Effect of rapid Lake Huron rise on plankton, phosphorus and temperature in waters of the Les Cheneaux Islands: 2013-2020.

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Les Cheneaux Watershed Council

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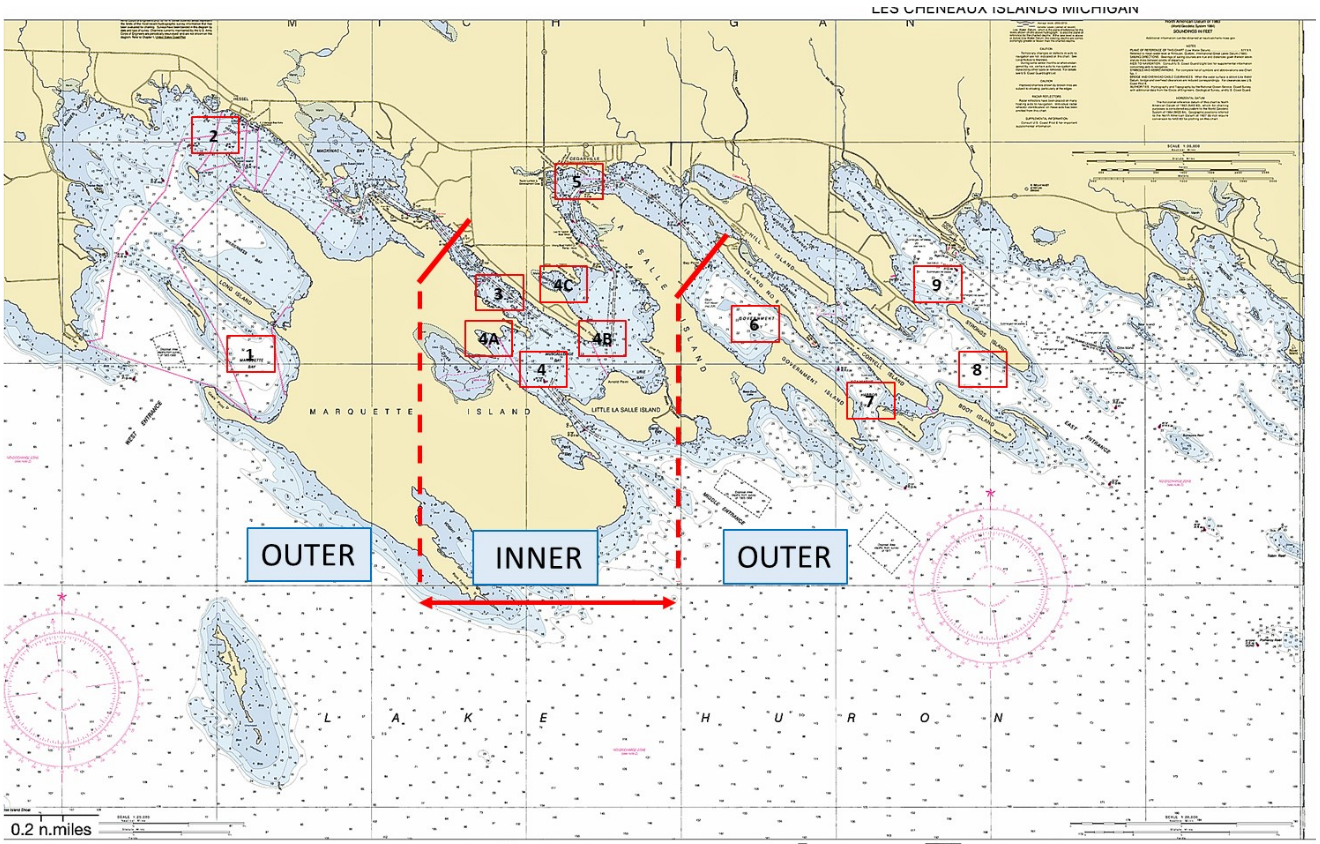
Abstract: Variation of Great Lakes water levels in the four-to-five foot range have been recorded since the mid-1800s. No lake level shifts of almost six feet over a short eight-year period have been recorded during that time. The Les Cheneaux Watershed Council (LCWC) took advantage of this unprecedented event to monitor plankton, phosphorus and temperature changes during the recent rapid Lake Huron (LH) rise. Each year, data and water specimens were collected monthly by LCWC from May through Sep and samples were subsequently analyzed at the Univ MI Biological Station, Douglas Lake. Water level increase within the Les Cheneaux Islands from an historic low in 2013 through the summer of 2020 to the historic high resulted in a LH increase of almost six feet, 67.4 in (171 cm) (Ref 5); water temperature dropped 5°C (9.5°F); total phosphorus concentrations decreased almost sixfold from a maximum of 11.3 µg/L to a minimum of 2.0 µg/L and plankton density decreased fivefold from a maximum of 2.0 µg/L to a minimum of 0.4 µg/L. Although annual variation occurred, trendlines for all three variables monitored had a downward slope during the study. Temperature decline attributed to the inflowing, cooler LH water appears to have decreased plankton metabolism and, therefore, overall plankton density. A dilution effect from the inflow of low-nutrient LH water would be expected to limit available phosphorus as a plankton energy source. However, any phosphorus dilution was apparently offset by higher water levels suspending organics from shorelines, which then became available as a plankton food source. Plankton growth deficits due to phosphorus availability were not obvious. These same variables will continue to be monitored as Lake Huron waters recede.

Introduction: The Les Cheneaux Watershed Council (LCWC) has monitored water quality variables within the Les Cheneaux Islands since 2001 under sponsorship of the Les Cheneaux Islands Association (Ref 1). Lake Huron (LH) levels fluctuated during the 2001 through 2005 period then began to slowly decline through 2012 until an all time low was recorded in Dec 2012-Jan 2013 (Ref 2,3,4). Water levels increased annually from 2013 through the summer of 2020 at rates of 4 to 16 inches ,until a record LH high was recorded in August of 2020. This report takes advantage of a rare opportunity in LH hydrology to monitor effects of the rapid LH rise on our primary water quality variables of plankton food source (phosphorus), temperature and plankton density itself.

Observed nutrient (trophic) patterns, aquatic conditions for a water body to support a specific level of plant and animal growth, have been delineated into an Outer Island Zone (OIZ), in which lower nutrient concentrations and conditions such as temperature and sunlight penetration to support growth are reduced, and an Inner Island Zone (IIZ) in which higher nutrient levels and conditions are available to support more dense growth (Fig. 1, App C). Study sites between the OIZ and the IIZ are considered Transition Zones (TZ) with intermediate levels of growth-supporting nutrients and growth conditions.

Fig. 1. Nutrient and productivity zones of the Les Cheneaux Islands. An Inner Island Zone (IIZ: higher nutrient and higher plant/animal productivity) is shown between the vertical/angled red lines and Outer Island Zones (OIZ: lower nutrients and less productive) are shown East and West of the Inner Island Zone. Numbers signify sample sites.



Materials and Methods.

