it has a narrow grass buffer devoid of shrubs and trees capable of providing shade, allowing for maximum sunlight penetration to elevate water temperatures.

In 2014, temperature criteria were exceeded at only one site: Prairie Creek upstream from the Bryan WWTP (RM 11.2). Much like the upper Brush Creek site, this reach of stream is shallow without a wooded riparian to alleviate temperature stress from direct sunlight.

The tributaries of the Tiffin River are exposed to natural stressors that make them prone to dissolved oxygen stress. The primary natural stressor is low stream gradient. Low gradient streams have a limited reaeration potential and export organic material slowly. Therefore, they are naturally prone to organic enrichment and external sources of organic material are poorly assimilated. Some external sources of organic material include point sources, such as municipal wastewater treatment plants, and nonpoint sources, such as wash-off of crop residue or other organic matter and excess sediments.

Because of its size and typical flow rate, the mainstem of the Tiffin River is less prone to naturally low DO than most of its tributaries. In 2013, when five sites along the Tiffin River were monitored, no DO exceedances were measured. The summer of 2012 presented an unusual scenario, with drought conditions and flow significantly below normal. Because of this, the Tiffin River began to take on characteristics typical of its tributaries, lacking sufficient flow for reaeration and flushing of material. All three free-flowing sites monitored during that summer (RMs 7.0, 14.1, and 18.7) had exceedances of both the DO minimum and average WQS criteria due to these conditions.

Most of the tributaries were measured well within acceptable DO ranges during both of the 2013 surveys. Brush Creek, with DO sags as low as 2.7 mg/l (RM 19.06) and 24-hour averages as low as 3.6 mg/l (RM 13.28), was the only tributary with DO exceedances in late July and mid-August. Brush Creek at RM 19.06 showed large DO swings that can be explained by excess primary production during the late summer. At Brush Creek RM 13.28, existing dissolved oxygen sags were exacerbated by organic-rich discharge from the Archbold WWTP.

In 2014, sampling efforts were concentrated in areas where biological impairment was documented; as such, many more exceedances were measured. Early morning minimum DO exceedances are typical in cases of high primary production. These signatures were seen in Deer Creek RM 4.56, Mill Creek RM 14.49, Brush Creek RM 15.25, Little Lick Creek RM 4.97, and Dry Creek RM 3.76. Much more prevalent in this watershed were signatures of organic enrichment, where consistently low DO readings led to exceedances of both minimum and average WQS criteria, typically for extended periods of time. Sites showing these patterns included Mill Creek RM 11.9, Bates Creek RM 1.65, Flat Run RM 0.4, Brush Creek RMs 15.25, 13.28, and 9.11, Little Lick Creek RM 0.8, and Dry Creek RM 3.76. Many of these streams have relatively low gradients that can inhibit the flushing of organic material and exacerbate organic enrichment issues. Sources of excess organic material can be both point and nonpoint in origin. Primary sources likely include biomass from crop residue, manure runoff from fertilizer application, and anthropogenic waste from municipal and on-site wastewater treatment.

No exceedances were observed within the Tiffin River or any tributaries for pH. Also, no trends appeared in the data leading to insight of important dynamics taking place in the stream.

While no WQS criterion exceedances for specific conductance were captured during the survey, conductance did increase noticeably in Brush Creek, Lick Creek, and Prairie Creek downstream from known wastewater treatment facilities (Archbold, Ney, and Bryan, respectively). Wastewater treatment plants are often significant sources of dissolved solids to streams and, as a strong indicator of dissolved solids, specific conductance is commonly used as a surrogate. Monitoring in 2014 also measured elevated specific conductance on Flat Run and Brush Creek upstream from the Archbold WWTP, although there are no known sources for high dissolved solids. It is possible that this elevated specific conductance in both streams is associated with diffuse home sewage treatment systems (HSTS) not captured by the Archbold WWTP, as both watersheds drain the periphery of town.

Trophic Evaluation

Two trophic states exist for streams, the autotrophic state and the heterotrophic state (Dodds 2007). Generally, the autotrophic state represents primary production and the heterotrophic state represents respiration. The trophic status is generally split into three categories; oligotrophic, mesotrophic, and eutrophic (Dodds *et al.* 1998). Oligotrophic systems are described as having low nutrients, low algal biomass and high clarity. Conversely, eutrophic systems are rich in nutrients, have high algal biomass, and have large DO swings. Mesotrophic systems have intermediate characteristics between oligotrophic and eutrophic systems. The transition from oligotrophic to eutrophic generally reflects a system that has shifted from heterotrophic dominance to autotrophic dominance and the process is commonly referred to as eutrophication. For the purposes of this evaluation, eutrophication will be defined as the process by which a stream becomes enriched with nutrients resulting in high chlorophyll-*a* concentrations and wide diel DO swings (USGS 2014). Therefore, the focus for identifying eutrophication requires effective monitoring of the autotrophic state, which is dictated by primary production (Odum 1956). The objective of a trophic status evaluation is to identify streams that are exhibiting eutrophication.

Ohio and other states have been developing nutrient reduction strategies in recent years to address cultural eutrophication (USEPA 2015, Ohio EPA 2014, Miltner 2010, Heiskary and Markus 2003). Wide diel DO ranges are associated with eutrophication, which is caused by excessive photosynthesis (O_2 production) during daylight hours and ongoing respiration, including decomposition (O_2 consumption), at night. The most recent investigations by Ohio EPA have identified a diel DO range of 6.5 mg/L as a threshold indicative of eutrophication in Ohio streams (Ohio EPA 2014).

Benthic algae (attached to bottom substrates) are monitored as the primary algal community in wadeable streams and small rivers, while sestonic algae (suspended in the water column) are monitored as the primary algal community in large rivers. However, stream factors such as width-depth ratio and longitudinal gradient may have a stronger influence on whether sestonic or benthic algae dominate the algal community than the stream size. Therefore, sestonic algae typically dominate streams defined as large rivers, and benthic algae typically dominate small streams. With that in mind, chlorophyll-*a* is used as an indicator of the level of benthic production primarily in smaller stream systems, and as an indicator of the concentration of sestonic organisms primarily in large rivers. The most recent work by Ohio EPA in assessing benthic chlorophyll-*a* concentrations identified break points for low, moderate, and high categories (Ohio EPA 2014). The low-moderate category breakpoint is identified as 182 mg/m^2 and the moderate-high category is identified as 320 mg/m^2. A review of studies on sestonic chlorophyll-*a* by Dodds (2006), which included some Midwestern streams, and work in Ohio (Miltner 2010) suggest that concentrations of 40-100 µg/l sestonic chlorophyll-*a* identify eutrophic conditions while concentrations >100 µg/l indicate hyper-eutrophic conditions.

Years ago, in pursuit of developing a nutrient strategy, Ohio EPA published a report (Ohio EPA 1999) that analyzed associations between nutrient concentrations and performance of aquatic organisms. The report proposed statewide water quality criteria (Table 18 & Table 19). The data that is collected throughout the biological assessment season and is summarized using the geometric mean for comparison against these target concentrations.

Table 18. Phosphorus concentrations proposed for the protection of aquatic life (Ohio EPA 1999). All units are in mg/L.

	WWH	EWH	MWH
Headwaters (<20 mi^2)	0.08	0.05	0.34
Wadeable (20 - 200 mi^2)	0.1	0.05	0.28
Small River (200 - 1000 mi^2)	0.17	0.1	0.25
Large River (>1000 mi^2)	0.3	0.15	0.32

Table 19. Nitrate + nitrite concentrations proposed for the protection of aquatic life (Ohio EPA 1999). All units are in mg/L.

	WWH	EWH	MWH
Headwaters (<20 mi^2)	1	0.5	1
Wadeable (20 - 200 mi^2)	1	0.5	1.6
Small River (200 - 1000 mi^2)	1.5	1	2.2
Large River (>1000 mi^2)	2	1.5	2.4

The proposed criteria were never adopted into rule; however, they can serve as benchmarks to identify elevated nutrient levels in streams. The presence of elevated nutrients increases the risk of eutrophication in streams but cannot alone serve to identify eutrophication. More recent work relative to developing nutrient criteria is considering risk levels relative to ratios between the macro-nutrients of nitrogen and phosphorus (D. Dudley, personal correspondence, Aug. 13, 2014).

Seasonality is an important consideration when examining eutrophication. Two factors influencing eutrophication are related to seasonality: light availability and temperature. When streams are turbid due to storm events, light penetration is not adequate to allow enough production of algae to cause eutrophic conditions. Dodds (2006) documents streams experiencing eutrophication in late spring/early summer before leaf canopy shades a stream. Then those same streams have drops in algal production, ameliorating the deleterious effect of excess nutrients once the canopy shades the stream channel. Streams that are of sufficient width or lack a wooded riparian due to anthropogenic management practices (i.e., channelization) do not have adequate canopy coverage to subdue photosynthetic primary production. Photosynthesis is a chemical reaction that is impacted by temperature; however, the kinetics are complicated because they involve biological organisms that have optimal temperature ranges as well. Dauta et al. (1990) examined four freshwater algae species and found maximal growth at 25 – 30 ^{o}C and a reduction in growth to the point of being insignificant around 10 ^{o}C. These factors complicate the definition of a critical time period for monitoring algae as indicators of eutrophication. However, DO is most impacted during summer low flows due to warmer temperatures and limited reaeration. While this may not always correspond to maximum algal biomass, Ohio EPA typically samples chlorophyll-*a* and diel DO at the same time. The advantage of coupling the two sampling efforts is that the algae sampled represent the productivity reflected in the diel DO regime. In addition, while DO and chlorophyll-*a* sampling targets low-flow critical conditions, ideal conditions are not always achieved. If conditions during a survey are less than ideal, an additional sampling event is often planned to capture low flow conditions.

For the purpose of trophic status evaluation, Ohio EPA designates ‘nutrient sites’ where benthic/sestonic chlorophyll-*a* concentrations and diel DO ranges are monitored. These sites coincide with grab sampling for chemistry that is then used to characterize the seasonal nutrient availability.

In the Tiffin River watershed, nutrient sampling was attempted at every sonde site. Out of the 36 sites visited with sondes over three years, benthic chlorophyll-*a* samples were collected at 21 sites. Benthic sampling was limited throughout the basin by fine stream substrates, as collection methods require substrates of gravel size or larger. At sites without appropriate substrates, sestonic chlorophyll-*a* was still collected. To assess the trophic state in the study area, two surveys were completed in each year for a total of six surveys. During these surveys, water quality sondes monitored DO on an hourly basis and both benthic and sestonic chlorophyll-*a* were sampled. The surveys occurred July 17-19 and August 7-9 in 2012, July 30-August 1 and August 20-22 in 2013, and July 15-17 and August 15-19 in 2014 (Figures 25-Figure 27).

Sampling events are expected to represent the potential of primary production. Therefore, the largest DO range found in these sampling events is used in the summary figures. The hourly samples from a 24-hour diel cycle are summarized in box plots that identify the minimum, maximum, average, median, 75th percentile and 25th percentile of values measured. If benthic or sestonic algae were sampled in multiple surveys the value corresponding to the highest DO range is shown. The complete chlorophyll-*a* and sonde dataset are reported in Appendices F and H. Instream nutrient concentrations are also considered as a contributing factor for assessing the trophic state. To assess nutrient concentrations, the geometric mean of the samples collected from May 1 – October 31, corresponding to the biological assessment season, is calculated. Total phosphorus and nitrate + nitrite are considered for comparison to the targets in Table 18 and Table 19. The critical data for assessing the trophic state are presented in Figures 35 - 39. Figure 35 and Figure 36 are presented as longitudinally-spaced plots, showing data appropriately spaced by river mile to represent the spatial extent of sampling. The Tiffin River and Brush Creek mainstems are presented in this manner. The third plot (Figure 37) shows all sites within the Lick Creek watershed, but is not spaced longitudinally. Figure 38 and Figure 39 show other tributaries that had fewer sites sampled, and these are not presented longitudinally.

