



Temporal dynamics of plankton populations in relation to silica in a freshwater beaver pond

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Introduction

Many limnological studies have shown that plankton populations change over time in response to environmental factors (Vanni, 1986; Gilbert, 1988; Tryfon & Moustaka-Gouni, 1997; Vijjanen et al., 2008). The shift from one plankton species to another indicates changes in the type of nutrients available (Graham et al., 2004) the role of competition between two or more species (Grover and Chrzanowski, 2006) or how light is affecting the system (Kirk, 1994).

Plankton are microscopic organisms that are divided into two main groups: phytoplankton and zooplankton. Phytoplankton are autotrophs and zooplankton are classified as heterotrophs because they rely on other organisms for their source of nutrients (Deibel, 2001). Phytoplankton are responsible for 50% of Earth's primary productivity (Falkowski et al., 2004). Zooplankton convert the phytoplankton's plant tissues into animal tissues and are the gateway to more complicated food webs (Goswami, 2004). Several groups of plankton are abundant in freshwater systems: diatoms, rotifers, copepods, and cladocerans (Dodds, 2002). Diatoms are a group of silica-based phytoplankton. They are unique because they use silica to create their cell walls (Wetzel, 2001). Rotifers are zooplankton that feed on other rotifers and phytoplankton (Suthers and Rissik, 2009). Copepods are zooplankton that utilize both diatoms and rotifers as a food source (Turner et al., 2001; Brandl, 2005). Cladocerans are also zooplankton but they compete with rotifers for similar food sources (Larsson and Weider, 1995).

Silica cycling in a freshwater system is what drives diatom dominance (Dodds, 2002). Diatoms require silica for their bodies. Dissolved silica can increase in unstratified spring waters when it is released from disturbed sediments. This is due to increasing temperatures. Past results have shown that a decrease in silica concentrations leads to a decline in diatom populations, which in turn affects zooplankton (Sommer and Stabel, 1983; Wetzel, 2001).

The purpose of this study was to observe the relationship between plankton populations and silica concentrations and among groups of plankton in a freshwater beaver pond. This research is significant to the field of aquatic ecology because the beaver pond has never been extensively studied and it is a shallow system. Only recently have shallow systems received attention from limnologists (Castro et al., 2005). Because the beaver pond is shallow, it is most certainly isothermic—having one temperature—and has no thermocline. With no thermocline present, plankton are capable of inhabiting all depths of the beaver pond (Dodds, 2002). This is the first known study to analyze temporal change in plankton populations in a shallow isothermic system.

Methods

Samples were obtained weekly in order to track the changes in abundance of various groups of plankton as well as physical and chemical changes in the water. Five 500-mL Nalgene® bottles were submerged below the surface of the water within each region (north, central, south) for nutrient analysis. Physical and chemical properties of the water were recorded from five locations within the three regions and then averaged overall. Nitrogen, temperature, dissolved oxygen, and pH were measured by a Vernier LabQuest® system. Phosphorus was measured using a Hach® DR/890 colorimeter. Silica was measured using a Hach® Silica, Pocket II Colorimeter Test Kit. Plankton sampling was conducted by taking fifty 50-mL samples from each region of the beaver pond. Samples were immediately transported back to the lab for preservation, using a 5% formalin solution (Findlay and Kling, 2001; Goswami, 2004). A 1-mL sample of water was removed from each 50-mL bottle and placed in the well of a Sedgewick-Rafter counting chamber. The slides were examined under a compound light microscope and plankton (cladocerans, copepods, diatoms, and rotifers) were counted. Once all 150 samples were examined, an average abundance for each group was calculated for that day. Data were analyzed using linear regression to look for relationships between water quality and plankton abundance, among various water quality parameters, and among groups of plankton.

