To Sink or Swim

A Snapshot Evaluation of the Fate and Types of Microplastics in Lake Tahoe

Surface and Municipal Waters Summary for TWSA

A collaborative original research study conducted by the
University of California Davis Tahoe Environmental Research Center and One Health Institute
with funding by the Nevada Division of Environmental Protection and the Tahoe Water Suppliers Association

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PROJECT OVERVIEW

ENVIRONMENTAL MICROPLASTIC POLLUTION

Due to the ubiquitous and largely unrestricted use of plastics, its frequent unintended release into the environment, and increasing recognition of potentially harmful effects; there is an urgent need to better understand the current levels, environmental fate, as well as the hazards posed to human, wildlife, and ecosystem health in order to appropriately assess risks associated with its presence.

Plastics are composed of synthetic (human-made) polymers typically derived from petroleum oils. These synthetic polymers are made up of repeating identical molecular sub-units (monomers) that are chemically linked together into long chains. The characteristics of a plastic are determined by the particular sub-unit's chemical properties that can be augmented with additive chemicals (like plasticizers, flame retardants, other polymers, or dyes) that are mixed into the plastic to adjust specific properties including rigidity, flexibility, durability, melting point, color, and clarity. Table 1 describes the characteristics and uses of the most commonly produced plastics are outlined below.

Table 1. Characteristics and uses of the most commonly produced plastics worldwide.

Commonly Produced Plastics						
Synthetic Polymer (Plastic)	**Abbr**	**Density g/cm^3**	**Sink or float**	**Global Plastic Product**	**Key Characteristics**	**Typical uses**
Polyethylene	PE	0.91 - 0.97	Float	36%	Durable Easily molded Lightweight	Bottles/food containers/bags Pipes Fishing gear/nets
Polypropylene	PP	0.9 - 0.91	Float	21%	Rigid and tough Fatigue resistant Susceptible to solvents Heat resistant	Food packaging Automotive parts Medical supplies Upholstery, consumer goods
Polyester & Polyethylene Terephthalate	PES PET	1.23 - 2.3 1.37 - 1.45	Sink	10%	Strong and stiff Resistant to shatter Lightweight	Clothing and textiles Bottles/food containers
Polyvinyl chloride	PVC	1.16 - 1.58	Sink	12%	Hard and durable Tensile strength Rigid or flexible forms	Constructions materials Pipes/Flooring/wiring Packaging
Polystyrene	PS	1.04 - 1.1	Sink	10%	Hard Rigid/brittle Forms plastic mixtures	Foam food containers Disposable cutlery Building insulation
Polyurethane	PU	1.2	Sink	10%	Abrasion resistant Rigid or flexible forms Bonds well	Building insulation Insulating foams/mattresses
Polyamide (Nylon)	PA	1.02 - 1.05	Sink	-	Tensile strength Low friction Resists abrasion Dries quickly	Clothing Industry/construction Fishing gear/nets Electronics/machine parts

PROJECT OVERVIEW

The term 'microplastic' is colloquially used to refer to any small piece of plastic and are generally defined as synthetic polymers measuring between 1 µm and 5 mm in size. Table 2 defines the more precise terminology is used in the scientific communities to refer to different size classes of plastic, however, debate continues as to the exact size encompassed by each term (Padervand et al. 2020).

Table 2. Size class definitions and descriptions of common "microplastic" terminology.

Commonly Terminology used for Microplastic Research	
Term	**Description**
Particle	General term referring to any small piece of matter with physical and chemical properties that may be used when the underlying composition is plastic, non-plastic, or unknown
Suspected Plastic Particle	Term referring to a particle that has characteristics consistent with or similar to plastic but that has not been definitively identified or confirmed to be composed of plastic.
Nanoplastic	A piece of plastic commonly measured in nanometers (usually 1-1000nm) by its longest dimension
Microplastic	A piece of plastic commonly measured in micrometers (usually 1-1000µm) by its longest dimension
Mesoplastic	A piece of plastic measuring 1-10mm by its longest dimension
Macroplastic	A piece of plastic measuring larger than 1cm by its longest dimension

Plastic is refractory to biodegradation, which makes it a resilient and durable material that is useful for many applications. Its chemical resilience means that pieces of plastic often physically break into smaller pieces long before it can chemically degrade. Because chemical degradation tends to occur at a much slower rate than physical break-down into smaller pieces, an accumulation of ever-smaller pieces of plastic (microplastics) may persist in contaminated environments for many decades to centuries or even millennia after being released.

While harmful effects of microplastic exposure have been researched and described, there is currently only a rudimentary understanding of the hazards posed by microplastic pollution. Much remains unknown about how microplastic characteristics and composition may contribute to harmful effects, how environmental fate of microplastics may affect exposure pathways, and at what environmental level harmful effects occur for different environmental matrices.

Although risk to human health from drinking water is considered low at this time, this conclusion assumes drinking water undergoes standard treatment and is based on currently understood health effects. This conclusion may not be appropriate to extrapolate to untreated water sources, other routes of exposure, and wildlife and ecosystem health.

