THE 2017 – 2020 SECCHI DIP-IN REPORT

Prepared by Leah Hicks

North American Lake Management Society

2021

Photo by Leah Hicks

Thank you to the North American Lake Management Society and 2017 – 2020 committee members for Supporting the Secchi Dip-In

Thank you to the volunteers who submitted data to the Secchi Dip-In throughout 2017-2020

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NALMS MISSION STATEMENT

The North American Lake Management Society (NALMS) is dedicated to forging partnerships among citizens, scientists, and professionals to foster the management and protection of lakes and reservoirs for today and tomorrow. This is achieved through the following goals:

1. To promote the exchange of information on aspects of managing lakes and their watersheds
2. To promote public awareness of lake ecosystems
3. To encourage public support for promoting management of lakes and their watersheds
4. To provide guidance to agencies involved in the management activities for lakes and their watersheds
5. To boost the professional status of those engaged in managing lakes and their watersheds
6. To identify needs and encourage research on lake ecology and watershed management

SECCHI DIP-IN PROGRAM DESCRIPTION

The Secchi Dip-In program is centered around community-based environmental monitoring programs throughout North America. These community-based monitoring programs are established by volunteers that contribute to monitoring, research, and reporting on environmental factors in the area in which they live, work, or visit. This way of collecting data increases the geographical range in which data can be collected, and enhances public awareness about a particular issue. Trained monitoring volunteers, environmental community-based monitoring programs and lake enthusiasts who participate in the Secchi Dip-In collect water quality data on an annual basis and increase awareness of the importance of water stewardship.

The annual Secchi Dip-In was established in 1994 by Drs. Robert Carlson, Dave Waller, and Jay Lee from the Kent State University to explore if there were regional variations in waterbody transparency, and to demonstrate that volunteer monitoring programs are an effective way to obtain data throughout North America. This was done with the help of 800 volunteers from six Midwest states. In 1995 the Secchi Dip-In had expanded to thirty-seven (37) U.S. states and two Canadian provinces with over 2,000 participating volunteers.

In 2015 Dr. Carlson retired and transferred the Secchi Dip-In to NALMS with the goal of expanding the Secchi Dip-In, updating the database and providing mobile app technologies for data entry in partnership with the U.S. Environmental Protection Agency (EPA) and the Global Lake Ecological Observatory Network (GLEON). The Oklahoma Water Resources Board (OWRB) was awarded a USEPA Exchange Network grant in 2018 that included funding to work in partnership with NALMS to provide a long-term solution for Secchi Dip-In data management using AWQMS and the GLEON Lake Observer mobile app. Since 2015, with the help of Secchi Dip-In participants NALMS has acquired 17,918 activity records, bringing the total number of activity records in the database to just over 105,000.

The Secchi Dip-In is traditionally a part of Lakes Appreciation Month, where participants celebrate our lakes throughout the month of July each year. With the new AWQMS database, participants are now encouraged to submit as much Secchi and related water quality data as they want from any time of year. We strongly encourage anyone who is interested in understanding and protecting aquatic environments to participate in the Secchi Dip-In. Collecting Secchi data is easy to do and can be done while out enjoying and recreating on a favourite lake.

MATERIALS AND METHODS

The Secchi Disk

The Secchi disk was invented in 1865 and is now one of the oldest water quality monitoring tools used by both limnologists and volunteers to measure the clarity of waterbodies as they are relatively inexpensive and easy to use. Secchi disks are typically 8-inch disks with alternating black and white quadrats but can also be all white, although this variation is less used.

To obtain a measurement Secchi disks are lowered into a lake until they can no longer be seen by the observer and then are pulled back up until a distinction between the black and white quadrats can be seen. The depths of disappearance and reappearance are recorded and then averaged. The average depth is known as the Secchi depth and provides a good indication of the transparency of a waterbody (Figure 1) as Secchi depth is inversely proportional to the amount of biological and mineral material in the waterbody (Pal *et al.*, 2015). Changes in the transparency of a waterbody can be related to the amount of dissolved organic matter, suspended inorganic matter and algae in the water (Pal *et al.*, 2015), which are impacted by human activity on the land surrounding the lake.

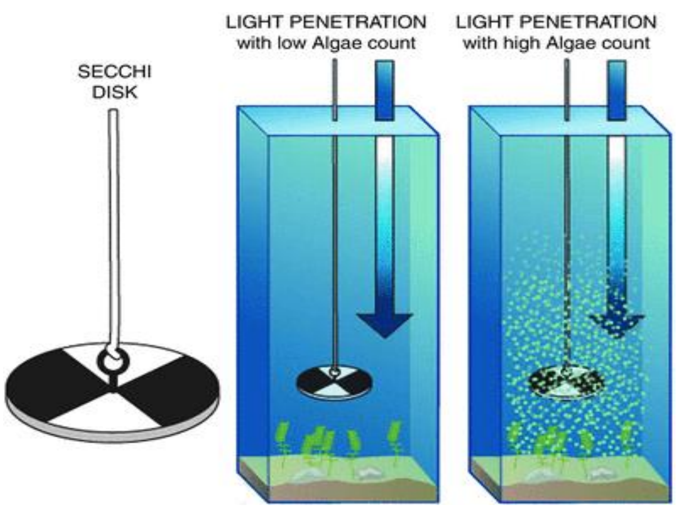

Figure 1: Secchi disk measurements range in depth depending on biological and mineral material content in a lake (Harrison., 2015)

Additional Water Quality Parameters

The Secchi Dip-In provides participants with the option to submit additional water quality data, such as water temperature, turbidity, dissolved oxygen content and pH. Volunteers are also encouraged to submit qualitative comments about the perceived water quality of the waterbody they are collecting data from.

