BIODIVERSITAS
Volume 19, Number 4, July 2018
Pages: 1220-1226

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d190406

Short Communication: The diversity of epipelic diatoms as an indicator of shrimp pond environmental quality in Lampung Province, Indonesia

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Manuscript received: 23 September 2017. Revision accepted: 4 June 2018.

Abstract. *Supono, Hudaidah S. 2018. Short Communication: The diversity of epipelic diatoms as an indicator of shrimp pond environmental quality in Lampung Province, Indonesia. Biodiversitas 19: 1220-1226.* Epipelic diatoms live by attaching to sediment. Their existence is strongly affected by water and sediment quality. The purpose of this research was to analyze the structure of epipelic diatom populations on the bottom of shrimp ponds and to determine the correlation between epipelic diatom diversity and the quality of water and of pond bottom sediment. This exploratory research was conducted on twelve shrimp ponds during the water preparation period (pre-stocking). Data were collected to analyze the correlation between water and sediment qualities. The results showed that *Nitzschia* and *Pleurosigma* were the dominant epipelic diatoms in the shrimp ponds. Epipelic diatom diversity in shrimp ponds was affected by water quality parameters (namely total alkalinity, organic matter and nitrate) as well as sediment quality parameters (namely cation exchange capacity, clay content and organic matter content).

Keywords: Epipelic diatoms, shrimp ponds, lens tissue trapping method, *Nitzschia, Pleurosigma*

INTRODUCTION

Water quality management has a very important role in the success of shrimp aquaculture due to its direct impact on shrimp health and growth. Determination of the best indicators of water quality is a developing research area. Before the 20th century, the determination of water quality was based only on analysis of physicochemical parameters. In the early 20th century, research began to be conducted on using aquatic biota, both individuals and communities, as indicators of water quality. Qualitative and quantitative measurements on organisms like plankton can describe the overall water condition and quality. This is due to the direct impact of water physicochemical factors on aquatic organisms.

However, plankton analysis cannot accurately assess the condition of the pond floor and its sediments important for bottom-dwelling organisms like shrimp. Therefore, analysis of the biota living on the pond bottom may be more appropriate for evaluating water quality phenomena near the bottom of shrimp ponds. A type of biota commonly found in sediments and water on the pond bottom is the epipelic diatoms. Epipelic diatoms are microalgae living on and inside the pond floor substrates. Their type and abundance are strongly influenced by the water quality and sediment conditions (Barbour et al. 1999; Garrido et al. 2013). According to Liboriussen and Jeppensen (2003), some lakes exhibit primary productivity of benthic algae that exceeds 190 g C/m^2/year. The use of diatoms as a water quality indicator is better than the Saprobic Index due to the diatoms' higher sensitivity towards conductivity and organic content (Almeida 2001; Cicek and Yamuc 2017).

The use of epipelic diatoms as an indicator of shrimp pond fertility rate is still rather limited compared with the use of plankton. However, the structure and abundance of benthic diatom populations are very important in determining the water ecological condition (Picinska 2007). Epipelic diatoms play an important role as a food source for meio-and micro-faunal grazers in shallow water ecosystems (Gould and Gallagher 1990; Althouse et al. 2014).

The purpose of the research described in this paper was to analyze the structure of epipelic diatoms at the bottom of shrimp ponds used in aquaculture in Lampung Province, Indonesia, and to determine the degree of correlation between epipelic diatom diversity and the quality of water and pond bottom sediments.

MATERIALS AND METHODS

Study area

Our research was located in shrimp pond units in the Village of Kuala Teladas, Dente Teladas Sub-district, Tulang Bawang District, Lampung Province, Indonesia. The research location is displayed in Figure 1, and the pond sites illustrated in Figure 2.