PROJECT OVERVIEW

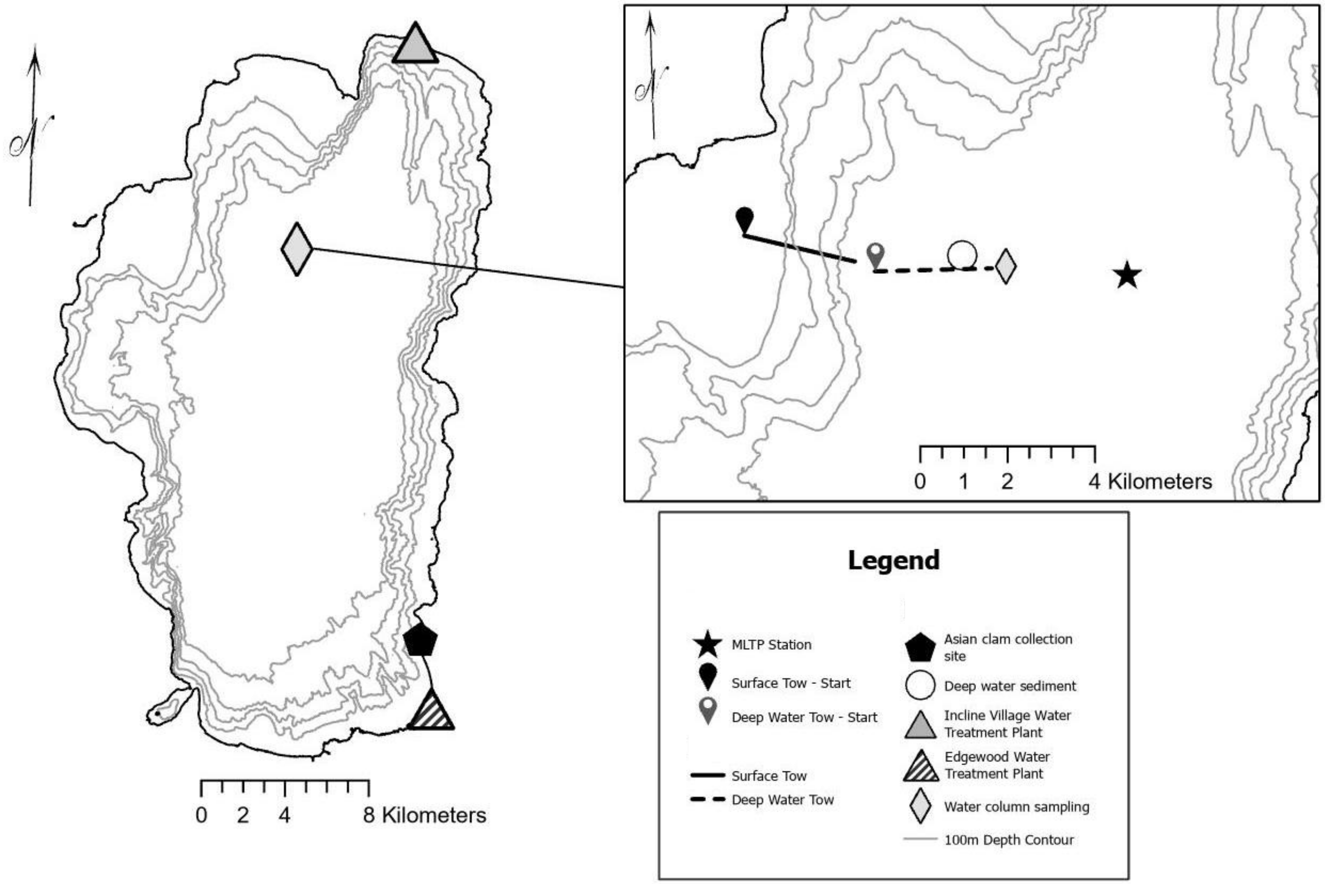


FIGURE 1. MAP OF LAKE TAHOE INDICATING PROJECT SAMPLING LOCATIONS. THE MAP INDICATES THE LOCATIONS WHERE EACH TYPE OF SAMPLE WAS COLLECTED. THESE LOCATIONS ARE CONSIDERED TO BE REPRESENTATIVE OF EACH TYPE OF ENVIRONMENT AT LAKE TAHOE, ALTHOUGH NO SPATIAL RECORD OF MICROPLASTIC POLLUTION EXISTS TO CONFIRM THIS ASSUMPTION. HOWEVER, BASED ON MANY DECADES OF LAKE MONITORING OF A BROAD RANGE OF ENVIRONMENTAL VARIABLES WE BELIEVE THAT THIS ASSUMPTION TO BE CORRECT

MATERIALS AND METHODS
HORIZONTAL TOWS OF SURFACE AND SUBSURFACE WATERS

MATERIALS AND METHODS
HORIZONTAL TOWS OF SURFACE AND SUBSURFACE WATERS

<u>Sample Collection</u>

A horizontal oceanic sampling trawl net with mesh size of 335µm was used to collect 12 monthly samples from surface and subsurface waters of Lake Tahoe during the period of August 27th, 2020 to August 4th, 2021. The trawl net was towed by boat for 30 minutes at 3 knots along a fixed heading transect between the Tahoe City Marina and Mid Lake Tahoe Profile (MLTP) monitoring site (see figure 1). The sampling net was towed alongside the vessel to prevent contamination from the boat or interference from the propeller. A water level data logger was attached to the net to measure actual tow depth during subsurface sample collection. GPS location, heading, speed and duration were recorded during each tow.

Following completion of a tow, the net was carefully brought onboard and all collected material was flushed into a pre-cleaned glass jar using de-ionized water. Field blank samples were collected prior to tows by rinsing two liters of pre-filtered de-ionized water through the suspended trawl net. Sample jars were stored in coolers until they were transferred to the lab.

Figure 1. Sampling of suspected plastic particles from Lake Tahoe surface waters. A tow net was used to collect samples from surface and subsurface waters (left image). Following a tow, all material from the net was transferred into a sampling jar (middle image). Samples from each jar were processed at the lab to remove organic material and isolate any potentially plastic particles for further analysis.

<u>Sample Preparation</u>

Each sample was then processed to isolate particles suspected to be plastic from other natural materials. These suspected particles were mounted onto double-sided tape attached to a pre-cleaned transparent plastic disc for validation using Raman microspectroscopy (see figure 3). See the full report for a detailed description of all field and laboratory methods.

