10-27-2014

Jackson Lake Limnology

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WATS 2014 Graduate Induction Course

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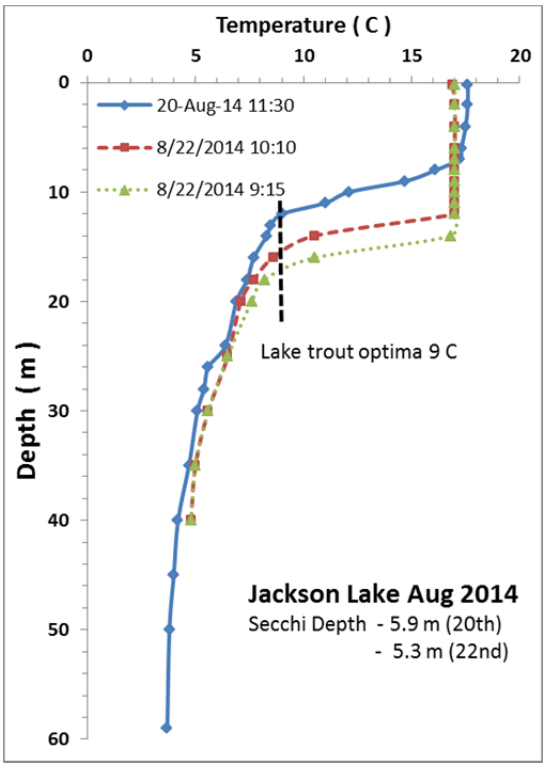
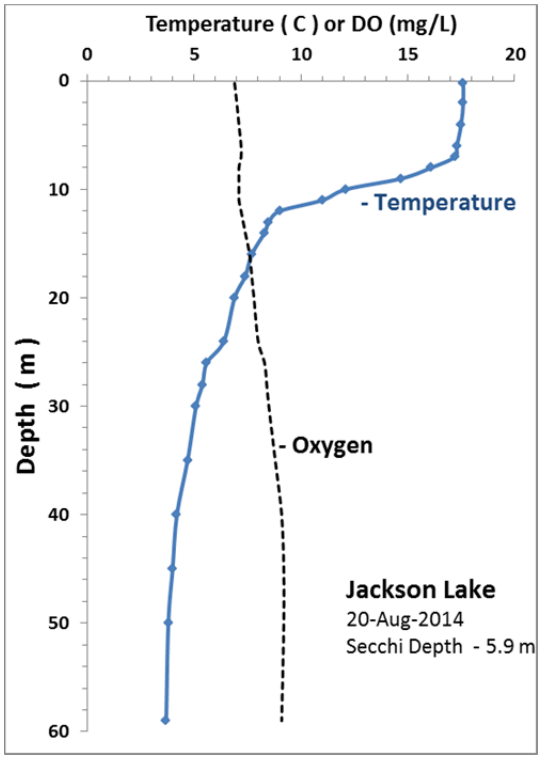
27 October 2014

The limnology of Jackson Lake has been studied very little, despite the fact that it is the uppermost large lake on the headwaters of the Snake River, one of the larger rivers in the country (Hayden 1969). It is also an important fishery, largely for introduced lake trout. In 2014 we took our incoming graduate students to the Jackson Hole and one part of this introductory course focused on the limnology of the lake. Prior to the arrival of the students, vertical profiles of limnological parameters were measured. Additionally, a nutrient addition bioassay was initiated to demonstrate an experimental approach to understanding what nutrients might control production processes of phytoplankton at the base of the plankton food web. Finally, on 22 August, students did vertical profiling of temperature, oxygen and light in the pelagic zone, and measured the Secchi disk transparency of the lake water.

Vertical profiling of temperature, oxygen and chlorophyll—A profile was conducted by the instructor (W. Wurtsbaugh) on 19 August 2014 when the bioassay water was collected. Although it was cloudy, conditions were calm. Profiles were also done by the students on 22 August, a stormy day with high winds that made it difficult to keep the profiling cable of the YSI Model 58 Meter vertical.