Relationship of Chl-a, TP and SRP: Three variables monitored during annual LCWC sampling of Les Cheneaux waters included Chlorophyll-a (Chl-a), Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP). The relationship of these three variables is an indicator of other water quality factors within the waters being examined. In a balanced, healthy water body the Total Phosphorus (TP) is present in a greater concentration than the Soluble Reactive Phosphorus (SRP). SRP is derived from TP and can be directly metabolized by plankton (free-floating algae, or phytoplankton) whereas the TP must first undergo a conversion, either microbiogically or chemically, in order to serve as a nutritional source for plankton (App. A,B).

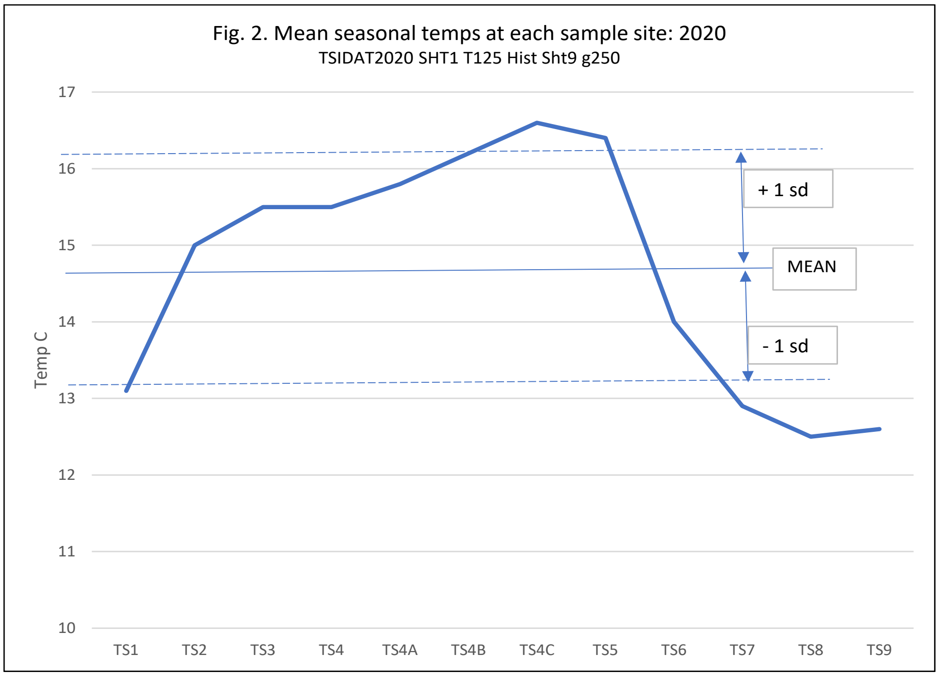
Chl-a is a measure of a specific classification of chlorophyll that is present in plankton at the time of each sampling. The Chl-a value is an indirect estimate of the plankton density. Higher, or more dense, plankton populations will consume greater amounts of phosphorus as an energy source. Thus a decrease in TP or SRP would indicate a greater demand for that component as a plankton food source.

Plankton Chl-a values are normally lower than SRP concentrations. It follows that, since SRP is a component of TP, that Chl-a values will also be lower than observed TP levels. Thus, ratios of Chl-a/SRP and Chl-s/TP can be used as a measure of that relationship for a given sample event or period.

Sample analysis: Water samples and filters through which known volumes of water had been passed through 0.45µ cellulose acetate filters were analyzed by chemists at the University of Michigan Biological Station at Douglas Lake. Methods used were as reported in Smith, 2006. (Ref. 1).

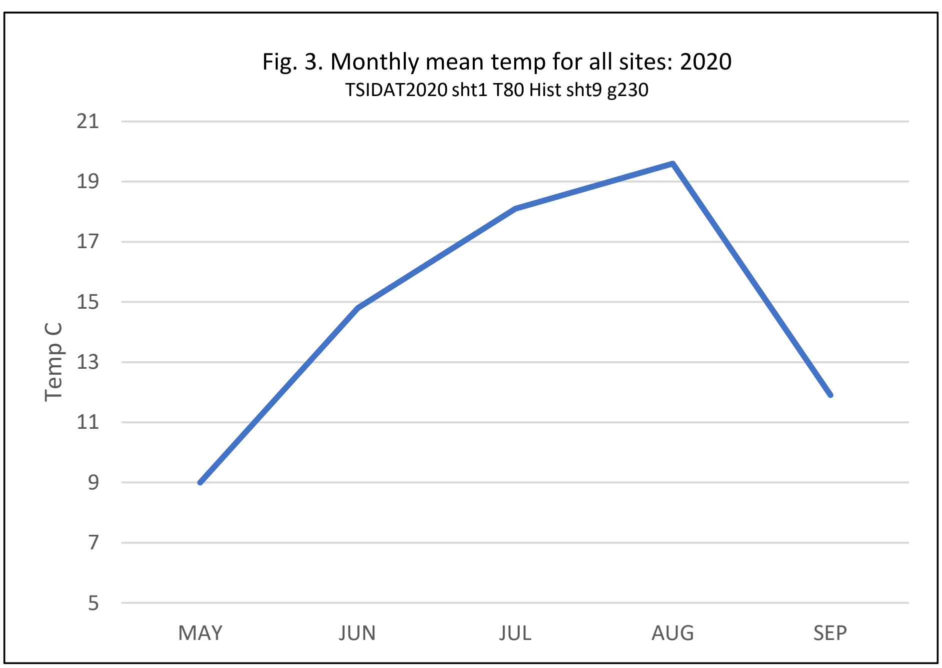
Results and Discussion:

Outer and Inner Island Zones (OIZ and IIZ) as seen in Fig. 1 and below in Fig.2 can be distinguished from transition areas by observing those sample sites that differ from mean temperatures by at least one standard deviation (sd) unit. Sites TS1, TS7,-8 and 9 are farthest below, and cooler than, mean island-wide temperatures. Sites TS4B, 4C and 5 are similarly farthest above, and warmer than, the mean island temperatures. Other sites have intermediate temperatures and are considered transition sites. Discussion hereafter will concentrate on comparison of variables in the OIZ and IIZ due to less variability within those sites compared to the transition areas.



Note: Alpha-numeric codes at the end of figure titles indicates the raw data source from which the graphs were developed.

Typical seasonal temperatures are displayed in Fig. 3 where monthly mean temperatures for all monitored sites are shown. The curve for 2020 is representative of annual temperature patterns in that they rise continuously from May into Jul, peak in Aug and then begin to decline during Sep.



Figures 4A and 4B show the similarity in temperature range within the OIZ and within the IIZ. Sample sites within the OIZ ranged from a seasonal high temperature of about 18°C in 2015 to a low of 11°C in 2018 and 2019 (Fig. 4A). Temperature trendlines for all sites were on a downward slope toward cooler temperatures from 2013 through 2020. Temperatures in the IIZ were warmer and ranged from a high of around 21°C in 2015 to a low of 16°C in 2019 (Fig. 4B). As with the OIZ, temperature trendlines for the IIZ sample sites were in a downward direction towards cooler temperatures during the study period. Temperatures varied similarly in the OIZ and in the IIZ during 2013,14 and 15. The most different of the OIZ temperature ranges was TS9. This site is farther from open waters of Lake Huron, yet is similar to the other OIZ sites in nutrition and plankton populations as will be seen in following text.