MATERIALS AND METHODS
HORIZONTAL TOWS OF SURFACE AND SUBSURFACE WATERS

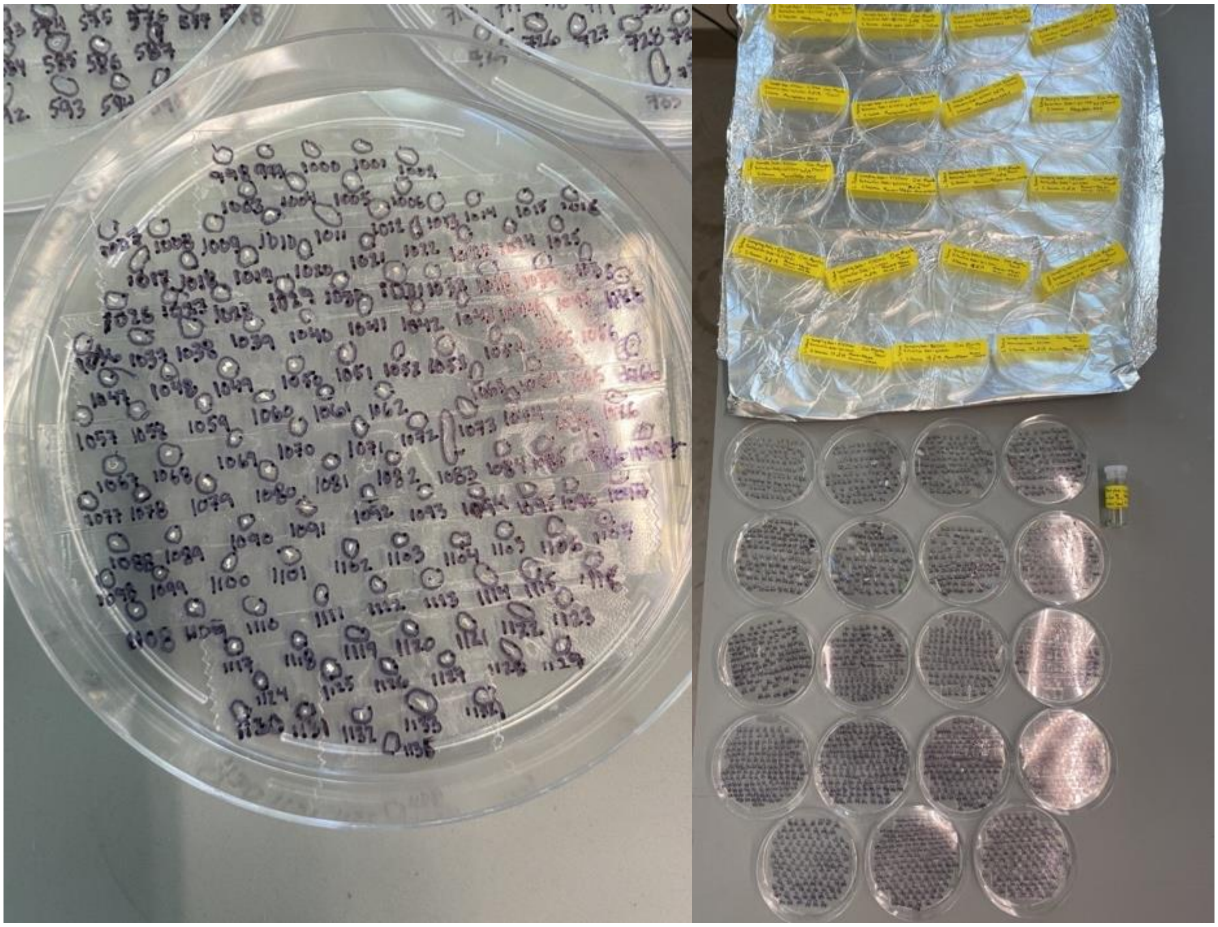


FIGURE 3. PREPARATION OF TRAWL NET SAMPLES FROM LAKE TAHOE SURFACE WATERS. FOLLOWING DIGESTION OF ORGANIC MATERIAL, EACH SUSPECT PARTICLE WAS TRANSFERRED AND MOUNTED FOR CHARACTERIZATION AND ANALYSIS.

MATERIALS AND METHODS - MUNICIPAL WATER

MUNICIPAL WATER

Sample Collection

Working with the Tahoe Water Suppliers Association (TWSA), quarterly samples were collected at two municipal drinking water intakes within the Lake Tahoe Basin. The Incline Village pump station, operated by the Incline Village General Improvement District (IVGID), served as the north shore sampling location. While the Edgewood pump station, operated by the Edgewood Water Company, served as the south shore sampling location. Municipal water samples for this project were collected from the same sample collection spigots used by the water operator to collect their water quality samples. At the Edgewood pump house, the sampling point was located off a large metal pipe which is estimated to have consistent high-water flows moving through it. All samples at the Edgewood pump house were collected from this point except for the summer quarterly sample due to repairs taking place on the spigot. An alternative sampling spigot was identified by the pump house manager and used for this one event. The sampling point for the Incline Village pump house was not off a main water pipe but a small PVC pipe that ran approximately 15m off the main line before the water could be collected from the sampling spigot. It is suspected that water inside the small PVC pipe was often stagnant since it was not a part of the main line constantly pumping water.

At the sampling spigots, water was flushed for 10 minutes prior to collecting the sample in order to move any stagnant water through the system. Once the water line had been purged, municipal water was collected directly into pre-cleaned 3.75 L glass jars. A duplicate sample was also collected at the Edgewood pump house. Field blanks were collected at each pump house by placing a pre-cleaned 3.75 L glass jar filled with DI water next to the sampling spigot with the lid off for the same amount of time it took to collect the municipal water. This was done in order to account for any airborne contamination which may have occurred during sample collection. Municipal water samples, duplicates, and blanks were stored in a dark 4° C cooler or cold room until samples could be filtered.

Municipal samples collected for the summer quarter were collected on different dates due to staffing changes at one of the pump houses. During the summer collection at the Edgewood pump house in August 2021, the Tahoe Basin was experiencing heavy smoke effects from the Caldor wildfire activity. Wildfire smoke had dissipated from the basin for approximately 2 weeks prior to the September 2021 water collection at the IVGID pump house.

Table 6. Sampling dates and locations for municipal water sampling at Lake Tahoe.

Municipal Water Sample Collection Dates		
Edgewood Water Company	**Incline Village GID**	**Quarter**
June 10, 2021	June 10, 2021	Spring
August 24, 2021	September 19, 2021	Summer
December 2, 2021	December 2, 2021	Fall
February 8, 2022	February 8, 2022	Winter

Table 7: TWSA partner agencies' intake length, depth, and distance from the lake bottom. Intake water depth is reported based on measurements from the lake's rim since water depth varies depending on water level.

Municipal Water Intake Pipe Systems			
Municipal Water Source	**Length (m)**	**Depth (m)**	**Bottom (m)**
Incline Village GID	204.2	9.1	1.2
Edgewood Water Company	1676.4	182.9	1.2

Sample Preparation

Samples were vacuum filtered onto a polycarbonate filter (10 µm pore size). All detectable particles on the filter surface were identified with the aid of a dissecting microscope. Each was mounted onto double-sided tape attached to a pre-cleaned transparent disc and labeled as previously described. The discs were stored inside pre-cleaned petri dishes until Raman microspectroscopic analysis and characterization could be performed.

