INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 14, No. 1, p. 121-130, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Species composition and diversity of periphytic diatoms along Umalag River, Philippines

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Article published January 26, 2019

Key words: Composition, Freshwater, Periphytic diatoms, Umalag, Philippines.

Abstract

Rivers are one of the providers of both economic and ecosystem services. However, it has been gradually degraded by general public. One of which is Umalag River, considered to be as one of the heavily stressed rivers due to different anthropogenic activities nearby. Consequently, not only locals are affected to these changes, but also the aquatic life as well. Hence, this study was conducted to assess the current water quality status of the river. It involved species composition, abundance and diversity of periphytic diatoms. Two sites were established, Site A described as a rocky substrate while Site B is a combination of rocky and muddy substrate. Simpson's Diversity Index was employed to attain the species diversity status in the two sites. Based on the results, fifteen (15) genera were found in two (2) sites, eleven (11) of which were identified in Site A, while eight (8) were found in Site B. *Navicula* sp., *Gomphonema* sp., and *Nitzschia* sp. dominated in Site A, while *Pinnularia* sp., followed by *Navicula* sp., and *Nitzschia* sp. were some of the species found in Site B. It was evident that both sites were dominated by *Navicula* sp., and *Nitzschia* sp. which are known to be pollution tolerant species. Site B obtained the highest diversity index of 0.823. The existence of periphtyic diatoms can be associated to the type of substrate, habitat preferences as well as to the varying environmental factors which may possibly poses an important implication to the water quality and biological integrity.

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Introduction

Many rivers in the world are severely degraded or at risk, which undermines their ability to provide critical ecosystem services and related benefits. The general public have become increasingly concerned about maintaining the quality of aquatic resources. Rivers are complex systems of flowing waters draining a specific land surfaces or areas. As defined by Oates and Parker (2016), rivers are natural streams of water flowing in channels and emptying into larger bodies of water. One of the measurements that provide quantitative data on the presence and levels of aquatic pollution and degradation are physical and chemical,but these parameters do not reflect the extent of environmental stress reaching the living organisms or the subsequent effects of this stress (Omar, 2010). However, they are only representative of short-term conditions found at the instant of sampling and do not provide information about the effects of these changes on biological communities.

In aquatic ecosystems, benthic algae are the main component. It is an important primary producers, chemical modulators, and important habitats for other organisms in those aquatic ecosystems (Stevenson *et al.,* 1996). Periphyton comprises an assemblage of organisms growing on free-surfaces of any objects such as plants, old leaves, woods, stones, rocks and plastic sheets submerged in water (Khan and Firuza 2012).The use of periphyton, or attached benthic algae, as an indicator of stream water quality has provided an important source of information for the detection and assessment of environmental degradation in streams and rivers (Herbst and Blinn, 2007). According to Porter *et al.,* (2008), the assessments of algal-community structure can reveal that eutrophication problems exist or that water-quality conditions are favorable for such problems to develop.

Umalag River in Tablon is one of the major river in Cagayan de Oro City traversing many big industries and residential settlements. The river supports livelihood to local populace for irrigation, bathing, fishing, and washing as well as the supply of potable water. As can be observed, undesirable happenings like improper disposal of garbage, application of fertilizer by some farmers, on-going constructions, quarrying, and effluent coming from industry that may result to many consequences such as congestion of waterways, loss of clean water supply, damage of aquatic ecosystem and the possibility of flooding due to overflowing river. The local government of Tablon as well as the residents is alarmed to drastic happenings in the river. As reported by Arasga of Remate ang Diaryo ng Masa (2015), the river has been experiencing several fish kill incidents due to toxic liquid waste material coming from a particular industry. Moreover, Fore*et al.,* (2010) stated that the index and metrics of periphyton derived in a particular water body is highly correlated with independent measures of human disturbance. Although there were recent studies conducted in the said river regarding physico-chemical properties of the water and species composition and distribution of phytoplankton, the study was the first to cover those benthic organisms particularly periphytic diatoms which can be a useful tool in biological monitoring. Fisher and Dunbar (2007) stated that diatoms, a relevant component of periphyton have long been used as a tool for monitoring surface water quality. Thus, the study determined the composition, abundance and diversity of periphytic diatoms as well as the present condition of water quality along the area of Umalag River.

