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SUBFOSSIL OSTRACOD ASSEMBLAGES AS INDICATORS OF ENVIRONMENTAL QUALITY AND HUMAN IMPACT IN TEMPERATE LAKES OF WISCONSIN

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INTRODUCTION

The diversity and abundance of ostracod assemblages preserved in cores of lake sediment can be used as a proxy for the history of the environmental quality of lakes. Ostracods are small, bivalved crustaceans that range from 0.1 to 2 mm (Rodriguez-Lazaro and Ruiz-Munoz, 2012) (Fig. 1). A low-magnesium calcite carapace that is held together by adductor muscles encloses these organisms (Rodriguez-Lazaro and Ruiz-Munoz, 2012). The ostracod fossil record extends back to about 450 million years ago, yet today there are 20,000 known living species, 2,000 of which live in non-marine aquatic environments.

Ostracods serve as informative proxies for Quaternary paleoclimate and paleoenvironmental change, specifically in non-marine waters because they have an excellent fossil record, are abundant and easily collected due to their small size, and are sensitive to environmental change (Rodriguez-Lazaro and Ruiz-Munoz, 2012). For these reasons, the subfossil assemblages of ostracods serve as records for living communities in the past and can be used to establish baselines for ecosystems during pre-human impact times to understand the extent of human impact on these ecosystems.

Figure 1. Candona ohioensis (left) and Candona elliptica (right) from the sample of 9-10 cm from the SHOW 3A core.

This study focuses on changes in abundance and diversity of five freshwater ostracod species in lake sediment cores from Lake Monona in Madison, Wisconsin and Shadow Lake in Waupaca, Wisconsin to determine changes in environmental quality due to anthropogenic activity. Lake Monona is considered an “impacted” lake because it has been subjected to heavy human impact in an urban area. For example, human activities in Madison have resulted in increased nutrient enrichment and resulting eutrophication in Lake Monona (Bortleson and Lee, 1974). Shadow Lake a “remediated” lake because it has faced human impact, yet has undergone various remediation efforts in an attempt to mitigate the consequences of anthropogenic activity. For example, in 1978, the city applied aluminum sulfate (alum) to the lake in an attempt reduce internal phosphorus loading that was contributing to eutrophication (McNelly & Turyk, 2012). Through analysis of ostracod diversity and abundance, I will determine the efficacy of these remediation treatments. Studying samples from these lakes can provide insight into the extent of human impact and the efficacy of remediation efforts.

Understanding the ecology of ostracods can provide insight into how ostracods respond to certain environmental changes. Factors affecting the occurrence and distribution of ostracods include sedimentation rates, grain size, food resources, hydraulic conditions and water chemistry: including salinity, temperature, pH and dissolved oxygen (Palacios-Fest et al., 1994). In general, fine-grained sediment and high sedimentation rates correlate to a decrease in the diversity and abundance of ostracods (Donohue and Irvine, 2003). In addition, deeper water is a less conducive environment for ostracods, and typically results in fewer species present in such environments (Smith, 2010). Ostracods are considered herbivores and detrivores in that they consume algae and detritus organic material (Smith, 2010). Ostracods prefer alkaline waters; nonmarine ostracods are rarely found in water with a pH value less than 5 because strongly acidic water makes it difficult for the organism to uptake calcium for the calcification of its carapace (Rodriguez-Lazaro, 2005). Finally, although different species can tolerate different ranges of dissolved oxygen in water, most ostracod species cannot survive in hypoxic or anoxic conditions (Yasuhara et al., 2012). In addition to the general ecological preferences and behaviors of ostracods, there are some distinctive characteristics of specific species that can provide further insight into the response of these species to changes in the environment (Table 1).

Correlating changes in ostracod abundance and species diversity with the ecological preferences and behaviors of ostracods in general and various species

Species	Ecological Preferences and Behaviors
C. elliptica	• Prefers sand and sandy silt environments, which are finer sediments that those preferred by other species (Palacios-Fest et al., 1994) • Particularly sensitive to acidic waters due to its more heavily calcified shell than other species (Hoff, 1912)
C. ohioensis	• Wider range of tolerable levels of dissolved oxygen in water than other species, 0-17 mg/L (Smith, 2010) • Particularly sensitive to acidic waters due to its more heavily calcified shell than other species (Hoff, 1912)
C. vidua	• Benthic swimmer (unlike the other species in these lakes), so it is able to survive in more turbulent waters (Hoff, 1912) • Wider range of tolerable levels of dissolved oxygen in water than other species, 0-20 mg/L (Smith, 2010)
D. stevensoni	• Prefers sandy silt and silty clay environments, which are finer sediments that those preferred by other species (Palacios-Fest et al., 1994) • Moderate range of tolerable levels of dissolved oxygen in water compared to other species, 2-14 mg/L (Smith, 2010) • High tolerance and optimum range values for pH, salinity and cold temperatures (Yilmaz, 2005)
L. verrucosa	• Prefers sandy silt and silty clay environments, which are finer sediments that those preferred by other species (Palacios-Fest et al., 1994) • Narrow range of tolerable levels of dissolved oxygen in water compared to other species, 7-14 mg/L (Smith, 2010)

