HYPOXIA & CLIMATE CONDITION OF THE CENTRAL BASIN OF LAKE ERIE, NORTH AMERICA: INSIGHTS FROM GEOCHEMISTRY AND OSTRACOD RECORDS DURING THE HOLOCENE

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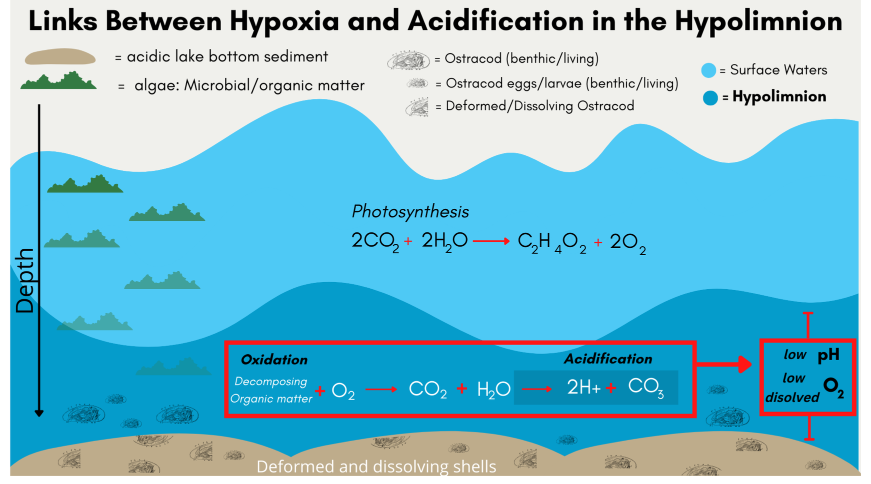
Abstract

An analysis of a 10 m long sediment core (84a) collected from Lake Erie's Central basin was conducted to understand the climate and hydrological controls on the development of summer bottom water hypoxia (low oxygen) over thousands of years. This analysis was done by generating new data on the presence and species abundance of ostracod (seed shrimp) shells separated from the sediment. It complements geochemical and sediment property data previously generated from the core by students at CWRU, Kent State University, and the University of Akron that showed a stepwise decrease of carbonate mineral abundance in the sediment between 6000 and 3000 years ago. This project was undertaken to test the hypothesis that the carbonate mineral loss records the origin and evolution of a low-pH, and low-oxygen layer of bottom water due to the development of seasonal thermal stratification. This work documented diverse ostracod species below the lower of the two carbonate shifts, including *Candona subtriangulata*, which requires well oxygenated waters. This work did not find ostracods above the shift, possibly attributable to lower abundance and small sample size. Comparison of the geochemical data (IC & OC) to shorter cores studied by L.D. Delorme (1982) shows that ostracods between the two carbonate shifts are limited to species that are tolerant of low oxygen conditions. Neither study found ostracods above the second shift in the youngest sediments of the cores. The absence of their shells is attributed to carbonate dissolution in low pH waters because live ostracods have been found in the central basin today, but their shells are not preserved. Knowing more about the presence of these conditions in Lake Erie's Central Basin is essential for ensuring the maintenance of its ecological diversity, water quality, and overall health, all of which are significantly valued and depended on by millions of people and many Ohio economies.

Objectives

- Test the hypothesis by Clotts et al. (2005) and Ratnayake et al. (in prep) that a middle Holocene decrease of sediment inorganic carbon in Central Basin cores records the development of acidic bottom waters in a hypolimnion
- Use ostracod shells as a paleo-oxygen meter to link the low oxygen to low pH in the hypolimnion
- Lay groundwork for future analyses of the early Holocene paleoenvironmental record of Lake Erie sediment

