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Detroit River Phytoplankton From Water Treatment Plant Data

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Key Takeaways

A new study of phytoplankton in the Detroit River follows significant changes to ecological and environmental conditions in the boundary waters and updates historical data research.

Measures to remediate river health in recent years can be evaluated through analysis of the abundance and diversity of phytoplankton communities at a higher taxonomic resolution.

By working with community partners to measure phytoplankton communities in the long term, water treatment plants can use the data gained to design an early-warning system for river changes.

Water Works Park historical water intake on the Detroit River, Detroit, Mich.

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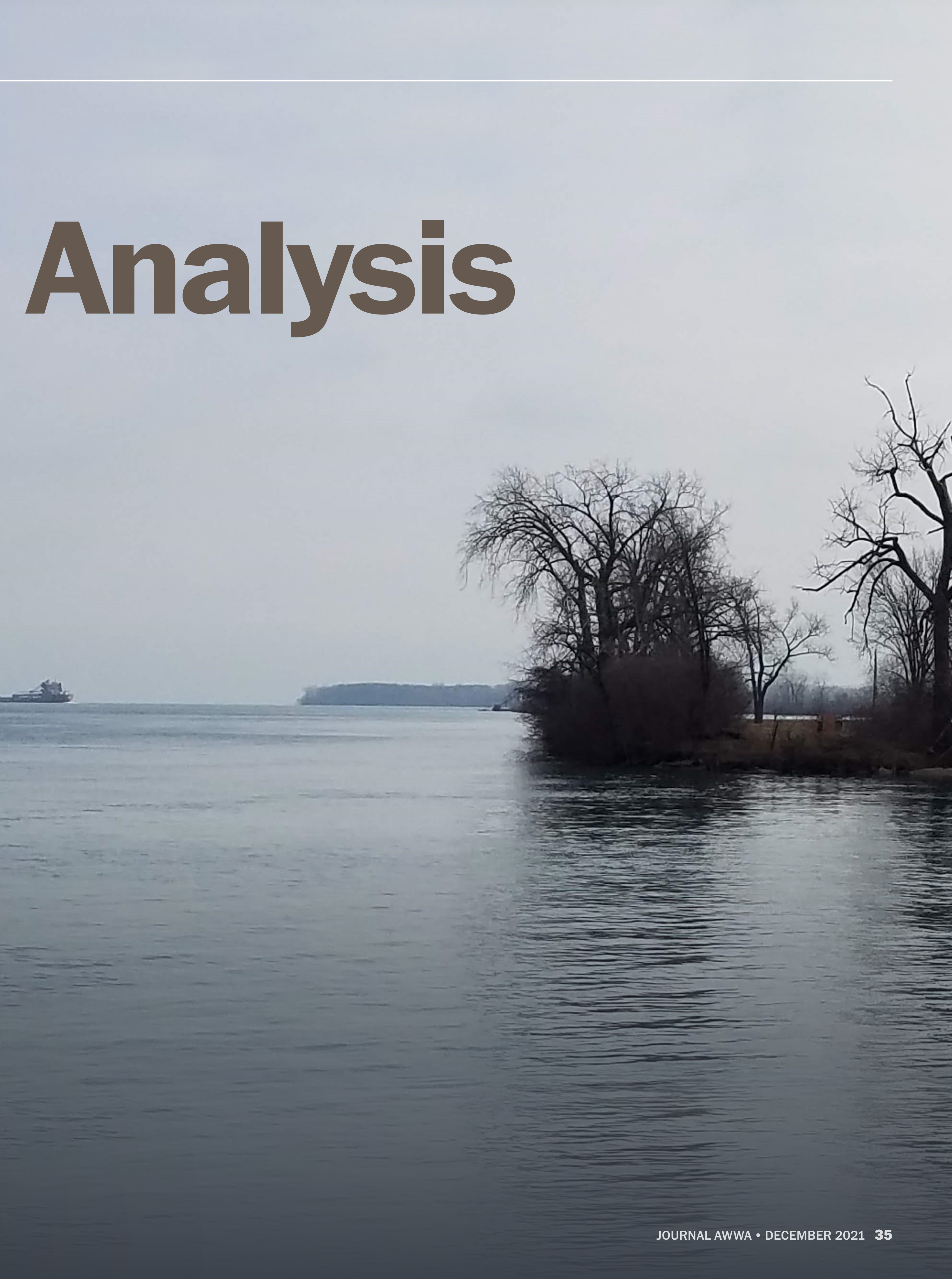
Analysis