<u>Particle Classification and Identification</u>

Following collection, processing, and isolation of particles suspected to be plastic, the particle composition must be determined. Raman spectroscopy is considered one of the current gold standards for confirming whether a particle is composed of plastic or another type of material. A Horiba XploRA™ Plus confocal Raman microspectroscopic unit operated using LabSpec6 spectroscopy suite software (Horiba Instruments Inc., 2890 John R Road, Troy, MI 48083, USA) was used for analysis.

Raman spectra from each particle were identified by peak matching comparisons to Raman spectral libraries using KnowItAll™ software (Wiley) in conjunction with KnowItAll™, SLOPP, SLOPP-E, and in-house Raman spectral libraries. Spectral library matches were then screened individually for appropriate particle identification. All full detailed description particle classification can be found in the final report.

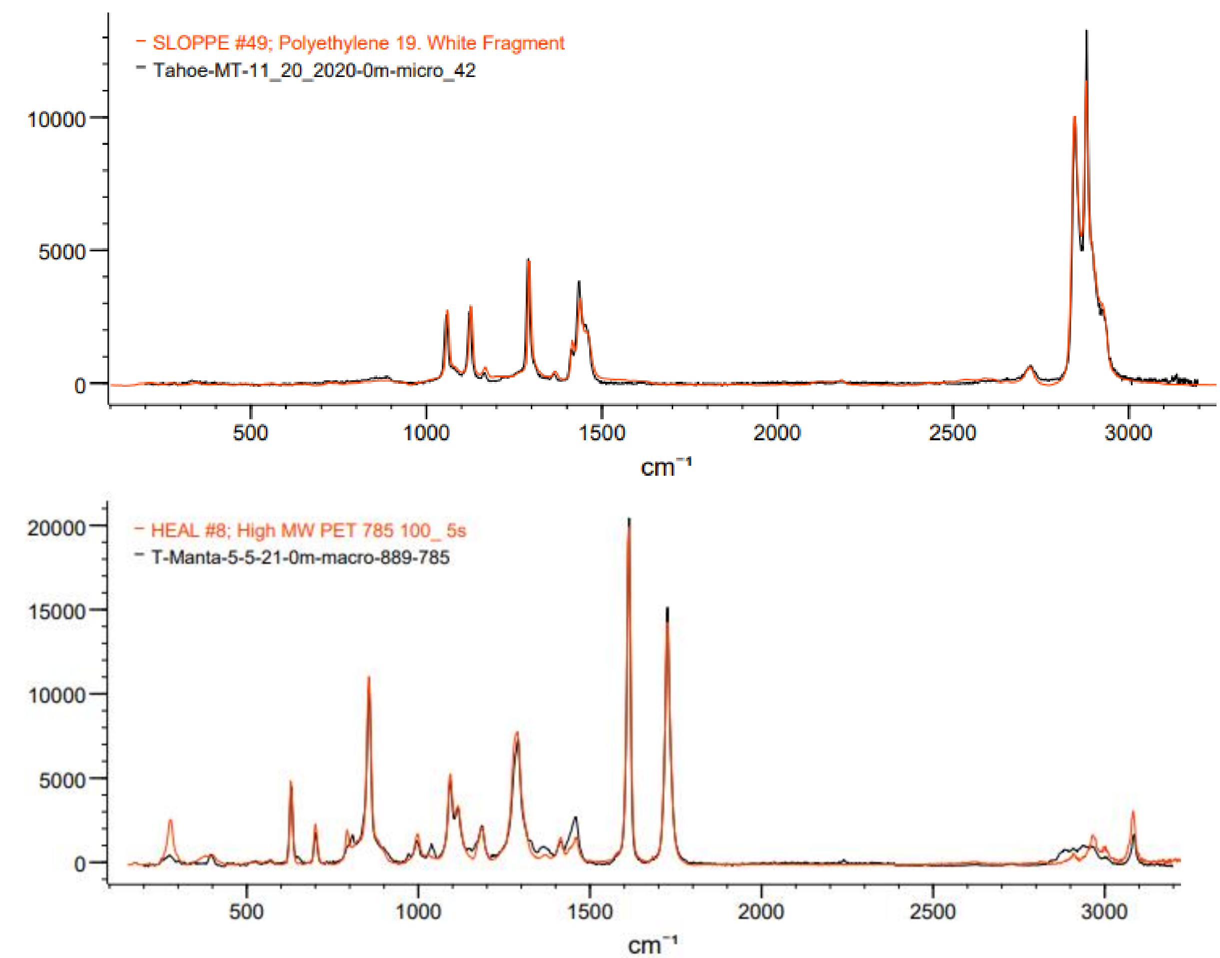


FIGURE 5. EXAMPLES OF SYNTHETIC POLYMER (PLASTIC) TYPES IDENTIFIED USING RAMAN MICROSPECTROSCOPY FOR MICROPLASTIC PARTICLES COLLECTED FROM SURFACE AND SUBSURFACE WATERS OF LAKE TAHOE. THE BLACK LINE IS THE SPECTRA OBTAINED FROM A SUSPECTED PLASTIC PARTICLE THAT IS COMPARED TO A REFERENCE LIBRARY SPECTRA INDICATED BY THE RED LINE TO IDENTIFY THE PARTICLE.

