Life on the Edge: The Spatial Structure of the Food Webs of Lakes Michigan and Huron Before and After the Major Expansion of Quagga Mussels into Deep Water

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Abstract/Conclusion

Thermal structure is an important driving force of extent of vertical migration before and after expansion of quagga mussels into the offshore region of Lakes Michigan and Huron.

Background and Evidence

Starting in 2004 we began to examine spatial structure of the food web of Lake Michigan with particular emphasis on the interactions among *Bythotrephes*, *Cercopagis*, and alewives. Feeding interactions we conceptualized in Fig.1 and onshore-offshore spatial interactions are conceptualized in Fig. 2.

2004 marked the beginning of expansion of the quagga mussels into deep water and by 2007-2008 they had reached maximum levels which continue approximately to this day. We conceptualized the depth zone of maximum mussel impacts—particularly on the east side of Lake Michigan with its sandy substrate—as the mid-depth sink (Fig. 3; Vanderploeg et al. 2010).

As a result of the mussel expansion there has been decreased chlorophyll and an increase in water clarity in mid-depth and offshore regions. In this poster we focus on vertical structure of plankton and fishes in Lake Michigan and Huron with special emphasis on diel vertical migration which would be expected to change because of increased water clarity and removal of chlorophyll by mussels.

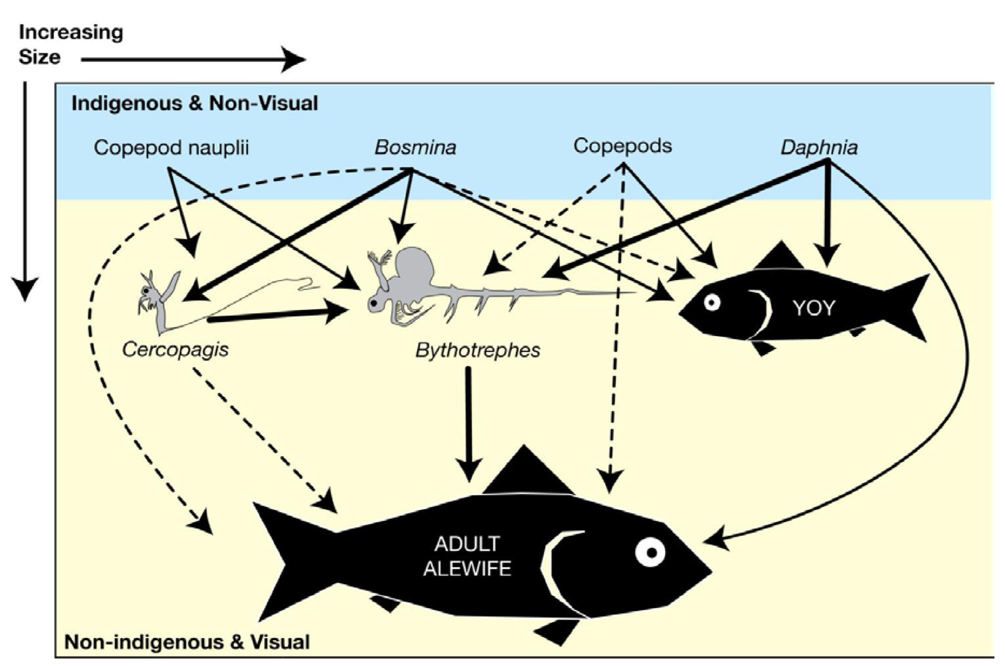

Figure 1. The current Great Lakes epilimnetic (and metalimnetic) food web is dominated by the visually preying non-indigenous vertebrate (alewife) and invertebrate predators (Bythotrephes and Cercopagis) that prey on the indigenous zooplankton. The thickness of the arrows indicates the strength of the selectivity coefficients.

