Upper Fox River Water Quality Monitoring Report

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Acknowledgements

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Table of Contents

Map List

Table List

Chart List

Photo List

Appendices List

Definitions

Aquatic Macroinvertebrates: Animals without backbones that can be seen without magnification and that spend all or a portion of their lifecycle in water.

Base flow: The typical flow rate for a given stream at a particular time of year. Usually, the contribution that groundwater flow makes in sustaining water yields in a stream during periods of no rainfall (Dunster 1996).

Biodiversity: The spectrum of life forms and the ecological processes that support and sustain them.

Chlorophyll A Analysis: A measure of the amount of algal production within the water column.

Emergent Aquatic Plants: Plants with parts extending above the water's surface.

Meander: Regular and repeated bends of similar amplitude and wavelength along a stream channel. A meandering stream has a single channel that winds snakelike through its valley, so that the distance 'as the stream flows' is greater than 'as the crow flies'.

Nonwadeable River: A river reach with more than 3 kilometers of continuous channel too deep to sample effectively by wading during summer base flow.

Nutrient: A substance or ingredient that promotes growth, provides energy, and maintains life.

Reference Condition: Relatively unimpacted by human influences.

Submersed Aquatic Plants: Plants with most of their leaves underwater, though some leaves may be floating on the surface.

Substrate: The stream/river bottom and/or rocks, sediment, wood, and other solid items that provide habitat for aquatic life.

Suspended Solids: A measure of the amount of sediment, algae and other organic and inorganic substances floating in the water column.

TMDL: The Total Maximum Daily Load (TMDL) study and implementation plan will provide a strategic framework and prioritize resources for water quality improvement in the Upper Fox-Wolf Basin.

Upper Pool Lakes: Refers to the group of Lakes Poygan, Winneconne, and Butte des Morts near Oshkosh, WI.

Water Quality Criteria (WQC): Refers to Wisconsin Administrative Code NR 102: Water Quality Standards for Wisconsin Surface Waters.

Watershed: An area of land that collects water from rainfall or snowmelt (used interchangeably with Basin).

Wetland: Land that has water either above ground or below at least part of the year, soils that were developed under wet conditions, and plants that have adopted to growing in water or wet soil.

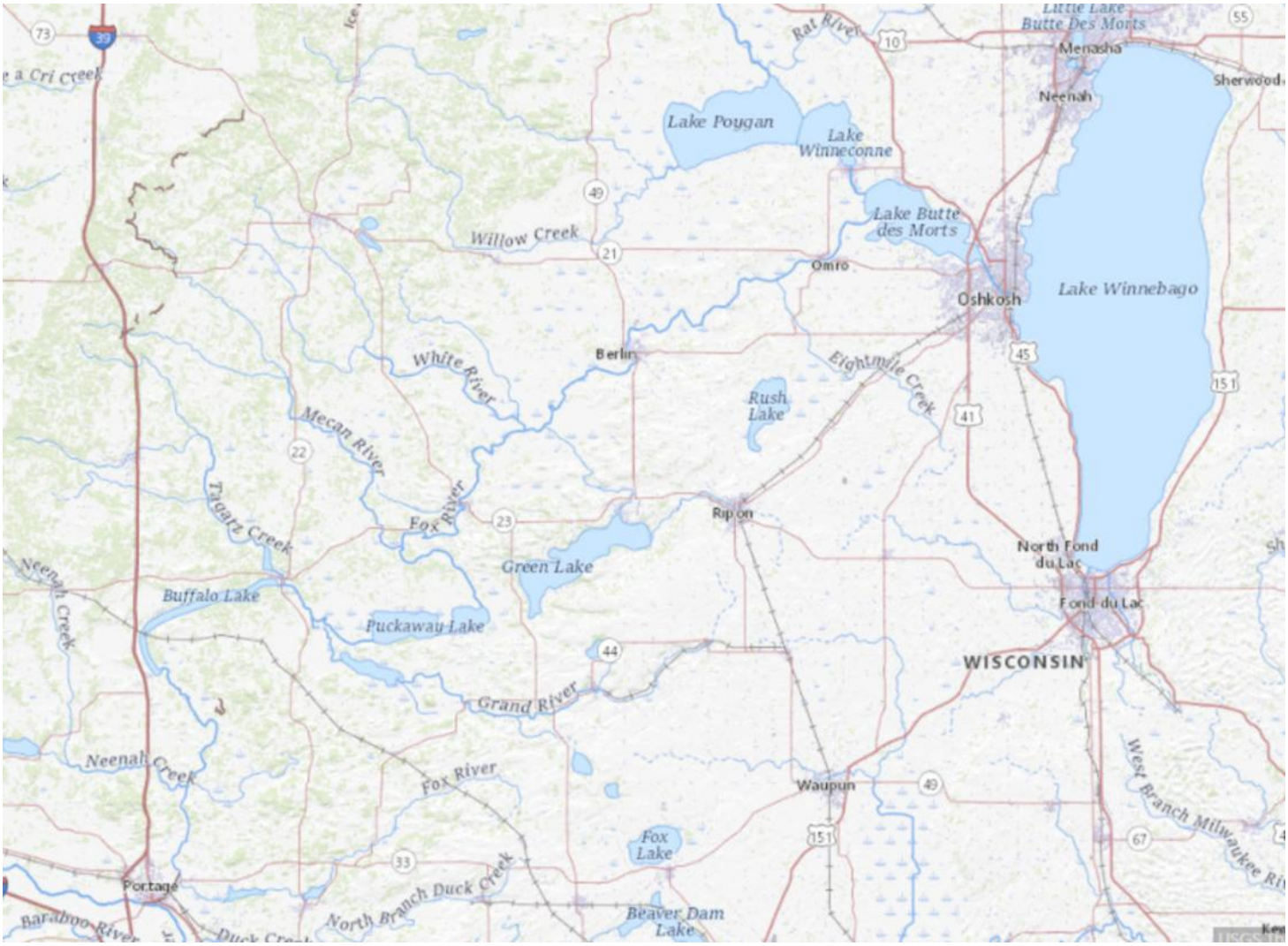
Winnebago Pool Lakes: Refers to the group of Lakes Winnebago, Butte des Morts, Winneconne, and Poygan near Oshkosh, WI.

Executive Summary

The Upper Fox River suffers from poor water quality and biotic communities impacted by the land uses within the Basin and the 4 lakes that it flows through as it makes its way toward Lakes Butte des Morts and Winnebago in northeast Wisconsin. There are many public uses within the Upper Fox River Basin; from recreational fishing and boating on the river, its many tributaries, and the Winnebago Pool Lakes, to hunting, hiking, and bird watching on the thousands of public land acres, to a landscape dominated by agriculture with a mix of industry driving the economy. Long term water quality monitoring, mainly nutrient concentration sampling, has been conducted on the Upper Fox River at relatively few places within the basin. This project aimed to expand that monitoring effort for a more thorough evaluation of both the water chemistry and biological communities.

Nutrient concentrations within the Upper Fox River over the growing season of 2019 were above reference (relatively unimpacted by human influence) conditions for Wisconsin Nonwadeable Rivers (USGS 2008) and near our Water Quality Criterion for Rivers in Wisconsin Administrative Code NR 102 (WDNR 2024). The biological communities, both fish and aquatic macroinvertebrates, and nutrient concentrations indicate very poor to fair water quality.

Map 1: Upper Fox River Basin



Introduction

The beautiful Upper Fox River begins its journey in rural Columbia and Green Lake Counties, flowing west before turning northeast toward Lake Winnebago in the Fox Valley of Wisconsin. The Upper Fox River Basin drains the western edge of the Lake Michigan Basin. The Upper Fox River Basin is located in east-central Wisconsin, which includes all of Marquette County and portions of Adams, Calumet, Columbia, Fond du Lac, Green Lake, Winnebago and Waushara Counties. The total area of the basin is 2,090 square miles. All streams draining to Lake Winnebago, with the exception of those in the Wolf River Basin, are located in the Upper Fox River Basin boundary. The Fox River flows through 4 lakes (Park, Swan, Buffalo, and Puckaway) which influence its water quality before flowing into Lake Butte des Morts where the flow from the Wolf River Basin joins prior to emptying into Lake Winnebago.

The Upper Fox River is the largest surface water resource for the communities that have been developed around it, driving economy, recreation, and agriculture.

Purpose

This project evaluated the water quality of the Fox River and five of its main tributaries. Fish and macroinvertebrate communities were surveyed as well as nutrient and suspended solids monitoring to evaluate water quality of each tributary and section of the Fox River. This water quality monitoring provides a good baseline assessment of the Upper Fox River and its main tributaries as the Upper Fox-Wolf River Total Maximum Daily Load (TMDL) is being implemented.

Methods

Inorganic Sampling

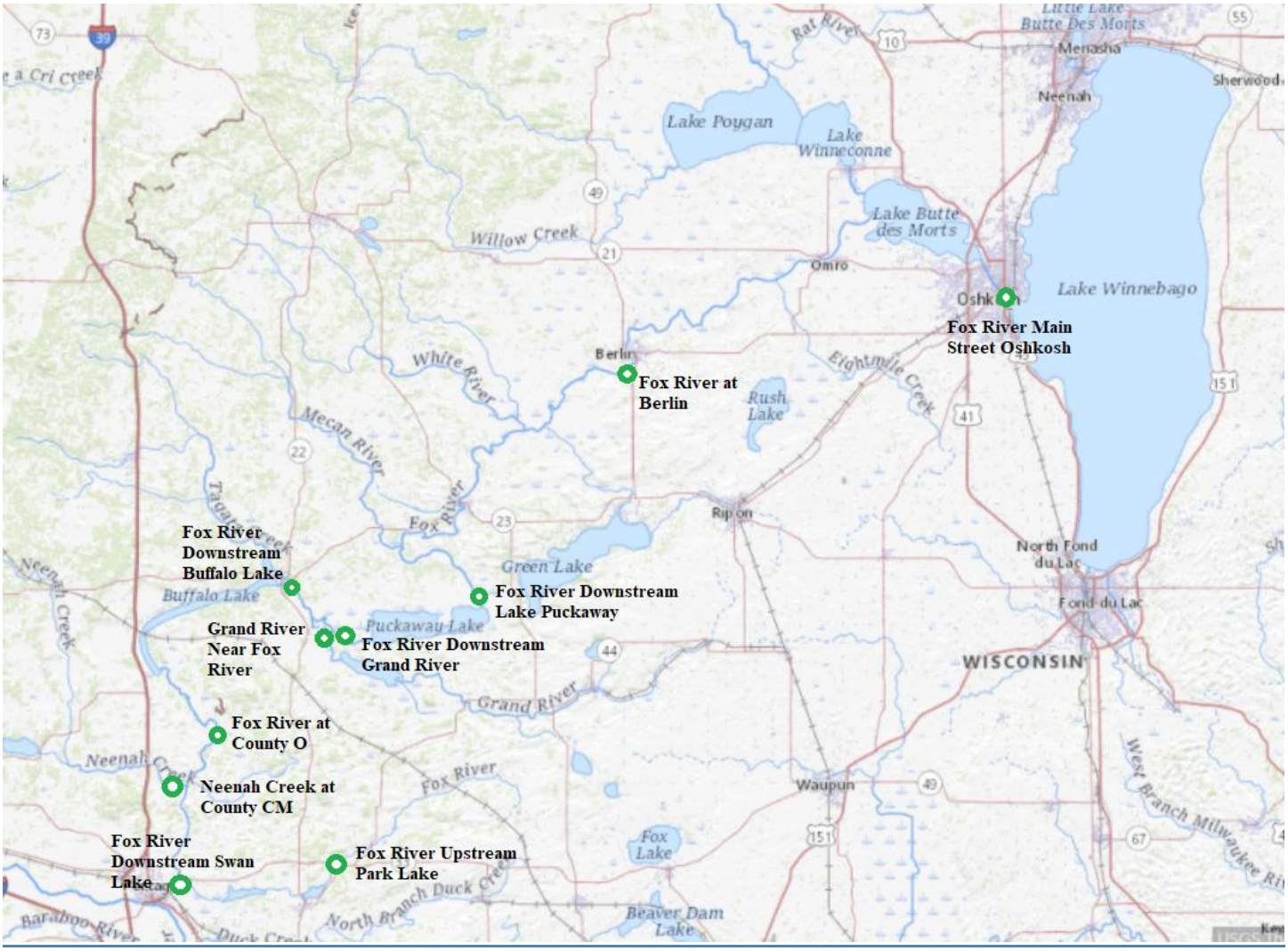
During the growing season of 2019, nutrient, chlorophyll A, and Total Suspended Solids samples were collected at 10 locations once per month from May through October (Table 1, Map 2, Photo 1-2) following the WDNR *Nutrient Chemistry Grab Sampling Method V3.3* (WDNR 2015). Nutrient analysis conducted on the monthly samples were Total Phosphorus (TP), Dissolved Orthophosphate (DOP), Total Nitrogen (TN), Dissolved Ammonia as N (NH3-N), Nitrite-Nitrates as N (NO_2+NO_3-N). Total Suspended Solids (TSS) is a measure of the amount of sediment, algae and other organic and inorganic substances floating in the water column. Chlorophyll A (Chl A) analysis is a measure of the amount of algal production within the water column. All samples were collected using the standard Wisconsin Department of Natural Resources (DNR) grab sampling method for a total of 60 samples (WDNR 2015). Neither baseflow nor storm event sampling were targeted during this project, following the protocol of Wisconsin Consolidated Assessment and Listing Methodology (WisCALM 2018). All nutrient samples were shipped to Wisconsin State Laboratory of Hygiene (SLH) for analysis. The SLH entered all sample analysis data into the DNR Surface Water Integrated Monitoring System (SWIMS) database.

Photos 1-2: Water Resources Staff Collecting Inorganic Chemistry Samples in the Fox River Basin May Through October 2019.

Table 1: Inorganic Chemistry Monitoring Sites Sampled in the Fox River Basin May Through October 2019.

