Seasonal dynamics of zooplankton resource use efficiency in hyper-eutrophic Shelburne Pond

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Introduction

- Zooplankton (ZP) link algae to higher trophic levels and are bio-indicators of aquatic ecosystem health.
- Cyanobacteria can dominate algal communities in eutrophic and hyper-eutrophic lakes during summer.
- Most ZP are inefficient consumers of cyanobacteria.
- **Resource use efficiency** (**RUE**) is the ratio of ZP to algae biomass and is a relative measure of energy transfer from one level to the next.
- We hypothesized that RUE would be maximized before and after summer, when relative abundance of cyanobacteria to other algae groups is comparatively low.

Methods

- ZP collected from Shelburne Pond, VT (Fig. 1) ~weekly from April '14 to April '15. Two replicate samples were collected per date.
- Used a 64-µm mesh plankton net towed vertically through the water column (Fig 2).
- Individuals identified to species or genus except for immature stages (Table 1), counted, and measured for length (Fig. 3) to estimate ZP density (#/L) and biomass (µg dry/L).
- Water quality metrics were measured with a YSI-Sonde profiler at 0.5m depth intervals.
- Chl *a* and phycocyanin (cyanobacteria pigment) fluorescence measured in relative frequency units (RFU) are used as proxy for relative abundance of primary producers:

$$\textbf{RUE} = ZP_{Biomass} / (\text{Chl } a + \text{Phycocyanin})$$

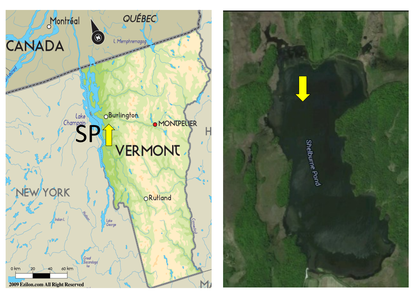

Fig. 1. Location of Shelburne Pond, VT (left) and position of the monitoring site used for sample collections (right).

Table 1. Summary of life history characteristics of common ZP taxa observed in Shelburne Pond.

Taxa	Mean Length (mm)	Month Peak Abundance
Acanthocyclops brevispinosus	1.1	May
Calanoid copepodid	0.7	June, October
Ceriodaphnia spp.	0.5	August
Chydorus spp.	0.3	August
Cyclopoid copepodid	0.6	May
Daphnia mendotae	1.3	June, Oct
Diaphanosoma spp.	0.9	July
Mesocyclops edax	1.4	August
Skistodiaptomus pallidus	1.3	July, September

Fig. 2. Sample Collection on Shelburne Pond (left) and female *Acanthocyclops brevispinosus* (right; source: USGS copepod key).

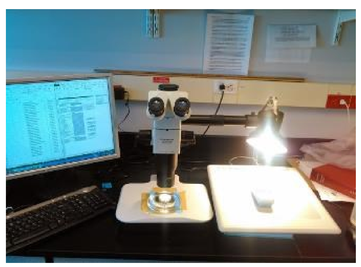

Fig. 3. Dissecting microscope equipped with digitizing tablet for ZP enumeration and measurements.

Results

- Phycocyanin RFU was highest from July to early September (Fig. 4).
- Total ZP biomass showed a spring, summer and fall peak (Fig. 5 & 6), mostly due to *Daphnia mendotae* (Fig. 5 & 7). Winter and early spring were dominated by cyclopoids copepodids.

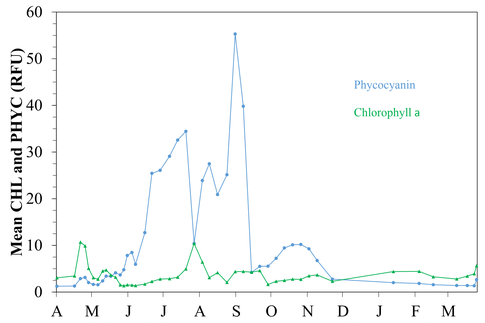

Fig. 4. Chl *a* and phycocyanin RFU averaged from sonde profiles each sampling date.

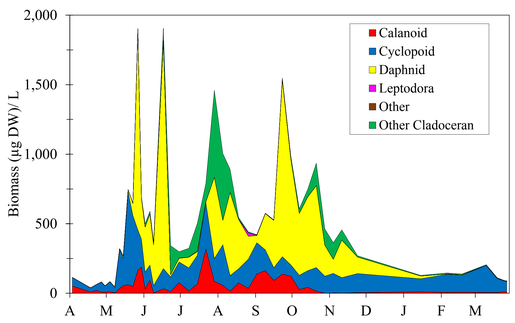

Fig. 5. Zooplankton biomass composition per date by major grouping.

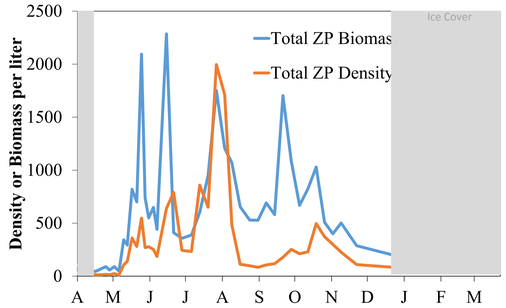

Fig. 6. Total ZP density and biomass.

