Seasonal Dynamics and Food Web Interactions of Planktonic Organisms in Big and Little Platte Lake, Benzie Co., Michigan.

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Objectives:

- Describe the plankton composition and seasonal dynamics of plankton populations in Big and Little Platte Lake, MI during 2007.
- Compare plankton composition and seasonal dynamics in 2007 with composition and dynamics in 2003- 2006.
- Describe the planktonic food web of Big Platte Lake, MI, including major feeding pathways.
- Relate phytoplankton composition and diversity to physical and chemical characteristics of Big and Little Platte Lake during 2007.

Methods:

Phytoplankton and zooplankton samples were collected from Big Platte Lake every two weeks in 2007 (January-November) unless ice conditions made sampling unsafe. Only one set of samples was collected in January, March, April and November. Phytoplankton samples were collected from Little Platte Lake every two weeks in 2007 (January-November) except in January, March, and April when sampling conditions were unsafe.

MDNR technicians sampled epilimnetic phytoplankton in Big Platte Lake with a 2-cm diameter silicone tube dropped vertically through the water column. The tube sampler was outfitted with a one-way foot valve on the lower end to facilitate sample collection. As the tube was withdrawn from the water, its contents were released into a clean container. MDNR personnel also collected discrete samples from 45, 60, 75 and 90 feet at one location and combined them in a single container to produce an integrated 45-90 foot sample. Little Platte Lake is shallow and well-mixed, so MDNR personnel sampled phytoplankton by filling three 250-mL bottles just below the surface.

Prior to June 27, MDNR personnel collected 3 tube samples from separate locations near the deep hole within the epilimnion of Big Platte Lake (0-30 ft.). Tube samples were combined in a single container. Three 250-mL sub-samples were collected from the 0-30 ft. container and the 45-90 ft. container. Between June 27 and August 8, MDNR personnel collected 3 tube samples from separate locations near the deep hole within the entire water column of Big Platte Lake (0-90 ft.). Tube samples were combined in a single container and three 250-mL sub-samples were collected. No deep water samples were collected. After August 8, MDNR personnel collected 3 tube samples from separate locations near the deep hole within the epilimnion of Big Platte Lake (0-30 ft.). Tube samples were combined in a single container. Three 250-mL sub-samples were collected from the 0-30 ft. container and one 250-mL sub-sample was collected from the 45-90 ft. container. All algal samples were preserved with Lugol's solution.

MDNR technicians collected zooplankton samples from Big Platte Lake using a 30-cm diameter, 64-µm mesh net. Three vertical net tows were collected from 1 m above the sediments to the surface at separate locations near the deep hole. The net was hauled no faster than 1 m/sec. The contents of each net tow was washed into separate, labeled 250-mL bottles and preserved with formalin.

Phytoplankton samples were examined by placing 5 ml of well-mixed sample into a settling chamber for 24 hours. Algal species were enumerated at 200-400x magnification using a Zeiss inverted compound microscope. All colonial and large solitary algal species in the sampling chamber were enumerated at 200x magnification (Table 1). Cell counts for large algal species were multiplied by 200 to get cells/liter. Small algal species in the sampling chamber were enumerated at 400x magnification using a sub-sampling technique (Table 1). All algae were counted within 38 rectangular fields of view along a single transect through the middle of the counting chamber. Cell counts for small algal species were divided by the proportion of rectangular field examined in the chamber (38/1663) and multiplied by 200 to get cells/liter. For some colonial and filamentous species (Table 1), it was easier to measure colony length or area and apply a correction formula to estimate the number of cells.

Table 1: Counting procedures used for algal types and genera found in Big Platte Lake, Benzie Co., Michigan.

Algae type	Counting Procedure	Algal Genera
Large/Colonial	magnification = 200 count entire chamber cells/L = counts * 200	*Stephanodiscus, Cyclotella, Cocsinodiscus, Cymatopleura, Amphipora, Asterionella, Diploneis, Pleuro/Gyrosigma, Rhizosolenia, Cymbella, Tabellaria, Pediastrum, Coelastrum, Mugeotia, Zygnema, Spirogyra, Gymnodinium, Peridinium, Chrysophaerella, Ceratium*
Small	magnification = 400 count fields cells/L = counts ÷ prop. chamber * 200	*Synedra, Achnanthes, Navicula Hantschia, Nitschia, Pinnularia, Mastigloia, Scenedesmus, microgreens, Golenkinia, Closterium, Mallamonas, Cryptomonas, Dinobryon, Epipyxis*
Filament	magnification = 200 count entire chamber counts = length * 5.5 cells/L = counts * 200	*Fragilaria*
Filament	magnification = 200 count entire chamber counts = length * 1.0 cells/L = counts * 200	*Melosira*
Colony	magnification = 200 count entire chamber counts = area * cells/area cells/L = counts * 200	*Microcystis*

Table 2: Shapes and geometric formulas for select algal taxa found in Big Platte Lake, Benzie Co., Michigan. Symbols: D = diameter, L = length, W = width, H = height.

	Fragilaria	*Melosira*	*Scenedesmus*	*Microcystis*	*Dinobryon*
Cell shape	elliptic prism	cylinder	prolate spheroid	sphere	ellipsoid
Formula	$L*W^{*}H*\pi/4$	$H*D^2*\pi/4$	$L*W^2*\pi/6$	$D^3*\pi/6$	$\frac{1}{2}(\frac{2}{3}L*W*T)*\pi/6 + \frac{1}{2}(\frac{1}{3}L*W*T)*\pi/6$

Algal biovolume was calculated as the product of cell density and average cell volume. Average cell volume was determined by measuring length, width, and depth of 20 randomly selected cells from 2003 samples and applying a published geometric formula that closely approximated the shape of each taxon (Table 2). The biovolume of colonial green algae was calculated as the product of colony density and average colony volume. Cell volumes (μm^3) were multiplied by 10^{-9} to give biovolume (µl). If one assumes that algal cell density is approximately 1.0 g/ml, biovolume (µl) is equivalent to dry biomass (mg). This assumption is good for green algae and cyanobacteria. It severely underestimates diatom biomass.

Zooplankton species were enumerated by counting 5-ml sub-samples in a Bogorov tray at 25x magnification using a Leica stereomicroscope. Zooplankton biomass was calculated as the product of species density and average individual dry weight. Average individual dry weights of copepod (calanoid, cyclopoid) and cladoceran (*Bosmina*, *Daphnia*, and *Holopedium*) species was determined by measuring 30 individuals of each taxon and applying a published length-weight regression to the average length (Culver et al. 1985). Average individual dry weights of rotifer species (*Polyarthra*, *Keratella*) found in Lake Michigan (Makarewicz et al. 1994) were used to estimate average individual dry weights in Big Platte Lake. Average individual dry weights of *Alona* and *Chydorus* in Lake Michigan (M. Edwards, unpublished data) were used estimate dry weight of animals found in Big Platte Lake. Average individual dry weight of *Leptodora* in Big Platte Lake was estimated by applying a published length-weight regression (Manca et al. 2000) to a 6 mm animal.

Results:

Phytoplankton in Big Platte Lake:

The abundance and seasonal succession of planktonic organisms depends to a large degree on the physical and chemical characteristics of a lake. In 2007, temperature profiles indicate that Big Platte Lake was well mixed until May 1 when stratification began (Fig.1a). Separation of warm surface water from cold bottom water continued until November 7 when the lake once again became mixed. Turbidity was high during spring and fall mixing events (Fig. 1b), but it was also high in late July 2007 suggesting a summer mixing event. Because shallow water (< 30 ft.) dominates the surface area of Big Platte Lake, sediments are easily mixed into the surface water by the wind. The lake water was alkaline with a moderate buffering capacity in 2007. Average surface pH was 8.2 and average surface alkalinity was 154 mg/L. Surface pH decreased on September 5, but alkalinity did not vary much during the season (Fig. 2).

Nutrient concentrations govern the abundance and composition of phytoplankton populations. In 2007, total phosphorus (TP) concentration in the epilimnion was fairly stable (mean = 7.19 μg/L) and never exceeded 10 μg/L in Big Platte Lake (Fig. 3a). Most phosphorus during spring mixing (especially on April 17) was dissolved and available to phytoplankton. Nitrate concentrations in the epilimnion were highest during spring mixing and dropped to very low levels (< 2 μg/L) in late July (Fig. 3b). In bottom waters, nitrate concentrations peaked during anoxic conditions in August.

Algal biomass, as estimated by chlorophyll a concentration, was more closely related to total phosphorus concentrations than nitrate concentrations during 2007 (Fig. 3). Chlorophyll *a* increased gradually during the summer months and reached peak levels in September-October when nitrate was lowest. Chlorophyll *a* concentrations are always higher in the summer and lower in the winter in Big Platte Lake (Fig. 4). Mean annual chlorophyll *a* concentrations, however, have changed over time. Chlorophyll *a* concentration increased from 1.85 μg/L in 2004 to 2.87 μg/L in 2006. In 2007, mean chlorophyll *a* concentration decreased to 2.31 μg/L. Mean annual chlorophyll *a* concentration was directly related to algal density. Mean epilimnetic phytoplankton density increased from 0.6 million cells per liter in 2004 to 2.5 million cells per liter in 2006 but decreased to 1.9 million cells per liter in 2007.

Planktonic algae were most abundant in spring and summer 2007 when peak cell counts were 2.3 and 3.0 million cells per liter, respectively (Fig. 5). Spring and summer phytoplankton abundance maxima have been a consistent feature of Big Platte Lake since 2003, even though the dates of peak abundance have varied slightly from year to year. In 2003 and 2005, the spring abundance peak occurred in June; whereas in 2004, 2006, and 2007 the spring abundance peak occurred in April (Fig. 5). The summer abundance peak occurred in August during all years except 2007 when it occurred in early September.

Small green algae, flagellates, diatom species, and blue-green bacteria were co-dominant in the epilimnion of Big Platte Lake in 2007 (Fig. 5). The most common green algae were *Scenedesmus, Coelastrum* and other colonial species, and single-celled micro-greens. The most common flagellates were *Dinobryon*, a colonial chrysophyte, and two cryptomonads (*Cryptomonas*, *Chroomonas*). In past years, the large *Cryptomonas* was referred to as a "Euglenoid." Common diatoms included colonial species such as

Asterionella, *Melosira,* and *Fragilaria*; pennates such as *Synedra, Navicula* and *Cymbella*; and small centrics. Blue-green bacteria were dominated by the colonial genera *Chroococcus, Merismopedium,* and *Microcystis*.

There was a distinct seasonal shift in phytoplankton composition in Big Platte Lake during 2007. Small flagellates and green algae were numerically dominant under the ice in winter and during the spring (Fig. 5). Diatoms and blue-green bacteria were abundant during mixing events in the spring, summer, and fall. Blue-green bacteria were numerically dominant in the fall. The compositional changes in 2007 were similar to those in past years except that blue-green algae were more prominently represented in late summer and fall.