The study aims to assess the species composition, abundance and diversity of periphytic diatoms along Umalag River, Tablon, Cagayan de Oro City. Specifically, the study aims to identify the species composition up to genus level, abundance and diversity of periphytic diatoms present in each site and to determine the substrate type of the two established sites.

Materials and methods

Research design

The research adopted the descriptive-comparative type of study. Descriptive since the study employed the water quality analysis in accordance to the parameters that were used. Meanwhile, it was comparative because the researchers compared the differences of the composition, abundance and diversity of periphytic diatoms as well as the physico-chemical parameters in the two established sampling sites of Umalag River.

Fig. 1. Map of the two (2) established sites in Umalag River.

Research setting

Umalag River is considered one of the heavily stressed rivers in Cagayan de Oro City because of its exposure to various anthropogenic activities such as bathing, cleaning, washing, quarrying and on-going construction that could be observed in the area (see Fig. 1). The area showed clear signs of industrialization where liquid and solid waste materials coming from households, small agricultural sector and industry may had emptied into the bodies of water. Site A has higher elevation surrounded with vegetation and lesser number of people was noted. In addition, the residents in the area depend on the river in terms of bathing, washing, irrigating plants/crops and watering farm animals. The area was observed to have a very rocky substrate with many large rocks. Whereas, Site B is considered to be the lower portion of the river. It was proximate to the sea and Umalag Bridge where there were many households, nearby industries and other urban settlements. A combination of muddy and rocky substrate was being noticed in the area.

Collection of Periphytic Diatoms

The collection of water samples for periphytic diatoms assessment was obtained in each site. This was done by composite sampling method on the established transect line in every site.Using a combination of scraping, brushing, and rinsing with stream water, all the algal materials from the known surface area of the rock were collected. It was then washed using minimal volume of distilled water.

Preservation of Periphytic Diatoms

The preservation of periphytic diatoms was done by preparing a concentrated formalin and it was then diluted with water sample. Composite samples were poured into a dark sample container and was transported and stored in a bucket filled with ice. It was then brought to the laboratory for cleaning and for initial identification by the researchers.

Identification of Samples

A compound microscope with a magnification of 100x, microscope slide, cover slip and dropper were used to initially identify the species composition of periphytic diatoms. Confirmation and validation was done by a periphyton expert using Lackey drop-transect method.

Species Richness and Diversity Index

(a) *Species richness* is determined by the number of species present in a community. The relative abundance for each species is calculated as:

Relative abundance = $(\frac{ai}{A})$ 100%

Where a_i the number of individuals is collected in the ith species and A is the total number of species collected.

(b) *Simpson's Diversity Index* is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

Results and discussion

Species Composition of Periphytic Diatoms along Umalag River

Diatoms belong to the algal division of *Bacillariophyta* which is divided into three (3) classes namely *Bacillariophyceae, Fragilariophyceae and Coscinodiscophyceae* (Round *et al.,* 1990). Fig. 2 shows the composition of periphytic diatoms along Umalag River.

Table 1. Presence and absence of periphytic diatoms species along Umalag River.

Genus Name			Sites	
			A	B
Class	Bacillariophyceae			
		Achnanthidium sp.	✓	✓
		Amphora sp.	X	✓
		Cymbella sp	X	✓
		Diadesmis sp.	✓	X
		Fallacia sp	✓	X
		Gomphonema sp.	✓	X
		Gyrosigma sp.	X	✓
		Navicula sp.	✓	✓
		Nitzschia sp.	✓	✓
		Pinnularia sp.	✓	✓
		Sellaphora sp.	✓	X
		Surirella sp.	✓	X
Class	Fragilariophyceae			
		Diatoma sp.	X	✓
		Staurosira sp.	✓	X
		Synedra sp.	✓	X

These species plays an important part in a river ecosystem which is used in environmental status assessment because of their importance in food webs, biochemical linkages and due to their sensitivity for physical, chemical and biological disturbances. Potapova and Charles (2002) added that multiple factors prevailing at different temporal and spatial scales play an important role in structuring benthic diatom communities in lotic systems of local environmental conditions. Most of the identified genera belong to the class of *Bacillariophyceae* such as *Achnanthidium* sp., *Amphora* sp., *Cymbella* sp., *Diadesmis* sp.,*Fallacia* sp., *Gomphonema* sp., *Gyrosigma* sp., *Navicula* sp., *Nitzschia* sp., *Pinnularia* sp., *Sellaphora* sp., and *Surirella* sp., except for *Diatoma* sp., *Staurosira* sp. and *Synedra* sp. which belong to *Fragilariophyceae*. The genus *Fallacia sp., Gyrosigma sp., Navicula sp., Pinnularia sp., Diadesmis sp.* and Sellaphora sp. belong to the order Naviculales.

