Mullett Lake Tributary Water Quality Monitoring Project

By Tip of the Mitt Watershed Council

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ABSTRACT

The water quality of Mullett Lake, located in northern Cheboygan County, Michigan, has been monitored for several decades, but little data exists for tributaries flowing into Mullett Lake. At the request of the Mullett Lake Area Preservation Society, the Tip of the Mitt Watershed Council monitored water quality in the Cheboygan River, Indian River, Little Sturgeon River, Pigeon River, and Mullett Creek two times during 2005. Water samples were collected for bacteriological and chemical analyses, physical water quality was measured, and discharge data collected on the tributaries in April and September. Parameters measured include: dissolved oxygen, pH, conductivity, temperature, total phosphorus, soluble reactive phosphorus, total nitrogen, nitrate nitrogen, chloride, fecal coliform bacteria and E. coli bacteria. Using chemical constituent concentrations and discharge data, pollutant loadings and relative percentage contributions were calculated for Indian River, Pigeon River, and Mullett Creek. Nutrient and bacteriological contamination appear to be occurring in the upper Mullett Creek watershed as a result of agricultural activity. Despite flowing through an urban area, this study did not expose any water quality problems in the Indian River. The Pigeon River may be experiencing nutrient contamination as, based upon percent loading contributions, total phosphorus loads were high in the April and total nitrogen loads were high in the September. Based upon results of this study, there is a need to adopt agricultural best management practices to protect and improve stream water quality, particularly in the Mullett Creek watershed. In addition, groundwater nitrate concentrations in the Mullett Creek watershed should be determined to safeguard public health. Further monitoring is necessary to collect a more comprehensive data set and to support the results of this study. Modification of field data collection methods in future monitoring projects would provide greater quality assurances.

INTRODUCTION

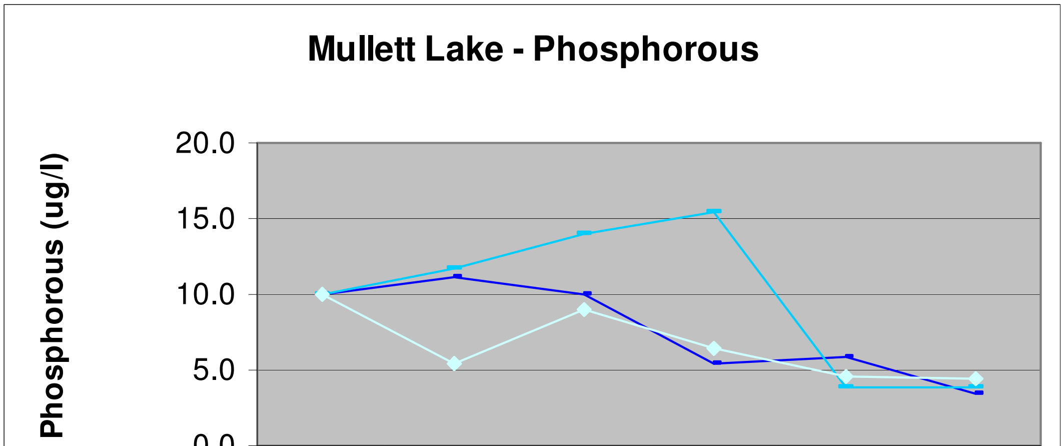
Background:

Mullett Lake, located in the northern tip of the Lower Peninsula of Michigan, sits at the bottom of a large watershed that includes Burt Lake, Douglas Lake, Crooked Lake, Pickerel Lake, the Maple River, the Sturgeon River and the Pigeon River. The water from all of these water bodies and more flows into and potentially impacts the water quality of Mullett Lake. A considerable amount of data has been collected on Mullett Lake attesting to its excellent water quality, but little is known about the water flowing in from the different tributaries. To determine water quality and impacts of major tributaries flowing into Mullett Lake, the Mullett Lake Area Preservation Society (MAPS) contracted the Tip of the Mitt Watershed Council to monitor water quality on the Indian River, the Cheboygan River, the Pigeon River, the Little Sturgeon River and Mullett Creek.

The water quality of Mullett Lake has been monitored consistently for many years. The Mullett Lake Preservation Society (MAPS) has actively supported water quality monitoring programs on Mullet Lake, providing volunteer help for volunteer water quality monitoring programs coordinated by the Watershed Council and the Michigan Lakes and Streams Association. In addition, Watershed Council staff monitor Mullett Lake water quality through the Comprehensive Water Quality Monitoring program (CWQM). Watershed Council databases contain volunteer lake monitoring and CWQM data that date back to 1986 and 1987 respectively. Data collected through these programs indicates that water quality remains high. Phosphorus data collected as part of the CWQM program show that levels have dropped throughout the last 20 years and are now consistently below 10 parts per billion (PPB), which is typical for high quality lakes of northern Michigan (Figure 1). The trophic status index figures generated from volunteer lake monitoring data show the lake to be oligotrophic, also typical for pristine lakes in the region (Figure 2).

