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Hydrological Parameters of East Kolkata Wetlands: Time Series Analysis

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ABSTRACT- Three decades data (1984 – 2015) was used to study the effect of surface water temperature, pH, dissolved oxygen, nitrate, phosphate and silicate on chlorophyll *a* concentration in three water bodies meant for fish culture (locally known as Bheries) in East Kolkata Wetlands. The data revealed significant spatio-temporal variations ($p < 0.01$). The increasing trend of temperature, nitrate and phosphate reflects the effect of intense urbanization at local level. The pronounced variation of dissolved oxygen and chlorophyll *a* (decreasing trend) may be attributed to increased load of sewage in the selected water bodies, which has posed an adverse impact on the phytoplankton standing stock as revealed through decreasing chlorophyll *a* trend.

Key-words- East Kolkata Wetlands (EKW), Phytoplankton, Chlorophyll *a*, Nutrients, ANOVA

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INTRODUCTION

Wetlands are one of the most productive ecosystems of the planet Earth [1-3]. East Kolkata Wetlands (EKW) present in the maritime state of West Bengal (India) has been designated as Ramsar Site and is noted for its high nutrient level and considerable fish production [4-6].

Many reports of EKW include management programmes to conserve this well known wetland which spans over the entire eastern outskirts of the metropolitan city of Kolkata [6-9]. However, very few works documented the inter-relationship between relevant hydrological parameters and phytopigment (chlorophyll *a*) which may serve as proxy to primary productivity of the aquatic system.

The present paper analysis the dependency of chlorophyll *a* on the nutrient levels in the aquatic phase of EKW. For this, a data bank of three decades (1984–2015) has been relied upon to interpret the result. This data bank is the average of three seasons in the three sampling bheries selected in EKW and is retrieved from the archives of Department of Marine Science, University of Calcutta.

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MATERIALS AND METHODS

Study Site

EKW is situated at the eastern outskirts of the mega city of Kolkata, India (22°25' to 22°40' N and 88°20' to 88°35' E). The fish ponds of the area offers important ecosystem services like flood control, recycling of municipal wastes and effluents (generated from urban and semi urban areas), aesthetic beauty, fish production, livelihood, etc. EKW is extremely dynamic from the point of view of primary production and is a unique reservoir of a galaxy of phytoplankton, which serve as the foundation stone of food chain existing in the system. The present sampling bheries were selected at Captain Bheri (22°33'06.7" N to 88°24'38.5" E), Munshir Bheri (22°34'18.3" N to 88°26'22.9" E) and Natur Bheri (22°32'49.9" N to 88°25'30.1" E) with the aim to analyze the chlorophyll *a* and few relevant physio-chemical variables (like surface water temperature, pH, dissolved oxygen, nitrate, phosphate and silicate).

Analysis of Hydrological Parameters

Surface water temperature was recorded by using a 0° - 100°C mercury thermometer and pH of the surface water was measured by using a portable pH meter (sensitivity±0.01). The dissolved oxygen was measured by a DO meter in the field and subsequently cross-checked in the laboratory by Winkler's method.

Surface waters for nutrient analyses were collected in clean

TARSON bottles and were transported to the laboratory in ice-freeze condition. Triplicate samples were collected from the same collection site to maintain the quality of the data. The standard spectrophotometric method [10] was adopted to determine the nutrient concentration in surface water. Nitrate was analysed by reducing it to nitrite by means of passing the sample with ammonium chloride buffer through a glass column packed with amalgamated cadmium filings and was finally treated with sulphanilamide solution. The resultant diazonium ion was coupled with N - (1-napthyl)- ethylene diamine to give an intensely pink azo dye. Determination of the phosphate was carried out by treatment of an aliquot of the sample with an acidic molybdate reagent containing ascorbic acid and a small proportion of potassium antimony tartarate. Dissolved silicate was determined by treating the sample with acidic molybdate reagent.