Although flagellates, small green algae, and blue-green bacteria were abundant in Big Platte Lake during 2007, diatoms contributed the most algal biomass (Fig. 6a). Diatom cells are much larger than the cells of most other algal taxa in Big Platte Lake. Only the dinoflagellate *Ceratium* has larger cells. Diatom biomass may be underestimated because mass of the glass frustule (cell wall) is not included in the biomass calculation. Diatoms comprised the majority of algal biomass (≥50%) in the epilimnion (0-30 ft.) of Big Platte Lake on all but 3 dates in 2007 (Fig. 6a). Diatom biomass was particularly high during spring, summer, and fall mixing events. Mixing events are less important for other phytoplankton taxa. Biomass of flagellates, green algae and blue-green bacteria were closely associated with total phosphorus concentrations (Fig. 6b). Peak blue-green biomass in late summer also exhibited an inverse relationship with nitrate concentration. In August and September, biomass of colonial blue-greens (*Chroococcus*, *Merismopedium*, and *Microcystis*) was high and nitrate concentrations were low (Fig. 6c). Interestingly, *Anabaena*, the only nitrogen-fixing blue-green in Big Platte Lake, did not respond to low nitrate conditions.

The distribution of algal biomass with depth reflects the mixing status and thermal properties of Big Platte Lake in 2007. In January, algal biomass was greatest near the surface indicating that the lake was not mixing (Fig. 7). A layer of ice most likely covered Big Platte Lake restricting mixing and light levels and encouraging the growth of small, mobile flagellates. Between April and June, Big Platte Lake alternated between periods of mixing and stratification. During mixing periods, algal biomass was similar at all depths (Fig. 7, March 29 and May 2). Heavy diatoms and nutrients from the bottom are brought to the surface by the moving water. When the wind stops, diatoms sink into the bottom waters (Fig. 7, April 17 and June 13). Between July and September, algal biomass was greatest near the surface indicating that the lake was stratified (Fig. 7). Green algae, flagellates and blue-green algae grew well in the warm surface waters. Diatom biomass in surface water decreased as heavy species sank toward the bottom. In late July, there was a *tremendous* centric diatom bloom after which the diatoms settled toward the bottom. In November, algal biomass was similar at all depths, indicating that Platte Lake had once again become mixed (Fig. 7).

In 2007, algal biomass in Big Platte Lake ranged from 0.41 to 3.73 mg/L, and mean annual algal biomass was 1.30 mg/L. Algal biomass was low (< 1.0 mg/L) during winter, late spring, and fall 2007 (Fig. 8). A centric diatom bloom was responsible for the large biomass peak in July. Mean algal biomass in 2007 was lower than in 2006 (2.2 mg/L) and comparable to that in 2005 (1.22 mg/L). Diatoms dominate algal biomass in Big

Platte Lake, particularly during spring, summer and fall mixing periods. Only during August 2003 and August-November 2005 were diatoms not an important contributor to algal biomass (Fig. 8).

Zooplankton in Big Platte Lake:

The zooplankton community of Big Platte Lake includes 5 copepod taxa (*Diacyclops thomasi*, *Mesocyclops edax*, *Diaptomus* spp., *Epischura lacustris*, and harpacticoids), 9 cladoceran taxa (*Bosmina*, *Eubosmina*, *Ceriodaphnia*, *Diaphanosoma*, *Daphnia*, *Holopedium*, *Sida*, *Chydorus*, *Leptodora*) and many rotifer species. The copepods *Diacyclops* and *Diaptomus* (both naupliar and copepodid stages) and the cladocerans *Bosmina* and *Daphnia* were the most common microcrustaceans in 2007. *Polyarthra* and *Keratella* were the most common rotifers.

Planktonic crustaceans and rotifers were most abundant during summer 2007 (Fig. 9). Rotifers exhibited two abundance peaks, one in July (80 animals per liter) and one in August (82 animals per liter). Crustaceans exhibited a large abundance peak in July (40 animals per liter) and a smaller peak (21 animals per liter) in late May. Crustacean abundance peaks coincided with rotifer abundance peaks in May and July. Rotifers were more abundant than crustaceans during the summer. Copepod nauplii dominated the crustacean plankton and cladoceran densities were low in 2007 (Fig. 9).

Zooplankton abundance and seasonal dynamics have changed during the past 5 years. Crustaceans were most abundant in 2003 (peak = 142 per liter) and 2006 (peak = 94 per liter) and least abundant in 2004 (peak = 35 per liter). Crustaceans typically exhibit 2-3 abundance peaks per year depending on the number of copepod cohorts (nauplii abundance peaks) and cladoceran blooms (Fig. 9). There were 3 distinct copepod cohorts in 2004 and 2005 and 2 distinct cohorts in 2006. A single large cladoceran bloom was evident in 2003 and 2005. Rotifers were also most abundant in 2003 (peak = 552 per liter) and least abundant in 2007 (peak = 82 per liter). Rotifers typically exhibited one large early-summer abundance peak and smaller abundance peaks in spring and fall. In 2004 and 2007, the summer abundance peak was delayed until August-September.

There was no distinct seasonal succession of zooplankton taxa in Big Platte Lake during 2007. However, in past years, a seasonal succession was evident. Cyclopoid copepods (nauplii and copepodids) typically dominate the crustacean plankton in the winter and spring but share dominance with cladocerans between June and October (Fig. 9). *Daphnia* replace *Bosmina* as the dominant cladoceran in July, but *Bosmina* become dominant once again in late summer. Rotifers are numerically dominant throughout the year, but particularly in late May.

In 2007, zooplankton biomass in Big Platte Lake ranged from 5 to 68 μg/L, and mean annual zooplankton biomass was 23 μg/L. Zooplankton biomass was highest in July (Fig. 10). Although rotifers and copepod nauplii were numerically dominant during most of the year, they only comprised a small portion of total zooplankton biomass in 2007. Juvenile and adult copepods dominated zooplankton biomass throughout the year (Fig. 10).

Mean and peak zooplankton biomass in Big Platte Lake has decreased between 2003 and 2007. Mean zooplankton biomass was 64 mg/L in 2003 and 34 mg/L in 2004 and only 23 in 2007. Two zooplankton biomass peaks were evident in all years except 2007 (Fig. 10). Cladocerans were responsible for summertime biomass peaks except during 2007 when cladocerans were low in abundance.

Phytoplankton in Little Platte Lake:

Unlike Big Platte Lake, Little Platte Lake is shallow and well-mixed when ice-free. Little Platte Lake was 1-4ºC warmer than Big Platte Lake during late winter and spring 2007 (Fig. 11a). Little Platte Lake reached a maximum temperature of 27ºC on June 27. Because Little Platte Lake was more vulnerable to wind induced mixing, it cooled more quickly than Big Platte Lake in fall 2007. As a result of frequent wind mixing, Little Platte Lake was consistently more turbid than Big Platte Lake in 2007 (Fig. 11b). Mean annual pH in Little Platte Lake (pH=8.2) was identical to that in the surface waters of Big Platte Lake during 2007. Mean annual alkalinity (122 mg/L) was slightly lower than that in the surface waters of Big Platte Lake. While surface pH in Big Platte Lake was fairly constant during 2007, pH in Little Platte Lake was low (7.8) in early spring and increased to 8.8 in summer (Fig. 2a). Alkalinity in Little Platte Lake did not vary much until October 2007 when it increased 20-30 mg/L (Fig. 2b).

In 2007, TP concentrations in Little Platte Lake were fairly stable (mean = 13.8 μg/L) and never exceeded 17.5 μg/L (Fig. 11c). TP was lowest in the winter and highest in early June, decreasing throughout the summer. Most phosphorus during spring mixing (April) was dissolved and available to phytoplankton. TP in Little Platte Lake was twice as high as TP in Big Platte Lake. Peak nitrate concentrations in Little Platte Lake were one third the concentration in Big Platte Lake. Nitrate concentrations in Little Platte Lake were highest during the winter, dropped to very low levels (< 10 μg/L) in early May and remained low until November (Fig. 11c).

Little Platte Lake algal biomass, as estimated by chlorophyll a concentration, was closely related to nitrate concentration during winter and early spring 2007 and total dissolved phosphorus concentration in the summer (Fig. 11c). Chlorophyll *a* decreased from 11.4 μg/L to 2.6 μg/L during the winter months and exhibited 2 peak levels in June (6.8 μg/L) and August (5.8 μg/L). Mean chlorophyll *a* concentration in Little Platte Lake was 4.4 μg/L in 2007. Chlorophyll *a* concentrations are always higher in Little Platte Lake than in Big Platte Lake. Mean annual chlorophyll *a* concentrations have not changed much over time; however, there was a large increase during winter 2006-07 (Fig. 4).

During the past 3 years, colonial blue-green species have been a prominent feature of the summer and fall phytoplankton assemblage in Little Platte Lake (Fig. 12). In contrast, the Big Platte Lake phytoplankton assemblage is dominated by green algae and flagellates (Fig. 5). Common blue-green genera in Little Platte Lake during 2007 included *Chroococcus, Merismopedium,* and *Microcystis*. Nitrogen-fixing *Anabaena* was also present in low numbers. Green algae, flagellates and diatoms were also present in Little Platte Lake during 2007. The most common green algae were *Scenedesmus, Ankistrodesmus,* and single-celled microgreens. Common flagellates included *Dinobryon* and two cryptomonads (*Cryptomonas*, *Chroomonas*). Centric and small pennate diatoms and the genus *Fragilaria* were abundant throughout the year.

Planktonic algae in Little Platte Lake were most abundant in summer and early fall 2007 when peak cell counts were 10.8 and 10.2 million cells per liter, respectively (Fig. 12). Mean phytoplankton density was higher in 2007 (6.7 million cells per liter) than in 2006 (5.4 million cells per liter) as a result of a large summer bloom of blue-green bacteria. In 2006, phytoplankton densities were high as a result of a spring bloom of green algae (Fig. 12). During the past 2 years, phytoplankton densities in Little Platte Lake were 2-3 times greater than in Big Platte Lake.

The seasonal succession of phytoplankton taxa in Little Platte Lake during 2007 was similar to that in Big Platte Lake except that diatoms do not play a prominent role. Diatoms were present in low numbers throughout the year in Little Platte Lake (Fig. 12). Flagellates were most abundant in the spring. Small green algae and colonial blue-green bacteria were most abundant during the summer and fall. The seasonal succession in 2007 was similar to that in 2005 but differed from that in 2006 when green algae exhibited a large springtime bloom (Fig. 12).

Although colonial blue-greens and flagellates were numerically dominant in Little Platte Lake during 2007, diatoms frequently contributed the most algal biomass (Fig. 13a). Diatom cells are much larger than the cells of most other algal taxa in Little Platte Lake. Diatoms dominated algal biomass during May, August, and November. High turbidity during these times (Fig. 11b) suggests that Little Platte Lake was being mixed by the wind.