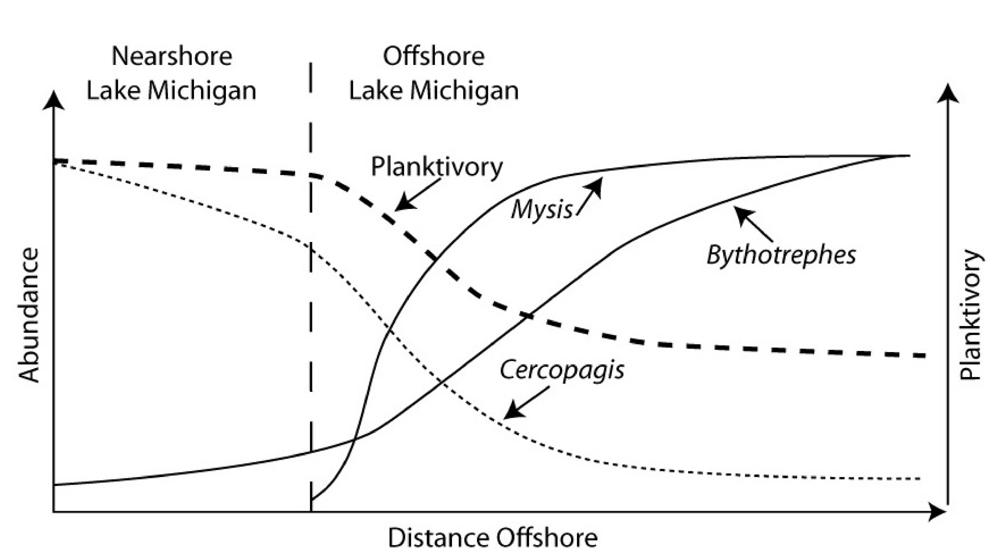

Figure 2. Interactions among invasive species: in the nearshore zone where planktivory from alewives and other fishes is high during summer, size selective predation by alewives focuses on the large cercopagid Bythotrephes, which relaxes predation on the small cercopagid Cercopagis.

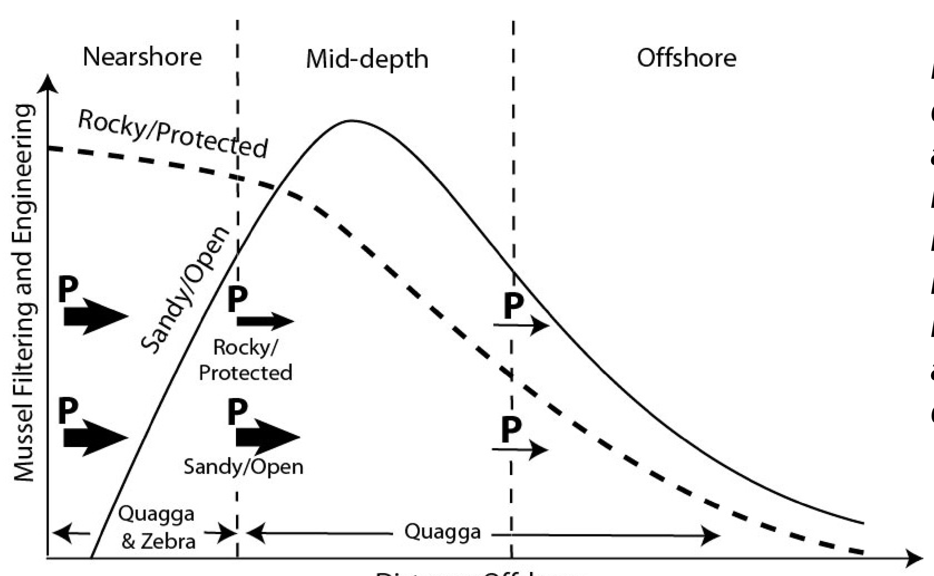

Figure 3. Because of the high abundance of mussels in the mid-depth zone most of mussel impact is felt there and downstream in offshore waters.

Methods

We used the plankton survey system (PSS; Vanderploeg et al. 2009) to map out physical variables, chlorophyll a, and optical plankton counts in different size bins which contain different zooplankton taxa (Table 1). We also used 0.5 m diameter 153-μm mesh vertical opening and closing net to sample zooplankton in broad depth zones: epilimnion, metalimnion, and upper and lower hypolimnion. In this poster we focus particularly on *Daphnia* and *Bythotrephes*. In addition on some cruises we collected fisheries acoustics data on PSS transects (Vanderploeg et al. 2009).