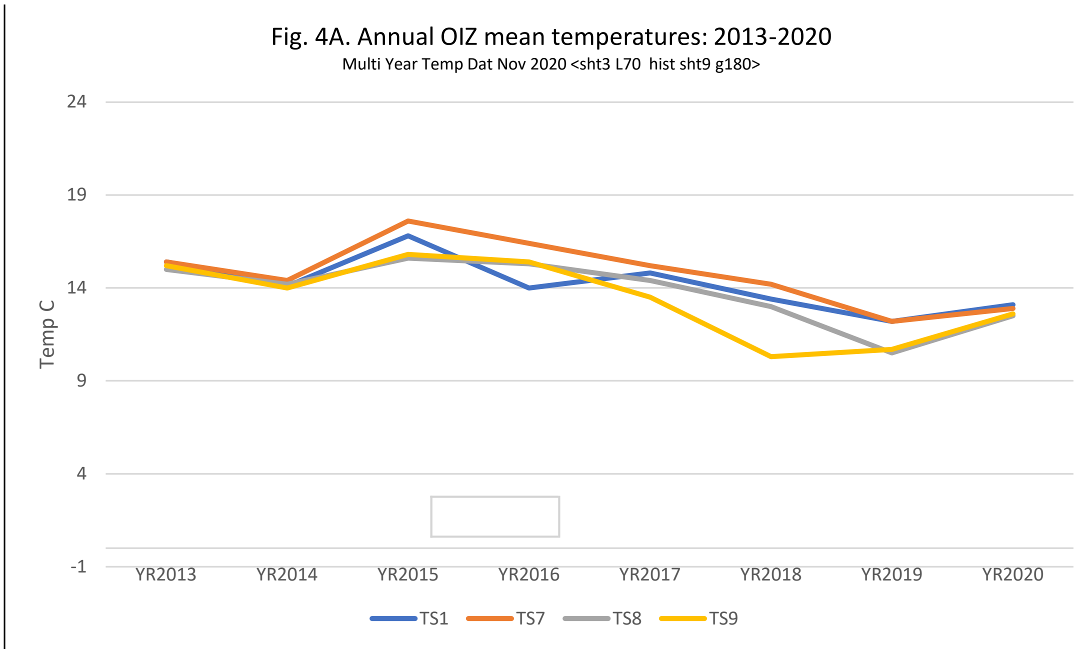


Fig. 4A. Annual OIZ mean temperatures: 2013-2020
Multi Year Temp Dat Nov 2020 <sht3 L70 hist sht9 g180>

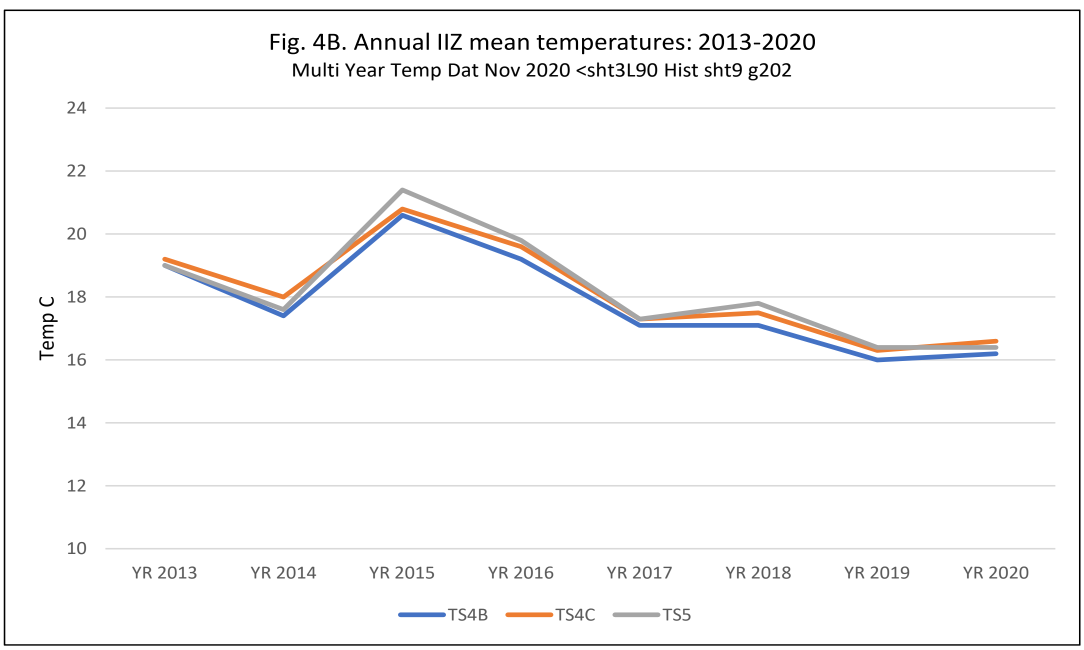


Fig. 4B. Annual IIZ mean temperatures: 2013-2020
Multi Year Temp Dat Nov 2020 <sht3L90 Hist sht9 g202

When mean annual temperature curves are generated for the OIZ and for the IIZ, their downward trendlines are parallel and exhibit a high correlation coefficient, or "r" of 0.91(Fig. 5). Also plotted in Fig. 5. is the annual increase in Lake Huron rise, in inches, on the right axis. One could speculate that the more shallow, warmer, IIZ waters would change temperature at a different rate, especially during different years, but that does not appear to be the case.

Fig. 5. Mean annual temp at OIZ & IIZ during L Huron rapid rise. <Hist sht6 AD60> sht9 g275