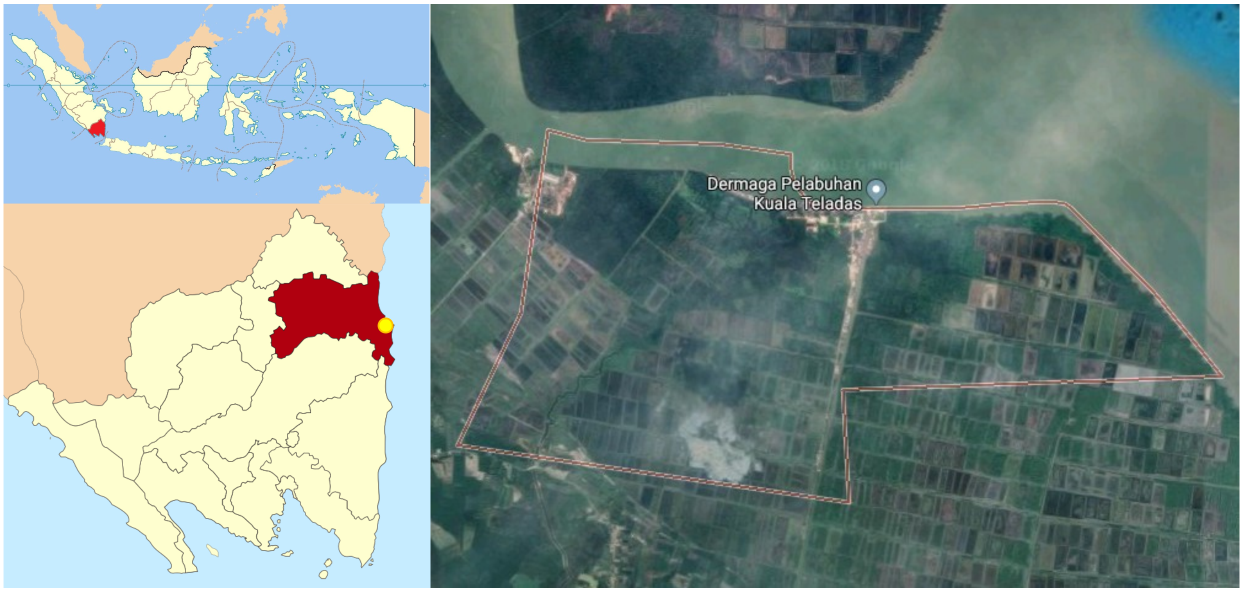

Figure 1. Research location in Village of Kuala Teladas, Dente Teladas Sub-district, Tulang Bawang District, Lampung Province, Indonesia

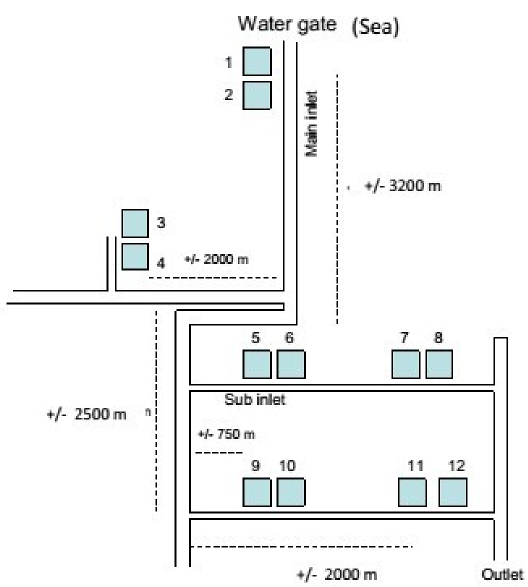

Figure 2. Pond sites illustration

Materials

This exploratory research studied the structure of epipelic diatoms populations in shrimp ponds and its relationship with pond environmental factors, particularly water and sediment quality. The main parameters assessed in this research were the epipelic diatoms type and abundance; sediment quality factors; and water quality factors. The sediment quality parameters consisted of total organic matter (TOM); cation-exchange capacity (CEC); soil pH; and soil texture. The water quality parameters consisted of water physical quality, namely temperature, transparency, and total suspended solids; as well as water chemical quality parameters of pH, dissolved oxygen (DO), salinity, nitrate concentration, phosphate concentration, total organic matter (TOM), alkalinity, and biological oxygen demand (BOD).