SWIMS Station ID	Site Name
10014339	Fox River upstream Park Lake
10017269	Fox River downstream Swan Lake
10011616	Fox River at County O
393006	Fox River downstream Buffalo Lake
10033617	Fox River downstream Grand River
10022806	Fox River downstream Lake Puckaway
243058	Fox River at Berlin
713056	Fox River at Main Street Oshkosh
113070	Neenah Creek at County CM
10033618	Grand River near Fox River

Map 2: Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Monitoring Locations in the Upper Fox River in 2019.



Water Clarity

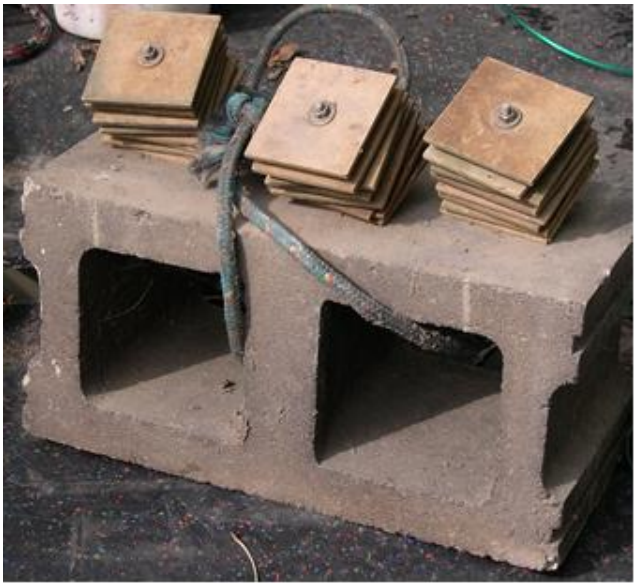
At each inorganic sampling event in May through October 2019, a measure of water clarity was conducted using a standard 120-centimeter water clarity tube for a total of 60 water clarity assessments (Table 1, Photo 3). The SLH entered all water clarity data into the DNR SWIMS database.

Photo 3: Water Clarity Tube Used In The Fox River Basin May Through October 2019.

Macroinvertebrate Sampling

Twelve river locations were sampled for aquatic macroinvertebrates between July and September 2019-2021 (Map 2, Table 2). Sites were sampled using the DNR *Large River Macroinvertebrate Sampling (V2.0) Water Quality Monitoring Program* (WDNR 2015). Each non-wadeable location was sampled by deploying Hester-Dendy artificial substrate samplers for a period of 6 weeks (Photo 4). The aquatic macroinvertebrates from the non-wadeable sites were preserved in a 70-80% ethanol solution inside quart "Mason" jars. Within the next 24 hours, the samples were represerved with another 70-80% ethanol solution. Samples were taken to the UWSP Aquatic Biology Laboratory (ABL) for lowest possible taxonomic identification. Staff at the ABL entered the data into the SWIMS database.

Photos 4-5: Non-wadeable Macroinvertebrate Collection Equipment and Deployment in the Upper Fox River Basin 2019-2021.



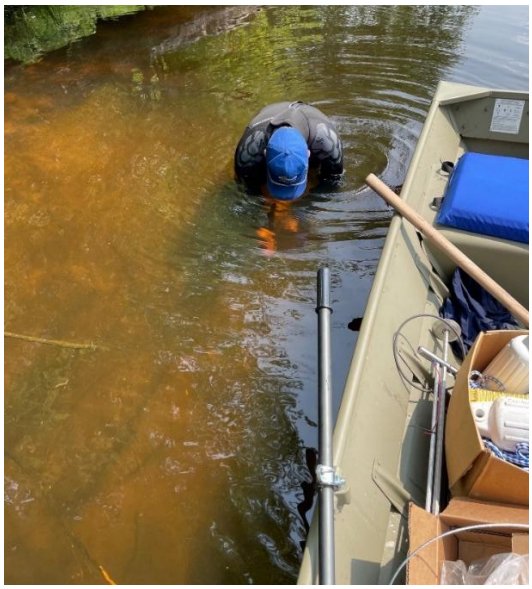
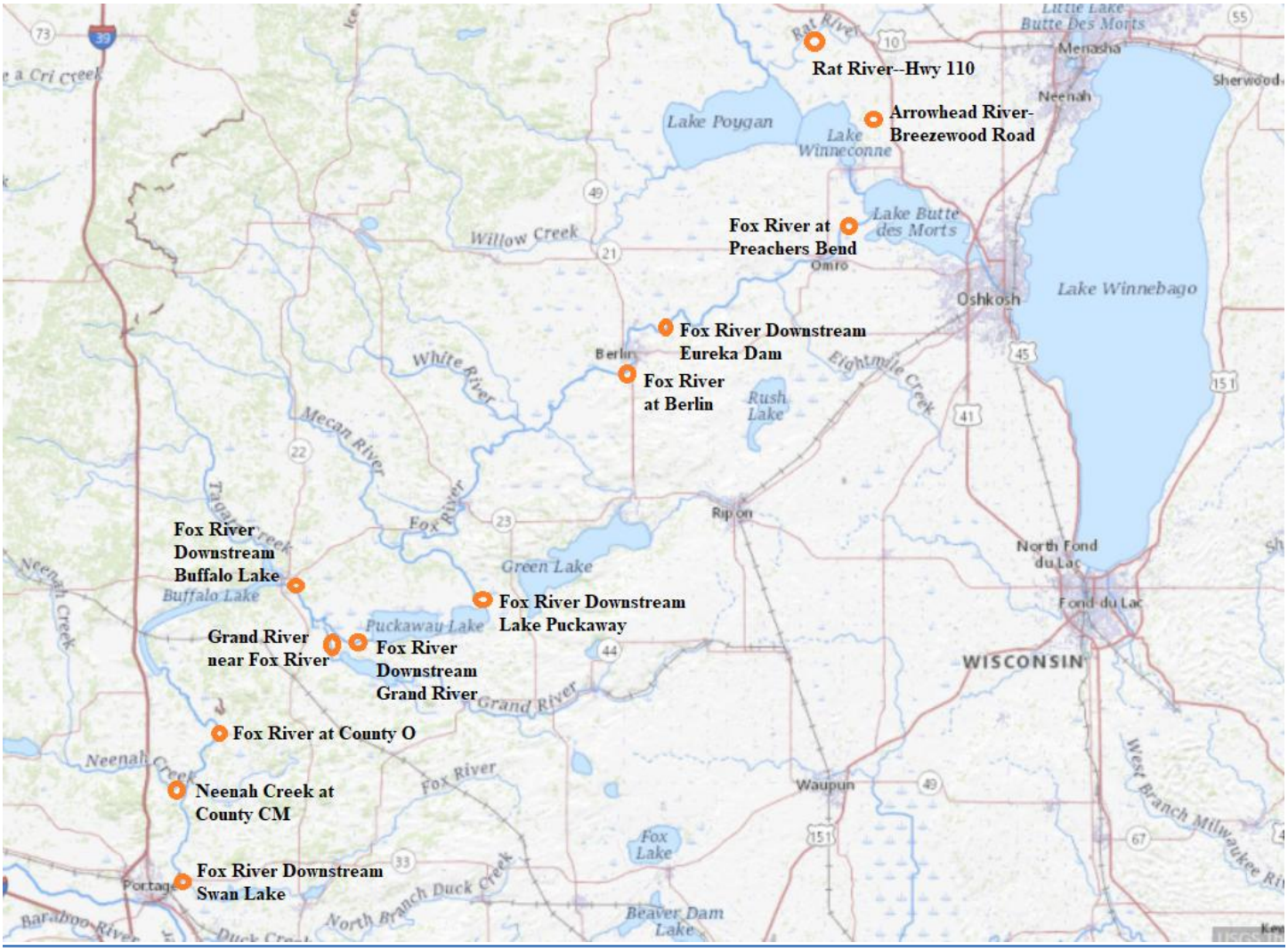


Table 2: Aquatic Macroinvertebrate Monitoring Locations Sampled in 2019-2021.

SWIMS Station ID	Site Name
10017269	Fox River downstream Swan Lake
10011616	Fox River at County O
393006	Fox River downstream Buffalo Lake
10033617	Fox River downstream Grand River
10022806	Fox River downstream Lake Puckaway
243058	Fox River at Berlin
10052990	Fox River downstream Eureka Dam
10052402	Fox River at Preachers Bend 2.0 miles upstream Lake Butte des Morts
113070	Neenah Creek at County CM
10033618	Grand River near Fox River
10016758	Rat River – Hwy 110
713267	Arrowhead River – Breezewood (Woodland) Road

Map 3: Macroinvertebrate Monitoring Locations in the Upper Fox River 2019-2021.



Fisheries Surveys

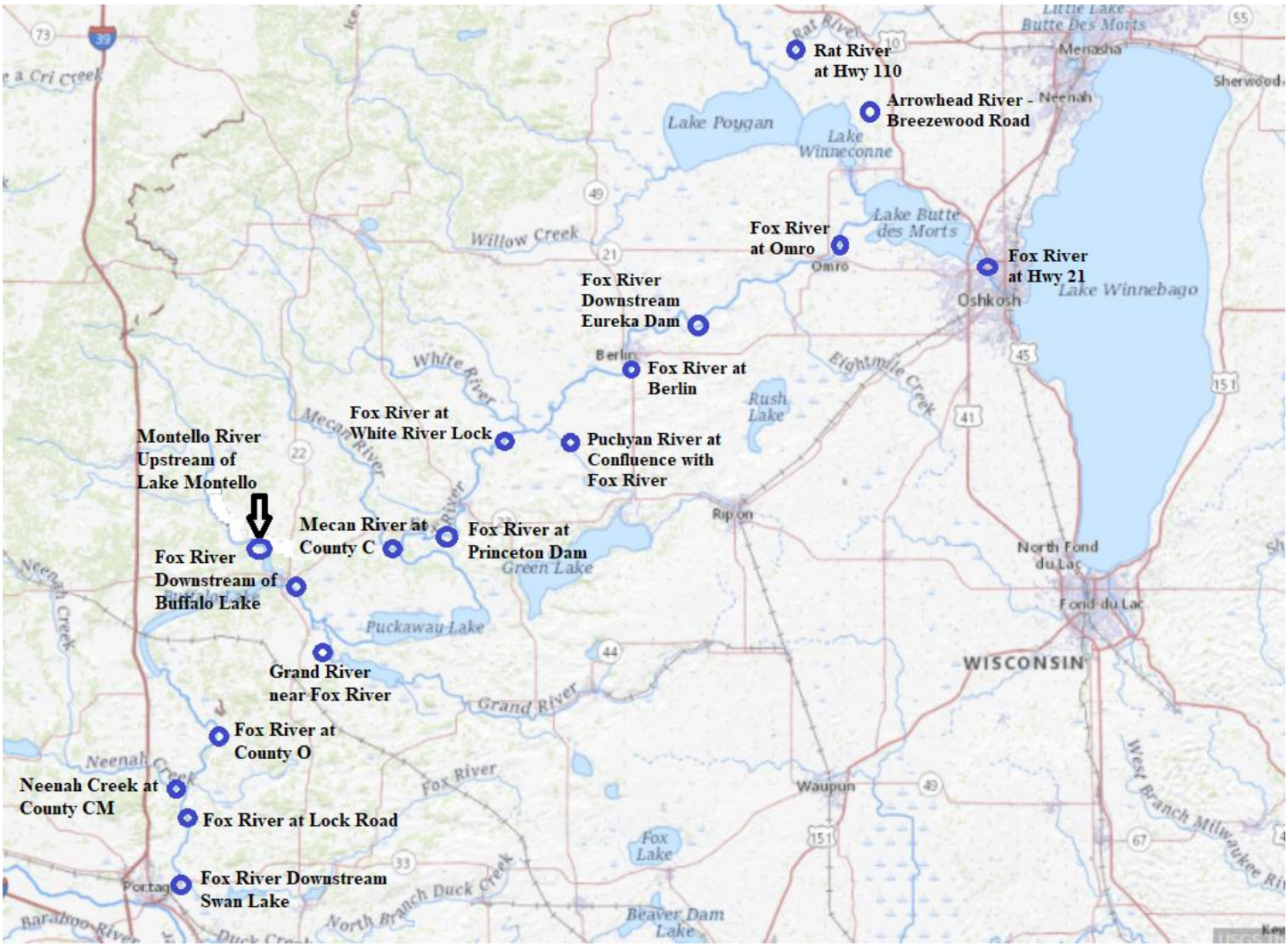
Between 2019 and 2020, seventeen river locations were surveyed for representative fish communities (Map 3, Table 3, Photo 6-7). The fish community at each location was surveyed following the *Baseline Monitoring – Non-Wadable Streams Protocols* (Lyons et. al. 2001). The protocol requires sampling 1 mile of contiguous main-channel-border habitats, which are relatively shallow shoreline areas along the river channel that carry the majority of the river flow. The 17 fish community surveys were conducted during the protocol required time between June 15th and September 30th. Standard equipment is a boat-mounted, pulsed-DC electrofishing unit (Photo 6). During the survey, a single person uses a 17mm-mesh dip net to attempt to capture all fish seen. Captured fish are identified to species, counted, and weighed (Photo 7). Game fish were measured for individual lengths and weights, but other species did not need length information and were weighed in aggregate. Fish were released after processing back to the river. Fish survey data was entered into the WDNR Fisheries Management Information System database (FMIS) by WDNR Water Resources staff.

Photos 6-7: Non-wadeable Fish Community Survey Equipment in the Upper Fox River Basin 2019-2020.

Table 3: Large River Fish Survey Locations Sampled in the Upper Fox River Basin between 2019 and 2020.

SWIMS Station ID	Site Name
10017269	Fox River downstream Swan Lake
113093	Fox River at Lock Road
10011616	Fox River at County O
393006	Fox River downstream Buffalo Lake
10056016	Fox River at Princeton Dam
10049421	Fox River at White River Lock
243058	Fox River at Berlin
10052990	Fox River downstream Eureka Dam
104481	Fox River at Omro
10049142	Fox River-Hwy 21/Oshkosh St Bridge
113070	Neenah Creek at County CM
10056021	Montello River Upstream Lake Montello
10033618	Grand River near Fox River
393005	Mecan River at County C
10056017	Puchyan River at Confluence with Fox River
10016758	Rat River – Hwy 110
713267	Arrowhead River – Breezewood (Woodland) Road

Map 3: Large River Fish Survey Locations in the Upper Fox River Basin 2019-2021.