RESULTS AND DISCUSSION - HORIZONTAL TOW SAMPLES

RESULTS OF HORIZONTAL TOW SAMPLES

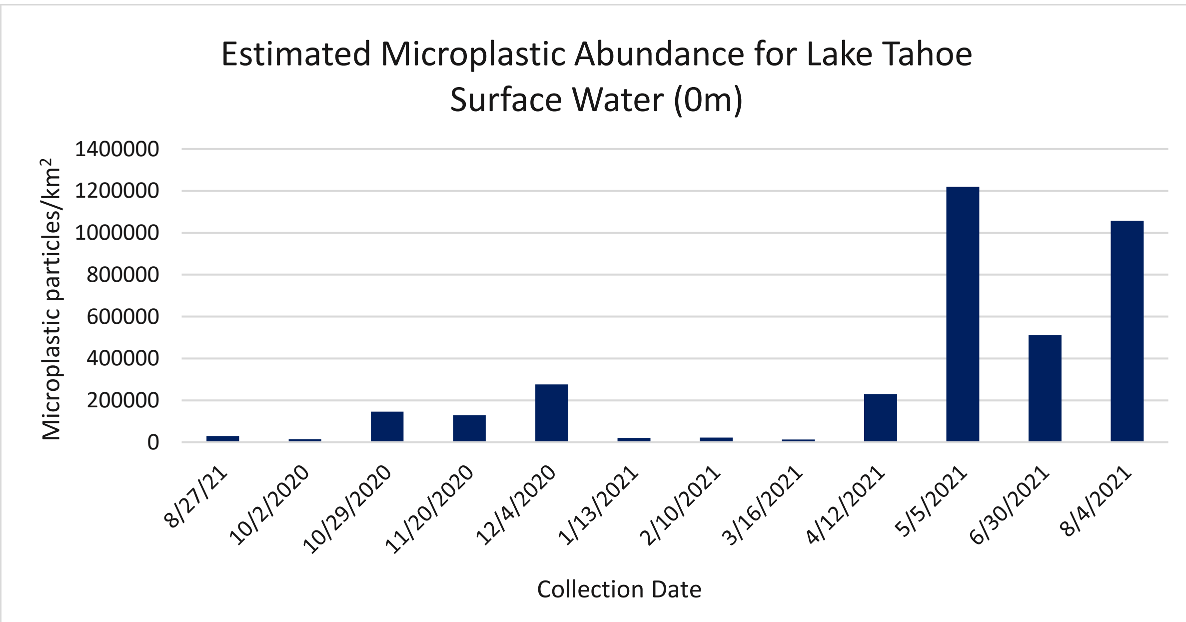
Microplastic Abundance

Estimated microplastic abundances in surface and subsurface waters of Lake Tahoe were calculated for each sampling date using the following formulas:

Microplastics/km^2 = (Total # Suspected Plastic Particles x % Confirmed Microplastics) / (Towing Distance x Trawl Net Width)

Microplastics/km^3 = (Total # Suspected Plastic Particles x % Confirmed Microplastics) / (Towing Distance x Trawl Net Area)

Assuming particles are evenly distributed throughout each water column plane, the average estimated abundance of microplastics at the lake surface (0m) was 306,044 (SD 417,012) microplastic particles/km^2 and 0.043 (SD 0.04) microplastic particles/km^3 in the lake's subsurface waters during the sampling period.



RESULTS AND DISCUSSION - HORIZONTAL TOW SAMPLES

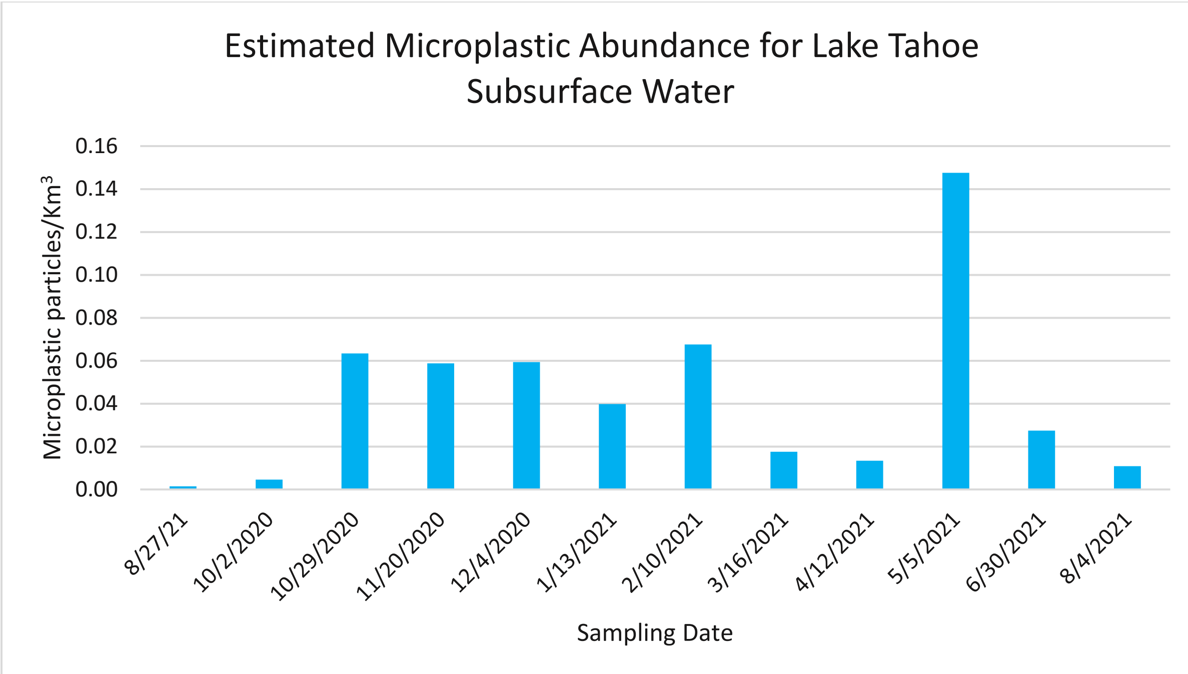


FIGURE 8. ESTIMATED MICROPLASTIC PARTICLE ABUNDANCE IN SURFACE AND SUBSURFACE WATERS OF LAKE TAHOE DURING THE PERIOD OF 8/27/2020 TO 8/4/2021.

Types of Microplastics

In addition to classifying particles as microplastics, the type of plastic composition for each microplastic particle was also determined using Raman microspectroscopy (Figure 10). The majority of analyzed plastic particles from surface waters were identified as polypropylene (41%) and polyethylene (39%) with a smaller proportion of particles identified as polyesters (15%). Additional synthetic polymers including polystyrene, nylon, acrylics, and co-polymer mixtures were also identified but made up less than 5% of all analyzed particles.

** Additional graphs and results available in the full final report**

DISCUSSION OF HORIZONTAL TOW SAMPLE RESULTS

The microplastic abundance on the surface waters of Lake Tahoe are some of the highest reported amongst North American lakes (range: 13,000 – 1,220,000 particles/km^2, mean: 306,000 particles/km^2) although higher values have been report in other systems such as Lake Taihu, China (range: 10,000 – 6,800,000 particles/km^2) and the San Francisco Bay (range: 34,000 – 1,800,000 particles/km^2, mean: 390,000 particles/km^2) (Su et al., 2016; Sutton et al., 2019). A comparison of surface water microplastic abundance in Lake Tahoe and other large North

American lakes is provided (Table 11). There are a number of factors which may contribute to this high abundance compared to other systems.