Biomass of flagellates, green algae and blue-green bacteria were closely associated with total dissolved phosphorus concentrations in Little Platte Lake during 2007 (Fig. 13a). Peak blue-green biomass in late summer also exhibited an inverse relationship with nitrate concentration. In August and October, biomass of colonial blue-greens (*Chroococcus* and *Merismopedium*) was high and nitrate concentrations were low (Fig. 13b). *Merismopedium* biomass was also high in early spring when nitrate concentrations were high. *Anabaena*, the only nitrogen-fixing blue-green in Little Platte Lake, did not respond to low nitrate conditions.

In 2007, algal biomass in Little Platte Lake ranged from 1.3 to 5.2 mg/L, and mean annual algal biomass was 2.5 mg/L. Algal biomass was low (< 2.0 mg/L) during winter and early summer 2007 (Fig. 14). In 2007, blue-green bacteria were a much larger proportion of total algal biomass than in past years. Mean algal biomass was slightly lower in 2007 than in 2006 (3.0 mg/L). Mean algal biomass in Little Platte Lake was approximately twice that in Big Platte Lake.

Discussion:

Big Platte Lake Food Web

Planktonic organisms in Big Platte Lake include bacteria, protozoans, algae, rotifers, and crustaceans. Bacteria and protozoans interact closely in a "microbial food web". Bacteria ingest organic molecules dissolved in lake water and protozoans eat the bacteria. Algae, rotifers, and crustacean plankton interact with one another, and with larger invertebrates and fish, in a traditional grazing food web (Fig. 15). The Big Platte Lake food web has remained unchanged since 2002. No unique or exotic plankton species were discovered in 2007.

Algae (phytoplankton) constitute the basis for the grazing food web in Big Platte Lake (Fig. 15). Algae use photosynthetic pigments to acquire energy from the sun. They use this energy to create sugars, which are eventually stored as starch or oil. Heavy algal taxa such as the diatoms are abundant during spring and fall overturn when the lake is mixed, top to bottom, by the wind. High diatom biomass in the epilimnion is usually indicative of mixing conditions.

When Big Platte Lake is not mixed, it stratifies into warm surface and cool deep-water layers. Heavy diatoms sink into the hypolimnion and lighter phytoplankton taxa such as green algae and flagellates become abundant. Small green algae and flagellates thrive during the spring and early summer when epilimnetic nutrients (nitrogen and phosphorus) are plentiful. During calm periods in late summer, epilimnetic nitrogen concentrations become low. Colonial blue-green algae become abundant because they can tolerate low nitrogen concentrations and have gas vacuoles that allow them to float near the surface. Added phosphorus during the late summer can enhance the growth of blue-green algae.

When diatoms, flagellates and green algae are abundant in Big Platte Lake, populations of herbivorous zooplankton (rotifers, copepod nauplii, and cladocerans) increase. Nauplii and rotifers are small (80-300 μm) and can only ingest single celled or small colonial green algae and flagellates (Fig. 15). Cladocerans such as *Bosmina* and *Daphnia* are large (400-2500 μm) and can ingest diatoms as well as small green algae and flagellates. Because they can eat a wider range of food sizes, cladocerans may out-compete rotifers and nauplii for food in June when all algal types are abundant.

Planktonic herbivores in Big Platte Lake are most abundant when densities of green algae and flagellates are high. Peak rotifer abundance coincided with green algae densities during each year of this study (compare Figs. 5 and 9). Peak cladoceran abundance coincided green algae peaks in 2003 and 2005 but also with a June flagellate peak in 2004. Rotifers and cladocerans reproduce asexually and their populations can increase quickly when food is abundant. Copepods reproduce sexually and rarely produce more than three sets of nauplii in a year. The copepods in Big Platte Lake produced nauplii in late May and August when edible algae were most abundant.

Among the cladocerans, the temporary replacement of *Bosmina* by *Daphnia* in July can be explained by species-specific growth rates and feeding ability. *Bosmina* is smaller than *Daphnia* and grows more quickly in the cool epilimnion early in the summer. As water temperature increases, so do *Daphnia* populations. By July, the large herbivore is abundant and feed heavily on green algae thereby reducing its abundance. In August, the blue-green alga *Microcystis* becomes abundant. *Microcystis* can be toxic to *Daphnia* and is difficult to ingest. *Bosmina*, however, can avoid the blue-green colonies and feed on green algae and flagellates. A growing *Bosmina* population soon surpasses the stagnant *Daphnia* population.

Abundance of planktonic crustaceans and rotifers was lower in 2004 than in other years because the density of edible green algae was low in 2004. Abundant green algae fueled fast-growing populations of rotifers and cladocerans. Green algal counts were never more than 400,000 per ml in 2004. Cladoceran abundance was low in 2006 even though the density of flagellates was quite high. Low abundance of edible green algae during 2006 or competition from abundant rotifers may have been responsible for poor cladoceran growth. Alternatively, cladocerans may be feeding on algae, but may in turn be eaten by planktivorous fish.

Predators in Platte Lake include cyclopoid copepods and planktivorous fish (Fig. 15). Cyclopoid copepods feed on protozoans and rotifers during all juvenile and adult (copepodid) life stages. Larval and juvenile fish are visual predators that actively select large prey such as adult copepods and cladocerans. Some fish species such as alewife, yellow perch, and sunfish also feed on plankton as adults. If fish predation is intense, small-bodied taxa (ex: rotifers, nauplii) will dominate the zooplankton.

Phytoplankton Growth in Big and Little Platte Lake

The growth of algal populations in Big and Little Platte Lake appears to be governed by mixing events, regional climate, and phosphorus concentrations. High turbidity and high diatom biomass during April and November are consistent with overturn events in a dimictic lake. During overturn, inorganic sediment and diatom frustules are re-suspended in the lake. Turbidity and diatom biomass data also indicate that Little Platte Lake and the epilimnion of Big Platte Lake are mixed by a prolonged wind events July and August. In Big Platte Lake, inorganic sediment and diatom frustules from shallow depths were re-suspended throughout the epilimnion as the wind blew. Multiple turbidity and diatom biomass peaks during summer 2007 suggest that Little Platte Lake is frequently mixed by the wind.

Regional climate may be an important factor governing the growth of phytoplankton in Big Platte Lake. The spring diatom biomass peak occurred later each year between 2003 and 2006 (Fig. 8), but appeared early once again in 2007. A multi-year cycle of warming and cooling may correspond to the appearance of the spring diatom bloom. Spring diatom peaks in Little Platte Lake show a similar pattern; however, additional peaks make interpretation difficult.

Mean TP and chlorophyll concentrations indicate that Big Platte Lake is meso-oligotrophic and Little Platte Lake is mesotrophic. In Big Platte Lake, mean TP concentration was below the cut-off for a mesotrophic lake (10 μg/L) but mean chlorophyll concentration was above the cut-off (2 μg/L). In Little Platte Lake, mean TP and chlorophyll concentrations were well within the range for a mesotrophic lake (TP: 10-30 μg/L, Chl: 2-9 μg/L).

Phytoplankton grow particularly well in Little Platte Lake during the summer. Algal biomass and chlorophyll a concentrations were twice as high in Little Platte Lake than in Big Platte Lake. High pH in Little Platte Lake during the summer is consistent with high algal photosynthetic rates. As algae use CO_2, the carbonic acid equilibrium shifts and hydrogen ions are no longer produced.

Close correspondence between chlorophyll a and phosphorus concentration indicates that phytoplankton growth in Big and Little Platte Lake may be limited by phosphorus, not nitrate. Although nitrate concentrations are inversely correlated with blue-green biomass in Big and Little Platte Lake, it is unlikely that there is a cause-effect relationship. The dominant blue-green bacterium in both lakes, the colonial genus *Merismopedium*, is not a nitrogen fixer and must obtain inorganic nitrogen (nitrate and ammonium) directly from the water. Moderate ammonium concentrations in Big and Little Platte Lake would permit the growth of *Merismopedium*. More likely, physical factors such as light, temperature or mixing are responsible for high biomass of *Merismopedium* during the summer.

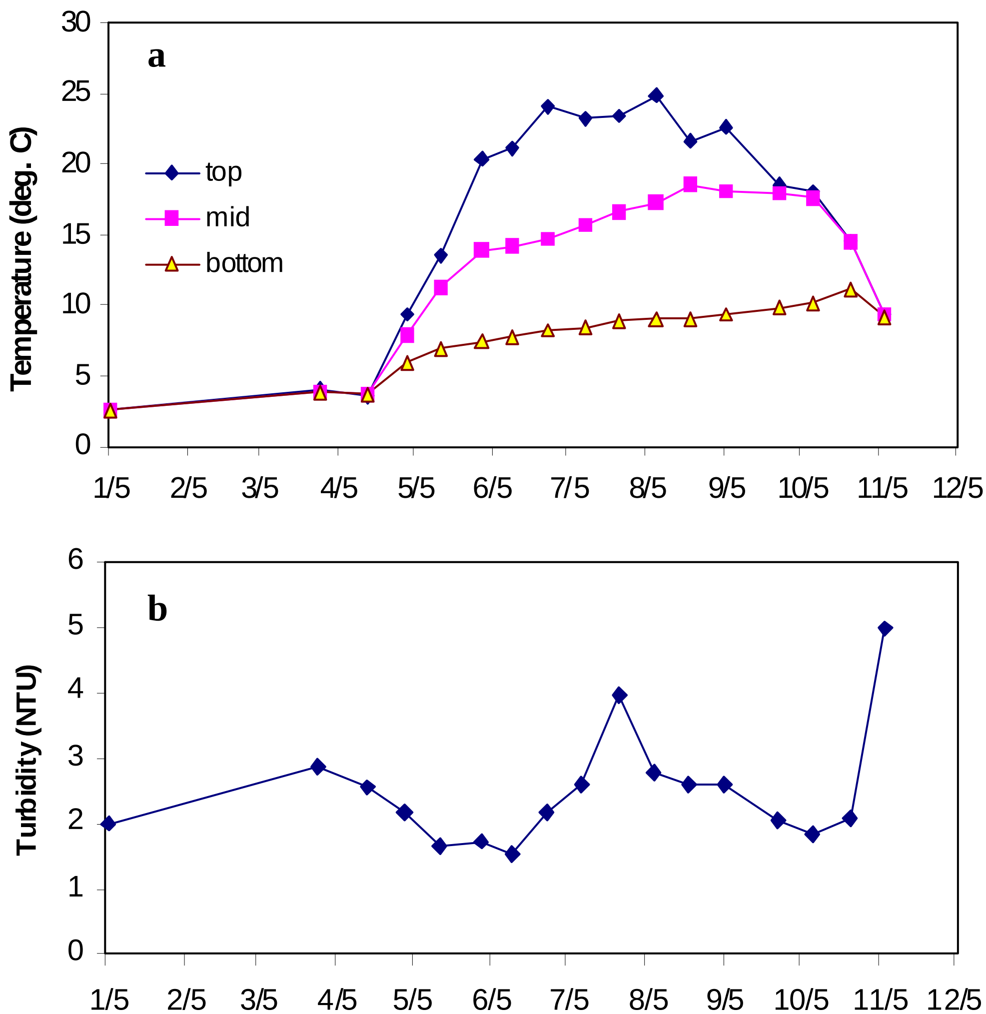

Figure 1: Temperature (a) and Turbidity (b) of top (0-15 ft.), middle (30-45) and bottom (60-90) waters in Big Platte Lake, MI during 2007.