Temperature

Temperature is one of the most important water quality parameters as it affects the rate of chemical reactions and biological activity. Dissolved oxygen, rate of photosynthesis, metabolic rate of fishes, and sensitivity of organisms to pollution are all influenced by the temperature of the water (Bhateria and Jain., 2016). Lake stratification is also a result of temperature gradients within a waterbody (Carlson and Simpson., 1996). Temperature gradients result in warmer and lighter water remining at the surface, while dense and cold water sits at the bottom of a lake. The mixing of water in a lake is restricted when the lake is thermally stratified which subsequently restricts the distribution of dissolved oxygen and nutrients.

Turbidity

Turbidity is a measure of the clarity of a lake. The greater the number of suspended solids in the water, the less clear the water will be and the higher the measured turbidity. Turbidity is typically measured using Secchi disks, although it can be measured using a turbidimeter. Turbidimeters measure the amount of cloudiness in water resulting from suspended particles in Nephelometric Turbidity Units (NTU) (Gorde and Jadhav., 2013). If turbidity values are high, many forms of aquatic life can be affected as light penetration into the waterbody is limited.

Dissolved Oxygen

Dissolved oxygen is a vital water quality parameter which is essential for aquatic life and nutrient cycling. Dissolved oxygen enters the water via diffusion with the atmosphere and through photosynthesis by aquatic plants (Gorde and Jadhav., 2013). Dissolved oxygen is influenced by temperature, when the lake is thermally stratified, higher concentrations can be found at the surface of the waterbody, while low dissolved oxygen concentrations are found lower in the water column. Dissolved oxygen influences the ability for aquatic organisms to survive, as they require at least than 3 – 5 mg/L of dissolved oxygen (Gorde and Jadhav., 2013).

pH

The pH of a waterbody indicates the hydrogen ion concentration of the water. High pH values (greater than 7) are found in water that is alkaline while low pH values (less than 7) are found in acid waters. The pH of lakes typically ranges from 5.5 – 9, where pH values lower than 5.5 significantly impact the survival of invertebrate and crustacean species (Bhateria and Jain., 2016).

Data Submission

Secchi Dip-In data collected from 2017 - 2019 were entered into an Access database accessible on the Secchi Dip-In website through a Cold Fusion form. More recently (2019 – present) data were entered into either the Ambient Water Quality Monitoring System (AWQMS), administered by NALMS, or via the GLEON Lake Observer mobile app. Data collected with the Lake Observer app is transferred from the GLEON database to AWQMS and all data are ultimately uploaded to the U.S. federal Water Quality Exchange (WQX) and Water Quality Portal (WQP) for public viewing and use. Data may be submitted throughout the year, however; NALMS encourages Secchi Dip-In participants to collect and submit data during the Secchi Dip-In event that occurs annually during the month of July.

Ambient Water Quality Monitoring System (AWQMS)

AWQMS is an online platform, created by Gold Systems, that NALMS uses to store and analyze Secchi Dip-In data. AWQMS can be accessed by participants of the Secchi Dip-In and the public, either by using the participant specific username and password login, or through the public portal which uses "nalmspublic" as the username with no password.

Secchi Dip-In data can be submitted into AWQMS manually or through a bulk data upload. Manual data entry requires filling out lake observations on either the Secchi Dip-In Entry Form (Appendix A) or another monitoring programs entry from in the field while collecting data, and then entering it into AWQMS database as a single entry under the enter tab. This method is typically used by individual Secchi Dip-In participants who are collecting a limited amount of data. Bulk data uploads are often used by state, tribal, treaty, and provincial volunteer monitoring programs that have a large amount of data entries. Bulk data uploads require the organization/participant to fill out the NALMS excel spreadsheet template and import it into AWQMS using the import tab. Bulk data uploads can be difficult to use, but NALMS helps with using the bulk upload template because it is a more efficient way of uploading multiple activity results when compared to manual data entry. Another option for organizations that have a large amount of data is to create a custom import configuration that matches the format the organization uses to store data that they collect. This method is typically used when the NALMS spreadsheet template does not match the submitting organization's own spreadsheet or database output. Bulk uploads and custom import configurations also allow volunteer monitoring programs to submit historical data.

Participants are encouraged to submit as much data as they are willing to share. 'How-to' videos and bulk upload templates can be found on the NALMS website under "The Secchi Dip-In" (www.nalms.org/secchidipin/), and custom import configurations can be made by contacting the Secchi Dip-In (secchidipin@nalms.org).

