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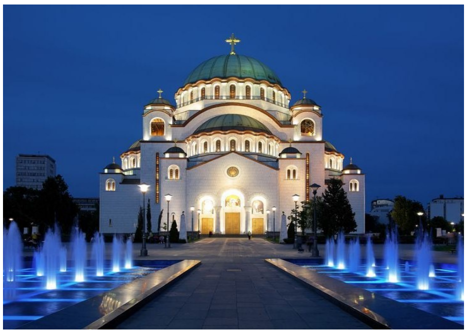

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CONTENT

WATER SUPPLY

SEWAGE MANAGEMENT AND WASTEWATER TREATMENT

"Blooming" Reservoir Response to a High Inflow Event - Case Study: the Vrutci Reservoir (Western Serbia)

D.Kostić*, A. Blagojevic**, G. Subakov Simic**, D. Predojevic**, Z. Naunovic*, N. Jacimovic*, S. Grasic***

* Faculty of Civil Engineering, Universtiy of Belgrade, Bulevar kralja Aleksandra 73, 11000 Belgrade, Serbia (E-mail: *dkostic@hikom.grf.bg.ac.rs)*
** Faculty of Biology, University of Belgrade, Studentski trg 16, 11000 Belgrade, Serbia (E-mail: *gsubak@bio.bg.ac.rs)*
*** Public Water Supply Utility JKP Vodovod-Kruševac, Dušanova 46, 37000 Kruševac, Serbia

Abstract
The influence of a high flood event on the population of potentially toxic cyanobacteria *Planktothrix rubescens* (DeCandolle ex Gomont) Anagnostidis & Komárek in the Vrutci Reservoir (Western Serbia) was investigated in the presented work. In December 2013, intensive bloom of potentially toxic cyanobacteria *P. rubescens*, took place in a multipurpose reservoir Vrutci. After a high precipitation event in May 2014, almost 25% of reservoir water were replenished with a runoff from the watershed area. High rate of water exchange flushed out phytoplankton significantly, reducing its abundance. Intensive mixing lead to a more uniform distribution of all water quality indices over the depth. High inflow caused strong horizontal advective flow which pushed the vast of the phytoplankton population closer to the dam (sampling location Vodozahvat). At the same time torrential tributaries introduced additional amounts of nutrients from catchment which is prone to the pluvial erosion. Inspite the decrease in overall algae abundance, *P. rubescens* retained its dominance in the phytoplankton community.

Keywords
Cyanobacterial bloom; flood event; multipurpose reservoirs

INTRODUCTION

Lake and reservoir ecology is strongly influenced by sporadic and intense events such as flood events and storms (Tartari, 2005). Due to this influence, the ecological behaviour of a lake (or reservoir) can be understood as an array of multiple impulses, rather than as a continuous process (Spiegel and Imberger, 1987). The phytoplankton community in reservoirs is highly influenced by high flow-through events due to nutrient and light limitations and direct algae flushing (Tartari, 2005; Vanni et. al, 2005; Reichwaldt and Ghadouani, 2012; Rolland et. al 2013).

The influence of a high flood event on the population of potentially toxic cyanobacteria *Planktothrix rubescens* (DeCandolle ex Gomont) Anagnostidis & Komárek in the Vrutci Reservoir (Western Serbia) was investigated in this research. *P. rubescens* is one of the most studied organisms among filamentous cyanobacteria, primarily due to early seasonal occurrence (can lead to a flowering of water in winter) and impressive visual appearance when flowering, but also because it can inflict a lot of damage if appear and "bloom" in lakes that are used for water supply (Dokulil and Teubner, 2011). This species is stenotherm, largely distributed in middle European cold waters (Reynolds, 1984) and Southern sub-alpine lakes (Garibaldi et al., 2000). Mass occurence of *P. rubescens* have been recorded in the metalimnion of oligo-mesotrophic lakes that are often used as drinking water supplies (Loizzio et al., 1988; Barco et al., 2004). In relation to other cyanobacteria Planktothrix spp. have been shown to contain the highest concentracions of microcystin per unit mass of dry weight (Fastner et al., 1999b). The mass occurrence of *P. rubescens* can be ascribed to efficient regulation of buoyancy via semi-permeable gas vesicles as well as production of photopigments enabling maximum utilisation of light energy and existence under low light conditions (allophycocyanin, phycocyanin and phycoerythrin) (Feuillade, 1994; Walsby and Schanz, 2002). Due to these capabilities, *P. rubescens* is usually located in compact metalimnetic layers overshadowed by the epilimnic community during summer stratification, and can grow under low light conditions during spring and autumn circulations or even below an ice cover during the winter (Blikstad-Halstvedt et al., 2007). Moreover, it has the physiological advantage as it is capable to utilize organic compounds of phosphorous in the absence of phosphates (Feuillade, 1994).