Links Between Hypoxia and Acidification in the Hypolimnion



Study Location and Previous Work on Hypoxia, Ostracods, & Carbonate in Lake Erie

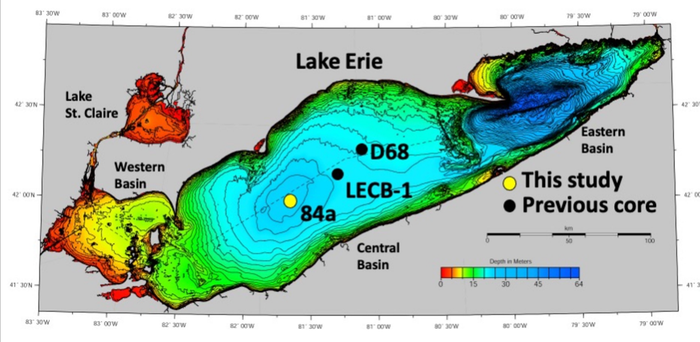


Fig. 1A. Lake Erie is the shallowest, most populated, and most environmentally impacted of the Laurentian Great Lakes.

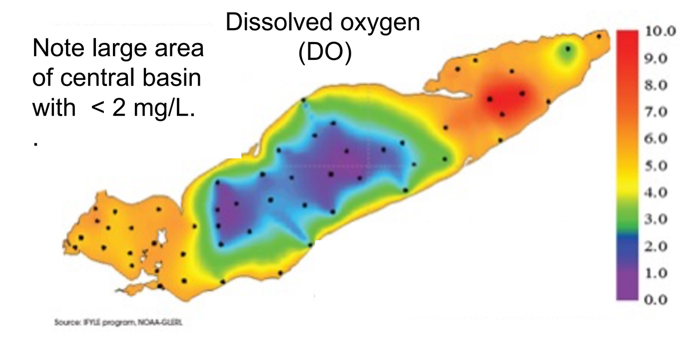


Fig. 1B. Low oxygen conditions develop seasonally in the hypolimnion, the thermally stratified bottom 1 to 5 m of Lake Erie's Central Basin.

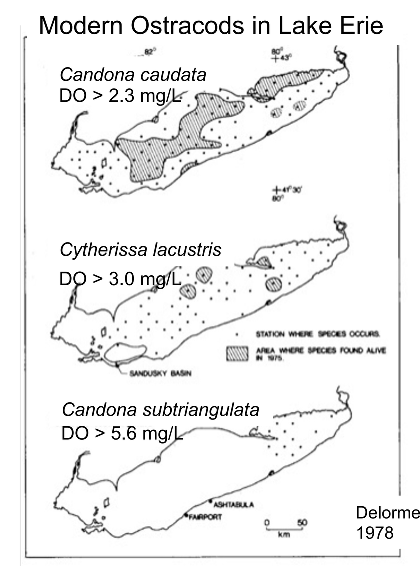


Fig. 1C. Only *Candona caudata* is widespread in Lake Erie today.

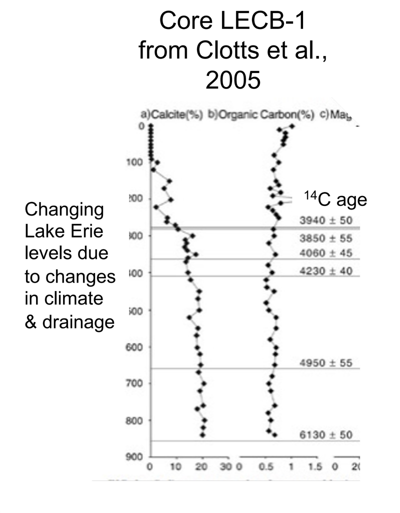


Fig. 1D. Shifts to low CaCO3 in Central Basin may be related to lake level & establishment of hypolimnion.