Procedures

Epipelic diatom sampling was conducted using the lens tissue trapping method. This technique is capable of capturing more than 70% of epipelic diatoms in aquatic sediments (Round 1993). Surface sediments and overlying water were taken using a glass tube, transported to the laboratory, and then poured out into a Petri dish. After removing the supernatant, the mud was covered with lens tissue and allowed to stand in the dark overnight. On the following day, the samples were put under low-level illumination. Epipelic diatoms moved up through the lens tissue and became attached to coverslips. The samples were preserved with 4% formaldehyde solution. The epipelic diatoms were counted on the identical area of the coverslip (Round 1993). The water quality parameters were measured using the standard methods described in APHA (1992). Identification of diatom species was carried out according to Davis (1955).

Data analysis

The epipelic diatom data were analyzed by calculating abundance, diversity index (Shannon-Weaver), uniformity (Evenness), true diversity measure (Jost 2006), and Nygaard index (Nygaard 1949). The correlation between epipelic diatom data and parameters of water and sediment quality were analyzed using nonparametric statistical methods (Spearman correlation) enabled by SPSS 14.0.

RESULTS AND DISCUSSION

The epipelic diatom data from 12 ponds is presented in Table 1. The data for physicochemical parameters of pond water and sediments are displayed in Table 2, 3, and 4. Forty-six species from eighteen epipelic diatom genera were found. *Nitzschia* was the dominant diatom genus found in all ponds with an abundance of 13 cells/cm^2, followed by *Pleurosigma* (12 cells/cm^2) and *Amphora* (5 cells/cm^2). The abundance of other genera were less than 4 cells/cm^2. The total abundance of epipelic diatoms varied among the ponds pond from 22 cells/cm^2 to 123 cells/cm^2, with an average of 54 cells/cm^2.

Table 1. Epipelic diatom species abundance for twelve shrimp ponds researched in Lampung Province, Indonesia

Species	**Pond no.**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	Epipelic algae abundance (cells/cm^2)											
Amphiprora alata (Ehrenberg) Kutzing		8	11	4			1			2		
Amphora hyaline (Kutzing)				5	1	2		1				
Amphora lineate Gregory	1	1		22	1	1	1					1
Coscinodiscus radiatus Ehrenberg	1	1	4		4	1	1		7	2	4	10
Cyclotella striata Kutzing			1	1	5				5			8
Dactyliosolen antarcticus Castracane								6				
Fragilaria intermedia Grunow	1	1	1					7	1			
Grammatophora angulosa Ehrenberg		1	4		5	3	1	3	3			
Grammatophora marina (Lyngbye) Kutzing			1					3				
Grammatophora serpentina (Ralfs) Kutzing	5	1		3	3	7				3		
Gyrosigma acuminatum (Kutzing) Rabenhorst							3	1				
Gyrosigma balticum (Ehrenberg) Rabenhorst		4										
Gyrosigma spenceri (W.Smith) Griffith&Henfrey		1										1
Gyrosigma strigile (W.Smith)				5		2	2	2	1	12	10	2
Licmophora abbreviata C.Agardh										1		
Mastogloia minuta Greville		2		1								
Nitzschia closterium (Ehrenberg) W.Smith		5	1	1		2	1				1	3
Nitzschia lanceolata W. Smith				1		1			1			
Nitzschia longissima (Brebisson) Ralfs					3			2	1		1	
Nitzschia paradoxa (J.F.Gmelin) Grunow	2	33	1	3	3	3	2		2		3	2
Nitzschia pacifica Cupp	1	2	1	1	1	1	1					
Nitzschia plana W.Smith		3		3								
Nitzschia seriata Cleve						3	2				1	
Nitzschia sigma (Kutzing) W.Smith	1	34		1	1		2	2	1		2	1
Nitzschia spectabilis (Ehrenberg) Ralfs		1		1				13				
Nitzschia vitrea G.Norman			1			1						
Navicula cancellata Donkin	1								1		1	3
Navicula lyra Ehrenberg		1					1	1			1	
Pleurosigma affine Grunow			26			1			1		1	1
Pleurosigma angulatum (Quekett) W.Smith	4			10		1	1					
Pleurosigma compactum Greville				2								1
Pleurosigma fasciola (Ehrenberg) W.Smith	3			3	1	7		15			3	
Pleurosigma nicobaricum Grunow								3				
Pleurosigma pelagicum Cleve				2	3			2	6			
Pleurosigma rectum Donkin	1	22				2	3			1	14	7
Rhabdonema adriaticum Kutzing			3		1			5	1	1	5	
Rhizosolenia styliformis T.Brightwell						1						
Rhizosolenia bergonii H.Peragalo				8								
Rhizosolenia delicatula Cleve				1								
Rhizosolenia robusta G.Norman						1						
Rhizosolenia setigera Brightwell				12		15				1		
Streptotecha indica Karsten G.	3			4						15		
Synedra gaillonii (Bory) Ehrenberg		2		2		12		5				
Thalassionema nitzschioides (Grunow)									1			
Triceratium reticulum Ehrenberg						1				1		
Triceratium rivale Schmidt										1		
Total Population	24	123	55	96	32	68	22	71	32	40	47	40
Total Species	12	18	12	23	13	21	14	16	14	11	13	12