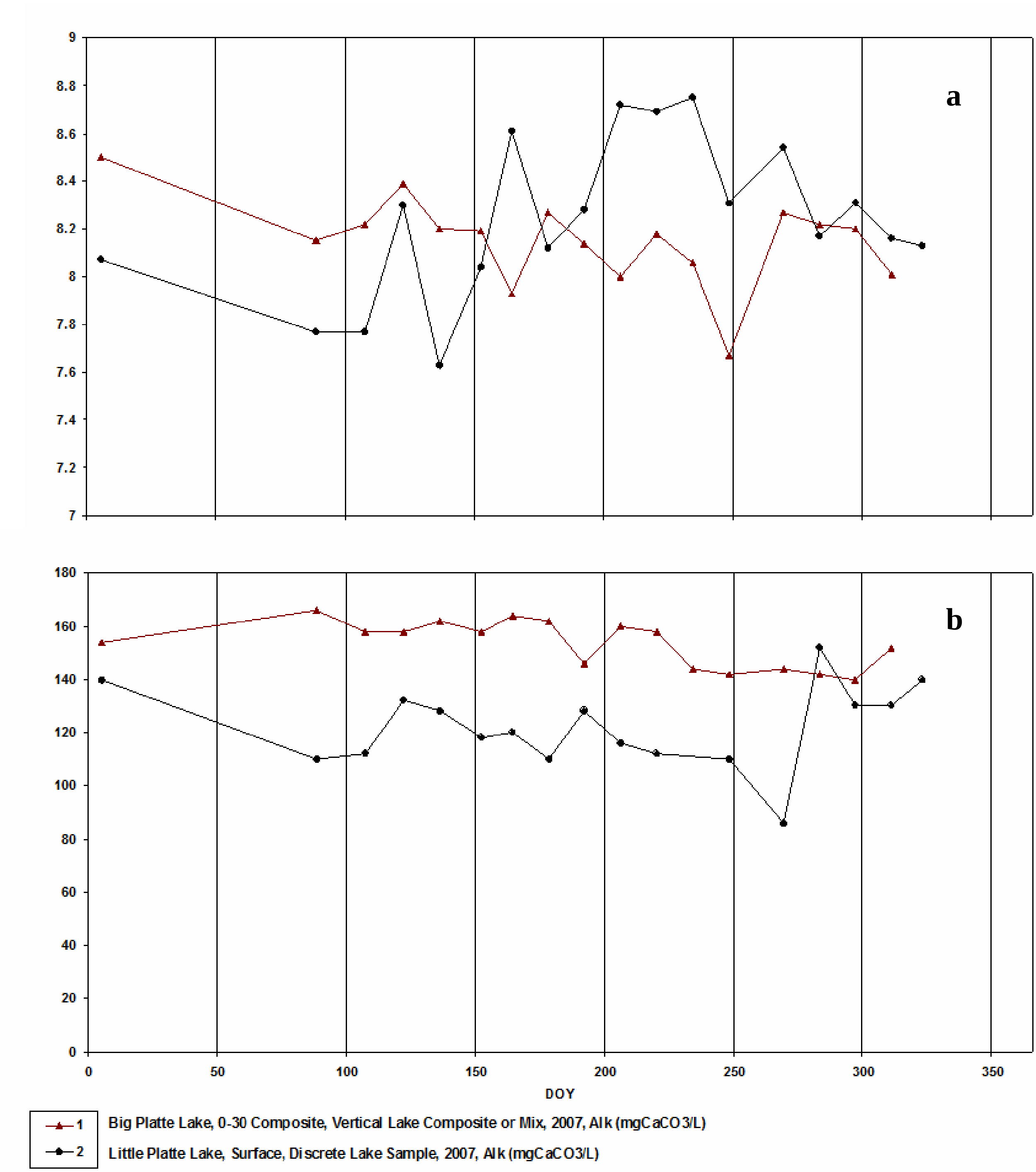

Figure 2: Surface pH (a) and epilimnetic (0-30 ft.) Alkalinity (b) in Big and Little Platte Lake, MI during 2007.

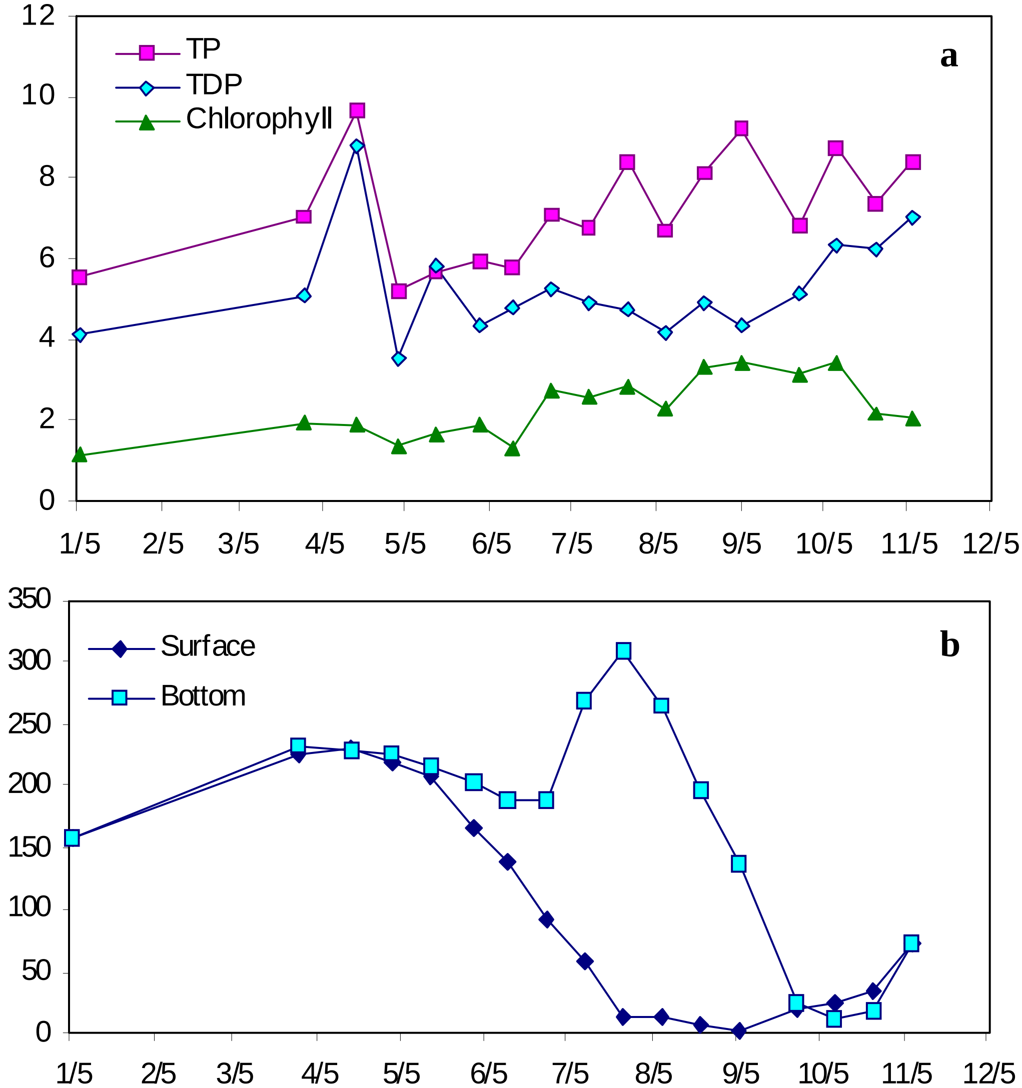

Figure 3: Epilimnetic phosphorus (total and total dissolved) and chlorophyll (a) and surface and bottom nitrate (b) in Big Platte Lake, MI during 2007.

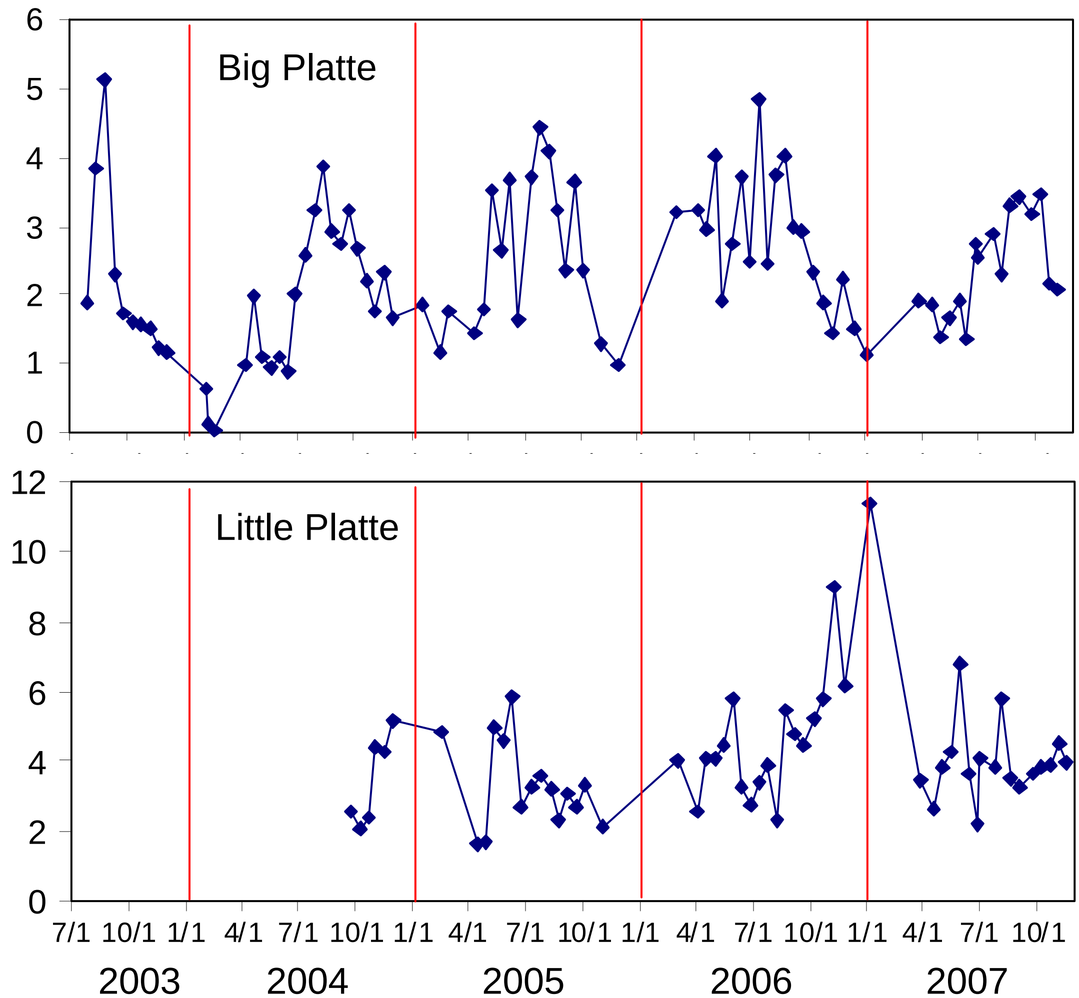

Figure 4: Epilimnetic chlorophyll a concentration in Big and Little Platte Lake, MI 2003-2007. Mean concentrations in Big Platte Lake during 2003-2007 were 2.19, 1.85, 2.53, 2.87, and 2.31 μg/L, respectively.