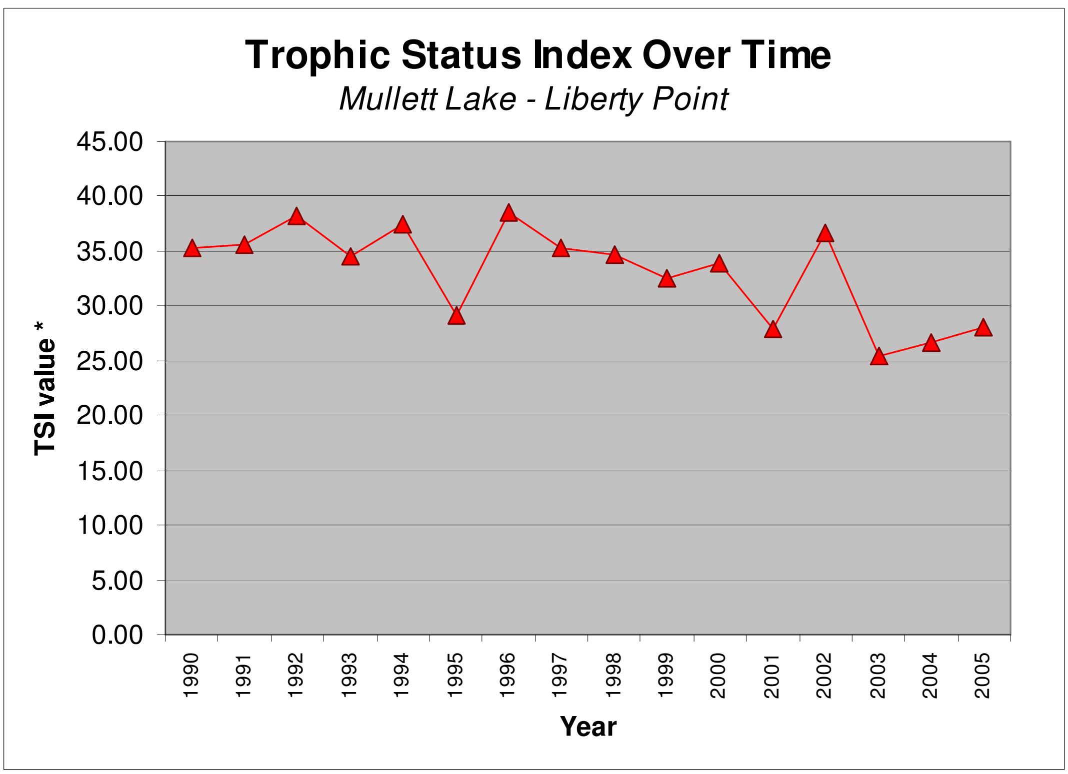
Regarding Mullett Lake tributaries, MAPS members are particularly concerned about contaminants contributed by urbanization along the Indian River and agricultural operations in the headwaters of Mullett Creek. The Indian River flows out of Burt Lake

Figure 1. Phosphorus data collected on Mullett Lake from the CWQM program.



	4/24/1987	5/06/1992	5/11/1995	5/19/1998	5/09/2001	5/5/2004
Surface	10.0	11.2	10.0	5.5	5.9	3.4
Middle	10.0	11.7	14.0	15.4	3.8	3.9
Bottom	10.0	5.4	9.0	6.5	4.6	4.5

Figure 2. Trophic status index data from volunteer monitoring on Mullett Lake.



*TSI determines trophic status of lake: 0-38 = oligotrophic (low productive system), 39-49 = mesotrophic (moderately productive system), and 50+ = eutrophic (highly productive system).

and through the town of Indian River before reaching Mullett Lake. Pollutants associated with roads, such as leaking fluids from automobiles, and those associated with houses, such as septic leachate, are among some of the potential sources of pollution that could be reaching the Indian River. Mullett Creek flows through agricultural areas that may contribute pollutants to the stream, such as nutrients from fertilizers and animal waste or sediments from soil erosion.

Considering the importance of the Inland Waterway to the local economy and the proximity to a major research facility (the University of Michigan BioStation), surprisingly little water quality data has been collected on the Indian River and Mullett Creek. Although more water quality information probably exists, only one source of water quality data from Indian River was uncovered in the Watershed Council library. According to the Mullett Lake Watershed Nonpoint Source Management Plan of 1989, water quality testing performed by the Surface Water Quality Division of the Michigan Department of Natural Resources in 1988 showed water quality in the river to be high, with impacts limited to nitrogen increases downstream of the community. Mullett Creek was recently added to the Watershed Council's Volunteer Stream Monitoring Program and has been monitored one time, in September of 2005. Preliminary results from this program show that bio-diversity in the Creek is high and comparable to other streams in the program (Table 1).

Table 1. Select results from Volunteer Stream Monitoring program 2005 activities.

Water Body	Boyne River	Boyne River	Eastport Creek	Eastport Creek	Mullett Creek	Mullett Creek	Kimberly Creek	Kimberly Creek
Sample Site	Dobleski Rd	City Park	Farrell Rd	M88	Crump Rd	M27	Montgomery Rd	Quarry Rd
Families*	15	19	23	19	17	21	20	18
EPT†	10	11	8	4	13	7	7	7

* Diversity expressed as number of macroinvertebrate families found at the site.
† Diversity expressed as number of sensitive macroinvertebrate families (from the Ephemeroptera, Plecoptera and Trichoptera families) found at the site.

Following discussions between Tip of the Mitt Watershed Council and MAPS a plan was developed to monitor water quality on the Indian River, the Cheboygan River, the Pigeon River, the Little Sturgeon River and Mullett Creek. Watershed Council staff monitored water quality at seven locations in the tributaries of Mullett Lake two times during 2005. In April and then again in September, water samples were collected for chemical and bacteriological analyses, physical parameters were measured, and discharge data collected at each site. Sampling in the spring was considered important for gauging the impacts of contaminants carried by surface runoff during snowmelt or large storm events and fall sampling is more likely to expose contamination from septic systems, after heavy use of these systems in summer months. Data gathered in the field was then used to calculate pollutant loadings to determine the relative amounts of pollutants flowing into Mullett Lake from each major tributary.