Table 3. Water quality chemical data for the twelve shrimp ponds in Lampung Province, Indonesia

Pond no.	Salinity (ppt)	pH	Alkalinity (mg/L)	BOD (mg/L)	DO (mg/L)	TOM (mg/L)	Phosphate (mg/L)	Nitrate (mg/Lm)
1	30	8.8	108	20.1	4.5	8	0.08	0.01
2	29	8.6	101	16.1	5.0	4	0.38	0.01
3	28	8.1	113	20.1	4.4	14	0.44	0.01
4	28	8.2	117	44.3	4.3	15	0.54	0.01
5	26	7.2	97	7.0	3.2	36	0.23	0.03
6	27	8.7	95	14.0	6.7	28	0.27	0.05
7	26	8.6	97	4.7	6.3	44	0.36	0.07
8	26	7.2	90	46.7	3.2	40	1.38	0.01
9	26	8.0	99	24.8	5.6	23	0.46	0.01
10	25	8.4	101	29.4	6.6	18	0.78	0.01
11	24+	8.4	90	20.1	6.7	3	0.57	0.01
12	26	8.7	100	8.4	8.7	24	0.19	0.01
Average	26.8	8.2	101	21.3	5.4	21	0.47	0.02

Note: BOD (Biological Oxygen Demand) is the amount of dissolved oxygen (mg) required by aerobic organisms to decompose the organic matter per volume (l) of water sample. DO (Dissolved Oxygen) is the concentration (mg/L) of dissoved oxygen present in the water sample. TOM is Total Organic Matter

Table 2. Water physical quality data in the twelve shrimp ponds in Lampung Province, Indonesia

Pond no.	Temperature (°C)	Transparency (cm)	TSS (mg/L)
1	30.0	30	144
2	32.0	80	144
3	28.6	65	147
4	29.3	70	1341
5	29.1	80	111
6	29.1	65	115
7	29.1	50	130
8	31.6	65	140
9	27.6	120	94
10	28.5	90	127
11	27.7	100	95
12	27.7	90	127
Average	29.2	76	124

Note: Transparency is a relative measure of the visual clarity of the water. TSS (Total Suspended Solids) is the dry weight of suspended particles per litre of water

Table 4. Sediment quality data for the twelve shrimp ponds in Lampung Province, Indonesia

Pond no.	Organic C (%)	CEC (me/100g)	pH	ORP (mv)	Soil texture
1	2.11	14.4	6.5	34	Loam
2	0.84	14.3	7.1	99	Loam
3	0.61	3.1	7.0	18	Sandy loam
4	0.42	3.1	7.4	47	Sand
5	0.82	13.1	6.9	118	Loam
6	1.84	14.7	6.5	68	Loam
7	1.15	13.9	6.7	69	Loam
8	1.76	12.5	6.8	49	Loam
9	1.93	12.7	6.8	107	Loam
10	0.97	10.4	6.7	126	Sandy loam
11	1.73	9.9	6.8	67	Sandy loam
12	0.89	12.3	6.7	109	Loam
Average	1.26	11.20	6.8	76	