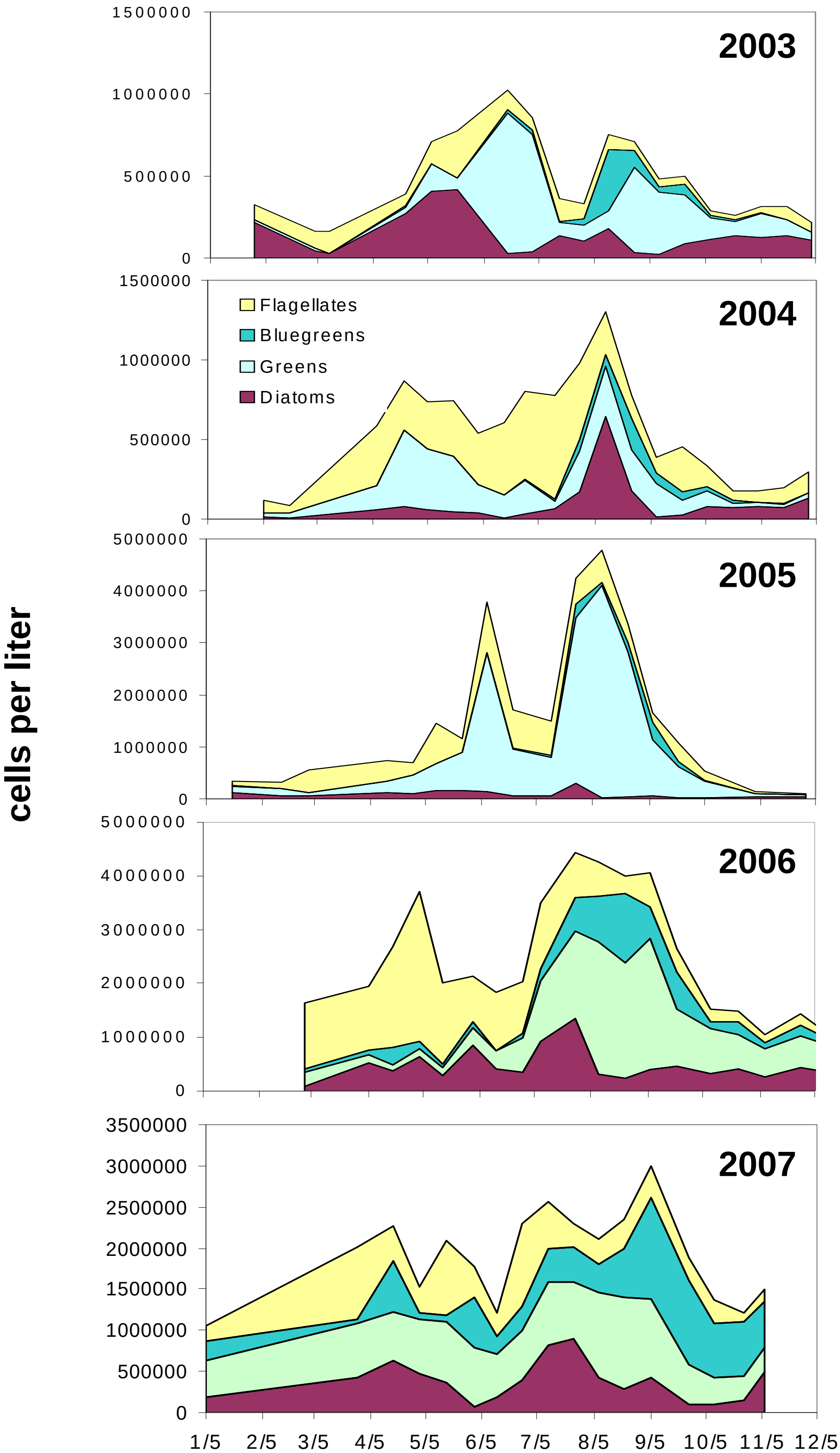

Figure 5: Epilimnetic phytoplankton density in Big Platte Lake, MI during 2003-2007. Note change of scale in 2005.

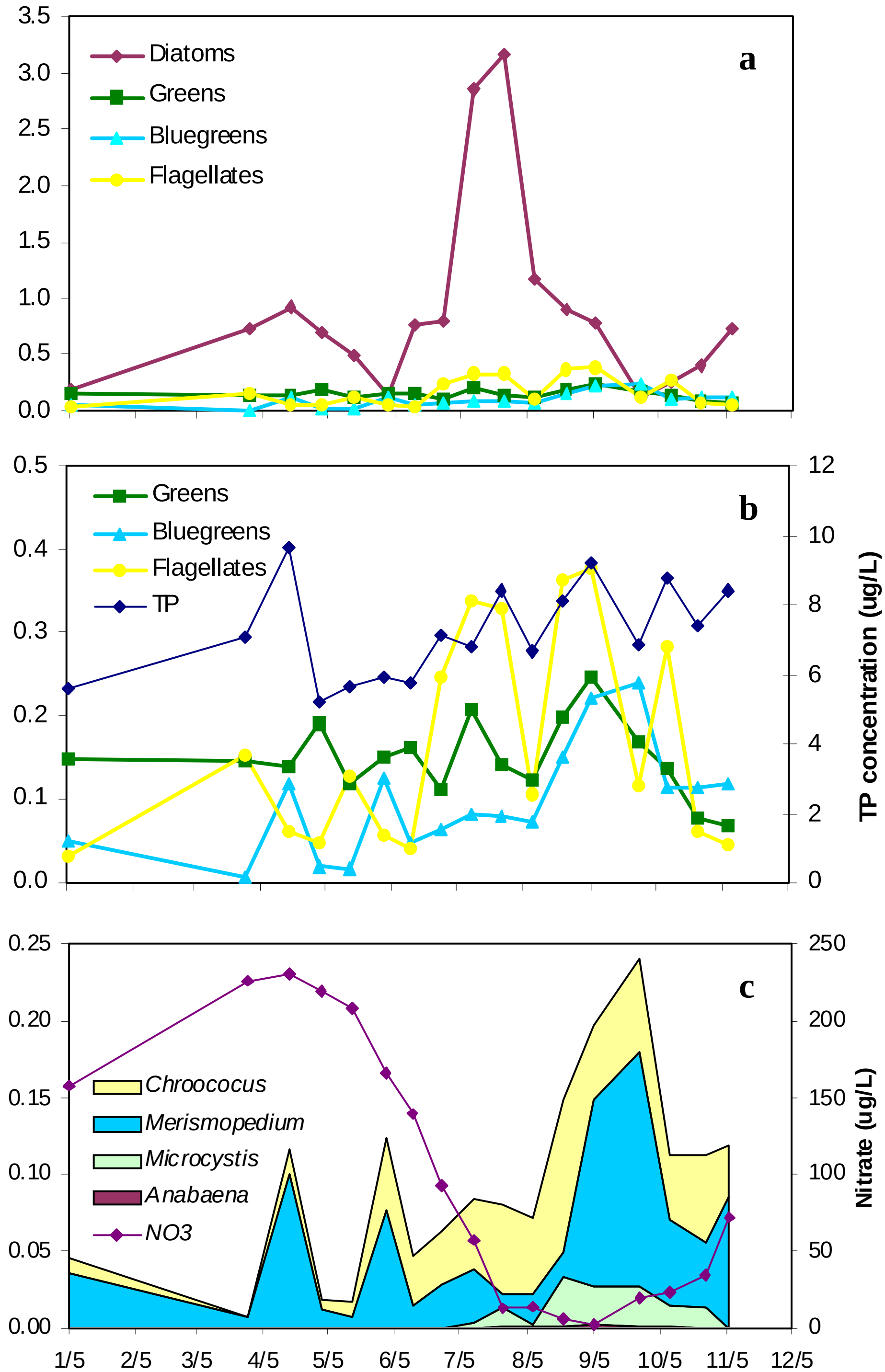

Figure 6: Biomass (wet wt.) of all phytoplankton groups (a), sub-dominant groups and total phosphorus (b), and blue-green taxa with nitrate (c) in Big Platte Lake, MI during 2007.

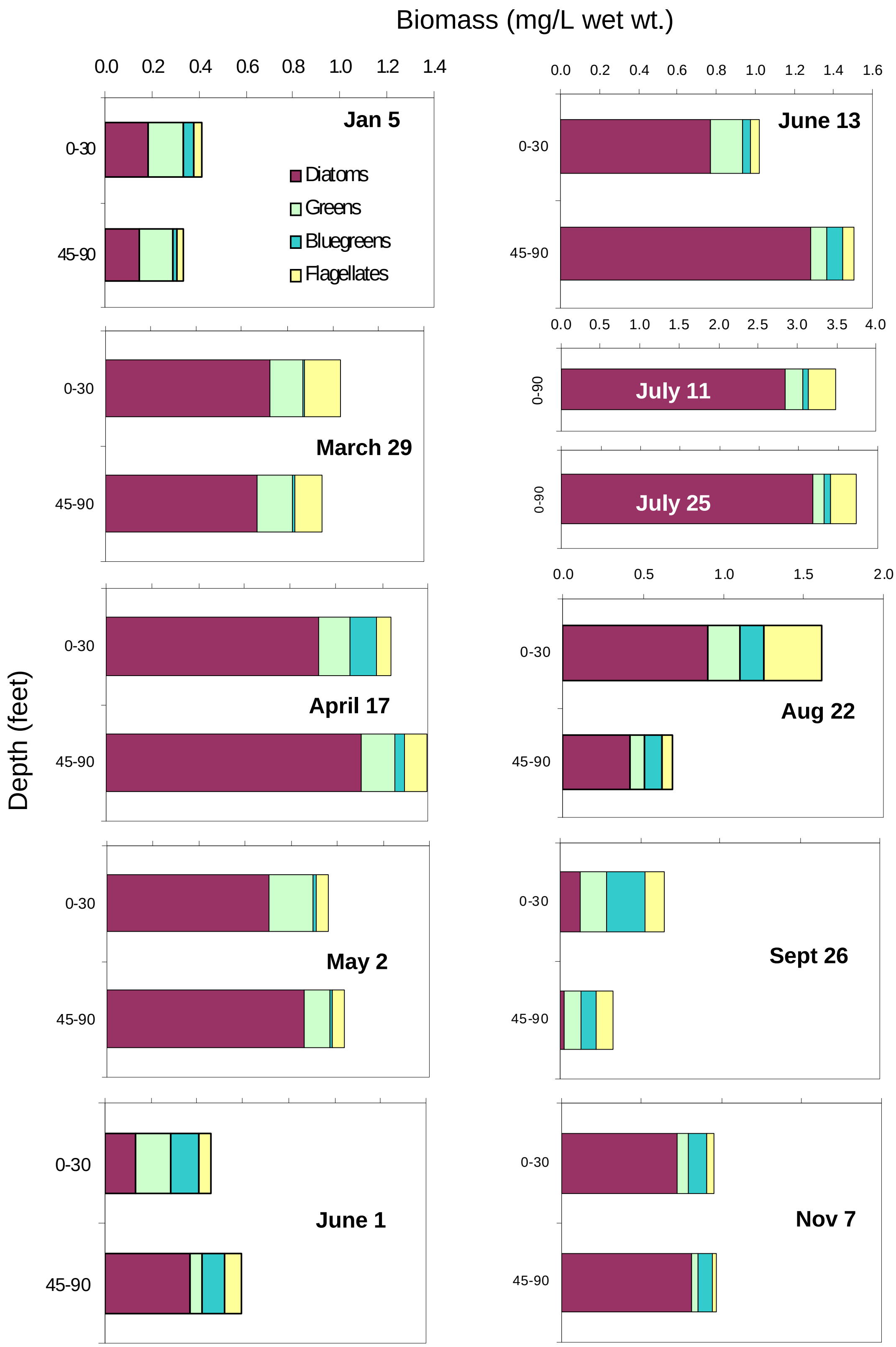

Figure 7: Phytoplankton biomass in the epilimnion (0-30 ft.) and hypolimnion (45-90 ft.) of Big Platte Lake, MI, 2007. Note change of biomass scale in July and August.