Results

The first series of experiments were performed at M60, a 60-m deep site near Muskegon, MI to determine diel vertical migration (DVM) of zooplankton and fish on different phases of the moon in August 2004; however, what became of interest was the effect of changing depth of thermocline on daytime depth of the *Daphnia* (measured by the optical plankton counter). On both cruises (Figs. 4-7), regardless of metalimnetic depth, they were found at the metalimnion-hypolimnion interface. Note that on the second cruise this would have brought *Daphnia* below the deep chlorophyll layer (Fig. 6). For point of reference the threshold light intensity for visual predation in *Bythotrephes* is in the range of 3 to 10 μmol m^{-2} s^{-1} and that for fish is below 0.2 μmol m^{-2} s^{-1}.

	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 copepods, small *Daphnia*, *Bosmina*	copepodites, small copepods, small *Daphnia*, *Bosmina*	copepodites, small copepods, 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*

Table 1. Optical plankton counter (OPC) and laser optical plankton counter (LOPC) size bins and common taxa which are typically detected within those bins for each depth zone when the lake is stratified.

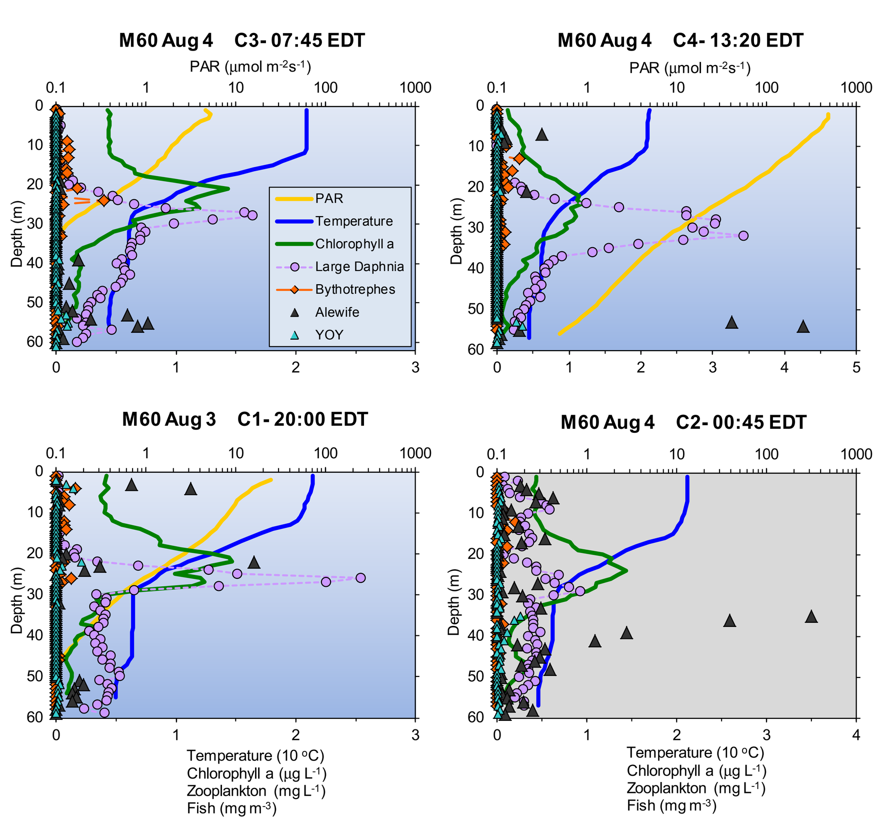

Figure 4. DVM of Daphnia, Bythotrephes and fish on August 3-4, 2004.

