THE RELATIONSHIP BETWEEN PLANT DENSITY AND MICROPLASTIC CONCENTRATION IN THE WATER IN LAKE BEMIDJI, MN

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***Abstract*—Microplastics, plastic particles smaller than 5 mm, are an increasing environmental threat, particularly due to their widespread distribution and toxicity. While much research has focused on larger freshwater and marine ecosystems, the presence and impacts of microplastics in smaller inland lakes remain less understood. This study investigates the relationship between plant density and microplastic concentrations in Lake Bemidji, a smaller freshwater lake. A total of 30 water samples were collected across varying vegetation conditions, ranging from open water (0%) to 90% plant coverage. Microplastics were identified and categorized into six morphological types: fibers, fragments, films, spheres/beads, and foam. The samples contained a total of 2,790 microplastic particles, with an average of 93 particles per sample and an average concentration of 8.16 microplastics per liter (SD = 3.06). The most abundant colors were blue (2,204 particles) and black (460 particles), while red and green were the least common. A regression analysis was conducted to directly test the relationship between the total count of microplastics and plant density, and there was a significant negative relationship between microplastic count and plant density ($P < 0.01$). The findings suggest that plant density does influence the distribution and deposition of microplastics in freshwater systems, with higher concentrations observed in areas with lower plant coverage.**

I. Introduction

Microplastics, plastic particles smaller than 5 mm, are becoming a looming environmental crisis, with their pervasive spread and toxicity posing a growing threat to ecosystems around the world. As Conowall et al. (2023) emphasize, microplastics are a significant concern because of their alarming global presence and the dangerous toxicity they introduce into the environment, furthering this growing environmental crisis. This problem has been worsened by the surge in plastic production, which surpassed 350 million tons as of 2019 (Negrete Velasco et al. 2020). The uncontrolled manufacturing and consumption of plastics, combined with their resistance to degradation, have resulted in their accumulation within the environment (Negrete Velasco et al. 2020).

While much of the research on microplastic pollution has focused on marine environments and large freshwater systems, there is a growing need to examine smaller, inland lakes like Lake Bemidji. One factor that may influence these microplastic concentrations in these ecosystems is plant density. Vegetation in aquatic systems can impact water flow, sedimentation, and particle retention, which may affect how microplastics are transported and deposited within lakes. This shift in research focus reflects the broader trend in science, where initial studies on marine plastic debris dating back to the around the 1970s eventually expanded as the ecological impact of plastic became more apparent. Once unnoticed, the accumulation of microplastics is now recognized as a major environmental concern across marine and freshwater systems (Andrady 2011).

Despite the importance of plant density in shaping the dynamics of microplastic pollution, limited research exists on how this factor influences microplastic concentrations in smaller freshwater lakes. This study aims to address this gap by investigating the relationship between plant density and the concentration of microplastics in the water of Lake Bemidji. By examining this relationship, the study seeks to enhance our understanding of the environmental factors that contribute to microplastic pollution and to inform future efforts to mitigate its impacts in freshwater ecosystems.

II. Methods

All water samples were collected from Lake Bemidji on the west side, just north of Cameron Park (47°30.2231'N 94°52.1179'W), on 8 October 2024. A total of 30 samples were taken across varying vegetation conditions to assess the impact of plant density on microplastic concentrations. Plant density was recorded put into categories: these plant densities were 0%, 5%, 10%, 25%, 50%, and 90%. Plant density was measured using a 0.5 m² quadrat, with the percentage of emergent and floating vegetation within the quadrat being visually estimated. Plant density values for the samples ranged from 0–90% coverage.

Water samples were collected using a 11.4 L stainless-steel stock pot, submerged to a depth of approximately 0.5 m. To avoid contamination, the stock pot was rinsed with distilled water before each use. After collection, the contents of the pot were poured through a 106 µm stainless-steel testing sieve to filter out larger debris. The material collected in the sieve was back washed with distilled water into pre-decontaminated glass mason jars. An approximate 12% hydrogen peroxide solution was added to each jar to break down organic material, and the jars were left to sit for at least one week.

After the organic material had been allowed to be broken down, the contents of each jar were examined under a dissecting microscope, in a glass dish, at 1-4x magnification. White paper was placed under the dish to help identify colored microplastics. Suspected microplastics underwent a stress test with a sterilized dissecting needle (with a wooden handle) to confirm their identity. Plastic particles were confirmed if they did not crumble or break under the pressure of the needle. Identified microplastics were separated into six morphological categories: fiber, fragment, film, sphere/bead, and foam. In addition, the color of each microplastic particle was recorded. A regression analysis was run to directly test for a relationship between the log-transformed total count of microplastics and plant density.

III. Results

Data was collected from Lake Bemidji across six varying plant density levels: 0%, 5%, 10%, 25%, 50%, and 90% plant coverage. The total microplastic count for each density level is summarized in Table 1, along with the average number of microplastics (ANMP) per sample and the microplastic concentration (MPC) per liter.

TABLE 1: TOTAL MICROPLASTIC COUNT, AVERAGE NUMBER OF MICROPLASTICS (ANMP), AND MICROPLASTIC CONCENTRATION (MPC), FOR EACH PLANT DENSITY LEVEL. COLLECTED ON 8 OCTOBER 2024 ON WEST SHORE LAKE BEMIDJI.