They are generally pennate diatom and boat-shaped.

Table 2. Relative abundance of identified periphytic diatoms in Site A.

Genus	No. of Individuals	Relative Abundance (%)
Achnanthidium sp.	80	2.1
Diadesmis sp.	240	6.3
Fallacia sp.	160	4.2
Gomphonema sp.	620	16.3
Navicula sp.	1600	42.1
Nitzschia sp.	400	10.5
Pinnularia sp.	60	1.6
Sellaphora sp.	80	2.1
Staurosira sp.	260	6.8
Surirella sp.	180	4.7
Synedra sp.	120	3.2
Total	3800	100.00

Their size ranges from 32 - 130 µm in length and 7 - 21 µm in width with cells that are rectangular in girdle view, and widely lanceolate in valve view (Phytoplankton Encyclopaedia Project, 2012).*Cymbella sp* and *Gomphonema sp.* are pennate diatom. They are typically benthic, often attaches to substrate with a mucilaginous stalk. Some members of this genus can form "rock snot" in creeks and rivers by forming colonial aggregates.

Table 3. Relative abundance of identified periphytic diatoms in Site B.

Genus	No. of Individuals	Relative Abundance (%)
Achnanthidium sp.	40	7.4
Amphora sp.	40	7.4
Cymbella sp.	40	7.4
Diatoma sp.	40	7.4
Gyrosigma sp.	40	7.4
Navicula sp.	120	22.2
Nitzschias p.	60	11.1
Pinnularia sp.	160	29.7
Total	540	100.00

The genus *Diatoma* sp., *Staurosira* sp. and *Synedra* sp. have Cell frustules swollen at the center. Cells are joined at center, forming ribbon-like colonies. Their size ranges from 40-170um in length and 2-5um in width (Phytoplankton Encyclopaedia Project, 2012).

In the study, there were a total of fifteen (15) genera of periphytic diatoms that were collected and identified in the two established sites of Umalag River as perceived in Table 1.

Table 4. Diversity index of periphytic diatoms in two sites.

Sites	Diversity Index of Periphytic Diatoms
A	0.770
B	0.823

Eleven (11) genera were present in Site A from the three thousand and eight hundred (3,800) individuals namely *Achnanthidium* sp., *Diadesmis* sp., *Fallacia* sp., *Gomphonema* sp.,*Navicula* sp., *Nitzschia* sp., *Pinnularia* sp., *Sellaphora* sp., *Surirella* sp., *Staurosira* sp., and *Synedra* sp. Whereas, eight (8) genera had been found from the five hundred forty (540) individuals in Site B specifically *Achnanthidium* sp., *Amphora* sp., *Cymbella* sp., *Gyrosigma* sp., *Navicula* sp., *Nitzschia* sp., *Pinnularia* sp., and *Diatoma* sp. As shown in Table 1, Site A had greater number of genera observed compared to Site B as shown in Table 2 and 3. This may due to the type of substrate observed in the area and the present physico-chemical factors that may influenced the presence or absence of these periphytic diatoms. The existence of these identified genera may have reflected the current condition of the river that has been exposed to variations in terms of physico-chemical parameters. As stated by Rocha (1992) species vary in their sensitivity and those more resistant to environmental changes, caused either by natural fluctuations or human activities, may be favored by selection.