Note: CEC (Cation Exchange Capacity) is a measure of how many cations can be retained on soil particle surfaces. Units are milliequivalents per liter (meq/l). ORP (Oxidation-Reduction Potential) is a measure of the cleanliness of water: its oxidizing or reducing tendency. Units are millivolts (mV)

Epipelic diatoms are microalgae that live by attaching to bottom substrates in aquatic habitats. According to Lysakova et al. (2007), epipelic diatoms dominate the benthic microalgae in a fish pond. The existence of epipelic diatoms is affected by sediment quality and water quality. Epipelic diatoms contain chlorophyll-a and exhibit positive phototaxis. Epipelic diatom species found in shrimp ponds have species similar to those in rivers (Gomez 1998; Kivrak and Uygun 2012), in coastal waters (Facca and Sfriso 2007) and in fish ponds (Lysakova et al. 2007). In the ponds in our study, the most abundant species were *Nitzschia paradoxa*, *Nitzschia sigma*, and *Pleurosigma rectum*. This observation was similar to the findings of Gottschalk et al. (2007) and Lysakova et al. (2007) regarding *Nitzschia* domination.

Diversity and Uniformity Index

Diversity index is a parameter used to indicate the level of stability of an observed community structure; which is closely related to the habitat characteristics occupied by the biota. On the other hand, uniformity index is used to assess the relative profusion of each individual organism. In our study, the diversity and uniformity indices of epipelic diatoms varied across sites (Figure 3). The diversity index of epipelic algae ranged between 1.7 (ponds 3 and 4) and 2.5 (pond 6 and 7) with an average value of 2.2, while the uniformity index ranged from 0.5 (pond 4) to 0.9 (ponds 1,5,7,8,9, and 12) averaging at 0.8. Pond 4 had a relatively low uniformity index characterized by *Amphora lineata* domination (22 cells/cm^2). Based on these diversity indexes, the ponds were judged to fall into a moderate category, signifying that the pond diatom population structure could be altered by small environmental changes. According to the classification of the Shannon-Wiener index, if the diversity index is lower than 1, then the biota communities would be regarded as unstable, whereas a diversity index of 1-3 would be considered moderately unstable, and a value higher than 3 would signify a stable or prime condition (Mokoginta 2016). This suggests that in our study, the pond environments at the beginning of culture were still relatively vulnerable to environmental changes; implying that fertilizing the ponds would be necessary. Nutrient enrichment by using fertilizer has the effect of significantly increasing epipelic diatom density (Licursi et al. 2015).

True diversities

The interpretation of diversity (H') and uniformity (E) values can be explained using true diversity values, by looking at the effective species (effective numbers of species) living in the ecosystem (Jost 2006). The true diversity values for each of the ponds in our study can be seen in Table 5. A pond exhibits a better true diversity value when it approaches the total number of species present in the pond (species richness). Pond 6 with a diversity index (H') of 2.55 and uniformity index (E) of 0.84 has a true diversity of 13; this means that it has an effective number of 13 species, out of a total number of 21 species present in the pond. For pond 6 two species were dominant in the pond, namely *Rhizosolenia setigera* and *Synedra goillonii*. On the other hand, pond 4 had a diversity index (H') of 1.70, uniformity index (E) of 0.54 and true diversity value of *6*, so the effective number of species was only 6 out of 23 species present; with two species dominant, namely *Amphora lineata* and *Rhizosolenia setigera*.

Having a high number of species is not necessarily better than having a fewer number; it all depends on the number of effective species living in the ecosystem (Jost 2006). Pond 6 with a total of 21 species proved to be better than pond 4 which has 23, because pond 6 had 13 types of effective species, compared to the 6 effective species found in pond 4.