MATHERIAL AND METHODS

Study Site and Case Scenario

The Vrutci Reservoir (43° 50' 34" N, 19° 41' 36" E), is a multipurpose reservoir on the River Djetinja in Western Serbia. It was formed in 1984, by damming river Djetinja for the purposes of: water supply, flood protection, sediment control and low flow enrichment. It is the main potable water source for the City of Uzice, the surrounding settlements and the local industry. Normal operational water table level is at the 621 m a.s.l. altitude and the reservoir has the total volume of 54 milion cubic meters. Residence time is approximately 400 days. Watershed has the area of 160 sqare kilometers and is rarely populated. Inspite the fact that reservoir Vrutci has been in use for almost 30 years it has been exploited without utilization permission due to the abscense of antierosion dams on torrential tributaries.

In December 2013, a severe *P. rubescens* bloom occurred in the reservoir and caused disruption of the regular water supply for more than 40 days. In the past, water quality of reservoir Vrutci was monitored once a year or once in a two years. Lack of comperhensive water quality database makes all today *a posteriori* analysis of the bloom triggers very difficult with high level of uncertainty.

An intensive flood event occurred between May 13th and 16th, 2014, when 110 mm of rainfall was recorded on the watershed during four consecutive days. Approximately 25% of the reservoir water was replenished. Diagrams on Figure 1, depicts water budget of reservoir Vrutci before, after and durrig the flood event.

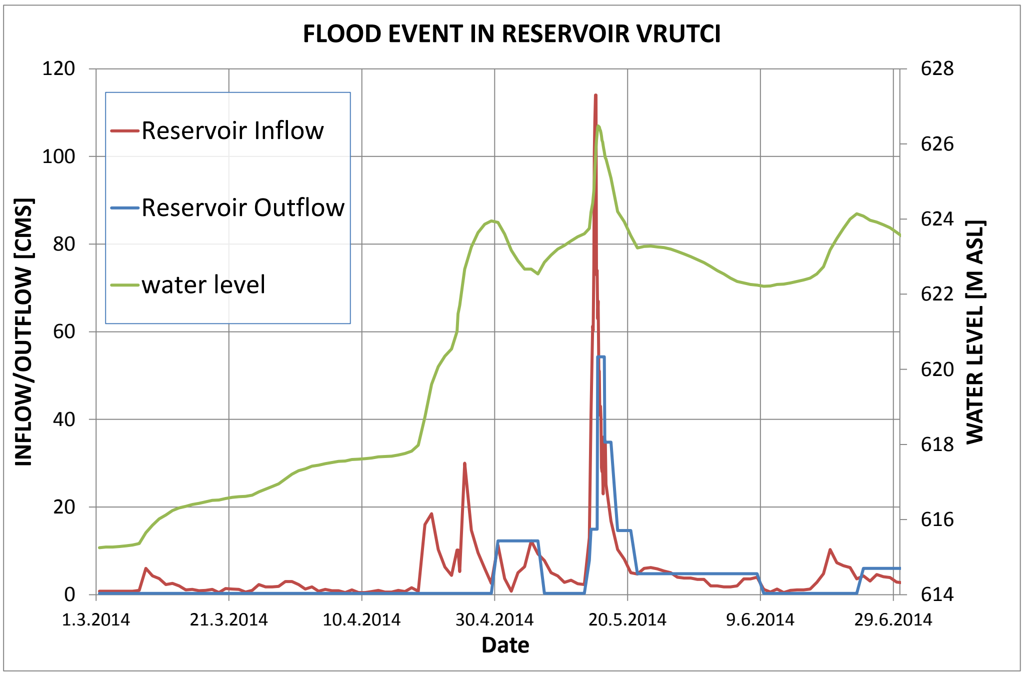

Figure 1. Water budget components: Inflow, Outflow and Water Level (Volume) of Vrutci before, during and after the flood event.