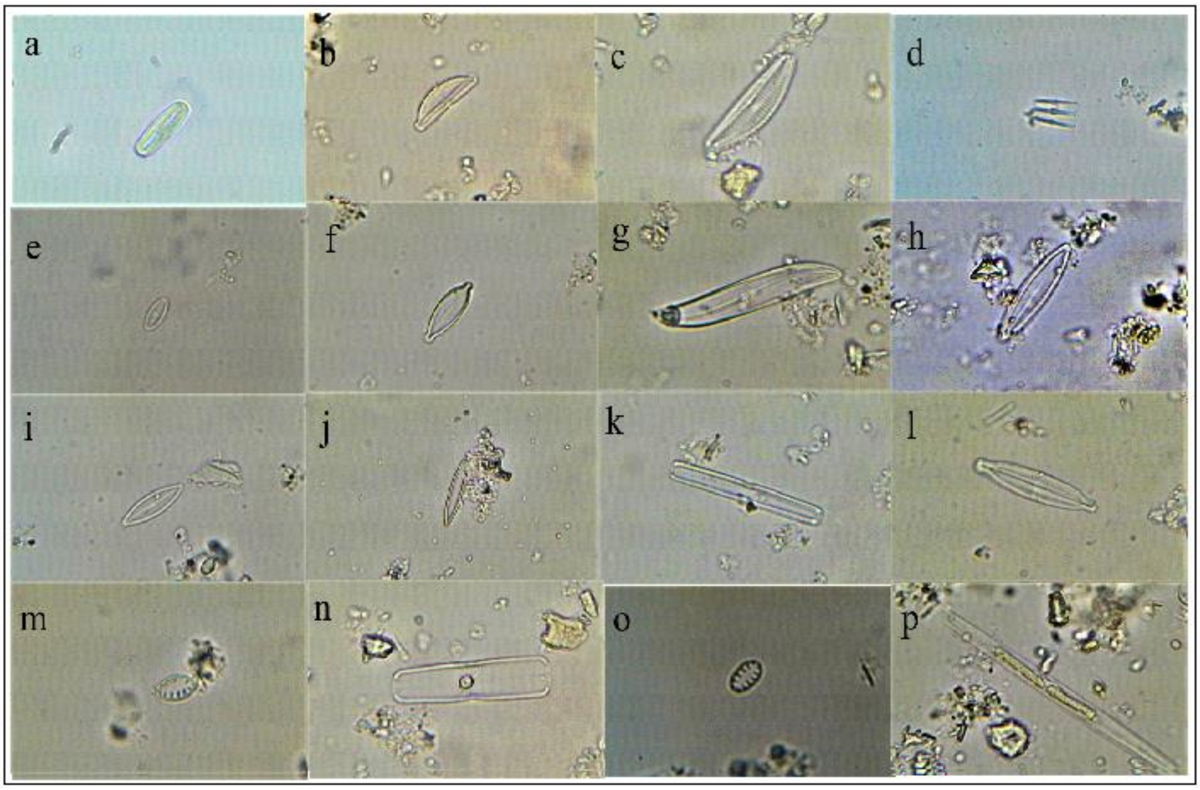

Fig. 2. Species Composition of Periphytic Diatoms along Umalag River. a- *Achnanthidium* sp., b- *Amphora* sp., c- *Cymbella* sp., d- *Diadesmis*sp., e- *Fallacia* sp., f- *Gomphonema* sp., g- *Gyrosigma* sp., h- *Naviculaerifuga*.,i- *Naviculacryptotenella*., j- *Nitzschia* sp., k- *Pinnularia* sp., l- *Sellaphora* sp., m- *Surirella* sp., n- *Diatoma* sp., o- *Staurosira* sp., p- *Synedra* sp.

Abundance of Periphytic Diatoms

The algal species that develop in an area depend on different environmental factors (Martin and Fernandez, 2012). In the study, the emergence of these species in the sampling sites may had been significantly affected by the type of substrate and the current physico-chemical conditions of the river such as nutrient load, conductivity, pH, turbidity, and water velocity. Table 2 showed that in Site A, the genus *Navicula* sp. acquired the highest abundance (RA=42.1%), followed by *Gomphonema* sp. (RA=16.3%) and *Nitzschia* sp. (RA=10.5%).

Whereas in Site B as presented in Table 3, *Pinnularia* sp. constituted the greatest abundance (RA=29.7%), followed by *Navicula* sp. (RA=22.2%) and *Nitzschia* sp. (RA=11.1%). Based on the data presented, greater generic richness was found in Site A as compared to Site B. Less number of organisms in Site B may due to several sources of pollution mostly from human activities that may be drained in this lower portion of the river. Barbour *et al.,* (1999) supported the results that generic richness is lowest in impacted sites where sensitive genera become stressed. Furthermore, the increase amount of dissolved and suspended solids and other compounds in Site B could be associated to the type of substrate which is a combination of muddy and rocky (mostly small rocks) that may influenced the species assemblage where high amount of soils/mud and sediments in the water may affect the substrate by blocking the sunlight.