Methods for Analysis of Ostracod Shells from Core 84a

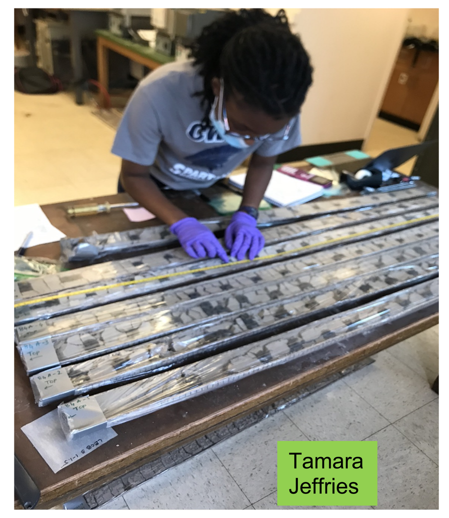


Fig. 2A. About 2 to 13 g of dried sample from 1 to 2 cm of core were selected from intervals throughout 84a, a 10 m piston core from the deepest waters of Lake Erie's Central Basin.

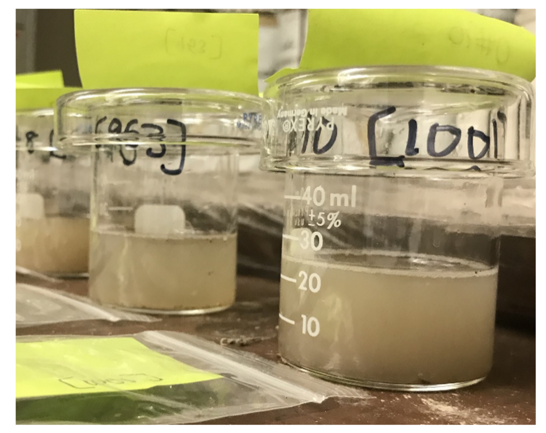


Fig. 2B. Soaked in deinonized water followed by sodiumhexametaphosphate, then wet sieved over stacked sieves 355μm, 250μm, 150μm and 38μm mesh.

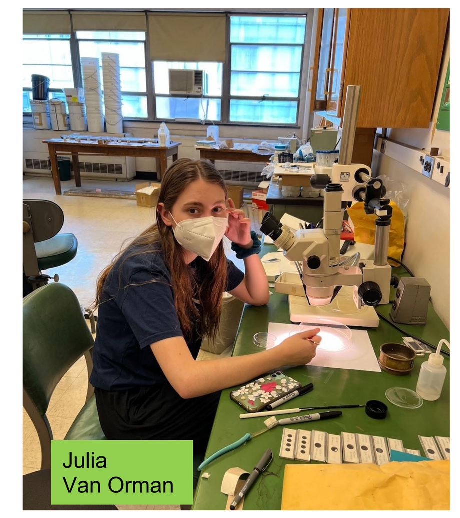


Fig 2C. Adult ostracods picked and identified by species under a stereomicroscope.

Fig. 2D. Scanning Electron Microscopy of Ostracod shells was conducted at the Swagelok Center for the Surface Analysis of Materials at CWRU using a ThermoFisher Apreo 2S.

Results

Reference images from Benson & Mcdonald 1963, Mischke et al. 2003, or Curry and Yansa 2005

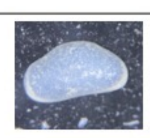
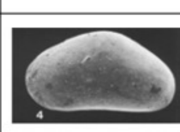
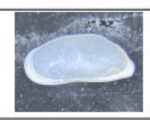
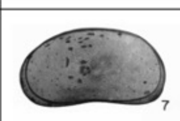
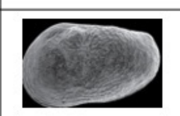
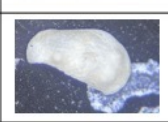
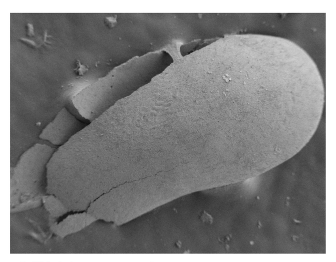
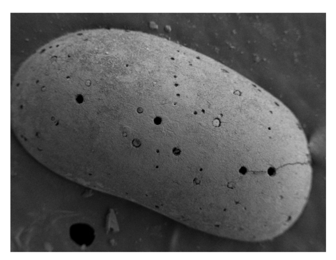
Species	Example image	Reference image	Habitat
Candona subtriangulata Benson and MacDonald, 1963			• DO > 5.6 mg/L • 1 year lifespan • cold, dilute, deep
Candona caudata Kaufmann, 1900 & C. novacaudata			• DO > 2.3 mg/L • lifespan in months • pH as low as 2.3
Candona rawsoni Tressler, 1957			• tolerate salinity and variable conditions • resides in temporary & permanent open water
Cytherissa lacustris Sars, 1863			• DO > 3 mg/L • 1 year lifespan • temperature influence on distribution
Limnocythere friabilis Benson & MacDonald, 1963			•dilute waters

