Can Tho University Journal of Science
website: sj.ctu.edu.vn

DOI: 10.22144/ctu.jen.2018.014

Using benthic diatoms as bio-indicators of water quality of the Saigon River, Vietnam

Pham Thanh Luu* and Nguyen Tan Duc

Institute of Tropical Biology, Vietnam Academy of Science and Technology, Vietnam

**Correspondence: Pham Thanh Luu (email: thanhluupham@gmail.com)*

Article info.

Received 14 Nov 2016
Revised 04 May 2017
Accepted 30 Mar 2018

Keywords

Benthic diatoms, bio-indicator, eutrophication, Saigon River, water quality

ABSTRACT

This study is aimed to evaluate the water quality in the Saigon River by using biological indices based on benthic diatom communities as indicators together with physic-chemical parameters. The samples were taken in dry and wet season at seven stations along the Saigon River. Physicochemical variables and benthic diatom metrics of abundance, taxa richness, Shannon Wiener diversity index, average tolerance score per taxon scores, Simpson's diversity index, and similarity index were used in the determination of water quality of the river. The results indicated that benthic diatom metrics and the concentrations of total nitrogen, total phosphate, chemical oxygen demand and biochemical oxygen demand after 5 days characterized that the downstream of the Saigon River had lower water quality than the upstream. Shannon–Wiener diversity index indicated that water quality differed significantly between the upper course sites and the lower course sites but no significant difference was found in dry and wet season. The results demonstrated that the benthic diatom composition was more sensitive and accurate than the routine investigation of water physico-chemical parameters. Therefore, it is important to use diatoms together with water physico-chemical variables for surface water quality assessment.

Cited as: Luu, P.T. and Duc, N.T., 2018. Using benthic diatoms as bio-indicators of water quality of the Saigon River, Vietnam. Can Tho University Journal of Science. 54(2): 106-111.

1 INTRODUCTION

The using of aquatic organisms in water quality assessment has been implemented for long history (Davis, 1995). Because of short generation and wide distribution, diatom assemblages are widely used as indicators of water quality in many countries (Chen *et al*., 2016). Diatom indices are the most common tool to summarize the information provided by the diatom assemblages (Weilhoefer *et al*., 2006). Several diatom indices have been developed, most of which are general pollution indices, especially indicative of eutrophication and organic pollution (Wang *et al*., 2006; Stevenson *et al*., 2008; Wu *et al*., 2012). These indices are thought to have universal applicability across geographic areas and environments because of the cosmopolitan nature of most diatom species (Bere *et al*., 2014).

In Ho Chi Minh City, the traditional method of water quality monitoring is mainly by examination of physical and chemical parameters, or by calculation of a comprehensive water quality index (Lan *et al*., 2011). However, whether water quality is good or bad is not reflected in terms of physical and chemical parameters of the index. Quality also should be reflected by the balance of all kinds of aquatic organisms, especially those that are considered to be sensitive to water environment changes, such as the diatoms (Chen *et al*., 2016).

The Saigon River is located in southern Vietnam that rises in southeastern Cambodia, then flows south and southeast downstream and empties into the Dong Nai River at Nha Be. The Saigon River has a total length of about 280 km, its catchment area covers about 4,750 km^2 and its average flow rate is

85 m^3/s (Nguyen *et al*., 2011b). The Saigon River is important to Ho Chi Minh City as it is the main water supply source as well as the host of Saigon Port. Over the past years, the industrial cluster and the urban population have grown considerably. This fast growth generated an increase of pollutants dumped in many spots of the river causing water quality deterioration (Nguyen *et al*., 2011a). The objectives of this research were to investigate the change in water quality and benthic diatom assemblage structure along the Saigon River in dry and wet seasons in 2009 and to examine whether the diatom assemblages can be used for water quality assessment. Providing a historical water quality data of the Saigon River, the data could be used to compare with the current water quality data and to predict the trends of water quality in near future. It is hoped that the results of this study can promote the dissemination of biological method for water quality monitoring in Vietnamese waters.