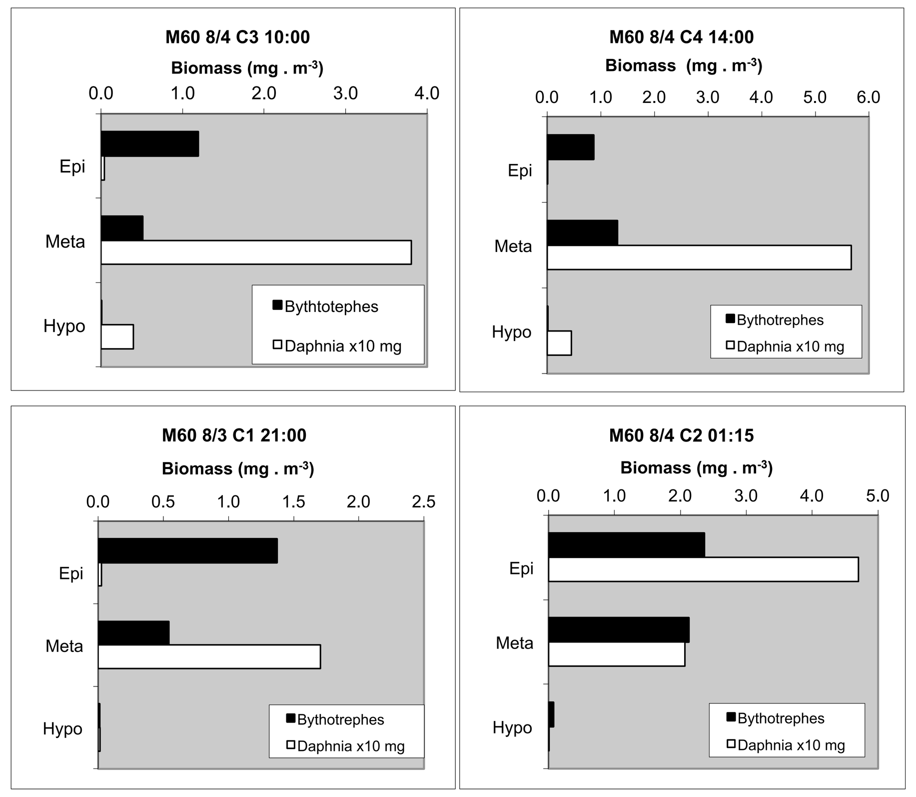

Figure 5. DVM as seen by net tows on August 3-4, 2004.

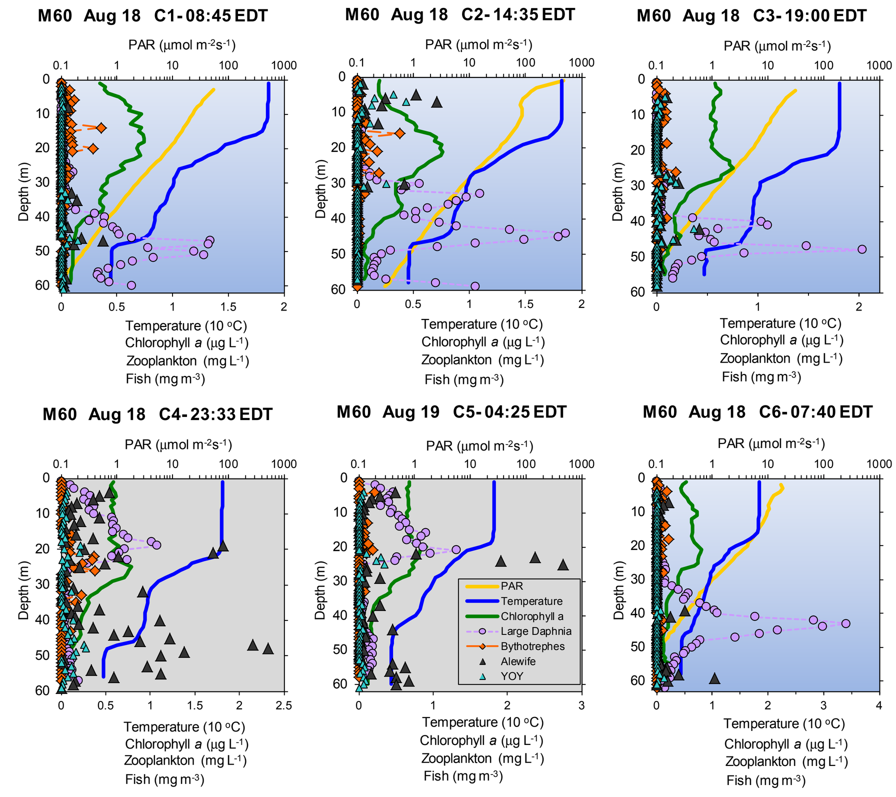

Figure 6. DVM of Daphnia, Bythotrephes, and fish on August 18-19, 2004.