Phytoplankton communities are sensitive bioindicators of change in aquatic systems, so they can be used as a measure of aquatic ecosystem health. The Detroit River is the source of drinking water for residents of the United States and Canada, and several regional and international agencies are involved in monitoring pollution and restoration initiatives in the Detroit River.

Phytoplankton Community Diversity and Abundance

To assess the Detroit River's phytoplankton abundance and diversity, we analyzed the cumulative phytoplanktonic observations for a recent period and compared them with historical records. The objectives of this study were threefold:

- To generate an update on the Detroit River phytoplankton community
- To compare recent findings with published historical Detroit River phytoplankton records
- To identify possible Detroit River abiotic factors that may cause shifts in Detroit River phytoplankton communities

Knowledge of the diversity and abundance of plankton communities informs the health status of freshwater ecosystems. Phytoplankton has been highlighted as an important bioindicator because of its sensitivity to changes in the biological, physical, or chemical composition of its habitats. Water contamination via anthropogenic pollution is of great concern, but it is often discovered only after long-term damage has already occurred. While the US Environmental Protection Agency has maintained the Great Lakes Phytoplankton Monitoring program for several decades, higher taxonomic resolution to genera- or species-level identifications has been lacking (Reavie et al. 2014).

Significant ecological and environmental changes have occurred in the Great Lakes recently, including the invasion of non-native species such as *Dreissena* mussels that have disrupted phytoplankton assemblages. Our study examined historical records spanning back 91 years. The current high anthropogenic impact on the Detroit River that results in environmental degradation, along with changes in regional and global climate, gives urgency to the study of Detroit River phytoplankton.

The Detroit River

The Detroit River is listed as one of the 43 Areas of Concern (AOC) in the Great Lakes, with beneficial-use impairments that include water contamination, degradation of macroinvertebrate benthic communities, and contamination of sediments. In 1985 it was listed as an AOC by the International Joint Commission. Since then, several restoration initiatives have been completed throughout the river to improve its health, including restoring fish spawning reefs, putting in soft shoreline engineering, and conserving riverfront wildlife habitat (Hartig et al. 2018).

Some work in the river on phytoplankton and macroinvertebrates suggests improving conditions in the Detroit River (Serran et al. 2020, Vasquez et al. 2020). Recommendations for continued assessment of the health of the river include monitoring and establishment of quantitative targets for phytoplankton bioindicators which can then be used in biological integrity measurements (Kane et al. 2008).

In the modern era, the Detroit River has been the primary source of drinking water for southeastern Michigan and Windsor, Ont. On the US side, extensive data have been collected by the Great Lakes Water Authority (GLWA) and its predecessor organizations, the Detroit Board of Water Commissioners and the Detroit Water and Sewerage Department.

Harmful algal blooms (HABs) in freshwater habitats such as Lake Erie have been observed to occur more often in recent years, with potential health implications in the communities surrounding the Great Lakes. The challenges HABs pose have increased interest in studying phytoplankton in regions such as the Great Lakes. Here we attempt to study both past and current data and report on two years of intense phytoplankton monitoring and analysis that demonstrate changes in the community. The result of these phytoplankton analyses could then be used as indicators or sentinels of additional changes in the Detroit River.

Research Approach

Plankton counts were recorded on a biweekly basis for the Detroit River water (termed "raw water" by plant operators) coming into the GLWA Water Works Park (WWP) drinking water treatment plant. Located in the city of Detroit beside the Detroit River, WWP was originally constructed in 1879 with the raw water intake drawing from the Detroit River, with a subsequent update of the intake in 1931 (see Figure 1). Detroit River water flows through racks at the intake to remove large debris, then passes through large rotating mesh screens (3/8-inch mesh) to remove smaller objects before entering the treatment plant. The water samples for this study were collected from the raw water sample sink in the WWP operations laboratory; it was not treated or filtered before plankton collection.

