Diel Vertical Migration Patterns in Lakes Michigan and Huron Observed at Fine Spatial Scale Using the Laser Optical Plankton Counter

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Introduction

Spatial structure of zooplankton is a key determinant of trophic interactions in aquatic ecosystems. In Lakes Michigan and Huron, recent changes in water clarity and phytoplankton concentration and distribution driven by dreissenid mussel filtration suggest the potential for changing patterns of spatio-temporal zooplankton structure. Using the fine-scale measuring capabilities of the Laser Optical Plankton Counter (LOPC), we examined the offshore vertical spatial distribution of zooplankton (i.e. LOPC size classes) for Lake Michigan in 2010-11 and Lake Huron in 2012.

Methods

In 2010 and 2011, we collected data along transects in Lake Michigan offshore from Muskegon, Michigan, and in 2012 in Thunder Bay, Lake Huron. We performed our surveys in April, July, and September. To obtain vertical as well as horizontal spatial structure, a plankton survey system (PSS) was continuously lowered and raised at ~0.25 m s^{-1} in a sinusoidal path from 1-2 m beneath the lake surface to 2-4 m above the bottom, with the LOPC logging data every 0.5 seconds as the boat moved at ~2.5 m s^{-1} along a transect. The PSS consisted of an LOPC (ODIM Brooke Ocean) to measure zooplankton along with various other instruments and sensors mounted on a v-fin to measure chlorophyll *a*, photosynthetically active radiation (PAR), dissolved oxygen, conductivity, and temperature. Vertical tows of zooplankton nets were made to determine species present and verify LOPC results.

Here we concentrate on the LOPC data collection. We collected the LOPC data over long transects and over 24 hour periods to reveal patterns and gain insights about spatial distribution and diel vertical migration. The LOPC can be used as a tool for estimating the spatial distribution of zooplankton taxa when size bins are correlated with data from zooplankton net tows. By calculating equivalent spherical diameters (ESDs) for animals of known lengths, we determined which zooplankters were likely to be represented in each of the LOPC size bins. Processing of the LOPC data produced results in five different size bins (mm ESD): (1) 0.09-0.25, (2) 0.25-0.50, (3) 0.05-1.00, (4) 1.00-1.90, and (5) 1.90-4.00. Knowledge of the species present, relative abundance, size, and preferred habitat are required to optimize zooplankton information obtained from LOPC data to construct a species depth profile at a specific site and time. Individual species usually cannot be distinguished in LOPC size-frequency distributions because there is often a significant size overlap among species and species often overlap size bins.

Table 1. LOPC size bins and common taxa which are typically detected within those bins for each depth zone when the lake is stratified.

	ESD (mm)	Epilimnion	Metalimnion	Hypolimnion
Bin 1	0.09 - 0.25	nauplii, Bosmina	nauplii, Bosmina	nauplii, Bosmina
Bin 2	0.25 - 0.50	copepodites, small diaptomids, small Daphnia, Bosmina	copepodites, small diaptomids, small Daphnia, Bosmina	copepodites, small diaptomids, small Daphnia, Bosmina
Bin 3	0.50 – 1.00	Daphnia, Epischura, diaptomids	Daphnia, Epischura, diaptomids	Daphnia, diaptomids, Limnocalanus
Bin 4	1.00 - 1.90	large Daphnia, Bythotrephes, Leptodora	large Daphnia, Bythotrephes	large Daphnia, Limnocalanus, Mysis
Bin 5	1.90 – 4.00	Bythotrephes	Bythotrephes	Mysis

Results

Below are some of the LOPC results for April, July, and September 2010-2012. Due to technical difficulties, we do not have LOPC results for July in 2010 and 2012. Results are shown for our offshore stations in Lake Michigan (M110) and Lake Huron (TB82). Table 1 shows the taxa typically found in each stratum of the lake and the size bins in which they are likely to be detected by the LOPC. Zooplankton net samples collected in Lake Michigan and Lake Huron showed that copepods dominated the zooplankton biomass in April with cladocerans increasing greatly by July and matching or surpassing copepods in September. For the zooplankton biomass depth profiles shown here (Figures 1-7), LOPC size classes are shown instead of species and only bins 2-4 are displayed.