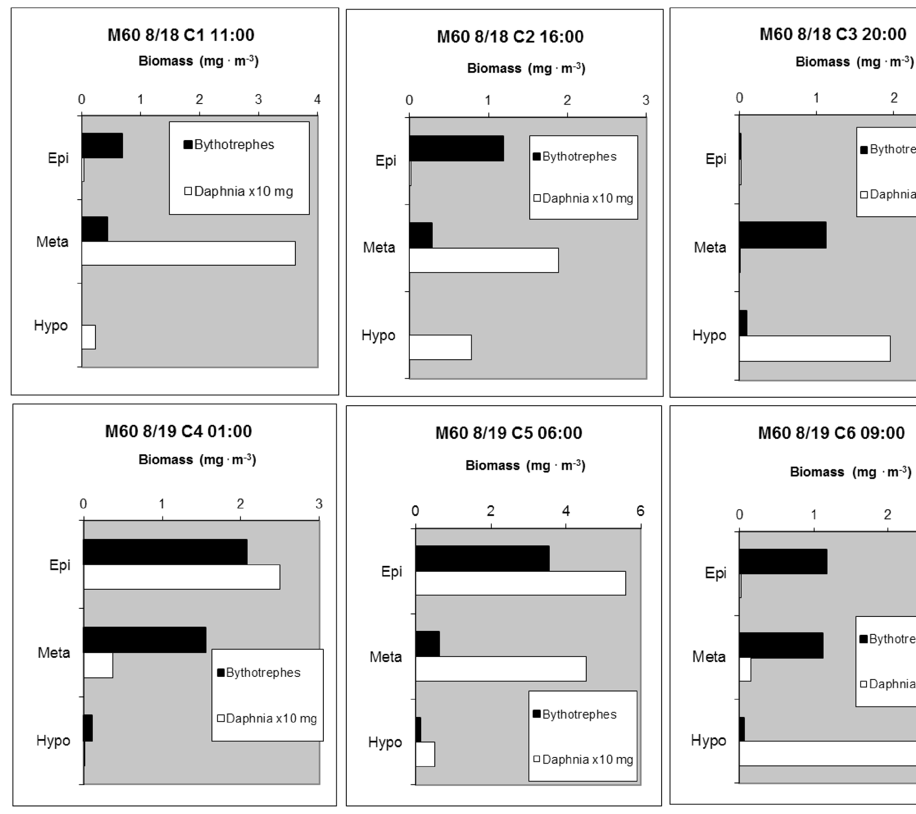

Figure 7. DVM as seen by net tows on August 18-19, 2004.

We repeated these late summer experiments in Lake Michigan in 2010 for midnight and midday distributions (Figs. 8 and 9) which again show the attraction of zooplankton to the metalimnetic-hypolimnetic interface. The same can be seen for results for Lake Huron in 2012 at the offshore 82-m depth station (Figs.10 and 11). Perhaps the most dramatic example of zooplankton tracking the metalimnion-hypolimnion interface can be seen in cross-isobath transect in Lake Huron showing a dome-like shape of the metalimnion along the transect. All along the transect, the zooplankton concentrated at this interface (Fig. 12).