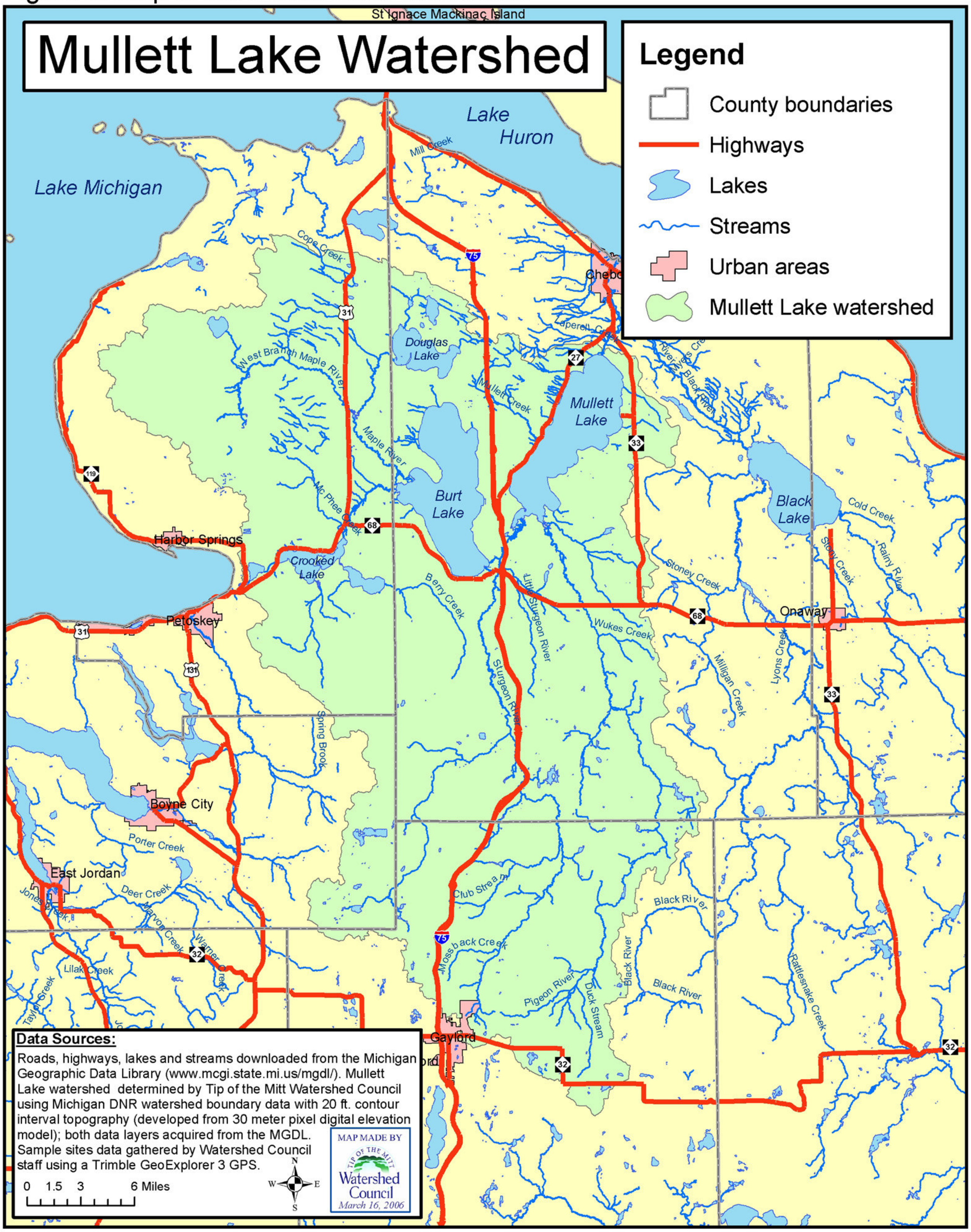
Study Area:

Mullett Lake is located in the townships of Inverness, Benton, Mullett, Aloha, Tuscarora and Koehler in northern Cheboygan County, Michigan (Figure 3). The surface area of Mullett Lake measures approximately 17,000 acres. The lake's deepest point, ~144 feet, is located toward the center of the lake, directly out from Long Point. Major inlets include the Indian and Pigeon Rivers, which both flow into the lake in the southwestern end. There are many minor inlets; the largest being Mullett Creek, which flows into the center of the lake from the northwest. Water flows out of Mullett Lake through the Cheboygan River in the northeastern end.

Mullett Lake is considered an oligotrophic lake. Oligotrophic lakes are characteristically deep, clear, nutrient poor, and with abundant oxygen throughout the water column. A general fish survey from 1988 documented the following types: brown trout, brown bullhead, carp, minnows, northern pike, pumpkin sunfish, redhorse suckers, rock bass, smallmouth bass, splake, walleye, white bass, white sucker and yellow perch (Sportsman's Connection 2002). From 1995 to 2001, splake, lake trout and walleye were stocked and in 2005 sturgeon were stocked.

The Mullett Lake Watershed encompasses approximately 560,000 acres of land and water, stretching nearly from the City of Gaylord in the south to the City of Cheboygan to the north (Figure 3). As determined by land cover data developed from the Coastal Great Lakes Land Cover Project in 2000, the watershed remains largely undeveloped with less than 3% urbanized and 8% agricultural (Table 2).

Figure 3. Map of the Mullett Lake watershed.



Over 70% of the Mullett Lake watershed drains into the lake through the Inland Waterway, arriving at the lake through the Indian River. The Indian River is the conduit for this water, beginning in the southeast corner of Burt Lake, flowing through the town of Indian River, and meeting up with the Little Sturgeon River before emptying into Mullett Lake. Land cover for the year 2000 in the 394,000-acre watershed draining into the Indian River was quite similar to that of the entire watershed with just over 10% covered with urban and agricultural (Table 2). The Little Sturgeon River land cover, which is a subset of the Indian River data, had much less agriculture and more forest, grassland and scrub/shrub.

Table 2. Mullett Lake watershed 2000 land cover statistics.

Land Cover Type	**Entire Watershed Acreage**	**Entire Watershed Percentage**	**Indian River Percentage**	**L. Sturgeon River Percentage**	**Pigeon River Percentage**	**Mullett Creek Percentage**
Urban	13,153	2.35	2.57	2.45	1.23	3.43
Agricultural	45,102	8.06	8.13	3.33	6.26	26.79
Grassland	82,856	14.82	15.09	17.59	15.04	18.02
Forested	276,088	49.37	50.57	57.26	55.12	30.70
Scrub/Shrub	18,273	3.27	3.27	6.25	3.79	2.06
Wetland	76,005	13.59	12.87	12.24	17.56	18.46
Barren/Shore	1,223	0.22	0.25	0.18	0.13	0.33
Water	46,544	8.32	7.27	0.70	0.87	0.21
Total	559,245	100.00	100.00	100.00	100.00	100.00

The watershed area drained by the Pigeon River is 107,880 acres and accounts for about 20% of the total for Mullett Lake. Land cover in the Pigeon River watershed in 2000 was predominantly forest, followed by wetlands and grasslands (Table 2). The Pigeon River watershed had the smallest percentage of urbanized land cover of the sub-watersheds of Mullett Lake at 1.2 %.

Mullett Creek is the third largest tributary of Mullett Lake with a watershed area of 11,874 acres. Land cover data from the year 2000 shows that the percentage of agriculture in the Mullett Creek watershed was three times greater than any other tributary in this study at 26% (Table 2). Furthermore, the Mullett Creek watershed had a greater percentage of urban land cover than the other tributary watersheds.