2 MATERIALS AND METHODS

2.1 Physico-chemical variables

The water samples were collected in dry and wet season 2009 at seven sampling stations (SG1-SG7) (SG1: close to Dau Tieng dam; SG2: close to Dau Tieng town; SG3: Ben Suc bridge; SG4: close to the confluence of the rivers of Saigon and Thi Tinh; SG5: Phu Long bridge; SG6 Binh Phuoc bridge; SG7: Saigon bridge) from the Saigon River (Figure 1). SG1-SG3 stand for the upper course with intensive farming; and SG4-SG7 stand for the lower course presenting urban and industrial uses. Water temperature (WT), electrical conductivity (EC), turbidity (TB), pH and dissolved oxygen (DO) were measure in situ by using a portable multi-parameter (Hach 156, CO, USA). The total suspended solid (TSS), biochemical oxygen demand after 5 days (BOD_5), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) were measured according to APHA (2005).

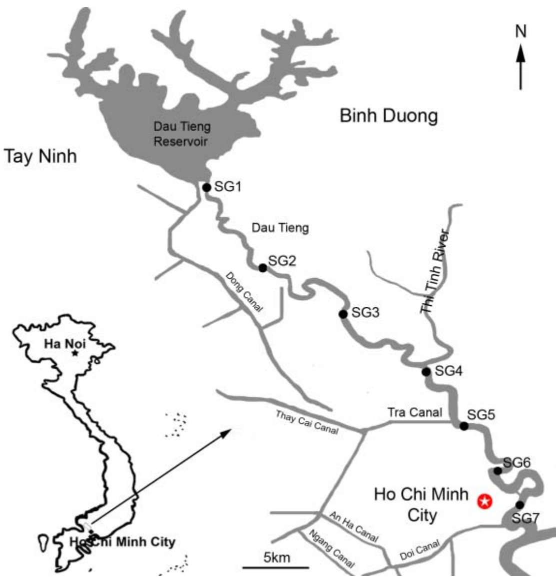

Fig. 1: Location of the Saigon River and the seven sampling stations SG1–SG7

2.2 Diatom sampling and identification

Diatom sampling and cleaning were based on the method of Wehr *et al*. (2003). Briefly, the benthic diatoms were collected on hard substrates by scraping five stones over a surface area of 50 cm^2. Samples were preserved in plastic bottles and fixed in lugol solution. In the laboratory, about 5–10 mL samples were cleaned with concentrated nitric acid, and washed with distilled water until they reached a circumneutral pH. An aliquot (1 mL) of the cleared sample was counted on Sedgewick rafter counting chamber. Diatoms were scanned with a light microscope (Olympus, Tokyo, Japan) at 400× magnification. A minimum of 500 diatom valves was counted on each slide. Valves of diatoms were identified to the species or sub-species level according to Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b).

2.3 Calculating diatom metrics

The average tolerance score per taxon (ATSPT) exploits the differences in tolerance among different families of benthic diatoms. ATSPT index was calculated based on the method of MRC (2010). The diatom community structural attributes of species richness (S), Shannon–Weiner index (H), species evenness (J) and Simpson's diversity index (D), that are commonly used in water quality bioassessment

(Stevenson *et al*., 2010), were used to characterize each site. All diatom metrics were calculated by using the PRIMER V.5 analytical package developed by Plymouth Marine Laboratory, U.K.

2.4 Statistical analysis

One-way analysis of variance (ANOVA) was used to test the significance of the differences between the urban upstream and downstream sites based on the log-transformed water physical and chemical variables and the diatom species structure metrics. The analysis was completed using Tukey's Honest Significant Difference (HSD) test significant difference. The Pearson correlation analysis was used to determined correlation among diatom metrics and physico-chemical variables. All statistical analysis was performed using SPSS v.16.0 (IBM Corp., Armonk, NY, USA).