Pigment Analysis

For pigment analysis, 1 litre of surface water was collected from each of the sampling sites and filtered through a 0.45 µm Millipore membrane fitted with a vacuum pump. The residue along with the filter paper was dissolved in 90% acetone and was kept in a refrigerator for about 24 hours in order to facilitate the complete extraction of the pigment. The solution was then centrifuged for about 20 minutes at 5000 rpm and the supernatant solution was considered for the determination of the chlorophyll pigment by recording the optical density at 750, 664, 647 and 630 nm with the help of Systronics UV-visible spectrophotometer model No-117 (micro controller based). All the extinction values were corrected for a small turbidity blank by subtracting the 750 nm signal from all the optical densities, and finally the phytoplankton pigment was estimated as per the following expression of Jeffrey and Humphrey (1975) [11].

$$\textbf{Chl } a = 11.85\, OD_{664} - 1.54\, OD_{647} - 0.08\, OD_{630}$$

All the extinction values were corrected for a small turbidity blank by subtracting the 750 nm signal from all the absorbance values. The values obtained from the equations were multiplied by the volume of the extract (in ml) and divided by the volume of the water (in litre) filtered to express the chlorophyll *a* content in $mg.m^{-3}$. All the analyses were done in triplicate (on the basis of collection of three samples from the same site) in order to ensure the quality of the data.

STATISTICAL ANALYSIS

It is the final phase in which statistical tools were applied to understand the spatio-temporal variation in the study site. For this, ANOVA was performed to evaluate statistically significant differences between years and selected bheries.

RESULTS AND DISCUSSION

Surface water temperature, pH, dissolved oxygen, nutrients level and chlorophyll *a* concentration recorded in the three sampling sites are shown in Figures 1-7.

All these hydrological parameters were subjected to ANOVA and significant variations ($p<0.01$) were observed between years and bheries (Tables 1-7). This may be due to different standing stock of phytoplankton present in the selected bheries (Annexure 1). The profiles of the selected hydrological parameters are discussed separately.

Temperature

Surface water temperature ranged from 29.2°C (in Natur Bheri during 1984) to 32°C (in Munshir Bheri during 2015) (Figure 1). There exist pronounced variations in surface water temperature between years and bheries ($p < 0.01$) as depicted in Table 1. The variation between the three selected bheries may be attributed to different degrees of exposure to solar radiations although they are located in the same geographical locale of EKW. The shades provided by the vegetations around the selected bheries may be related to such local level variations.

The yearly variation pointed out towards the gradual warming of the atmosphere due to climate change induced warming in this tropical belt as pointed out by earlier researchers [2-3, 12-13].

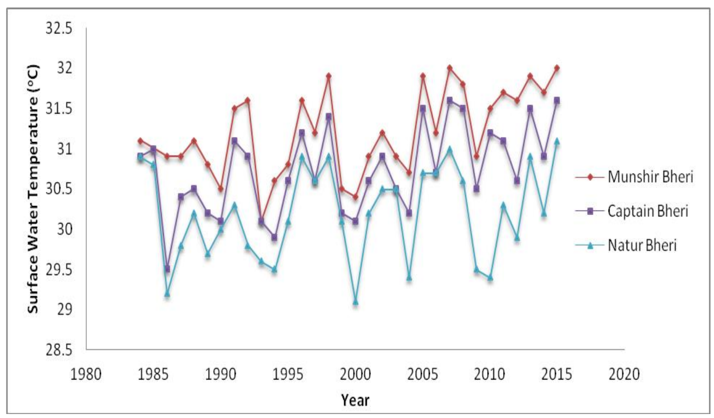

Fig. 1: Decadal variations of surface water temperature

Table 1: ANOVA result for Surface Water Temperature

Source of Variation for Surface water temperature	SS	df	MS	F	P-value	F crit
Between Years	29.37	31	0.95	23.70	3.97×10^{-24}	1.64
Between Bheries	2.34	2	1.17	29.30	1.1×10^{-09}	3.15
Error	2.48	62	0.04			
Total	34.19	95				

pH

The pH of the waters in the study sites ranged from 6.7 (in Captain Bheri during 1990) to 8.2 (in Captain Bheri during 2015) (Figure 2). It is interesting to note that unlike other parameters, the pH of the aquatic phase in the selected bheries of the bheries of EKW did not exhibit any pronounced variation (Table 2). This is due to the fact that all these bheries are managed by the local people who use lime on regular basis to maintain the acid-base balance of the water bodies.