METHODS

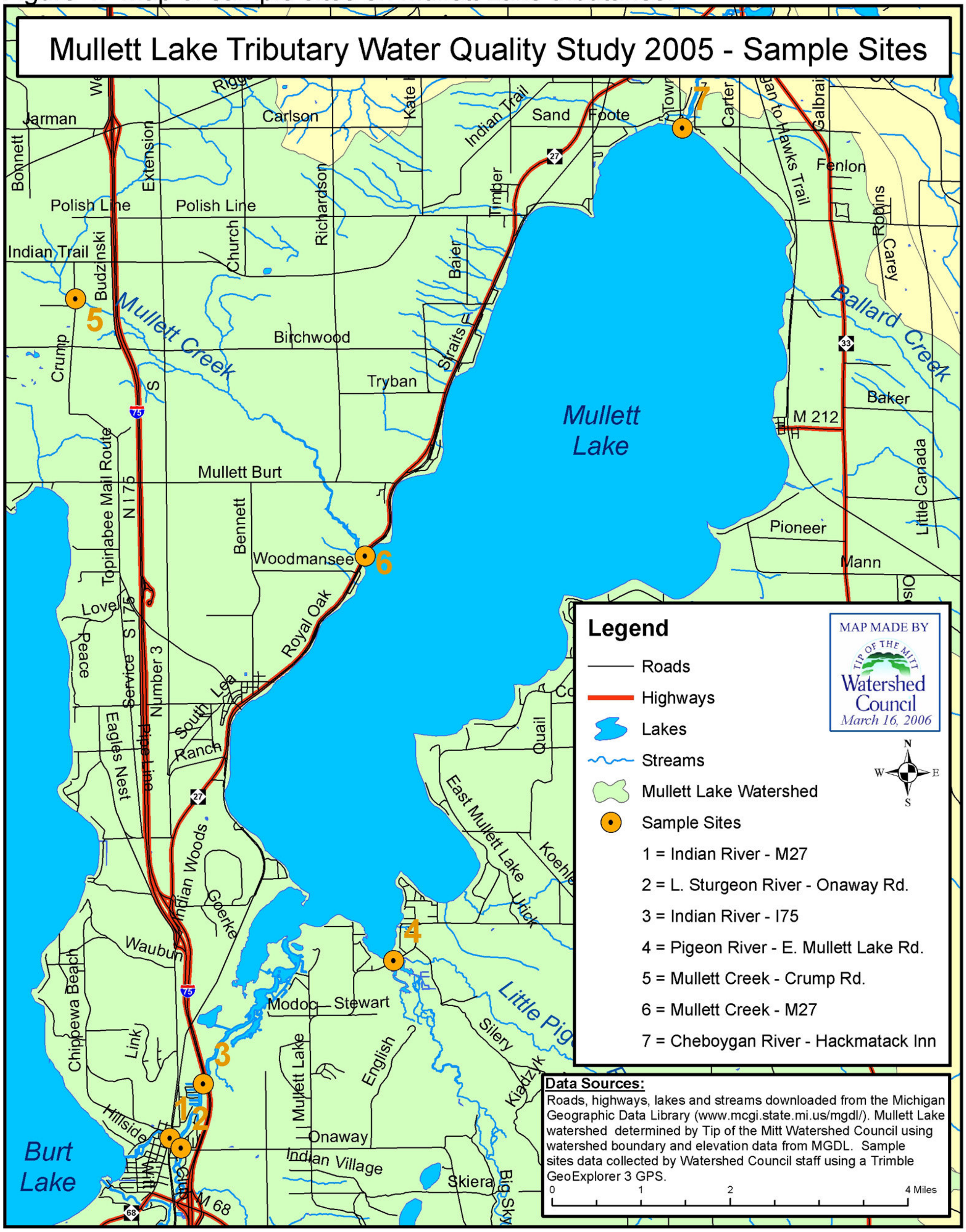
Field Data Collection:

Water quality and discharge data were collected from seven sites on streams flowing into or out of Mullett Lake (Figure 4). Field data were collected in April and September, immediately following precipitation events with the objective of determining maximum pollutant concentrations in streams as a result of stormwater runoff. Water quality data collection consisted of physical measurements in the field and both chemical and bacteriological analysis of water samples. Discharge data were collected measuring flow and depth across stream transects.

At each sample site, water samples were collected in separate containers for chemical and bacteriological analysis. Water samples were collected at sites on the Little Sturgeon River and Mullett Creek by wading and on the Indian River, Pigeon River, and Cheboygan River using a Kemmerer sampling device. The Kemmerer was rinsed three times prior to collecting the water sample by lowering the device into the water, withdrawing, and lowering it again. All sample water was collected in the middle of the stream and at approximately mid-depth. Acid-rinsed containers used to collect samples for chemical analysis were rinsed three times with stream water (both bottle and cap) prior to collecting sample. Sterilized containers acquired from the Michigan Department of Environmental Quality (DEQ) in April and Emmet County Health Department in September were used to collect water samples for bacteriological analysis. These samples were not rinsed with stream water per instructions provided by DEQ and the Health Department, but instead filled only once.

All water samples were immediately placed in a cooler containing ice. Water samples collected for bacteriological analysis in April were shipped overnight to the DEQ Drinking Water Laboratory in Lansing, exceeding the eight hour time limit set by DEQ for quality assurance. Those collected in September were delivered directly to the Health Department Laboratory in Gaylord within six hours of sample collection. Water samples collected for chemical analysis were delivered directly to the University of Michigan Bio-station.

Figure 4. Map of sample sites on Mullett Lake tributaries.



Bacteriological analysis for water samples collected in the fall measured fecal coliform organisms per 100 milliliters and those collected in the fall measured E. coli organisms per 100 milliliters. Water samples collected for chemical analysis were analyzed for soluble reactive phosphorus ($PO4^-$), total phosphorus (TP), nitrate-nitrogen ($NO3^-$), total nitrogen (TN), and chloride (CL^-).

Following water sample collection, physical water quality data was collected using a Hydrolab MiniSonde®. The MiniSonde® was calibrated each morning prior to field work, using methods detailed in the Hydrolab manual. Dissolved oxygen was calibrated with the percent saturation method, using actual barometric pressure as measured by a sensor contained in the Surveyor4a Data Display unit. Conductivity was calibrated using a standard solution of 447 microSiemens/cm and pH was calibrated using standard buffer solutions of 7 and 10 units pH.

At each sample site the MiniSonde® was lowered into the water at mid-channel to approximately half the total depth and then measurements were saved to memory in the Surveyor4a and also written on a paper field data collection sheet. Upon returning to the office, data was transferred from the Surveyor4a to a computer and all data consolidated in a Microsoft Excel workbook.