Diatom assemblages and their relation to physico-chemical variables were examined using canonical correlation analysis (CCA). All physico-chemical variables were $\log_{10}+1$ transformed to normalize their distribution prior to the analysis. Species with relative abundances >10% were included in the analysis. CCA was performed using the CANOCO software V 4.5 for window (Ter-Braak and Smilauer, 1998).

3 RESULTS AND DISCUSSION

3.1 Physico-chemical variables

Physico-chemical variables were showed in Table 1. Values of physico-chemical variables fluctuated between upper and lower courses sites during the present study. ANOVA and Tukey's HSD test showed that there were significant differences ($p < 0.05$) in some physico-chemical variables during study period (Table 1). Electrical conductivity is one of physico-chemical variable changed from 114 to 1931 µS/cm between dry and wet seasons. There was not significant change in water temperature, turbidity, pH, BOD_5 and COD between dry and wet seasons. DO values showed a significant variation ($p = 0.037$) between seasons and decreased at lower course sites. Significant differences in TSS, TN and TP values were found in the river. All the three mentioned variables increased in the lower course sites. Based on BOD_5, COD and total nitrogen, water quality of the Saigon River was classed in to A_1 class according to Vietnam National Technical Regulation on surface water quality (QCVN 08-MT2015/BTNMT). The results of this study were in line with the observations of Nguyen *et al*. (2011a) that the lower section of the Saigon River had lower water quality than the upper section.

Table 1: Median water quality variable (range min-max in parentheses) from upper course sites and lower course sites of the Saigon River in March and October 2009

Parameters	Unit	Dry season		Wet season	
		Upper course sites (n=9)	Lower course sites (n=12)	Upper course sites (n=9)	Lower course sites (n=12)
Turbidity	NTU	47.3 (42.6-53.5)	**75.3** (60.6-103.4)**	47.4 (35.1-55.3)	**78.2** (64.0-98.3)**
WT	°C	29.7 (29.6-29.9)	29.4 (29.2-29.6)	28.5 (28.1-28.9)	29.0 (28.6-29.5)
EC	µS/cm	554.2 (140.8-913.3)	**1931.3** (1358.7-2340.4)***	86.5 (81.2-89.7)	***113.9*** (107.0-125.9)**
pH	mg/L	5.9 (5.3-6.2)	6.3 (6.0-6.6)	5.8 (5.6-6.1)	6.1 (5.7-6.5)
DO	mg/L	4.9 (4.8-5.1)	3.9 (3.5-4.4)	4.2 (3.8-4.6)	***3.0*** (2.7-3.2)*
TSS	mg/L	66.9 (62.1-70.3)	79.9 (69-87)	47.6 (22.0-65.0)	***109.2*** (73.0-148.4)**
BOD_5	mg/L	4.4 (3.0-5.8)	5.8 (5.3-6.7)	4.5 (4.3-4.8)	5.4 (4.8-6.3)
COD	mg/L	5.8 (4.7-6.5)	6.6 (5.9-7.4)	5.9 (5.7-6.3)	6.5 (5.3-7.6)
TN	mg/L	1.24 (0.87-1.55)	**2.0** (1.8-2.2)*	1.48 (1.27-1.47)	**1.75** (1.56-2.05)*
TP	mg/L	0.15 (0.11-0.18)	0.17 (0.14-0.19)	0.29 (0.17-0.51)	***0.64*** (0.44-0.78)*

$^{*}p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$. Bold type indicated significant difference between upper and lower courses; Bold and italic type indicated significant difference between upper and lower course; and between dry and wet seasons. The value of n is the number of water samples measured in the sites