Table 2: ANOVA result for pH

Source of Variation for pH	SS	df	MS	F	P-value	F crit
Between Years	2.52	31	0.08	1.31	0.18	1.64
Between Bheries	0.09	2	0.04	0.70	0.50	3.15
Error	3.86	62	0.06			
Total	6.48	95				

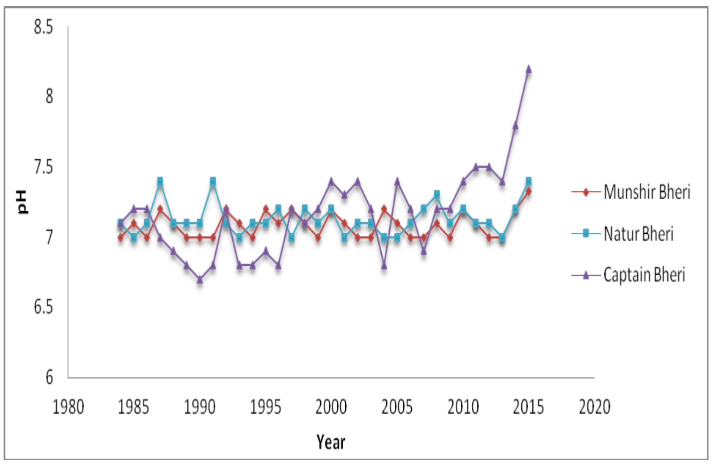

Fig. 2: Decadal variations of pH

Dissolved Oxygen

Dissolved Oxygen (DO) ranged from 3.92 ppm (in Munshir bheri during 2003) to 6.77 ppm (in Munshir bheri during 2009) (Figure 3). There exist pronounced variations in DO between years and bheries ($p < 0.01$) as depicted in Table 3. The variation between the three selected bheries may be attributed to different degrees of exposure to solar radiations although they are located in the same geographical locale of EKW. The variation is the outcome of different degree of photosynthetic rate due to difference in the standing stock of phytoplankton (Annexure 1). The yearly variation (decreasing trend) may be the effect of increased load of sewage with the rapid pace of urbanization in and around EKW. The gradual decrease of DO in the study area was also pointed out by earlier researchers [14].

Table 3: ANOVA result for Dissolved Oxygen

Source of Variation for Dissolved Oxygen	SS	df	MS	F	P-value	F crit
Between Years	10.12	31	0.33	4.44	2.99×10^{-07}	1.64
Between Bheries	6.51	2	3.26	44.28	1.14×10^{-12}	3.15
Error	4.56	62	0.07			
Total	21.19	95				

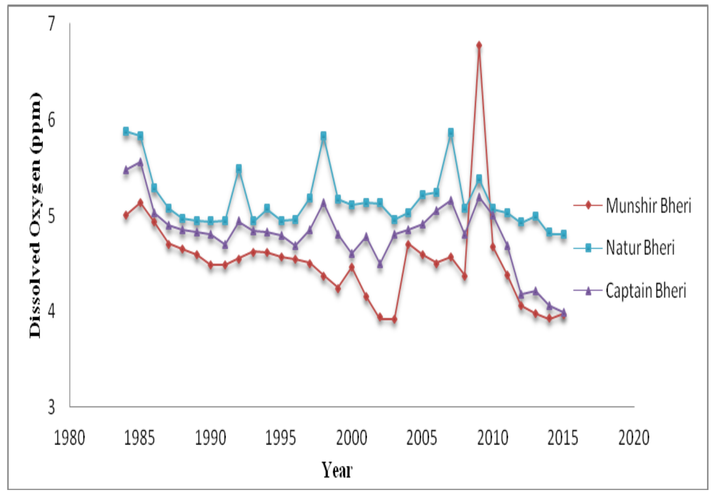

Fig. 3: Decadal variations of Dissolved Oxygen

Nutrients

The nitrate concentration varied from 24.17 μg at l^{-1} (in Munshir bheri during 1984) to 55.89 μg at l^{-1} (in Natur bheri during 2015) (Figure 4) and the phosphate concentration ranged from 2.51 μg at l^{-1} (in Munshir bheri during 1984) to 6.73 μg at l^{-1} (in Natur bheri during 2015) (Figure 5). These two nutrients are primarily generated from municipal waste discharge, which is gradually increasing on account of rapid pace of industrialization and urbanization [4, 15-16]. Both of them showed pronounced variation between years and bheries ($p < 0.01$) (Table 4 and 5). The silicate concentration ranged from 54.48 μg at l^{-1} (in Munshir bheri during 2014) to 102.93 μg at l^{-1} (in Munshir bheri during 2009) (Figure 6). Silicate which is primarily produced due to churning action of the underlying pond substratum and regulated by phytoplankton community [16-17] also exhibited pronounced spatial and temporal variations (Table 6). The spatial variation is regulated by phytoplankton stock in the selected ponds and the temporal variation is keenly related to erosion and other physical factors that have increased in recent times.