After physico-chemical data collection, discharge data were collected at each site. A nylon measuring tape was tied across the stream channel perpendicular to flow. Current velocity, water depth, and stream width (location along the transect) were recorded at irregular intervals across the transect. Positions along the transect for data collection were selected based upon changes in depth and current velocity. Using a Marsh McBirney digital current meter and a top-setting wading rod, depth placement of the current velocity sensor was adjusted at each location along the transect using the 0.6 depth method. All data, including total channel width were recorded on a field data sheet and later inputted into a Microsoft Excel spreadsheet.

<u>Data Processing:</u>

Upon completing field data collection and data input, stream discharge and loads were calculated for each sample event at every sample site. Total phosphorus, total nitrogen, and chloride loadings were calculated for all sites using discharge and chemical concentration values. Subsequently, the percentage of discharge and load contributed by individual tributaries flowing into Mullett Lake were calculated.

Discharge was calculated for each section along the transect, i.e., between data collection points. The volume passing through each section per unit of time was calculated by multiplying the width, average depth and average current velocity. Discharge figures for individual sections were summed and the total was multiplied by a substrate friction coefficient to calculate total stream discharge. Substrate friction coefficients ranged from 0.8 to 0.9, depending upon substrate type observed in the field. The percentage of discharge contributed by Indian River, Pigeon River and Mullett Creek were calculated by dividing discharge data from the most downstream site into the summed total discharge of all three sites and multiplying it by 100.

Loads were calculated by multiplying the nutrient concentration, discharge and a conversion factor of 190.4794 (0.1904794 for TP, which was measured in ug/l). Loads were calculated and reported in pounds per day. As with discharge calculations, the percentage of load was calculated using data from the most downstream point of tributaries flowing into Mullett Lake. Load figures calculated at individual sites were divided into the summed load of the three tributaries and multiplied by 100. Final results show the percentage of the total load that is contributed by each tributary to Mullett Lake for individual chemical constituents.

RESULTS

Bacteriological:

During the first sampling event, water samples collected for bacteriological analysis were tested for fecal coliforms. Test results ranged less than 10 to 60,000 fecal coliform organisms per 100 milliliters (Table 3). Although there are no DEQ water quality standards for fecal coliforms in surface waters, R 323.1062 of Part 4 Water Quality Standards states that "discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 milliliters." The threshold of 200 fecal coliform bacteria per 100 milliliters was only exceeded at Crump Road on Mullett Creek.

Water samples collected for bacteriological analysis in September were analyzed for E. coli. Test results ranged from 2 to 727 E. coli bacteria per 100 milliliters (Table 3). Rule 62 (R 323.1062) of DEQ Part 4 Water Quality Standards does have a provision for E. coli concentrations in surface water: "All waters of the state protected for total body contact recreation shall not contain more than 130 Escherichia coli (E. coli) per 100 milliliters, as a 30-day geometric mean." Rule 62 also states: "At no time shall the waters of the state protected for total body contact recreation contain more than a maximum of 300 E. coli per 100 milliliters." As with the testing conducted in the spring, Mullett Creek at Crump Road was the only site where bacteria concentrations exceeded limits set by the State of Michigan.

Table 3. Bacteria concentrations in Mullett Lake tributaries.

Sample Site	Bacteria – April*	Bacteria – September**
Indian River - M27	<10	14.4
L. Sturgeon River – Onaway Rd.	100	88.2
Indian River - I75	20	20.1
Pigeon River – E. Mullett Lake Rd.	No data***	105
Mullett Creek – Crump Rd.	60000	727
Mullett Creek – M27	140	61.3
Cheboygan River – Hackmatack Inn	<10	2

*Reported in units of fecal coliform bacteria per 100 milliliters.
**Reported in units of E. coli bacteria per 100 milliliters.
*** No data collected due to time constraints.

Chemical:

Nutrient analyses of water samples show levels within typical ranges for all sites except those on Mullett Creek (Table 4). Typical ranges were determined using nutrient concentration values contained in the Watershed Council Comprehensive Water Quality Monitoring (CWQM) program database. Comparisons were made using high, low and average concentration values in CWQM data collected from 1992 to 2004 on Mullett Lake and from all rivers monitored in the CWQM program (Table 5).

Table 4. Nutrient concentrations in Mullett Lake tributaries.

	April 2005 *				September 2005 *			
Sample Site	**$PO4^-$**	**TP**	**$NO3^-$**	**TN**	**$PO4^-$**	**TP**	**$NO3^-$**	**TN**
Indian River - M27	2.3	4.5	154.4	336	2.5	4.7	19.2	186
L. Sturgeon River – Onaway Rd.	2.3	14.4	132.1	361	4.5	5.9	54.9	209
Indian River - I75	1.8	6.4	156.8	299	2.7	4.3	17.6	159
Pigeon River – E. Mullet Lake Rd.	2.0	15.1	104.5	292	2.9	3.5	38.9	210
Mullett Creek – Crump Rd.	82.0	143.4	871.8	1645	20.1	28.7	789.1	1260
Mullett Creek – M27	13.9	25.9	384.7	653	10.5	18.2	117.3	444
Cheboygan River – Hackmatack Inn	2.2	3.7	109.3	266	2.4	3.8	26.4	175

*$PO4^-$ = soluble reactive phosphorus, TP = total phosphorus, $NO3^-$ = nitrate-nitrogen, TN = total nitrogen. All data reported in ug/l (parts per billion).

Table 5. Typical nutrient and chloride concentrations from CWQM program data.

	TP*	**$NO3^{-*}$**	**TN***	**CL^- ***
Mullett Lake – Low	3.4	40	197	5.4
Mullett Lake – High	15.4	110	430	10.0
Mullett Lake – Average	7.7	88	319	7.1
All Rivers – Low	2.0	21	290	4.3
All Rivers – High	18.3	782	876	11.1
All Rivers – Average	7.4	206	485	7.2

*TP = total phosphorus, $NO3^-$ = nitrate-nitrogen, TN = total nitrogen, CL^- = Chloride. All data reported in ug/l (parts per billion), except chloride, which is mg/l (parts per million).