Study Results

During the growing season of 2019, nutrient, chlorophyll A, total suspended solids and water clarity analysis was conducted at 10 locations once per month from May through October in the Upper Fox River Basin (Map 1). The results for each location are listed in Tables 4-13.

Table 4: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River Upstream of Park Lake in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River Upstream of Park Lake	May-19	0.076	0.012	3.77	0.015	2.9	14.0	17.3	120
	Jun-19	0.114	0.039	3.92	0.051	3.3	19.4	4.3	73
	Jul-19	0.102	0.069	4.92	0.069	0.1	13.4	3.4	74
	Aug-19	0.074	0.057	4.30	0.033	3.7	4.6	3.4	120
	Sep-19	0.150	0.085	2.37	0.040	1.2	9.6	2.7	100
	Oct-19	0.078	0.042	4.23	0.068	3.5	9.3	1.1	104
Median		0.090	0.050	4.08	0.045	3.1	11.5	3.4	102
Average		0.099	0.051	3.92	0.046	2.4	11.7	5.4	99

Table 5: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River Downstream of Swan Lake in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River Downstream of Swan Lake	May-19	0.042	0.002	1.91	0.033	1.170	2.4	3.4	120
	Jun-19	0.036	0.002	1.53	0.072	0.739	3.6	3.2	120
	Jul-19	0.059	0.022	1.09	0.022	0.022	2.2	2.1	120
	Aug-19	0.048	0.014	1.05	0.096	0.182	7.6	6.3	120
	Sep-19	0.047	0.006	0.87	0.028	0.074	8.2	14.6	86
	Oct-19	0.052	0.024	1.30	0.301	0.284	3.8	7.5	120
Median		0.048	0.010	1.20	0.052	0.233	3.7	4.9	120
Average		0.048	0.012	1.29	0.092	0.412	4.6	6.2	114

Table 6: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from Neenah Creek at County CM in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Neenah Creek at County CM	May-19	0.071	0.003	1.46	0.018	0.636	13.00	15.80	77
	Jun-19	0.083	0.015	1.44	0.058	0.649	11.20	9.13	105
	Jul-19	0.126	0.047	0.99	0.047	0.047	14.50	17.50	65
	Aug-19	0.103	0.044	0.87	0.047	0.085	8.75	10.80	103
	Sep-19	0.076	0.030	0.89	0.033	0.243	5.20	7.07	120
	Oct-19	0.053	0.020	1.71	0.054	0.994	4.00	4.96	120
Median		0.079	0.025	1.21	0.047	0.440	9.98	9.97	104
Average		0.085	0.027	1.22	0.043	0.442	9.44	10.88	98

Table 7: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River at County O in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River -County O	May-19	0.060	0.005	1.48	0.023	0.636	7.0	10.8	97
	Jun-19	0.081	0.015	1.46	0.071	0.618	7.8	10.1	112
	Jul-19	0.097	0.040	1.06	0.040	0.040	6.2	11.7	98
	Aug-19	0.083	0.037	0.99	0.054	0.210	4.4	6.6	120
	Sep-19	0.068	0.022	0.98	0.043	0.259	4.6	8.2	120
	Oct-19	0.057	0.024	1.56	0.089	0.713	3.8	3.8	120
Median		0.074	0.023	1.26	0.048	0.439	5.4	9.1	116
Average		0.074	0.024	1.25	0.053	0.413	5.6	8.5	111

Table 8: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River Downstream Buffalo Lake in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River Below Buffalo Lake	May-19	0.046	0.002	1.05	0.015	0.178	5.2	15.6	78
	Jun-19	0.073	0.021	1.07	0.076	0.216	5.2	9.1	101
	Jul-19	0.153	0.073	1.13	0.073	0.073	9.2	27.3	64
	Aug-19	0.096	0.037	0.83	0.021	0.036	6.6	22.6	101
	Sep-19	0.046	0.011	0.76	0.023	0.135	3.2	5.7	120
	Oct-19	0.051	0.026	1.30	0.041	0.484	3.5	5.5	120
Median		0.062	0.024	1.06	0.032	0.157	5.2	12.3	101
Average		0.078	0.028	1.02	0.041	0.187	5.5	14.3	97

Table 9: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Grand River Near the Fox River in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Grand River Near the Fox River	May-19	0.127	0.016	1.25	0.020	0.071	7.6	24.3	76
	Jun-19	0.151	0.107	0.99	0.054	0.075	5.6	2.0	120
	Jul-19	0.225	0.220	1.23	0.220	0.220	2.4	2.6	120
	Aug-19	0.106	0.088	1.20	0.105	0.179	2.0	3.3	120
	Sep-19	0.187	0.121	1.81	0.416	0.329	2.8	18.9	120
	Oct-19	0.125	0.085	1.68	0.042	0.532	2.2	4.4	120
Median		0.139	0.098	1.24	0.079	0.200	2.6	3.8	120
Average		0.154	0.106	1.36	0.143	0.234	3.8	9.3	113

Table 10: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River Downstream of Grand River in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River DS Grand River	May-19	0.052	0.002	1.09	0.015	0.214	6.0	18.2	74
	Jun-19	0.093	0.021	1.33	0.096	0.394	6.8	9.9	120
	Jul-19	0.151	0.080	1.06	0.080	0.080	10.4	24.1	75
	Aug-19	0.084	0.028	0.81	0.015	0.045	8.0	20.1	101
	Sep-19	0.133	0.075	1.43	0.233	0.287	4.6	12.6	120
	Oct-19	0.051	0.026	1.38	0.042	0.589	3.3	5.0	120
Median		0.088	0.027	1.21	0.061	0.251	6.4	15.4	111
Average		0.094	0.039	1.18	0.080	0.268	6.5	15.0	102

Table 11: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River Downstream of Lake Puckaway in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River Downstream Lake Puckaway	May-19	0.068	0.002	0.96	0.015	0.036	9.8	9.3	73
	Jun-19	0.070	0.006	0.99	0.015	0.036	10.3	26.6	81
	Jul-19	0.220	0.030	2.94	0.030	0.030	40.0	159.0	24
	Aug-19	0.150	0.025	1.66	0.032	0.036	41.0	89.8	29
	Sep-19	0.058	0.003	0.92	0.015	0.036	16.0	19.4	65
	Oct-19	0.064	0.011	1.39	0.015	0.340	13.8	23.3	63
Median		0.069	0.008	1.19	0.015	0.036	14.9	25.0	64
Average		0.105	0.013	1.48	0.020	0.086	21.8	54.6	56

Table 12: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River at Berlin in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River at Berlin	May-19	0.097	0.045	1.12	0.097	0.115	3.2	4.2	120
	Jun-19	0.115	0.025	1.21	0.039	0.183	13.8	29.1	82
	Jul-19	0.175	0.029	2.87	0.202	0.029	22.3	102.0	34
	Aug-19	0.135	0.032	1.88	0.107	0.453	31.3	66.7	45
	Sep-19	0.083	0.008	1.24	0.026	0.241	19.7	28.6	69
	Oct-19	0.036	0.007	1.34	0.015	0.398	3.5	22.3	120
Median		0.106	0.027	1.29	0.068	0.212	16.8	28.9	76
Average		0.107	0.024	1.61	0.081	0.236	15.6	42.2	78

Table 13: Summary of Nutrient, Suspended Solids, Chlorophyl A, and Water Clarity Results from the Upper Fox River at Main Street in Oshkosh in 2019.

Location	Sample Date	TP (mg/L)	DOP (mg/L)	TN (mg/L)	Ammonia (mg/L)	NO3+NO2-N (mg/L)	TSS (mg/L)	Chl A (mg/L)	Water Clarity (cm)
Fox River - Main St Oshkosh	May-19	0.058	0.006	1.17	0.016	0.036	20.7	50.2	54
	Jun-19	0.082	0.007	1.32	0.019	0.230	22.2	51.3	51
	Jul-19	0.122	0.020	1.68	0.023	0.064	28.3	96.3	41
	Aug-19	0.118	0.118	2.12	0.020	0.371	31.0	97.2	36
	Sep-19	0.109	0.010	1.79	0.015	0.299	42.0	65.5	39
	Oct-19	0.057	0.057	1.63	0.015	0.636	17.5	38.4	120
Median		0.095	0.015	1.66	0.017	0.265	25.3	58.4	46
Average		0.091	0.036	1.62	0.018	0.273	27.0	66.5	57

Chart 1: Total Phosphorus Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.

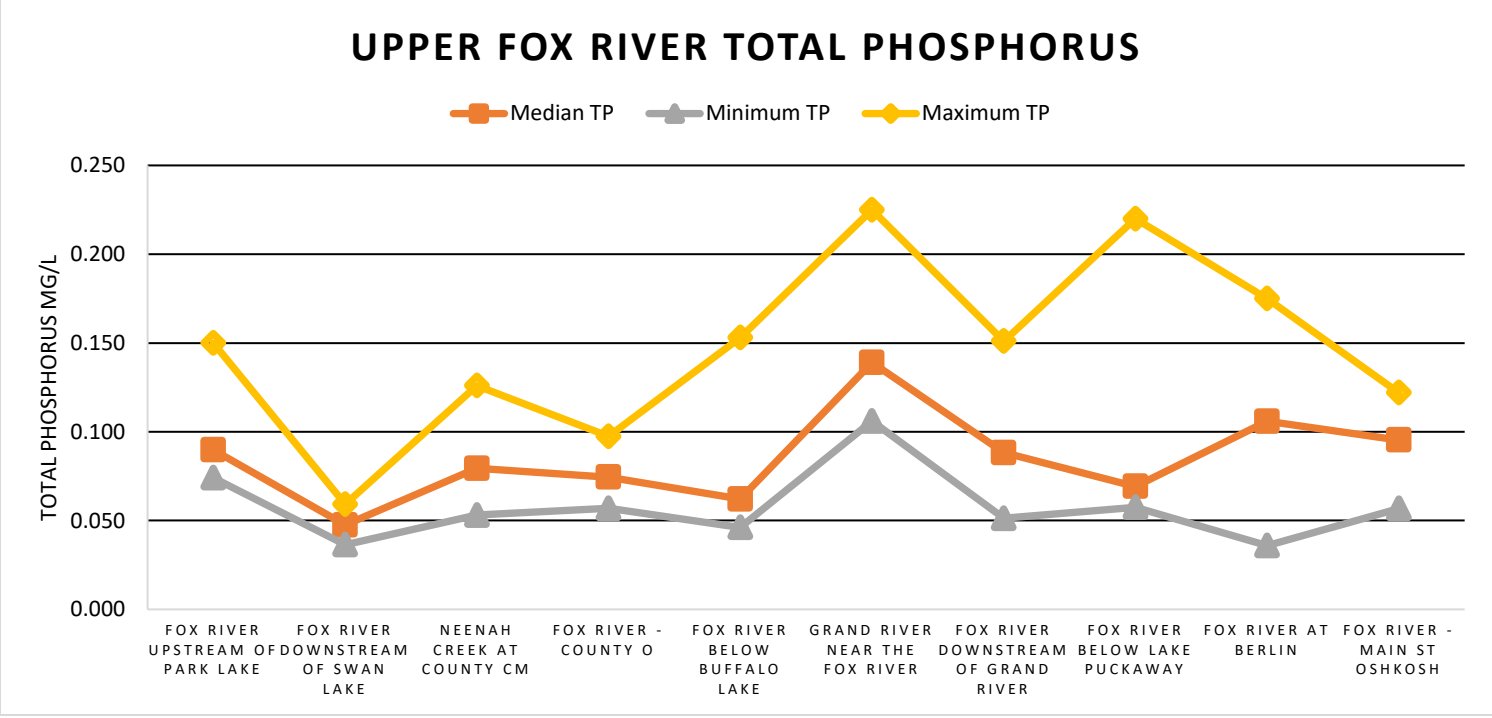


Chart 2: Dissolved Orthophosphate Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.

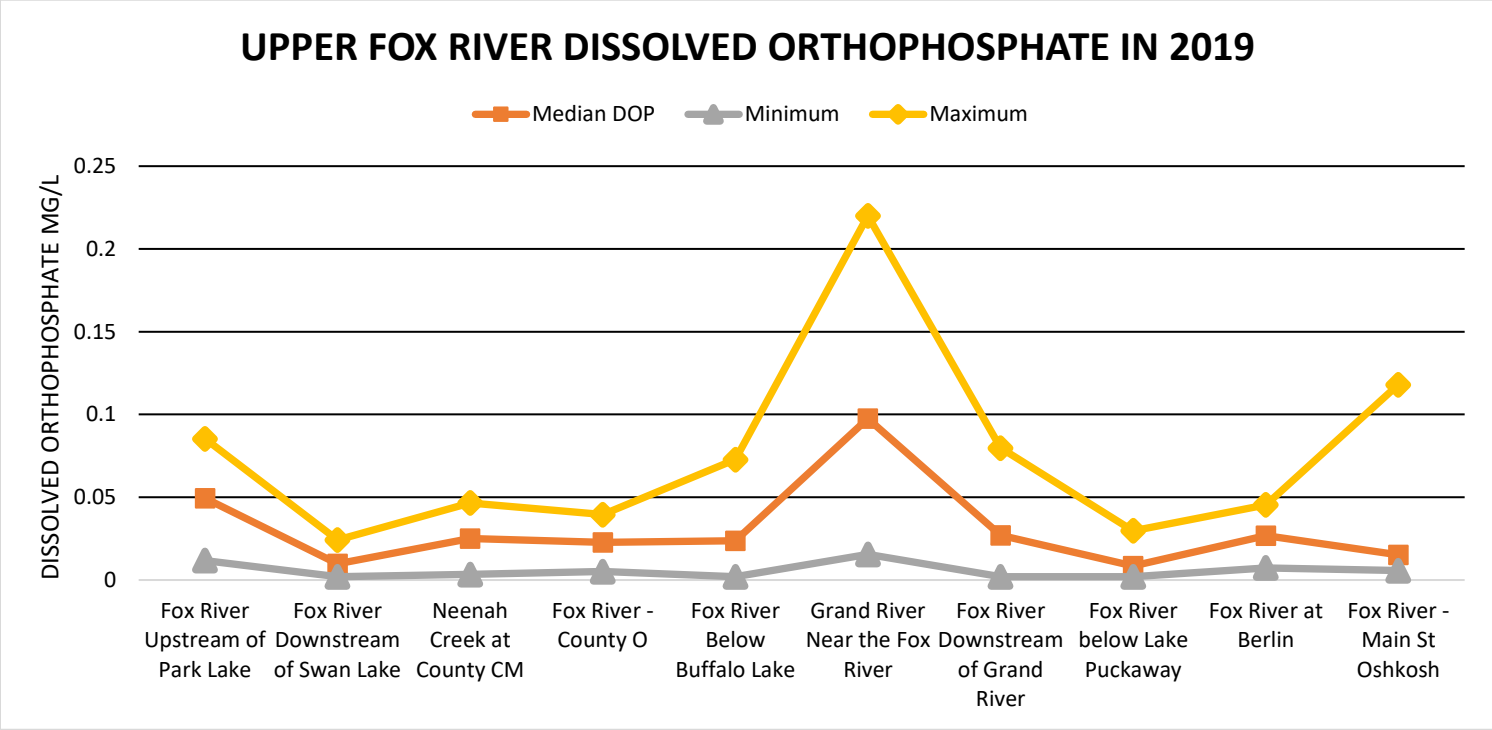


Chart 3: Total Nitrogen Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.