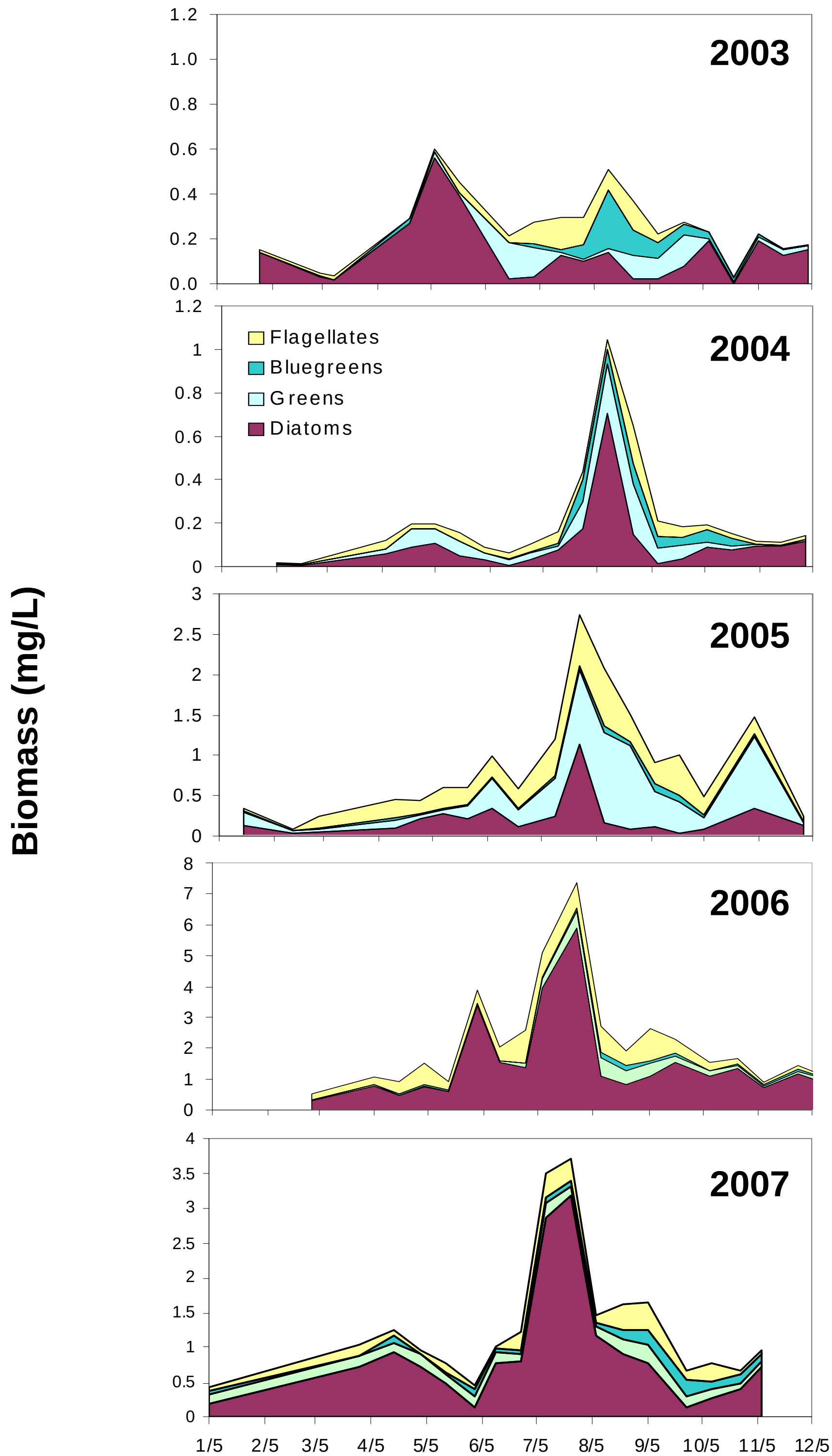

Figure 8: Epilimnetic phytoplankton biomass (wet wt.) in Big Platte Lake, MI during 2003-2007. Note change of scale in 2005.

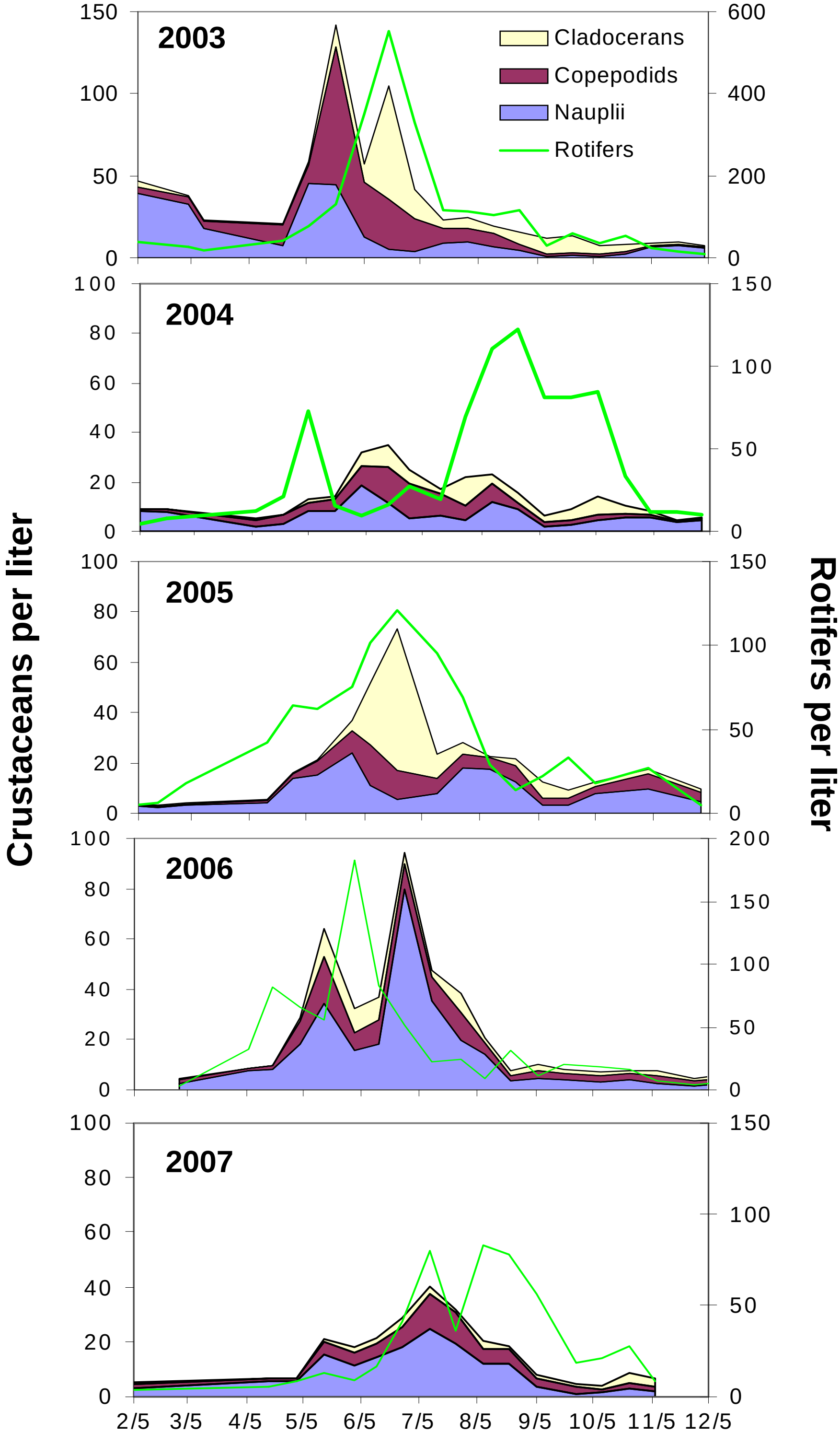

Figure 9: Average zooplankton density in Big Platte Lake, MI during the years 2003-2007. Note change in scales.