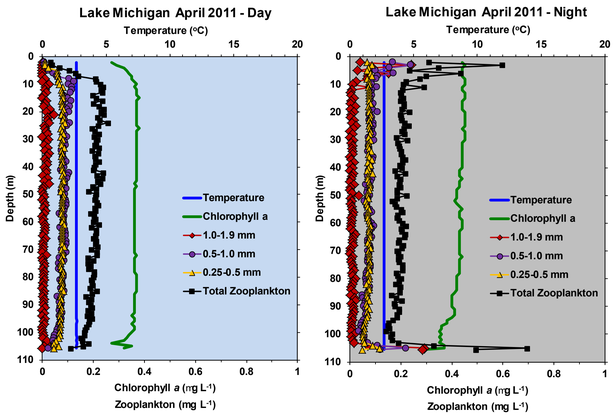

Figure 3. LOPC zooplankton biomass data with chlorophyll and temperature profiles from offshore Lake Michigan on April 27, 2011 during the day (left panel) and night (right panel). The size classes of zooplankton represented (0.25-0.5, 0.5-1.0, 1.0-1.9) are mm ESD. The category "Total Zooplankton" includes all size bins. In April, zooplankton are mostly copepods.

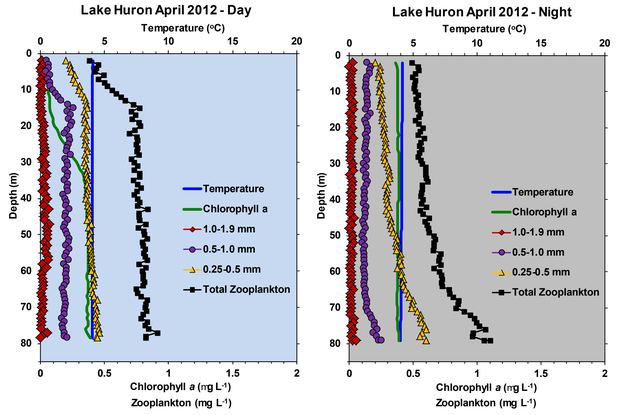

Figure 6. LOPC zooplankton biomass data with chlorophyll and temperature profiles from offshore Lake Michigan on April 25, 2012 during the day (left panel) and night (right panel). The size classes of zooplankton represented (0.25-0.5, 0.5-1.0, 1.0-1.9) are mm ESD. The category "Total Zooplankton" includes all size bins. In April, zooplankton are mostly copepods.

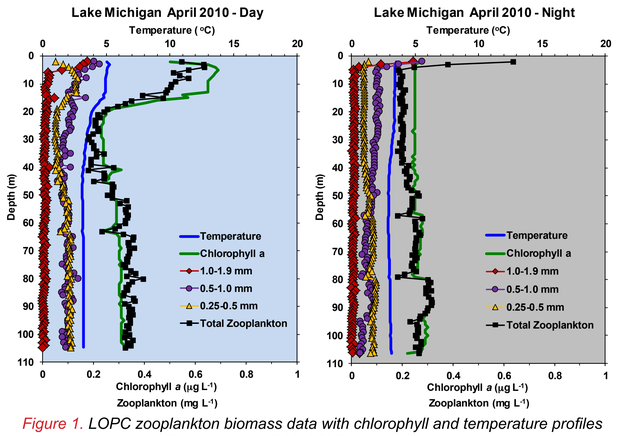

Figure 1. LOPC zooplankton biomass data with chlorophyll and temperature profiles from offshore Lake Michigan on April 14, 2010 during the day (left panel) and night (right panel). The size classes of zooplankton represented (0.25-0.5, 0.5-1.0, 1.0-1.9) are mm ESD. The category "Total Zooplankton" includes all size bins. In April, zooplankton are mostly copepods.

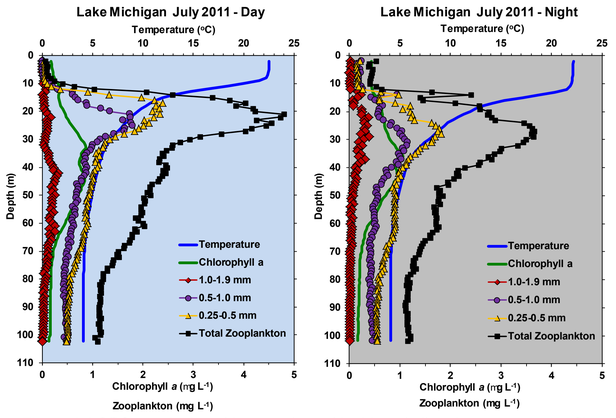

Figure 4. LOPC zooplankton biomass data with chlorophyll and temperature profiles from offshore Lake Michigan on July 26, 2011 during the day (left panel) and night (right panel). The size classes of zooplankton represented (0.25-0.5, 0.5-1.0, 1.0-1.9) are mm ESD. The category "Total Zooplankton" includes all size bins.

