Diatom as organism, diatom as tool: considerations in assessing environmental impact

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Diatoms have been applied successfully as environmental indicators in a number of fields.

Yet, several issues remain that, if solved, would make diatoms more powerful tools.
To make diatoms more useful as tools, we need to be more accurate
Consider species biology and autecology
Utilize indicator taxa
Recognize regional distributions of species
Deposit samples in permanent, publicly accessible archives
diatom
from Greek, meaning to “cut into two”
van Heurck
living colonies of *Meridion circulare*

Chloroplasts, cytoplasm in silica cell wall
Staurosirella – genus separated from Fragilaria recently (1987) grows attached to sand grains, some planktonic species example of recent nomenclatural changes reflecting ecological and habitat preference
mucopolysaccharide filaments extend through raphe slit, which are controlled internally by microtubules
benthic, attached to substrate by mucilaginous stalks

160 species in the genus *Gomphonema* reported from North America, genus level distinction probably not helpful

includes “weedy” species (*G. parvulum*), and species considered to be endemic or rare, with narrow ecological tolerance
*Encyonema minuta*— widespread benthic species, attached to substrate by mucilaginous tubes, cells move within tubes
raphe well developed and raised onto a keel
the more raphe length, the greater the cell motility

*Entomoneis ornata*
Samples from flowing waters may have diatom valves that originated upstream.

Live cells

Dead cells

It is important to recognize that possibility -

Attached species

Planktonic species

Soil species
Utilize indicator taxa – abundant vs. rare species

• Do common, widely distributed species tend to exhibit wide ecological tolerances?
Abundant taxa

- A small diatom (*Achnanthidium minutissimum*) may dominate samples
- Analyses are based on counts of 600 diatom valves (300 cells)
- *A. minutissium* determines the precision of counts of rare taxa
Didymosphenia geminata is an invasive species. It has huge cells, grows on stalks in fast flowing, cold waters, forms extensive "felts" on rock surfaces in nuisance blooms, expanding its range in Colorado, abundant in drought years for short time periods.
<table>
<thead>
<tr>
<th>Taxon name</th>
<th>% of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Achnanthidium minutissimum</em> (Kutzing) Czarnecki</td>
<td>59.7</td>
</tr>
<tr>
<td><em>Rhoicosphenia curvata</em> (Kutzing) Grunow ex Rabenhorst</td>
<td>42.6</td>
</tr>
<tr>
<td><em>Gomphonema parvulum</em> (Kutzing) Kutzing</td>
<td>41.1</td>
</tr>
<tr>
<td><em>Navicula minima</em> Grunow</td>
<td>41.0</td>
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<tr>
<td><em>Navicula cryptotenella</em> Lange-Bertalot</td>
<td>39.8</td>
</tr>
<tr>
<td><em>Amphora pediculus</em> (Kutzing) Grunow</td>
<td>39.4</td>
</tr>
<tr>
<td><em>Cocconeis placentula</em> var. <em>euglypta</em> (Ehrenberg) Cleve</td>
<td>37.8</td>
</tr>
<tr>
<td><em>Nitzschia inconspicua</em> Grunow</td>
<td>36.3</td>
</tr>
<tr>
<td><em>Nitzschia amphibia</em> Grunow</td>
<td>33.2</td>
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<tr>
<td><em>Nitzschia palea</em> (Kutzing) W. Smith</td>
<td>32.2</td>
</tr>
<tr>
<td><em>Encyonema minutum</em> (Hilse in Rabenhorst) D.G. Mann</td>
<td>32.0</td>
</tr>
<tr>
<td><em>Reimeria sinuata</em> (Gregory) Kociolek and Stoermer</td>
<td>31.0</td>
</tr>
<tr>
<td><em>Navicula gregaria</em> Donkin</td>
<td>29.4</td>
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<tr>
<td><em>Gomphonema pumilum</em> (Grunow) Reichard and Lange-Bertalot</td>
<td>29.1</td>
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<tr>
<td><em>Navicula capitoradiata</em> Germain</td>
<td>27.5</td>
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<tr>
<td><em>Cocconeis placentula</em> var. <em>lineata</em> (Ehrenberg) Van Huerck</td>
<td>26.8</td>
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<tr>
<td><em>Achnanthes lanceolata</em> (Breb. in Kutzing) Grunow</td>
<td>26.4</td>
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<tr>
<td><em>Melosira varians</em> Agardh</td>
<td>24.3</td>
</tr>
<tr>
<td><em>Navicula germainii</em> Wallace</td>
<td>24.0</td>
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<tr>
<td><em>Nitzschia frustulum</em> (Kutzing) Grunow</td>
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<tr>
<td><em>Nitzschia dissipata</em> (Kutzing) Grunow</td>
<td>22.6</td>
</tr>
<tr>
<td><em>Navicula tripunctata</em> (O.F. Muller) Bory</td>
<td>22.5</td>
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<tr>
<td><em>Staurosirella pinnata</em> (Ehrenberg) Williams and Round</td>
<td>22.5</td>
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<tr>
<td><em>Achnanthes rostrata</em> Ostrup</td>
<td>22.1</td>
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<tr>
<td><em>Fragilaria vaucheria</em> (Kutzing) Peterson</td>
<td>20.8</td>
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<td><em>Nitzschia archibaldii</em> Lange-Bertalot</td>
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<td><em>Cocconeis pediculus</em> Ehrenberg</td>
<td>18.1</td>
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<tr>
<td><em>Nitzschia palea</em> var. <em>debilis</em> (Kutzing) Grunow</td>
<td>17.0</td>
</tr>
<tr>
<td><em>Cymbella affinis</em> Kutzing</td>
<td>16.8</td>
</tr>
<tr>
<td><em>Synedra ulna</em> (Nitzsche) Ehrenberg</td>
<td>16.7</td>
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Achnanthidium minutissimum