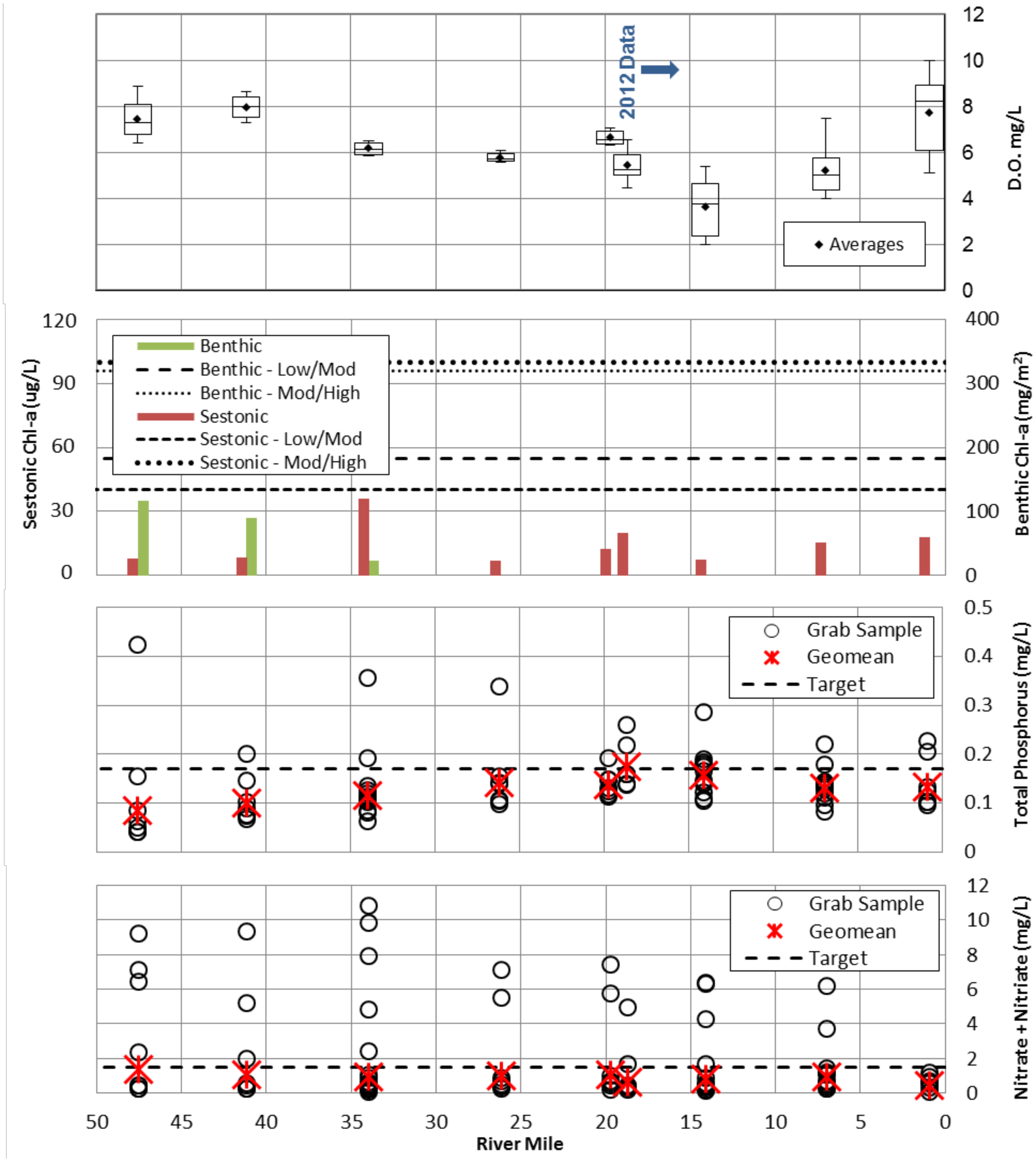

Figure 35. Longitudinal representation of DO, benthic/sestonic chlorophyll-*a*, total phosphorus, and nitrate + nitrite for a trophic assessment of the Tiffin River. Relevant targets for chlorophyll-*a* and nutrient concentrations are presented on the respective plots. Sampling at RMs 18.7, 14.1, 7.0, and 0.9 was completed in 2012, which was hotter and drier than other sampling years. The high sestonic result at RM 33.95 was the only sestonic sample taken on the Tiffin River in 2014, a hotter and drier year than 2013.

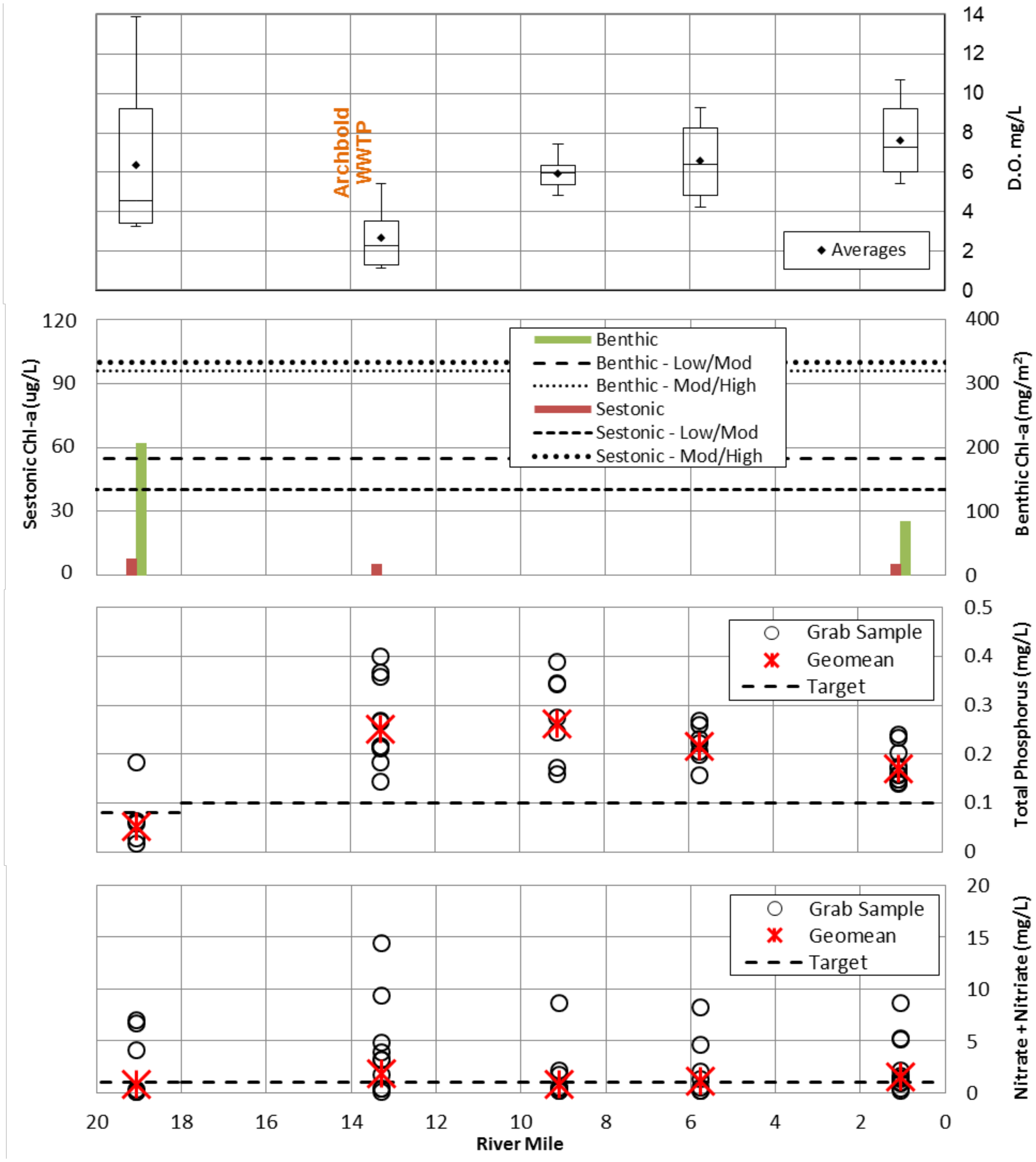

Figure 36. Longitudinal representation of DO, benthic/sestonic chlorophyll-*a*, total phosphorus, and nitrate + nitrite for a trophic assessment of Brush Creek. Relevant targets for chlorophyll-*a* and nutrient concentrations are presented on the respective plots.

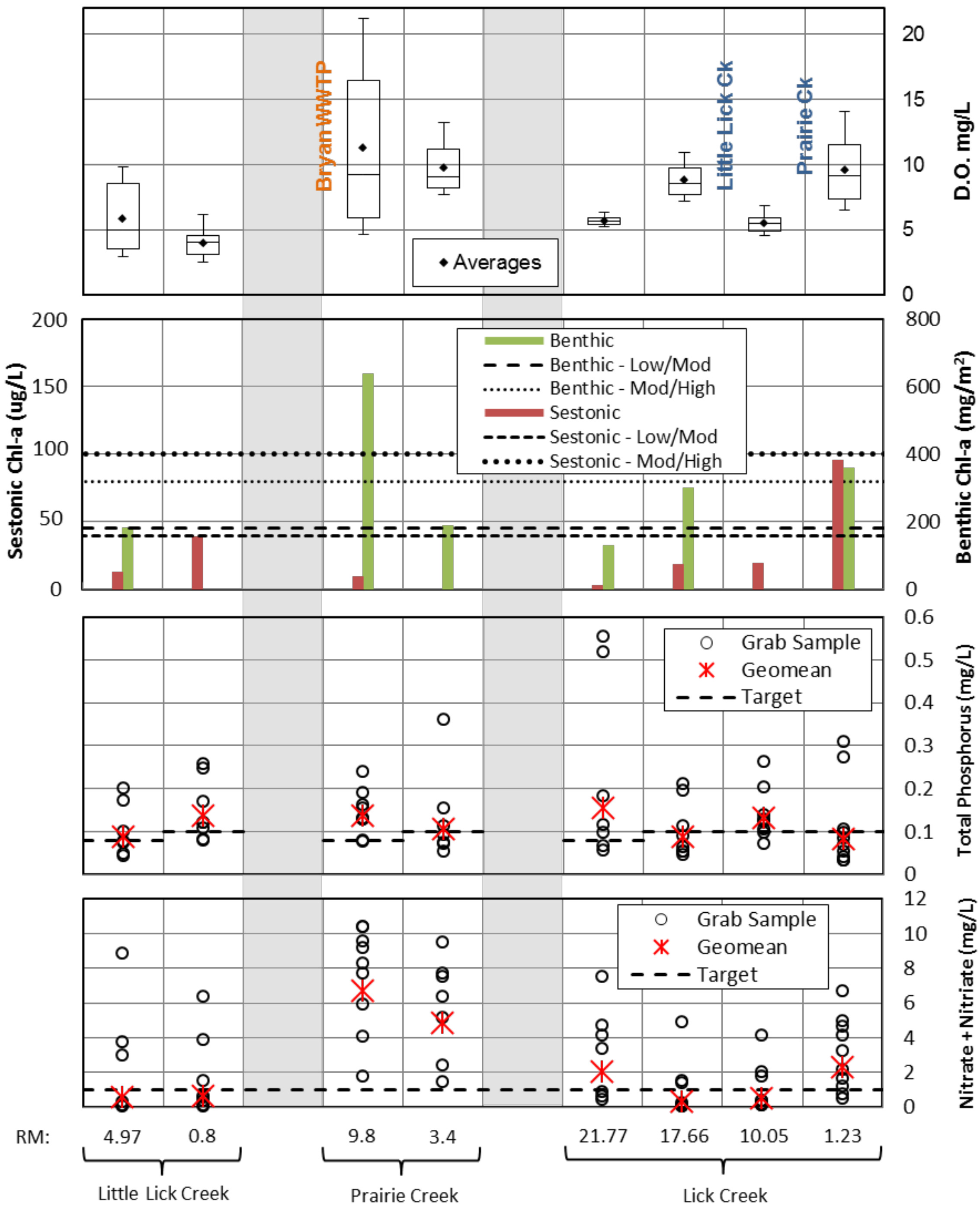

Figure 37. Data used for a trophic assessment of streams in the Lick Creek watershed. The assessment includes DO, benthic/sestonic chlorophyll-*a*, total phosphorus, and nitrate + nitrite. Relevant targets for chlorophyll-*a* and nutrient concentrations are presented on the respective plots.