Sample colection in the field and Laboratory Measurements

After the cyanobacterial bloom in December 2013, University of Belgrade (Faculty of Civil Engineering and Faculty of Biology) has established water quality monitoring of the reservoir Vrutci on the monthly basis under the national grant TR37009 (Ministry of Education, Science and Technology of the Republic of Serbia). Monitoring consists from measurements of the basic water quality indices by the aid of multiparameter probe and from phytoplankton analysis. Phytolankton is samped on three locations (Figure 1), while water quality profiling is being done on the two additional locations. Before water sampling for quantitative and qualitative phytoplankton analysis, vertical profiles of basic water quality indices were sampled with multiparameter probe (YSI 6600V2-2). Multiparameter probe is capable to sample and logg few parameters at the time: water temperature, actual depth, conductivity, pH, TDS, DO concentration, DO saturation and Chlorophyll a. In the case of the appereance of peaks on the vertical profile of Chl a, water samples were taken from that particular depth, otherwise samples were taken randomly over the depth, but at least with 5 meter increments.

Composite samples for qualitative analyses of phytoplankton were collected with a plankton net (30 cm mouth, mesh size 22-23 µm), while samples for quantitative analyses were collected using Ruttner bottle (volume 1 L). Samples were placed in a flasks and preserved with Lugol's solution. The algal taxa were identified with the aid of the Karl Zeiss Imager M1 AvioCam MRc5 light microscope using standard keys. The total abundance of phytoplankton was determined by the Utermöhl method (Utermöhl, 1958) on Leica inverted light microscope and expressed as number of individuals per mililiter (ind/mL) and as a number of cells per mililiter (cell/mL). Estimates of species cell mass/volume were adopted from the literature and expressed as biomass (mg/L).

Figure 2. Water sampling positions: Vodozahvat, Nikolici and Omar marked with placeholders on the Google map

RESULTS AND DISCUSSION

Qualitative analysis of phytoplankton

There is a mixed community of algae and cyanobacteria in phytoplankton of reservoir Vrutci. Phytoplankton are characterized by low diversity of taxa and the dominant presence of cyanobacteria *Planktothrix rubescens*, Table 1. The presence of seven phyla was determined: Cyanobacteria, Bacillariophyta, Chlorophyta, Euglenophyta, Cryptophyta, Dinophyta and

Chrysophyta. The same number of species were determined in April and in May (22 species). The greatest diversity is represented in Chlorophyta (7 taxa), while the lowest at under Chrysophyta (2 taxa). Diversity of algae is uniform. There is no significant difference in phytoplankton composition between April and May 2014.

Table 1. Qualitative composition of phytoplankton in reservoir Vrutci in April and May 2014

Phylum	Taxa	April	May
Cyanobacteria	*Aphanocapsa holsatica* (Lemmermann) G.Cronberg & Komárek	+	+
	Aphanothece clathrata West & G.S.West	+	+
	Planktolyngbya limnetica (Lemmermann) J.Komárková-Legnerová & G.Cronberg	+	
	Planktothrix rubescens (De Candolle ex Gomont) Anagnostidis & Komárek	+	+
Bacillariophyta	*Cyclotella comta* (Ehrenberg) Kützing	+	+
	Cyclotella ocellata Pantocsek	+	+
	Fragilaria crotonensis Kitton	+	+
	Fragilaria ulna var. *angustissima* (Grunow) Krammer & Lange-Bertalot	+	+
	Nitzschia acicularis (Kützing) W.Smith		+
	Pinnularia Eh. sp.	+	
Chlorophyta	*Chlamydomonas* Ehrenberg sp.	+	+
	Monoraphidium arcuatum (Korshikov) Hindák	+	
	Monoraphidium griffithii (Berkeley) Komárková-Legnerová		+
	Monoraphidium indicum Hindak		+
	Monoraphidium minutum (Nägeli) Komárková-Legnerová	+	+
	Oocystis marssonii Lemmermann	+	+
	Tetraedron minimum (A.Braun) Hansgirg	+	+
Euglenophyta	*Trachelomonas oblonga* Lemmermann	+	+
	Trachelomonas volvocina (Ehrenberg) Ehrenberg	+	+
Cryptophyta	*Cryptomonas erosa* Ehrenberg	+	+
	Cryptomonas marssonii Skuja		+
	Rhodomonas minuta var. *nannoplanctica* H.Skuja	+	+
Dinophyta	*Gymnodinium helveticum* Penard	+	
	Sphaerodinium cinctum (Ehr.) Wol.	+	+
	Woloszinskia coronata Thompson	+	
Chrysophyta	*Dinobryon divergens* O.E.Imhof	+	+
	Kephyrion litorale Lund		+

Quantitative analysis of phytoplankton

Population of *P. rubescens* almost exclusively dominated in communities of phytoplankton. There is insignificant presence of other algae comparing with representatives of cyanobacteria. In the case of the number of individuals, silicate and green algae have the greatest abundance, but their share in the number of cells and total biomass is insignificant, Figure 3 and Figure 4. All given results are related to the measurement location Vodozahvat in the close vicinity of the dam.