The ponds that had the highest values for diversity and true diversity were ponds No. 5, 6, 7 and 8. The ponds happened to have low values for alkalinity, high values for Total Organic Matter (TOM) and mainly high values for nitrate concentration int heir water. The epipelic diatom that dominated in these ponds was *Gramatophora angulosa* (Table 6).

While lowest diatom diversities and true diversities were found in ponds No. 3, 4, and 10. These ponds had generally low cation exchange capacity (CEC) values and organic C content, as well as sandy/sandy-loam soil texture. *Amphiprora alata* dominated in these ponds (Table 7).

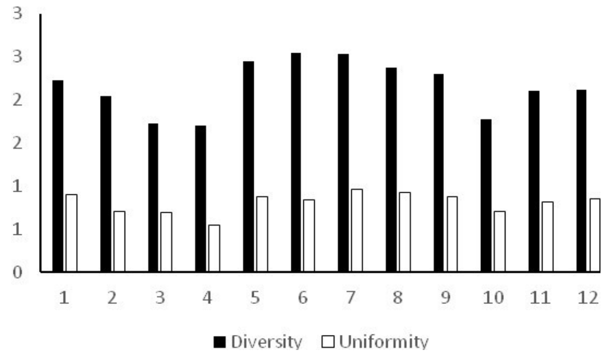

Figure 3. Diversity and Uniformity Index of epipelic diatoms in the twelve shrimp ponds evaluated in Lampung Province, Indonesia

Table 5. The Diversity Index (H') compared with the True Diversity of epipelic diatoms in the twelve research ponds evaluated in Lampung Province, Indonesia

Pond no.	Total species	Diversity	
		H'	True diversity
1	12	2.23	9.29
2	18	2.05	7.78
3	12	1.73	5.62
4	23	1.70	5.48
5	13	2.45	11.58
6	21	2.55	12.80
7	14	2.54	12.67
8	16	2.38	10.78
9	14	2.30	10.00
10	11	1.78	5.91
11	13	2.11	8.28
12	12	2.12	8.35

Table 6. Water quality, and diatom diversity and true diversity for the best four ponds of the twelve evaluated in Lampung Province, Indonesia

Pond no.	Diversity	True diversity	Alkalinity (mg/L)	TOM (mg/L)	Nitrate (mg/L)	Epipelic diatom
6	2.55	12.80	95	28	0.05	*Gramatophora*
7	2.54	12.67	97	44	0.07	*angulosa*
8	2.38	10.78	90	40	0.01	

Table 7. Sediment quality, diversity and true diversity for the worst three ponds of the twelve evaluated in Lampung Province, Indonesia

Pond no.	Diversity	True diversity	CEC (me/100g)	Organic C (%)	Soil texture	Epipelic diatom
3	1.73	5.62	3.1	0.61	Sandy loam	*Amphiprora alata*
4	1.70	5.48	3.1	0.42	Sandy	
10	1.78	5.91	10.4	0.97	Sandy loam	

Nygaard Index (In)

Nygaard index is determined by dividing the number of diatom species of the order Centrales by the number of species number of the order Pennales (Nygaard, 1949). Relatively high number of species in the order Centrales indicates eutrophic conditions, whereas a relatively higher number of species in the order Pennales indicates oligotrophic conditions. The range of Nygaard index falling into these categories is summarised here:

0-0.2 : Habitat is oligotrophic

>0.2 : Habitat is eutrophic

The analysis of Nygaard Index values for each of the twelve ponds can be seen in Table 8.

The Nygaard Index values for the research ponds varied from 0 (pond no. 8) to 0.82 (pond no.12), with an average of 0.24. According to the analysis, ponds with oligotrophic conditions were ponds No. 1, 2, 3, 7, 8,10, and 11, while ponds with eutrophic condition were ponds No. 4, 5, 6, 9 and 12.

According to our analysis of True Diversity and Nygaard Index, the most productive pond in terms of epipelic diatoms was pond No.6 while the pond with lowest productivity was No. 3. Pond No. 6 had the highest True Diversity and was grouped among the eutrophic ponds, while pond No. 3 had the lowest True Diversity and was grouped among the oligotrophic ponds.