All total phosphorus concentrations on Mullett Creek were above CWQM program data averages and highs. Total phosphorus concentrations on other tributaries exceeded CWQM program data averages only two times, but were still below the highs reported in the CWQM data. Although nitrate-nitrogen and total nitrogen concentrations from Mullett Lake tributaries commonly exceeded averages reported for Mullett Lake, only Mullett Creek sites exceeded averages from rivers monitored in the CWQM program. Mullett Creek nitrogen concentrations exceeded CWQM river averages during both sample events at Crump Road and during April only at M27. In addition, nitrogen concentrations at Crump Road were above the CWQM river highs during both sampling events.

DEQ Part 4 Water Quality Standards does not include nutrient concentration threshold values for surface waters. Regulation for surface waters is limited to the following passage from Rule 60 (323.1060): "nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi or bacteria which are or may become injurious to the designated uses of the waters of the state." The United States Environmental Protection Agency (EPA) recommends that total phosphorus concentrations in streams discharging into lakes not surpass 50 parts per billion (PPB) (Muller and Helsel, 1999). This value was exceeded only once, at Crump Road on Mullett Creek during April.

Chloride concentrations were commonly above averages and highs reported for CWQM program data from both Mullett Lake and all rivers (Table 6). The highest chloride concentrations occurred in Mullett Creek. Rule 51 (323.1051) in DEQ Part 4 Water Quality Standards regulates chloride concentrations in public water supply sources as follows: "The waters of the state designated as a public water supply source shall not exceed 125 milligrams per liter of chlorides as a monthly average, except for the Great Lakes and connecting waters, where chlorides shall not exceed 50 milligrams per liter as a monthly average." Regardless of monitored tributaries being public water supply sources, measured concentrations did not exceed state standards at any site.

Table 6. Chloride concentrations in Mullett Lake tributaries.

Sample Site	Chloride – April*	Chloride – September*
Indian River - M27	9.7	9.4
L. Sturgeon River – Onaway Rd.	14.2	9.8
Indian River - I75	10.2	9.3
Pigeon River – E. Mullet Lake Rd.	7.3	5.3
Mullett Creek – Crump Rd.	16.5	21.3
Mullett Creek – M27	19.9	23.2
Cheboygan River – Hackmatack Inn	10.7	9.3

*All data reported in mg/l (parts per million).

Physical:

Physical water quality measurements were typical for surface waters in the northern Lower Peninsula (Table 7). Most data recorded during tributary monitoring fell within ranges of data from the CWQM program (Table 8).

Table 7. Physical parameter data from Mullett Lake tributaries.

	April 2005 *				**September 2005 ***			
Sample Site	**Temp**	**DO**	**Cond**	**pH**	**Temp**	**DO**	**Cond**	**pH**
Indian River - M27	6.17	11.97	282.1	8.15	16.55	9.34	277.8	8.42
L. Sturgeon River – Onaway Rd.	9.25	10.41	282.8	7.96	11.40	10.71	290.8	8.09
Indian River - I75	6.25	12.11	283.1	8.06	15.83	10.06	278.8	8.44
Pigeon River – E. Mullet Lake Rd.	8.56	9.89	317.8	8.11	10.85	9.28	322.8	8.11
Mullett Creek – Crump Rd.	6.92	10.45	299.9	7.85	9.83	9.83	366.3	8.00
Mullett Creek – M27	11.86	7.59	345.9	7.84	11.26	7.68	387.4	7.65
Cheboygan River – Hackmatack Inn	8.62	11.98	291.1	8.26	14.79	10.04	264.4	8.36

*Temp = temperature (℃), DO = dissolved oxygen (mg/l or PPM), Cond = specific conductivity (microSiemens/cm).

Table 8. Typical physical parameter values from CWQM program data.

	DO*	**Cond***	**pH**
Mullett Lake – Low	9.50	274	7.43
Mullett Lake – High	12.52	357	8.46
Mullett Lake – Average	11.36	304	7.94
All Rivers – Low	8.33	272	7.39
All Rivers – High	13.00	405	8.41
All Rivers – Average	10.16	315	8.05

*DO = dissolved oxygen (mg/l or PPM), Cond = specific conductivity (microSiemens/cm).

Water temperatures ranged from 6.17° to 11.86° Celsius in April and from 9.83° to 16.55° Celsius in September. According to DEQ Part 4 Water Quality Standards, monthly maximum temperatures for streams capable of supporting cold water fish are set at 54° Fahrenheit (12.22° Celsius) for April and 63° (17.22° Celsius) Fahrenheit for September. None of the temperatures recorded exceeded state limits.

Dissolved oxygen concentrations in the Mullett Lake tributaries ranged from 7.59 to 12.11 parts per million (PPM). Mullett Creek at M27 was the only site where levels were lower than the range of CWQM program data. Dependent upon the aquatic ecosystem type, DEQ Part 4 Water Quality Standards minimum dissolved oxygen concentrations for surface waters range from 5 to 7 PPM (Rules 64 and 65). All dissolved oxygen levels recorded in this study were above these minimums.

Specific conductivity in the Mullett Lake tributaries ranged from 264 to 397 microSiemens/cm. Although a few readings were just below the lows recorded in the CWQM program, no readings were above CWQM program highs, which is of greater concern as high conductivity may indicate pollution. Conductivity is not specifically addressed in DEQ Part 4 Water Quality Standards, though Rule 51 (323.1051) provides a framework for regulating total dissolved solid (TDS) concentrations from point source discharge. TDS in mg/l can be estimated from specific conductivity readings by using the widely accepted multiplication factor of 0.67. All conductivity measurements and therefore, estimated TDS concentrations, from Mullett Lake tributaries were well below the Rule 51 TDS maximum of 750 PPM.

Hydrogen ion concentration, expressed as pH, ranged from 7.65 to 8.44 in the Mullett Lake tributaries. All values fell within the range of data collected in the CWQM program as well as the range of 6.5 to 9.0 that must be maintained in all Michigan surface waters according to DEQ Part 4 Water Quality Standards, Rule 53 (323.1053).

Discharge and Pollutant Loadings:

Discharge measurements ranged from a low of 0.11 cms on Mullett Creek at Crump Road to a high of 16.92 cms on Indian River at Interstate 75 (Table 9). During both sampling events, Indian River discharged the greatest volume of water per unit time into Mullett Lake, while Mullett Creek discharged the least. Of the total discharge flowing into Mullett Lake from the three largest tributaries, Indian River contributed 72-75%, Pigeon River contributed 22-26% and Mullett Creek contributed ~2-3% (Table 9).