Table 4: ANOVA result for Nitrate

Source of Variation for Nitrate	SS	df	MS	F	P-value	F crit
Between Years	3933.01	31	126.87	59.39	1.47×10^{-35}	1.64
Between Bheries	131.92	2	65.96	30.88	4.96×10^{-10}	3.15
Error	132.46	62	2.14			
Total	4197.39	95				

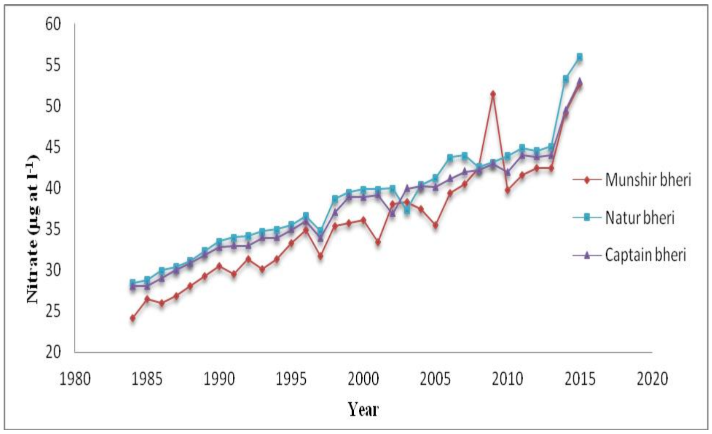

Fig. 4: Decadal variations of Nitrate

Table 5: ANOVA result for Phosphate

Source of Variation for phosphate	SS	df	MS	F	P-value	F crit
Between Years	39.62	31	1.28	6.21	5.8×10^{-10}	1.64
Between Bheries	21.83	2	10.91	53.04	3.74×10^{-14}	3.15
Error	12.76	62	0.21			
Total	74.20	95				

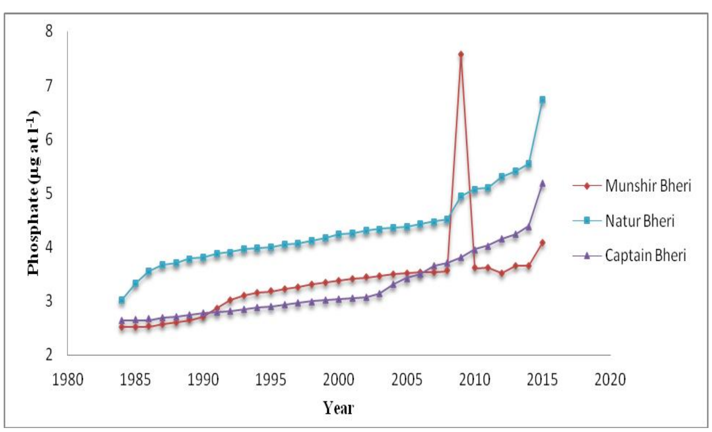

Fig. 5: Decadal variations of Phosphate

Table 6: ANOVA result for Silicate

Source of Variation for Silicate	SS	df	MS	F	P-value	F crit
Between Years	5566.70	31	179.57	7.411	1.47×10^{-11}	1.64
Between Bheries	2245.80	2	1122.90	46.34267	4.91×10^{-13}	3.15
Error	1502.28	62	24.23			
Total	9314.77	95				