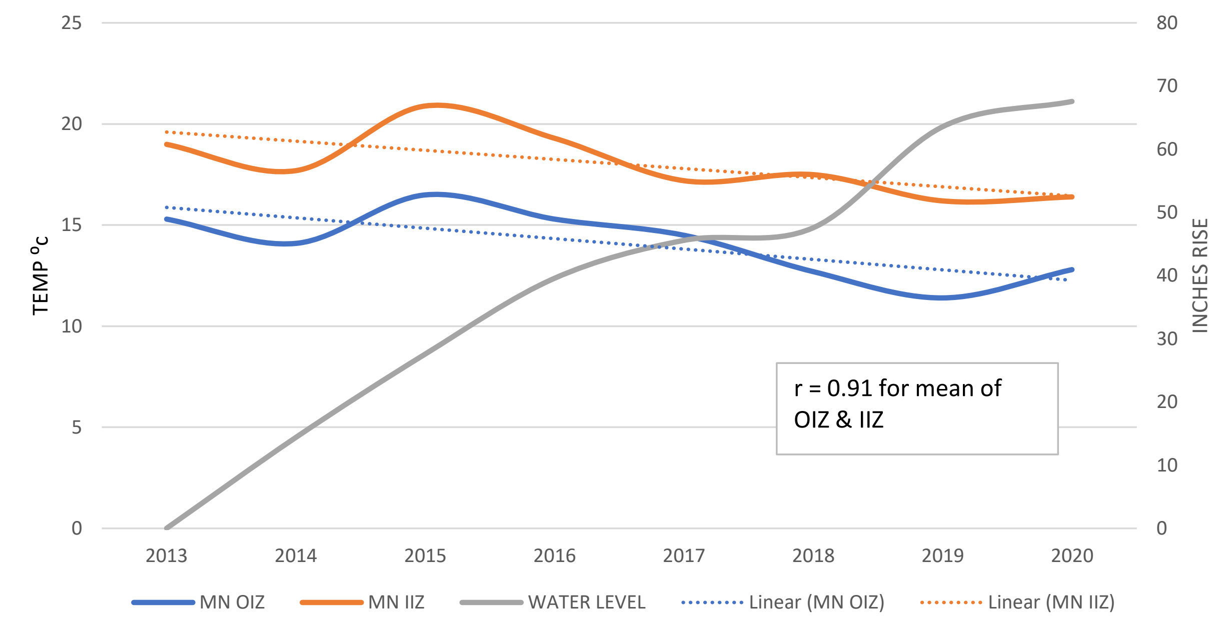
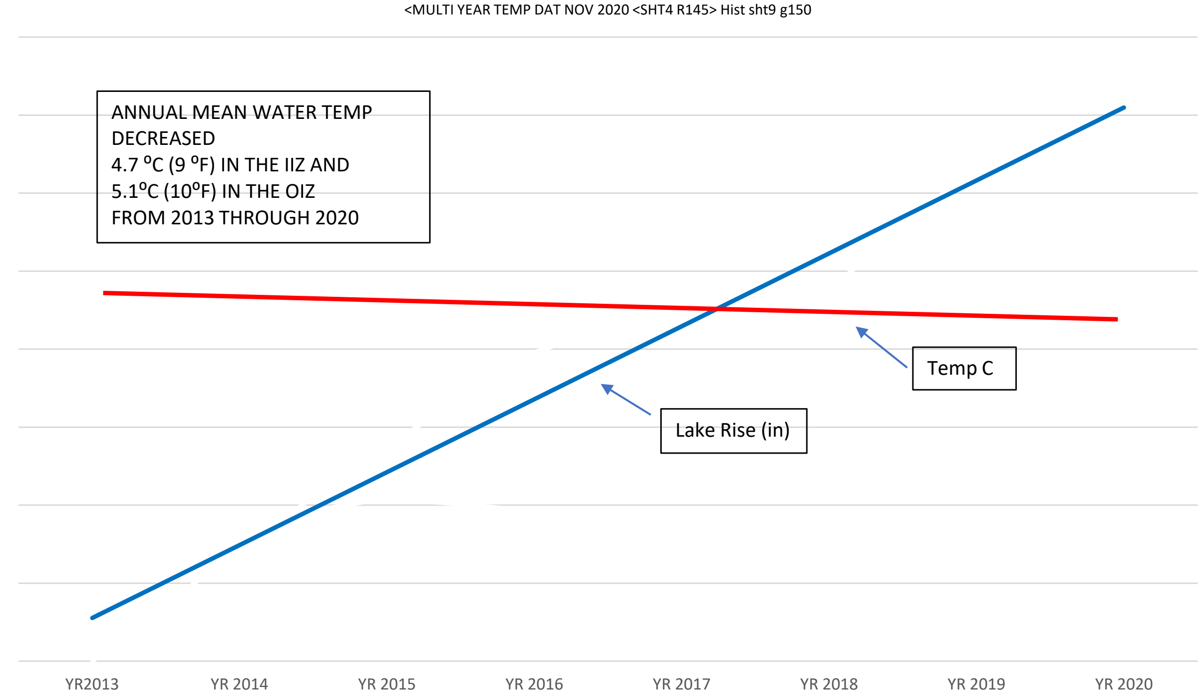
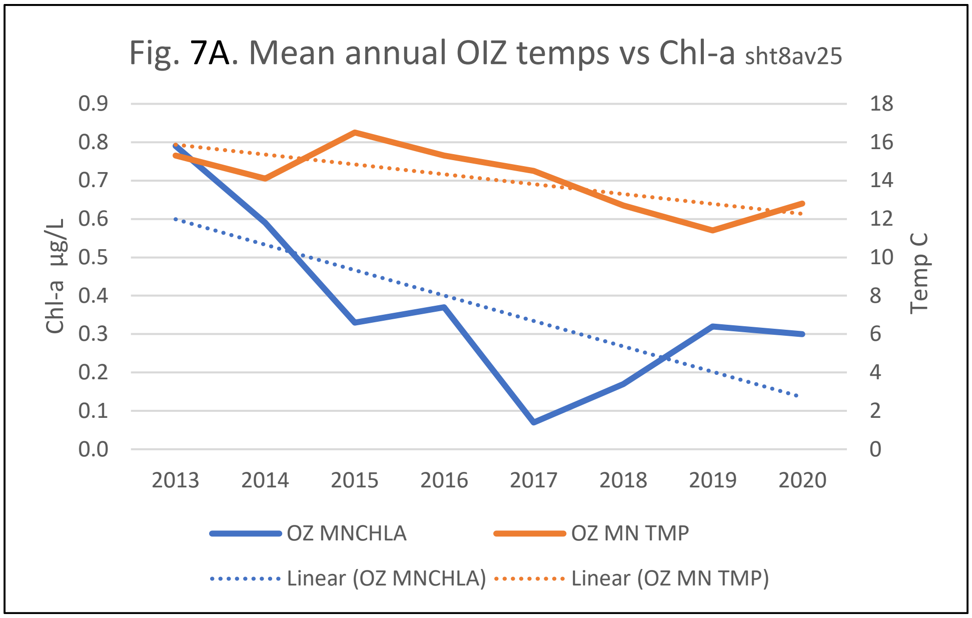


Fig. 6 shows the relationship between Lake Huron rise and mean annual temperature shifts in the OIZ and IIZ. The combined downward shift in mean temperature in the OIZ and in the IIZ during the eight-year period was 5.1°C (10°F) and 4.7°C (9.1°F), respectively, as the Lake Huron level increased 171 cm (67.4) (Ref. 5). Cooler water temperatures and diluted nutrients from the nutrient-poor waters of Lake Huron could be expected to have a limiting effect on the plant life, the lower food web and the Les Cheneaux aquatic ecosystem in general.

Fig. 6. LCI water temps declined during a period of annual Lake Huron rise: 2013-2020.
<MULTI YEAR TEMP DAT NOV 2020 <SHT4 R145> Hist sht9 g150



As expected, plankton (Chl-a) densities decreased during the study period in parallel with the measured temperature drop in both the OIZ and the IIZ (Fig. 7A & 7B). The correlation coefficient of Chl-a curves for the OIZ and the IIZ was in high agreement with r= 0.93. Trendlines for the Chl-a decline was downward in both the OIZ and IIZ.



