Digital imagery of diatoms from the Upper Ohio River Basin and selected tributaries, a work in progress

Joshua T. Cooper, Diane K. McCubbin, and Dr. Miriam Steinitz-Kannan

Department of Biological Sciences
and
Center for Integrative Natural Science and Mathematics
Northern Kentucky University
Highland Heights, KY 41099

Abstract

As a cosmopolitan group of organisms, algae are important water quality indicators. Diatom taxonomy has been recorded from many aquatic systems all over the world. Distinguishing between diatom species involves observations of detailed physical characteristics and specific measurements. We are compiling a taxonomic database of diatom images from the Ohio River Basin as a baseline for identifying common species. The Ohio River was sampled every 5 miles from Pittsburgh, Pennsylvania to Rising Sun, Indiana, including selected tributaries. The samples were collected using a 10 µm mesh plankton net during the first week of August 2001 and 2002. Samples were boiled in concentrated nitric acid to remove all organic material to ensure an unobstructed view of diatom physical characteristics. The diatoms were mounted in Naphrax® mounting medium and counted under oil immersion (1000×) using a compound light microscope. The images were captured using an Olympus D-12 digital camera. Common taxa consisting of mostly centric forms include five species of *Aulacoseira* and five species of *Cyclotella*, which are found throughout the length of the river. These species or varieties can be difficult to identify. This database will be useful to help researchers distinguish among similar species found in the Ohio River Basin so that indicator species can be identified more easily.

Introduction

The Ohio River is an important resource, not only for water consumption, but also for recreation. Algae are a cosmopolitan group of organisms that are important primary producers of plankton and periphyton. Therefore, this group is sensitive to changes in water chemistry, which makes them water quality indicators. Specifically, diatoms have been used as environmental indicators; therefore, the ability to identify species is critical (Lowe 1974).

From the 1900s to the present, diatom taxonomy has been recorded from aquatic systems all over the world, including fossil records from lake and marine deposits. These taxonomic descriptions are based on specific physical measurements of valve shape, dimension, and ornamentation. Because of morphological and size variances, diatom taxonomy can overlap; thus, a picture atlas is helpful for identifying species. This database will be useful for distinguishing among similar species found in the Ohio River Basin so that indicator species can be identified more easily.

Methods

Sample Preparation

The Ohio River was sampled every 5 miles for 503 miles, including selected tributaries from Pittsburgh, Pennsylvania to Rising Sun, Indiana. Water samples of 2 to 4 liters were filtered through a 10 µm plankton net preserved with Lugol’s iodine solution and stored in 20 ml scintillation vials.

The water samples were boiled in nitric acid to remove organics, and then rinsed with distilled water until the sample reached a pH of 7. After settling, the samples were decanted and evaporated on coverslips in triplicate. The dried coverslips containing diatoms were then mounted on a slide with Naphrax®, a highly refractive index medium (Battarbee 1986, Patrick and Reimer 1966).

Microscope Identification and Counts

The slides were counted using a Nikon OptiPhot Phase Contrast microscope using an oil immersion lens.
at 1000x. This phase microscope allowed the sediments in the samples to become transparent, thereby improving the diatoms’ picture quality. At least 500 valves were counted per slide, as were the number of fields, to determine the population of organisms per liter, per river mile. The diatoms were identified as to species and variety, if possible, using standard taxonomic keys (Hustedt 1930, 1975; Krammer and Lange-Bertalot 1988; Collins and Kalinsky 1977; Patrick and Riemer 1996). Diatom species were counted only if they contained a central area and at least 50% or more of the valve. Slides were also scanned for rare and uncommon species that were not found during the counting.

Photographs

The photographs of the diatoms were taken using an Olympus D-12 Digital Microscopy Camera mounted to the Nikon scope. Digital photographs of the many different species of diatoms were modified later using Adobe Photoshop and Microsoft PhotoEditor. These photographs were resized, edited, and compiled in a picture atlas of the upper Ohio River Basin and selected tributaries. With each of the photographs, exact measurements of the diatom’s physical characteristics were taken.