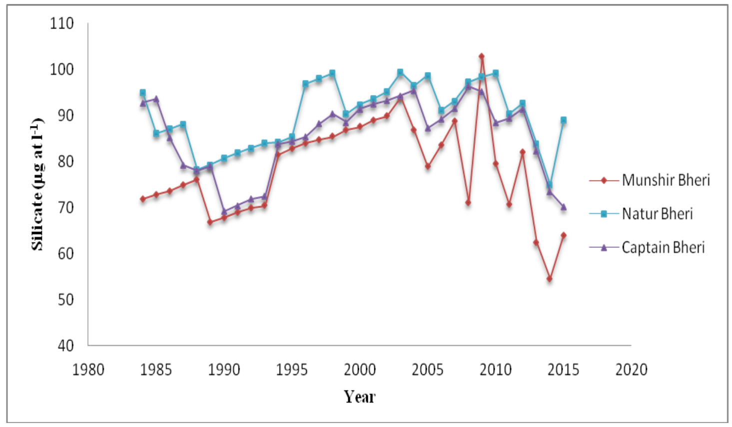

Fig. 6: Decadal variations of Silicate

Chlorophyll *a*

Chlorophyll *a* serves as proxy to phytoplankton standing stock and ranged from 4.19 mg.m^{-3} (in Natur Bheri during 2012) to 12.29 mg.m^{-3} (in Munshir Bheri during 1984) in the study area (Figure 7). The pronounced spatial and temporal variations (Table 7) of the phytopigment may be the result of variation in phytoplankton population, which again is controlled by nutrient level of the ambient aquatic phase. The dependency of phytoplankton on nutrient is revealed from the expression $(CH_2O)_{108}(NH_3)_{16}H_3PO_4$ and in case of diatoms it is slightly modified as $(CH_2O)_{108}(NH_3)_{16}H_3PO_4(SiO_4)_{40}$ [18]. These constituents of phytoplankton suggest the necessity and subsequent utilization of nitrate, phosphate and silicate from the ambient waters [19- 23]. The significant negative correlation between nutrient level and phytoplankton speaks in favour of the uptake of nutrients by the phytoplankton, as these nutrients act as building blocks of phytoplankton.

Chlorophyll *a*, the primary constituent of phytoplankton needs special importance with respect to maintenance of ecological stability, primary production and energy flow through the food chains spun in the water bodies of EKW through long evolutionary period of time. The decreasing trend of chlorophyll *a* is a warning signal in context to primary production of the system as the dynamics of energy flow in any aquatic system is regulated by phytoplankton standing stock with chlorophyll *a*, as its major constituents. Hence regular monitoring and conservation of these free floating tiny producer community is extremely important to upgrade the ecological health of the system. The dependency of phytoplankton on nutrient levels demands the regulation of waste discharge in the EKW so as to optimize the growth of phytoplankton. The local economy and livelihood of EKW is primarily piscicentric and therefore the primary producer community needs to be conserved in order to generate a sustainable secondary production.

Table 7: ANOVA result for Chlorophyll *a*

Source of Variation for Chlorophyll a	SS	df	MS	F	P-value	F crit
Between Years	104.29	31	3.36	26.52	1.76×10^{-25}	1.64
Between Bheries	253.92	2	126.96	1000.96	6.44×10^{-48}	3.15
Error	7.86	62	0.13			
Total	366.07	95				

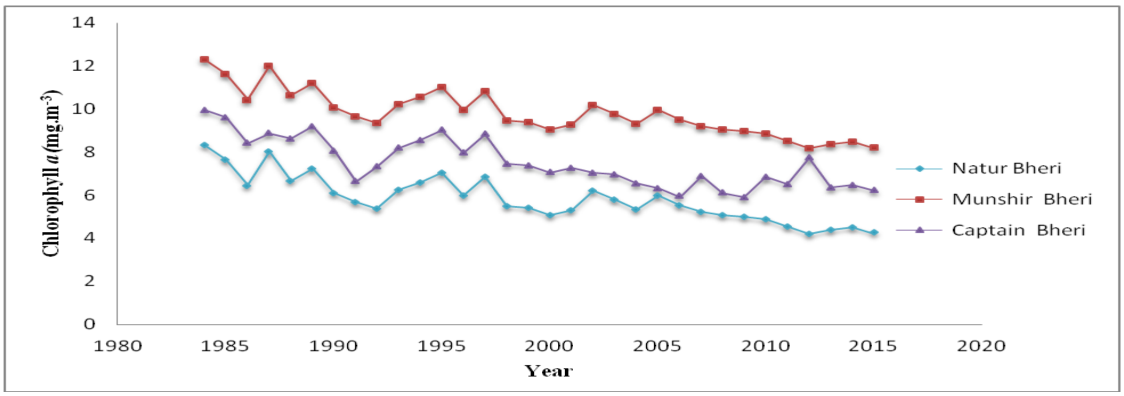

Fig. 7: Decadal variations of Chlorophyll *a*

CONCLUSIONS

The time series analysis on the selected hydrological parameters of EKW highlights few core findings as listed below:

Significant variations of hydrological parameters exist between the selected bheries (except aquatic pH), which might be due to different nutrient supply (preferably through sewage) to the bheries.