Considered to prefer low concentrations of total phosphorus in weighted averaging (WA) models:

British Columbia  14 µg/l  TP  
(Reavie et al. 1995)

Mid-Atlantic Highlands  17 µg/l  TP  
(Pan et al. 1996)
Rare taxa as indicators

- Rare species often confined to oligotrophic, less impacted sites
- More sensitive than abundant species
- However, counts of samples (600) are controlled by dominant species.
- Rare taxa may not significant and dropped from inclusion in metrics.
36% of diatom species rare (in 10 or fewer sites)

Over 50% of rare taxa are undescribed

Genus sp. #1

Trend of decreasing number and relative abundance of rare species along gradient of anthropogenic impact (nutrient concentration and watersheds as urban or agricultural)

Rare diatoms in USA Rivers

Potapova & Charles (in press)
Regional differences

- Geographic distribution of species may be regional
- Ecological tolerance of species may be regional
Detrended correspondence analysis of 2735 sample NAWQA data set A) ecoregions B) diatom taxa.

From Potapova & Charles 2002
Cocconeis fluviatilis Wallace

Synedra mazamaensis
Sovereign

Navicula aikenensis
Patrick

Gomphonema apuncto
Wallace

Achnanthes lanceolata var. apiculata Patrick

Gomphoneis eriense (Grunow) Skvortzow

Navicula wallacei Reimer

Synedra parasitica (W. Smith) Hustedt
**Planothidium lanceolatum**

Depending on region, this taxon varies in total phosphorus tolerance in WA models:

<table>
<thead>
<tr>
<th>Region</th>
<th>Phosphorus Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Columbia</td>
<td>12 µg/l TP</td>
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<tr>
<td>(Reavie <em>et al.</em> 1995)</td>
<td></td>
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<tr>
<td>Mid-Atlantic Highlands</td>
<td>185 µg/l TP</td>
</tr>
<tr>
<td>(Pan <em>et al.</em> 1996)</td>
<td></td>
</tr>
<tr>
<td>Illinois Rivers</td>
<td>210 µg/l TP</td>
</tr>
<tr>
<td>(Leland &amp; Porter 2002)</td>
<td></td>
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</tbody>
</table>
Gomphonema clevei Fricke
Reported from North American rivers (NAWQA)

When slides were reexamined, the specimens were found not to include *G. clevei*, but two other taxa:

*Gomphonema minutum* Agardh

*Gomphonema kobayasi* Kociolek & Kingston

Described in 1999. Since then, analysts have adopted taxonomy, and *G. clevei* is no longer reported.
Southern Rockies REMAP
(Griffith et al. 2002)
Diatoms are a poorly known group of organisms

- USGS National Water Quality Program (NAWQA) reported 2735 diatom species from North America
- 26% were not identified
- That is, over 700 species were undescribed = not known to science
Unknown species

- Are often “shoe horned” into existing taxa
- Are unavailable for use in ecological assessment, because
- Species without names and ecological tolerances are dropped from analyses. In REMAP studies, approximately 15% of diatom taxa
- No taxonomy, no autecology, no metrics
correctness

versus

consistency
Taxonomic consistency

- EMAP datasets are subject to significant problems with taxonomic inconsistency
- Permanent, publicly accessible reference collections are essential
European legacy

- North American keys are incomplete
- Taxonomic keys are based on dated European floras
  - Results in a practice of fitting the taxon to the name
  - Comparable to using “Flowering plants of Europe” to identify plants in Colorado
- European autecology (A coded checklist... the Netherlands, van Dam et al. 1994)
Biological analyses in EMAP

- Internal consistency in taxonomy determines the power of ecological assessment
- Design of EMAP includes a strong quality assurance for sample analysis
- Yet, in practice, a consistent taxonomy requires additional effort
Opportunity to recognize aquatic biodiversity

- New scientific discovery of biodiversity was not stated in EMAP design
- Algal samples will be useful for making ecological assessments of biological integrity
- Contribute to an understanding of diversity of diatoms and distribution across North America
Determine anthropogenic impact on diatom assemblages

Incorporate biological information in analysis of datasets - cell size, habitat preferences, updated taxonomy

Refine metrics to reflect regional species distributions and regional autecology using WA techniques

Recognize rare taxa with narrow ecological ranges as indicators using stratified counting methods

Evaluate the effects of recent (old) taxonomy?
What is next?

- Permanent, accessible archive of EMAP diatom slides
- Emphasize internal consistency over correct taxonomy
- Create more accurate, verifiable taxonomic records
- National programs ought to be utilizing consistent taxonomy
- Reveal existing biodiversity of species
- Opportunity for discovery - a North American diatom flora