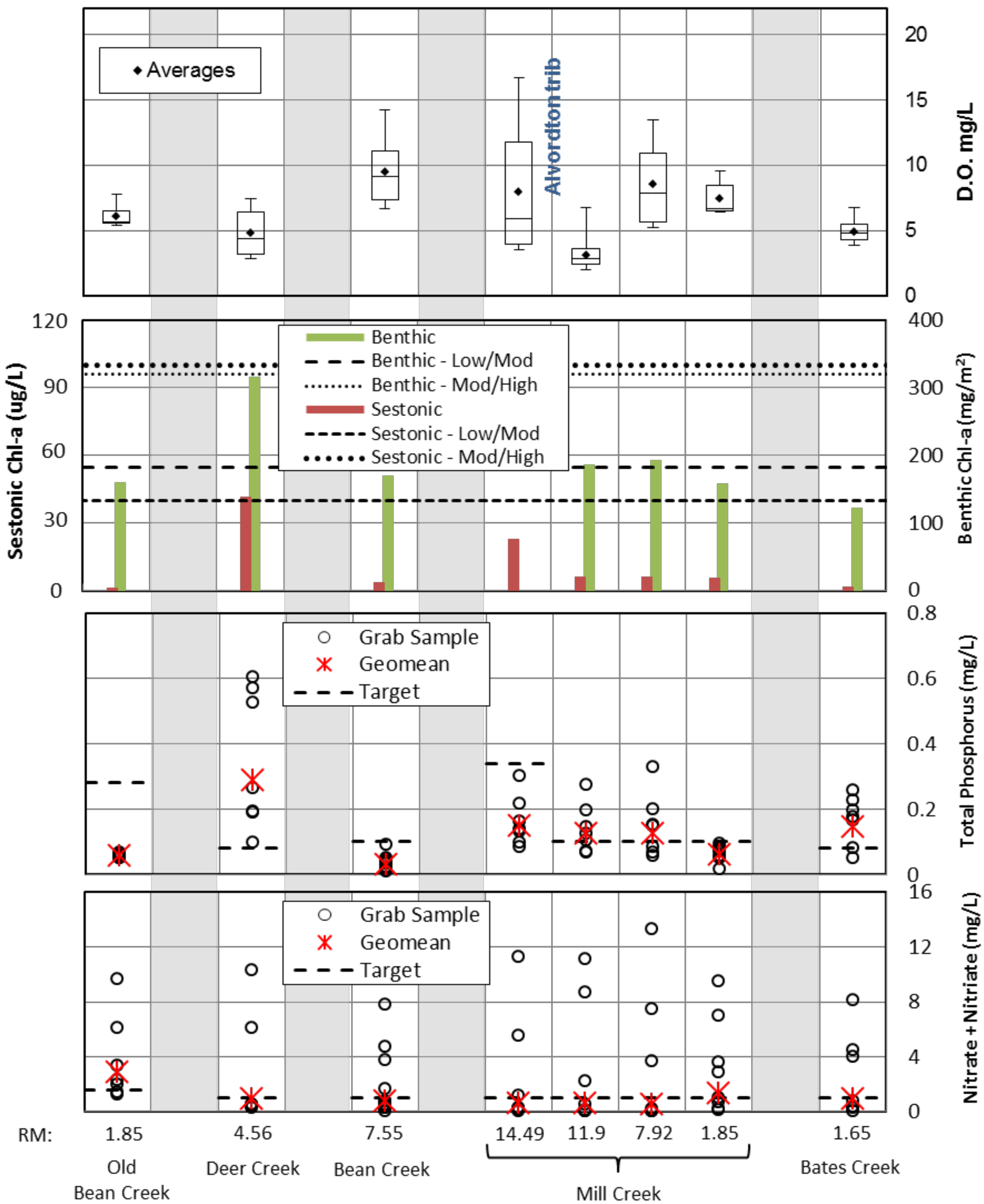

Figure 38. Data used for a trophic assessment of upper tributaries to the Tiffin River. The assessment includes DO, benthic/sestonic chlorophyll-*a*, total phosphorus, and nitrate + nitrite. Relevant targets for chlorophyll-*a* and nutrient concentrations are presented on the respective plots.

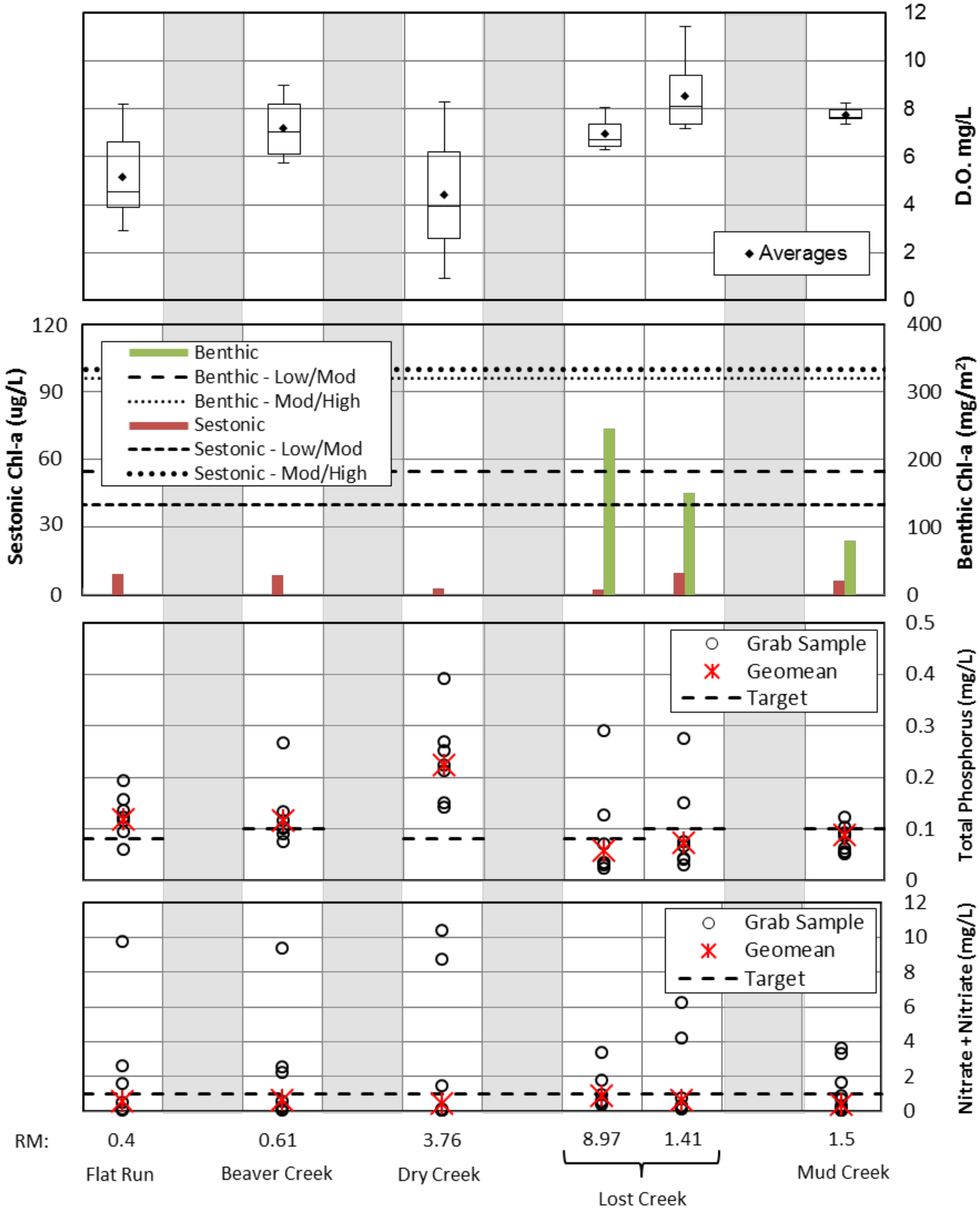

Figure 39. Data used for a trophic assessment of lower tributaries to the Tiffin River. The assessment includes DO, benthic/sestonic chlorophyll-*a*, total phosphorus, and nitrate + nitrite. Relevant targets for chlorophyll-*a* and nutrient concentrations are presented on the respective plots.

Diel DO ranges and chlorophyll-*a* concentration are the primary indicators of eutrophication. If both indicators fall into an elevated range there is strong evidence that the stream is exhibiting an advanced eutrophic state. If one or the other indicator is in an elevated range there is evidence of a system imbalance, but it is less conclusive regarding a eutrophic state. Some of the reasons for inconclusive results could be less than ideal sampling conditions or one sample misrepresenting the total character of the stream. After these two indicators identify the location of the stream on the trophic spectrum, nutrient concentrations in the stream are evaluated. The response to excess nutrients varies from stream to stream so using nutrient concentrations as an assessment endpoint is not always effective. However, if elevated nutrients are present, the risk of eutrophication increases. Sites are assessed following this logic and those demonstrating eutrophication are identified.

The stream depth and high turbidity of the Tiffin River limit light availability, decreasing the potential for benthic algal growth in this system. Moderate shading along most of the mainstem and cool water temperatures throughout the summer further limit benthic and sestonic algal production. As shown in Figure 35, the existence of benthic algal communities diminishes as drainage area increases; sites downstream from RM 33.95 are characterized solely by sestonic algae. None of the sites monitored on the Tiffin River mainstem showed indicators of eutrophication in 2012 or 2013, with DO ranges below 5.0 mg/L on all surveys.

Brush Creek is a direct tributary to the Tiffin River that drains primarily agricultural land and the city of Archbold. In the upper reaches of Brush Creek and many of its small tributaries, channelization and a wide-scale lack of riparian shading is pervasive. Brush Creek RM 19.06 is demonstrative of these conditions, which is reflected in DO ranges above 10.6 mg/L and benthic algae results in the moderate range. Limited shading, shallow stream depth, and a predominance of gravel or larger substrates make this site ideal for increased primary production. Downstream from this site, Brush Creek shifts to channel conditions more typical in the overall Tiffin River watershed—stagnant and pooled with substrates dominated by fine sediment. These conditions lead to a system more dominated by organic enrichment than nutrient enrichment. Organic loading from external sources—primarily the Archbold WWTP—exacerbate the existing conditions. All sites downstream from Archbold have sustained low DO concentrations and little to no algal production.

Sampling in the Lick Creek watershed covered the mainstem and its two largest tributaries, Little Lick Creek and Prairie Creek. In addition to extensive agriculture, Prairie Creek and Lick Creek are heavily influenced by runoff and wastewater from the city of Bryan. Diel DO ranges above 6.5 mg/L were measured at Little Lick Creek RM 4.97, Prairie Creek RM 9.8, and Lick Creek downstream from Prairie Creek at RM 1.23. Prairie Creek RM 9.8 displayed a maximum diel DO range of 16.54 mg/L, with benthic algae concentrations well above the high threshold. These results indicate severe eutrophication in a system that is dominated by phosphorus-rich wastewater. Phosphorus from point sources is typically high in the soluble reactive phosphorus (SRP) component of TP, which is more readily converted into algal biomass. This differs from the nonpoint source loading at other sites where phosphorus typically has a high percentage of particulate phosphorus, which is only 30% available for biomass production (Baker 2011). The quick uptake of soluble reactive phosphorus downstream from the wastewater outfall explains the rapid drop in algal production from RM 9.8 to RM 3.4. At the downstream site, riparian vegetation and improved shading also ameliorate algal growth and diel DO swings. These issues resurface on the Lick Creek mainstem downstream from its confluence with Prairie Creek. Channel widening on Lick Creek increases light availability, explaining an increase in benthic and sestonic algal growth while phosphorus values decrease.

Other sites with indicators of increased primary production include Deer Creek RM 4.56, Bean Creek RM 7.55, Mill Creek RMs 14.49 and 7.92, and Dry Creek RM 3.76 (Figure 38 and Figure 39). Deer Creek had benthic chlorophyll-*a* concentrations on the high end of the moderate range, but did not have corresponding large diel DO swings. This site was only visited once for continuous data monitoring, and that survey did not have the low flow and high temperatures that are ideal to capture the critical condition. Compared to trends from all other sites visited that week and later in the summer, it is likely that Deer Creek would have seen larger D.O. swings under higher stress conditions.

Bean Creek is a very wide, shallow stream that has very little riparian shading. These conditions would typically lead to a highly eutrophic system, but Bean Creek is buffered by connectivity to groundwater and a lack of larger substrates for benthic algae to grow. The relatively high velocity of this stream would scour algae growing on the existing sandy substrates. The swings in D.O. measured at this site track directly with changes in temperature due to direct sunlight, but the minimums remain high due to overall low temperatures.

The Mill Creek watershed is dominated by agricultural land uses and drains multiple unsewered communities. The Mill Creek RM 14.49 site is actively channelized and has a very narrow grassy riparian. The lack of shade and assimilative capacity has led to a highly eutrophic state, with diel DO swings as large as 13.2 mg/L. Larger substrates required to collect benthic chlorophyll-*a* were largely absent; therefore, an assessment was based on DO alone. Between RM 14.49 and 11.69, an unnamed tributary joins Mill Creek draining the unsewered community of Alvordton. While benthic chlorophyll-*a* concentrations at RM 11.69 are moderate, DO is depressed by excess loading of organic material; therefore, no large swings are measured. By RM 7.92 organic enrichment no longer dominated the system and both D.O and chlorophyll-*a* again indicated excess primary production (eutrophication). Downstream from RM 7.92, Mill Creek flows through Harrison Lake, which effectively assimilates phosphorus and leads to decreased TP concentrations and DO ranges at RM 1.85.

Dry Creek is a very low velocity stream with silty substrates and indicators of natural organic enrichment. While the substrates in Dry Creek are not appropriate for Ohio EPA sampling methods of benthic chlorophyll-*a*, visual assessment by staff indicated significant algal growth in pools and stagnant edges of the channel. Algae and organic material are not flushed from the system due to the extremely low velocity at this site, leading to DO indicators of both organic and nutrient enrichment over the length of the sampling season. The later sampling period, which followed a long stretch of warm, dry weather, saw a diel DO swing of 7.4 mg/L in Dry Creek, which is indicative of eutrophication.

Chemistry – Surface Water Metals

Metals were measured routinely at 13 locations in 2013 and four locations in 2012 with 18 parameters tested (Appendix F). Iron exceeded the statewide WQS criterion for the protection of agricultural uses throughout the watershed and a single aquatic life copper exceedance occurred in Mud Creek at Trinity Road in 2013 (Table 13). Currently, there is no standard for aluminum; however, elevated levels as compared to other results reported during the monitoring period occurred in Lick Creek at Trinity Road, Mud Creek at Trinity Road, and in the Tiffin River at County Road C in 2013. The iron and aluminum results were likely a consequence of the surrounding geology and influences from ground water. The source of the copper exceedance in Mud Creek at Trinity Road may be from runoff due to high flows observed in the stream during sample collection. No other metal exceedances were found throughout the study area in 2013 and no metal exceedances occurred in 2012.