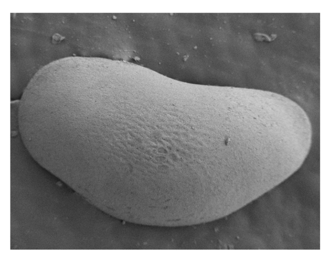
Fig. 3A. Core 84a contains ostracod species not present in the modern Lake Erie, including species with high oxygen requirements, particularly *C. subtriangulata*. Most ostracod species in 84a are typically found in cold, dilute waters in the deeper parts of lakes, but *C. rawsoni* tolerates a wide range of salinity and temperature.



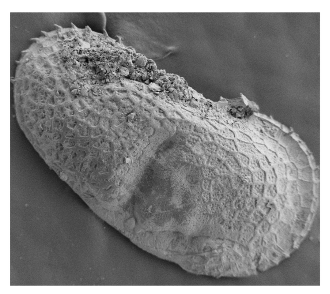
SEM image of *Candona caudata*



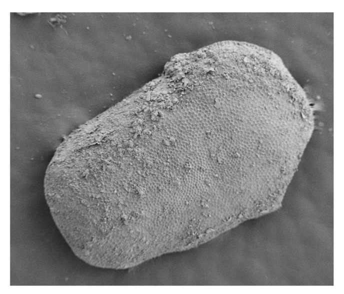
SEM image of *Candona rawsoni*



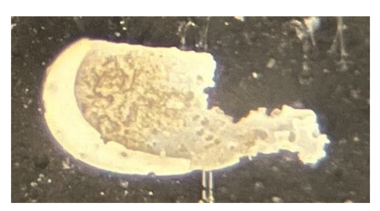
SEM image of *Candona subtriangulata*



SEM image of *Limnocythere friabilis*



SEM image of *Cytherissa lacustris*



Stereomicroscope image of bored & corroded, unidentified ostracod

Fig. 3B. Ostracod preservation in 84a is excellent, including articulated shells and shells with details of ornamentation. Some shells, particularly shells of *C. rawsoni* exhibit smalls holes that may be gastropod borings. Other shells, particularly above 580 cm are more broken and more extensively corroded.