GLEON Lake Observer App

The GLEON Lake Observer App enables Secchi Dip-In participants to submit water quality data using their mobile smart devices from the field or via a user-friendly web-based app. Although the mobile app can be used in the field, NALMS encourages users to record a paper copy of their data in case of an issue with the data submission or if clarification of participants' results is needed. Step-by-step instructions on how to install, register and use the Lake Observer

App can be found on the Lake Observer website (www.lakeobserver.org/guide). GLEON has also added a bulk data upload feature via the web-based app with significant data submissions based on user feedback.

Interpreting Secchi Depth Results

Trophic State

Trophic state is a classification system used in the aquatic sciences to define the level of productivity of a lake. Based on this classification system lakes are categorized into one of four categories (Figure 2). Oligotrophic lakes are associated with high transparency and low productivity, mesotrophic lakes indicate medium transparency and productivity, eutrophic lakes indicate low transparency and high productivity, and hypereutrophic lakes have very low transparency and very high productivity (Bhateria and Jain., 2016). Lake transparency is influenced by amount of suspended particle matter and algae in the water column, it is important to understand a specific waterbody before classifying it based only on Secchi depth. Carlson's trophic state index (TSI) is a mathematical method of classifying lakes into their respective trophic state based on Secchi depth, chlorophyll-*a* content, total phosphorus, and total nitrogen (Figure 3) (Carlson, 1997). The TSI can be used to classify lakes solely based on Secchi depth measurements, but it is more often used to monitor the changes in a waterbody's trophic status over time.

Classification	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Transparency	Clear	Less clear	Transparency <2 meters	Transparency <1 meter
Nutrients	Low TP < 6 µg/L	Moderate TP 10-30 µg/L	High TP > 35 µg/L	Extremely high TP > 80 µg/L
Algae	Few algae	Healthy populations of algae	Abundant algae and weeds	Thick algal scum Dense weeds
D.O.	Hypo has D.O.	Less D.O. in hypo	No D.O. in the hypo during the summer	No D.O. in the hypo during the summer
Fish	Can support salmonids (trout and salmon)	Lack of salmonids, Walleye may predominate	Warm-water fisheries only. Bass may dominate	Rough fish dominate, summer fish kills possible May discourage swimming and boating

TSI(Chl) = TSI(TP) = TSI(SD)

Figure 2: The relationship between water quality parameters and lake trophic state (Laney, 2016)

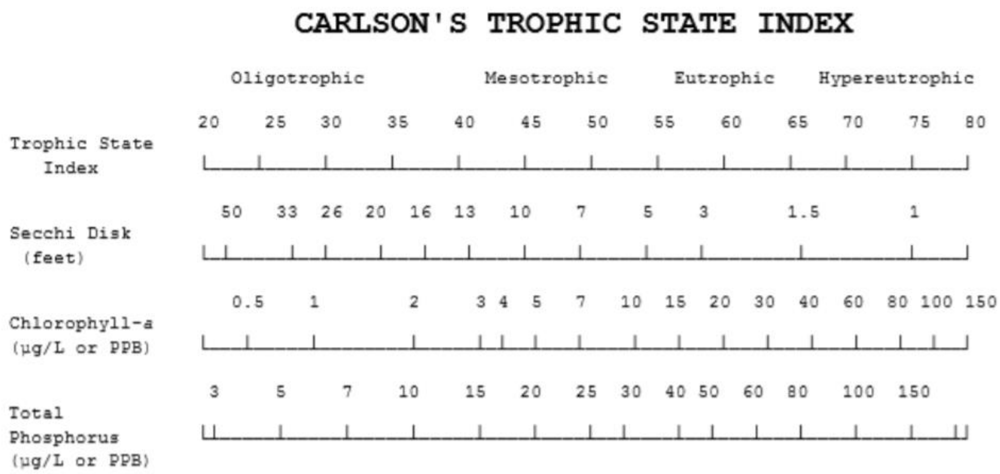

Figure 3: Carlson's Trophic State Index (Carlson, 1997)

Ground Truthing Remote Sensing Data

Ground truthing remote sensing data requires data collected on the ground to be compared to the pixel of an image taken by an airborne camera, which improves the accuracy of models and allows scientists to extrapolate their models to areas that have not been ground-truthed. Community-based monitoring programs, like the Secchi Dip-In are extremely important when it comes to ground truthing data as they provide a source of in situ data that is publicly available and has been collected from many different water bodies in North America. Secchi depth is a good indicator of water quality parameters within a lake, and remote sensing methods are semi-accurate when obtaining Secchi depth readings (Komatsu et al., 2019), which makes Secchi depth measurements extremely useful when ground truthing remote sensing data. Databases like WQX are often used as a source of data for ground truthing satellite imagery, which allows scientists to accurately extrapolate their models to lakes that do not have Secchi depth readings, thus allowing them to monitor the water quality of many lakes remotely. Without large databases and community-based monitoring programs, like the Secchi Dip-In and WQX, remote sensing data would not be as accurate and could not be used to remotely monitor lakes where data has not been collected.