NPDES Permitted Facilities

A total of 31 National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water, and/or industrial storm water into the Tiffin River watershed (04100006) within Defiance, Fulton, and Williams counties. Each facility is required to monitor their discharges according to sampling and monitoring conditions specified in their NPDES permit and report results to Ohio EPA in a Discharge Monitoring Report (DMR). Individual NPDES permits in the Tiffin River watershed are listed in Table 20. The city of Bryan and the village of Archbold are considered major dischargers based on the volume (>1 MGD) and type of waste they discharge. All other individual NPDES permitted facilities in the watershed are considered minor dischargers. Minor dischargers include two CAFOs, eight activated sludge sewage treatment plants, four sewage lagoons, four package plants, and two industrial storm water discharges.

General NPDES permits are a potential alternative for facilities that have a minimal effect on the environment, have similar operations, and meet certain eligibility criteria. There are several different types of general permits including, but not limited to, small sanitary sewer discharges, petroleum bulk storage, and non-contact cooling water. A list of facilities covered under each type may be found at http://epa.ohio.gov/dsw/permits/NonStormgplist.aspx . There are also several types of general permits specific to storm water including, but not limited to, small municipal separate storm sewer systems (MS4s), construction sites, industries, and marinas. The only small MS4 in the study area covered by an NPDES permit is the city of Defiance. A list of facilities covered under each type may be found at http://epa.ohio.gov/dsw/permits/gplist.aspx .

Table 20. Facilities regulated by an individual NPDES permit for the Tiffin River Watershed Assessment Unit (04100006).

Facility Name	Ohio EPA Permit No.	Receiving Stream	River Mile	Wastewater Type and Treatment System
BP Amoco Oil Corp Bulk Plant Bryan	2IN00177	Storm Sewer to Prairie Creek	1.22	Storm Water Sedimentation Basin
Bryan Metal - Global Suspension Systems	2IC00039	Storm Sewer to Ditch 40	0.64	Noncontact cooling water
Bryan WTP	2IY00002	Storm Sewer to Prairie Creek	11.67	Filter backwash water
Bryan WWTP	2PD00018	Prairie Creek	11.0	3.14 MGD Activated Sludge
Durham Estates WWTP	2PG00085	Tributary to Lick Creek	N/A	0.02 MGD Activated Sludge
Hickory Hills Subsewer District	2PG00084	Tributary to Owl Creek	0.77	0.0055 MGD Activated Sludge
Hillside Nursing Home	2PG00086	Beaver Creek	15.4	0.042 MGD Sand Filter
Kunkle Schoolhouse	2PR00129	Tributary to West Fork Mill Creek	N/A	0.0071 MGD Package Plant
Lakeland Woods	2PG00087	Beaver Creek	4.65	0.03 MGD Activated Sludge, sand filter

Facility Name	Ohio EPA Permit No.	Receiving Stream	River Mile	Wastewater Type and Treatment System
Manufactured Housing Enterprises	2PR00141	Little Lick Creek	9.6	0.006 MGD Lagoon System
Norlick Place	2PG00067	Lick Creek	21.76	0.048 MGD Activated Sludge
Ohio Turnpike Commission Kunkle Maintenance	2PP00047	Tributary to Beaver Creek	N/A	0.0015 MGD Package Plant
Spangler Candy Company	2IH00107	Storm Sewer to Ditch 40	N/A	Noncontact cooling water
Springfield Dairy LLC	2IK00041	Tributary to Prairie Creek	N/A	Storm Water, manure discharge to fields
Stryker WWTP	2PB00009	Tributary to Tiffin River	0.28	0.350 MGD Aerated Lagoon System
Altenloh Brinck Co., AKA Tru Fast LLC	2PR00105	Tributary to Little Lick Creek	2.2	0.008 MGD Package Plant
West Unity STP	2PB00021	Walnut Run	3.75	0.325 MGD Activated Sludge
Williams Co S. Central Sewer District	2PH00018	Miller Creek	1.8	0.127 MGD Stabilization Pond
Williams County Landfill	2IN00124	Lick Creek & Tributary to Miller Creek	25.3	4 Storm Water outfalls from sedimentation ponds
Evansport WWTP	2PG00055	Tiffin River	20.6	0.050 MGD Activated Sludge
Evergreen Lane Office Complex	2PG00052	Tiffin River	7.3	0.015 MGD Activated Sludge
Ney WTP	2IV00112	Little Lick Creek	2.99	0.005 MGD sand filtration backwash water
Ney WWTP Lagoon	2PA00095	Lick Creek	10.5	0.041 MGD Stabilization Pond
Northeastern Local Schools - Tinora	2PT00018	S. Branch Behrens Ditch	1.9	0.022 MGD Extended Aeration with sand filters
Park Place MHP	2PY00065	Tributary to Tiffin River	1.03	0.0125 MGD Sand Filtration
Vander Made Dairy LLC	2IK00021	Tributary to Dry Creek	4.66	Storm Water, manure discharge to fields
Archbold WWTP	2PD00017	Brush Creek	13.95	2.5 MGD Contact Stabilization

Facility Name	Ohio EPA Permit No.	Receiving Stream	River Mile	Wastewater Type and Treatment System
Fayette WWTP	2PB00045	Tributary to Deer Creek	0.25	0.26 MGD Lagoon System – controlled discharge
Harrison Lake State Park	2PP00001	Mill Creek	4.92	0.040 MGD Package Plant – sand filtration
Pettisville WWTP	2PG00014	Tributary to Brush Creek	2.0	0.116 MGD Lagoon System – controlled discharge

The city of Bryan and the village of Archbold WWTPs are considered major dischargers and are discussed in detail below. The West Unity WWTP is also discussed in detail below due to *E. coli* and ammonia permit violations.

City of Bryan WWTP (Ohio EPA Permit # 2PD00018)

The city of Bryan WWTP serves approximately 9,230 residents in Pulaski Township, Jefferson Township, and the city of Bryan itself. Sewer services for the City are provided by a municipal sanitary sewer wastewater treatment plant with an average daily design flow of 3.14 MGD. Sanitary waste from the City receives preliminary treatment through a bar screen, secondary treatment with aeration/sedimentation and activated sludge, and final clarification in the clarifiers. The treated effluent then undergoes chlorination and de-chlorination during the recreational season prior to discharge to Prairie Creek.

The sanitary sewer collection system for the City is made up of 100% separate sanitary sewers; however, sanitary sewer overflows directly to Prairie Creek (RM 11.0) occur during excessive flows in the system. A bypass exists that discharges to an equalization basin during high flow events. The City is completing inspections to identify sources of clean water to the sanitary sewer system to reduce unnecessary flow to the system especially during high flow events.

Ohio EPA most recently conducted a compliance sampling inspection and bioassay of the Bryan WWTP on May 9-10, 2011. The effluent from outfall 002 was not acutely toxic to *Pimephales promelas* (fathead minnows) or *Ceriodaphnia dubia* (a microcrustacean).

Pollutant loadings from the city of Bryan WWTP between 2003 and 2013 were evaluated and annual statistics for nitrate + nitrite and total phosphorus loadings are displayed in Figure 40 and Figure 41. The plant discharged at a fairly consistent flow during the evaluation period. The annual nitrate + nitrite loadings have remained fairly steady; however, annual average discharge concentrations are high. Phosphorus loads have decreased over the past 9 years.

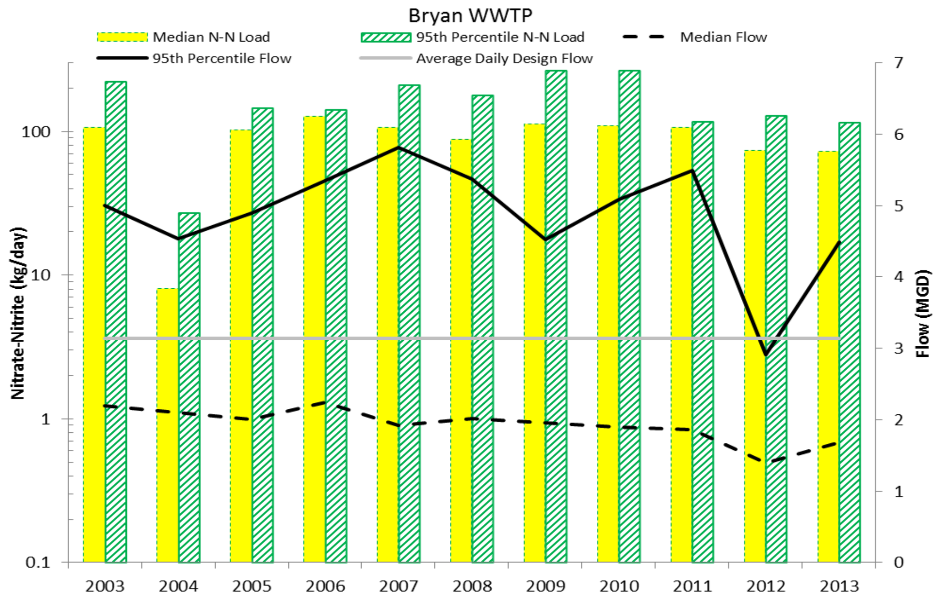

Figure 40. Annual nitrate+nitrite loadings for the Bryan WWTP from 2003-2013.

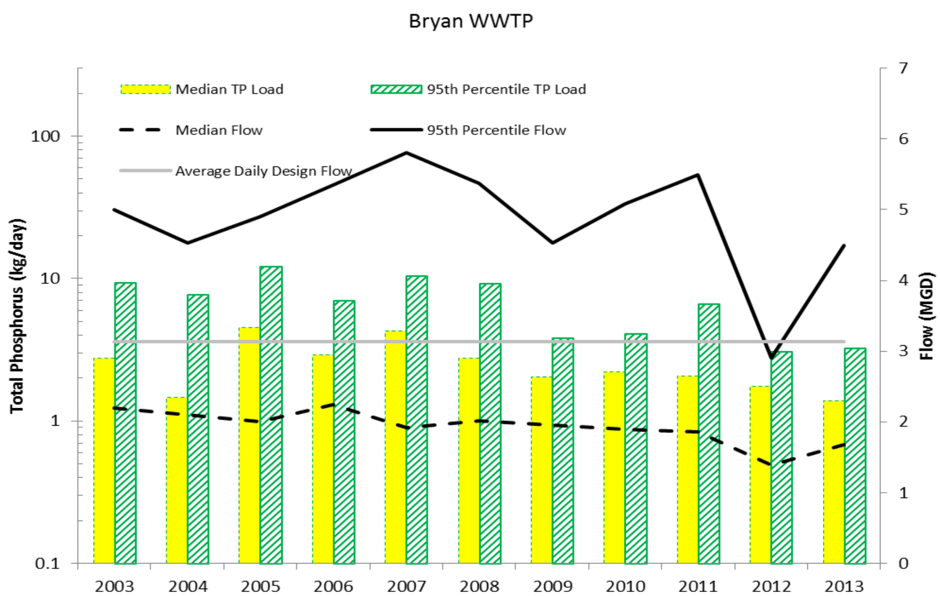

Figure 41. Annual total phosphorus loadings for the Bryan WWTP from 2003-2013.

Village of Archbold WWTP (Ohio EPA Permit # 2PD00017)

The village of Archbold WWTP serves approximately 5,290 residents in the Elmira-Burlington area, Ridgeville Township, and the village of Archbold. Sewer services for the Village are provided by a municipal sanitary sewer wastewater treatment plant with an average daily design flow of 2.5 MGD. Sanitary waste from the Village receives preliminary treatment through a bar screen, secondary treatment with aeration/sedimentation and contact stabilization (activated sludge), and final clarification in the clarifiers. The treated effluent then undergoes chlorination and de-chlorination during the recreational season prior to discharge to Brush Creek at River Mile 13.95.

Table 21. Archbold WWTP permit violations. *Note:* All *E. coli* values are expressed as colony forming units (cfu) per 100 ml of water.

Permit No	Reporting Period	Station	Parameter	Limit Type	Limit	Reported Value	Violation Date
2PD00017	July 2013	002	*E. coli*	7D Conc.	362	1133.00	7/8/2013
2PD00017	July 2013	002	*E. coli*	30D Conc.	161	251.029	7/1/2013
2PD00017	August 2013	002	*E. coli*	30D Conc.	161	201.217	8/1/2013
2PD00017	September 2013	002	*E. coli*	7D Conc.	362	527.133	9/8/2013
2PD00017	September 2013	002	*E. coli*	30D Conc.	161	170.231	9/1/2013

The sanitary sewer collection system for the Village is made up of 100% separate sanitary sewers. The Archbold WWTP had permit limit violations for *E.coli* bacteria from July to September 2013 contributing to the non-attainment status of the class B primary contact recreation criterion in Brush Creek during the 2013 sampling. Permit violations for *E.coli* are summarized in Table 21. The most recent compliance sampling inspection and bioassay of the Archbold WWTP on May 7-8, 2012 specified that the effluent from outfall 002 was not acutely toxic to *Pimephales promelas* or *Ceriodaphnia dubia*.