The temperature profiles suggest that the high winds on the 21st and 22nd initiated an internal wave (seiche) that modified the thermal structure. On the 20th the mixed layer extended to about 8 m, and the thermocline ranged from 8-14 m. Below this, temperatures in the hypolimnion decreased steadily to near 4 C near the maximum depth measured (59 m). However, when students did the profile on the 22nd, the mixed layer (epilimnion) extended to depths of 12-15 m, and the thermocline was sharper. Although an internal seiche of this magnitude is entirely possible, the difficulties with keeping the sampling line vertical on the 22nd should make us cautious about this interpretation.


Stormy conditions on 22 Aug.

The implications of the temperature profiles are quite important. The preferred temperature of adult lake trout is near 9 C. On the 20th, this would have meant that the adults of this species would have utilized water up to about 12 m depth. However, if the seiche deepened the mixed layer, their optimal temperature would have been below 15 m.

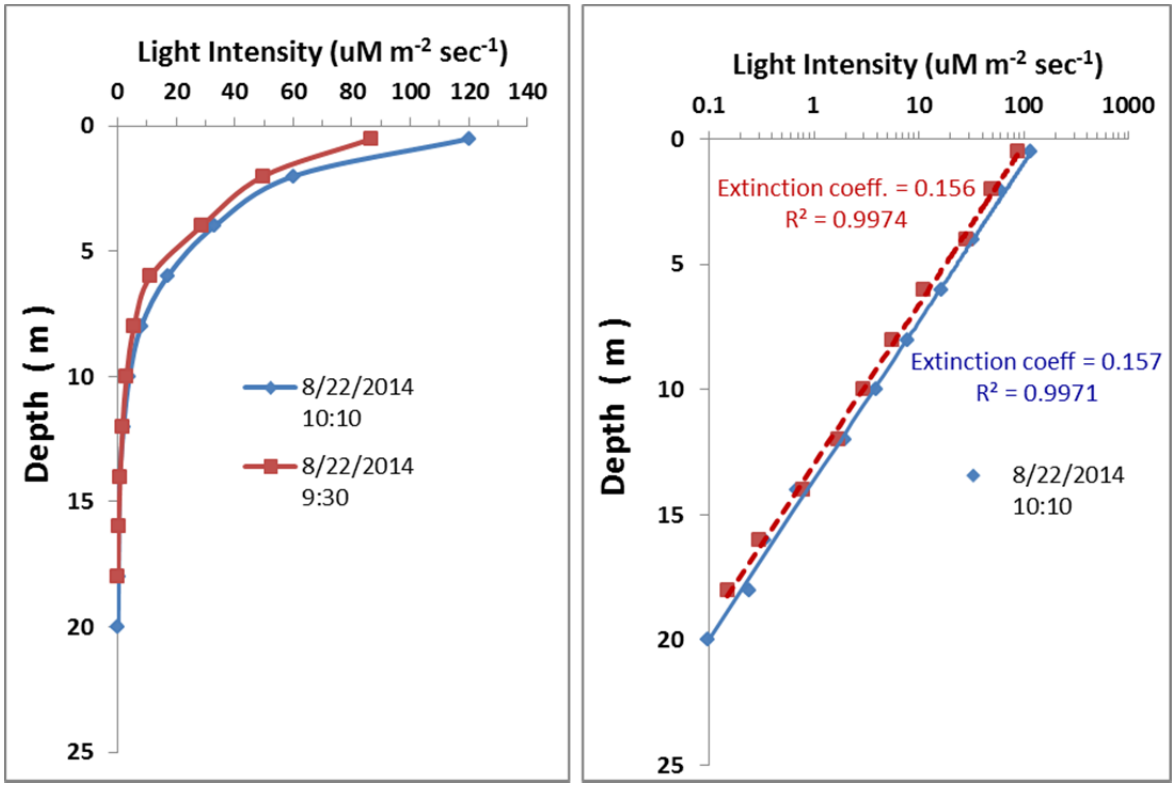
The potential for a seiche also has important implications for the temperature of water released from Jackson Lake Dam. With internally-oscillating seiches, release temperatures might change periodically from those of the epilimnion (ca. 17 C when we sampled), to cold thermocline water. These temperature oscillations in the river water would have important effects on the metabolism of the insects and fish in the Snake River.

The oxygen profile suggests that Jackson Lake is oligotrophic (unproductive). In more productive systems, sedimenting algae and other organic matter decomposes in the hypolimnion and uses up the oxygen there. However, the oxygen profiles we took (only the 20 Aug data is shown here), suggest that oxygen rose steadily in the hypolimnion, likely as a consequence of the colder water's capacity to hold more dissolved gasses at saturation. It would have been interesting to profile deeper into the water column (maximum depth was > 90 m) to see if oxygen declined at all in the deepest water, but our sampling cable extended only to 59 m.