RESULTS AND DISCUSSION

Program Participation

During the time that Dr. Carlson oversaw the Secchi Dip-In, program participation throughout the years of 1995 – 2003 was the highest with an average of 3098 yearly participants, but participation decreased throughout 2004 to 2015 (Figure 4). Since NALMS took over the Secchi Dip-In, there has been an annual increase in the total number of participants, peaking in 2018 with a total of 2205 participants (Figure 4). The growth of participation in the Secchi Dip-In since NALMS took over meets both the goal that NALMS made for the Secchi Dip-In when

Dr. Carlson transferred it, and the purpose of the USEPA Exchange Network grant. Participation in the Secchi Dip-In decreased in 2019 and 2020 (Figure 4), likely resulting from a learning curve associated with the transition to the new Ambient Water Quality Monitoring System (AWQMS) in 2019, and restrictions associated with the COVID-19 pandemic in 2020. An unexpected positive outcome of the Exchange Network grant has been interest in using bulk upload and custom import configurations to submit data via AWQMS and the Lake Observer app. These methods of data submission that also include historical data are now a significant source of new Dip-In data.

Monitoring locations used by Secchi Dip-In participants from the years of 2016 to 2020 were relatively similar, with the largest number occurring in 2018 (Figure 5). The peak in monitoring locations used, is consistent with the peak in program participation (Figure 4). The Secchi Dip-In program receives data that is not only Secchi depth measurements, but also other water quality parameters such as water temperature, dissolved oxygen, and turbidity. Due to the reporting of water quality parameters other than Secchi depth measurements, the number of monitoring sites used (Figure 5) is higher than the total number of Secchi depth measurements for the respective years (Figure 6).