Results

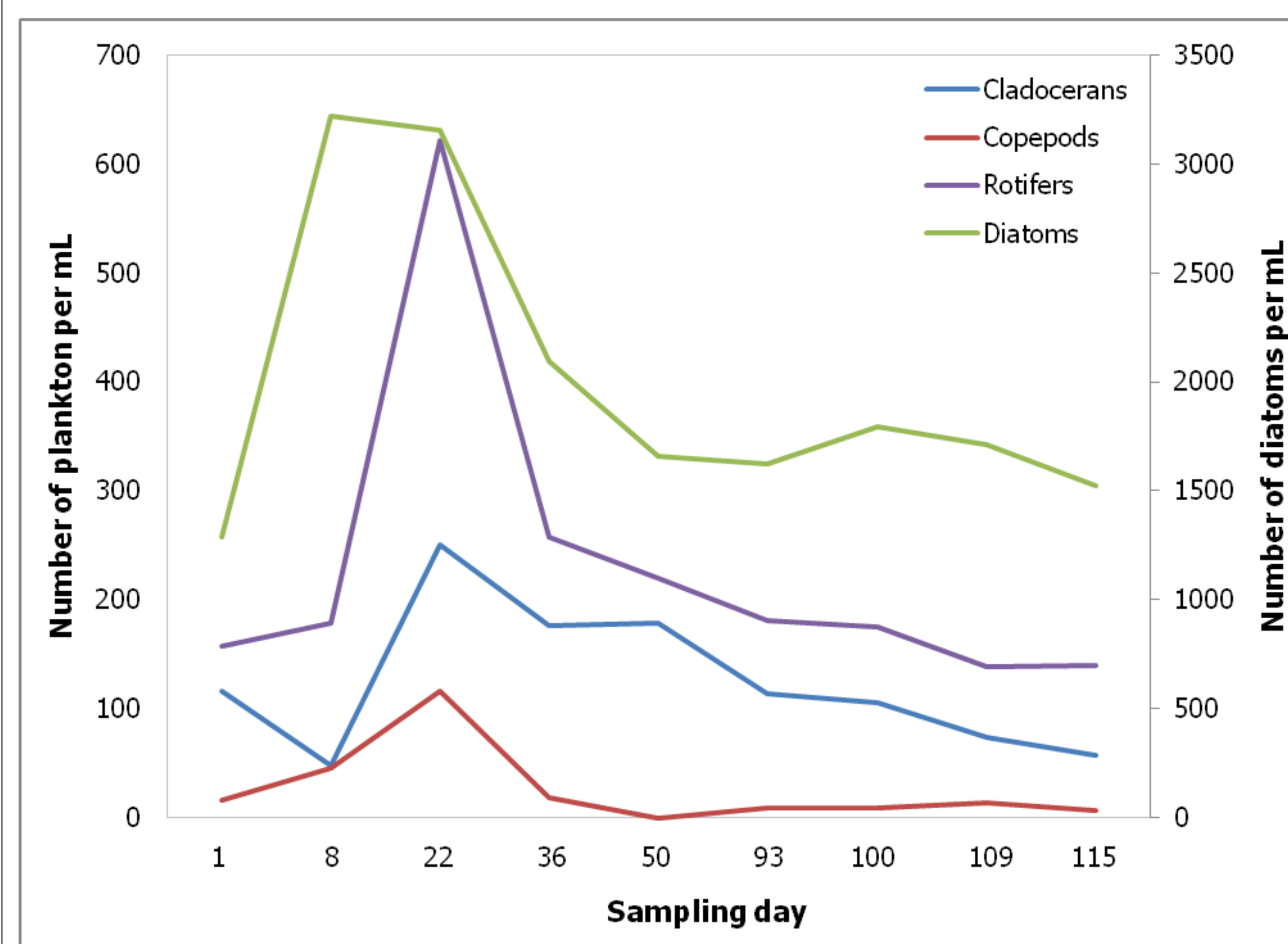


Figure 1. Changes in abundance of plankton from mid-summer until early autumn. Zooplankton and diatoms are graphed on separate axes.

At the beginning of the sampling period (mid-June), there were relatively few zooplankton. As the diatom population rapidly increased, so did the populations of the zooplankton. The mid-summer decline in diatoms, possibly triggered by nutrient depletion (see Figure 2 below), was followed closely by a decline in zooplankton abundance.