Plankton counts for 2018 and 2019 are from 1-L grab samples taken from raw water that was allowed to settle at 4 °C for 24 hours; subsequently, 900 mL of water was removed using a 0.13-inch rubber siphon tubing attached to a glass rod. This allowed plankton to be concentrated by siphoning the water out very slowly and not agitating the bottom, thus providing a 100-mL sample of concentrated plankton. A 1-mL sample was then obtained using a pipette and transferred to a Sedgewick Rafter counting chamber (Structure Probe Inc., West Chester, Pa.), followed by plankton identification and counting using a compound microscope.

Phytoplankton assemblages were identified using taxonomic keys from the literature and the online taxonomy tool found at https://diatoms.org. A simplified dichotomous key was prepared for the GLWA laboratory (see Figure 2) on the basis of the literature as well as expert opinions; namely, Judy Anne Westrick from Wayne State University and Miriam Steinitz Kannan from Northern Kentucky University helped to identify and confirm the identification. The key was simplified to allow for quick and correct identification.

Historical data regarding phytoplankton diversity and abundance for the Detroit River were obtained from the literature, largely from the Detroit WWP drinking water plant. Our data, which date from 2018 (May–December) and 2019 (January–November) were compared with two data sets collected in 1928–1929 (Hudgins 1931) and 1962–1963 (Wujek 1967). Hudgins (1931) and our data were collected in the same way since they were both from the same drinking water plant. Wujek (1967) abundance data was collected using a different method reported in Vaughan & Harlow (1965). The historical data sets were collected over different time periods. These technical limitations are to be noted when interpreting the results.

Historical Detroit River discharge data were obtained from the Detroit District, US Army Corps of Engineers (USACE), for the period 1900–2019. The discharge values were calculated using stage-discharge relationships for stage data associated with mean monthly water level at the head of the Detroit River (Windmill Point). In the present study, differences in the distribution of total discharge values observed between January and December for the years 1900–2019 were evaluated with respect to an expected homogeneous distribution using a contingency table (two-factor chi-square) analysis. The changes in the total annual discharge values over a 120-year timeline (1900–2019) were evaluated using a linear regression analysis in Statistica (TIBCO Data Science, Palo Alto, Calif.).

Differences in the distribution of phytoplankton richness sampled monthly between May 2018 and November 2019 were evaluated with respect to an average homogeneous distribution. The observed richness of phytoplankton in monthly samples was evaluated as a percentage of the predicted richness maximum–minimum range for the respective month and year.

The relationships among abiotic factors pertaining to water quality were evaluated using a (square-matrix) Spearman's rank-order correlation. The relationship of all abiotic factors with respect to the phytoplankton taxon

Phytoplankton Sampling Sites in the Detroit River

The yellow square represents the historical water intake for the Water Works Park (WWP) and site of data collection for Hudgins (1931), purple circles represent sampling sites of Vaughan & Harlow (1965), and blue triangle represents the water intake for WWP and site of data collection for the present work.

Figure 1

Simplified Dichotomous Key to Allow for Efficient Identification of Phytoplankton Genera