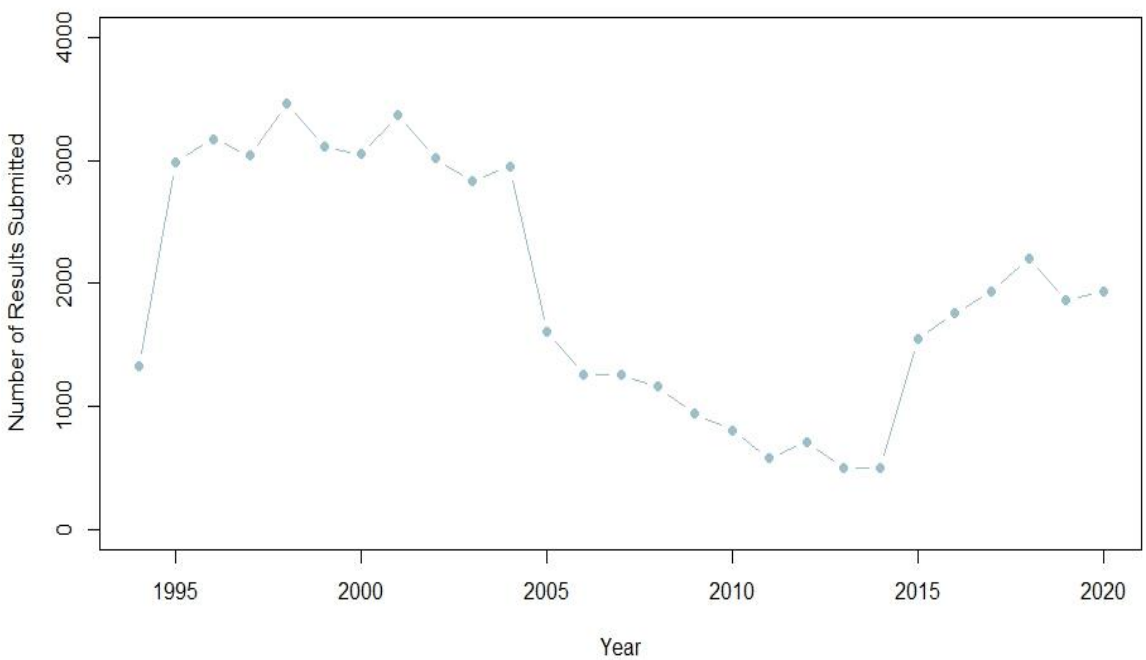

Figure 4: Secchi Dip-In Program Participation for the Years of 1994 – 2020

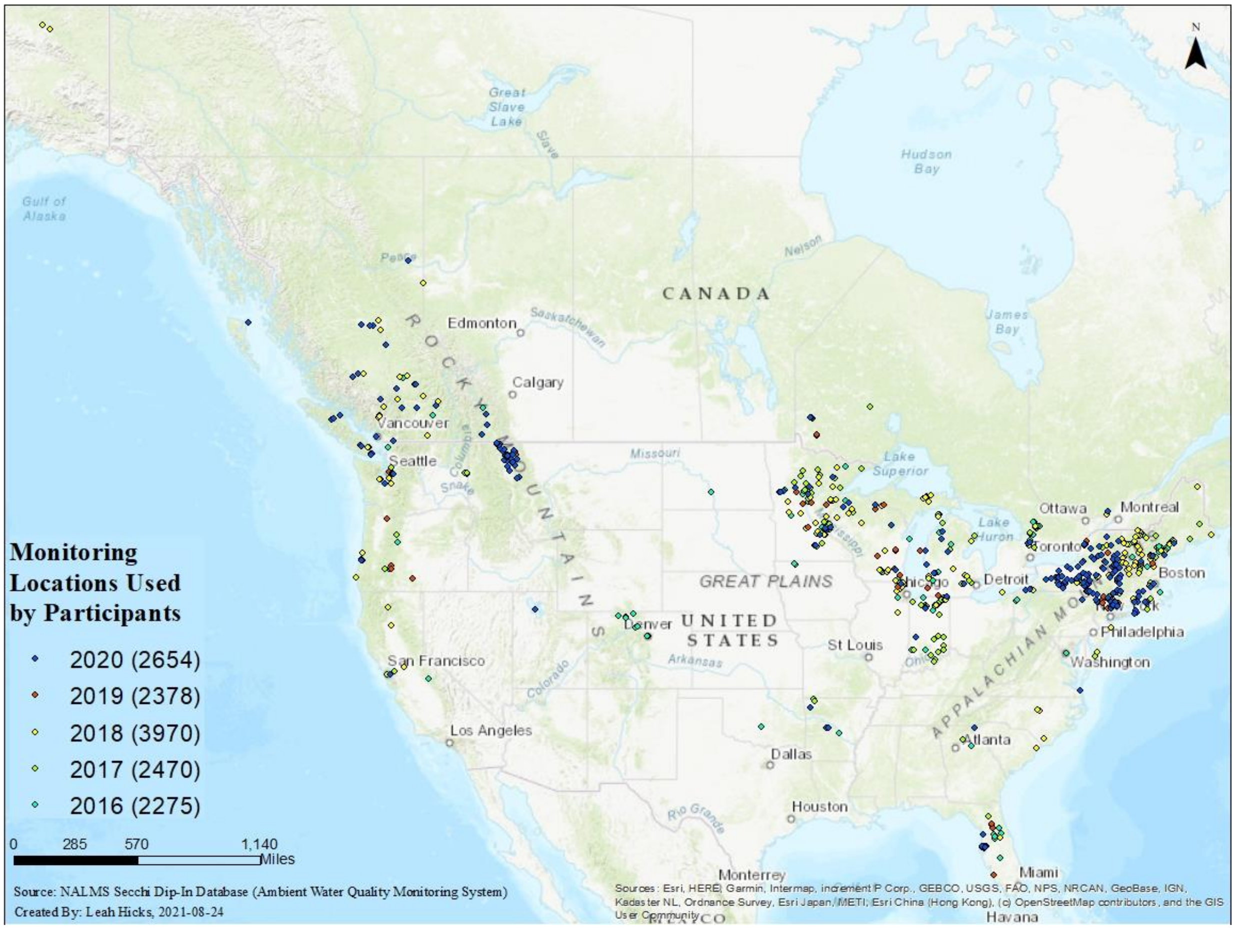

Figure 5: Monitoring Locations Used by Participants throughout the Years of 2016 - 2020

Secchi Depth Measurements

The total number of Secchi depth measurements submitted from 2016 to 2020 ranged from 1761 (2016) to 1936 (2017) (Figure 6). Unlike the trends in program participation (Figure 4), the number of Secchi depth measurements submitted for 2019 and 2020 were respectively the third and second highest of the five-year span (Figure 6). This is likely a result of the collaboration between NALMS and program partners who submit the data that their volunteers collect. Some of the largest contributors of data to the Secchi Dip-In are GLEON Lake Observer, Oregon Lake Watch, Minnesota Citizen Lake Monitoring Program, New York Citizens Statewide Lake Assessment Program (CLASP), British Columbia Lake Stewardship Society and the Ontario Lake Partner Program.