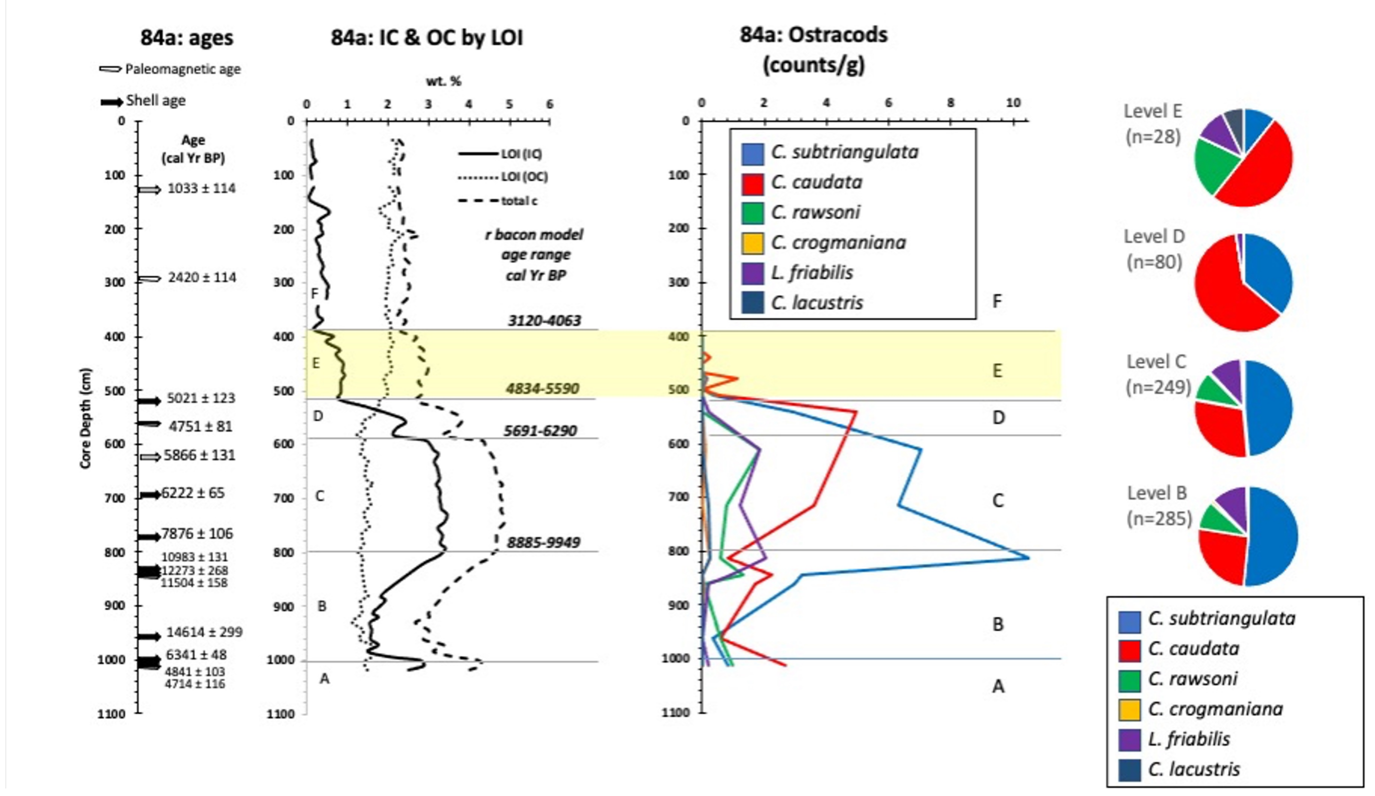


Fig. 3C. *C. subtriangulata* is the most abundant ostracod species in level C and part of B indicating high bottom water oxygen conditions. Its abundance drops through D and it was only found in the lowest 10 cm of E. There are no ostracods in F and almost no inorganic carbon (IC). While some ostracod species are capable of surviving under modern conditions, their shells are not preserved due to dissolution carbonate in sediments of the acidic hypolimnion at that time. Age, IC, and organic carbon (OC) data from Rathnayake et al. (in prep).