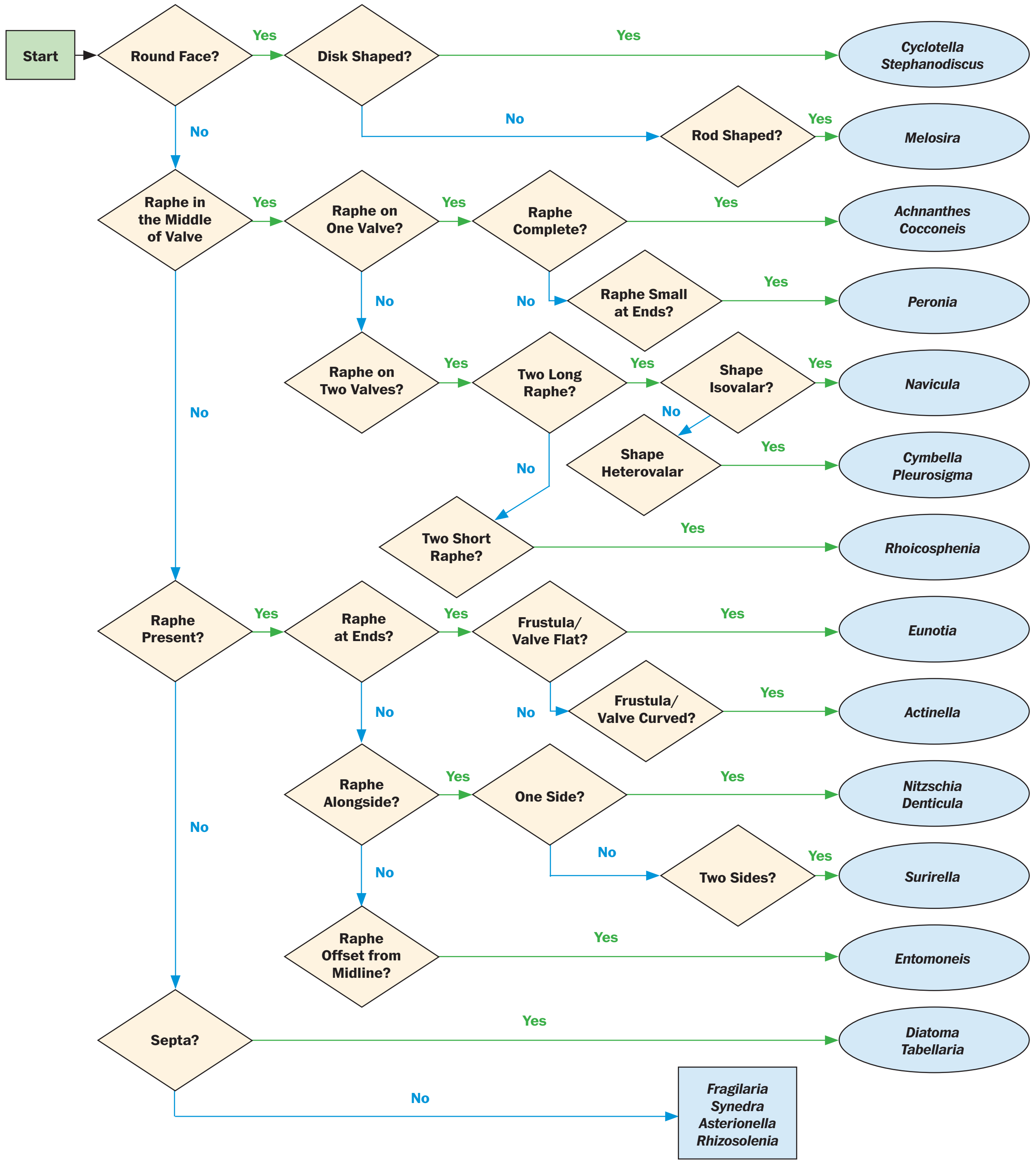


Figure 2

proportional abundance relative to all taxa collected during sampling month (proportional abundance) was evaluated using a (two-list) Spearman's rank-order correlation.

Phytoplankton Observations

Phytoplankton counts from the period May through December 2018 (eight months) totaled 2,021. Phytoplankton counts for the period January through November 2019 (11 months) totaled 4,012.

A total of 39 unique genera were included in the counts from 2018 and 2019. The 2018 observations included 20 of the genera, while the 2019 observations included 29 of the genera. For the 2018 observations, the following genera comprised at least 10% of the specimens counted: *Cyclotella* (21%), *Navicula* (29%), and *Nitzschia* (11%). For 2019, the genera representing at least 10% of the specimens included *Cyclotella* (13%), *Melosira* (10%), *Navicula* (25%), and *Synedra ulna* (10%).

Figure 3 represents graphs of the complete list of genera with total abundances observed in 2018 (part A) and 2019 (part B). Figure 4 illustrates micrographs of the most abundant observed genera during 2018 and 2019. The richness and distribution of phytoplankton observed across May 2018 and November 2019 did not differ significantly between the two years.