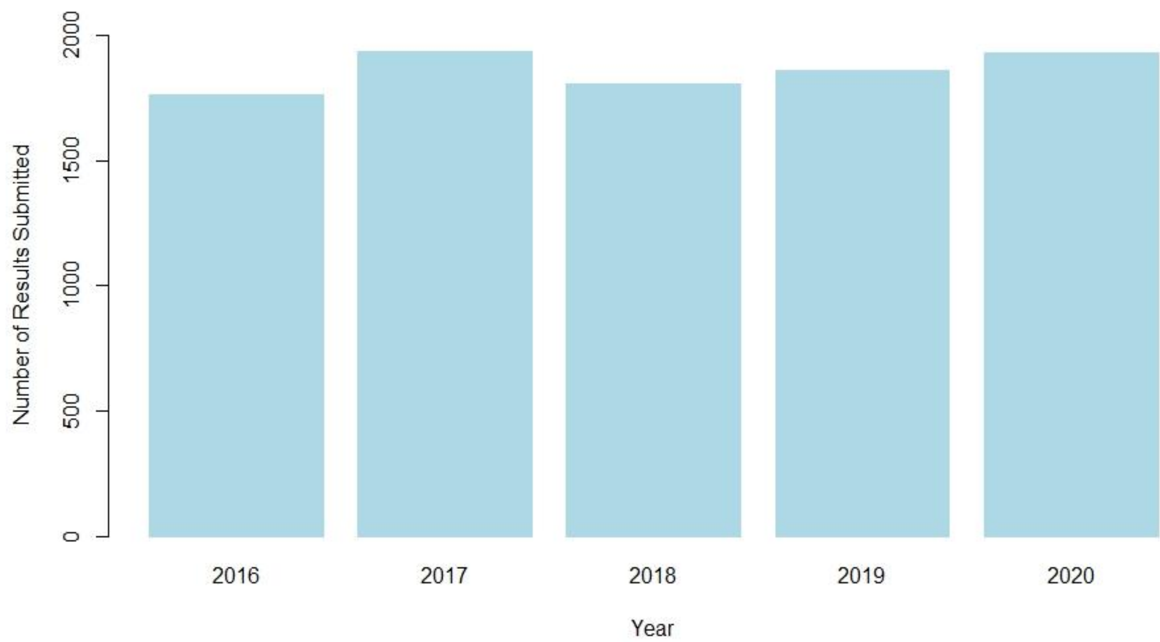

Figure 6: Number of Secchi Depth Measurements for the Years 2016 - 2020

Trends in Secchi depth were consistent throughout 2016 to 2020, with the yearly average remaining around 3.2 meters (Figure 7). Future analysis should be done to compare the trends in measured Secchi depth with the EPA regions and different land uses. Conducting an analysis that compares the different land uses to the measured Secchi depths would allow for analysis of the impacts that land uses (such as agriculture, urban, or forested) land have on the waterbodies in the region.

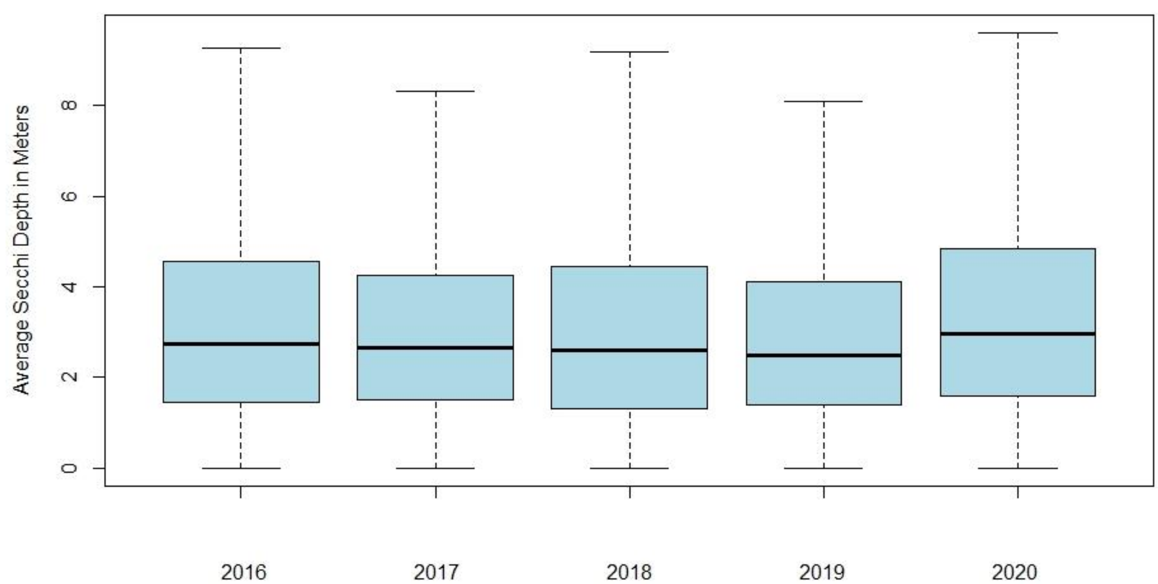

Figure 6: Average Secchi Depth for the years 2016 to 2020

Trophic State Index

Carlson's trophic state index (TSI) is a good indicator of long-term water quality trends, as it is closely related to the transparency, suspended particle matter, and number of algae in the water column (Carlson., 1997). Although the TSI is typically used with other water quality parameters to determine the trophic state of a waterbody, it can be determined with only Secchi depth and is often used to monitor long term changes when calculated this way. The trophic state of lakes that had Secchi depth measurements submitted for the years of 2016 to 2020 were determined using the TSI (Figure 3). Secchi depth measurements that fell between trophic states were regarded as 'unclassified' while the other Secchi depth measurements were either 'hypereutrophic', 'eutrophic', 'mesotrophic' or 'oligotrophic' (Figure 7). The total number of lakes classified as a trophic state remained similar over the five-year period, with mesotrophic being the dominant state for the years 2016, 2017 and 2020 and eutrophic being the dominant state for 2018 and 2019 (Figure 7). This is expected as the average Secchi depth for the same time period remained stable (Figure 6) and Secchi depth is used to calculate TSI (Figure 3). The difference between a lake being classified as mesotrophic or eutrophic is approximately 1.5 meters, while the difference between oligotrophic and mesotrophic is approximately 5 meters (Figure 3). The closeness of the mesotrophic and eutrophic classification depths explains why the dominant trophic state change between mesotrophic and eutrophic over the five-year period. If this analysis were to be reconducted in the future it would be recommended to compare the Secchi depth calculated TSI to the U.S. EPA table on the percent of lakes in each trophic state based on EPA region.