Pollutant loadings from the village of Archbold WWTP between 2008 and 2013 were evaluated and annual statistics for nitrate + nitrite and total phosphorus loadings are displayed in Figure 42 and Figure 43. Data are evaluated beginning in 2008 because of upgrades to the plant; the old polishing pond was converted into an equalization basin and the outfall was moved to discharge from clarification/chlorine tanks which were put online in May 2007. The plant discharged at a fairly consistent flow during the evaluation period. The annual nitrate + nitrite loadings steadily declined from 2008 to 2011 but began to increase in 2012-2013. Phosphorus loads display a slight decreasing trend over the 6-year period.

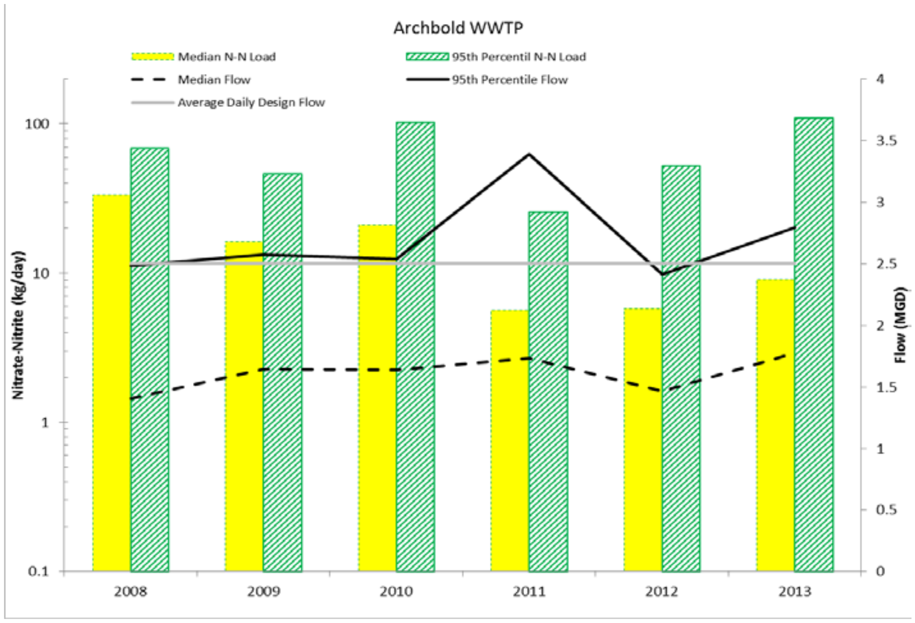

Figure 42. Annual nitrate+nitrite loadings for the Archbold WWTP from 2003-2013.

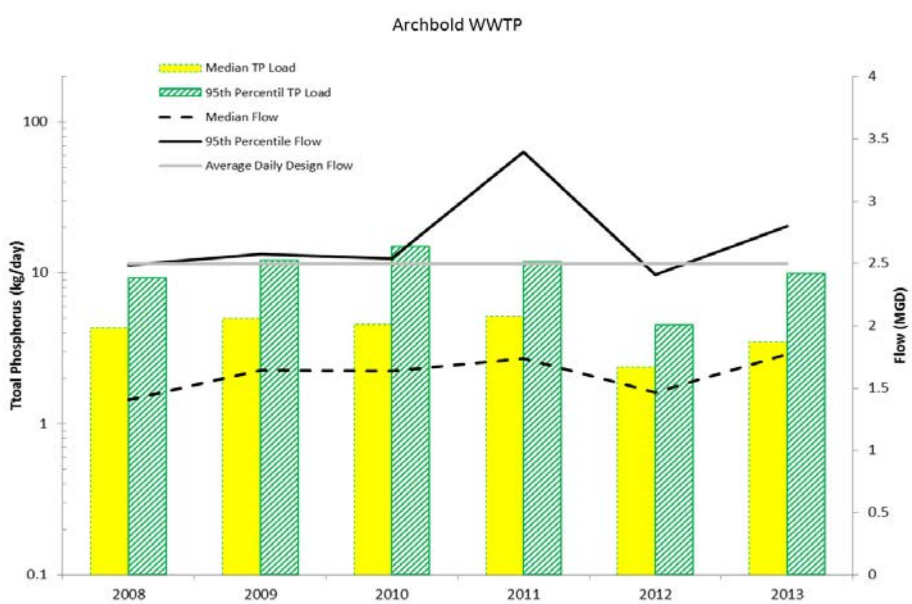

Figure 43. Annual total phosphorus loadings for the Archbold WWTP from 2003-2013.

Village of West Unity WWTP (Ohio EPA Permit # 2PB00021)

The village of West Unity WWTP provides sanitary wastewater treatment to approximately 1,730 people. The municipal wastewater treatment plant consists of an activated sludge plant with an average daily design flow of 0.325 MGD. The Village's sanitary waste discharges into Walnut Run (RM 3.75) that flows into the Tiffin River at RM 41.14.

The West Unity WWTP had permit limit violations for *E.coli* in May 2013 and from August to September 2013 contributing to the non-attainment status of the class A primary contact recreation criterion downstream in the Tiffin River during the 2013 sampling. Ammonia permit limit exceedances occurred at the facility in July 2013 but violations of the ammonia criteria were not observed at the nearest downstream monitoring location on the Tiffin River. The permit limit exceedances of *E.coli* and ammonia are documented in Table 22.

Table 22. West Unity WWTP permit limit violations. *Note:* All *E. coli* values are expressed as colony forming units (cfu) per 100 ml of water.

Permit No	Reporting Period	Station	Parameter	Limit Type	Limit	Reported Value	Violation Date
2PB00021	May 2013	001	*E. coli*	7D Conc.	362	424.264	5/22/2013
2PB00021	July 2013	001	Ammonia (NH3)	7D Conc.	2.1	4.5	7/1/2013
2PB00021	July 2013	001	Ammonia (NH3)	7D Conc.	2.1	7.9	7/8/2013
2PB00021	July 2013	001	Ammonia (NH3)	30D Conc.	1.4	3.4	7/1/2013
2PB00021	August 2013	001	*E. coli*	7D Conc.	362	2754.99	8/22/2013
2PB00021	September 2013	001	*E. coli*	7D Conc.	362	2877.49	9/1/2013
2PB00021	September 2013	001	*E. coli*	7D Conc.	362	916.515	9/15/2013

Pollutant loadings from the village of West Unity WWTP between 2003 and 2013 were evaluated and annual statistics for nitrate + nitrite, total phosphorus, and ammonia loadings are displayed in Figure 44 through Figure 46. The annual nitrate + nitrite loadings have remained steady. Phosphorus loads fluctuated with flow, but the overall trend remained steady. Median (50th percentile) ammonia loading from the plant has displayed an increasing trend since 2008 and exceeded ammonia permit limits in 2013 as noted above. Evaluation of Walnut Run should be considered in the next assessment of the Tiffin River watershed.

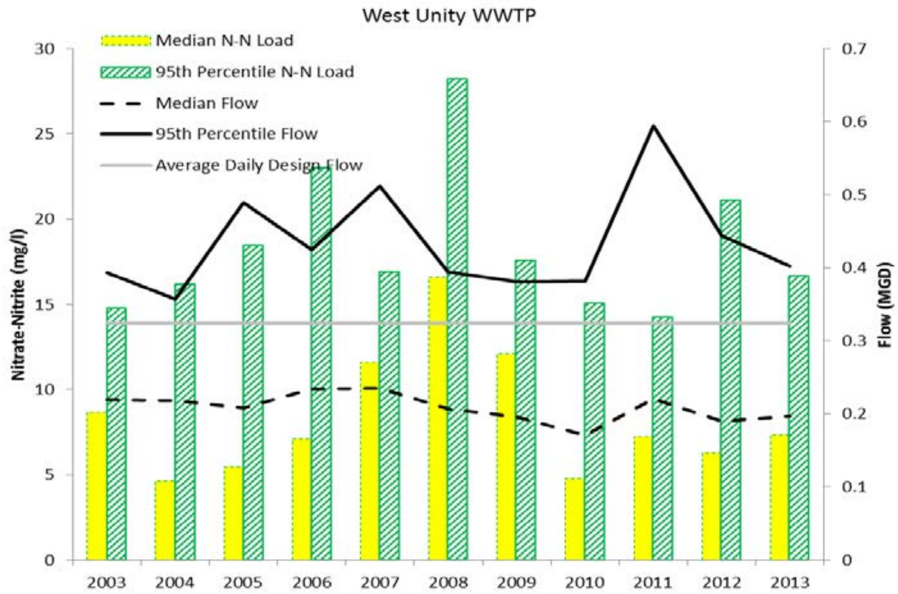

Figure 44. Annual nitrate+nitrite loadings for the West Unity WWTP from 2003 – 2013.

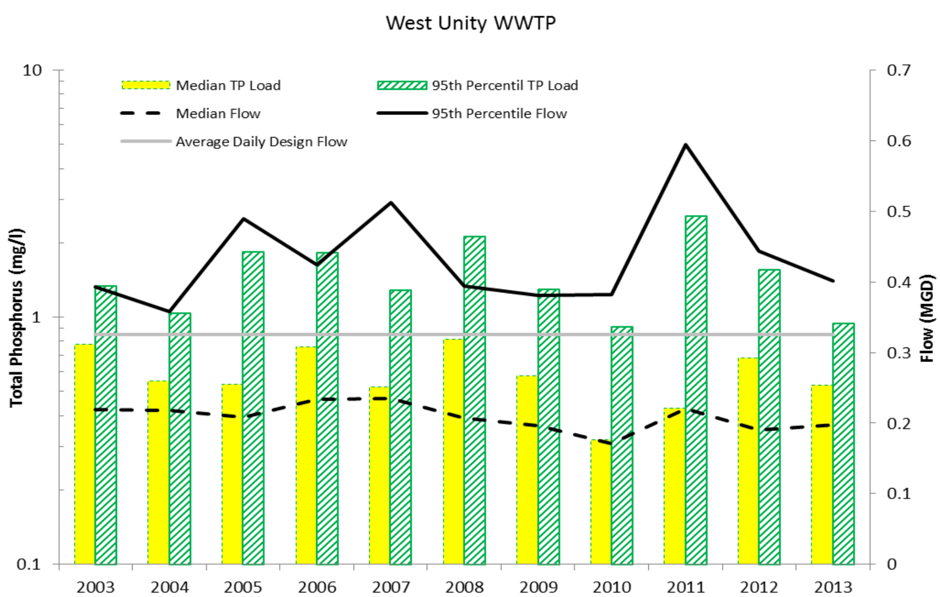

Figure 45. Annual total phosphorus loadings for the West Unity WWTP from 2003 – 2013.

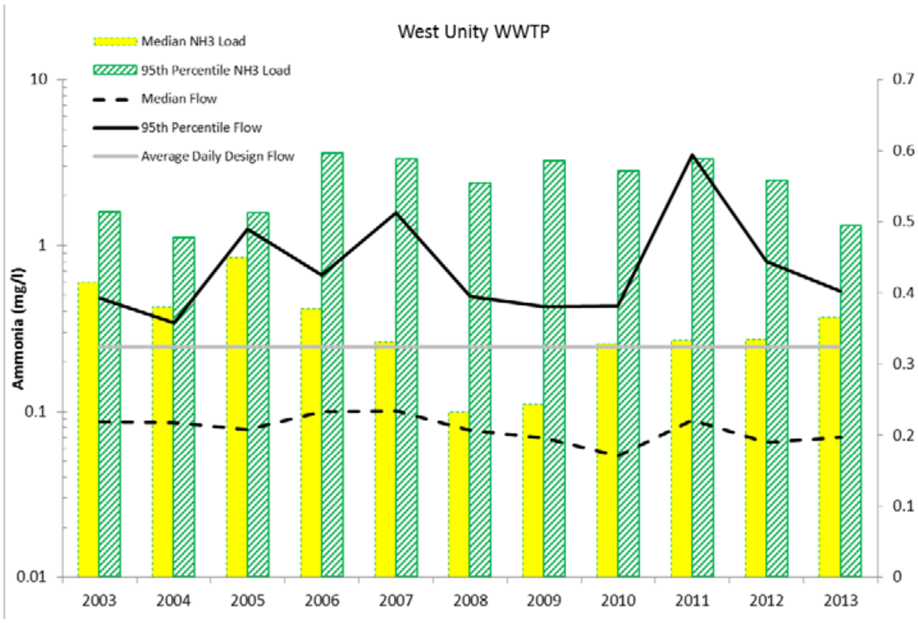

Figure 46. Annual ammonia loadings for the West Unity WWTP from 2003 – 2013.

SEDIMENT CHEMISTRY

Sampling locations were selected to determine background sediment quality, assess the impact from point sources and urban nonpoint runoff, and evaluate downstream transport and recovery. Samples were collected following the *Sediment Sampling Guide and Methodologies, 3rd Edition* (Ohio EPA 2012c). The goal is to collect a representative sample that is composed of > 30% silt and clay particles. These fine grained particles are much more physically, chemically, and biologically reactive because they hold more interstitial water and have unbalanced electrical charges that can attract contaminants.