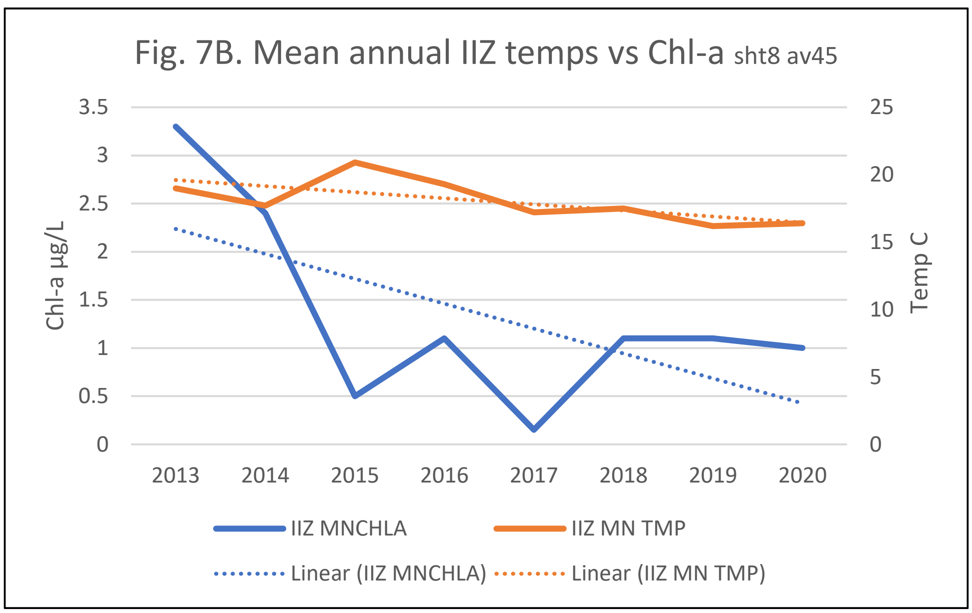
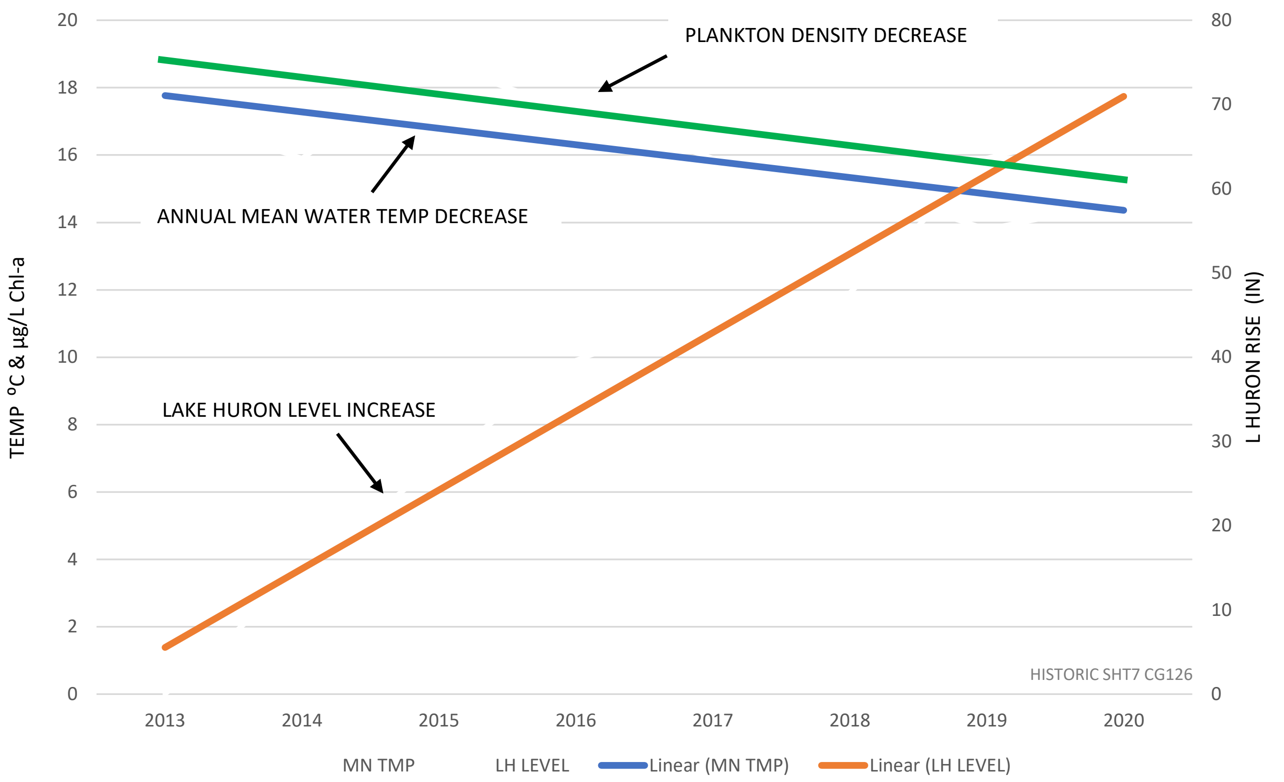


Fig. 8 displays a clear view of the relationship between water temperature decline and plankton density decrease during the period of Lake Huron rise. Downward trendlines for water temp and plankton represent mean values calculated from both OIZ and IIZ data presented in earlier figures.