Table 11. Comparison of microplastic abundance in the surface waters of North American lakes.

Microplastic abundance in the surface waters of North American lakes						
	Lake Winnipeg	**Lake Superior**	**Lake Michigan**	**Lake Erie**	**Flathead Lake**	**Lake Tahoe**
Surface area (km^2)	25,514	82,100	58,030	25,744	510	490
Mean depth (m)	12	147	85	19	50	300
Residence time (years)	4	191	99	2.6	2.2	650
Population in watershed	7,000,000	600,000	12,000,000	12,000,000	121,000	40,000
Watershed area (km^2)	982,900	127,700	118,000	78,000	7,615	1,298
Wastewater treatment	30% combined, 70% sanitary with separate system for stormwater treatment	Combined	Combined	Combined	~70% of residents and business' on spectic systems	All wastewater removed from basin. No treatment of stormwater
Mean microplastic abundance (# per km^2)	193,420	30,000	17,276	105,503	189,000	306,044
Standard deviation	± 115,567			± 173,587		± 417,012
Dominate particle type	Fiber (90%)	Fiber (67%)	Fragment (79%)	Pellets (48%)	Fiber (79%)	Fragment (61%)
Dominate polymer	n/a	Polyethylene (51%)	Polyethylene (46%)	n/a	Polyethylene	Polyethylene (44%)
Sample collection	Manta trawl, 333 µm	Paired nueston net, 500 µm	Manta trawl, 333 µm	Manta trawl, 333 µm	Paneled trawling net, 330 µm	Manta trawl, 335 µm
Sample analysis	WPO digestion, SEM/EMS validation	WPO digestion, FTIR validation	WPO digestion, FTIR and SEM/EMS validation	Density separation, SEM/EMS validation	WPO digestion, Raman validation	Density separation, KOH digestion, Raman validation
Sample size (n=)	36	187	59	8	12	12
Citation	Anderson et al., 2017	Cox et al., 2021	Mason et al., 2016	Eriksen et al., 2013	Xiong et al., 2022	Present study

RESULTS AND DISCUSSION - HORIZONTAL TOW SAMPLES

Sampling Methodology

The field of microplastics has long struggled with inconsistent sampling methods making it difficult to compare results across multiple studies (Tamminga et al., 2019). The studies in Table 11 were chosen for comparison because the methodology was most similar, although not identical, to our own. Larger mesh sizes (Cox et al., 2021) and the lack of sample digestion (Eriksen et al., 2013) may have caused an underestimation of microplastics in lakes Superior and Erie compared to what would have been detected using methods described in this study.

Treatment of Stormwater Effluent

Combined sewer systems are common in the Great Lakes watershed potentially preventing the release of microplastics collected from the landscape, into local waters. Combined sewer systems collect both household wastewater and stormwater runoff from rain and snowmelt for processing at a wastewater treatment plant (WWTP) prior to release back into the environment. While combined sewer systems can have a number of drawbacks, the most critical being the system can be overwhelmed by copious volumes of wastewater during large precipitation events causing untreated stormwater and wastewater to discharge directly into nearby waterbodies, they may still prevent many microplastics found in stormwater, from entering local waterways. Grbić et al. (2020) found anthropogenic particle concentrations in untreated stormwater runoff from the Lake Ontario watershed averaged 15.4 particles L^{-1}. There is currently no treatment system for stormwater in the Tahoe Basin prior to it flowing into the lake potentially contributing to a large microplastic load from a range of sources such as trash, rubber tire wear and road paint. Microplastics deposited by atmospheric deposition may also be a contributor.

As an initial step towards understanding factors that may influence the presence of microplastics in surface water of Lake Tahoe, data for environmental factors and human activities were obtained for the months during the study period (Figure 13). As a proxy measurement for snow melt, average monthly water discharge data for Ward Creek was obtained (located 7 km southwest of the horizontal tow sampling transect). Monthly average hotel room nights for South Lake Tahoe obtained from the Lake Tahoe Visitors Authority was used as an indicator of tourism activity in the vicinity of the lake. Monthly precipitation data for Tahoe City was obtained from the National Oceanic and Atmospheric Administration. Out of these factors, it appears there could be relationships related to runoff from precipitation and snow melt that warrant further investigation. Due to the unusual circumstances related to the COVID-19 Pandemic and its effect on the tourism industry during the period of this study, it is unclear whether there is any relationship between tourism activity in the region and the abundance of microplastics in Lake Tahoe.