3.2 Spatial patterns of diatom assemblage structure

A total of 79 diatom species, belonging to 19 genera, were identified. *Achnanthidium*, *Eunotia*, *Gomphonema*, *Gyrosigma*, *Navicula*, *Nitzschia*, *Pseudostaurosira*, *Sellaphora*, *Surirella* and *Synedra* were the dominant genera (Figure 2A). The relative abundance of each dominant genus among sites was quite different. In upper course sites, *Achnanthidium*, *Eunotia*, and *Navicula* reached the highest (15% in at least one sample) relative abundance. Diatoms *A. minutissima*, *E. robusta* and *N. palea* were the most dominant species (a relative abundance of 10% in at least once) in upper sites. In lower course sites, the genera *Navicula*, *Nitzschia*, *Pseudostaurosira* and *Staurosira* had the highest relative abundance. In particular, the *Nitzschia* relative abundance reached 52%. The most abundant species were *Navicula fonticola, N. cryptocephala, Nitzschia palea*, *N. umbonata*, *Pseudostaurosira brevistriata, and Sellaphora* sp.. *A. minutissima*, *E. robusta* and *Navicula cryptocephala,* considered to be a low nutrient indicator species (Chen *et al*., 2016), were of the dominant species in the upper sites. *Navicula fonticola, Nitzschia palea*, *N. umbonata* and *Pseudostaurosira brevistriata* were reported to be tolerant of mild pollution were dominant in the lower sites (Li *et al.*, 2012). *N. palea*, a species tolerant to very heavy pollution in many areas (Besse-Lototskaya *et al*., 2011; Chen *et al*., 2016), was the dominant species in urban downstream sites. Probably, *Nitzschia* was one of the indicator in polluted streams in urban areas.

Analysis of diatom assemblage species diversity metrics, including ATSPT, S, H, J and D, showed that there were significant differences between upper course sites and lower course sites (Anova, $p < 0.05$). The lower course sites scored lower of all groups in S, H and J, but had the greater percent relative abundance of dominant taxa and tolerance ATSPT score (Figure 2B). The high ATSPT score in the lower course sites indicated higher impact from urbanization in lower course sites of the river.

Benthic diatoms are routinely used as bio-indicators of water quality or ecosystem health (Chen *et al*., 2016). The results of diatom metrics showed that water quality in the Saigon River varied from moderate to poor status based on the classification systems of Sven *et al*. (2010). This was corroborated for the biological indices, which revealed that the water quality from SG1 to SG5 was moderate status during most of the sampling period, while SG6 and SG7 presented, in general, poor water quality. The decreasing trend in indices values as water flows down is due to an increase in human pressures and industrial activities on the surrounding lands. Some points of domestic sewage discharge were also observed downstream of this area. According to previous studies, water quality of the Saigon River contaminated from the medium level to severe level mainly organic matter, heavy metal and microorganisms (Nguyen *et al*., 2011a, 2011b). The results of this study showed water quality of the Saigon River was also contaminated with nutrient concentration, particularly nitrogen and phosphorus. In addition, storm water runoff, increasing urban development and other catchment activities such as agriculture and industrial wastewater discharge may also contribute to the river pollution. Compared with physicochemical parameters, the use of multivariate indicators of diatoms together achieved a more realistic approach and given more additional information for water quality assessment. Biological indices are shown to be one of the most effective tools for monitoring the biological quality and ecological status of the river.