Table 1. Description of ecological preferences and behaviors of the five ostracod species present in Lake Monona and Shadow Lake.

can provide insight into how the environmental quality of the lakes has changed in the past. In doing so, we can better understand the extent to which anthropogenic activities have impacted these lakes. For example, it is reasonable to predict an increase in overall ostracod abundance as a result of increased nutrient input and algal growth due to human activities.

METHODS

The samples from which I conducted analyses of ostracod abundance and diversity were obtained from the cores of sediment that were collected from predetermined transects in the lakes using a piston corer and processes similar to those described in Wright et al. (1984), 1 cubic centimeter (cc) of sediment was removed from every centimeter of the following four cores: MONA 1A, MONA 5A, SHOW 1A and SHOW 3A, the shallowest and deepest cores from each lake. Each 1 cc subsample of sediment was given two cycles of a slightly modified "freeze-thaw treatment" using deionized water, which was based on the method described in Danielopol et al. (2002).

A 125-micron sieve was used to further separate the ostracods from the sediment and sort the grain size so that the sample would only contain adult ostracods (Danielopol et al., 2002). The samples were then examined under a microscope to pick, count and identify different ostracod species. Each ostracod valve was individually picked out of the samples using a fine tipped paintbrush and each carapace was stored on an individual cell of a gridded micropaleontology slide. The species of each carapace was identified and the number of valves of each species per sample was recorded. These processes were completed for the top 20 centimeters of sediment in the cores and at four-centimeter intervals for the remainder of the core.

RESULTS

The five species found in the samples from these temperate Wisconsin lakes are *Candona elliptica, Candona ohioensis, Cypridopsis vidua, Limnocythere verrucosa* and *Darwinula stevensoni*.

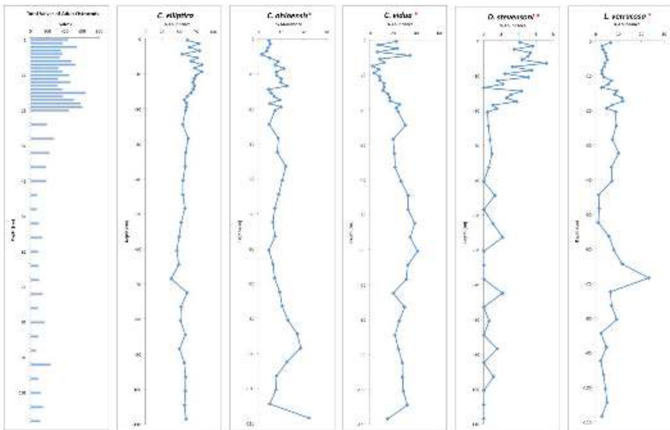

*Figure 2. Graphs depicting total valves of adult ostracods and percent species composition for each cubic centimeter of sediment samples in the core MONA 1A (the first 20 centimeters and every four centimeters for the remainder of the core). The * indicates that the scale for the percent composition of each species has been modified from 100% for the purpose of seeing the more subtle changes.*

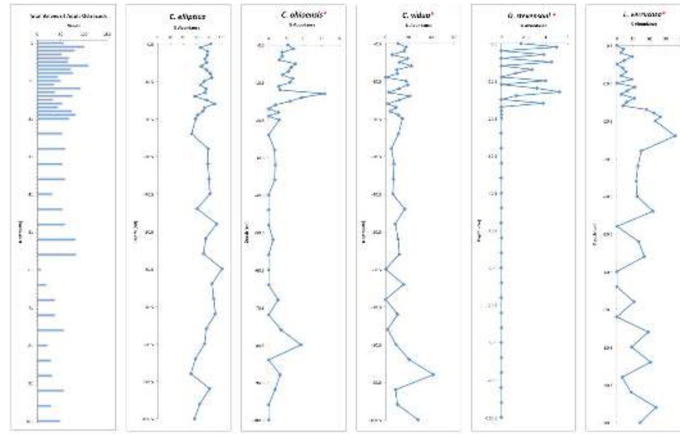

*Figure 3. Graphs depicting total valves of adult ostracods and percent species composition for each cubic centimeter of sediment samples in the core SHOW 3A (the first 20 centimeters and every four centimeters for the remainder of the core). The * indicates that the scale for the percent composition of each species has been modified from 100% for the purpose of seeing the more subtle changes.*