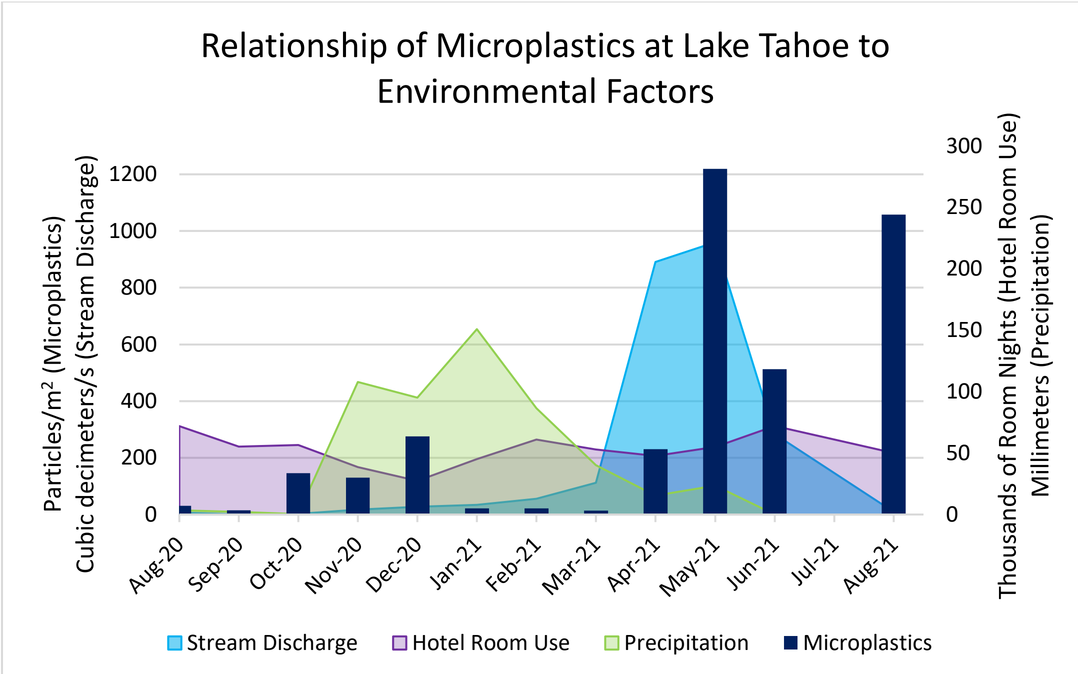


FIGURE 23. ESTIMATED MICROPLASTIC ABUNDANCE AT THE SURFACE OF LAKE TAHOE IS SHOWN OVERLAYED WITH DATA FOR STREAM DISCHARGE, HOTEL ROOM USE, AND PRECIPITATION FOR THE SAMPLING PERIOD AS A PRELIMINARY EXPLORATION INTO POTENTIAL RELATIONSHIPS BETWEEN MICROPLASTIC ABUNDANCE, SNOW MELT, TOURISM ACTIVITY, AND PRECIPITATION.

Tourism and Litter in the Tahoe Basin

The Tahoe Basin sees an enormous fluctuation in population throughout the year. 40,000 – 60,000 people reside year-round in the basin with 15 million visitors estimated as coming to the lake each year. During peak days, the Tahoe Basin can see a total population of 300,000 people putting immense pressure on local resources and intensifying anthropogenic impacts. The majority of microplastics removed from surface tow samples in the present study were identified as fragments (61%). Fragments are likely secondary microplastics created by the weathering and subsequent breakdown of anthropogenic trash which has been improperly disposed of. From 2014 to 2020, community beach clean ups conducted after popular summer holidays (e.g. Fourth of July, Labor Day, etc.) have removed over 48,500 lbs of trash from the shoreline of Lake Tahoe (The League to Save Lake Tahoe, 2022). Additionally, over 25,000 lbs of submerged anthropogenic waste was removed from Tahoe's nearshore areas in 2020 – 2021 (Clean Up The Lake, 2022).

RESULTS - MUNICIPAL SAMPLES

MUNICIPAL WATER

A total of 155 suspected plastic particles were collected from municipal waters obtained via samples collected quarterly from two separate sites. A total of 19 particles were composed of plastic based on Raman microspectroscopic analysis. Out of these 19 particles, 84% (n=16) matched to control spectra obtained from blanks and background spectra. Three microplastic particles were composed of plastics not found in control samples. Two particles were composed of polypropylene and one particle was composed of polyester.

Microplastic Particles From Municipal Water Samples						
Date	**Site (# replicates)**	**Total Sample Volume (L)**	**Suspected plastic particles**	**Confirmed plastic particles**	**Microplastic abundance**	**Plastic type**
		L	**number**	**number**	**particles/L**	
6/13/2021	Edgewood (3)	10.49	10	1	0.100	PP
	IVGID (2)	6.91	18	1	0.055	PP
8/24/2021	Edgewood (2)	7.45	8	0	0.000	
	IVGID (2)	7.38	10	0	0.000	
11/15/2021	Edgewood (3)	10.67	21	1	0.094	PES
	IVGID (2)	7.21	39	0	0.000	
2/9/2022	Edgewood (3)	10.99	38	0	0.000	
	IVGID (2)	7.34	11	0	0.000	
All dates	Edgewood (11)	39.6	77	2	0.050	
	IVGID (8)	28.84	78	1	0.035	
All dates	**All sites**	**68.44**	**155**	**3**	**0.044**	**PP, PES**

Discussion
Pivoknosky et al. (2018) monitored three water treatment plants in the Czech Republic for microplastic presence in treated drinking water using methods similar to those in the present study. A microplastic abundance of 338 ± 76 to 628 ± 28 particles L^{-1} was found in the treated water from those plants which is orders of magnitude greater than the results of this study. Additionally, Oßmann et al. (2018) found the amount of microplastics in bottled mineral water varied from 2649 ± 2857 per liter in single use PET bottles and up to 6292 ± 10521 per liter in glass bottles illustrating that packaging water has the potential to contribute a significant amount of microplastics to drinking water. One notable difference between the present study and the others discussed, is the lower size detection limit. Both studies are of the very few to determine microplastics down to the size of 1µm, while the lower size detection limit of the Lake Tahoe study is 10µm. Pivoknosky found microplastics smaller than 10µm were the most plentiful treated water samples, accounting for up to 95% while Oßmann concluded 90% of microplastics detected in bottled water were smaller than 5µm.

RESULTS - MUNICIPAL SAMPLES

Additional research on microplastic abundance in drinking water sources is needed but monitoring microplastics in drinking water has struggled with lack of standardized methods as seen in other branches of the field. In May 2022, California's State Water Resources Control Board issued the world's first standard protocols for monitoring microplastics in drinking water (SWB-MP2-rev1) establishing a critically important standard for future research and monitoring programs to adhere to.

Beginning in 2023, water suppliers within the TWSA will begin mandatory water sample collections in compliance with the Fifth Unregulated Contaminant Monitoring Rule (URCM 5) established by the U.S. Environmental Protection Agency (EPA). URCM 5 requires nationwide monitoring for 29 per- and polyfluoroalkyl substances (PFAS) and lithium in public drinking water systems from 2023 – 2025. Microplastics, such as polytetrafluorethylene used as nonstick coating on cooking pans, can be composed of PFAS meaning they will be monitored in the municipal waters of Lake Tahoe under URCM 5. This monitoring is a critical first step but additional monitoring is recommended using protocols set forth by the California State Water Resources Control Board to understand microplastic presence in municipal water supplies for polymers that are not included under URCM 5.

RECOMMENDATIONS

This work has established the presence of microplastics throughout the water column of Lake Tahoe as well as in biota and municipal waters. It is not possible to say whether microplastics are increasing or decreasing. However, the data collected have established a baseline, one in which Tahoe is surprisingly high in microplastics relative to other water bodies. Additional data may indicate how large the year-to-year variability is in the short term.

Additional work with biota could be considered in the future as the amount of sampling in this project was not sufficient to come to strong conclusions. In particular zooplankton sampling for microplastics could be undertaken in the future. Because of the prey size of many Tahoe zooplankton, they could be an important pathway for removing accumulated microplastics.