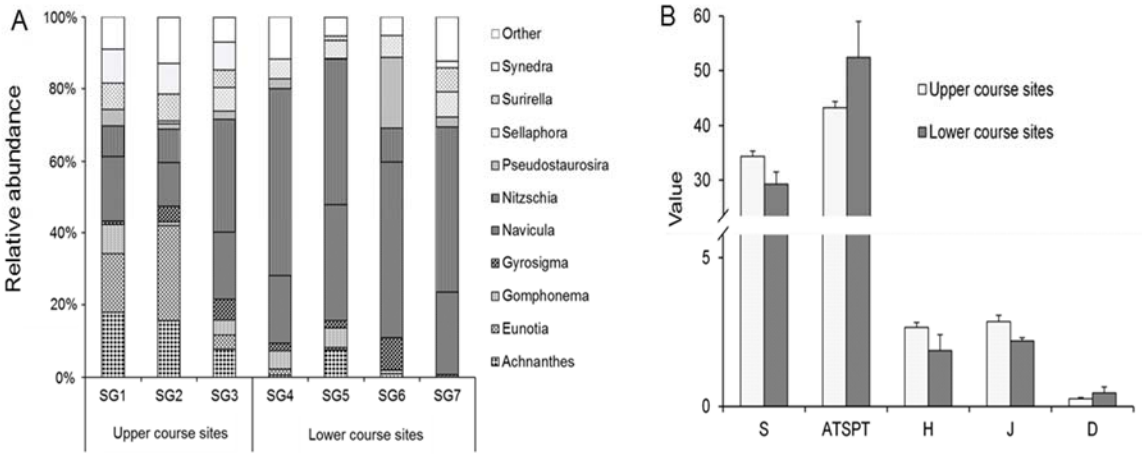

Fig. 2: (A) composition of 10 most dominant diatom genera in the Saigon River and (B) diatom metrics (S, ATSPT, H, J, D) between upper course sites and lower course sites

3.3 Relationship of diatom assemblages to environment variables

The first two CCA axes explained about 65.4% of the variance for diatom assemblages at the urban and rural sites. Axis 1 was positively correlated with TN, TB, EC, COD, BOD_5 and negatively with DO. It may represent an upper course to lower course of water quality gradient. Axis 2 was positively correlated with TP, SS, Temperature, pH and negatively with DO, and it may represent an urban impact or water quality degradation gradient (Figure 3).

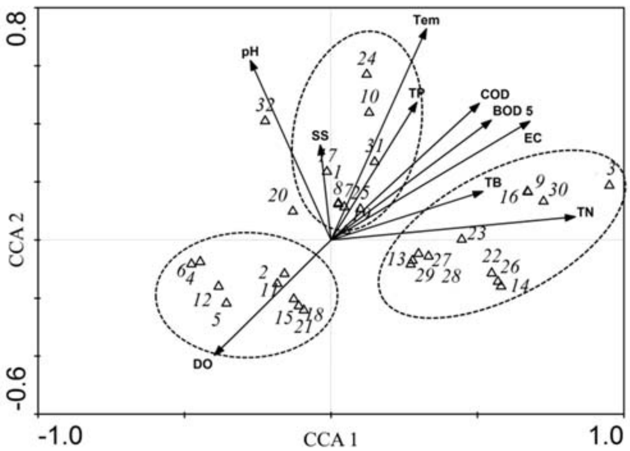

Fig. 3: Canonical correspondence analysis (CCA) for selected physico-chemical variables and most frequently occurring diatom taxa

Of the 105 diatom taxa identified in this investigation, 32 taxa, with relative abundance ≥ 10%, were included in data analysis using CCA (Figure 5). Results of CCA enable to relate diatom distribution to diatom succession during sampling period. The CCA ordination clearly separated the samples into three groups, characterizing three different diatoms community structures. The first was positively correlated with DO indicating a higher water quality in the upper course sites (SG1, SG2, SG3 and SG4). These sites were associated with high DO and low EC, TB, TSS compared to the lower course sites. These parameters were highly positively associated with diatom *Achnanthidium, Cymbella, Eunotia* and *Navicula*. The second and third group mainly composed of lower course sites (SG5, SG6, SG7, SG8, SG9 and SG10) were associated with high TN, TP, TB, EC, TSS, BOD_5, COD, and low DO. These environmental conditions were highly positively correlated with diatom *Aulacoseira* sp., *Nitzschia* sp., and *Surirella* sp..