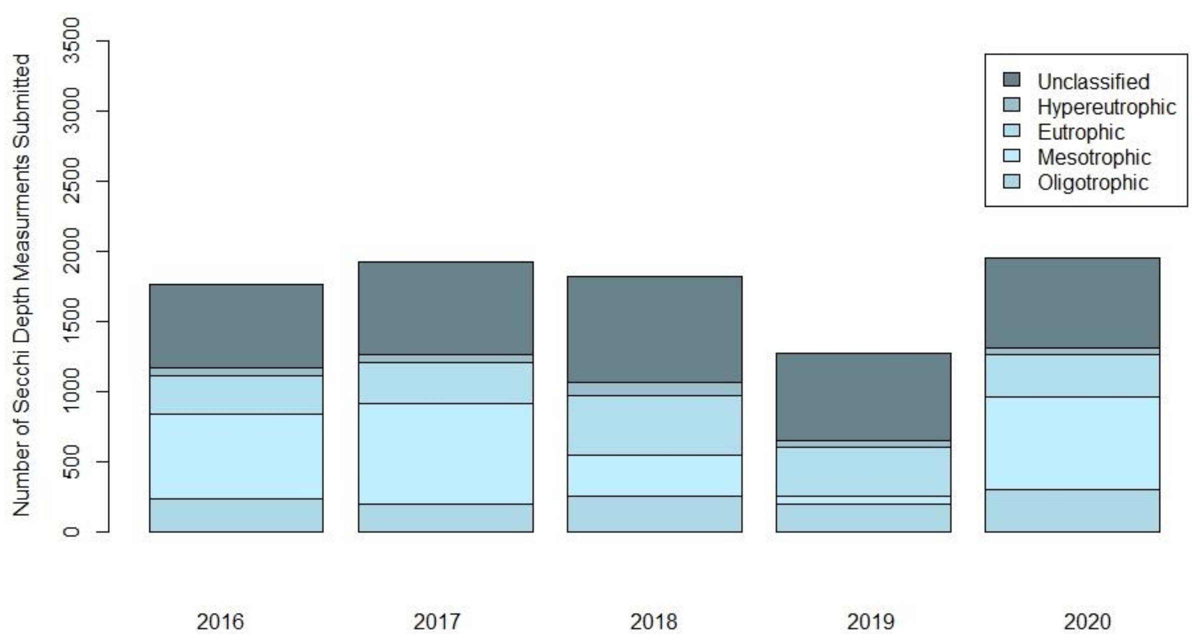

Figure 7: Distribution of TSI Classifications for Secchi Depth Measurements Submitted from 2016 - 2020

CONCLUSIONS

The Secchi Dip-In is an important citizen science program that provides the public, scientists and academics with a long-term data set and the ability to observe trends in waterbodies throughout North America. Programs that rely heavily on citizen science also rely on a consistent or rising number of participants. After NALMS took over the Secchi Dip-In program in 2015, participation has risen as a result of outreach activities including social media campaigns, Lakes Appreciation Month, and outreach to existing citizen science programs. Although participation in the past few years has decreased resulting from a learning curve associated with the transition to the new AWQMS database and the COVID-19 pandemic, NALMS anticipates an increase in program participation in the future, especially from bulk uploads and custom import configurations that also include historical data. As global temperatures continue to rise and other climate change impacts affect freshwater resources, it is of utmost importance that long-term monitoring programs like the Secchi Dip-In continue.

Climate change is already impacting the water quality of lakes, ponds, reservoirs, and streams throughout the world. Algal blooms are a sign of eutrophic conditions resulting from excess nutrients (phosphorus and nitrogen), and high atmospheric CO2 concentrations (Nazari-Sharabian et al., 2018). Urbanization, intensive agricultural practices, and industrial development impact both the atmospheric CO2 concentration and nutrient over-enrichment that led to eutrophication and algal blooms in waterbodies (Nazari-Sharabian et al., 2018). It is predicted that as human activities and urbanization increase, the quality of inland waterbodies will decrease. Secchi depth readings, and the resulting calculated TSI, are a cost-friendly way to monitor changes of waterbodies and classify them into their respective trophic state. It is important to monitor the changes of waterbodies as they will likely occur slowly.

All data submitted prior to August 19th, 2021, was used in the data analysis for this report, all data submitted afterwards will be included in future Secchi Dip-In reports. Data analysis was conducted to provide a glimpse of the state of waterbodies throughout North America and results are broad as they report the results of all waterbodies not specific regions. For improved analysis and a better understanding of waterbodies in North America it is recommended that analysis be done for specific regions. The Secchi Dip-In database will remain publicly available via the AWQMS database, as well as WQX and WQP, so that the long-term data collected can be used by the public, professionals and, decision makers throughout North America to model and monitor changes in waterbodies.