Most of the Tiffin River mainstem contains little in the way of very fine grained sediment in large enough volumes to have much of an ecological impact, as its sediment composition is more of a sandy-pea gravel type. This is due in part to reductions in the overall amount of silts and fine sediments being washed into the stream from agricultural practices and storm water management, and relatively intact riparian corridors. Exceptions to this may include impounded segments, eddies and depositional areas, areas of low local gradient, and in headwaters where feeder streams are channelized.

Sediment sample results were evaluated using Tier I procedures for aquatic life described in the *Guidance on Evaluating Sediment Contaminant Results* (Ohio EPA 2010a). Numeric Sediment Quality Guidelines (SQGs) that are used include Ohio Sediment Reference Values (SRVs) for metals contained in the *Ecological Risk Assessment Guidance* (Ohio EPA 2008) and toxicity values in the *Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et al. 2000). When contaminants are at concentrations above the SQGs either appropriate treatment options should be explored to remediate the problem or consideration should be given to investigate if bioavailability affects toxicity, which would likely require further studies to be done.

A total of four sediment samples were collected in the Tiffin River between RM 47.54 and RM 7.09. One sediment sample was collected in Brush Creek at RM 13.28 and one sediment sample was collected in Prairie Creek at RM 9.8; both of these locations are downstream from WWTPs. Sediment samples were analyzed for metals including mercury and s-VOCs, also known as polycyclic aromatic hydrocarbons (PAHs). The laboratory reporting limit for silver was greater than the SQG due to matrix interference for all six sampling locations and, thus, was not able to be evaluated as a part of this study.

Heavy metals and PAHs are common contaminants in urban areas because of vehicular emissions, asphalt pavement and their use in industrial processes. For example, mercury is used in the production of chlorine gas and caustic soda and in the manufacture of batteries and compact fluorescent light bulbs. It is also common in the atmosphere from coal burned to produce electricity. Besides urban storm water runoff and atmospheric deposition, other likely sources include municipal and industrial wastewater and combined sewer overflows in municipal sewage collection systems. For example, the city of Bryan WWTP discharges to Prairie Creek and has several significant categorical industries that use the system; however, there are no combined sewer overflows that exist in the collection system.

All sediment metals sampled were below Ohio Sediment Reference Values. The only s-VOCs detected were PAHs in Prairie Creek RM 9.8 downstream from the Bryan WWTP (Appendix G). The concentrations were above the threshold effect concentration (TEC), but below the probable effect concentration (PEC) and are unlikely to cause any harmful effects.

Recreation Use

Water quality criteria for determining attainment of the recreation use are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the quantities of bacteria indicators (*Escherichia coli*) present in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are normally present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour 1977). There is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more feasible. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease-causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor every type of pathogen. Fecal indicator bacteria in and of themselves, including *E. coli*, are typically not pathogenic. However, some strains of *E. coli* can be pathogenic and are capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one or multiple sources. Swimming or other recreation-based contact with water having a high *E. coli* count may result in ear, nose, and throat infections, as well as gastrointestinal disturbances, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

Portions of the Tiffin River watershed are designated Primary Contact Recreation (PCR) in OAC Rule 3745-1-07 and 3745-1-11. Water bodies with a designated recreation use of PCR "...are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking, and scuba diving" [OAC 3745-1-07 (B)(4)(b)]. At the time of completion of this basin survey, there were three classes of PCR use to reflect differences in the potential frequency and intensity of use. Streams designated PCR class A support, or potentially support, frequent primary contact recreation activities. Streams designated PCR class B support, or potentially support, occasional primary contact recreation activities. A majority of streams in the study area are designated as Class A and Class B PCR waters. Revisions to the WQS recreation rules, which eliminate the three PCR classes and establish one PCR class with a new criterion, will become effective in January, 2016.

The *E. coli* criterion that applies to PCR Class A streams is a geometric mean of ≤126 colony forming units (cfu)/100 ml. The *E. coli* criterion that applies to PCR class B streams is a geometric mean of ≤161 cfu/100 ml. The geometric mean is based on two or more samples and is used as the basis for determining the attainment status of the recreation use (Table 23). The complete bacteria result dataset is reported in Appendix I.

Thirty-three locations in the watershed were tested for *E. coli* levels five times between May 29, 2013 and September 5, 2013. Evaluation of *E. coli* results revealed that 30 of the 33 locations sampled failed to meet the applicable geometric mean criterion, indicating non-attainment of the recreation use at these locations (Table 23).

Four locations in the LRAU portion of the Tiffin River were tested for *E. coli* five times between May and September, 2012. Evaluation of *E. coli* results revealed that 3 of the 4 locations sampled failed to meet the applicable geometric mean criterion, indicating non-attainment of the recreation use at these locations (Table 24).

Plausible sources of *E. coli* contamination at locations not attaining the recreation use criteria are unsanitary conditions from agricultural manure runoff, underperforming WWTPs, failing HSTS, and unsewered communities. Runoff from livestock manure application and livestock grazing areas could be improved by the installation of buffers between the activity and the stream. Attainment of the recreation use standards near unsewered communities could potentially be achieved with the installation of sewers and a treatment system in the community. The unsewered communities of Alvordton and Kunkle discharge to tributaries of Mill Creek and have been documented to cause a public health nuisance based on *E. coli* sampling in those streams. Other areas listed in non-attainment of the recreation use standard for failing HSTS may need individual system improvements to reduce the discharge of bacteria.

Table 23. Recreation beneficial use attainment table for 33 locations in the Tiffin River Watershed, May 1 through October 31, 2013. *Note:* All *E. coli* values are expressed as colony forming units (cfu) per 100 ml of water. Shaded values exceed applicable criteria.

Location	River Mile	Rec Class*	Number of Samples	Geometric Mean†	Attainment Status	Potential Source(s) of Bacteria
Tiffin River (04-600)						
TIFFIN R. NW OF ARCHBOLD @ CO. RD. G	47.54	A	5	440	**NON**	
TIFFIN R. @ CR 22.75 / CR I.25	41.1	A	5	283	**NON**	West Unity WWTP
TIFFIN R. AT EVANSPORT @ ST. RT. 191	35.28	A	5	220	**NON**	
TIFFIN R. SW OF STRYKER @ ST. RT. 34	30.97	A	5	372	**NON**	
TIFFIN R. DST. STRYKER @ OAK GROVE CHURCH RD.	26.17	A	5	415	**NON**	
TIFFIN R. @ CO. RD. 22/A	19.7	A	5	322	**NON**	
Old Bean Creek (04-632)						
OLD BEAN CREEK SE OF FAYETTE @ OLD ANGOLA RD.	1.85	SCR	5	669	FULL	
Deer Creek (04-628)						
DEER CREEK DST. FAYETTE @ CO. RD. 23	4.56	B	5	1293	**NON**	Fayete CSOs (sewers now separate)
Bean Creek (04-626)						
BEAN CREEK E OF POWERS @U.S. RT. 20	6	B	5	177	**NON**	
BEAN CREEK SE OF FAYETTE @ OLD ANGOLA RD.	2.2	B	5	471	**NON**	
Mill Creek (04-624)						
MILL CREEK SE OF ALVORDTON @ CO. RD. P	11.9	B	5	363	**NON**	Alvordton (Unsewered Community)
MILL CREEK SE OF ALVORDTON @ CO. RD. 28	7.92	B	5	330	**NON**	Kunkle (Unsewered Community)
MILL CREEK S OF FAYETTE @ OLD ANGOLA RD.	1.85	B	5	665	**NON**	

Location	River Mile	Rec Class*	Number of Samples	Geometric Mean†	Attainment Status	Potential Source(s) of Bacteria
Bates Creek (04-622)						
BATES CREEK E OF WEST UNITY @ CO. RD. 25-2	1.65	B	5	745	**NON**	
Flat Run (04-620)						
FLAT RUN NE OF STRYKER @ CO. RD. 22.75	0.4	B	5	1090	**NON**	Failing HSTS, Agricultural run-off
Leatherwood Creek (04-619)						
LEATHERWOOD CREEK N OF STRYKER @ CO. RD. H	1.15	SCR	5	749	FULL	
Beaver Creek (04-617)						
BEAVER CREEK AT BEAVER CREEK WILDLIFE AREA @ CO. RD. 16	12.66	B	5	406	**NON**	
BEAVER CREEK S OF PULASKI @ U.S. RT. 127	7.52	B	5	1413	**NON**	Pulaski (Unsewered Community)
Brush Creek (04-614)						
BRUSH CREEK UPST. ARCHBOLD @ ARCHBOLD-LUTZ RD. (CR D)	19.06	B	5	603	**NON**	
BRUSH CREEK DST. ARCHBOLD @ CR 24	13.28	B	5	695	**NON**	Archbold WWTP
BRUSH CREEK NEAR EVANSPORT AT CR 22-60	1.05	B	5	468	**NON**	
Coon Creek (04-616)						
COON CREEK E OF EVANSPORT @ CO. RD. 23	0.62	B	5	531	**NON**	
Miller Creek (04-612)						
MILLER CREEK W OF BRYAN, ADJ. CO. RD. 309 / D	1	B	5	304	**NON**	
Little Lick Creek (04-611)						
L. LICK CREEK AT NEY, UPST. RR	0.8	B	5	605	**NON**	

Location	River Mile	Rec Class*	Number of Samples	Geometric Mean†	Attainment Status	Potential Source(s) of Bacteria
Prairie Creek (04-609-001)						
PRAIRIE CREEK DST. BRYAN WWTP, ADJ CR C	9.8	B	5	790	**NON**	
PRAIRIE CREEK NE OF NEY @ FLICKINGER RD. (LOWER CROSSING)	3.4	B	5	348	**NON**	
Lick Creek (04-609)						
LICK CREEK AT NEY @ THE BEND RD.	10.05	B	5	615	**NON**	
LICK CREEK N OF OXBOW LAKE @ TRINITY RD.	1.23	B	5	559	**NON**	
Dry Creek (04-608)						
DRY CREEK @ CO. RD. 124 (OPENLANDER RD.)	3.75	B	5	346	**NON**	
Lost Creek (04-606)						
LOST CREEK N OF SHERWOOD @ BEHNFELDT RD.	1.41	B	5	778	**NON**	Livestock, pasture land, failing HSTS
Mud Creek (04-605)						
MUD CREEK NW OF BRUNERSBURG @ TRINITY RD.	1.5	B	5	432	**NON**	
Buckskin Creek (04-604)						
BUCKSKIN CREEK NW OF BRUNERSBURG @ ST. RT. 15	1.2	B	5	140	FULL	None
Webb Run (04-602)						
WEBB RUN @ FLORY RD.	3	B	5	241	**NON**	

* Recreation class may include primary contact recreation classes (A, B or C); bathing waters (BW); or secondary contact recreation (SCR).

† Attainment status is determined based on the seasonal geometric mean. The status cannot be determined at locations where fewer than two samples were collected during the recreation season.

Table 24. Recreation beneficial use attainment table for four locations in the Tiffin River Large River Assessment Unit, May 1 through October 31, 2012. *Note:* All *E. coli* values are expressed as colony forming units (cfu) per 100 ml of water. Shaded values exceed applicable criteria.

Location	River Mile	Rec Class*	Number of Samples	Geometric Mean†	Attainment Status	Potential Source(s) of Bacteria
HUC 12 (Coon Creek – Tiffin River 04100006 05 04)						
Tiffin River @ State Route 191	18.7	A	5	269.22	**NON**	Failing HSTS / Agriculture Runoff
Tiffin River @ Stever Road	14.1	A	5	254.07	**NON**	Failing HSTS / Agriculture Runoff
HUC 12 (Buckskin Creek – Tiffin River 04100006 06 04)						
Tiffin River @ Evansport Road	7.0	A	5	211.19	**NON**	Failing HSTS / Agriculture Runoff
Tiffin River @ Dey Road	0.9	A	5	104.94	FULL	

* Recreation class includes primary contact recreation classes A.

† Attainment status is determined based on the seasonal geometric mean. The status cannot be determined at locations where fewer than two samples were collected during the recreation season.

PUBLIC DRINKING WATER SUPPLIES

The Public Water Supply (PWS) beneficial use in the WQS (OAC 3745-1-33) currently applies within 500 yards of drinking water intakes and for all publicly owned lakes. Ohio EPA has developed an assessment methodology for this beneficial use which focuses on source water contaminants not effectively removed through conventional treatment methods. The 2012 Integrated Water Quality Monitoring and Assessment Report describes this methodology in Section H, and is available on Ohio EPA's website: http://www.epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

Impaired source waters may contribute to increased human health risk or treatment costs. For the case when stream water is pumped to a reservoir, the stream and reservoir will be evaluated separately. These assessments are designed to determine if the quality of source water meets the standards and criteria of the Clean Water Act. Monitoring of the safety and quality of treated finished drinking water is regulated under the Safe Drinking Water Act and evaluated separately from this assessment. For those cases when the treatment plant processes do not specifically remove a source water contaminant, the finished water quality data may be considered representative of the raw source water directly feeding into the treatment plant. There is one public water system, the village of Archbold, directly served by surface water sources within the study area. Table 25 provides a summary of exceedances for the PWS use while Appendix K contains all of the water quality analytical results.