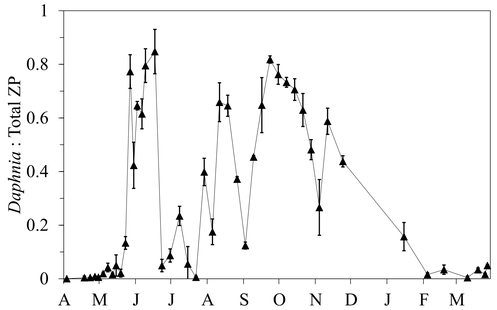

Fig. 7. Average proportion of *Daphnia mendotae* to total ZP community biomass observed per date (± SD).

- ZP average size was lowest during late June-August when *Chydorus* spp. became abundant (Figs. 6 & 8). Average size was highest in fall months due to larger- sized *Daphnia mendotae*.

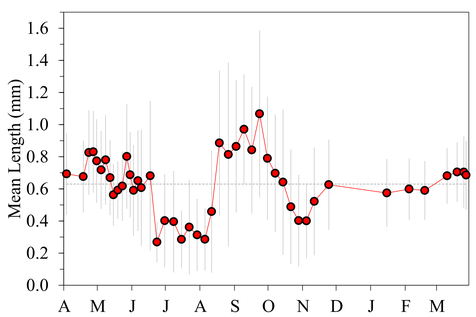

Fig 8. Average size (± SD) of ZP observed (N > 400 organisms measured per date). Grey dashed line indicates the annual average size.

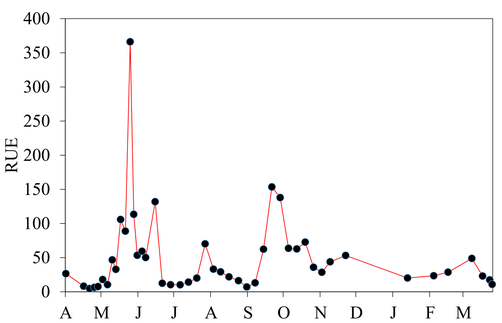

Fig 9. Relative resource use efficiency (RUE) by sample date.

- RUE was highest at intermediate temperatures observed during spring and fall, corresponding to peak *Daphnia* biomass (Fig. 9 & 10).
- RUE was lowest following ice-out during April, and also at high temperatures during late summer (Fig. 10).

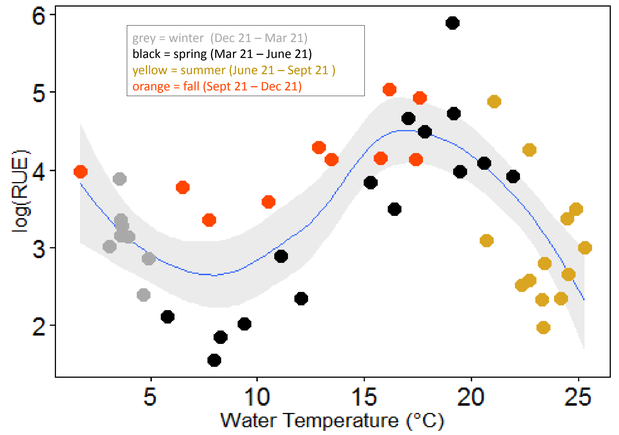

Fig. 10. Log RUE as a function of water temperature. A smoothed loess trend line (blue) was fit to the data for visualization and the grey ribbon represents 95% confidence interval.

- CCA ordination indicates that winter and early spring communities are similar, and that late spring and fall communities are also distinct (Fig. 11).

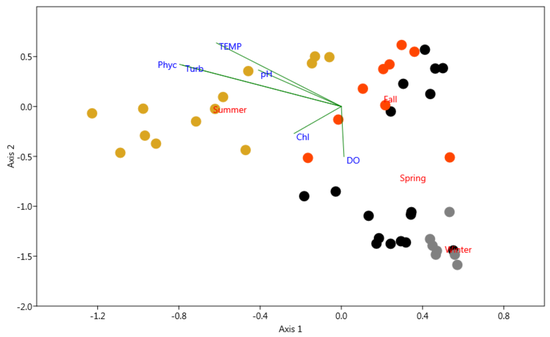

Fig 11. CCA ordination of community biomass composition and environmental variables over the study period. Colors are coded to the following seasons (grey = winter, black = spring, yellow = summer, orange = fall).

Discussion

- RUE was maximized before and after summer, consistent with our hypothesis. Summer represents a generally inefficient time period for ZP.
- RUE was higher during winter than early spring following ice-out when water temperature was cool and phytoplankton production was low.
- Ongoing collections will provide further evaluation of the relationship between ZP biomass conversion and the main biotic and abiotic parameters influencing the relative efficiency of energy transfer.

Acknowledgements:
We thank Dongjoo Joung, Brad Roy, Nemesis Ortiz, Peter Isles, Trevor Gearhart, and Yaoyang Xu for sample collections. Jessica Mailhot, Genevieve Meller, Ben Szydlowski, and Beverley Wemple helped get the project started. This work was supported in part by the Lake Champlain Research Consortium and Vermont EPSCoR (NSF Grant EPS-1101317).