Plant Density (%)	Total # of plastics	ANMP (particles/per sample)	MPC (particles/ per liter)
0	1362	136.20	11.95
5	629	104.83	9.20
10	472	98.25	8.62
25	231	77.00	6.75
50	99	33.00	2.89
90	76	19.00	1.67

TABLE 2. MICROPLASTIC MORPHOLOGY DISTRIBUTION IN LAKE BEMIDJI SAMPLES. PERCENTAGE AND TOTAL COUNT OF EACH SHAPE ARE SHOWN. COLLECTED ON 8 OCTOBER ON WEST SHORE LAKE BEMIDJI.

Microplastic Morphology	Total # of Plastics	Morphology Distribution (%)
Fiber	289	10.36
Fragment	2420	86.77
Film	32	1.15
Sphere/Bead	47	1.68
Foam	1	0.04

TABLE 3. MICROPLASTIC COLOR DISTRIBUTION IN LAKE BEMIDJI SAMPLES. PERCENTAGE AND TOTAL COUNT OF EACH COLOR TYPE ARE SHOWN. COLLECTED ON 8 OCTOBER ON WEST SHORE LAKE BEMIDJI.

Color	Total # of Plastics	Color Distribution (%)
Blue	2204	79.00
Black	460	16.49
Clear/White	88	3.15
Magenta	34	1.22
Red	2	0.07
Green	2	0.07

As plant density increased, both the total number and the concentration of microplastics in the samples decreased. At 0% plant coverage, the average microplastic count per sample was 136.20 particles, and the microplastic concentration was 11.95 particles per liter (Table 1). In contrast, at 90% plant coverage, the average count per sample dropped to 19.00, with a concentration of only 1.67 particles per liter. The breakdown of microplastic types demonstrated that most particles were fragments, making up 86.77% of the total microplastics (Table 2). Fibers accounted for 10.36%, followed by films (1.15%), spheres/beads (1.68%), and foams (0.04%). In terms of color distribution, blue microplastics dominated the sample, comprising 79.00% of the total microplastic particles (Table 3). Black microplastics were the second most abundant at 16.49%, while clear/white particles made up 3.15%. Magenta, red, and green particles were found in trace amounts, representing 1.22%, 0.07%, and 0.07%, respectively.

A regression analysis was conducted on the log-transformed total count of microplastics to directly test the relationship with plant density, and there was a significant negative relationship between microplastic count and plant density with a p-value < 0.01, suggesting a strong inverse correlation between plant density and microplastic concentration in the lake (Figure 1).

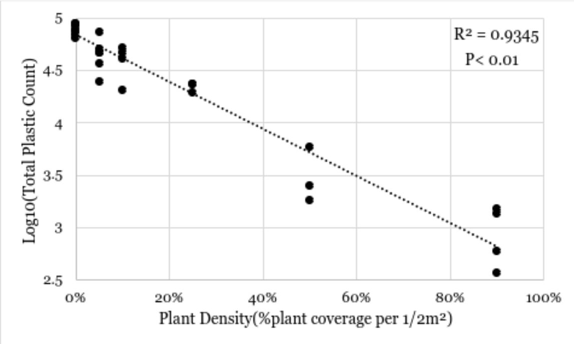

Figure 1: Log-transformed total plastic count data from the regression analysis for all of the samples in Lake Bemidji, MN (8 October 2024).

IV. DISCUSSION

The primary finding of this study is the strong inverse relationship between plant density and microplastic concentrations in Lake Bemidji, as higher vegetation coverage was associated with lower concentrations of microplastics. This result aligns with findings by Helcoski et al. (2020), who reported higher vegetation cover and stem density in wetlands reduced microplastic retention, in an urban tidal freshwater wetland in Washington DC, USA. A potential explanation for this pattern is that dense aquatic vegetation acts as a natural buffer, reducing water flow and trapping microplastics in sediments or plant structures before they can remain suspended in the water column. Inversely, in open water with little or no vegetation, microplastics are likely to remain suspended due to higher water flow and turbulence, leading to higher concentrations.

An additional finding is that microplastic fragments dominate the samples from Lake Bemidji, accounting for 86.77% of the total particles, followed by fibers at 10.36%. This distribution contrasts with global trends, where Yang et al. (2022) report fibers are the most common morphology in Asian lake waters (64.5%) and sediments (93.5%), while fragments dominate European lakes (68.8% in water and 29.9% in sediments). In the Americas, fibers are the primary morphology in water (56.2%), but sediments show a more balanced distribution between fibers (37.0%), fragments (31.8%), and foams (29.9%). African lakes, in contrast, are dominated by pellets in both water (75.7%) and sediments (70.3%), likely reflecting specific industrial inputs. Lake Bemidji's predominance of fragments, alongside the limited presence of films, foams, and pellets, highlights regional differences in plastic use, degradation, and hydrodynamic conditions offering valuable insights into the localized sources and pathways of microplastics into freshwater systems.

An important note in this study is the appearance of blue, black, and clear/white microplastics as the most common colors in the samples. This color distribution mirrors findings by Conowall et al. (2023), who observed a similar prevalence of these colors in microplastic samples from four inland lakes in Minnesota. The dominance of blue and black microplastics may be linked to their frequent use in consumer products, such as textiles and packaging materials, which are common sources of microplastic pollution. Clear/white microplastics may represent degraded or weathered plastics that have lost pigmentation over time. The trace presence of other colors, like magenta, red, and green, suggests limited contributions from specific or localized sources of these hues, such as fishing lines or plastic toys.

In summary, the study highlights the critical role of plant density in reducing microplastic concentrations, underscores the dominance of fragments as the primary microplastic type, and reveals a distinct color distribution pattern with blue and black microplastics as the most common. These findings enhance our understanding of the environmental dynamics of microplastics in smaller freshwater systems and provide valuable insights for targeted mitigation efforts in Lake Bemidji and similar ecosystems.

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