Fig.8. Water temp & plankton decrease during Lake Huron Rise:2013 - 2020

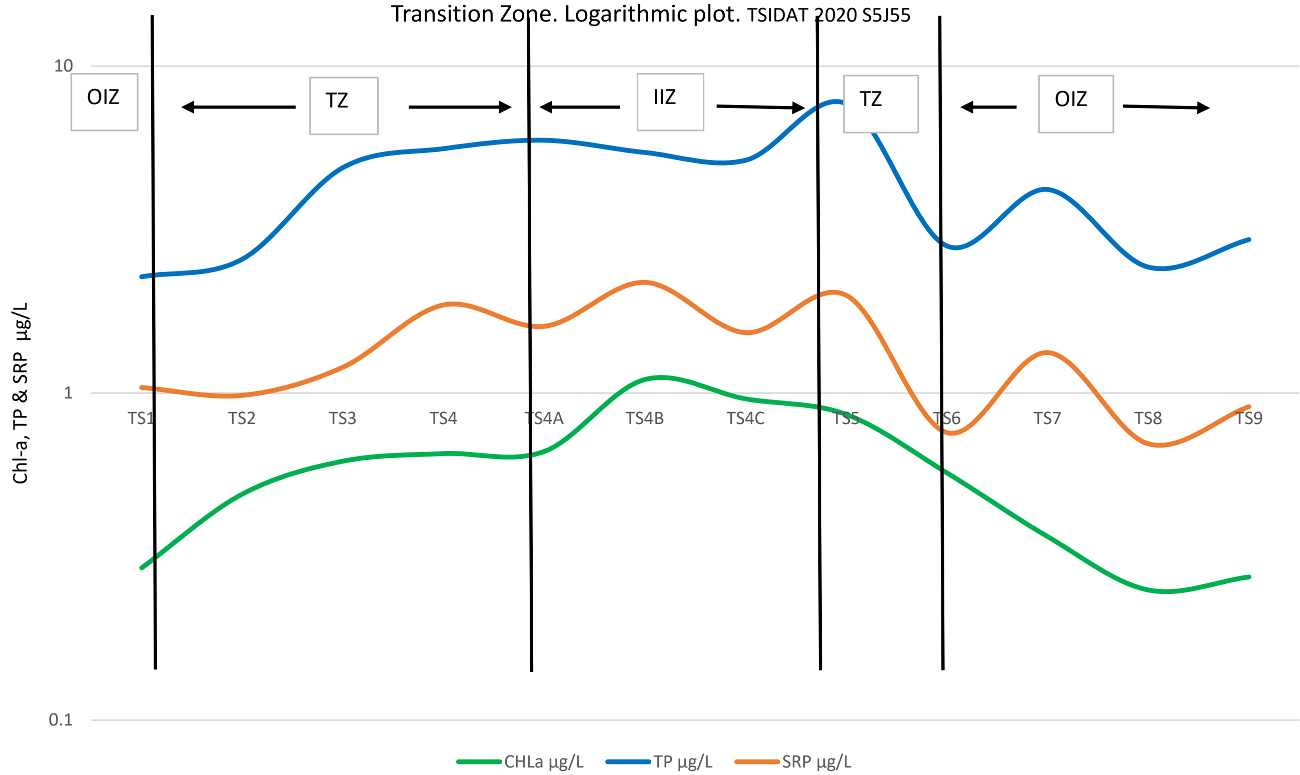


Phosphorus and plankton dynamics:

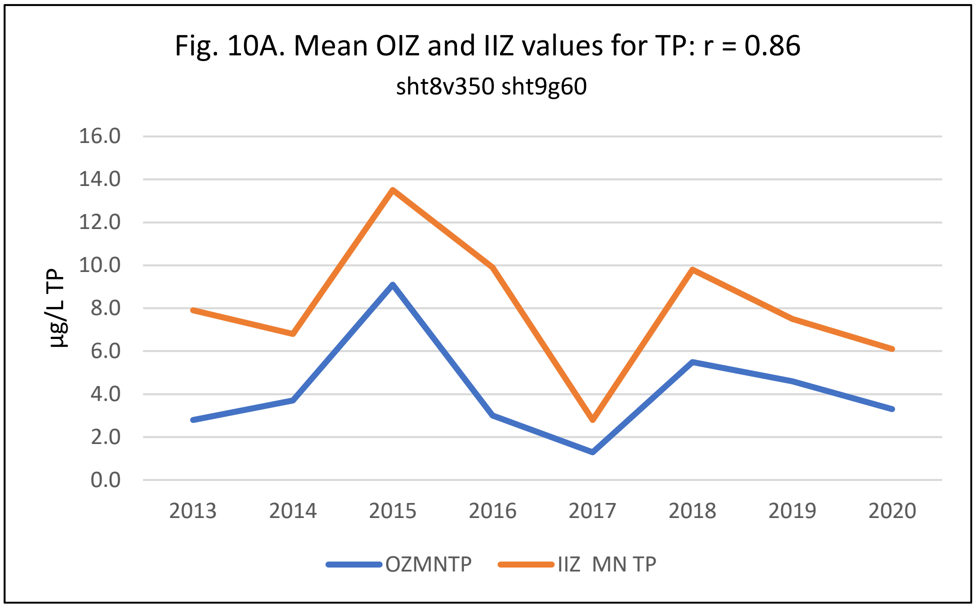
Fig. 9 curves reflect a healthy aquatic ecosystem across the Les Cheneaux sample station spectrum in that the TP, SRP and Chl-a, relative to one another, are at expected levels for each station. That is: at any given site, concentrations of TP were higher than SRP which, in turn, were higher than levels of Chl-a. Also, concentrations were uniformly higher in the previously described IIZ than in the OIZ (Fig. 2). Intermediate concentrations of each variable were recorded in the TZ areas.

The mean concentration of all three variables was greater in the IIZ than in the OIZ which, from the historical perspective, was expected (Fig. 9). TP and SRP concentrations of the IIZ were 2X greater than OIZ values and the IIZ Chl-a level was 3X greater than the OIZ concentration. Fig. 7A and 7B reinforce the expectation that higher nutrients promote more robust algae growth conditions in the IIZ than in the OIZ.

Fig. 9. Island-Wide mean values for Total Phosphorus (TP), Soluble Reactive Phosphorus, SRP and Chlorophyll-a (Chl-a) for the 2020 season: May-Sep. OIZ:Outer Island Zone; IIZ: Inner Island Zone; TZ: Transition Zone. Logarithmic plot. TSIDAT 2020 S5J55



The OIZ/IIZ TP relationship is closer than the OIZ/IIZ SRP correlation whereby the correlation coefficient for TP was r=0.86 vs r=.71 for SRP (Figs. 10A and 10B). Given the more uniform TP/SRP correlation for phosphorus in this study, only the TP values will be used hereafter in this document.