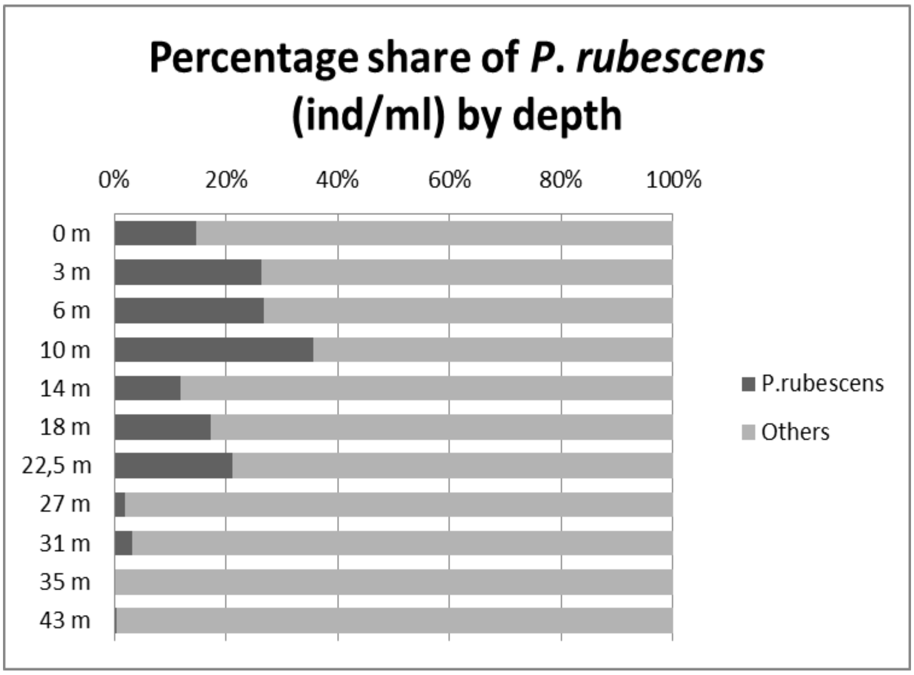

Figure 3. Percentage share of *P. rubescens* (individuals per milliliter) by depth in April of 2014