SHOW 1A and MONA 5A

These cores contained a very low overall abundance of ostracods and low species diversity and richness. In SHOW 1A, the maximum number of valves per cubic centimeter was four, and only two species, *Candona elliptica* and *Cypridopsis vidua*, were present. In MONA 5A, although five species were present, the maximum number of valves per cubic centimeter was 14. Consequently, the data from these two cores were not used for paleoenvironmental analysis because of low overall abundance and species richness.

MONA 1A

Overall, this core had the greatest total abundance of ostracod valves (Fig. 2). Above 20.5 centimeters, the overall abundance began to increase and remained greater than 300 valves per cubic centimeter. Throughout the entire core, the species composition per cubic centimeter of sediment for *C. elliptica* remained relatively constant, as it was always the most abundant species. The percentages of composition for the other four species were more variable.

In addition to general patterns in abundance and species composition, there are specific depths at which there are positive and inverse correlations between changes in different species. At 4.5 cm there is an apparent increase in the percent composition of *C. vidua,* while *C. elliptica* and *C. ohioensis* decrease in percent at the same interval. Additionally, there is a clear decrease in percentage of *D. stevensoni* between 14.5 cm to 13.5 cm, which corresponds with noticeable decreases in the percentage of *C. ohioensis* and *L. verrucosa* at the same depth. At 68.5 cm, *L. verrucosa* reaches its maximum abundance while *C. elliptica* shows a minimum. Finally, at the bottom of the core from 108.5 cm to 104.5 cm, there was a notable increase in percent composition of *C. vidua*, as well as a decrease in *C. ohioensis*.

SHOW 3A

The overall abundance of valves fluctuated throughout the core yet generally remained higher above 60.5 cm (Fig. 3). Throughout the entire core, *C. elliptica* was the dominant species and comprised over 50% of the valves at each depth. The percent composition of *C. ohioensis* and *D. stevensoni* increase and oscillate in the upper 20 cm of the core. In contrast, in the top 20 cm of the core, the composition of *C. vidua* varies yet doesn't increase or decrease noticeably in comparison to the rest of the core, and the percentage of *L. verrucosa* decreases markedly.

There are also correlations between changes in composition of different species at various depths throughout the core. For example, peaks in the percentage of *D. stevensoni* at 1.5 cm, 3.5 cm and 7.5 cm correlate with peaks in the percentage of *L. verrucosa* at the same depths. In addition, the maximum percentage of *D. stevensoni* occurred at 13.5 cm, which correlates to the maximum percentage of *C. ohioensis* at the same depth and a significant increase in the percentage of *C. vidua*, also at the same depth. Finally, the maximum percentage of *C. vidua* at 76.5 cm corresponds with the minimum percentage of *C. elliptica* at the same depth, and the minimum percentage of *C. elliptica* at 88.5 cm corresponds to the maximum percentage for *C. vidua* at that same depth.

DISCUSSION

The data for ostracod diversity and abundance in the four cores from Lake Monona and Shadow Lake reveal intriguing patterns that correlate to human activities and environmental changes caused by their impact.

MONA 1A

The general increasing trend in the overall abundance of ostracod valves moving up-core in MONA 1A is likely a result of the increased eutrophication in Lake Monona due to the intensification in nutrient runoff and eutrophication as human development and agricultural practices became more prominent. Although eutrophication often impedes the survival of organisms, an increase in nutrients and algae in this lake may have created an environment that was more conducive to ostracod reproduction and survival. Since ostracods are herbivores and detrivores that feed on algae and organic detritus, an increase in eutrophication and algae would provide a greater food supply for ostracods (Smith, 2010). Therefore, an increase in algae could result in an increase in ostracod abundance, as seen in this core. In addition, more abundant algal cover and aquatic plants can reduce the impact of potentially harmful water turbidity on the ostracods (Palacios-Fest et al., 1994). Although Lake Monona has little to no current, increased human activity, such as boating and flooding, can create higher energy water movement that, without the presence of algae as a buffer, could negatively impact the ostracod populations. Furthermore, the increase in overall ostracod abundance moving up-core may also be a result of higher pH levels of the water due to eutrophication as a result of increased nutrient runoff from human land use changes (Michaud, 1991). Aquatic environments with higher pH levels are ideal for ostracod survival because it is easier for the organism to calcify and produce its carapace in more alkaline waters (Rodriguez-Lazaro, 2005).