Thus, inhibiting periphytic diatoms' ability to perform photosynthetic activity.

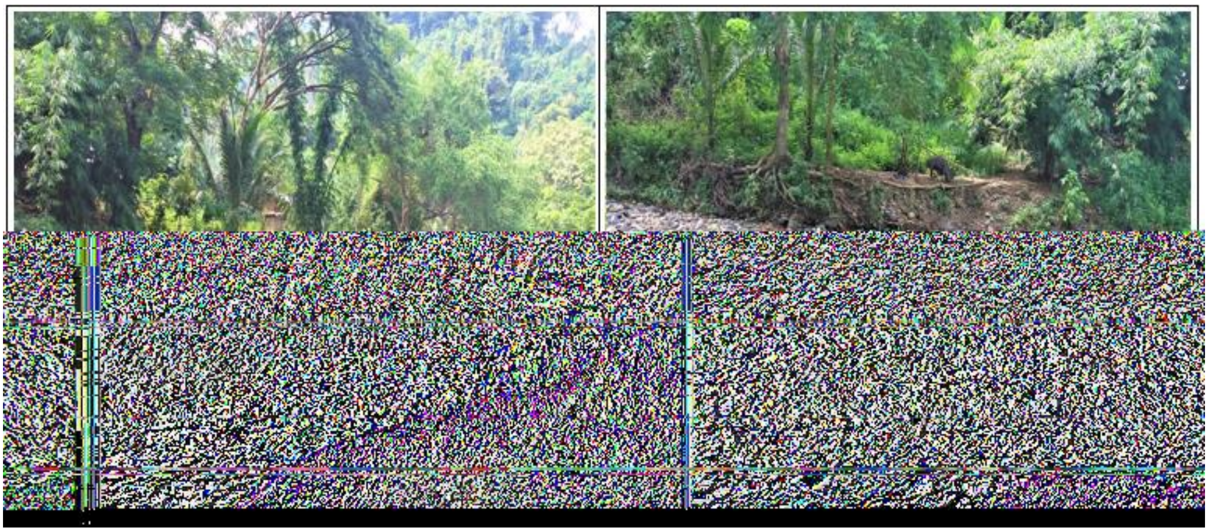

Fig. 3. Site A of Umalag River located at Purok 7.

The genera that dominated were *Navicula* sp. and *Nitzschia* sp. which occurred in the two sampling sites. They are motile diatoms that are known to be organic pollution and eutrophication tolerant species (Silva 1996). According to Fore and Grafe (2002) and Kelly (2003), motility is an essential adaptation to prevent burial by siltation and most motile species tend to display a greater tolerance to organic pollutants. Furthermore, *Navicula* sp. which had the most number of individuals in Site A was the largest diatom genus found in variety of habitats as said by Mann (1999). *Gomphonema* sp. which is abundant as well in Site A are found in nutrient-rich water (Kova´cs*et al.,* 2006; Gottschalk and Kahlert, 2012). These are taxa attached by stalks that prefer to uptake nutrients dissolved in water than nutrients absorbed in substratum (Pringle, 1990; Berthon*et al.,* 2011). In addition, Lange-Bertalot (1979) classified *Gomphonema* sp. and *Nitzschia* sp.in particular as highly pollution tolerant diatoms. The presence of *Nitzschia* sp. is typical in phosphate enriched or organically polluted waters (Juttner*et al.,* 1996; Gomez & Licursi, 2001; Fore & Grafe, 2002) that may be related to the increase of phosphate concentration in Site B as compared to Site A. Moreover, the taxa *Pinnularia* sp. is often abundant in low conductance water (Spaulding and Edlund 2009), which was contrary to the result in Site B where high conductivity was observed. In addition, results showed that the general concentration of nutrients (nitrates and phosphates) in accordance to DAO 34 for both sites are negligible even though in Site B, the amount of phosphates was higher than Site A as mentioned earlier. This perhaps may due to the time of sampling that occurred during wet season. Silva (1996) explained that the decline of these nutrients at the end of the rainy season may be the result of dilution process where water quality improves as the initial surge subsides. Hence, the differences in diatom species composition and distribution may have to do with the varying environmental factors as well as the habitat preferences of each species in a specific area.