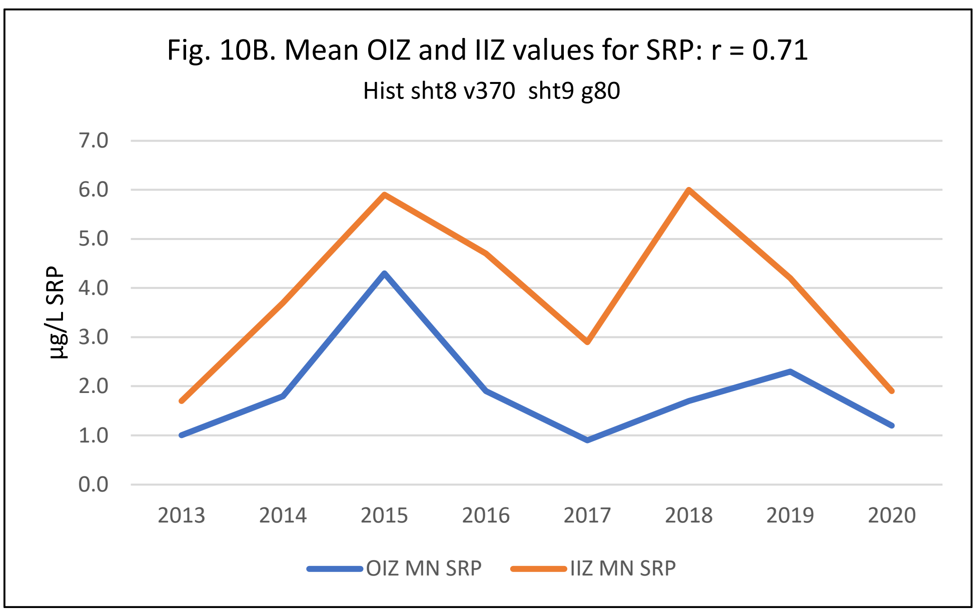
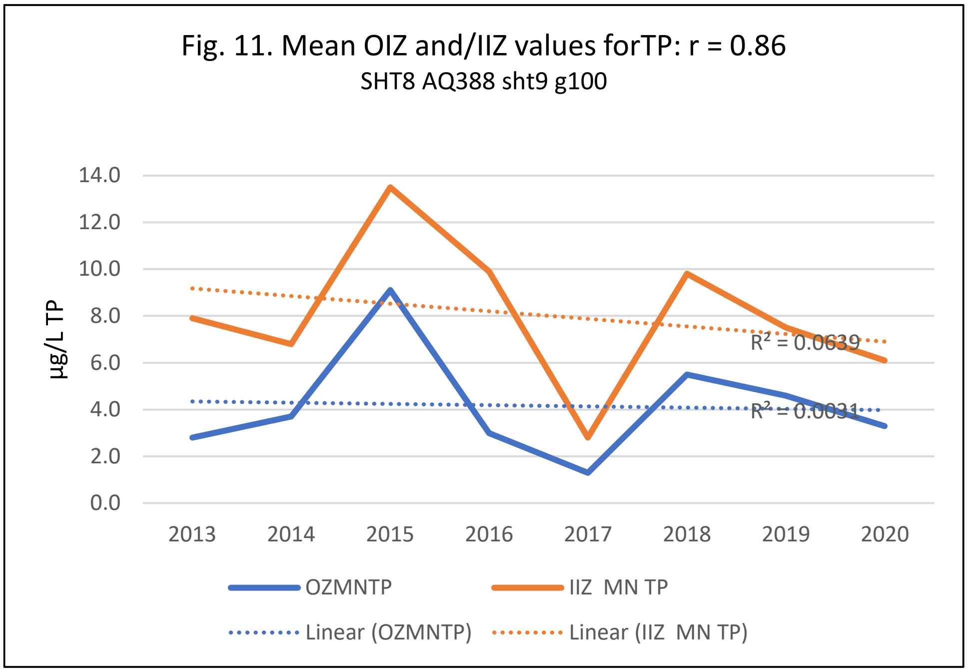
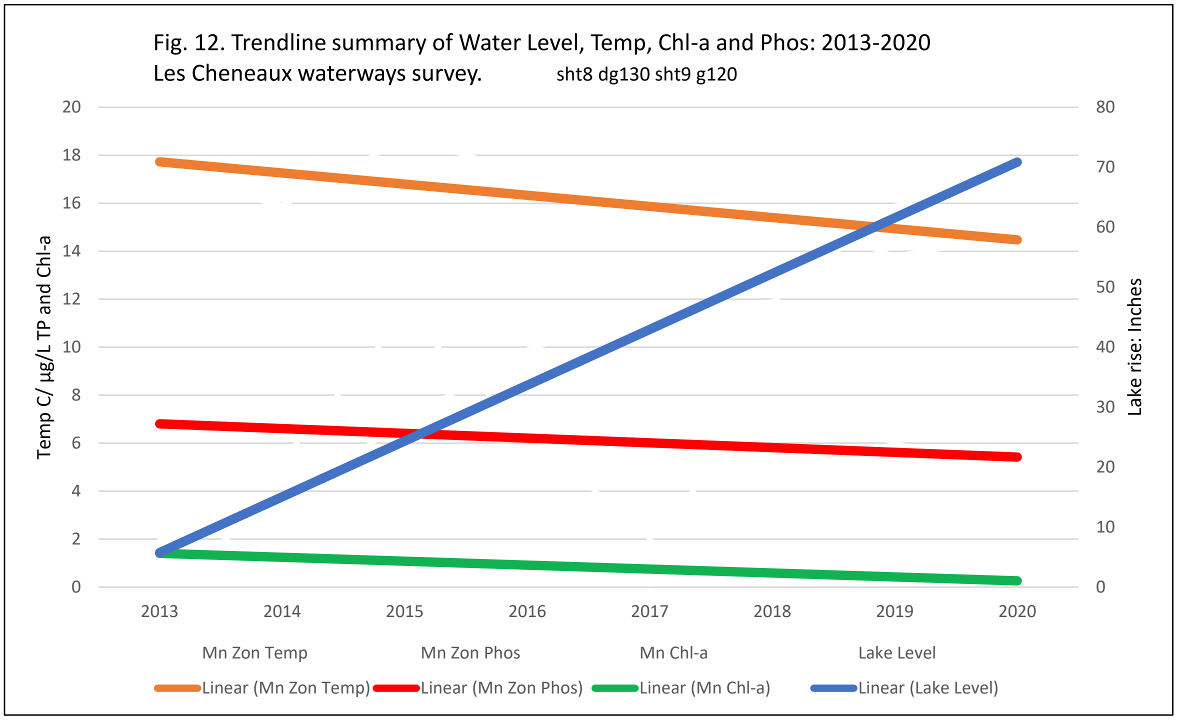


Fig. 11. differs from Fig. 10 in that mean trendlines are included to emphasize the similarity and difference between TP concentrations of the two curves for the study period vs the differing annual values. The correlation coefficient (r) between OIZ & IIZ TP curves for the eight-year period is high at r=0.86 (Fig 11) and is visually observed as the OIZ curve closely matches the IIZ curve.

It is surprising to see the close annual similarity of TP values between the OIZ and the IIZ, given their differences in depth, temperature, nutrients and plankton densities. The data do not, however, fit a coefficient of determination (r^2) ,or goodness of fit, from one season mean TP value to the next as indicated by the low r^2 of 0.064 and 0.003 (Ref. 6). The variance of annual data for the study duration would not be expected to exhibit a straight-line data fit of the uncontrolled variables which were monitored.





This study was undertaken to monitor key indicators of Les Cheneaux water quality during a time of unprecedented Lake Huron rise (LHR). Results from the eight-year study of the effect of LHR are summarized in Fig. 12. During the time of LHR, island-wide impacts included decreased temperatures, lower nutrient (phosphorus) availability and decreased plankton (Chl-a, algae) density.

The lake level rise of 67.4 inches (171 cm) during an eight year period is unprecedented during the time lake levels have been monitored, the mid-1800s. The temperature decrease at inner island sites is understandable, given the nearly six feet of cooler Lake Huron water (46°F...7.7°C, Ref.7) flowing into the channels during this period. The closeness of temperature drop (5.1°C in the OIZ vs 4.7°C in the IIZ) was likely due to the nearly constant ebb and flow of currents between Lake Huron and the inner Les Cheneaux channels. Accompanying the lower water temperature was a decrease in plankton densities as reflected by the depressed Chl-a concentrations. Lower plankton density undoubtedly indicates other perturbations to the lower food web that affected other algae, rooted plants, microinvertebrates and macroinvertebrates as well.

One would expect the TP concentration to decrease more than was measured. Had no other source of phosphorus been present that would probably be the case. However, as the lake level increased, organic debris from the over 200 miles of Les Cheneaux shoreline became suspended in the water and, therefore, additional phosphorus then became an energy source in the forms of TP and SRP at increased concentrations.

An additional factor absent from the above discussion is the dilution of micronutrients, such a iron and manganese, as water levels increased. An ongoing study is addressing micronutrient concentrations in Les Cheneaux waters.

ACKNOWLEDGMENTS:

Sincere appreciation is expressed to several people involved during this lengthy study, they include:

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Sample analysis: Tim Veverica and staff at the Univ Mich Biol Station at Douglas

Sample collection: Scott Myers, Lynn Wolters, Neil Williams, Mark Clymer, Mike & Laurel Jellison, Fred and Joyce Moore, Barb Smith, Mary Baker, Dave Dunn.