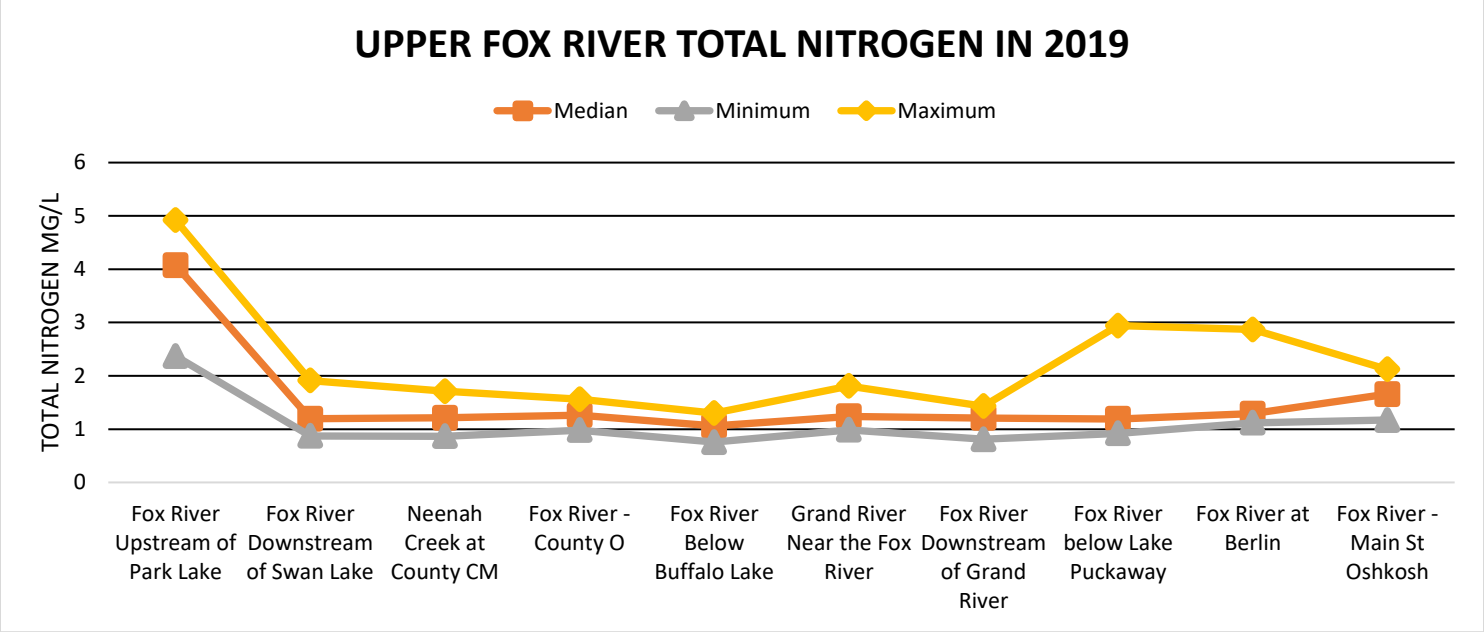


Chart 4: Ammonia Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.

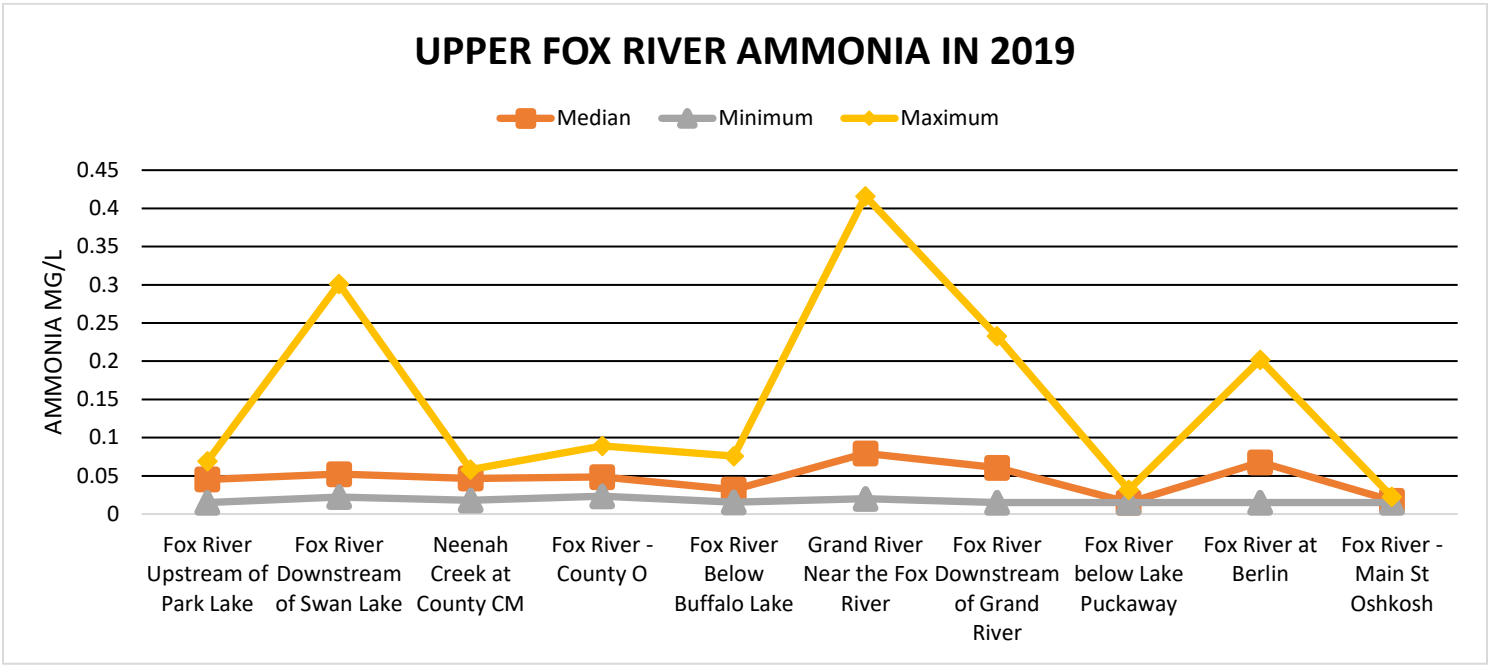


Chart 5: Nitrate + Nitrite as N Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.

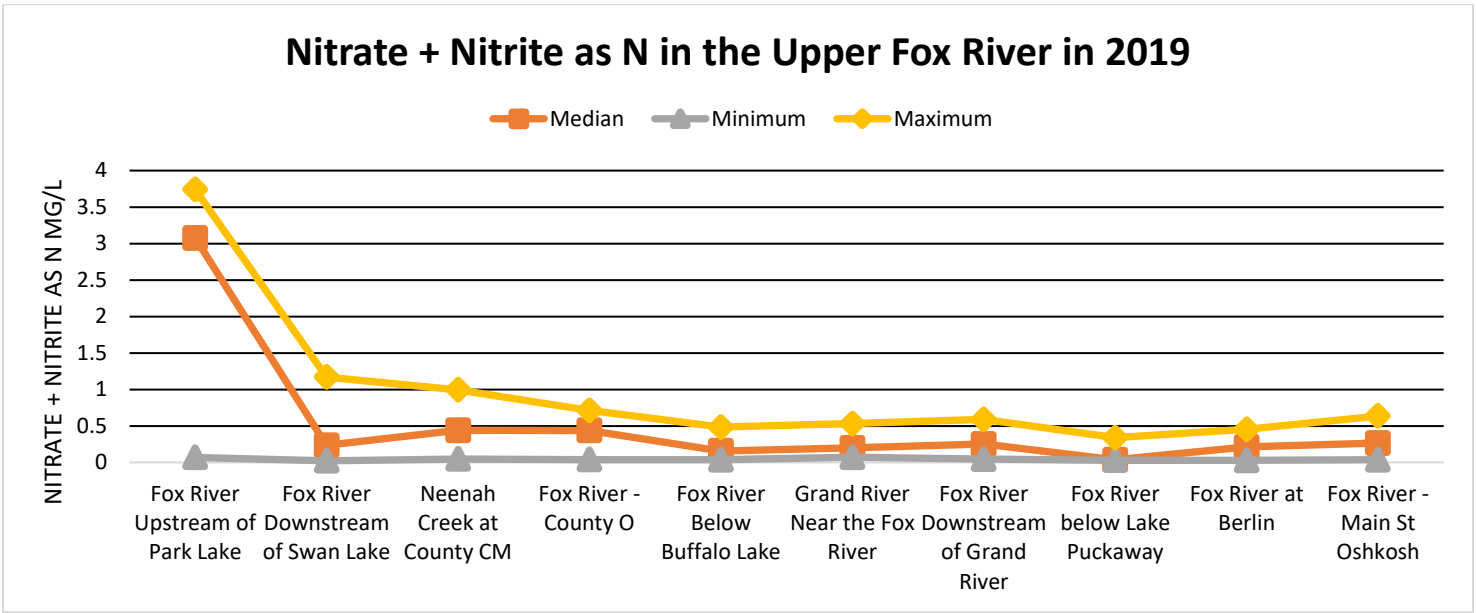


Chart 6: Total Suspended Solids Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.

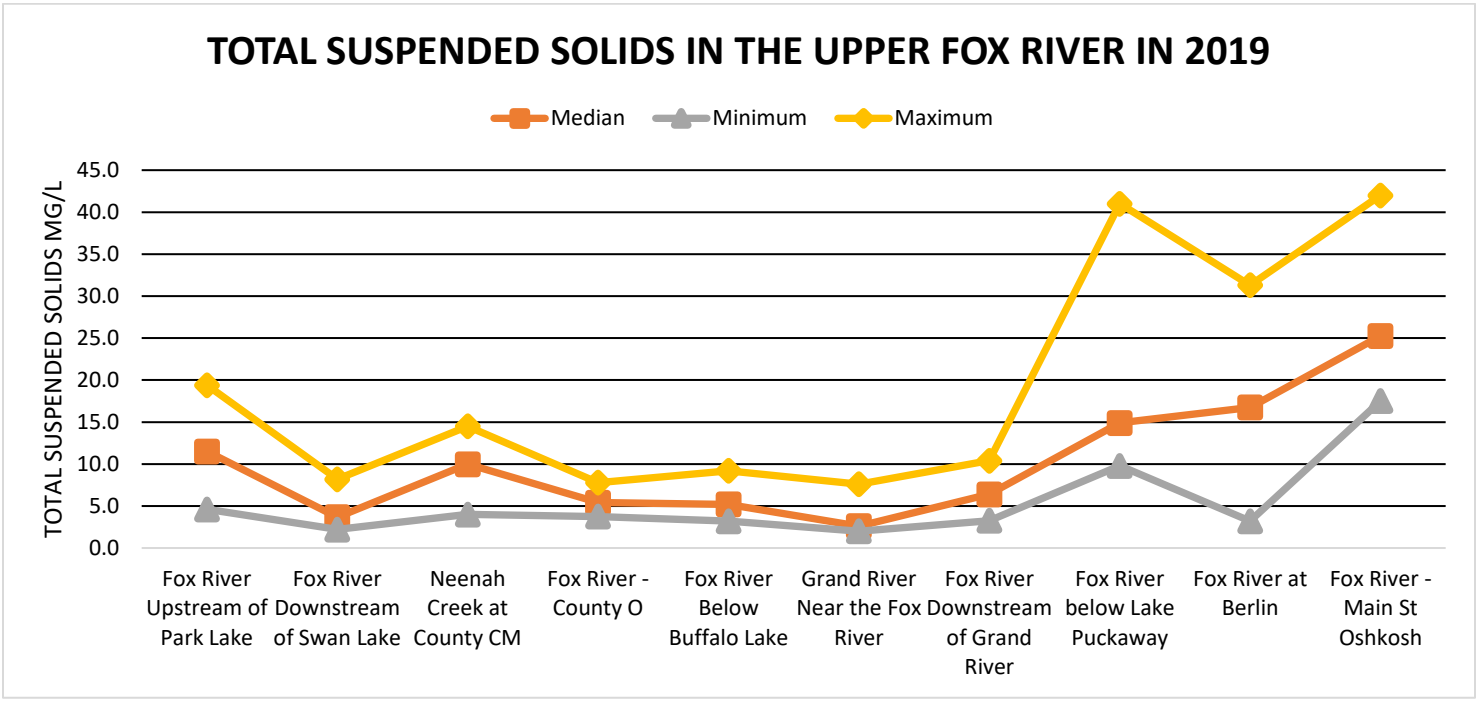


Chart 7: Chlorophyl A Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.