CCA results showed that DO, TN, TP, and TSS were the most important factors in structuring benthic diatom communities in the study area. The diatom composition in lower course sites were greatly influenced by high TN, TP, TB, EC and TSS, which may be due to the emissions of urban sewage and industrial wastewater, that is associated with urbanization (Nguyen *et al*. 2011b). TN and TP are the two most important nutrients for phytoplankton (Xu *et al*., 2010): however, in turbid systems with high TB and TSS, light availability seems to play a key role in the control of phytoplankton abundance (Gameiro *et al*., 2010). EC estimates the amount of total dissolved salts or the total amount of dissolved ions in the water (Walker and Pan, 2006). In this research, the average of EC concentration in the lower course sites was higher than that in the upper course sites ($p < 0.01$). EC was also considered to be the determining factor of diatom species composition and distribution of the benthic diatoms in U.S. Rivers (Stevenson *et al*., 2008). The results of this study were also in line with previous observation that nutrients EC and TB were the most important environmental factor to distinguish the diatom gradient from urban to suburban sites (Chen *et al*., 2016; Newall and Walsh, 2005; Walker and Pan, 2006).

4 CONCLUSIONS

There was large variability in physico-chemical variables and in diatom diversity indices between upper course sites and lower course sites of the Saigon River, but there was no significant difference in physico-chemical variables among sites in each group. The results showed that the benthic diatom composition was more sensitive and accurate than the routine investigation of water based on physico-chemical parameters. It provides important complimentary information for water quality and conditions in the Saigon River, Vietnam. Therefore, it is necessary to use diatoms together with water physical and chemical parameters for surface water quality assessment.

ACKNOWLEDGEMENTS

The authors acknowledge financial support from Japan Student Services Organization (JASSO) and Basic Research Foundation from Institute of Tropical Biology (ITB).

REFERENCES

APHA, American Public Health Association, 2005. Standard methods for the examination of water and wastewater. Washington DC., USA, 1496 pages.

Bere, T., Mangadze, T., Mwedzi, T., 2014. The application and testing of diatom-based indices of water quality assessment in the Chinhoyi Town, Zimbabwe. Water SA, 40 (3): 503-512.

Besse-Lototskaya, A., Verdonschot, P.F., Coste, M., and Vijver, B.V., 2011. Evaluation of European diatom trophic indices. Ecological Indicator, 11(2): 456-467.

Chen, X., Zhou, W., Steward, T.A.P., Weifeng, L., Lijian, H., and Yufen, R., 2016. Diatoms are better indicators of urban stream conditions: a case study in Beijing, China. Ecological Indicators, 60: 265–274.

Davis, W.S., 1995. Biological assessment and criteria: building on the past. In: Davis W.S., Simon T.P., (Eds.). Biological assessment and criteria: tools for water resource planning and decision-making. Boca Raton: Lewis Publishers, Boca Raton, Florida, USA, pp. 15–29.

Gameiro, C., Zwolinski, J., and Brotas, V., 2011. Light control on phytoplankton production in a shallow and turbid estuarine system. Hydrobiologia, 669(1): 249–263.

Krammer, K., and Lange-Bertalot, H., 1986. Bacillariophyceae. 1. Teil: Naviculaceae. In: Ettl H., Gerloff J., Heynig H. and Mollenhauer D. (Eds.). Süsswasser flora von Mitteleuropa, Band 2/1. Gustav Fischer Verlag: Stuttgart, New York, 876 pages.

Krammer, K., and Lange-Bertalot, H., 1988. Bacillariophyceae. 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. In: Ettl, H., Gerloff, J., Heynig, H., Mollenhauer, D., (Eds.). Süsswasserflora von Mitteleuropa, Band 2/2. VEB Gustav Fischer Verlag: Jena, 596 pages.

Krammer, K., and Lange-Bertalot, H., 1991a. Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. In: Ettl, H., Gerloff, J., Heynig, H., Mollenhauer, D., (Eds.). Süsswasserflora von Mitteleuropa, Band 2/3. Gustav Fischer Verlag: Stuttgart, Jena, 576 pages.