The uniformity of aquatic pH may be attributed to application of lime on regular basis, which is a common practice of the beneficiaries of the bheries of EKW.

Chlorophyll *a*, which is proxy to the productivity of the bheries oscillates as a function of nutrient load of the aquatic phase. Hence, regulation of nutrients is of utmost importance to maintain the productivity of the bheries located in the EKW.

Annexure 1: Standing stock of phytoplankton species in the selected sites of East Kolkata Wetlands

S. No.	Phytoplankton Species	Standing Stock (No./L)		
		Captain Bheri	Munshir Bheri	Natur Bheri
1	*Merismopedia trolleri*	10132.49	8952.38	12632.06
2	*Merismopedia glauca*	9133.41	8797.29	10700.41
3	*Merismopedia minima*	2384.49	2250.07	2762.49
4	*Merismopedia punctata*	33519.31	31950.14	35252.09
5	*Synechococcus elongatus*	4316.18	4158.55	4699.3
		3522.94	3404.25	4046.49

6	*Synechocystis aquatilis*			
7	*Coelosphaerium pallidum*	225131.2	218202.63	227153.21
8	*Rhabdogloea rhaphidioides*	23381.79	21894.74	24735.6
9	*Rhabdoderma irregular*	867.82	651.18	1209.82
10	*Rhabdoderma lineare*	413.65	324.78	533.65
11	*Rhabdogloea fascicularis*	1420.8	1255.07	1555.88
12	*Rhabdogloea smithii*	20300.37	19240.8	20768.98
13	*Microcystis aeruginosa*	3603.63	3757.13	4301.63
14	*Chroococcus disperses*	4724.94	4171.14	5334.15
15	*Chroococcus dispersus var. minor*	4152.08	3764.9	4590.08
16	*Chroococcus limneticus*	1185.05	1005.77	1474.05
17	*Chroococcus turgidus*	1170.16	1009.27	1284.2
18	*Gomphosphaeria aponina*	37792.22	36521.99	39088.83
19	*Spirulina subsalsa*	40750.11	37024.92	42018.74
20	*Spirulina nordstedtii*	38358.4	35577.78	39671.08
21	*Spirulina subtilissima*	2259.56	2241.1	3861.23
22	*Spirulina laxissima*	1832.76	1901.92	2565.09
23	*Pseudanabaena catenata*	1634.5	1649	2467.42
24	*Planktolyngbya contorta*	1838.47	1644.05	2018.14
25	*Pseudanabaena galeata*	2338.18	2151.66	2704.98
26	*Oscillatoria subbrevis*	3478.13	3188.87	3821.97
27	*Oscillatoria limnetica*	16495.92	15691.4	17228.5
28	*Oscillatoria rubescens*	28315.68	26456.24	29066.02
29	*Oscillatoria acutissima*	108.37	85.8	242.27
30	*Cyanarcus hamiformis*	8852.51	8316.51	9318.79
31	*Anabaenopsis raciborskii*	35155.48	33211.39	36309.34
32	*Anabaenopsis arnoldii*	3290.73	3213.38	3901
33	*Anabaenopsis circularis*	283.3	212.06	404.23
34	*Anabaenopsis Tanganyika*	2152.19	1981.33	2507.89
35	*Navicula cryptocephala*	299.45	240.1	409.46
36	*Navicula peregrine*	127.6	85.39	197.536

37	*Navicula tripunctata*	185.46	154.16	266.12
38	*Navicula phyllepta*	2654.14	2548.63	2969.27
39	*Craticula halophila*	1327.03	1216.92	1558.98
40	*Craticula cuspidate*	45702.66	41648.81	48377.66
41	*Cymbella lanceolata*	2480.27	2228.71	2731.72
42	*Pleurosigma angulatum*	492.5	386.43	613.5
43	*Amphora coffeaeformis*	449.5	318.33	629.39
44	*Nitzschia acicularis*	587.8	439.2	732.92
45	*Nitzschia frustulum*	613.2	475.34	745.29
46	*Nitzschia palea*	4868.8	4479.54	5170.93
47	*Nitzschia fruticosa*	661.5	585.46	758.9

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