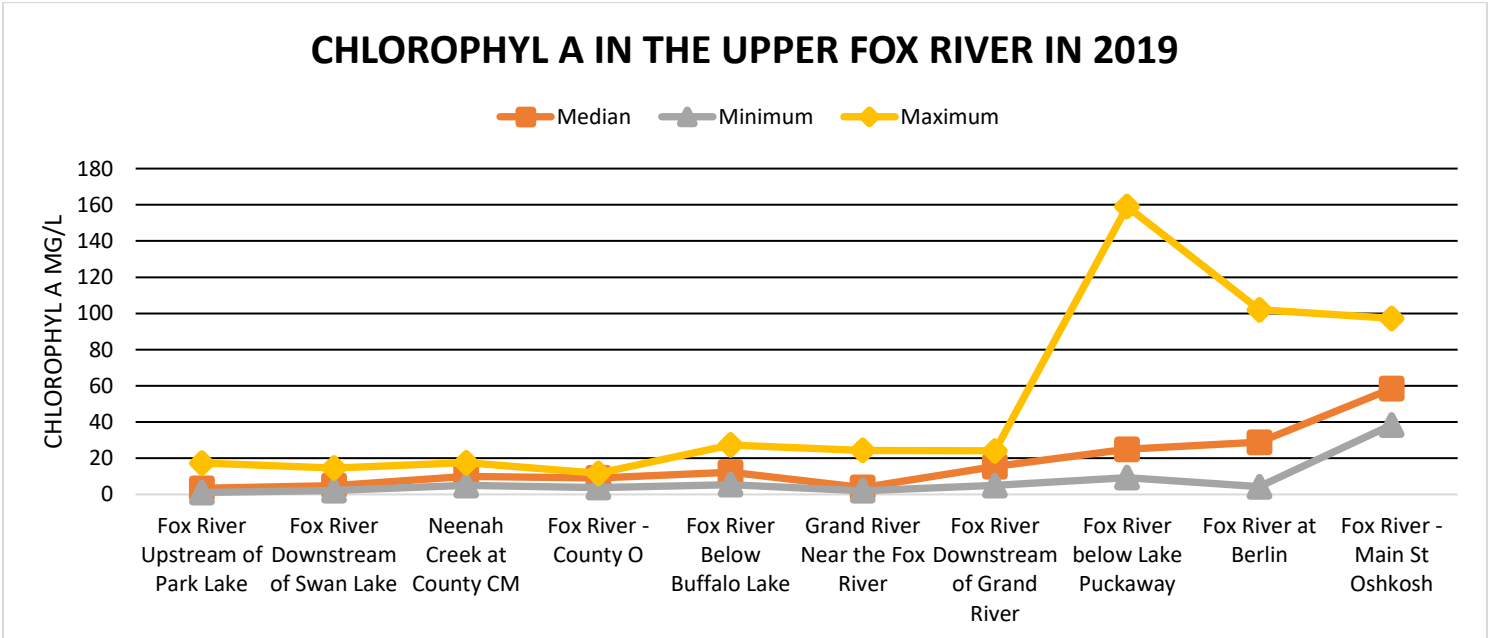
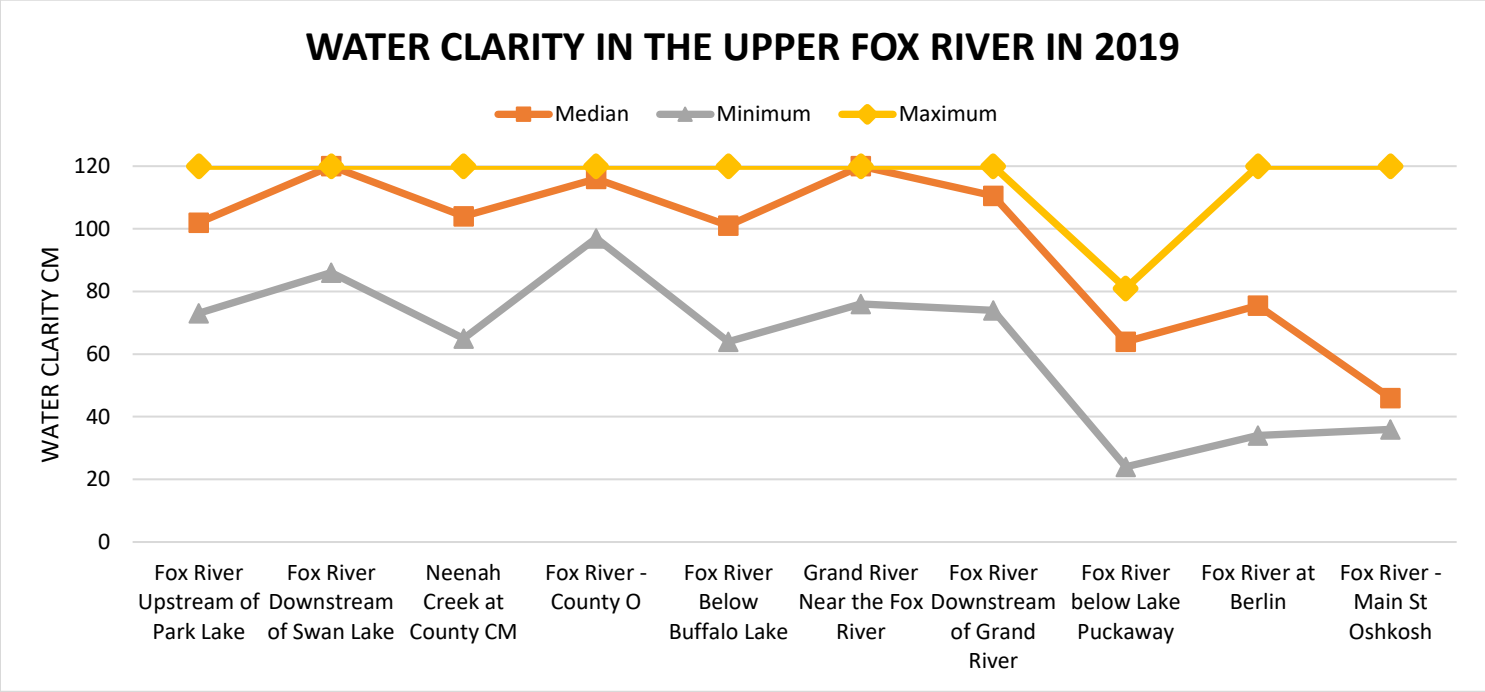


Chart 8: Water Clarity Minimum, Maximum and Median Values of Samples Collected in the Upper Fox River, Neenah Creek, and the Grand River in 2019.



Aquatic macroinvertebrate communities were sampled at 12 locations between July and September, within the years of 2019 to 2021 (Table 2). Some aquatic macroinvertebrate species are tolerant of environmental degradation, while some species are moderately tolerant, and some others are intolerant. Based upon the representative macroinvertebrate sample collected and their associated tolerance to environmental degradation, an Index of Biotic Integrity was calculated to indicate the water quality condition of the river (Table 14, Chart 9-10). The non-wadable IBI is scored on a scale of 0-100. In the non-wadable IBI scoring, the higher the IBI score, the better the water quality rating for a waterbody. The IBI scores in the non-wadable locations ranged from 5 in the Fox River downstream of Swan Lake to 45 in Neenah Creek at County CM with condition categories ranging from Very Poor to Fair (Table 14, Chart 9-10).

Table 14: Aquatic Macroinvertebrate Index of Biotic Integrity Scores and Water Quality Condition Categories in the Upper Fox River Basin in 2019-2021.

SWIMS Station ID	Site Name	Macroinvertebrate IBI Score	Water Quality Condition
10017269	Fox River downstream Swan Lake	0	Very Poor
10011616	Fox River at County O	40	Fair
393006	Fox River downstream Buffalo Lake	20	Poor
10033617	Fox River downstream Grand River	20	Poor
10022806	Fox River downstream Lake Puckaway	10	Very Poor
243058	Fox River at Berlin	10	Very Poor
10052990	Fox River downstream Eureka Dam	15	Very Poor
10052402	Fox River at Preachers Bend 2.0 miles upstream Lake Butte des Morts	10	Very Poor
113070	Neenah Creek at County CM	45	Fair
10033618	Grand River near Fox River	15	Very Poor
10016758	Rat River – Hwy 110	5	Very Poor
713267	Arrowhead River - Breezewood (Woodland) Road	30	Poor

Chart 9: Aquatic Macroinvertebrate Index of Biotic Integrity Scores and Water Quality Condition Categories in the Upper Fox River in 2019-2021.

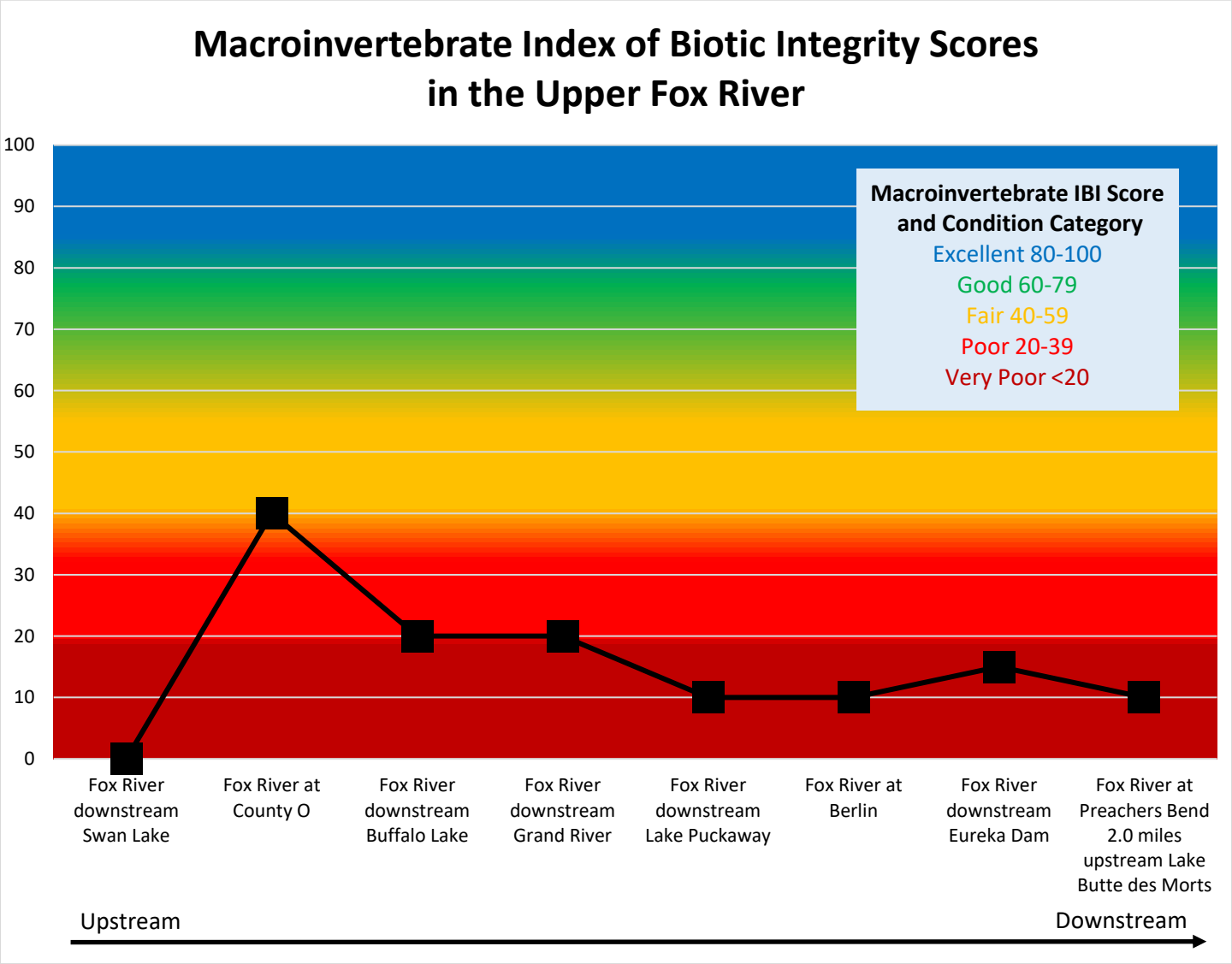
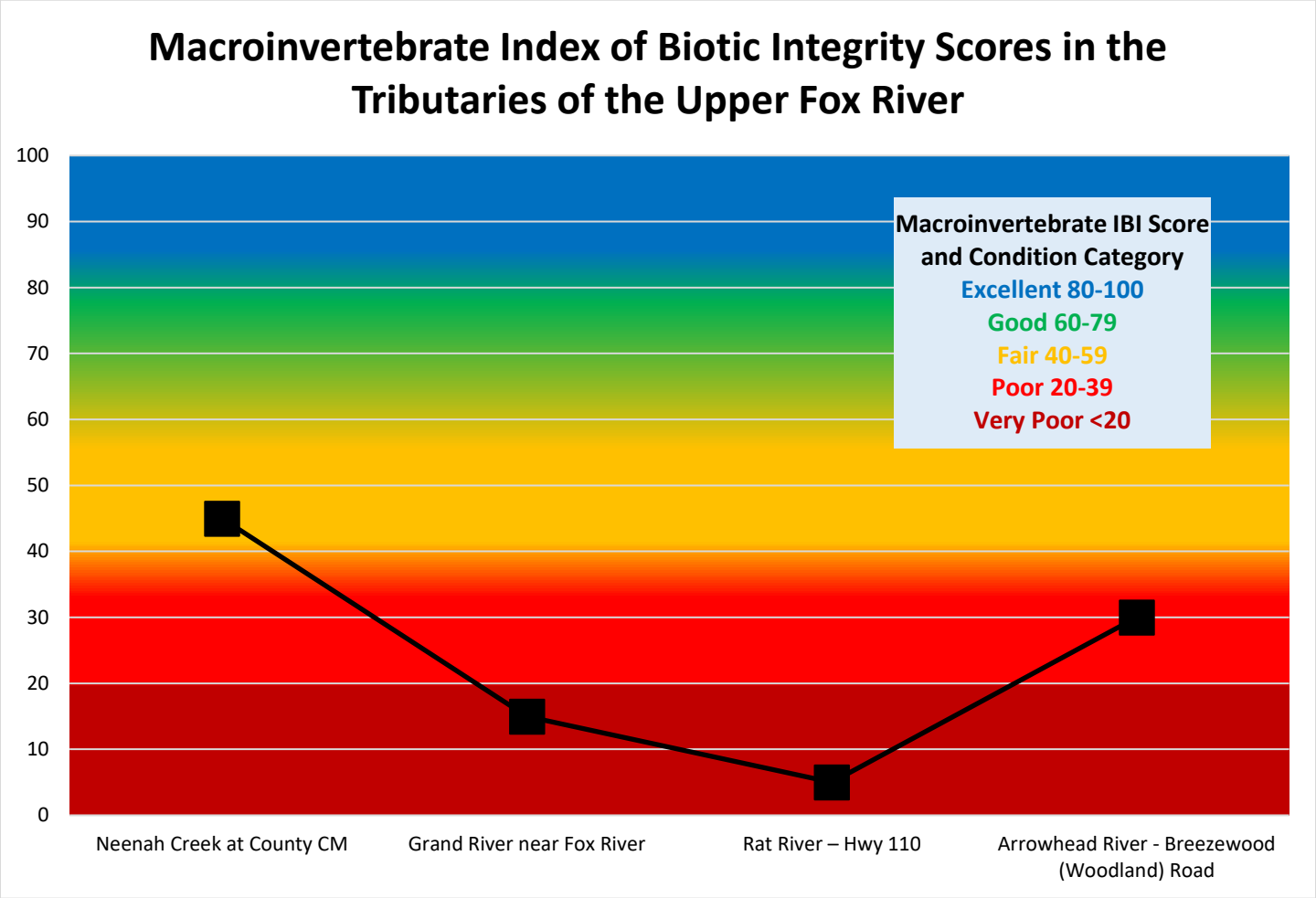