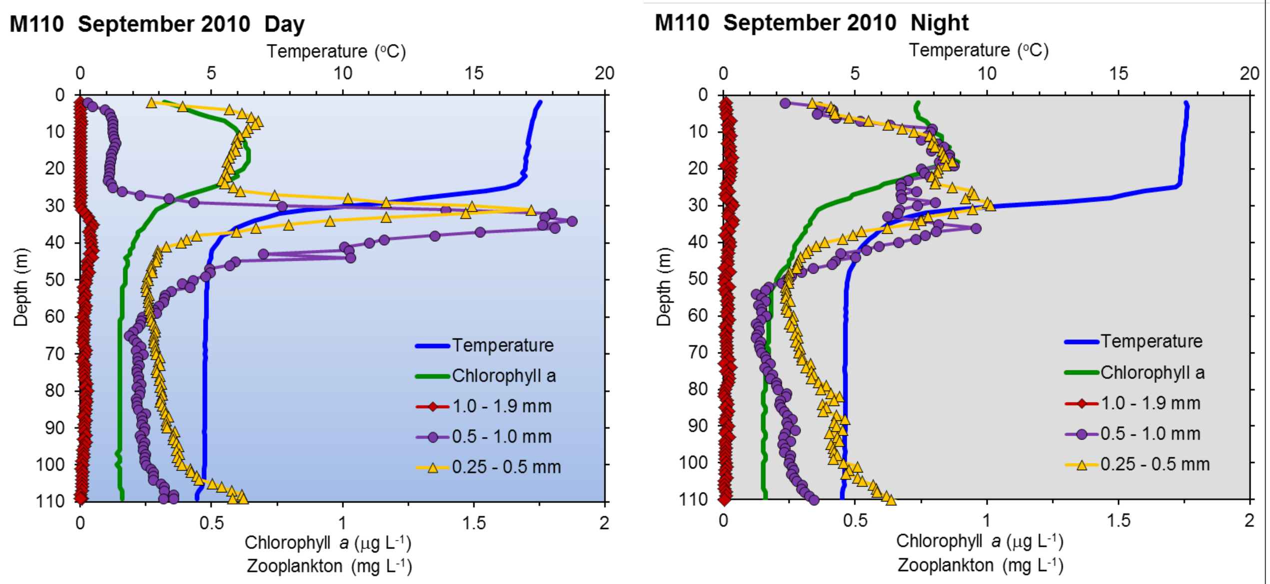

Figure 8. Midday and midnight distributions of different size zooplankton at the Muskegon, Lake Michigan site.

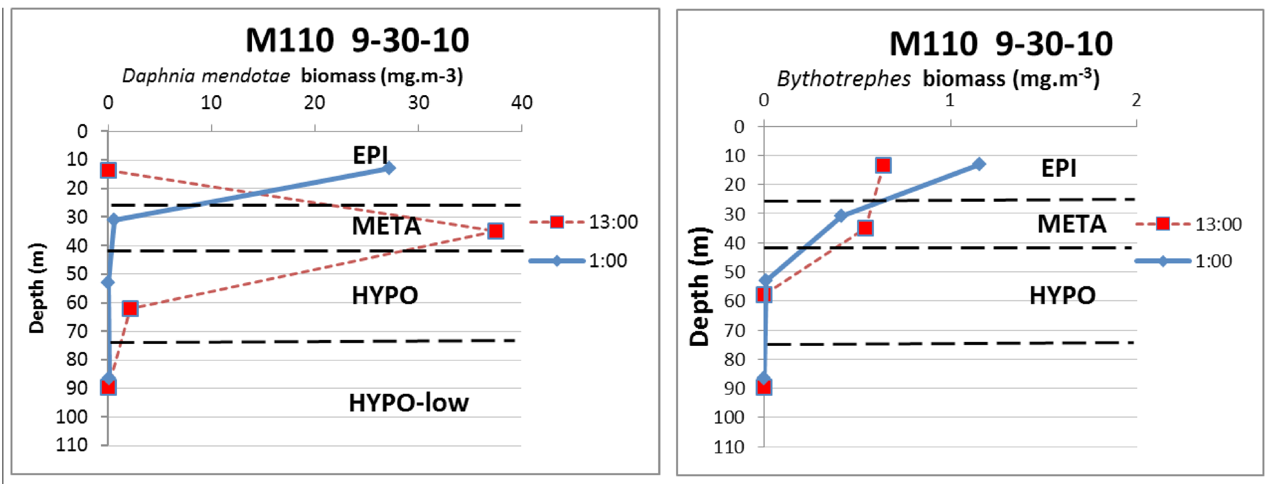

Figure 9. M110 net tow results for 2010.