Table 9. Discharge measurements from Mullett Lake tributaries.

	April 2005 *		**September 2005 ***	
Sample Site	**Q (cms)**	**Q (cfs)**	**Q (cms)**	**Q (cfs)**
Indian River - M27	15.22	537.45	9.55	337.37
L. Sturgeon River – Onaway Rd.	1.19	42.05	0.59	20.95
Indian River - I75	16.92	597.38	11.56	408.21
Pigeon River – E. Mullett Lake Rd.	5.28	186.59	4.17	147.26
Mullett Creek – Crump Rd.	0.20	7.20	0.11	3.74
Mullett Creek – M27	0.59	20.98	0.28	9.78
Cheboygan River – Hackmatack Inn	9.51	335.68	NO DATA**	NO DATA**

*Q = discharge, cms = cubic meters per second, cfs = cubic feet per second.
**Weather prevented discharge data collection in September

As expected based upon discharge, Indian River was responsible for the greatest amount of pollutant loading into Mullett Lake, followed by Pigeon River and then, Mullett Creek (Table 10). Relative to discharge, the Pigeon River contributed a large percentage of total phosphorus to Mullett Lake during the first sampling event and a large percentage of total nitrogen during the second event (Table 11). Conversely, the Indian River contributed a small percentage of total phosphorus during the first sampling event and a small percentage of total nitrogen during the second event. Mullett Creek contributed more than its share of total phosphorus and total nitrogen during both sampling events. Chloride loads were heaviest in Mullett Creek and Indian River, relative to discharge, during both sampling events.

Table 10. Pollutant loadings from Mullett Lake tributaries.

	April 2005 *		**September 2005 ***	
Sample Site	**TP (lbs/day)**	**TN (lbs/day)**	**TP (lbs/day)**	**TN (lbs/day)**
Indian River - M27	13.04	974.02	8.55	338.46
L. Sturgeon River – Onaway Rd.	3.27	81.88	0.67	23.62
Indian River - I75	20.62	963.43	9.47	350.09
Pigeon River – E. Mullett Lake Rd.	15.20	293.88	2.78	166.80
Mullett Creek – Crump Rd.	5.57	63.87	0.58	25.40
Mullett Creek – M27	2.93	73.88	0.96	23.41
Cheboygan River – Hackmatack Inn	6.70	481.61	NO DATA**	NO DATA**

*All loads reported in pounds per day. TP = total phosphorus and TN = total nitrogen.
**Weather prevented discharge data collection in September.

Table 11. Percent of discharge and pollutant loads from major tributaries of Mullett Lake.

	April 2005 *				**September 2005 ***			
Tributary	**%Q**	**%TP**	**%TN**	**%CL^-**	**%Q**	**%TP**	**%TN**	**%CL^-**
Indian River	75.24	53.22	72.37	77.31	72.22	71.69	64.80	79.03
Pigeon River	22.12	39.22	22.08	17.38	26.05	21.05	30.87	16.25
Mullett Creek	2.64	7.56	5.55	5.31	1.73	7.27	4.33	4.72

* Q = discharge, TP = total phosphorus, TN = total nitrogen, and CL^- = Chloride.

DISCUSSION

Bacteriological Monitoring:

Results from bacteriological analyses show elevated levels that surpass State of Michigan surface water quality standards only for water samples collected from Mullett Creek. Due to sampling objectives, it is not surprising that bacteria levels were highest at the Crump Road stream crossing, which is located just downstream from an agricultural operation with livestock. The alarmingly high fecal coliform levels (60000/100 mL – Table 3) during the April sampling period were probably the result of samples being collected after the larger of the two precipitation events (April stream discharge was double that recorded in September – Table 9). Even during the lesser of the two precipitation events, E. coli levels at Crump Road greatly exceeded State surface water quality standards. However, bacteria levels downstream at the M27 road crossing were within limits.

Although flowing through an urban area Indian River displayed some of the lowest bacteria levels (Table 3). Mullett Lake residents have expressed concerns regarding Indian River water quality degradation from the town of Indian River and research has repeatedly shown that urbanization has negative impacts on water quality (Klein 1979, Jones and Clark 1987, and Steedman 1988). However, the town of Indian River is a relatively small urban area and the large discharge of Indian River appears to effectively dilute the impacts of urbanization.

Physico-Chemical Monitoring and Pollutant Loads:

Physical measurements taken in the field did not reveal any immediate water quality problems. All temperatures recorded were low enough to sustain cold water fisheries. Both conductivity and pH in all tributaries were found to be at typical levels and dissolved oxygen concentrations were consistently above minimums established by the State of Michigan.

Although above the minimum required level, dissolved oxygen concentrations recorded at M27 on Mullett Creek were approaching the threshold value of 7 PPM. The lower levels at the mouth of Mullett Creek are probably due to the fact that the creek flows slowly through wetland areas that are exposed to the sun just upstream of M27. Slow or stagnant waters have lower atmospheric diffusion rates than that of fast turbulent waters and therefore, typically have lower dissolved oxygen concentrations. In addition, warm water holds less dissolved oxygen than cold water. However, low dissolved oxygen levels can also result from the addition and decomposition of excess organic matter to the stream system.

Results of chemical analyses of water samples showed concentrations at typical levels for most sample sites. Nutrient (phosphorus and nitrogen) and chloride levels were higher in Mullett Creek than the other tributaries and nutrient concentrations were highest at the Crump Road stream crossing. As with bacteria, elevated phosphorus and nitrogen concentrations were not unexpected at Crump Road due to agricultural operations in the watershed. Runoff from agricultural areas often exhibits high nutrient concentrations, particularly concerning nitrogen (Sullivan, 1999), which originate from farm field fertilizer application and livestock waste.

Excessive nutrient inputs have the potential to disrupt an aquatic ecosystem and even pose a danger to human health. Both phosphorus and nitrogen are required by plants for survival. If excess nutrients are available in the aquatic ecosystem, then algae and higher aquatic plants will thrive. Excessive plant growth could affect biological organisms by altering in-stream habitat composition. In stream reaches with slow flow, or in ponds and lakes, excessive plant growth could lead to dissolved oxygen deficits, particularly during the night when plants respire and consume oxygen. Furthermore, nutrient enrichment may cause nuisance algae blooms, some types of which are toxic to animals, including humans.