Results and Discussion

Ohio River Diatoms

The most abundant species found throughout the Ohio River were *Cyclotella meneghiniana*, *Cyclotella atomus*, *Nitzschia palea*, and several species of *Aulacoseira* (Figure 1). Some uncommon species that are good water quality indicators are displayed in Figure 2. Species consistently found along the length of the Ohio River were mostly centric species that included *Aulacoseira islandica*, *A. ambigua*, *Cyclotella caspia*, *C. stelligera*, and *Synedra ulna*.

During the process of counting, identifying, and classifying the diatoms as pennate or centric, based upon their respective morphology (Figure 1), a trend was noted. A larger percentage of centric species was observed in the upstream Ohio River near Pennsylvania and West Virginia, whereas an increased abundance of pennate species appeared downstream at river mile 400 (Figure 3). The diatom counts recorded from river mile 50 to 500 reveal that there are a greater number...
ber of species found around Pennsylvania. The species richness decreases downstream (Figure 4).

Note that the diatom samples were collected above and below the mouth of the Kanawha River, a large tributary at river mile 266. At the time of collec-

Figure 2. Uncommon species found in the Ohio River Basin that can be used as water quality indicators. *Diatoma moniliformis*, for example, may have been deformed by heavy metal ion concentrations in the water. Deformities occur because the ions are incorporated into the diatoms.

![Deformed Diatoma moniliformis](image)

![Pleurosira laevis](image)

Figure 3. Centric diatoms dominate the main channel of the Ohio River, except where large tributaries, the Kanawha and the Big Sandy, enter the river.

![Graph showing percentage of Diatom Type](image)
tion, the Kanawha River was experiencing a 100-year flood event. The downstream increase in pennate species may have been caused by this flood event, which brought more species from various habitats into the main channel of the Ohio River system (Figure 3). The increased presence of attached diatoms such as Cocconeis sp, Cymbella sp, Gomphonema sp, and Surirella sp, illustrate the scouring power of high flow during flood events. Scouring of attached algae from small streams and resuspension of sediments containing diatom frustules may have also contributed to the increase in pennates, thus increasing diversity (Figure 4). The increase in diversity may also have resulted from the input of the tributaries, such as the Kanawha, into the main channel of the Ohio.

Tributary Diatom Species

The tributaries held the most diverse assemblages of diatom species because of the many microhabitats and varying land use found within the smaller stream systems. These tributaries had larger abundances of pennate species than the main channel (Figure 3). Common species found in the tributaries included Cyclotella atomus, C. meneghiniana, and Nitzschia dissipata. Individually, the tributaries had different assemblages of species, but some species were characteristic of certain tributaries (Table 1).

Environmental Indicators

Water quality can be assessed by analyzing the species found in the tributaries. The type of species can be used to determine impact on water parameters in the form of land use, high conductivity/salinity, eutrophication, high nutrients, acidic conditions, and sedimentation (Van Dam 1994). For example, uncommon or rare species that have deformed valves can occur under variable metal ion concentrations. Proliferation of diatom species that can tolerate more acidic conditions (lower pH) and high sedimentation can suggest influences of land usage such as acid mine drainage. Geologically, most of the upper Ohio River is Pennsylvanian and Mississippian in age, containing strip-mined coal deposits with iron and sulfur residues that react with air and water, causing acidic conditions. The coal fuels the many power plants and industries that line the upper Ohio River to provide energy for a growing population.

Certain genera, such as the centric Cyclotella (Figure 5) and Aulacoseira (Figure 6), are found throughout the system. Hours can be spent trying to differentiate between the Aulacoseira species found in a single water sample or slide. The close resemblances among Aulacoseira species such as size variability, number of puncta (pores), similarity of the valve ends,
and pore density, can be observed in Figure 6. Cataloging many pictures of the same species can help alleviate confusion among these groups whose morphologies are closely related. The occurrences of overlapping characteristics are also seen in the Cyclotella taxa (Figure 5). Table 2 lists the 134 taxa identified and photographed to date. These will be included in the Ohio River Diatom Database/Atlas being prepared. Additional detailed information that has been collected about each taxa and its habitat will be included in the atlas to produce a baseline for diatom identification and future studies in the Ohio River Basin.

**Acknowledgements**

This project was funded by the Center for Integrative Natural Science and Mathematics (CINSAM).