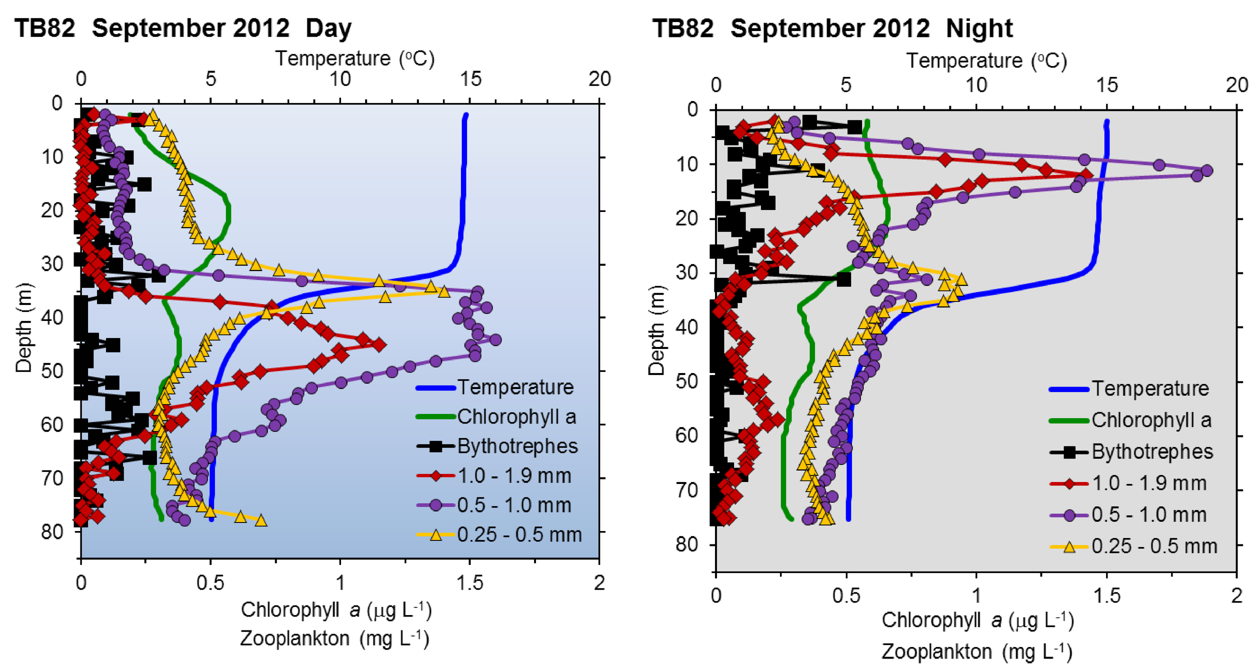

Figure 10. Depth distribution of different sized zooplankton at deep-water station in Lake Huron. Bythotrephes was (arbitrarily) assigned to the > 1.9 mm size category. Some of them likely appear in the 1-1.9 mm size range.

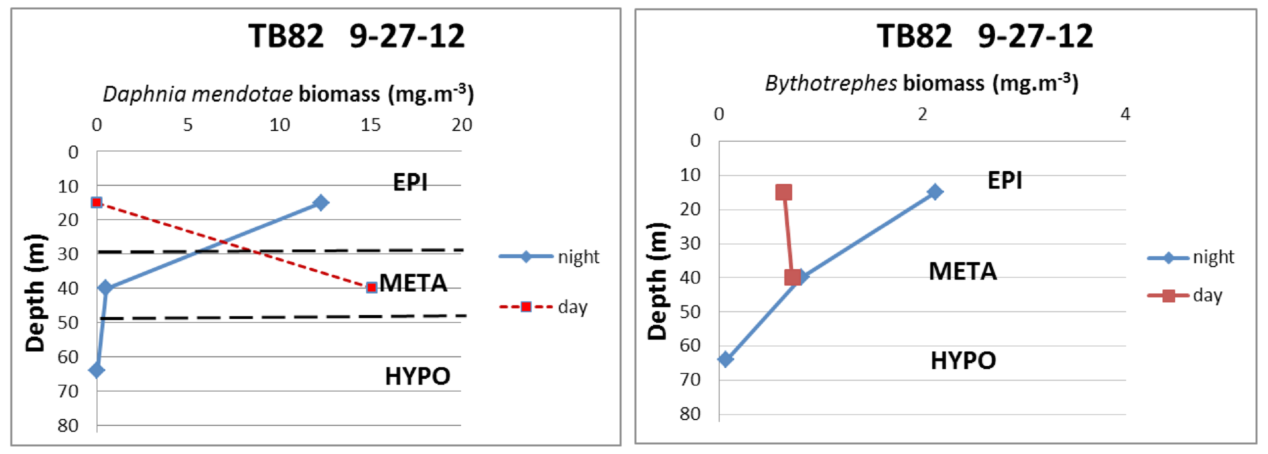

Figure 11. DVM of Daphnia and Bythotrephes as seen by net tows.