Navicula was seen as the most abundant phytoplankton present during the years 2018 and 2019 a notable difference when compared with historical phytoplankton diversity and abundance obtained from peer-reviewed literature. Hudgins (1931) did not report the presence of *Navicula* in his study, which was based on data from the late 1920s and collected from the Detroit drinking water plant, the same location from where we obtained the data for our present study. Hudgins (1931) stated that *Navicula* caused problems at other drinking water plants but was not reported in Detroit River water samples.

Table 1 lists the average percentage observed for several taxa based on sampling timelines 91 years apart. We also compared our observations with a study carried out during 1962–1963. Table 2 lists the taxa seen by the Wujek study at 10% or higher and lists the percent

Average Percent Abundance of Genera

Genus	1928 July–Dec.[a] %	1929 Jan.–June[a] %	2018 May–Dec.[b] %	2019 Jan.–Nov.[b] %
Asterionella	6.4	16	4.1	3.4
Synedra	8.2	8.3	5.3	10
Tabellaria	7.3	17.2	1.2	3.1
Fragilaria	19.2	14.1	6.4	3.7

[a]Data from Hudgins (1931)

[b]Data from current study

Table 1

Diatom Genera Percent Abundance

Genus and Number of Species (*n*) Represented	1962–1963 May–Aug.[a] %	2018 May–Dec.[b] %	2019 Jan.–Nov.[b] %
Cyclotella (2)	>10	21.3	12.6
Melosira (3)	>10	2.2	10
Coscinodiscus (1)	>10	Not observed	Not observed
Stephanodiscus (2)	>10	0.79	0.07
Fragilaria (2)	>10	6.4	3.7
Synedra (2)	>10	5.3	10
Tabellaria (1)	>10	1.2	3.1
Navicula[c]	<10	28.9	25.4

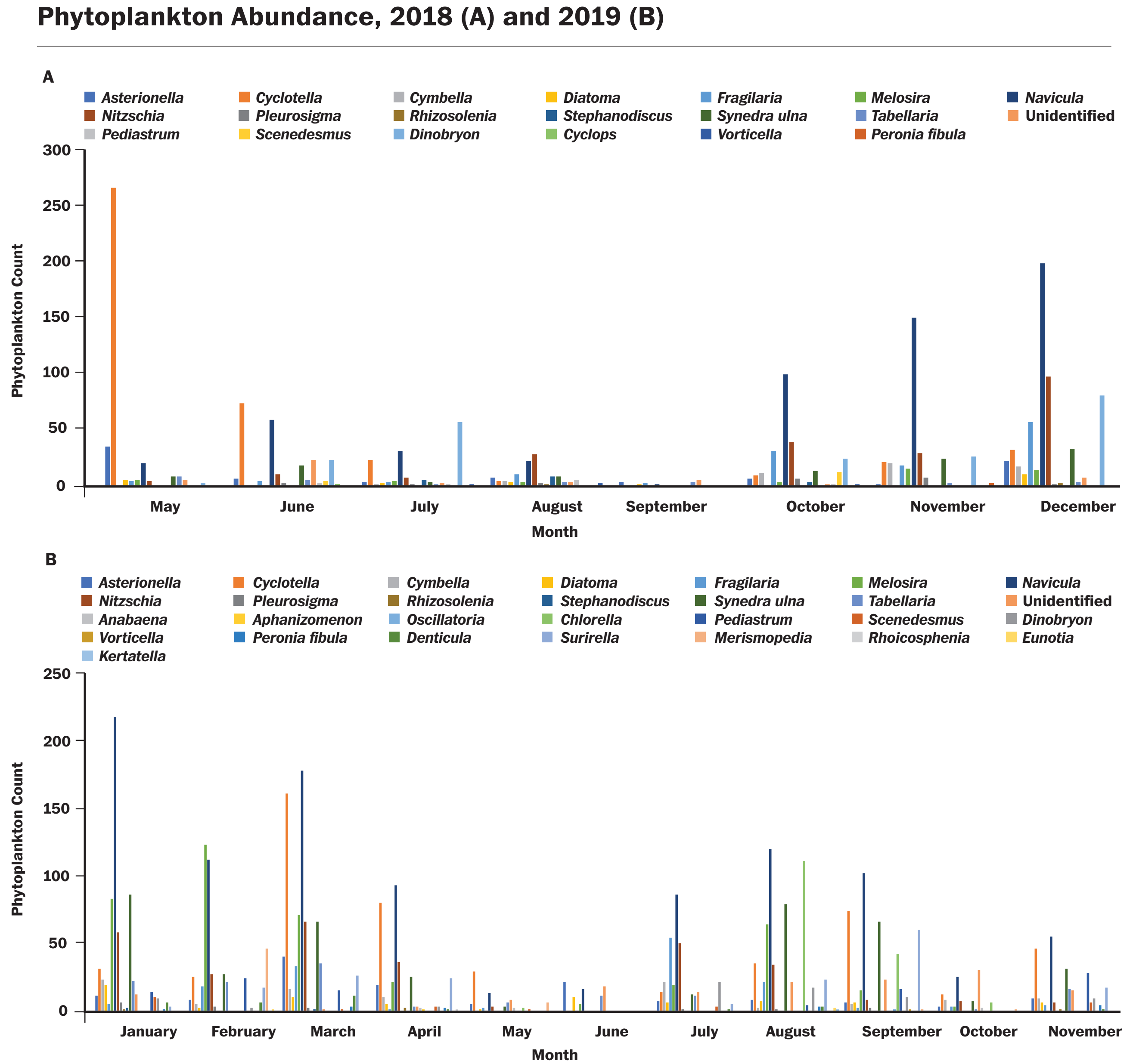
[a]Data from Wujek (1967)