Sediment results from this study were inconclusive so additional sampling may be warranted to understand polymer abundance and type potentially accumulating in Lake Tahoe. Given the variation in polymer density and ability to settle out of the water column, sampling sediment centered on stormwater inflows and urbanized tributaries in addition to mid lake sites may improve our understanding of microplastic abundance in lake sediments.

For any future microplastic research in Lake Tahoe, it is imperative to include analysis of smaller size classes, specifically the 1 – 10µm range. This work is critical as plastics continue to accumulate in our natural environment breaking into ever smaller pieces but not fully degrading. These smaller particles will impact lake clarity (the degree to which they do so is unknown until further research has been conducted). These small particles may also pose the greatest risk for accidental ingestion by humans and wildlife. The long-term health impacts of plastic consumption is an area of current research worldwide.

WORKS CITED

Anderson, P. J., Warrack, S., Langen, V., Challis, J. K., Hanson, M. L., and Rennie, M. D.2017. Microplastic contamination in lake Winnipeg, Canada. *Environmental pollution*, *225*, 223-231.

Boening, D. W. 1999. An evaluation of bivalves as biomonitors of heavy metals pollution in marine waters. *Environmental monitoring and assessment*, *55*, 459-470.

Clean Up The Lake. *2021 Projects*. Retrieved December 20, 2022, from https://cleanupthelake.org/2021-projects/

Cox, K., Brocious, E., Courtenay, S. C., Vinson, M. R., and Mason, S. A. 2021. Distribution, abundance and spatial variability of microplastic pollution on the surface of Lake Superior. *Journal of Great Lakes Research*, *47*(5), 1358-1364.

Eriksen, M., Mason, S., Wilson, S., Box, C., Zellers, A., Edwards, W., Farley, H., and Amato, S. 2013. Microplastic pollution in the surface waters of the Laurentian Great Lakes. *Marine pollution bulletin*, *77*(1-2), 177-182.

European Commission Joint Research Center. 2013. Guidance on monitoring of marine litter in European Seas. Publications Office of the European Union: Luxembourg, 10, 99475.

Grbić, J., Helm, P., Athey, S., and Rochman, C. M. 2020. Microplastics entering northwestern Lake Ontario are diverse and linked to urban sources. *Water research*, *174*, 115623.

Lake Tahoe Visitors Authority. Data and Statistics: ADR & Occupancy City of South Lake Tahoe. Retrieved January 20, 2023, from https://ltva.org/industry/data-statistics/

League to Save Lake Tahoe. *Community Beach Clean Up Map*. Keep Tahoe Blue. Retrieved December 20, 2022, from https://www.keeptahoeblue.org/join-us/cleanups/

Lenaker, P. L., Baldwin, A. K., Corsi, S. R., Mason, S. A., Reneau, P. C., and Scott, J. W. 2019. Vertical distribution of microplastics in the water column and surficial sediment from the Milwaukee River Basin to Lake Michigan. *Environmental science & technology*, *53*(21), 12227-12237.

Mason, S. A., Kammin, L., Eriksen, M., Aleid, G., Wilson, S., Box, C., Williamson, N., and Riley, A. 2016. Pelagic plastic pollution within the surface waters of Lake Michigan, USA. *Journal of Great Lakes Research*, *42*(4), 753-759.

National Oceanic and Atmospheric Administration. Monthly precipitation summary water year 2021. Retrieved January 20, 2023, from https://cnrfc.noaa.gov/monthly_precip_2021.php

Oßmann, B. E., Sarau, G., Holtmannspötter, H., Pischetsrieder, M., Christiansen, S. H., and Dicke, W. 2018. Small-sized microplastics and pigmented particles in bottled mineral water. *Water research*, *141*, 307-316.

Padervand, M., Lichtfouse, E., Robert, D., and Wang, C. 2020. Removal of microplastics from the environment. A review. *Environmental Chemistry Letters*, *18*, 807-828.

Pivokonsky, M., Cermakova, L., Novotna, K., Peer, P., Cajthaml, T., and Janda, V. 2018. Occurrence of microplastics in raw and treated drinking water. *Science of the total environment*, *643*, 1644-1651.

State Water Resources Control Board. Standard Operating Procedures for Extraction and Measurement by Raman Spectroscopy of Microplastic Particles in Drinking Water. May 27, 2022.

https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/microplastics/swb-mp2-rev1.pdf

Su, L., Cai, H., Kolandhasamy, P., Wu, C., Rochman, C. M., and Shi, H. 2018. Using the Asian clam as an indicator of microplastic pollution in freshwater ecosystems. *Environmental pollution*, *234*, 347-355.

Su, L., Xue, Y., Li, L., Yang, D., Kolandhasamy, P., Li, D., and Shi, H. 2016. Microplastics in Taihu lake, China. *Environmental Pollution*, *216*, 711-719.

Sutton, R., Lin, D., Sedlak, M., Box, C., Gilbreath, A., Holleman, R., Miller, L., Wong, A., Munno, K., and Zhu, X. 2019. Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region. SFEI Contribution No. 950. San Francisco Estuary Institute: Richmond, CA.

Tamminga, M., and Fischer, E. K. 2020. Microplastics in a deep, dimictic lake of the North German Plain with special regard to vertical distribution patterns. *Environmental pollution*, *267*, 115507.

Tamminga, M., Stoewer, S. C., and Fischer, E. K. 2019. On the representativeness of pump water samples versus manta sampling in microplastic analysis. *Environmental pollution*, *254*, 112970.

United States Geological Survey. Ward C at Hwy 89 NR Tahoe Pines CA August 2020 – September 2021. Retrieved January 15, 2023, from https://waterdata.usgs.gov/monitoring-location/10336676/#parameterCode=00065&startDT=2020-08-01&endDT=2021-09-01

Xiong, X., Tappenbeck, T. H., Wu, C., and Elser, J. J. 2022. Microplastics in Flathead Lake, a large oligotrophic mountain lake in the USA. *Environmental Pollution*, *306*, 119445.

Yang, R., Xu, X., Xue, Y., Zhang, L., Guo, J., Wang, L., Peng, M., Zhang, Q., and Zhu, Y. 2022. Horizontal and vertical distribution of microplastics in Gehu Lake, China. *Water Supply*, *22*(12), 8669-8681.