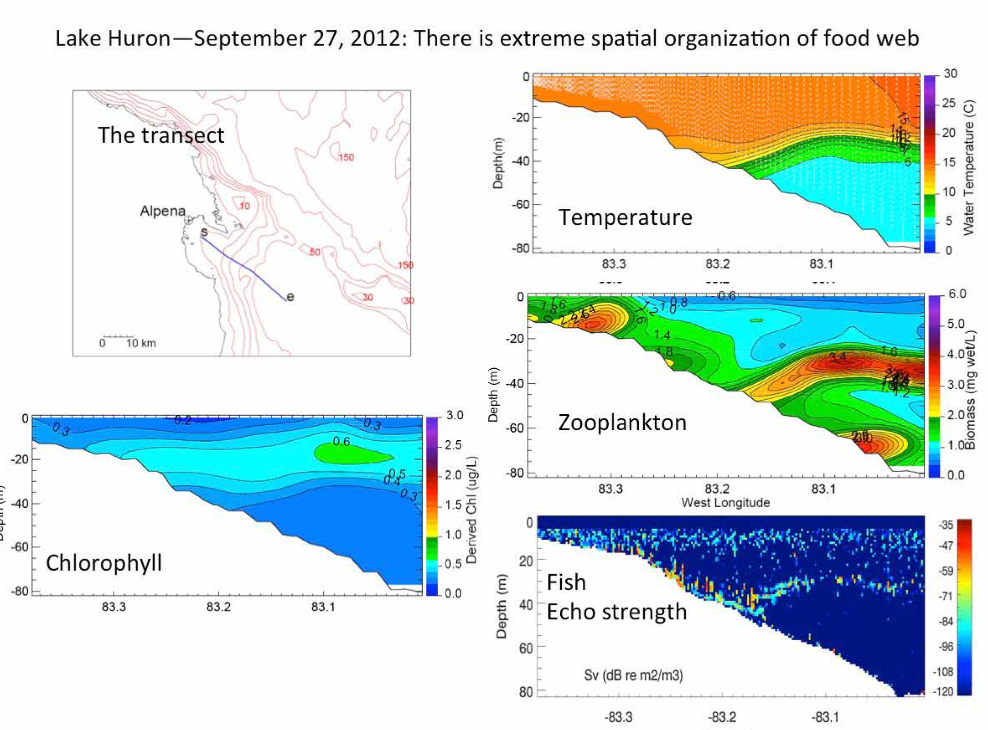

Figure 12. Thermal structure, chlorophyll a, zooplankton concentration, and fish acoustic target strength along a cross-isobath transect in Lake Huron on September 27, 2012.

References

Vanderploeg H.A., Ludsin S.A., Ruberg S.A., Hoeoek T.O., Pothoven S.A., Brandt S.B., Lang G.A., Liebig J.R. & Cavaletto J.F. (2009) Hypoxia affects spatial distributions and overlap of pelagic fish, zooplankton, and phytoplankton in Lake Erie. *Journal of Experimental Marine Biology and Ecology*, 381, S92-S107.

Vanderploeg H.A., Liebig J.R., Nalepa T.F., Fahnenstiel G.L. & Pothoven S.A. (2010) Dreissena and the disappearance of the spring phytoplankton bloom in Lake Michigan. *Journal of Great Lakes Research*, 36, 50-59.

Discussion and Conclusion

In all cases shown, it is obvious that during the day the metalimnetic-hypolimnetic boundary is the location preferred by *Daphnia* and other zooplankton, regardless of its depth, chlorophyll concentration, or light intensity. We were only able to see this connection with the optical plankton counter on the PSS because net tow depth discrimination was too coarse.