Diversity Status of Identified Periphytic Diatoms

As can be inferred in the results (see Table 4), the index value for Site B indicated a closer value to a diverse community that was contrary to the low diversity in Site A though it had the most number of genera.

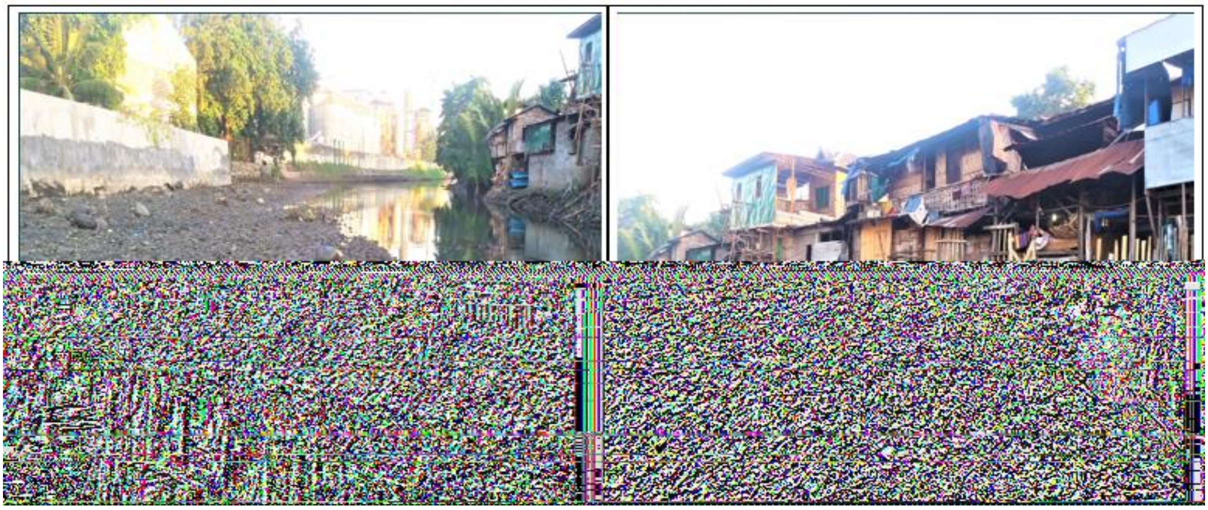

Fig. 4. Site B of Umalag River located at Purok 4.

The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity (Barcelona Field Studies Centre S.L., 2016). Whittaker (1965) stated that Simpson's Diversity Index is always higher where the community is dominated by less number of species and when the dominance is shared by large number of species which was being observed also in Site B. This is consistent to the number of organisms and the occurrence of dominant species in each site that possibly affected the species distribution and evenness. According to Archibald (1972), Sudhakar *et al.,* (1991) and Stevenson and Pan (1999), taxa better adapted to unfavorable conditions (e.g., nutrient enrichment or chemical toxicity) will have an advantage resulting in an uneven distribution of individuals among taxa.

Identification of Substrate Type

In the study, Site A was found to have a clear water and rocky substrate with a lot of larger rocks (see Fig. 3). This may be relevant to the number of genera found in Site A since larger rocks perhaps means greater number of species can occupy. The clarity of the water and the sizes of rocks may inhabit the favorable growth of periphytic diatoms on the rocks.

In the lower slope of the river, Site B is a combination of muddy and rocky substrate (see Fig. 4). The water was observed to be murky where sediments accumulation is rapid on the substrate that possibly limit the primary productivity of periphytic diatoms making it unfavorable habitat for some species.

During community development the species competition may occurred. A part of them could make the substrate available for other species. Brown and Austin (1973) also suggested that the variation in numbers of periphytic diatoms may be due to direct competition among them, as well as to the differences in the physico-chemical environment.

Conclusion

The two established sites of Umalag River constituted a wide variety of periphytic diatoms which may signifies that the river is a preferable habitat for some periphytic diatoms or some of them may able to compete to the varying environmental conditions. Based on the findings their presence maybe attributed to the type of substrate in the area and to the seasonal and temporal variation. Thus, the existence of these identified genera in each site may provide important environmental information to the biological integrity as well as to the present quality of the river.

Moreover, it is highly recommended to have regular assessment of the species occurrences and distribution patterns and identify periphytic diatoms up to species level in order to consider each species unique characteristics and properties.

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