[b]Data from current study

[c]Historically, *Navicula* was <10% and now is the most abundant.

Data for 1962–1963 are shown as less than or greater than 10%.

Table 2



Color-coded bars indicate abundance of phytoplankton during the given month.

Figure 3

abundance of our taxa. We show that *Navicula* was seen by Wujek but was not an abundant taxon (10% or higher).

The distribution of Detroit River water discharge values collected by USACE observed from January to December in the period 1900–2019 differed significantly from an expected homogeneous distribution (see Figure 5). The average discharge values were found to increase 5.5 m^3/s per year between 1900 and 2019.

Natural Flow Regimes and River Health

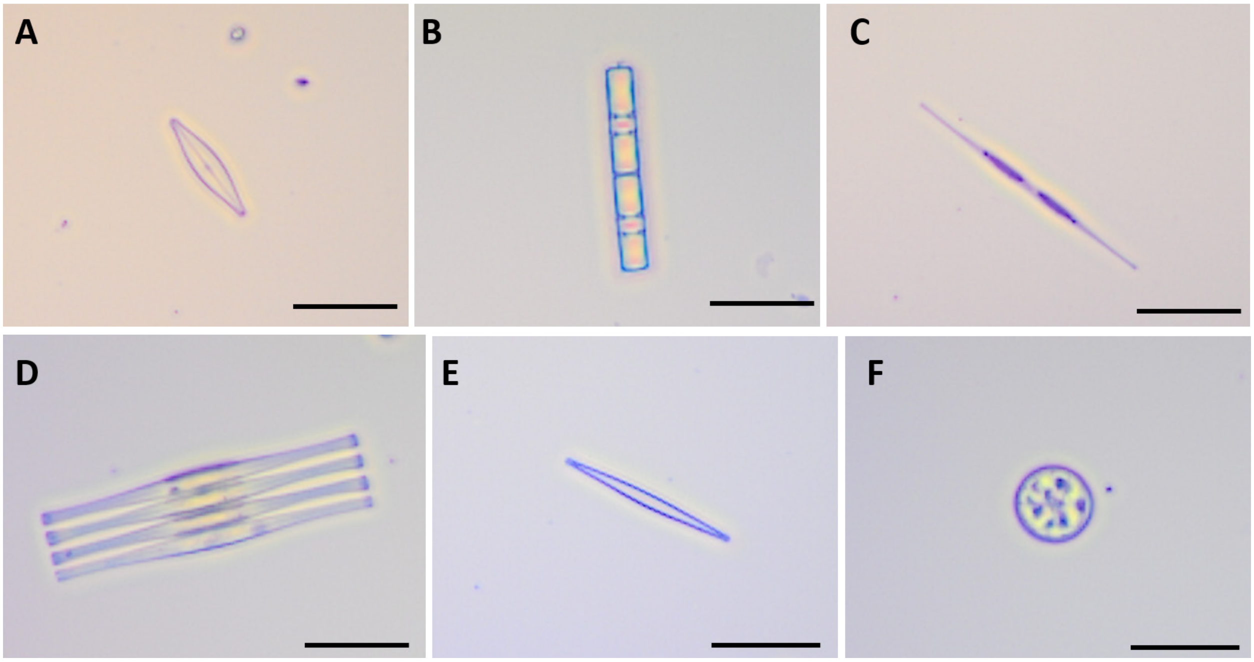
Comparing the data collected by GLWA over a period of two years with historical Detroit River phytoplankton abundance data revealed shifts in the phytoplankton community. We also found that *Navicula* is presently the most abundant phytoplankton taxa in the Detroit River, and that it was not reported as abundant in past historical studies. Comparatively, the genus *Fragilaria* was observed in high numbers in the late 1920s and 1960s but was found in lower numbers in our data.