At 4.5 cm, the percentage of *C. ohioensis* reaches its minimum for the core, the percentage of *C. elliptica* significantly decreases, and the percentage of *C. vidua* noticeably increases. *C. ohioensis* is especially sensitive to low levels of dissolved oxygen (Curry and Filippelli, 2010), whereas *C. vidua* can thrive in a wide range of dissolved oxygen levels, 0-20 mg/L (Smith, 2010). Therefore, this pattern potentially indicates the presence of an environment with low levels of dissolved oxygen and increased eutrophication since nutrients and algal growth typically result in decreased dissolved oxygen (Michaud, 1991). This interpretation of this specific pattern in consistent with the evidence of increased eutrophication moving upcore, as seen by patterns in the overall abundance. Therefore, it is apparent that human activities have had an impact on the ostracod communities in Lake Monona due to changes that occur between the bottom of the core to the top of the core.

SHOW 3A

Similar to the pattern seen in the overall abundance of ostracods in the MONA 1A core, the slight increase in total valves beginning at 60.5cm in the SHOW 3A is likely a result of increased eutrophication in Shadow Lake due to an increase in nutrient runoff as human development and agricultural practices became more prominent. However, despite the general increase in abundance in the upper portion of the core, there are still significant fluctuations in the number of valves at each depth. It is possible that these variations occurred as a result of impacts of the remediation approaches applied to Shadow Lake.

In addition, correlating specific changes in the percentage of species present throughout the core can provide further insight into the relationship between these changes and environmental characteristics. For example, at 88.5 cm, the percentage of *C. elliptica* is at its minimum for the core and the percentage of *L. verrucosa* noticeably decreases, whereas the percentage of *C. vidua* reaches its maximum. Given the preferred ranges of dissolved oxygen levels for *L. verrucosa* and *C. vidua*, an increase in both of these species suggests somewhat high dissolved oxygen levels between 7-14 mg/L (Smith, 2010). Since higher dissolved oxygen is typically associated with acidic pH and lower nutrient levels (Michaud, 1991) and *C. elliptica* is sensitive to low pH, a decrease in *C. elliptica* and *L. verrucosa* and an increase in *C. vidua* potentially indicates the presence of an environment with low pH and little eutrophication during this time.

Further up core, at 13.5 cm, there is another correlation between all five species. At this depth, the maximum percentage of *C. ohioensis* and *D. stevensoni* occur, the percentage of *C. vidua* increases, and the percentages of *L. verrucosa* and *C. elliptica* decrease. Similar to the patterns at 88.5 cm, *C. elliptica* likely decreases due to its sensitivity to low pH and *L. verrucosa* decreases due to the narrow range of dissolved oxygen levels in which it can survive (Smith, 2010). In contrast, *C. ohioensis, D. stevensoni* and *C. vidua* likely increase due to the moderate to high range of dissolved oxygen levels in which they can survive (Smith, 2010). Therefore, these patterns also suggest an environment with low pH and little eutrophication, like from a time prior to prominent human impact and nutrient input.

In general, the patterns in overall abundance suggest that there was an increase in pH and eutrophication moving up core. However, correlations in the changes of species diversity indicate the potential for periods of low pH and low eutrophication in the uppermost portion of the core. Therefore, these patterns may verify that the remediation efforts in Shadow Lake were successful, yet this conclusion is not definitive with a correlation between depth of the core and time.

CONCLUSIONS

Overall, the abundance and species diversity of ostracods in the MONA 1A and SHOW 3A cores reflect environmental changes and human impacts in Lake Monona and Shadow Lake, specifically with regard to nutrient input and eutrophication. The patterns seen in the cores potentially indicate an increase in eutrophication from nutrient runoff in both Lake Monona and Shadow Lake. In Shadow Lake, there is evidence that suggests that remediation efforts to reduce eutrophication have been somewhat successful, yet this conclusion is merely an estimate without concrete dates for depths of the core. However, since there is a visible layer of alum in one of the cores at approximately 18.5 cm, and there is increased variation in abundance and diversity of ostracods in the upper 20 cm of the core, these two events are likely related. The high algal cover, high pH and high dissolved oxygen levels associated with increased nutrients and eutrophication allow for the reconstruction of past environments by correlating changes in ostracod diversity and abundance with the ecological characteristics and preferred habitats of different ostracod species.