Secchi disk measurement in a mesotrophic portion of Lake Powell.

Light profiles—Two light profiles were measured by the students on the 22nd. Again, boat drift and vertical sampling lines were an issue, particularly on the first profile done at 9:30. Nevertheless, the profiles demonstrate clearly how light intensity declines

exponentially through the water column. Light levels at the surface on this cloudy day were only about 10% of what one can expect on a clear, sunny day. The figure below on the left shows the exponential decline and the similarity of the two profiles done by the two groups. When this exponential decline is graphed on a log scale (right frame), a linear relationship results. Limnologists use the slope of this line (depth as independent variable) to calculate the extinction coefficient, which was 0.156 and 0.157 for the two profiles. These are low extinction coefficients, characteristic of relatively clear lakes. We can use the extinction coefficient to predict that the photic zone where photosynthesis can occur would extend to about 13 m in the lake (1% light level).



The Secchi depth transparency measured on the 20th was 5.9 m, and 5.3 for the one measurement taken on the wavy 22nd when conditions were less the ideal. As a rule of thumb, the photic zone is assumed to be 2-3 Secchi depths (11-16 m), which is not that different than that estimated by the extinction coefficients and the assumed cessation of net photosynthesis below the 1% light level.

Chlorophyll profile—Water samples were collected at 8 depths, with replicate samples at 3 of these depths. Fifty-ml aliquots from each sample were filtered on Gelman AE filters with a nominal pore size of 1 µm, frozen and the chlorophyll was subsequently extracted for 24 h in 95% ethanol. The chlorophyll concentrations were measured in a Turner 10AU fluorometer utilizing the Welschmeyer (1994) technique.

Chlorophyll concentrations in the lake were very low. In the epilimnion (1 m) the mean concentration was 0.9 µg/L and this increased slightly to 1.2-1.5 µg/L in the upper part of the metalimnion, and then decreased to a depth of 30 m. The concentration at 45 m was unexpectedly higher (2.0 µg/L), and then decreased again at 65 m. Deep chlorophyll layers commonly occur in oligotrophic lakes (e.g. Pilati and Wurtsbaugh 2003), but the high concentration at 45 m was not expected because it was well below the photic zone (~0-14 m). The deep concentration may consequently represent non-growing algae that had settled and accumulated at this depth. Additionally, a replicate sample was not taken at 45 m, so additional sampling will be needed to establish the overall pattern in the lake at different times of the year. Nevertheless, the overall low concentrations of chlorophyll indicate that the lake is very oligotrophic (unproductive).

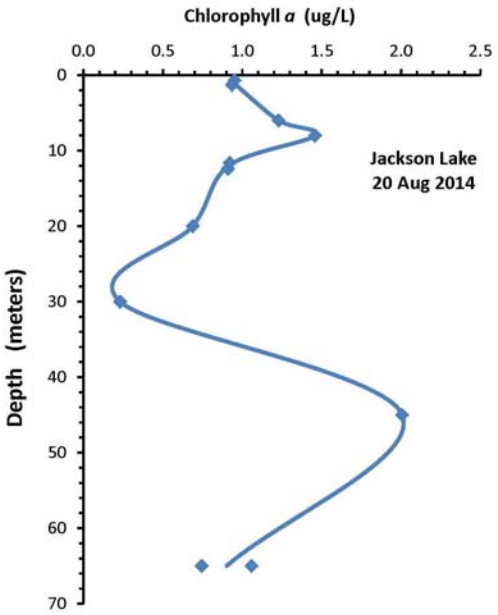
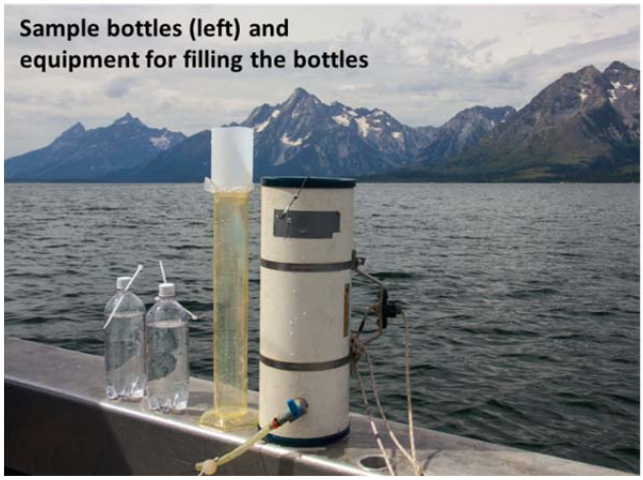
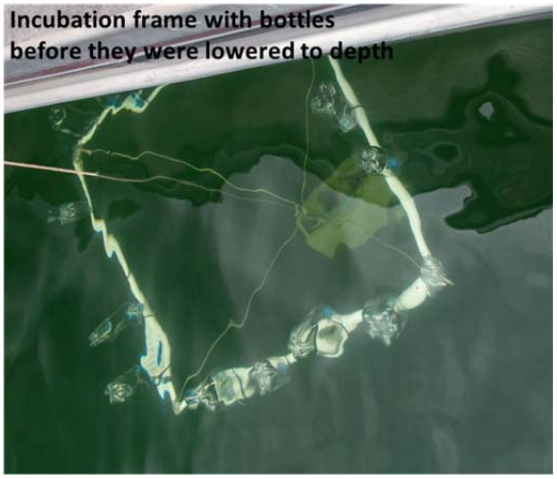