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APPENDIX A: Secchi Dip-In Entry Form

The Secchi Dip-In Entry Form

Please submit the data at our website (http://www.secchidipin.org) and keep this form as a record. If you have no computer access, mail this form to the Secchi Dip-in address given at the end of this form.

Person Taking Reading:

Last Name: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐ **First Name:** ☐☐☐☐☐☐☐☐☐☐☐☐

Telephone Number (____) ____________________ **E-mail Address:**________________________________

Your Monitoring Program Name (if applicable):__________________________________

Please enter the following information on your waterbody

Waterbody Name:_____________________ **State/Province**_______________ **Country**_______________

County/Region ______________________ **Zip/Postal Code of waterbody nearest town to site**_____________

Longitude of Site: ________________ Degrees ________Minutes _____Sec_______

Latitude of Site: ________________ Degrees ________Minutes _____Sec_______

Please include map locating the waterbody and site if you don't know the map coordinates.

Waterbody Type: O Natural Lake/Pond (No Dam) O Reservoir (Dam) OStream/River OEstuary OMarine
O Other waterbody type _________________

Size (Lake or Reservoir Only) O Less than 5 Acres O 5-10 Acres O 10-100 Acres O 100-500 Acres O> 500 Acres

Actual Size (If known):___________ O Acres O Hectares **Depth at Site** (If known):___________ O Ft O Meters

Please enter the transparency measurement below.

Date of Reading: Month: OJune OJuly Enter Date: _______ Year: 20___

Time of Observation: _______ OAM OPM (To the nearest 15 minutes)

Site Name or Site Number (As Used in Your Normal Program Monitoring): ________________

Weather: O Sunny O Partly Cloudy O Overcast O Rain

The reading was taken from a O Boat/canoe O Dock O Bridge O Wading O Other______________

	Secchi Disk	Turbidity Tube	LaMotte Turbidity	Vertical Black Disk	Turbidity Meter
Reading:					

My Reading is measured in O Feet OInches O Meters O Centimeters O NTU O JTU O FTU

***It is very important that you add the Units of Measure** (Feet, Inches, Meters, etc) so that we can accurately estimate transparency.*

Please answer the following if you used a Secchi Disk

Was the disk resting on the bottom? OYes O No

Is the disk OAll White OBlack and White

Did you use a viewscope? OYes ONo
If Yes, is it an OOpen tube or has
OClear glass or plastic on bottom?

Did you view the disk on the OSunny or OShady side of boat

Did you wear sunglasses? OYes ONo

Please answer the following if you used a Turbidity tube

Length of tube:_____ OInches or OCentimeters

Was the bottom of the tube visible when full? OYes O No

Please enter other variables you measured here			**What is the general water quality of your waterbody?**	**Has the quality changed in the past 5 years?**
Temp Surface _____ Bottom _____ 8 Degrees F 8 Degrees C	**Oxygen** (ppm or mg/L) Surface______ Bottom ______ Bottom depth____	**pH**______ O Meter O pH paper O Comparator O _________	O Beautiful, No Problems O Minor Problems O Slight Use Impairment O Substantial Impairment O Use Totally Impaired	O Better O Worse O No change O Don't know

What factors (if any) negatively affect the general water quality at your site?

Problem	I Don't Know	Beautiful, Causes No Problems	Causes Minor Problems	Causes Slight Use Impairment	Causes Substantial Use Impairment	Causes Use To Be Totally Impaired
Algal Scums						
Aquatic Weeds (Seaweed)						
Turbidity (from sediments and erosion)						
Boats/Boating (Congestion, Safety, Noise)						
Poor Fishing						
Personal Watercraft (Jet Skis)						
Bacteria						
Dense Housing						
Filling-In						
Trash and Litter						
Pest Wildlife (Raccoons, Geese, Ducks, etc.)						
Noise (Non-Boating: neighbors, traffic, etc.)						
Swimmers Itch						
Too Many Rules and Regulations						
Other ________________						

Dip-In Instructions

- Measure transparency on **any day during the Dip-In period. Please do not go out if it is raining, if there is abnormally high boat traffic, or if your safety would be at risk.** A clear, calm day is best.
- Go to the site or sites where you normally measure transparency. Follow your normal monitoring procedures.
- Enter the data at our web site (**http://www.secchidipin.org**) or, ***Carefully and completely*** **record your findings on this form.** We may not be able to use your information unless the blanks are filled in correctly**.**
- Please be sure to add your telephone number and e-mail address in case we have questions about your answers.
- It is very important to know where your sampling site is. If you supplied this information in the past, you do not have to add it again.
- Be sure to **mark the type of transparency device** you use, whether it is a Secchi disk, a turbidity tube, a LaMotte® turbidity column, a turbidimeter, or a vertical black disk. It is especially important that you enter the units (feet, inches, meters, centimeters, etc.) in which the transparency reading was measured.
- **If you have participated in the past**, please participate again so that we can examine trends in transparency.
- **Do you have any questions?** Look at our website (**http://www.secchidipin.org**), e-mail us at secchidipin@nalms.org or write us at:

The Secchi Dip-In
PO Box 5443
Madison, WI 53705