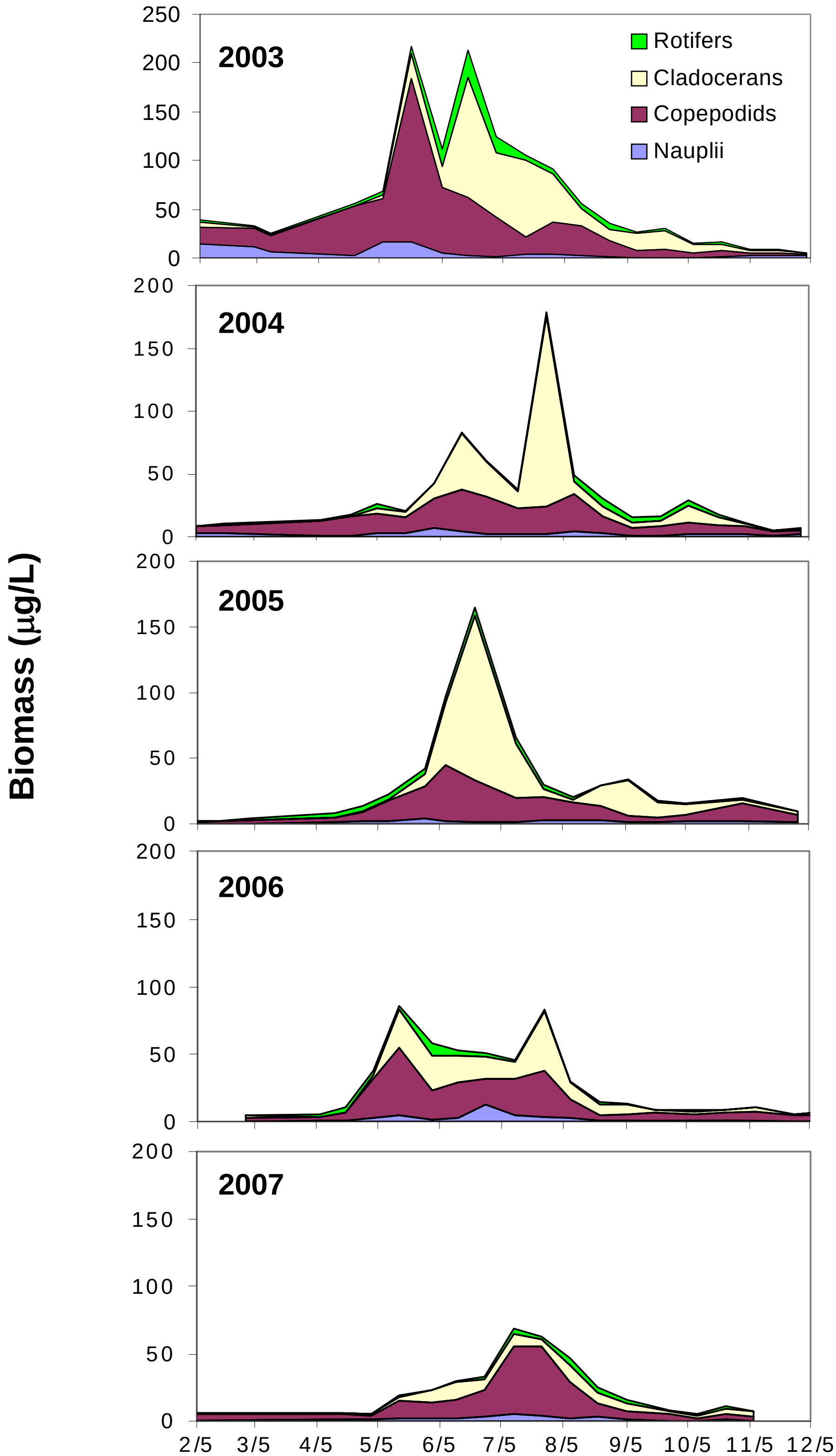

Figure 10: Average zooplankton biomass (dry wt.) in Big Platte Lake, MI during the years 2003-2007.

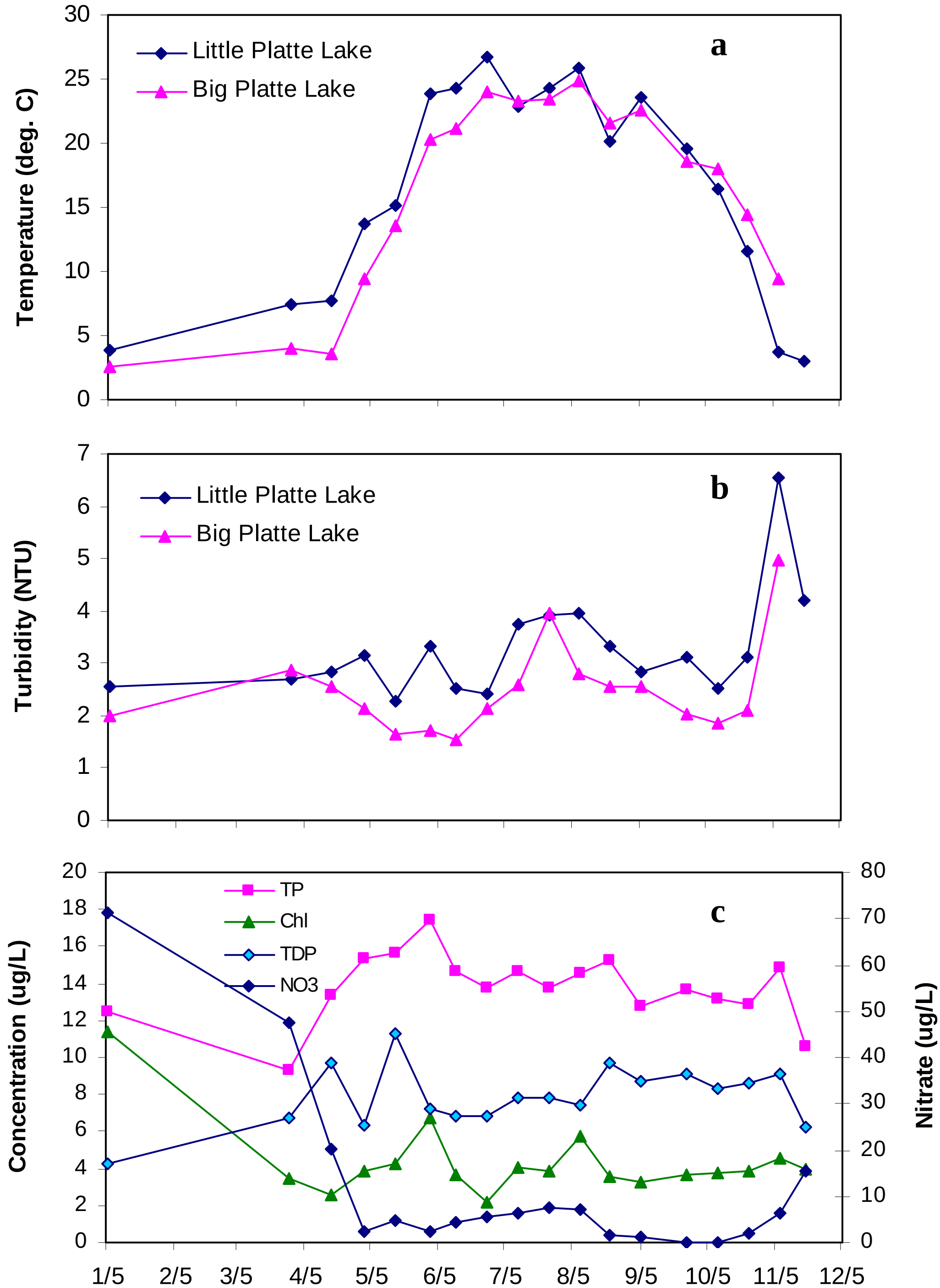

Figure 11: Temperature (a) and turbidity (b) in Little and Big Platte Lake, MI during 2007. Nutrients (total phosphorus, total dissolved phosphorus, nitrate) and chlorophyll *a* (c) in Little Platte Lake, MI during 2007

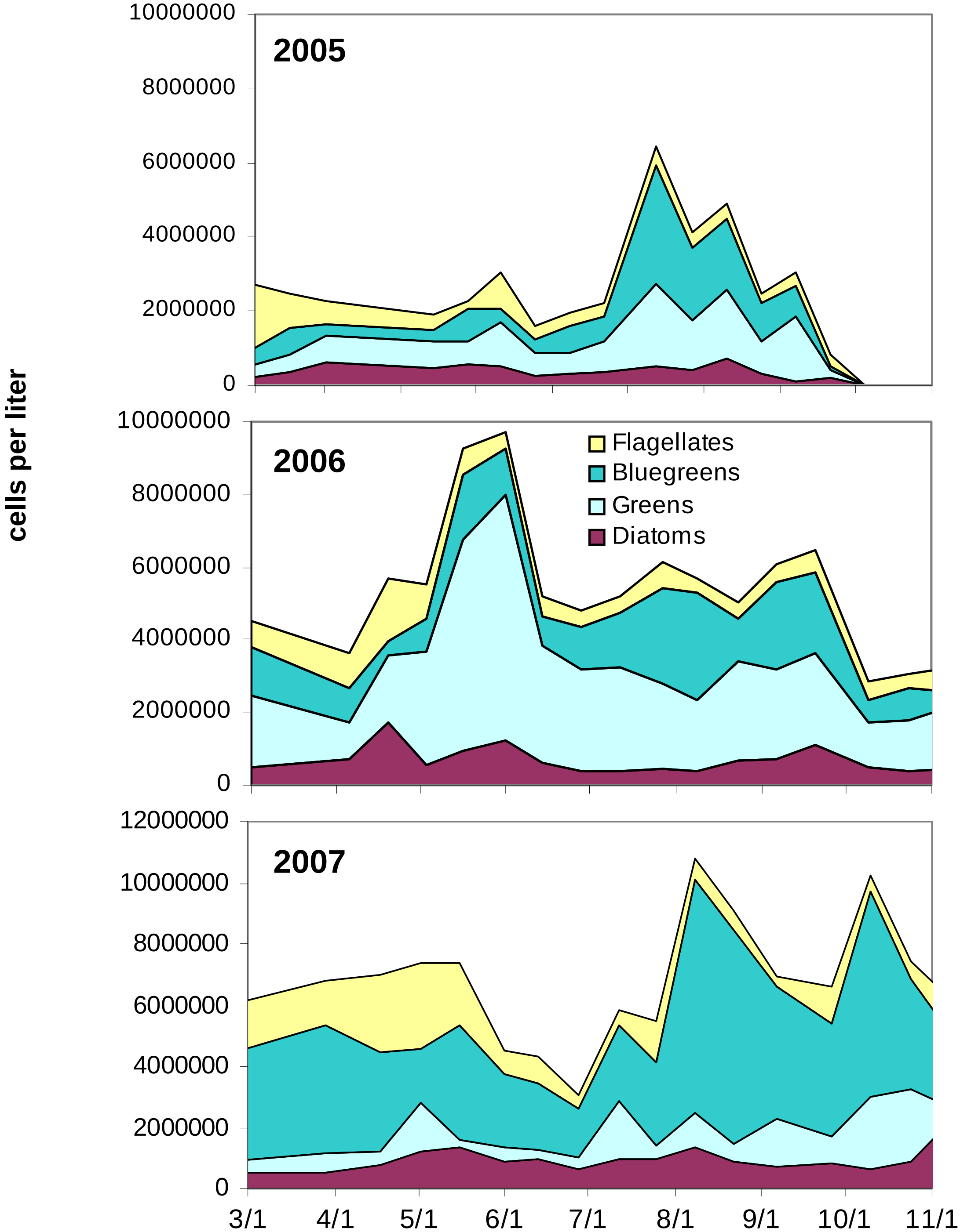

Figure 12: Phytoplankton density Little Platte Lake, MI during 2005-2007. Note change in scale.