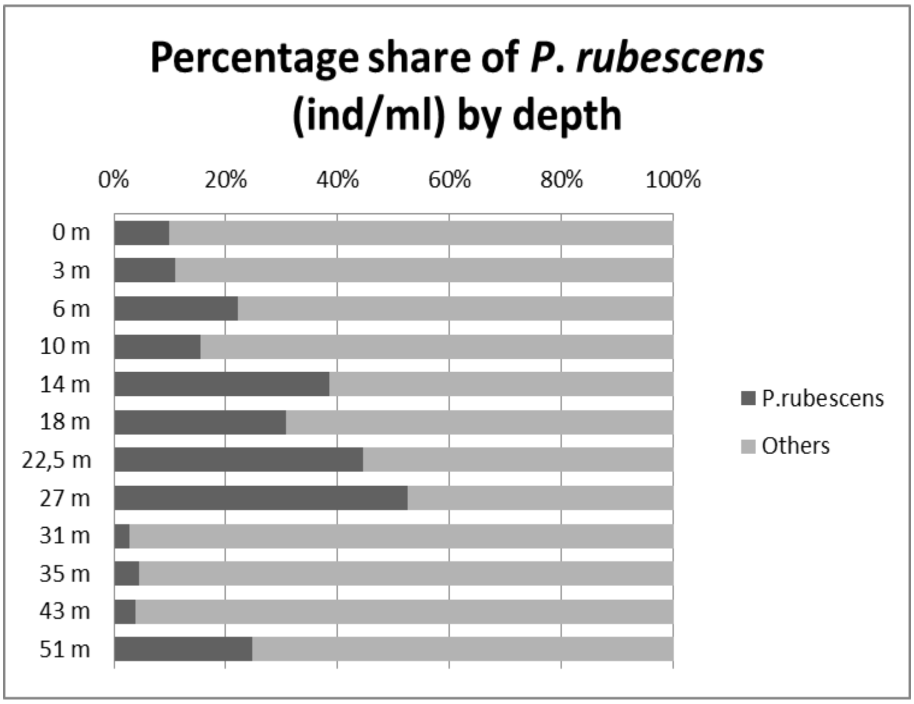

Figure 4. Percentage share of *P. rubescens* (individuals per milliliter) by depth in May 2014

April 2014. P. rubescens cells have the greatest number along the entire vertical profile of reservoir, exept for the deepest parts (over 30 m) (Fig. 2). At these depths the presence of coccal, colonial cyanobacteria *Aphanocapsa holsatica* (Lemmermann) G.Cronberg & Komárek and *Aphanothece clathrata* West & G.S.West was recorded. The dominance of *P. rubescens* can be best seen if we look at the vertical profile of the phytoplankton biomass. High concentration of potentially toxic *P. rubescens* at 6 meters depth is obvious, where its biomass was 4,31 µg/L (Figure 5).

May of 2014. After the flood event in May of 2014, the decrease in overall phytoplankton abundance was significant. However, *P. rubescens* cells remained dominant along the entire profile, (except at the great depths, over 30 m) but now have an uniform distribution (Figure 6). There is a great number of its cells at all depths. The maximum abundance of *P. rubescens* was observed at the depth of 3 m, where its biomass was 2,90 µg/L (Figure. 7).