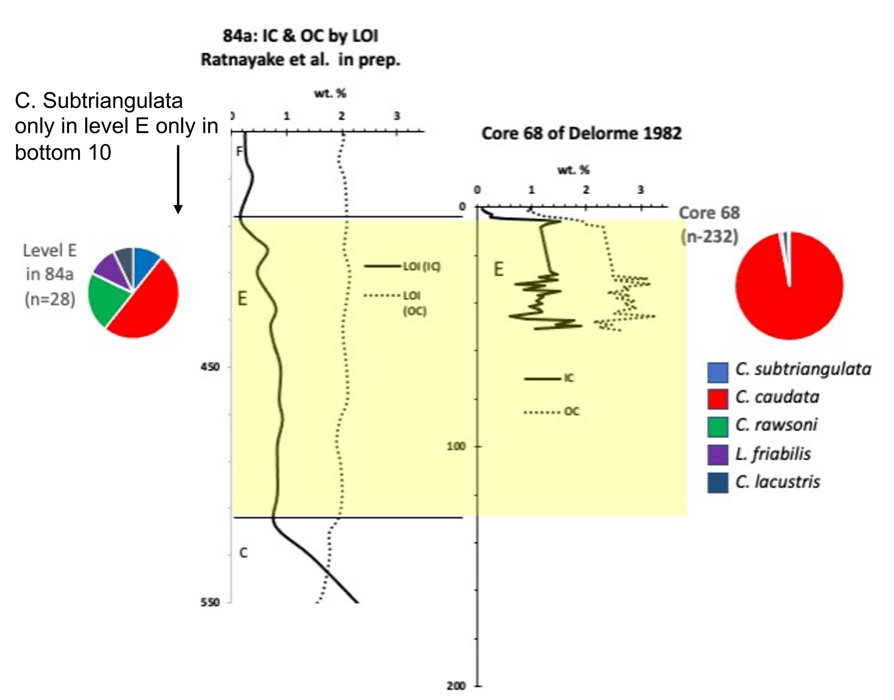


Fig. 3D. Shifts in inorganic carbon (IC) correlate between 84a, LECB-1, and shorter cores (<1.5 m) studied by Delorme (1982). Level E, which has low IC, also primarily has ostracod species that tolerate low oxygen conditions. These finding indicates Central Basin-wide decreases in pH and dissolved oxygen. Clotts et al. (2005) and Rathnayake et al. (in prep) related the changes in IC to middle Holocene changes in lake level.

Implications, Future work, and Conclusions

1. A relative high abundance of *C. subtriangulata* in Lake Erie's central basin prior to ~5,000 years ago indicates well oxygenated bottom waters at that time. A stepwise upward decrease and loss of *C. subtriangulata*, and a corresponding stepwise decrease and loss of sediment inorganic carbon, record decreases in dissolved oxygen and pH in a Central Basin hypolimnion. The establishment of the hypolimnion and the intensity of hypoxia and acidification were likely controlled by lake level fluctuations due to changes in drainage and climate (Fig. 4).

2. While ostracods served as useful paleo-oxygen meters for analyzing central basin sediments, analysis of mollusks and pollen is being conducted to further understand the climate and hydrological changes within Lake Erie and the Great Lakes Region.

3. This work increases understanding of natural controls on Central Basin hypoxia and acidity which has affected lake ecosystems over thousands of years. Understanding natural changes is critical to quantifying human-caused impacts and designing strategies for remediation. As climate change continues to exacerbate the decline of environmental health within the Great Lakes Region, it is important that we use our science to aid in the preservation of the ecological, societal, economic, and intrinsic values of Lake Erie.

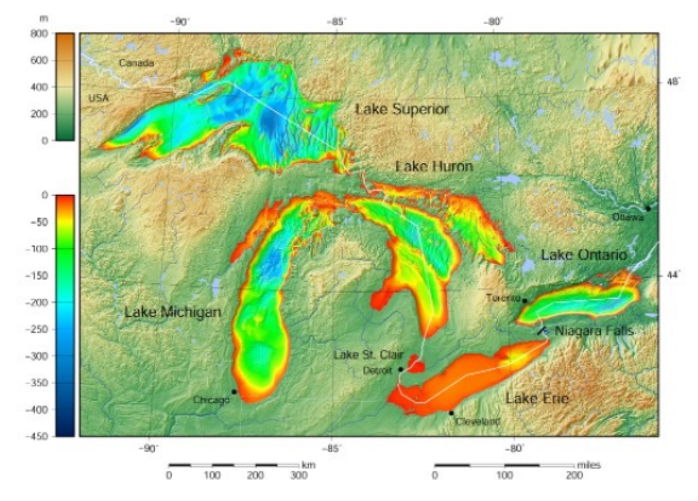


Fig. 4: Middle Holocene changes in Lake Erie water level were controlled by changes in the amount of water received from the upper Great Lakes, changes in outlet levels, and possibly changes in regional climate.

References & Acknowledgments

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