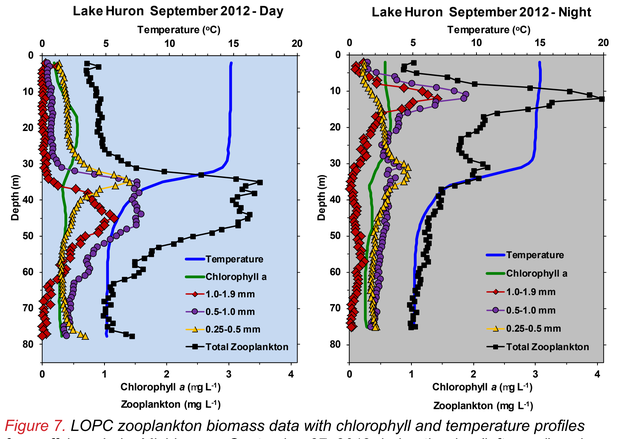

Figure 7. LOPC zooplankton biomass data with chlorophyll and temperature profiles from offshore Lake Michigan on September 27, 2012 during the day (left panel) and night (right panel). The size classes of zooplankton represented (0.25-0.5, 0.5-1.0, 1.0-1.9) are mm ESD. The category "Total Zooplankton" includes all size bins. Vertical migration consists of mostly cladocerans.

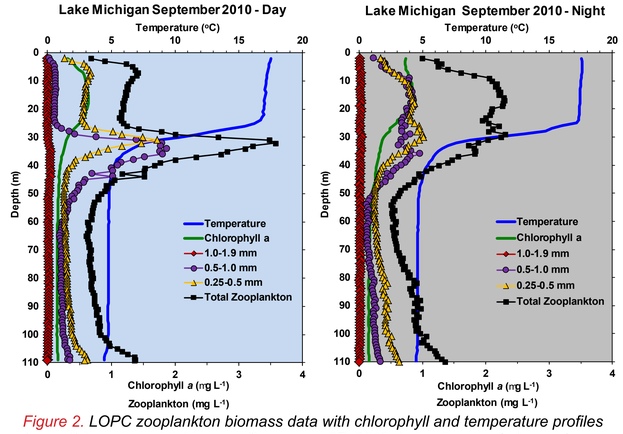

Figure 2. LOPC zooplankton biomass data with chlorophyll and temperature profiles from offshore Lake Michigan on September 27, 2010 during the day (left panel) and night (right panel). The size classes of zooplankton represented (0.25-0.5, 0.5-1.0, 1.0-1.9) are mm ESD. The category "Total Zooplankton" includes all size bins. Vertical migration consists of mostly cladocerans.

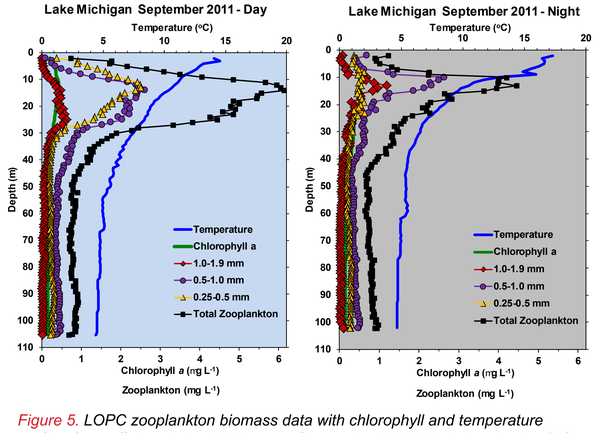

Figure 5. LOPC zooplankton biomass data with chlorophyll and temperature profiles from offshore Lake Michigan on September 13, 2011 during the day (left panel) and night (right panel). The size classes of zooplankton represented (0.25-0.5, 0.5-1.0, 1.0-1.9) are mm ESD. The category "Total Zooplankton" includes all size bins. Vertical migration consists of mostly cladocerans.

Conclusions

Overall, the zooplankton structure and migration pattern is similar in both lakes. Zooplankton concentrations are fairly uniform from top to bottom when the lake is not stratified in April, and zooplankters, mostly copepods, do not appear to be migrating much. In September, zooplankton biomass is concentrated in the metalimnion to upper hypolimnion during the day and in the mid to upper epilimnion at night with some species staying in the metalimnion. Vertical migration is happening mainly with cladocerans and is more pronounced in Lake Huron in September 2012 than in Lake Michigan in 2010 and 2011.