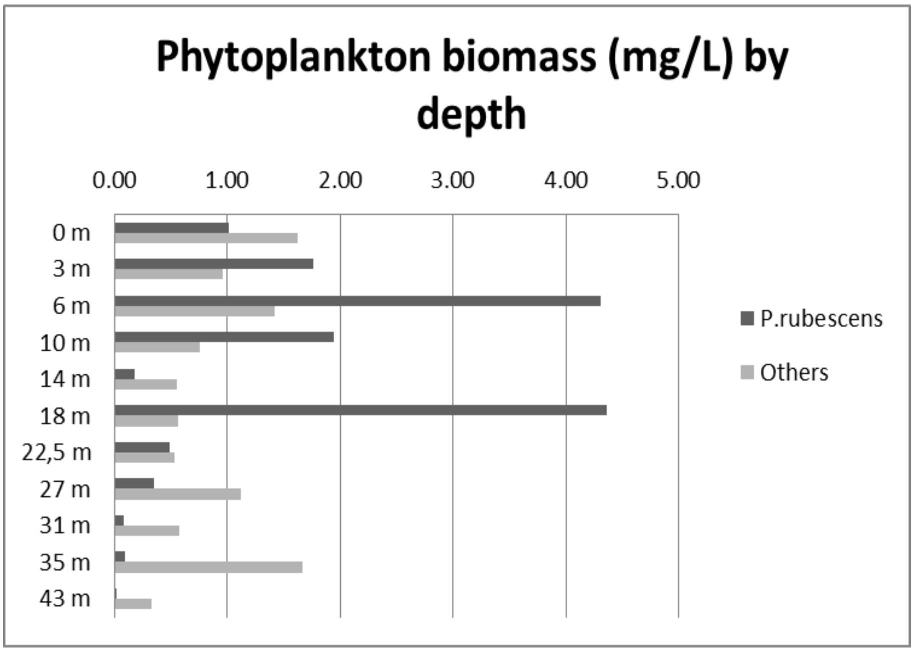

Figure 5. Biomass of *P. rubescens* and others by depth (mg/L) in April of 2014

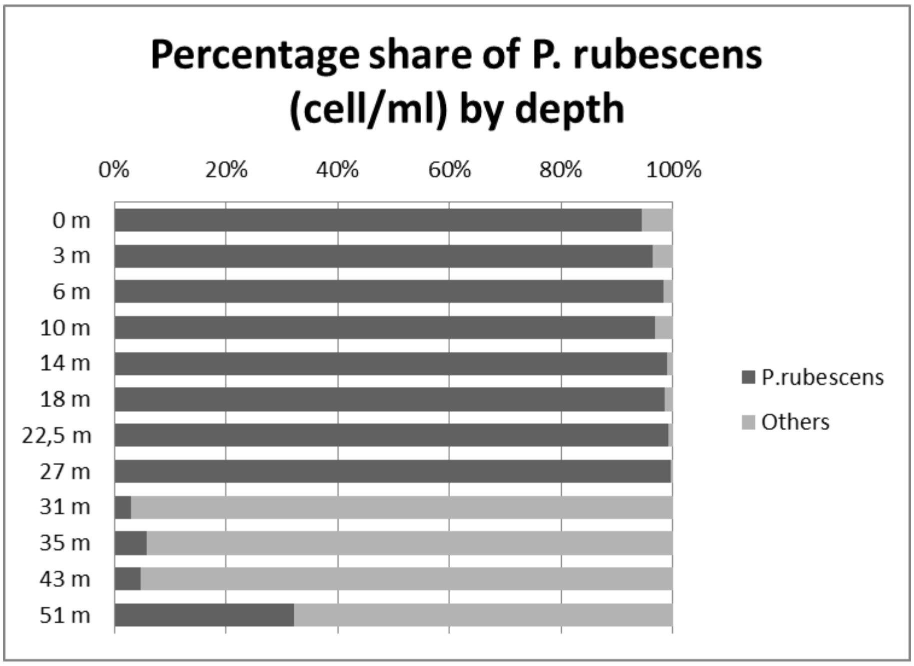

Figure 6. Percentage share of *P. rubescens* (cells per milliliter) by depth in May of 2014

CONCLUSIONS

Lake and reservoir ecology is strongly influenced by sporadic and intense events such as flood events and storms. In this research significant influence of the high inflow event to the phytoplankton community in reservoir Vrutci has been proven. High rate of water exchange flushed out phytoplankton significantly, reducing its abundance. Intensive mixing lead to a more uniform distribution of all water quality indices over the depth. High inflow caused strong horizontal advective flow which pushed the vast of the phytoplankton population closer to the dam (sampling location Vodozahvat). At the same time torrential tributaries introduced additional amounts of nutrients from catchment which is prone to the pluvial erosion. Inspite the decrease in overall algae abundance, *P. rubescens* retained its dominance in the phytoplankton community.

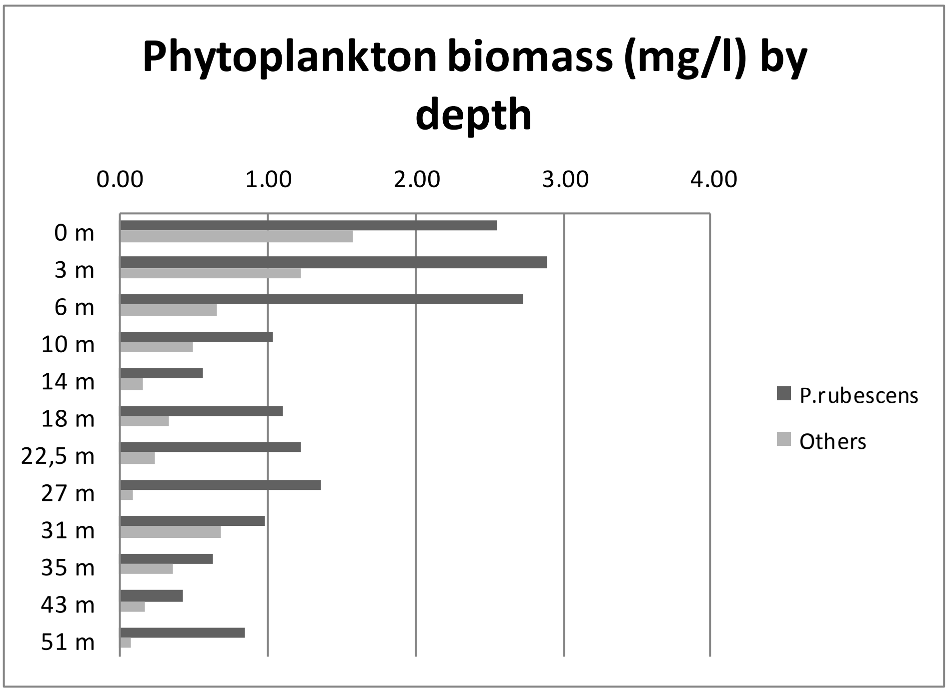

Figure 7. Biomass of *P. rubescens* and others by depth (mg/L) in May of 2014.

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