Correlation between epipelic diatoms and the quality of water and soil

Based on non-parametric statistical analysis (Spearman Correlation) of data from the twelve ponds, the diversity index for epipelic diatoms is correlated with several parameters of water and sediment quality. The water quality parameters closely correlated with diversity index were alkalinity with a correlation coefficient (r) of 0.75, total organic matter (r = 0.71), and nitrate (r = 0.66) as presented in Tables 4, 5 and 6. The main components of water alkalinity are bicarbonate anion (HCO_3^-), carbonate ($CO_3^=$), and hydroxide (OH^-). Bicarbonate anions are used by algae as a carbon source for photosynthesis, thus its availability greatly affects aquatic algae existence. Yang et al (2010) demonstrated that CO_2 concentration affects the existence of epipelic diatoms in aquatic environments.

Table 8. Nygaard Index values for epipelic diatoms in the twelve ponds evaluated in Lampung Province, Indonesia

Pond no.	Ordo Centrales	Ordo Pennales	Nygaard Index	Classification
1	1	23	0.04	Oligotrophic
2	1	122	0.01	Oligotrophic
3	5	50	0.10	Oligotrophic
4	22	74	0.30	Eutrophic
5	10	22	0.45	Eutrophic
6	19	49	0.39	Eutrophic
7	1	21	0.05	Oligotrophic
8	0	71	0.00	Oligotrophic
9	12	20	0.60	Eutrophic
10	3	37	0.08	Oligotrophic
11	4	43	0.09	Oligotrophic
12	18	22	0.82	Eutrophic
Average			0.24	

A sufficient quantity of dissolved organic material is needed by the algae. Research by Miho et al. (2005) showed that total organic matter as a mesure of fertility affects the diatom index. The organic matter decomposes, making nitrogen available, which is needed by the algae for their growth. Cicek and Yamuc (2017) showed that water temperature, pH, and conductivity positively affects the abundance of epilithic algae dominant species. However, excess organic material can have negative impacts on species diversity. Kivrak and Uygun (2012) revealed that the values for epipelic diatom diversity gradually decreased in response to increasing water pollution.

The sediment quality parameters in our study that closely related to epipelic diatom diversity were soil cation-exchange capacity (CEC) (r = 0.72), clay content (r = 0.65), total organic matter (r = 0.62). The soil's ability to absorb or exchange cations is important for plant nutrient uptake, soil fertility, nutrient retention, and the response to fertilizing. The CEC affects the ability of soil colloid surfaces to bind nutrients added through fertilization. Soils with higher CEC value will have a higher level of fertility. Soil organic matter is a nitrogen source required for algae growth as well as a carbon source for photosynthesis. Total organic matter (TOM) in sufficient quantity is needed by the algae. The correlation between epipelic diatom diversity and water and sediment qualities in our study suggests that it can be used as an indicator to assess pond environmental quality. The finding is similar to the results of research conducted by Kivrak and Uygun (2012), Licursi et al. (2015), and Facca and Sfriso (2007).

A number of water and sediment quality parameters exhibited an association with the epipelic diatom True Diversity values. Alkalinity between 95-100 mg/L generated good growth of epipelic diatom, while the optimal levels of total organic matter value for epipelic algae growth ranged between 28 mg/L and 44 mg/L. Soil texture also affected the True Diversity of the epipelic algae. Loam soils appeared to be more suitable for epipelic diatom's growth compared to sandy soils, while sufficient total organic C (1%-2%) was required for epipelic diatom optimum growth.

ACKNOWLEDGEMENTS

This research was funded by DIPA University of Lampung, Indonesia. The authors would like to express their gratitude to the Department Head of Water Quality Laboratory, P.T. C.P. Bahari, Lampung, Indonesia, for providing the facilities to carry out the research.

REFERENCES

Almeida SFP. 2001. Use of diatom for freshwater quality evaluation in Portugal. Limnetica 20 (2): 205-213.