Chart 10: Aquatic Macroinvertebrate Index of Biotic Integrity Scores and Water Quality Condition Categories in the Upper Fox River Basin Tributaries in 2019-2021.



Between 2019 and 2020, seventeen river locations were surveyed for representative fish communities in the Upper Fox River Basin. A total of 2,692 fish were captured during the surveys including 48 different species of fish (Appendix A-B). Some fish species are tolerant of environmental degradation, while some species are moderately tolerant, and some others are intolerant. Based upon the representative fish collected during the survey and their associated tolerance to environmental degradation, an Index of Biotic Integrity (FIBI) was calculated to indicate the water quality of each river. The FIBI scores in the Upper Fox River ranged from 10 downstream from Swan Lake to 55 at Eureka and Omro (Table 15, Chart 11). The FIBI scores in the 7 tributaries to the Upper Fox River ranged from 5 in the Rat River (Tributary to the Wolf River) to 75 in the Mecan River (Table 15, Chart 12). The water quality condition categories for the 10 Upper Fox River sites ranged from Very Poor to Fair, indicating severe to significant environmental degradation throughout the Upper Fox River. The water quality condition categories for the tributaries of the Upper Fox River ranged from Very Poor to Good, indicating severe to slight environmental degradation.

Table 15: Non-Wadeable Fish Index of Biotic Integrity Scores and Water Quality Condition Categories in the Upper Fox River Basin between 2019 and 2020.

SWIMS Station ID	Site Name	Fish IBI Score	Water Quality Condition Category
10017269	Fox River downstream Swan Lake	10	Very Poor
113093	Fox River at Lock Road	25	Poor
10011616	Fox River at County O	30	Poor
393006	Fox River downstream Buffalo Lake	40	Fair
10056016	Fox River at Princeton Dam	40	Fair
10049421	Fox River at White River Lock	30	Poor
243058	Fox River at Berlin	45	Fair
10052990	Fox River downstream Eureka Dam	55	Fair
104481	Fox River at Omro	55	Fair
10049142	Fox River-Hwy 21/Oshkosh St Bridge	50	Fair
113070	Neenah Creek at County CM	15	Very Poor
10056021	Montello River Upstream Lake Montello	45	Fair
10033618	Grand River near Fox River	25	Poor
393005	Mecan River at County C	75	Good
10056017	Puchyan River at Confluence with Fox River	10	Very Poor
10016758	Rat River – Hwy 110	5	Very Poor
713267	Arrowhead River – Breezewood (Woodland) Road	30	Poor

Chart 11: Non-Wadeable Fish Index of Biotic Integrity Scores and Water Quality Condition Categories in the Upper Fox River between 2019 and 2020.

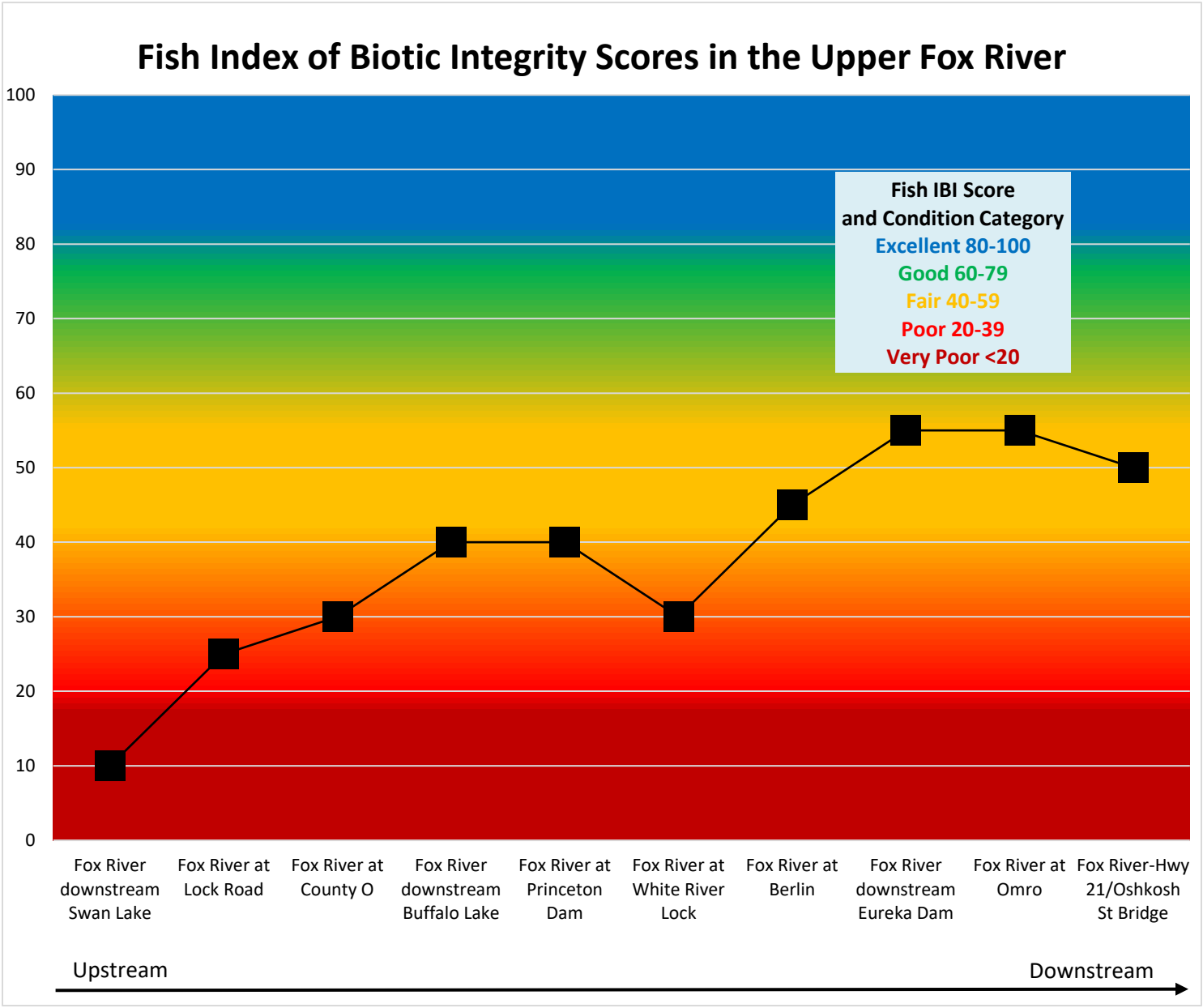
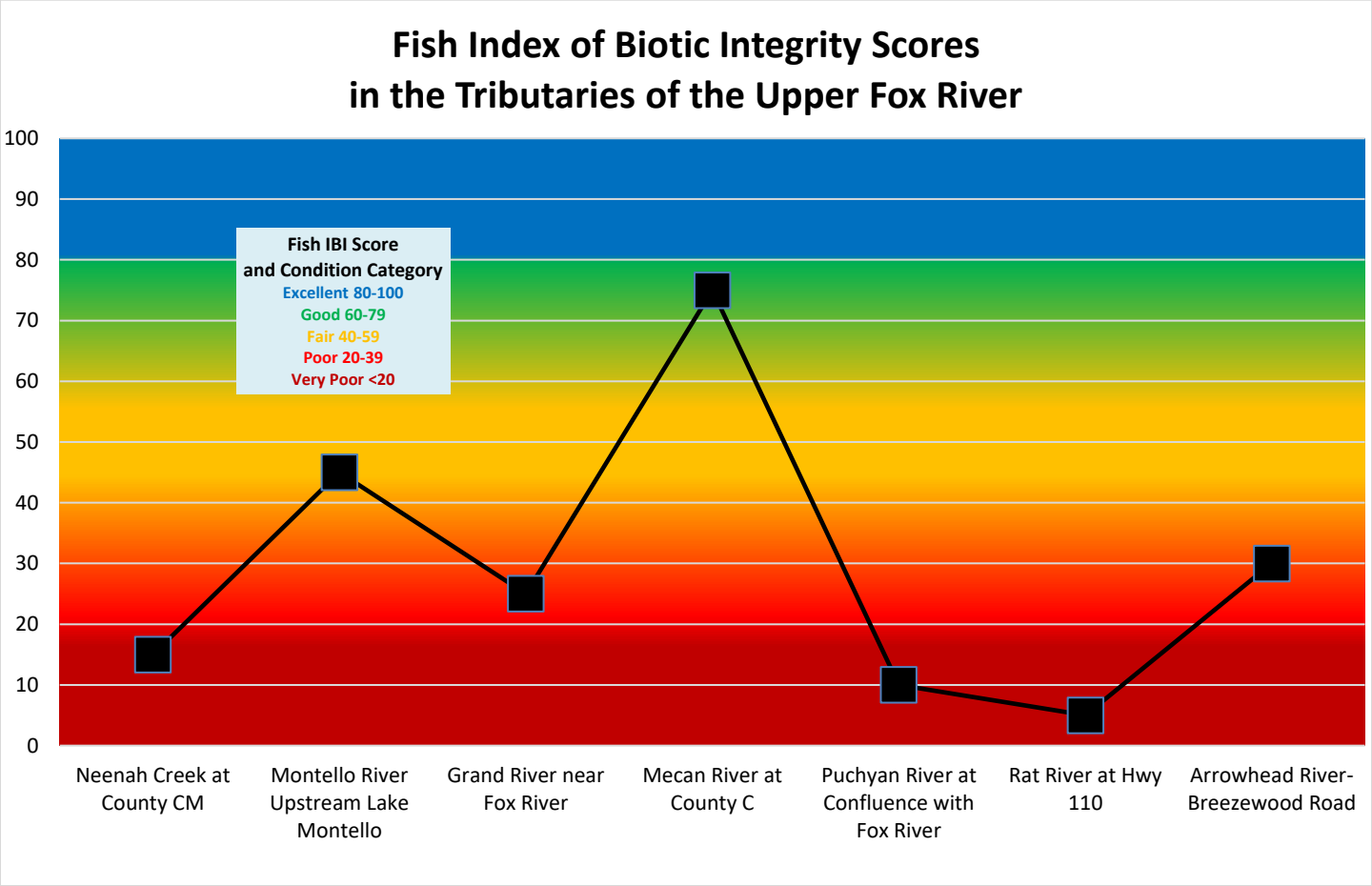


Chart 12: Non-Wadeable Fish Index of Biotic Integrity Scores and Water Quality Condition Categories in Tributaries to the Upper Fox River between 2019 and 2020.