Other phytoplankton taxa that were more abundant in the 1920s were flagellates. In our collections, only genus *Dinobryon* was observed, in 2018 at 11% and in 2019 at 2%. The 1960s study only focused on diatoms and so no comparison could be made with flagellates during that collection year.

One reason for the shift in phytoplankton communities could be the invasion of Dreissenid (Zebra and Quagga) mussels in the Great Lakes, which occurred in the late 1980s. Mussel species of the *Dreissena* genus have been shown to have selective preferences for which phytoplankton they eat. Once *Dreissena* mussels were introduced into the Great Lakes in the 1980s, they eventually dispersed into all the Great Lakes and are believed to be one of the primary causes of the plankton shift in diversity and abundance. Studies identifying the shift in plankton communities by the mussels are unclear, however our data, when compared with historical data, identified changes in phytoplankton taxa possibly as a result of the mussels' invasion.

Navicula could be rejected by *Dreissena* mussels since the mussels prefer flagellates over diatoms for food, so the shift of phytoplankton taxa might be a result of the mussels' feeding preferences (Tang et al. 2014). Therefore, the use of phytoplankton monitoring has great potential to help us better understand the ecological impacts of invasive species. Even though there has been great progress with sensors that record phytoplankton abundances using chlorophyll *a* and phytoplankton carbon concentration, these sensor methods were not always in line with the assemblages that resulted from actual taxonomic work studying phytoplankton assemblages using

Micrographs of Phytoplankton Found in Detroit River: *Navicula* (A), *Melosira* (B), *Nitzschia* (C), *Fragilaria* (D), *Synedra ulna* (E), and *Cyclotella* (F)