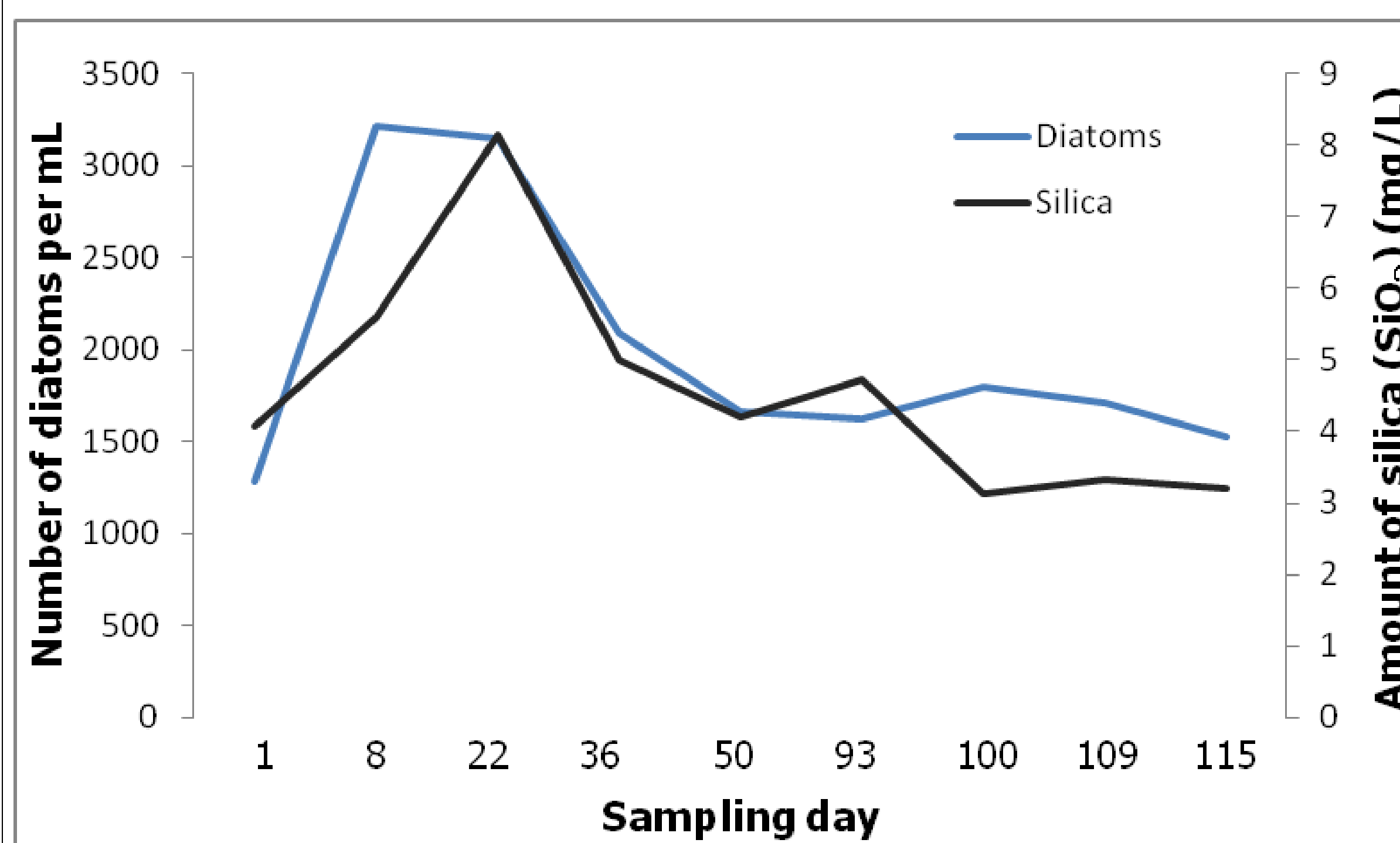
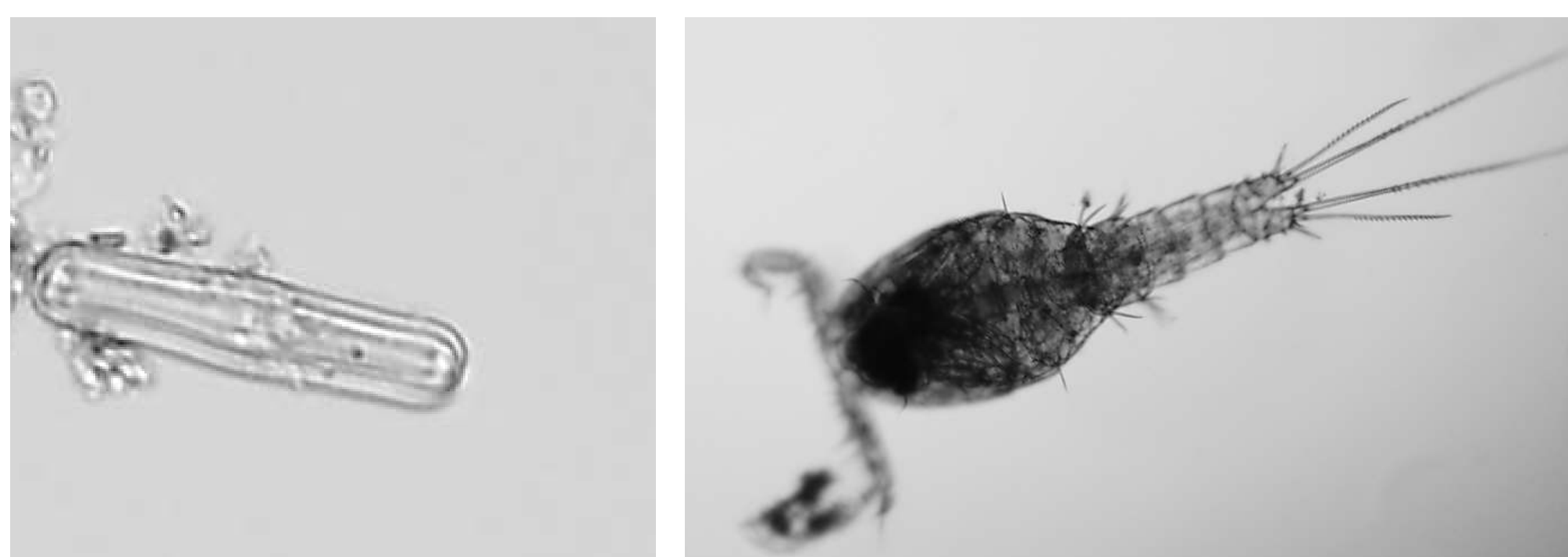