Although overall ostracod abundance appears to have increased due to human impacts, this result is not necessarily indicative of a beneficial response for the ecosystems. One of the primary purposes of conservation paleobiology is to establish baseline conditions for ecosystems that represent a pre-human impact environment. Therefore, any significant variation from this determined baseline has the potential to disrupt the overall community in question and the larger ecosystem in which it resides. Despite the ability of ostracods to survive and in some cases thrive in an anthropogenically-altered environment, the ecosystem is not the same as it used to be prior to European settlement and the impacts of human activity.

REFERENCES

Bortleson, G.C., & Lee, F.G. (1974). Recent sedimentary history of Lake Monona, Wisconsin. *Water, Air and Soil Pollution, 4,* 89-98. doi: 10.1007/BF01794132

Curry, B.B., & Filippelli, G.B. (2010). Episodes of low dissolved oxygen indicated by ostracodes and sediment geochemistry at Crystal Lake, Illinois, USA, *Limnology and Oceanography, 6,* 2403-2423. doi:10.4319/lo.2010.55.6.2403

Danielopol, D.L., Ito, E., Cronin, T.M., & Baltanas, A. (2002). Techniques for collection and study of Ostracoda. *The Ostracoda: Applications* *in Quaternary Research,* 65-97. doi: 10.1029/131GM04

Donohue, Ian, & Irvine, Kenneth (2003). Effects of sediment particle size composition on survivorship of benthic invertebrates from Lake Tanganyika, Africa. Archiv fur Hydrobiologie, 157, 131-144. doi: 10.1127/0003-9136/2003/0157-0131.

Hoff, C.C., 1912, The Ostracods of Illinois – Their Biology and Taxonomy: Urbana, Illinois, University of Illinois Press, 21 & 151-161 p.

Michaud, J.P. (1991). A Citizen's Guide to Understanding and Monitoring Lakes and Streams: Puget Sound, WA, Puget Sound Water Quality Authority and Washington State Department of Ecology.

Palacios-Fest, Manuel R., Cohen, Andrew S., & Anadon, Pere (1994). Use of Ostracodes as Paleoenvironmental Tools in the Interpretation of Ancient Lacustrine Records. Revista Espanola de Paleontologia, 9, 145-164. ISSN: 0213-6937.

Rodriguez-Lazaro, J., & Ruiz-Munoz, F. (2005). Tolerance, optimum ranges, and ecological requirements of freshwater Ostracoda (Crustacea) in Lake Aladag (Bolu, Turkey). Ecological Research, 21, 165-173. doi: 10.1007/s11284-005-0121-2.

Rodriguez-Lazaro, J., & Ruiz-Munoz, F. (2012). A general introduction to ostracods: morphology, distribution, fossil record and application, *in* Horne, D.J., Holmes, J.A., Rodriguez-Lazaro, J., & Viehberg, F.A., eds., Ostracoda as Proxies for Quaternary Climate Change Developments in Quaternary Science: Burlington, MA, Elsevier, v. 17, p. 1-14.

Smith, A.J., & Delorme, D., 2010, Ostracoda, *in* Thorp, J.H., & Covich, A.P., eds., Ecology and Classification of North American Freshwater Invertebrates: Oxford, UK, Academic Press, p.725-771.

Van Doninck, K., Schon, I., Martens, K., & Goddeeris, B. (2003). The life-cycle of asexual ostracod *Darwinula stevensoni* (Brady & Robertson, 1870) (Crustacea, Ostracoda) in a temperate pond. *Hydrobiologia, 500,* 331-340. doi: 10.1023/A:1024656920904

Wright, H.E., Mann, D.H., & Glaser, P.H. (1984). Piston Corers for Peat and Lake Sediments. *Ecology, 65*, 657-659. http://www.jstor.org/stable/1941430

Yasuhara, M., Hunt, G., Breitburg, D., Tsujimoto, A., & Katsuki, K. (2012). Human-induced marine ecological degradation: micropaleontological perspectives. *Ecology and Evolution, 2,* 3242-3268. doi: 10.1002/ece3.425

Yilmaz, F., & Kulkoyluoglu, O. (2005). Tolerance, optimum ranges, and ecological requirements of freshwater Ostracoda (Crustacea) in Lake Aladag (Bolu, Turkey). *Ecological Research, 21,* 165-173. doi: 10.1007/s11284-005-0121-2

Zang, C., Huang, S., Wu. M., Du, S., Scholz, M., Gao, F., Lin, C., Guo, Y., & Dong, Y., (2010). Comparison of relationships between pH, dissolved oxygen and chlorphyll a for aquaculture and non-aquaculture waters. *Water, Air, & Soil Pollution, 219,* 157-174. doi: 10.1007/s11270-010-0695-3