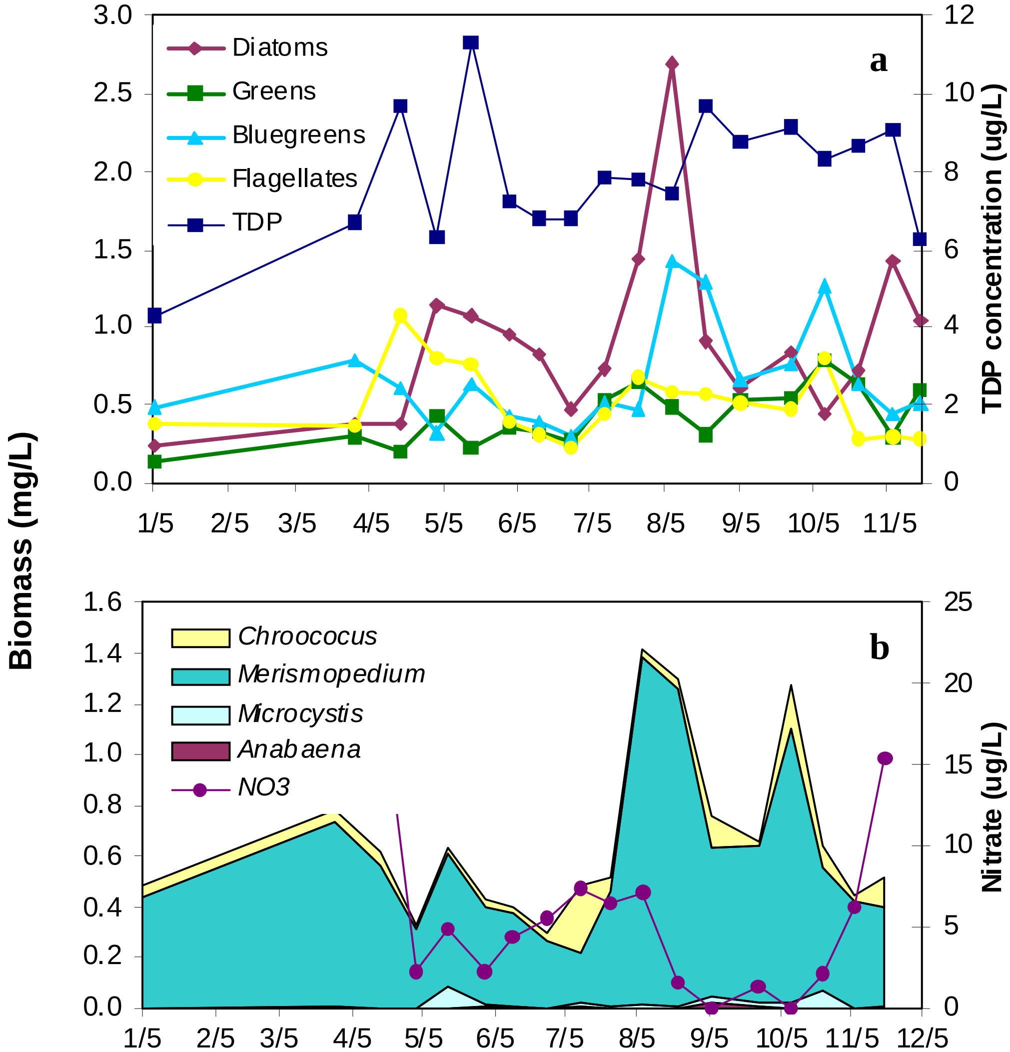

Figure 13: Biomass (wet wt.) of all phytoplankton groups and blue-green taxa with nitrate (b) in Little Platte Lake, MI during 2007.

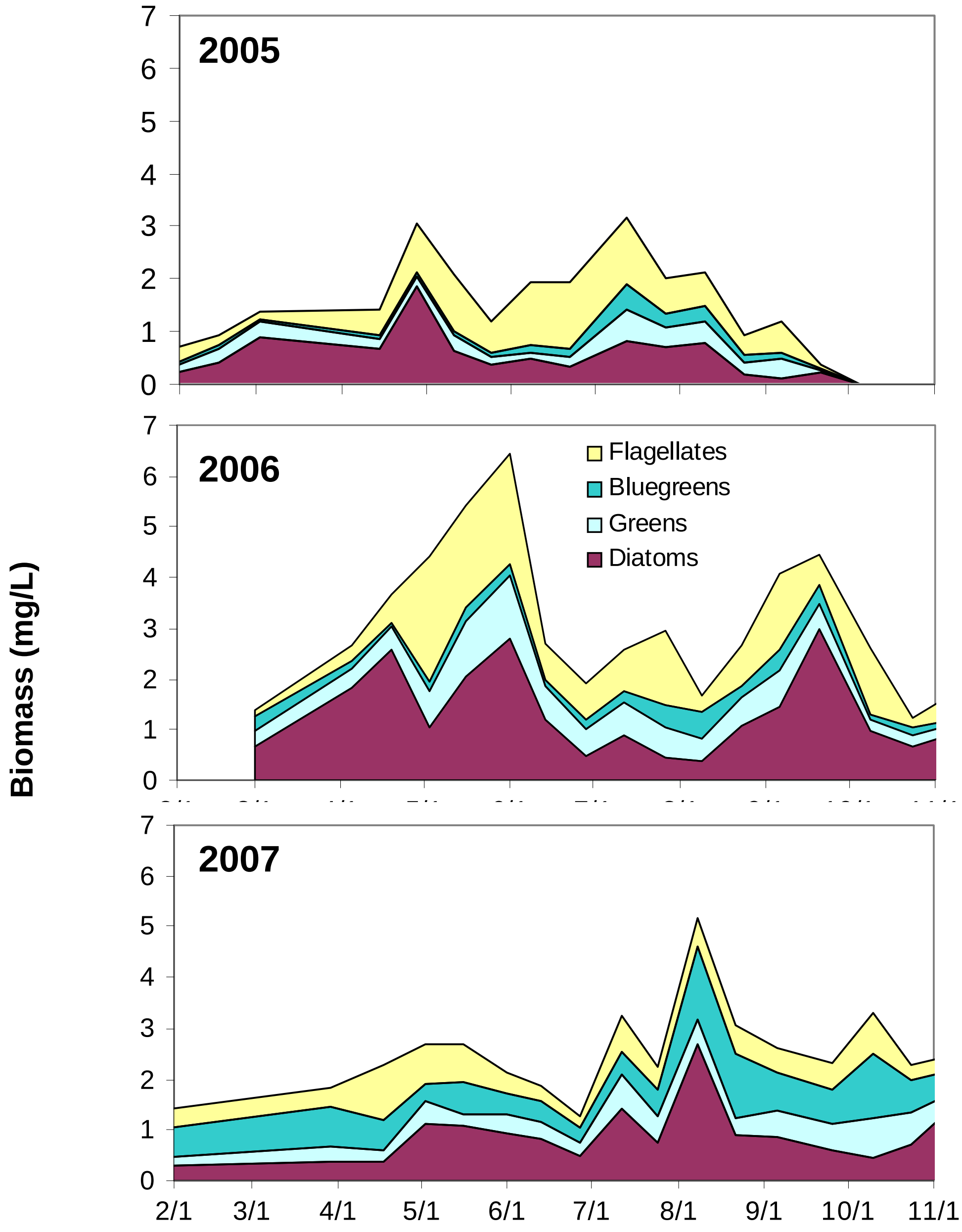

Figure 6: Phytoplankton biomass (wet wt.) in Little Platte Lake, MI during 2005-2007.

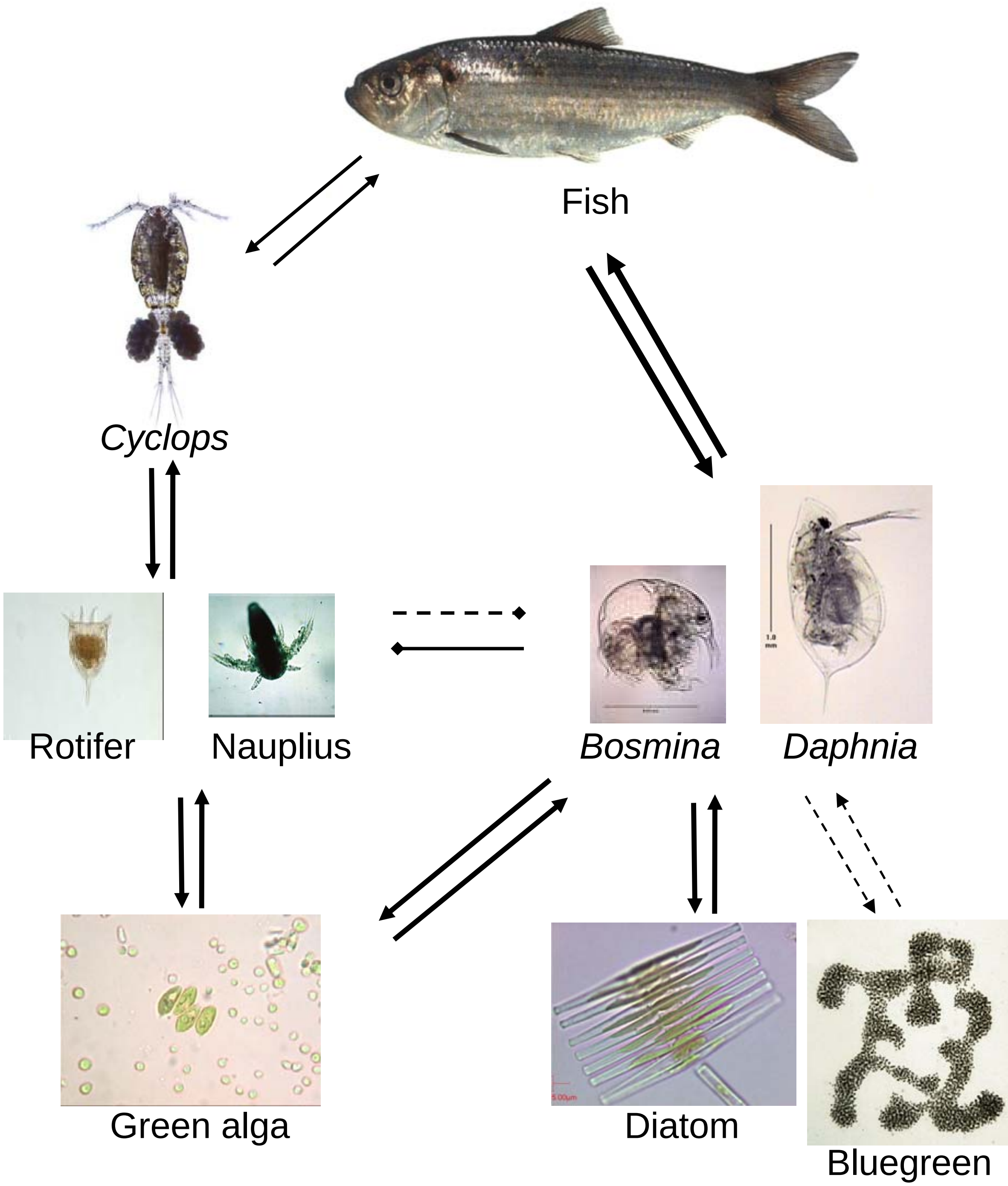

Figure 11: Platte Lake Food Web. Sharp arrow heads indicate direct feeding relationship (positive/negative interaction). Blunt arrow heads indicate indirect competition (negative/negative interaction). Thickness of arrow is proportional to strength of the interaction.