Iron exceedances of the public drinking water supply human health criterion were found within 500 yards of the village of Archbold water treatment plant intake on the Tiffin River RM 47.54 in every sample collected at this location. Iron exceedances of the drinking water human health criterion occur in a majority of the samples collected at all sampling locations throughout the mainstem. Iron only has a secondary drinking water standard that was set based on the aesthetics of the water and the potential to need additional water treatment equipment to remove excess iron from the system. Iron is abundant in the soils and rock in the area and routinely results in elevated iron levels existing in many ground water and surface water sources in northwest Ohio.

Chloride levels also exceeded the WQS criterion for the protection of human health in the Lake Erie drainage basin at multiple locations. However, this standard only applies to sampling locations that are located within five hundred yards of a drinking water intake. At every location where there was an exceedance of the criterion, there was no drinking water intake at that location. Sources of chloride at both sampling locations on Prairie Creek and the sampling location on Lick Creek NW of Bryan at CR 13 could potentially be from the city of Bryan WWTP discharge and the Norlick Place WWTP, respectively. The potential source of elevated chloride in Buckskin Creek at SR 15 on August 22, 2013 is undetermined. A full assessment of the results of sampling in regard to potential impact to the village of Archbold drinking water intake can be reviewed below.

Village of Archbold

The village of Archbold operates a community public water system that serves a population of almost 6,000 people through approximately 2,500 service connections. The Village has an intake on the Tiffin River mainstem at RM 47.54 and also conveys drinking water to two upground reservoirs for storage before use. The system's treatment capacity is approximately 7.6 MGD, but current average production is 1.4 MGD. The village of Archbold's treatment processes include rapid sand filtration, coagulation, and sedimentation (for particulate removal); gaseous chlorination (for disinfection); lime-soda ash and re-carbonation (for softening); permanganate and ion exchange (for taste and odor control); powdered activated carbon (for organics removal); hexametaphosphate (for corrosion control); and fluoridation.

To assess the PWS beneficial use, samples were analyzed for nitrate and pesticides at the Tiffin River intake and on Reservoir #2. Ohio EPA collected a total of 14 water quality samples to be tested for nitrate and 10 water quality samples to be tested for atrazine on the Tiffin River near Archbold's public water supply intake during 2013 and 2014. Nitrate ranged from 0.23 mg/L to 9.21 mg/L and averaged 2.87 mg/L. All results were below the human health water quality criterion for nitrate (10.0 mg/L). Atrazine ranged from below detection limit (BDL) to 0.42 ug/L. All results were below the human health water quality criterion for atrazine (3.0 mg/L).

Starting in 2014, a new core indicator, based on algae and associated cyanotoxins, was used for PWS assessments. Archbold's village reservoir was sampled for evidence of harmful algal blooms in 2013 and 2014. Six samples (one in 2013, five in 2014) were collected and analyzed for microcystin. All results were below detection.

Table 25. Summary of available water quality data for parameters of interest at sampling sites near/at PWS intakes.

Location(s)	**PWS Parameters of Interest**					
	Nitrate+Nitrite WQC = 10 mg/L[a]		**Atrazine WQC = 3.0 ug/L[b]**			
	Average (sample count)	**Maximum (# samples >WQC)**	**Average (sample count)**	**Quarterly Average (2013)**	**Quarterly Average (2014)**	**Maximum Single Detect.**
Tiffin R. NW of Archbold @ Co. Rd G	2.87 mg/L n=14	9.21 mg/L (0)	2.39 ug/L (10)	0.29 ug/L	0.825 ug/L	1.99 ug/L
Archbold Reservoir #2, L-1	0.30 mg/L n=10	0.94 mg/L (0)	0.26 ug/L (9)	0.14 ug/L	0.11 ug/L	0.42 g/L

a Nitrate water quality criterion (WQC) evaluated as maximum value not to be exceeded, impaired waters defined as having two or more excursions about the criteria. Bold indicates addition to the watch list for nitrate.

b Atrazine WQC evaluated as annual average of the quarterly averages. Bold indicates addition to the watch list for atrazine.

LAKE SAMPLING

Inland Lakes Monitoring

Ohio EPA has implemented a sampling strategy that focuses on evaluating chemical conditions near the surface and physical conditions in the water column of inland lakes. Physical profile measurements are summarized either for the entire water column or the epilimnion depending on thermal stratification. The sampling target consists of an even distribution of a total of ten sampling events divided over a two-year period and collected during the index period of May 1 – October 31. Key parameters used to determine the attainment status of lakes include chlorophyll-*a*, ammonia, dissolved oxygen, pH, total dissolved solids and various metals. Other parameters used to evaluate the degree of support or non-support includes secchi depth, TP, and total nitrogen. Details of the sampling protocol are outlined in Appendix 1 of the Ohio EPA Surface Water Field Sampling Manual (Ohio EPA 2010b), available on Ohio EPA's web page at:
http://www.epa.ohio.gov/portals/35/inland_lakes/Lake_Sampling_Procedures.pdf.

Water Quality Standards for the Protection of Aquatic Life in Lakes

Presently, lakes in Ohio are designated as EWH with respect to the aquatic life use designation. Revisions to Ohio's WQS that would change the aquatic life use from EWH to Lake Habitat (LH) were proposed for adoption in December, 2011, but were subsequently withdrawn. A future rulemaking is anticipated but the timeframe is unknown. A primary reason for this revision is that in Ohio, a set of biological criteria applies to rivers and streams, whereas no biocriteria apply to lakes. The numeric chemical criteria to protect the LH use will remain the same as the criteria to protect the EWH use that currently applies to lakes, with a suite of nutrient criteria added. These criteria are tiered based on the type of lake and the ecoregion of its location. A set of numeric criteria that applies to all surface waters for the protection of aquatic life, regardless of specific use designation, also apply to inland lakes and are referred to as "base aquatic life use criteria" in the proposed WQS rules. The base aquatic life use criteria will be the same aquatic life numeric criteria that currently apply to lakes. Examples include various metals such as copper, lead, and cadmium as well as organic chemicals such as benzene and phenol. Specific details concerning the progress of revisions to Ohio's Water Quality Standards involving the proposed Lake Habitat aquatic life use and associated criteria can be found at the following Ohio EPA web site as information becomes available: http://www.epa.ohio.gov/dsw/rules/draftrules.aspx. Details of the proposed use designation, draft criteria and assessment methodology are previewed in the Ohio EPA 2012 Integrated Water Quality Monitoring and Assessment Report, available on Ohio EPA's web page at: http://epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

Archbold Reservoir # 2

Archbold Reservoir # 2 is located in in the village of Archbold in Fulton County, Ohio. It is a manmade upground reservoir that was constructed in 1960 to help the village meet increasing demand for water. This type of lake is typically built on flat ground using earthen levees with roughly 2:1 inside slopes that are covered with limestone riprap to protect them from wave erosion. The reservoir covers a surface area of about 45 acres and has a maximum depth of 14.5 ft. with a storage capacity of 204 million gallons. Source water is obtained from the Tiffin River via an automated pump station located at river mile 47.54. The lake is open to public fishing and there is a concrete boat ramp. Only electric boat motors are permitted and swimming is not allowed. Fish management activities include routine stocking, population monitoring and angler harvest studies.

Key Attributes
Lake Type: Upground Ecoregion: Huron Erie Lake Plains
Surface Area: 45 acres Maximum Depth: 14.5 ft.

Lake Habitat Use
Environmental samples were collected during the 2013-14 recreation seasons. Data used to determine status of the use are summarized in Table 26. Base aquatic life parameters that were evaluated include dissolved solids, arsenic, cadmium, chromium, copper, lead, nickel, selenium and zinc. Individual sample concentrations are first compared to outside mixing zone average (OMZA) numeric criteria. If the OMZA is exceeded in more than 10% of the total samples tested for any parameter, the use is considered non-support.

Tiered aquatic life parameters are evaluated using various different methods. Chlorophyll-*a*, TP, total nitrogen, and secchi depth are evaluated by first calculating a median value from the two year dataset, and then comparing this value to the criteria in Table I-1 of the 2012 Integrated Report. DO, pH, and ammonia are evaluated in a manner similar to the base aquatic life parameters. DO (average) and pH (median) concentrations are calculated from profile readings taken in either the epilimnion or the entire water column if the lake is not stratified. Status of the LH use is considered non-support if chlorophyll-*a*, DO, pH or ammonia exceeds criteria based on their assessment method. A watch list designation is assigned if TP, total nitrogen or secchi depth values exceed their criteria. The LH use of Archbold Reservoir # 2 is considered non-support due to median chlorophyll-*a* and total phosphorus levels exceeding the target values. In addition, more than 10% of dissolved oxygen measurements in the epilimnion were below the target value.

Useful information can be obtained from samples collected in the hypolimnion. This area near the bottom of the reservoir can become hypoxic if the consumption of DO by organisms breaking down organic matter exceeds re-aeration by atmospheric diffusion and photosynthesis. Fish access to habitat, cool water, and benthic prey can be limited if conditions become hypoxic (DO < 2 mg/L). Archbold reservoir is quite shallow throughout and experiences thorough mixing; thus, hypoxia or thermal stratification was not documented during sampling events.

A surface sediment sample was collected in October, 2013 and analyzed for metals, nutrients, s-VOCs (PAHs), PCBs, and pesticides (organo-chlorine insecticides). Most compounds tested were either not detected or were well below guidelines used by Ohio EPA to evaluate sediment data. The exception was copper which was detected at 451 mg/kg which is significantly above the ecoregion reference value of 42 ppm and exceeds the probable effect concentration (PEC) of 149 ppm above which harmful effects to aquatic life are likely to be observed. Effects could include reduced growth and survival of fish eggs, fry and macroinvertebrates. The source is most likely copper-based algaecides. Manganese and strontium were measured above the ecoregion reference values. Both are natural occurring elements and most likely are settling out of the water column and concentrating in the bottom sediments as a result of stream water being pumped to maintain the reservoir holding capacity.

Recreation Use

The recreation use was evaluated by measuring levels of *E. coli* bacteria at the lake (L-1) station. Each site was sampled 10 times over the two-year assessment period and respective geometric mean values were compared to the bathing water criterion of 126 cfu/100 ml. The recreation use is considered in support since the geometric mean was 2.8 cfu/100 ml at L-1.

Public Drinking Water Use

The public drinking water supply use was evaluated. Archbold Reservoir #2 supported the PWS water quality criteria and values for protecting human health for water bodies located in the Lake Erie drainage basin.

Fish Consumption Use

The fish consumption use was evaluated. No consumption advisors have been issued beyond the state wide advisory.

Table 26 - Summary of data used to determine status of the Lake Habitat use in Archbold Reservoir #2.

Parameter	Chl. *a* (µg/L)	Secchi (m)	Total Nitrogen (µg/L)	TP (µg/L)	D.O. (mg/L)	pH (SU)	NH_3-N (mg/l)
Draft Criteria	**≤6.0**	**≥2.60**	**≤1225**	**≤18**	**≥6.0**	**6.5>pH<9.0**	**(WQS)**
5/22/13	36.1	0.8	1100	18	9.63	8.34	<0.05 (0.6)
6/13/13	17.2	0.7	1590	34	7.19	8.20	0.08 (0.9)
7/18/13	27.3	1.09	150	rejected	5.27	8.69	<0.05 (0.2)
8/12/13	8.1	0.66	810	29	4.01	8.35	<0.05 (0.3)
9/18/13	85.6	0.52	540	87	8.00	8.33	<0.05 (0.5)
5/28/14	11.8	1.41	1090	19.9	8.59	8.15	<0.05 (0.7)
6/19/14	37.7J	N/A	780	22.5	N/A	N/A	<0.05
7/14/14	35.1	0.8	1040	70	6.76	8.18	<0.05 (0.5)
8/21/14	49.5	0.8	1120	50.7	7.38	8.22	<0.05 (0.5)
9/30/14	22.5	1.03	470	18.7	8.92	7.99	<0.05 (1.3)
Median	**31.2**	**0.8**	**925**	**29**	**N/A**	**N/A**	**N/A**
% Exceeded	**N/A**	**N/A**	**N/A**	**N/A**	**22%**	**0%**	**0%**
Narrative	Non-support	watch list	support	watch list	Non-support	support	support

FISH TISSUE CONTAMINATION

Ohio has been sampling streams annually for sport fish contamination since 1993. Fish are analyzed for contaminants that bioaccumulate in fish and that could pose a threat to human health if consumed in excessive amounts. Contaminants analyzed in Ohio sport fish include mercury, PCBs, DDT, mirex, hexachlorobenzene, lead, selenium, and several other metals and pesticides. Other contaminants are sometimes analyzed if indicated by site specific current or historic sources. For more information about the chemicals analyzed, how fish are collected, or the history of the fish tissue contaminant program, see State Of Ohio Cooperative Fish Tissue Monitoring Program (Ohio EPA 2012b) or the Sport Fish Consumption Advisory Program web page: http://www.epa.state.oh.us/dsw/fishadvisory/index.aspx .