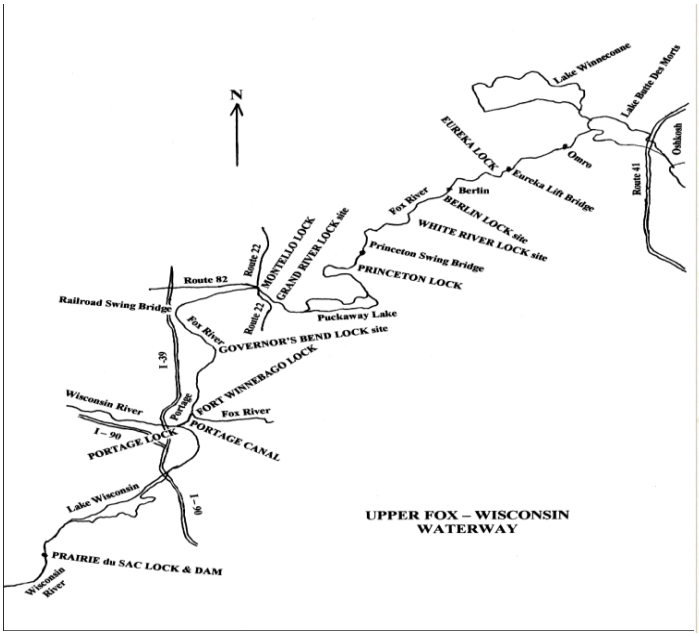
Discussion

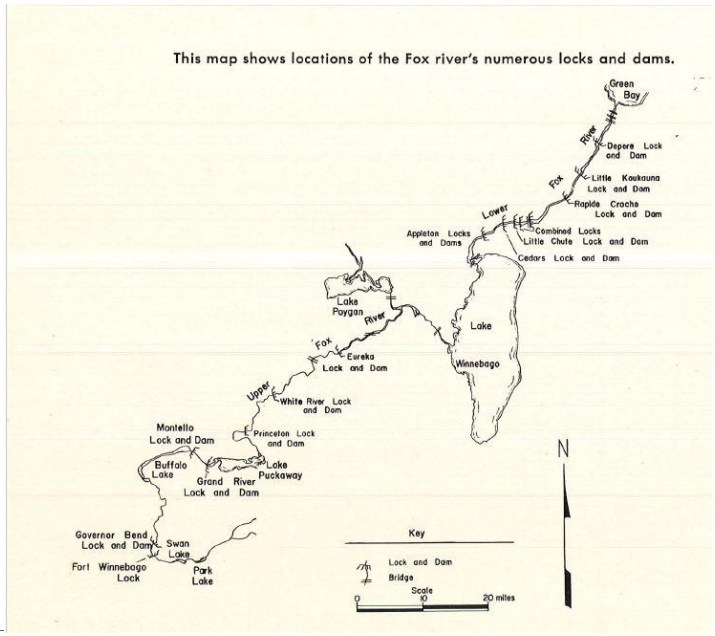
This project evaluated the water quality of the Upper Fox River (UFR) and a few of its main tributaries. Fish and macroinvertebrate communities were surveyed as well as nutrient and suspended solids monitoring were used to evaluate water quality of each tributary and the UFR (Tables 4-15, Charts 1-12). This water quality monitoring provides a good baseline assessment of the UFR and its main tributaries as the Upper Fox-Wolf River Total Maximum Daily Load (TMDL) is being implemented (WDNR 2020). The nutrient, aquatic macroinvertebrate, and fish community monitoring in this project demonstrated that the water quality and habitat in the UFR is between very poor and fair condition, while the tributary water quality and habitat ranged from very poor to good. When determining the drivers behind the water quality and health of biotic communities within the Upper Fox River and the Winnebago Pool Lakes, there is a combination of factors that have an influence.

All streams and rivers draining to Lake Winnebago, excluding those in the Wolf River Basin, are within the UFR Basin. The river has a long history as a travel corridor and a bridge between the Mississippi River and the Great Lakes. In the mid-1800s, the Portage Canal and a lock and dam system was built to allow for commercial traffic carrying primarily lumber, coal, and grain. By the late-1800s, commercial travel faded out; however, the UFR remains a major attraction for recreational boating and fishing. Remnants of the mid-1800s lock and dam system and river channel dredging are still present (i.e. Montello and Eureka Dams) (Maps 5-6) (ACS 2025). An unfortunate side effect of putting dams on a river is

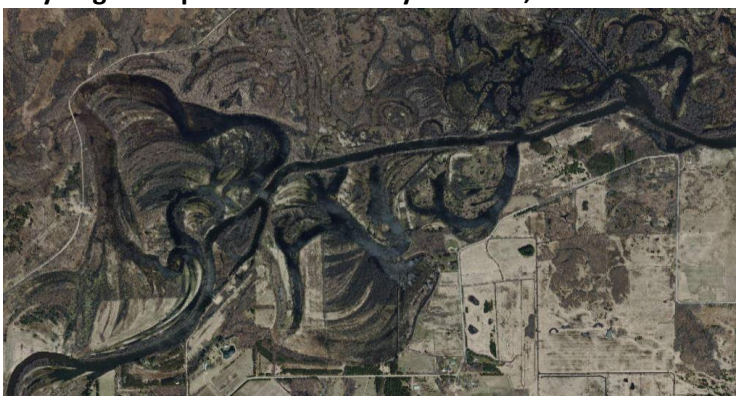
the creation of fish and aquatic life barriers, habitat separation, and lower biodiversity. Additionally, the dams may have been built where unique habitats were present which are now unavailable for spawning and recruitment of certain fish species and habitation by aquatic macroinvertebrates. The substrate of the UFR is predominantly sand with finer sediments deposited along the margins and in slow moving areas. The lack of diverse substrates (limited cobble/gravel areas) from Swan Lake to Lake Butte des Morts may limit the diversity of fish and macroinvertebrate communities. By volume, soil is the largest pollutant reaching rivers and streams in Wisconsin which covers important river substrates and increases turbidity and water temperatures (Miller et. al. 2014). The UFR, as with all rivers and streams, will and has moved over time. Especially during flood events, riverbanks will be cut and new channels will be formed. A river channel's ability to move over time allows for large woody debris recruitment which creates fish and aquatic life habitat. The historic river channel dredging may be inhibiting the UFR to meander and create those new habitats that are so important for biodiversity and water quality. Evidence of old meandering (meander scars) can be seen by viewing aerial photos (Photo 8-9) (ex. between Bufffalo Lake and Lake Puckaway). Some good news is that fish passage has been installed on several of the remaining dams along the UFR, including Montello, Eureka, and Princeton dams. Also, the White River, Grand River, Governor Bend Lock and Dams have been removed. Over time, the fish community may improve as migration increases.

Map 5-6: Historic Upper Fox River Canal, Lock, and Dam System (Left) and Upper and Lower Fox River Lock and Dam System (Right).



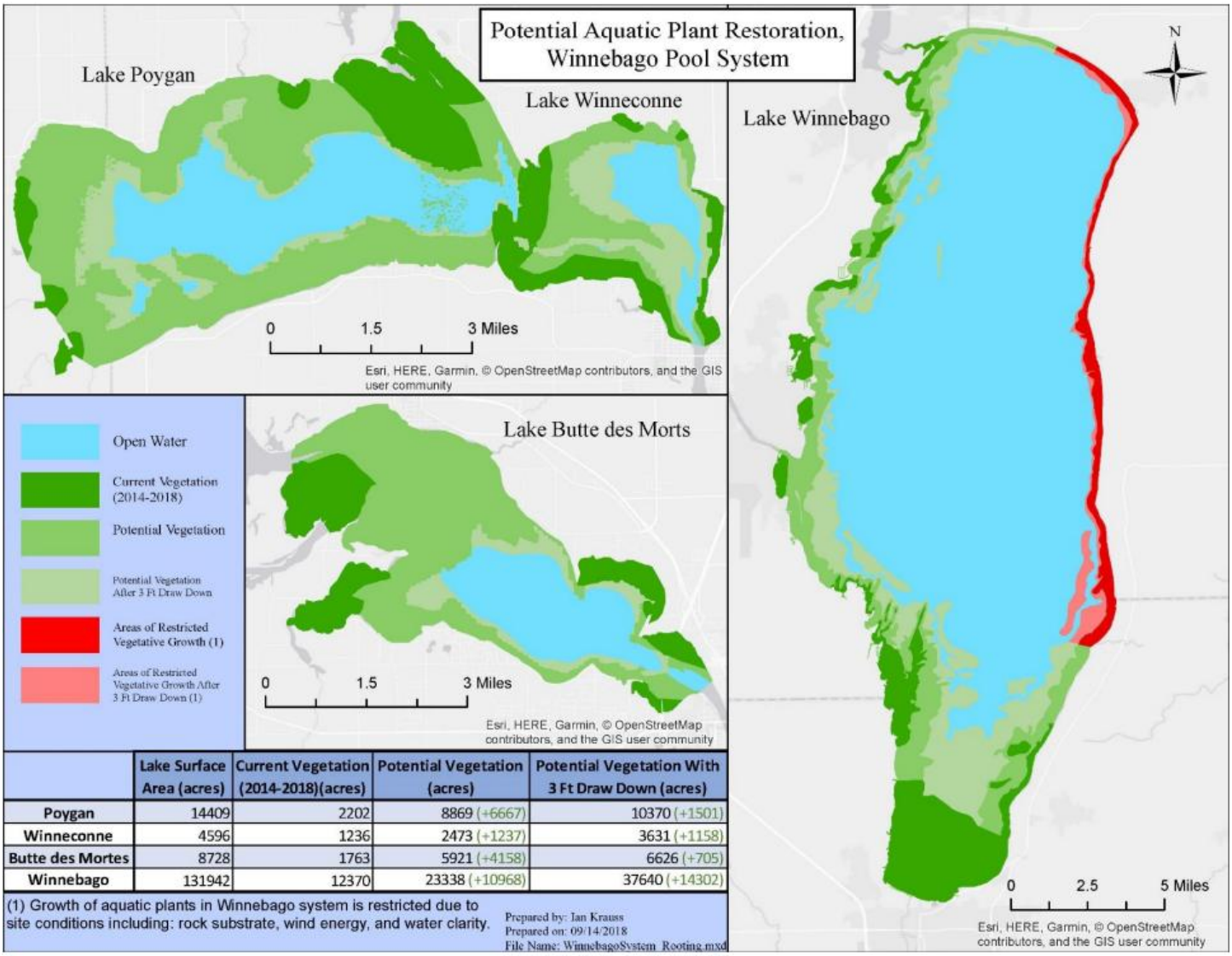


Photos 8-9: Meander Scarring along the Upper Fox River. Photos taken via WDNR Surface Water Data Viewer by D. Bolha on April 3rd, 2025. Left is just upstream Lake Puckaway. Right is upstream of the City of Berlin, WI.



The UFR Basin drains a 2,090 square-mile watershed. The Upper Fox River flows through 4 lakes (Park, Swan, Buffalo, and Puckaway), 6 when you include Lakes Butte des Morts and Winnebago, which influence its water quality. Some lakes within the Upper Fox Basin are impaired by excessive phosphorus and sediment loading, which leads to nuisance algae growth, oxygen depletion, fish kills, reduced submerged aquatic vegetation, water clarity problems, and degraded habitat. These impairments adversely affect fish and aquatic life, drinking water supplies, recreation, and potentially navigation. Unfortunately, the river and tributaries have been a source of too much soil and nutrients from the watershed; in turn, some of the lakes along the UFR release excessive TSS and nutrients back to the river (Tables 4-13, Chart 1-8). Lake management strategies to promote submersed and emergent aquatic plant growth to reduce wind-driven sediment suspension, are needed to achieve the phosphorus loading and concentration goals in the Winnebago Pool Lakes (WDNR 2018). For example, the potential for aquatic plant restoration in the Winnebago Pool Lakes was developed during the TMDL drafting process. The restoration plan modeled the potential aquatic plant growth increases with a new water level management strategy, including during a 3' drawdown. The Winnebago Pool Lakes have been significantly changed since the Neenah-Menasha dams were built in the 1850s. The Neenah-Menasha dams increased water levels in the Lakes and created an artificial water level fluctuation regime which inhibits the promulgating of aquatic plants. From the 1850s to 1930, the three Upper Pool Lakes experienced significant loss of privately owned land and wetlands as floating bogs were formed by the deeper water and then broken down by wind and waves (FWWA 2020). The Winnebago Pool Lake emergent/submersed aquatic plant habitats continue to be eroded away to this day. Efforts to protect and restore these areas is critical to improving the water quality and fish and aquatic life communities.

Map 7: Potential Aquatic Plant Restoration in the Winnebago Pool Lake System (WDNR 2018).



	Lake Surface Area (acres)	Current Vegetation (2014-2018)(acres)	Potential Vegetation (acres)	Potential Vegetation With 3 Ft Draw Down (acres)
Poygan	14409	2202	8869 (+6667)	10370 (+1501)
Winneconne	4596	1236	2473 (+1237)	3631 (+1158)
Butte des Mortes	8728	1763	5921 (+4158)	6626 (+705)
Winnebago	131942	12370	23338 (+10968)	37640 (+14302)

(1) Growth of aquatic plants in Winnebago system is restricted due to site conditions including: rock substrate, wind energy, and water clarity.

Prepared by: Ian Krauss
Prepared on: 09/14/2018
File Name: WinnebagoSystem_Rooting.mxd

Wetlands play a crucial role to the health of the UFR. Wetlands within the Basin and along the river margins enhance water quality, flood protection, fish and wildlife habitat, and provide aesthetic beauty that the river is known for. Wetlands filter nutrients and sediments, hold floodwaters which reduces erosion, and increases species richness. The UFR Basin has a relatively significant portion as wetland land use at 14% (Chart 13) (WDNR 2020). These wetlands need to be protected from agricultural drainage and urban development. Major urban areas include the Cities of Fond du Lac and Oshkosh on the shores of Lake Winnebago. Wetland destruction was identified in the State of the Fox River Basin 2001 as an increasing threat, specifically in the urban areas of Fond du Lac and Oshkosh.

The landuses within the UFR Basin are dominated by agriculture cropland and pastures (Chart 13) (WDNR 2020). Typically, as increases in agricultural landuse occur, there is a correlating increase in TP concentrations in streams and rivers in Wisconsin. The Fox River is the largest tributary to Lake Michigan and has been determined to be its largest contributor of phosphorus and its second largest contributor of TSS/sediment (Robertson and Saad 2019). Cropland and pasture landuses are the largest sources of phosphorus and TSS, 53% and 90%, respectively within the UFR Basin (Chart

14-15). Phosphorus and TSS are a primary driver of poor water quality in the UFR and the Winnebago Pool Lakes. Besides agriculture sources, municipal and industrial sources contribute phosphorus and TSS, 29% and 7%, respectively, within the UFR Basin (Chart 14). Since the approval of the TMDL in 2020, permitted municipal and industrial facilities have made upgrades and changes to reduce the phosphorus and TSS being added to the river from their effluent discharges. Implementation of the TMDL nutrient and suspended solids reduction goals from agriculture and municipal and industrial sources is critical for restoring water quality and fish and aquatic life communities.

Chart 13: Land Uses within the Upper Fox Basin (WDNR 2020).