Fig. 1. Chlorophyll concentration from 1-65 m in Jackson Lake. Replicate samples were taken at 1, 12 and 65 m. The points from 1 and 12 m were offset slightly so that both replicates would be visible

Nutrient Addition Bioassay— Water was collected from 5 m in Jackson Lake on August 19th ca. 12:00 and 850 ml was placed into 15, 1000 ml acid-washed polycarbonate bottles (Coke bottles). Macro-zooplankton were removed with a 153 um mesh net, except for 1 treatment where zooplankton collected with a net were added back to three replicates. The bottles were incubated at ~ 4.5 m depth off of the University of Wyoming's dock. Clouds were intermittent until the bottles were pulled on 22 August at 8:30 AM.

Treatments (3 replicates each)	
	Form
Nutrient Control (no addition)	---
Nutrinet Control + macro-zooplankton grazers	
+ N (350 ug N/L)	NH_4NO_3
+ P (50 ug N/L)	$NaHPO_4$
+N + P (350/50 ug/L)	both





A sample from each bottle was filtered on 1-µm glass fiber filters by the students, frozen on dry ice, placed in 95% ethanol in 15-ml centrifuge tubes for 2.75 hrs., and then read in an Turner Aquafluor fluorometer. The results were quite variable, so the bottles were left on a table in cloudy light until 13:30, transported to USU and placed in a temperature controlled chamber (17 C) and 150 µE/m^2/second light intensity until 18:00 on 24 August. 60-ml samples were again filtered using a Millipore filtration assembly. The filters were frozen in the lab freezer for 30 minutes, placed in 95% ethanol, and extracted for 22 hours before they were read with the Aquafluor fluorometer.

The results of the bioassay (Fig. 2) indicated that neither nitrogen or phosphorus, or the combined addition of both, stimulated phytoplankton growth. One replicate of the nitrogen treatment was identified as a statistical outlier, and was removed from the subsequent analyses. An analysis of variance and a post-hoc Tukey test demonstrated that the treatment with added zooplankton was statistically lower than the controls, suggesting that in the lake that top-down control of the phytoplankton could be important. However, the amount of zooplankton added to this treatment was not carefully controlled, so the magnitude of this effect *in-situ* would need to be determined with more careful measurements.

The lack of stimulation of the phytoplankton by N, P or N+P is unusual. Experimental analyses have shown that streams in the region are N-limited or co-limited by N and P (Kunza and Hall 2013), and analyses of nutrient content of phytoplankton also suggest they are largely N-limited (Interlandi et al. 1999). The lack of stimulation of the phytoplankton might mean that a micronutrient such as Fe or Mo was limiting, or alternatively that the low light during much of the experiment reduced the response. Further work is clearly needed.

The overall chlorophyll levels in the bioassay were low (< 0.7 µg/L), indicative of very oligotrophic conditions in the lake.