Pollutant loading calculations show largely what one would expect: tributaries with greater discharge contribute more nitrogen, phosphorus and chloride. However, not all streams and rivers contributed the same proportion of pollutants as discharge. Indian River, which contributed over 70% of the discharge to Mullett Lake during both sampling periods only contributed 53% of the total phosphorus during the first sampling period and 65% of the total nitrogen during the second sampling period. Conversely, the Pigeon River contributed more total phosphorus relative to discharge during the first sample period and more nitrogen during the second.

Based upon these calculations, it would appear that there are water quality issues on the Pigeon River. Although much of the Pigeon River flows through protected lands, such as Pigeon River Country, there are branches that flow through agricultural, residential and even some commercial/industrial areas. However, phosphorus and nitrogen do occur naturally and are deposited through atmospheric deposition, so there is the possibility that sampling simply captured a natural spike. In addition, sample contamination may explain the irregularity as only one water sample was collected at each site during each sampling event. The Pigeon River did contribute little chloride to Mullett Lake in relation to discharge, which is evidence of the pristine state of its watershed (i.e., natural and undeveloped).

CONCLUSION

The Mullett Lake Tributary Water Quality Monitoring Project was carried out to fill a gap by collecting water quality data that formerly did not exist. For the first time, the Mullett Lake Area Preservation Society has a good water quality data set for the major tributaries flowing into Mullett Lake. Results support suspicions that nutrient pollution and bacterial contamination were occurring in Mullett Creek, yet did not support the same suspicions for the Indian River. Where there were no suspicions, on the Pigeon River, results raised an alarm of nutrient pollution possibly occurring.

Particular attention should be given to nutrient contamination occurring in the Mullett Creek watershed. The indirect impacts of nutrient enrichment could lead to dissolved oxygen deficits and the occurrence of nuisance or harmful algae blooms in the stream and conceivably in a localized area of Mullett Lake. Furthermore, nitrate contamination of ground water poses a direct threat to human health as nitrate in drinking water is known to cause “blue-baby” syndrome. Nitrate-nitrogen in drinking water is regulated by DEQ and should not exceed 10 PPM. Testing of groundwater was not undertaken in this study and was not researched to determine if data already exists. More information should be gathered on nitrate levels in drinking water supplies in the Mullett Creek watershed. If little or no data exists or if the data are dated, then it is recommended that ground water nitrate concentrations be monitored.

In agricultural areas, livestock should not be allowed access to streams. In addition to bacteriological and nutrient contamination from waste, livestock accelerate stream bank erosion. Eroding stream banks expose soils and contribute excessive sediments, which can have many negative impacts on the aquatic ecosystem, including: smothering habitat and clogging gills of fish and macroinvertebrates, increasing stream temperature as suspended solids absorb sunlight energy, and reducing stream greenbelts. In situations where a stream crossing is needed to allow livestock movement, impacts can be minimized by using fencing to limit stream access and building concrete, broken rock or gravel approaches to reduce erosion.

As is the case with lakes, stream ecosystems benefit from well-vegetated buffers (i.e., greenbelts) along stream margins. Greenbelts effectively absorb surface runoff and by doing so filter out pollutants, reduce peak stream discharge during rain events, provide shade to maintain water temperatures necessary for cold water fisheries and prevent erosion. Naturally vegetated stream banks also provide critical habitat and a food energy source for both aquatic and terrestrial organisms. Research has shown that optimal greenbelt width for stream protection to be 100 feet or more, but that greenbelts of 35 feet of width provide many benefits to stream water quality and biology (Wenger 1999). Riparian owners in all streams throughout the Mullett Lake watershed should be encouraged to maintain greenbelts of the greatest width possible.

Although filling a gap in water quality data for the Mullett Lake area, there were limitations to the study. Due to funding and personnel limitations as well as site accessibility issues, field data collection occurred only two times and did not include all tributaries. Personnel and equipment limitations may have resulted in some inaccuracies, particularly in performing discharge measurements. Additionally, collecting and analyzing replicate water samples would have provided quality assurances for the results.

An objective set out in this study was to collect data during peak discharge conditions to gauge the full effect of stormwater runoff. Due to equipment and timing issues, field data collection was not carried out during the biggest snowmelt or precipitation events in the spring or fall and thus, pollutant concentrations and loadings may not represent the maximum that occurred during 2005. Ideally, data should be collected over a period of several years, sampling throughout all seasons and hydrologic conditions (i.e., low, normal and high discharge). Additional tributary water quality monitoring should be conducted in order to: 1) collect a more representative data set by monitoring in other seasons and under a variety of discharge conditions, 2) fill data gaps by monitoring more tributaries, and 3) support or refute the results of this study.

There are now many different tools and instruments used for measuring discharge. The equipment used by the Watershed Council for this study may not have been the most appropriate for the large rivers, but was nevertheless accurate. If further monitoring is conducted, alternate methods should be considered. At some sites, a bridge board system would facilitate field data collection, though such a system would not be appropriate for use on the interstate bridge due to safety hazards. More advanced technologies such as Doppler sonar may be more suitable for the circumstances. In addition, the method used for this study and others that have been mentioned would be easier to employ with extra field hands.

Dependability and accuracy of the data generated from chemical and bacteriological analysis of collected water samples could be improved during future monitoring projects. Although it would take more time and incur more laboratory costs, replicate samples should be collected at each site during each sample period for quality assurance. The biggest hurdle for collecting dependable bacteriological data was time. According to EPA guidelines, water samples have to be delivered to the laboratory performing the analysis within six hours of collection. When collecting physical, chemical, bacteriological and discharge data from multiple sites around a large water body, it is extremely difficult to perform all field work and then, deliver the water samples to the closest laboratory (in Gaylord) in a six hour time period. At least two people should conduct the fieldwork to ensure that water samples are collected and delivered to the laboratory within time limits.

This study was not intended to produce a comprehensive, all-inclusive water quality data set for every tributary of Mullett Lake, but rather provide a base of information that can be used to determine the best course of action for protecting and improving water quality. In spite of the limitations, a unique set of valuable data was collected and is available to MAPS to guide lake management decisions and to strategize future monitoring efforts. Lake users and the lake ecosystem will ultimately benefit from MAPS taking the initiative to better understand and therefore, better manage Mullett Lake and its tributaries.

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