Fish contaminant data are primarily used for three purposes: 1) to determine fish consumption advisories; 2) to determine attainment of the human health (fish contaminants) WQS criteria; and 3) to examine trends in fish contaminants over time.

Fish Consumption Advisories

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (e.g., two meals a week, one meal a month, do not eat), and a fish advisory is issued for applicable species and locations. Because mercury mostly comes from nonpoint sources, primarily aerial deposition, Ohio has had a statewide one meal a week advisory for most fish since 2001. Most fish are assumed to be safe to eat once a week unless specified otherwise in the fish advisory, which can be viewed at http://www.epa.state.oh.us/dsw/fishadvisory/index.aspx.

The minimum data requirement for issuing a fish advisory is three samples of a single species from within the past 10 years.

The following advisories were in place for the Tiffin River prior to the 2013 sampling:

- "One meal per month" advisories for common carp, freshwater drum, northern pike, and smallmouth bass, all due to mercury.

As a result of the 2013 sampling, the following adjustments were made:

- The northern pike advisory was adjusted to only include fish 25" and greater (denoting an improvement for that species),
- A "one meal per month" advisory for channel catfish 20" and greater was added due to mercury,
- A "one meal per month" advisory was added for all flathead catfish due to mercury.

Neither Mud Creek nor Lick Creek had consumption advisories in place prior to the current sampling, and no advisories were added as a result of the sampling.

A summary of fish tissue data collected from the Tiffin River and tributaries in support of the advisory program and how the data compare to advisory thresholds is contained in Appendix J.

Human Health (Fish Contaminants) Use Attainment

In addition to determining safe meal frequencies, fish contaminant data are also used to determine attainment with the human health WQS criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health criteria are presented in water column concentrations of µg/Liter, and are then translated into fish tissue concentrations in mg/kg. See Ohio's 2010 Integrated Report, Section E (http://www.epa.state.oh.us/portals/35/tmdl/2010IntReport/Section%20E.pdf) for further details of this conversion (Ohio EPA 2012d).

In order to be considered in attainment of the human health WQS criteria, the sport fish caught within a HUC-12 in the Lake Erie basin must have a weighted average concentration of the geometric means for all species below 0.350 mg/kg for mercury, and below 0.023 mg/kg for PCBs.

The following table summarizes changes to the study area watersheds as a result of the 2013 sampling (note that these updates are estimates of anticipated changes to Ohio's 2016 Integrated Report):

Table 27. Anticipated updates to the human health (fish contaminants) use attainment status of watersheds assessed as part of the Tiffin River survey, 2013. Sites shaded in red are in non-attainment, while sites shaded in green are in attainment of the human health water (fish contaminants) WQS criteria.

HUC12	Name	Previous status	Was previous data current?	Sufficient data to reassess?	Outcome
04100006 06 02	Mud Creek	Unimpaired	No	No	No change
04100006 04 04	Lower Lick Creek	Unassessed	NA	No	No change
04100006 05 03	Village of Stryker-Tiffin River	Unassessed	NA	Yes	Unimpaired
04100006 03 01	Bates Creek-Tiffin River	Impaired	No	Yes	Unimpaired

Fish Contaminant Trends

Fish contaminant levels can be used as an indicator of pollution in the water column at levels lower than laboratory reporting limits for water concentrations but high enough to pose a threat to human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain types of chemicals like PCBs, and because of stricter permitting limits on dischargers for other chemicals. However, data show that PCBs continue to pose a risk to humans who consume fish, and mercury concentrations have been increasing in some locations because of increases in certain types of industries for which mercury is a byproduct that is released to air and/or surface water.

For this reason, it is useful to compare the results from the survey presented in this report with the results of the previous survey(s) done in the study area. Recent data can be compared against historical data to determine whether contaminant concentrations in fish tissue appear to be increasing, decreasing, or staying the same in a water body or watershed.

The primary difficulty in assessing contaminant trends is that fish tissue contamination can be affected by a number of factors other than time, including water body, location, trophic level, species, age, and size. Additionally, during surveys, relatively limited sample sizes may be collected, the characteristics of which generally vary between survey years. For example, different species may be collected during different years, or different size classes, or fish from different locations. Therefore, assessing the temporal trend of tissue contamination is often difficult unless the trend is very pronounced and the sample size is relatively large. As a result, the present analysis is limited to the Tiffin River mainstem.

One method that aids in this process is the use of 3D graphs to separate the effect of two predictor variables. In the charts below, tissue contamination is viewed by both year and species. It remains important to bear in mind that samples from the same species collected in two different years may not be equivalent—sampled fish may have been different sizes or collected from different river reaches, which has the effect of introducing statistical noise into the trends.

Figure 47 reflects fish tissue PCB contamination in the Tiffin River mainstem according to year and species. PCBs were detected at moderate levels in 1982, followed by a decline and stable levels in subsequent years. It is apparent that the Tiffin River is relatively unimpacted by PCB contamination. Even the higher values reflected on this chart (on the order of 0.60 ppm PCBs, observed in 1982) are considered moderate. Most samples results were non-detect over time.

Figure 48 below reflects fish tissue mercury contamination in the Tiffin River mainstem. No particular trend is apparent in the data. Mercury contamination appears to be relatively stable over the long term, with substantial fluctuation between individual samples. This is a common trend for mercury contamination in Ohio's fish.

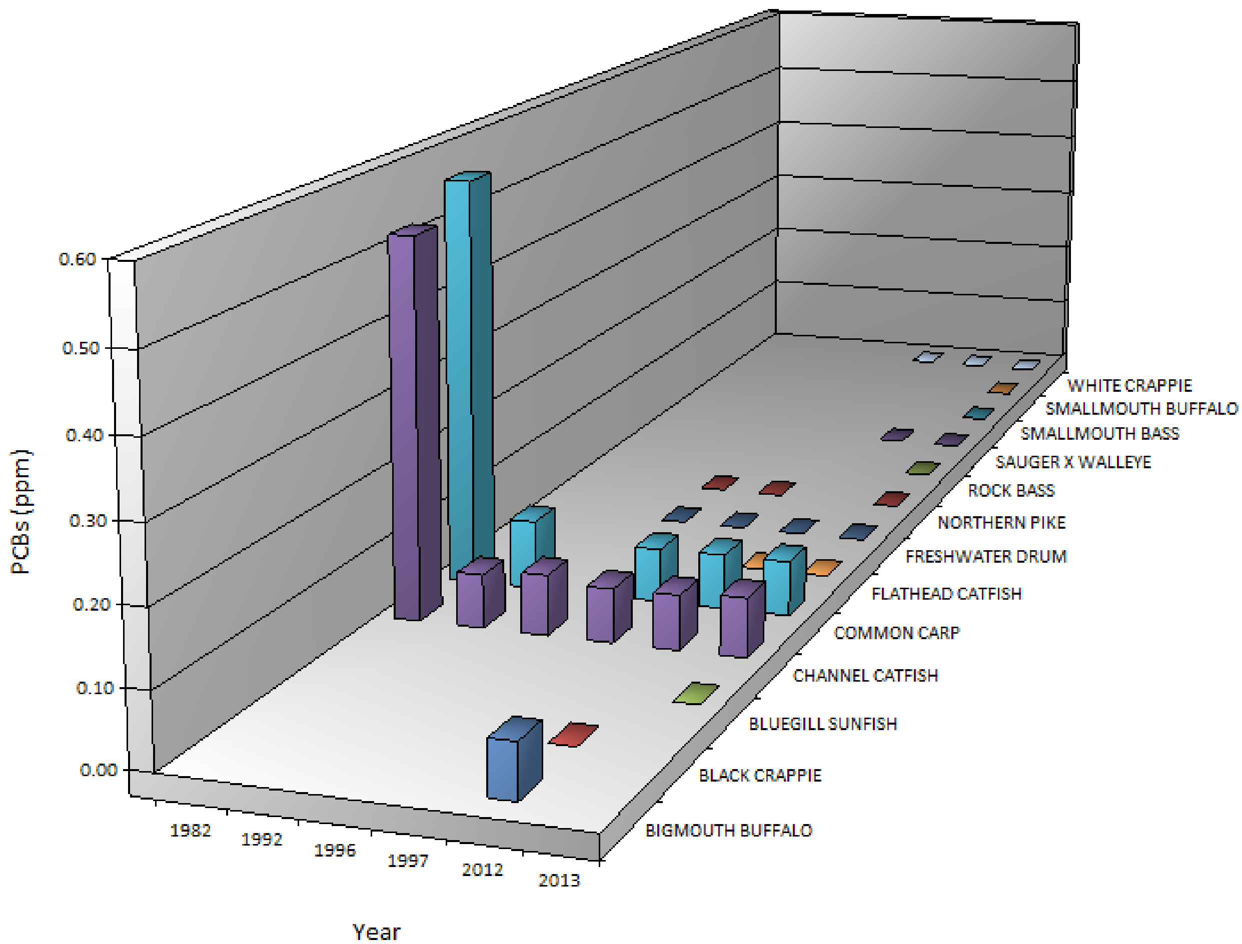

Figure 47. PCB contamination in Tiffin River fish, by year and species.

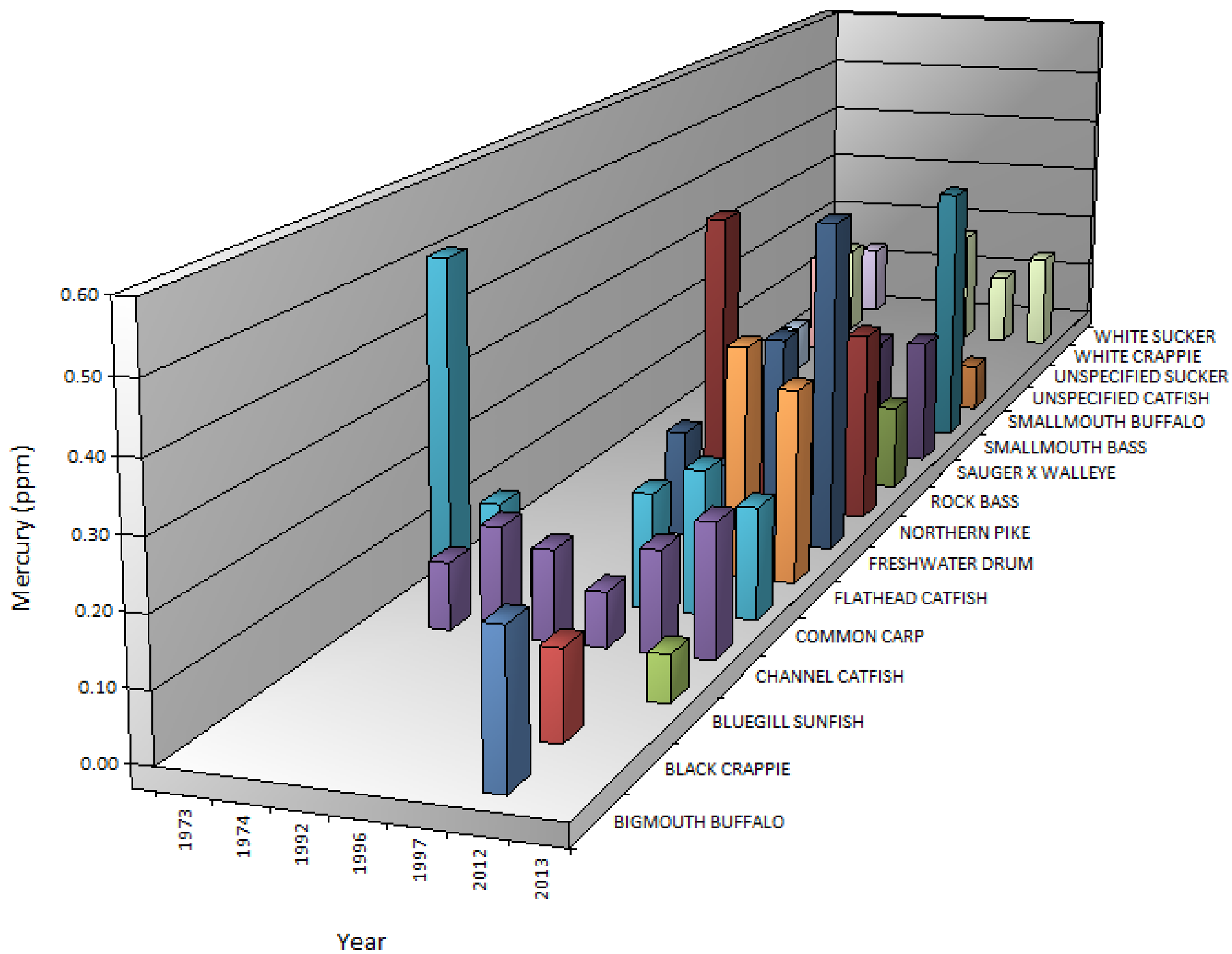

Figure 48. Mercury contamination in Tiffin River fish, by year and species.

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