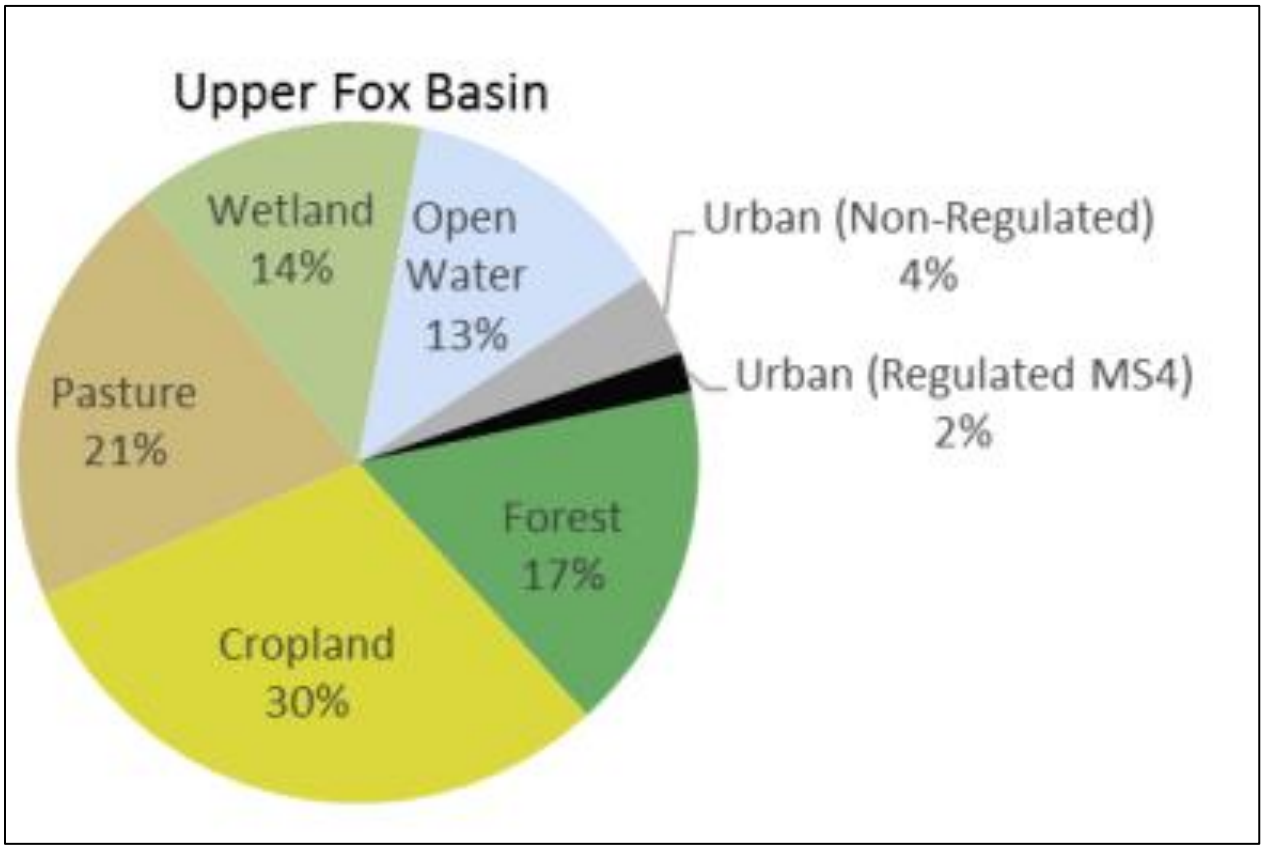


Chart 14: Total Phosphorus Loading by source in the Upper Fox Basin (WDNR 2020).

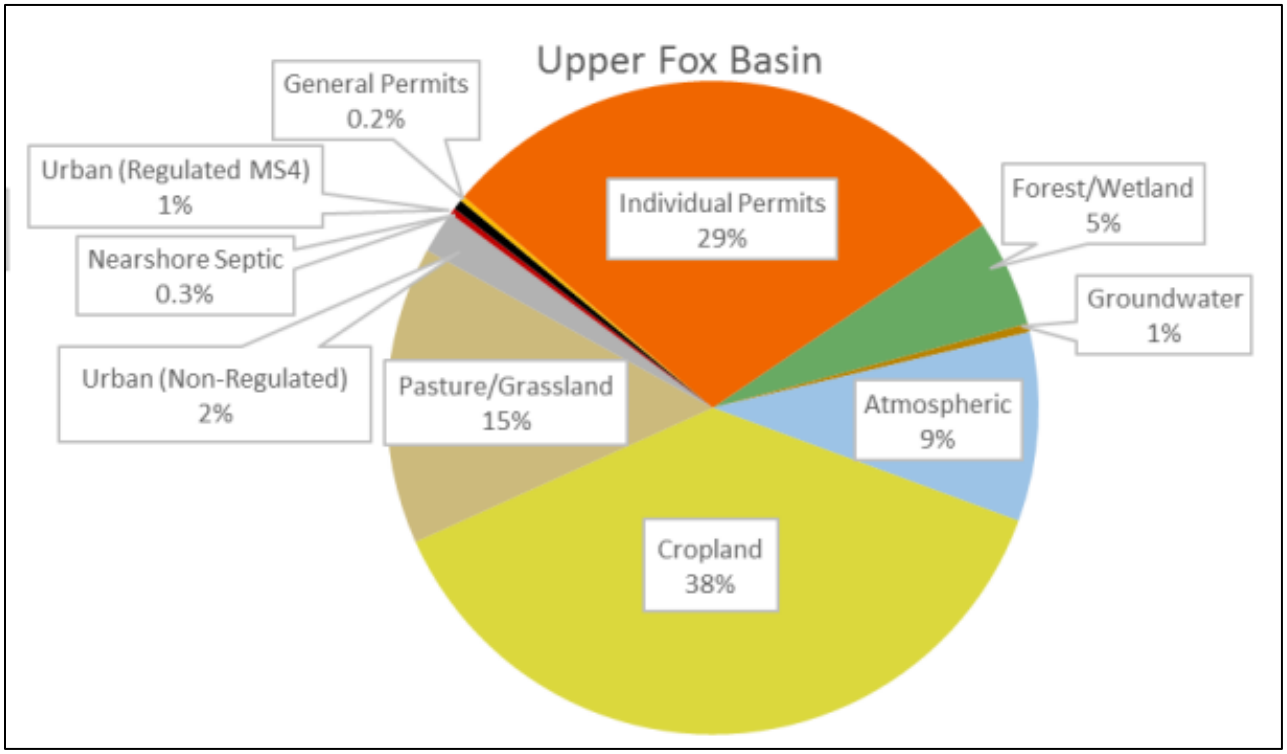
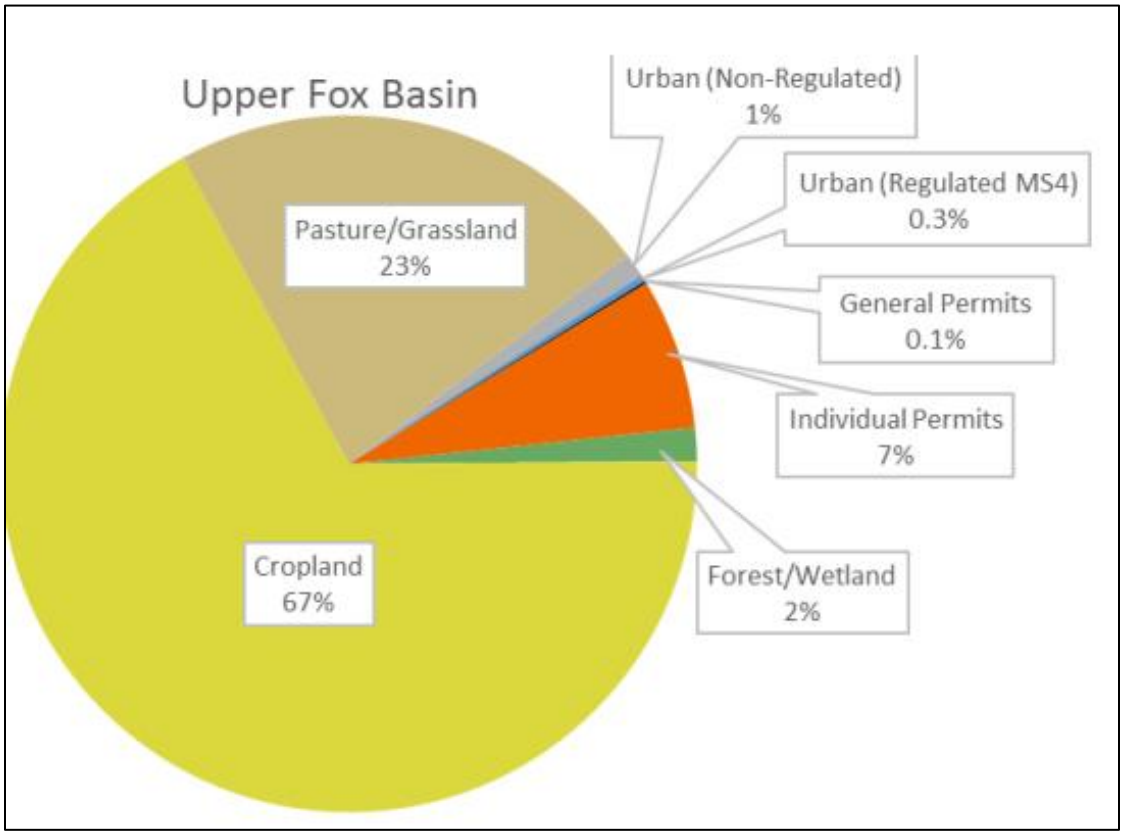


Chart 15: Total Suspended Solids Loading by source in the Upper Fox Basin (WDNR 2020).



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Appendices

Appendix A: Non-Wadable Fish Community Evaluations in the Upper Fox River in 2019 and 2020.

Fish Species Common Name	Downstream Swan Lake	Lock Road	County O	Downstream Buffalo Lake	Princeton Dam	White River Lock	Berlin	Downstream Eureka Dam	Omro	Hwy 21/Oshkosh St Bridge	Total
Bowfin	4	2	2	7	1	2	3	3	3		27
Gizzard Shad										2	2
Freshwater Drum	1	2	5	11	2	3	6	2	21	38	91
Spotfin Shiner		3	1	14	41	8	20	8			95
Golden Shiner	1	17	8	33	6	3	21	5	25	2	121
Emerald Shiner				8		2		14		549	573
Mimic Shiner								28			28
Common Shiner										1	1
Bullhead Minnow						12		2			14
Bluntnose Minnow		1	1	11	3	11		6	1		34
Common Carp	17	13	8	26	2	8	5	15	7	4	105
Central Mudminnow	1					7					8
White Sucker	3	13	7	3							26
Spotted Sucker					2		29	18	46		95
Silver Redhorse										1	1
Shorthead Redhorse		3				4		1		1	9
Greater Redhorse					1						1
Bigmouth Buffalo		1		1	1						3
Quillback				4							4
Black Bullhead						1					1
Yellow Bullhead	3		1	1							5
Tadpole Madtom		1									1
Flathead Catfish						2	4	2	2	2	12
Channel Catfish		1	3	3	12	19	3	4	1		46
White Bass										4	4
Rock Bass	1	2	1	2				1			7
Pumpkinseed Sunfish			1				3	11	1		16
Bluegill	14	20	11	85	2	11	12	63	2	9	229
Green Sunfish					2	5	2			1	10
Smallmouth Bass			4	8		2				47	61
Largemouth Bass	57	10		6	6	8	3	9	3	1	103
Black Crappie			1	2		3	3	1	10	1	21
Yellow Perch	76	11	14		1	4	9	29	41	19	204
Northern Pike	3	3	1	6	1		1	3			18
Grass Pickerel		2	1								3
Walleye								1	1	18	20
Burbot				1							1
Logperch				6				2	3	29	40
River Darter										1	1
Total Fish Captured	**181**	**105**	**70**	**238**	**83**	**115**	**124**	**228**	**167**	**730**	**2041**
Total Species Captured	**12**	**17**	**17**	**20**	**15**	**19**	**15**	**22**	**15**	**19**	**39**
Fish IBI Score	**10**	**25**	**30**	**40**	**40**	**30**	**45**	**55**	**55**	**50**	
Fish IBI Category	**Very Poor**	**Poor**	**Poor**	**Fair**	**Fair**	**Poor**	**Fair**	**Fair**	**Fair**	**Fair**	

Appendix B: Non-Wadable Fish Community Evaluations in the Tributaries of the Upper Fox River in 2019 and 2020.

Fish Species Common Name	Neenah Creek at County CM	Montello River Upstream Lake Montello	Grand River near Fox River	Mecan River at County C	Puchyan River at Confluence with Fox River	Rat River – Hwy 110	Arrowhead River – Breezewood (Woodland) Road	Total
Shortnose Gar							1	1
Bowfin		2	38		3	9		52
Gizzard Shad			10					10
Freshwater Drum				3			8	11
Spotfin Shiner	3			54				57
Spottail Shiner							1	1
Golden Shiner			7	7	4	1	16	35
Emerald Shiner							18	18
Mimic Shiner				1				1
Common Shiner	1	53						54
Blackchin Shiner		1						1
Sand Shiner				2				2
Weed Shiner			1					1
Bluntnose Minnow		4	9	2			1	16
Common Carp	5	7	8				2	22
Central Mudminnow	1				14			15
White Sucker	1	1	1	2			7	12
Northern Hog Sucker		16						16
Silver Redhorse							2	2
Shorthead Redhorse				14				14
Golden Redhorse				14				14
Bigmouth Buffalo	1							1
Black Bullhead	1							1
Yellow Bullhead		1	1					2
Brown Bullhead			4					4
Tadpole Madtom			2					2
Flathead Catfish				1				1
Channel Catfish	4		2	2				8
Rock Bass	1	3					2	6
Pumpkinseed Sunfish	2		11					13
Bluegill	8		28		1		2	39
Smallmouth Bass		11		13				24
Largemouth Bass	2	4	29				2	37
Yellow Perch	1	18	74	15			18	126
Northern Pike	1	4	16	3				24
Walleye				2			3	5
Logperch	1			1				2
Banded Darter				1				1
Total Fish Captured	**33**	**125**	**241**	**137**	**22**	**10**	**83**	**651**
Total Species Captured	**15**	**13**	**16**	**17**	**4**	**2**	**14**	**38**
Fish IBI Score	**15**	**45**	**25**	**75**	**10**	**5**	**30**	
Fish IBI Category	**Very Poor**	**Fair**	**Poor**	**Good**	**Very Poor**	**Very Poor**	**Poor**	