CITATIONS

Except for the USACE and Coastwatch citations, the following are internal documents and can be found at the LCWC Website in the Library section.

1. Smith, R.A. 2005. Trophic status of water from selected sites in the Les Cheneaux Islands. 2001-2005.

2. Smith, R.A. 2020. Water temperatures declined withing the Les Cheneaux Islands during a period of unprecedented rise in Lake Huron water level.

3. Smith, R.A. 2021. Status of Les Cheneaux water quality.

4. Smith, R.A. 2012. Trophic history of Les Cheneaux waters: 2001-2012.

5. USACE. U.S. Army Corps of Engineers, Detroit. <lre.usace.army.mil/missions/great-lakes-information/ great-lakes-information-2/water-level-history.

6. Microsoft Statistics Exec Tech. 2020.

7. <coastwatch.glerl.noaa.gov/statistics> Nov 2020.

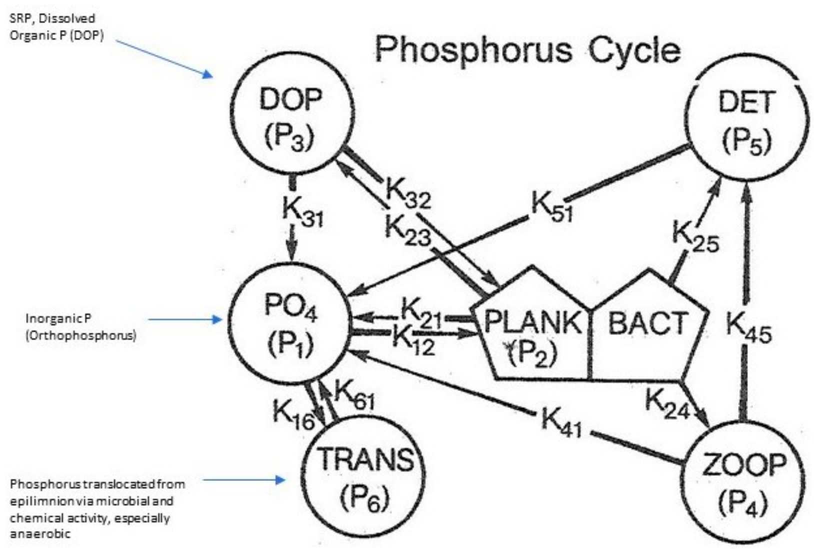
APPENDIX

Plate A. Chemistry of the phosphorus cycle.

Plate B. Fate of phosphorus in Cedarville Bay.

Plate C. Carlson Trophic State Index

App Plate A. Chemistry of the phosphorus cycle. 2001. NOAA Tech memorandum ERL GLERL-60. A review: Phosphorus-Plankton dynamics and Phosphorus cycling in aquatic systems. SJ Tarapchak. GLERL, Ann Arbor. 1987.



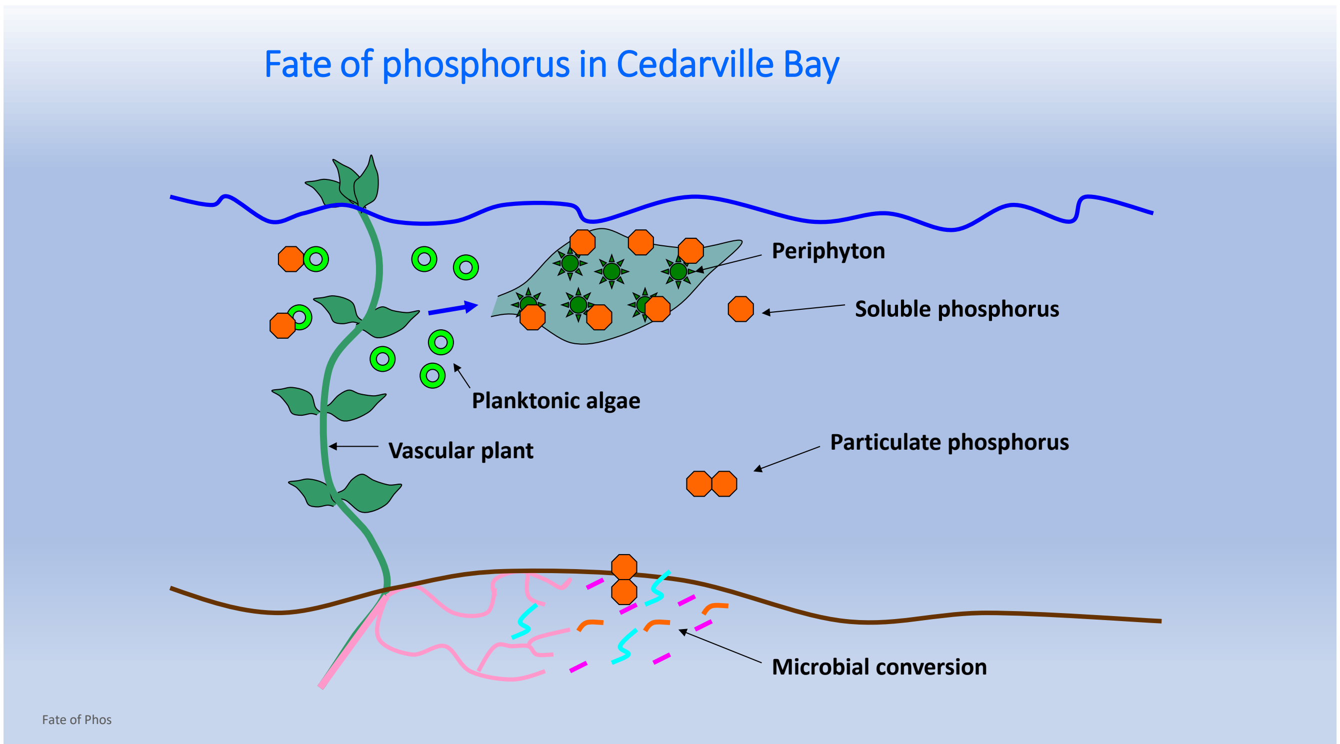
Phos Cycle 2021 from:
NOAA Tech Memorandum ERL GLERL-60
A review: Phosphorus-Plankton dynamics and Phosphorus cycling in aquatic systems.
Stephen J. Tarapchak; GLERL, Ann Arbor. 1987

Figure **1**.--**A** Conceptual diagram of the phosphorus cycle in freshwater lakes (after Rigler, 1973 and Golterman, 1973). Compartments are orthophosphate (P_1), phytoplankton (P_2), dissolved organic phosphorus (P_3), zooplankton (P_4), and detritus (P_5); transport (P_6) out of the epilimnetic zone. Bacteria are considered part of P_2. K's are the rate constants for phosphorus movement among compartments.

App Plate: B

The sketch below shows how bioavailable Soluble Phosphorus is readily metabolized by planktonic algae, by algae attached to plant surfaces (periphyton) or by rooted plants themselves. Particulate phosphorus must undergo a microbial or chemical conversion before it becomes a usable, or bioavailable form.

From: LCI Nutrient Dynamics 180218.



App. C. Carlson Trophic State Index.