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Jl. Ir. Sutami 36A Surakarta 57126. Tel. +62-271-7994097, Tel. & Fax: +62-271-663375, email: editors@smujo.id

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

SUPONO*, SITI HUDAIDAH
Department of Aquaculture, Faculty of Agriculture, Universitas Lampung. Jl. Sumantri Brojonegoro No. 1, Bandar Lampung 35145, Lampung, Indonesia. Tel./Fax. +62-721-783682, *email : supono_unila@yahoo.com


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/m²/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.
Materials
This exploratory research studied the structure of epipelic diatom 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

<table>
<thead>
<tr>
<th>Species</th>
<th>Pond no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<tbody>
<tr>
<td><em>Amphiprora alata</em> (Ehrenberg) Kutzing</td>
<td></td>
<td>8</td>
<td>11</td>
<td>4</td>
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<tr>
<td><em>Amphora hyaline</em> (Kutzing)</td>
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<td>1</td>
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<tr>
<td><em>Amphora lineate</em> Gregory</td>
<td></td>
<td>1</td>
<td>1</td>
<td>22</td>
<td>1</td>
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<td><em>Coscinodiscus radiatus</em> Ehrenberg</td>
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<td>4</td>
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<td><em>Cyclotella striata</em> Kutzing</td>
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<td><em>Dactyliosolen antarcticus</em> Castracane</td>
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<td><em>Fragilaria intermedia</em> Grunow</td>
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<td><em>Grammatophora angulosa</em> Ehrenberg</td>
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<td><em>Grammatophora marina</em> (Lyngbye) Kutzing</td>
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<td><em>Grammatophora serpentina</em> (Ralfs) Kutzing</td>
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Table 3. Water quality chemical data for the twelve shrimp ponds in Lampung Province, Indonesia

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<tr>
<th>Pond no.</th>
<th>Salinity (ppt)</th>
<th>pH</th>
<th>Alkalinity (mg/L)</th>
<th>BOD (mg/L)</th>
<th>DO (mg/L)</th>
<th>TOM (mg/L)</th>
<th>Phosphate (mg/L)</th>
<th>Nitrate (mg/L)</th>
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</table>

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 dissolved 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

<table>
<thead>
<tr>
<th>Pond no.</th>
<th>Temperature (°C)</th>
<th>Transparency (cm)</th>
<th>TSS (mg/L)</th>
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<tr>
<td>Average</td>
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<td>76</td>
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</table>

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

<table>
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<th>Pond no.</th>
<th>Organic C (%)</th>
<th>CEC (me/100g)</th>
<th>pH</th>
<th>ORP (mv)</th>
<th>Soil texture</th>
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<tr>
<td>11</td>
<td>1.73</td>
<td>9.9</td>
<td>6.8</td>
<td>67</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>12</td>
<td>0.89</td>
<td>12.3</td>
<td>6.7</td>
<td>109</td>
<td>Loam</td>
</tr>
<tr>
<td>Average</td>
<td>1.26</td>
<td>11.20</td>
<td>6.8</td>
<td>76</td>
<td></td>
</tr>
</tbody>
</table>

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/cm²). 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 in their 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).

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

<table>
<thead>
<tr>
<th>Pond no.</th>
<th>Total species</th>
<th>Diversity</th>
<th>True diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>2.23</td>
<td>9.29</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>2.05</td>
<td>7.78</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>1.73</td>
<td>5.62</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
<td>1.70</td>
<td>5.48</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>2.45</td>
<td>11.58</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>2.55</td>
<td>12.80</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>2.54</td>
<td>12.67</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>2.38</td>
<td>10.78</td>
</tr>
<tr>
<td>9</td>
<td>14</td>
<td>2.30</td>
<td>10.00</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>1.78</td>
<td>5.91</td>
</tr>
<tr>
<td>11</td>
<td>13</td>
<td>2.11</td>
<td>8.28</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>2.12</td>
<td>8.55</td>
</tr>
</tbody>
</table>

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

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

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

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

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

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