Figure 2. Relationship between the number of diatoms and the amount of silica from mid-summer until early autumn. Diatoms and silica are graphed on separate axes.

This graph shows a strong relationship between the amount of silica and the abundance of diatoms. Regression analysis revealed a highly significant relationship ($p = 0.009$, $r^2 = 0.650$).

Figure 3. Pictures of plankton: diatom (left) and copepod (right)



	Cladocerans	Copepods	Diatoms	Rotifers
Cladocerans		0.125	0.496	0.005
Copepods			0.007	< 0.001
Diatoms				0.063
Rotifers				

Table 1. Results of regression analyses of the abundance of the different plankton groups. Significant p -values are indicated in red.

Significant relationships were found between cladocerans and rotifers ($p = 0.005$, $r^2 = 0.693$), copepods and diatoms ($p = 0.007$, $r^2 = 0.666$), and copepods and rotifers ($p < 0.001$, $r^2 = 0.819$). The relationship between abundance of copepods and diatoms indicates that the copepod population may be dependent on the diatom population. The relationship between abundance of copepods and rotifers implies the copepods rely more on rotifers as a food source than they do on diatoms.

	Cladocerans	Copepods	Diatoms	Rotifers
Silica	0.049	< 0.001	0.009	0.001
Temperature	0.053	0.113	0.188	0.089
pH	0.262	0.721	0.520	0.656
Dissolved oxygen	0.209	0.162	0.086	0.196
Phosphate	0.784	0.367	0.098	0.838
Nitrate	0.250	0.842	0.797	0.735

Table 2. Results of regression analyses of the relationship between the abundance of plankton groups and various abiotic factors. Significant p -values are indicated in red.

The only significant relationships were between silica and each of the plankton groups. None of the other chemical or physical factors were significant, indicating that silica alone drives the plankton dynamics of the beaver pond.

Discussion

These results indicate that the dynamics of plankton in the beaver pond are driven by silica. Analysis revealed that 65% of the variation in diatom numbers depends on variation in silica concentrations. This corroborates results of previous studies. Wetzel (2001) explains that one thing that is certain about freshwater systems is that silica is a necessary for diatom existence. This is supported by data in Table 2 and in Figure 2. This significant result indicates that diatoms do depend on silica. Diatoms use silica for their structures and for reproduction (Vinyard, 1979; Wetzel, 2001).

Because diatoms are phytoplankton, they are the foundation for many aquatic food webs. The primary predators of diatoms are copepods (Turner et al., 2001). The data collected indicate that the copepod population is dependent on the diatom population. If more diatoms are present, then there is a larger food source available for the copepods. If fewer diatoms are present, there are fewer copepods. One explanation for the mid-summer decrease in copepods could be that diatoms are producing antimetabolic compounds that inhibit copepod fecundity and egg-hatching success (Turner et al., 2001).

Rotifers also utilize phytoplankton as a food source. In addition, they also serve as a food source for copepods. This relationship is more significant than the relationship between diatoms and copepods, which would imply that copepods rely on rotifers as a food source more than they do on diatoms. Furthermore, the rotifer population may be determined by the presence of small-bodied cladocerans (body length measuring < 1.2 mm). Cladocerans and rotifers compete for similar food sources. Gilbert (1988) found that freshwater systems favor rotifer populations when small-bodied cladocerans are present. Figure 1 shows that there are more rotifers than cladocerans during each sampling day, which supports Gilbert's findings.

Throughout the study, silica concentrations were lower than the average of most freshwater systems (Wetzel, 2001). This suggests that the silica is being used by diatoms and that it strongly influences diatom population sizes. In turn, the diatoms influence zooplankton populations. As a result, silica is the primary factor driving the dynamics of plankton in this shallow freshwater ecosystem.

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