Althouse B, Higgins S, Vander ZMJ. 2014. Benthic and planktonic primary production along a nutrient gradient in Green Bay, Lake Michigan, USA. Freshw Sci 33 (2): 487-498.

APHA. 1992. Standard Methods for The Examination of Water and Wastewater, 16th Edition. American Public Health Association, Washington DC.

Barbour MT, Gerritsen J, Snyder, BD, Stribling JB. 1999. Rapid Bio-Assessment Protocols for use in Stream and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington D.C.

Cicek NL, Yamuc F. 2017. Using epilithic algae assemblages to assess water quality in Lake Kovada and Kovada Channel (Turkey), and in relation to environmental factors. Turkish J Fish Aquat Sci 17 (4): 701-711.

Davis CC. 1995. The Marine and Freshwater Plankton. Michigan State University Press. New York.

Facca C, Sfriso A. 2007. Epipelic diatom spatial and temporal distribution and relationship with the main environmental parameters in coastal waters. Estuar Coast Shelf Sci 75 (1-2) : 35-49

Garrido AB, Romo S, Villena MJ. 2013. Diatom species composition and indices for determining the ecological status of coastal Mediterranean Spanish Lakes. Anales der Jardin Botánico de Madrid 70 (2): 122-135.

Gomes N. 1998. Use of epipelic diatoms for evaluation of water quality in the Matanza-Riachuelo (Argentina), a Pampean plain river. Water Res 32 (7): 2028-2034

Gottschalk S, Uthicke S, Heimann K. 2007. Benthic diatom community composition in three regions of the Great Barrier Reef, Australia. Coral Reefs 26 (2) : 345-357.

Gould DM, Gallagher ED. 1990. Field measurement of specific rate, biomass, and primary production of benthic diatoms of Salvin Hill Cove, Boston. Limnol Oceanogr 35 (8): 1757-1770.

Jost L. 2006. Entropy and diversity (Opinion). Oikos 113 (2): 363-375.

Kivrak E, Uygun A. 2012. The structure and diversity of the epipelic diatom community in a heavily polluted stream (the Akarc¸ay, Turkey) and their relationship with environmental variables. J Freshw Ecol 27 (3): 443–457.

Liboriussen L, Jeppesen E. 2003. Temporal dynamic in epipelic, pelagic and epiphytic algal production in a clear and a turbid shallow lake. Fresh Water Biol 48 (3): 418-431.

Licursi M, Gómez N, Sabater S. 2016. Effects of nutrient enrichment on epipelic diatom assemblages in a nutrient-rich lowland stream, Pampa Region, Argentina. Hydrobiologia 766 (1): 135–150

Lysakova M, Kitner M, Poulickova A. 2007. The epipelic algae of fishpond of Central and Northern Moravia (The Czech Republic). Fottea 7 (1): 69-75.

Miho A, Cake A, Carcani. 2005. Diatom in the stomach content of Barbel (*Barbus meridionalis*) from Shkumbini River (Central Albania). J Environ Protect Ecol 6 (2): 253-259

Mokoginta MM. 2016. Tree species diversity at the protected forest of Mountain Masinggi, North Bolaang Mongondow, Indonesia. Intl J Agric For 6 (2): 69-73

Nygaard G. (1949). Hydrobiological studies on some Danish ponds and lakes. Part 2. The quotient hypothesis and some new or little-known phytoplankton organisms. Det Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter **7** (1): 1–293.

Picinska FJ. 2007. Ecological Status of the River Nysa Luzycka (Lausitzer Neisse) Assessed by Epilithic Diatoms. Proceeding of The 1st Central European Diatom Meeting. Berlin-Dahlem, 23–25 March 2007.

Round FE. 1993. A Review and Methods for The use of Epilithic Diatoms for Detecting and Monitoring Change in River Water Quality. Methods for The Examination of Water and Associated Materials. HMSO Books, London.

Yang H, Roger JF, Richard WB. 2010. An improved coverslip method for investigating epipelic diatoms. Eur J Phycol 45 (2): 191-199.