Krammer, K., and Lange-Bertalot, H., 1991b. Bacillariophyceae. 4. Teil: Achnanthaceae, Kritische Ergänzungen zu Navicula (Lineolatae) und Gomphonema, Gesamtliteraturverzeichnis Teil 1-4. In: Ettl, H., Gärtner, G., Gerloff, J., Heynig, H., Mollenhauer, D., (Eds.). Süsswasserflora von Mitteleuropa, Band 2/4. Gustav Fischer Verlag: Stuttgart, Jena, 437 pages.

Lan, T.T. and Long, N.P., 2011. Assessment of surface water quality by water quality index (WQI) at the Cai Sao canal, An Giang province, Vietnam. Livestock Research for Rural Development, 23(7): article 151.

Li, L., Sun, T., Liu, H., et al., 2012. Distribution of diatoms in central city of Beijing. Journal of Forensic Medicine, 28(4): 265-268.

MRC, Mekong River Commission, 2010. Biomonitoring methods for the lower Mekong aasin. Mekong River Commission, Vientiane, 65 pages.

Newall, P., and Walsh, C.J., 2005. Response of epilithic diatom assemblages to urbanization influences. Hydrobiologia, 532(1): 53-67.

Nguyen, T.T.N., Nguyen, T.V.H., and Suthipong, S., 2011a. Risk assessment of the Saigon River water quality for safety water supply to Ho Chi Minh City. Vietnam Journal of Science and Technology, 09: 1-10.

Nguyen, T.V.H., Satoshi, T., Kumiko, O., and Nguyen, V.P., 2011b. Sources and leaching of manganese and iron in the Saigon River Basin, Vietnam. Water Science Technology, 63(10): 2231-2237.

Stevenson, R.J., Pan, Y., Manoylov, K.M., Parker, C.A., Larsen, D.P., and Herlihy, A.T., 2008. Development of diatom indicators of ecological conditions for streams of the western US. Journal of the North American Benthological Society, 27(4): 1000-1016.

Stevenson, R.J., Pan, Y., and Van Dam, H., 2010. Assessing environmental conditions in rivers and streams with diatoms. In: Smol J.P., Stoermer E.F. (Eds.). The diatoms: applications for the environmental and earth sciences. Cambridge University Press, Cambridge, 57-85.

Sven, E.J., Liu, X., Robert, C., 2010. Handbook of ecological indicators for assessment of ecosystem health, Second Edition. CRC Press, 498 pages.

Ter-Braak, C.J.F., and Smilauer, P., 1998. CANOCO Reference Manual and User's Guide to CANOCO for Windows: Software for Canonical Community Ordination. Version 4. Microcomputer Power, Ithaca, New York, 496 pages.

Walker, C.E., and Pan, Y., 2006. Using diatom assemblages to assess urban stream conditions. Hydrobiologia, 561(1): 179-189.

Wang, Y.-K., Stevenson, R.J., Sweets, P.R., and DiFranco, J., 2006. Developing and testing diatom indicators for wetlands in the Casco Bay watershed, Maine, USA. Hydrobiologia, 561(1): 191-206.

Wehr, J.D., Robert, G.S., and Patrick, J.K. 2003. Freshwater algae of North America: ecology and classification. Elsevier, Sandiego, CA., USA, 935 pages.

Weilhoefer, C.L., and Pan, Y., 2006. Diatom assemblages and their associations with environmental variables in Oregon coast range Streams, USA. Hydrobiologia, 561(1): 207–219.

Wu, N., Cai, Q., and Fohrer, N., 2012. Development and evaluation of a diatom-based index of biotic integrity (D-IBI) for rivers impacted by run-of-river dams. Ecological Indicators, 18: 108-117.

Xu, H., Paerl, H.W., Qin, B., Zhu, G., and Gaoa, G., 2010. Nitrogen and phosphorus inputs control phytoplankton growth in eutrophic Lake Taihu, China. Limnology and oceanography, 55(1): 420-432.