A–D scale = 20 µm, E–F scale = 100 µm

Figure 4

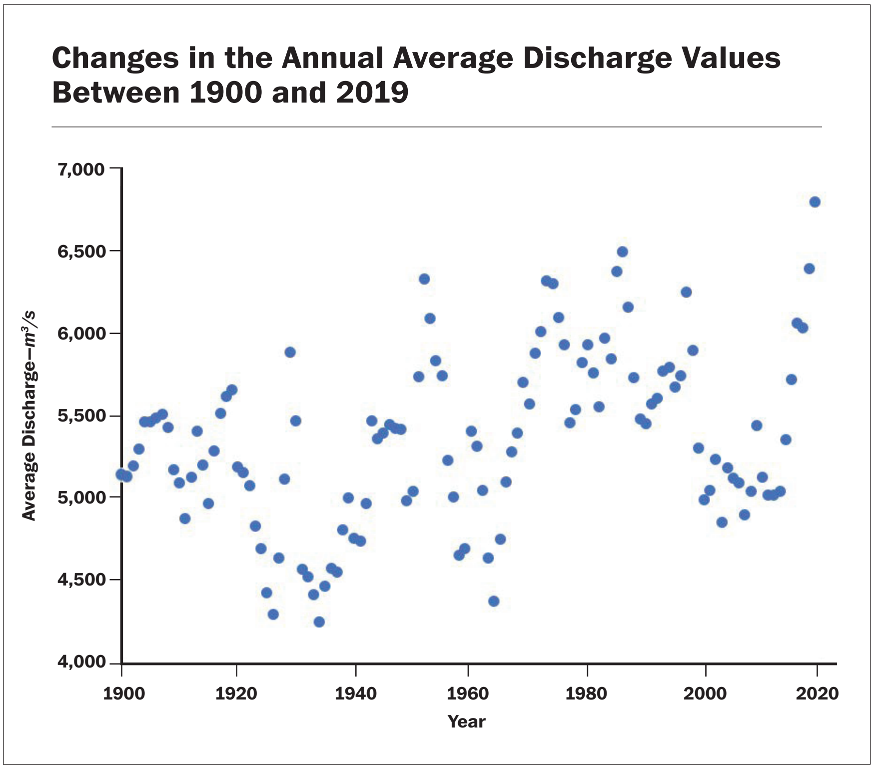


Figure 5

and June 2019 had community shifts. These dates are close to the spring turnover that occurs in Lake St. Clair and this could be the reason for the changes to the plankton composition since large storm events are known to affect phytoplankton assemblages (Hudgins 1931). Although it is possible that natural events could have caused shifts, they could also be a response to upstream dredging, since the Detroit River has to be dredged periodically to facilitate transportation. Abiotic factors that were specifically related to changes in phytoplankton abundance were silica, dissolved oxygen, pH, and temperature. Dredging might have an effect on the availability of silica or other minerals such as phosphorus, which affect phytoplankton abundance and diversity.

The nonmetric multidimensional scaling clustering analysis method we used on the Detroit River plankton data could be a tool to detect shifts in phytoplankton communities of the Detroit River as a result of abiotic or biotic changes in the river. The GLWA WWP collects this information from the river, and those data could be used for long-term monitoring. Long-term monitoring is an expensive process, but collaboration between drinking water plants and other stakeholders could be a useful way to allay costs.

Annual total Detroit River water discharge for the past 120 years showed heterogeneity across a monthly distribution and increased by 44.5 units annually between 1900 and 2019. It is possible that, using the historical Detroit River water discharge data, we can observe the river undergoing "flood pulse," which is an important contributor to the health and ecological integrity of river–floodplain systems (Junk et al. 1989). The health and ecological integrity of rivers depend on maintaining natural flow regimes, but changes in flow might also explain the observed changes in phytoplankton communities during the same period.

taxonomic methods (Tang et al. 2014). This limitation, along with the high cost of monitoring phytoplankton communities, highlights the need to investigate the use of data that is already being collected by drinking water treatment plants.

Our biodiversity analysis of the phytoplankton community of the Detroit River showed a stable community across the 19-month sampling period. A stable community can reveal subtle phytoplankton community shifts, which serve as a warning of possible changes occurring in the river. The methodology used in this work could be used in future biological integrity assessments of the Detroit River to warn regulators of possible external influences on the river that warrant more investigation. Source water quality information collected by water treatment plants could help local and regional water protection efforts. Working with other groups and stakeholders, these data could be shared in a central database, and when combined with other efforts and even the work of citizen scientists, used in environmental monitoring of important freshwater resources.

On the basis of our research, the composition of phytoplankton assemblages in the Detroit River remained stable for 84% of the sampling events. However, May 2018

New Studies on Phytoplankton Communities Reveal River Changes

This work on the diversity and abundance of phytoplankton observed in the Detroit River, along with comparisons with previous records, allowed us to identify major shifts of phytoplankton communities. *Navicula* is the most abundant phytoplankton in the river when compared with historical data. Abiotic and biotic changes in the Detroit River during the years we investigated might have affected phytoplankton assemblages. The methodology presented here could be used to design an early warning system against potential environmental threats on the basis of the changes detected in phytoplankton communities. However, heavily impacted rivers like the Detroit River cannot achieve stability unless they are allowed to have undisturbed flow regimes.

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