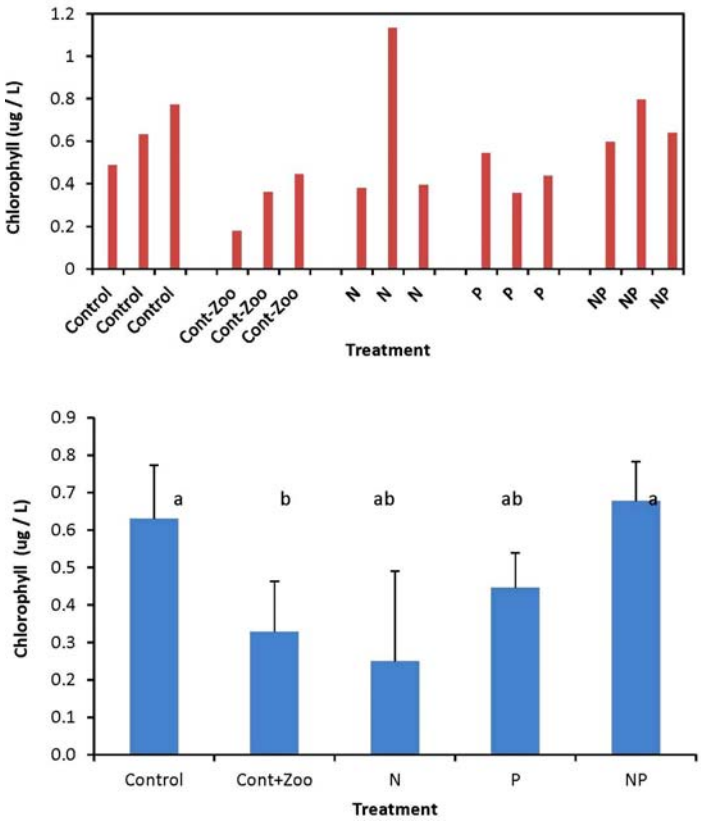


Fig. 2. Bioassay responses at the end of the 5-day incubation. The top frame shows the results of the 3 replicates from each treatment, and the bottom frame shows the mean +- s.d. In the bottom frame, histograms that share a common letter are not statistically different.

After these readings the bioassay bottles were inadvertently left in the incubation chamber at 17-20^{o}C and 150 uE/m2/sec for 64 days. After this interval distinct differences in responses to the nutrients were visible, so the algae were again filtered and extracted in 95% ethanol and the chlorophyll concentrations were measured fluorometrically using the Welschmeyer (1994) technique. Zooplankton were not visible in that treatment, so the Control + zooplankton treatment was not analyzed. Variability between treatments was high and consequently, the concentrations were log-transformed prior to ANOVA analysis and a Tukey-test post-hoc analysis.

The results of the long-term bioassay indicated that phosphorus was the primary limiting nutrient (Fig. 3). As mentioned, variability was high. For example, chlorophyll concentrations in the +P treatment varied from 16-93 µg/L, and one of these treatments was dominated by green algae and the other which was visibly brown-colored, was dominated by diatoms.

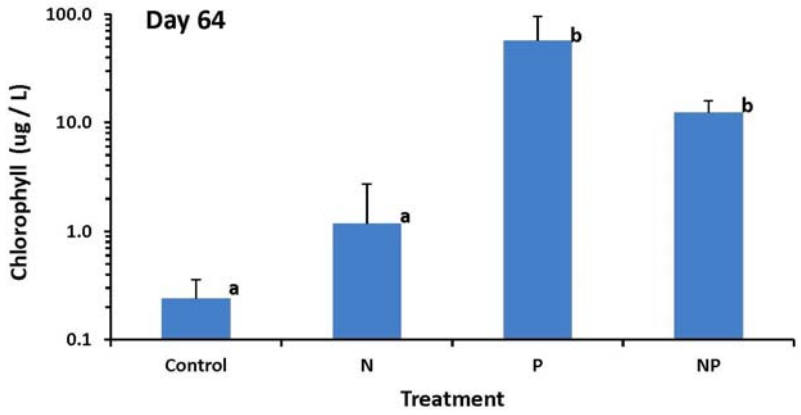


Fig. 3. Bioassay responses of Jackson Lake phytoplankton after a 64-day incubation. Mean +- s.d. Histograms that share a common letter are not statistically different. Note the log scale.

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