---

**Table 1. Species Characteristic to a particular Tributary**

<table>
<thead>
<tr>
<th>Kanawha River</th>
<th>Big Sandy</th>
<th>Scioto River</th>
<th>Great Miami River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cymbella silesiaca</td>
<td>Achnanthes altaica</td>
<td>Navicula capitatoradiata</td>
<td>Cyclotella distinguenda</td>
</tr>
<tr>
<td>Cymbella sinuata</td>
<td>Achnanthes exilis</td>
<td></td>
<td>Navicula pupula</td>
</tr>
<tr>
<td>Cymbella tumida</td>
<td>Amphora aequalis</td>
<td></td>
<td>Nitzschia capitella</td>
</tr>
<tr>
<td>Epithemia adnata</td>
<td>Amphora normalis</td>
<td></td>
<td>Nitzschia paleaeosa</td>
</tr>
<tr>
<td>Gomphonema subclavatum</td>
<td>Caloneis bacillum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gryosigma exile</td>
<td>Deformed pennate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hannoaea arcus</td>
<td>Diatoma vulgar var. breve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navicula radiosa</td>
<td>Fragilaria capucina var. vaucheria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhopalodia gibba</td>
<td>Fragilaria parasitica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surirella tenera</td>
<td>Navicula heulleri var. leptocphala</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Navicula meniscus</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Navicula pseudoreinhardtii</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nitzschia reversa</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nitzschia reversa</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nitzschia vitrea</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surirella minuta</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Figure 5. Cyclotella species have centric morphology, similar characteristics, and similar size ranges. These were photographed at 1000X magnification and digitally enhanced.
We thank the River Run 2002 Crew, which included representatives from Thomas More College, Marshall University, University of Cincinnati, and Northern Kentucky University for assistance in the field. The Department of Biological Sciences, Northern Kentucky University, provided the equipment used to analyze the data.

References


Figure 6. The *Aulacosiera* species have centric morphology, overlapping characteristics, and similar size ranges. These were photographed at 1000X magnification and digitally enhanced.
Cooper, McCubbin, and Steinitz-Kannan


Table 2. List of diatom taxa from upper Ohio River Basin and selected tributaries

<table>
<thead>
<tr>
<th>Acnanthes</th>
<th>Cyclotella</th>
<th>Fragilaria</th>
<th>N. dententa</th>
<th>Pleurosigma laevis</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. altaica</td>
<td>C. atomus</td>
<td>F. capucina var.</td>
<td>N. halophila</td>
<td></td>
</tr>
<tr>
<td>A. exigua</td>
<td>C. caspia</td>
<td>vaucheriae</td>
<td>N. heuffleri var.</td>
<td></td>
</tr>
<tr>
<td>A. exilis</td>
<td>C. distinguenda</td>
<td>F. crotonensis</td>
<td>leptocelphala</td>
<td></td>
</tr>
<tr>
<td>A. lanceolata</td>
<td>K. kutzingiana</td>
<td>F. parasitica</td>
<td>N. menisculus</td>
<td></td>
</tr>
<tr>
<td>A. linearis</td>
<td>M. meneghiniana</td>
<td>F. pinnata</td>
<td>N. minanscula</td>
<td></td>
</tr>
<tr>
<td>A. microcephala</td>
<td>O. ocellata</td>
<td></td>
<td>N. notha</td>
<td></td>
</tr>
<tr>
<td>A. minutissima</td>
<td>Sp.</td>
<td></td>
<td>N. phylepta</td>
<td></td>
</tr>
<tr>
<td>A. minutissima var.</td>
<td>stelligera</td>
<td>F. rhomboidei</td>
<td>N. pseudeureinhardtii</td>
<td></td>
</tr>
<tr>
<td>A. inconspicua</td>
<td></td>
<td>F. vulgaris</td>
<td>N. populia</td>
<td></td>
</tr>
<tr>
<td>A. wellsiae</td>
<td>Cymatopleura solea</td>
<td></td>
<td>N. radiosa</td>
<td></td>
</tr>
<tr>
<td>A. rhynchocepha</td>
<td></td>
<td></td>
<td>N. rhynchocepha</td>
<td></td>
</tr>
<tr>
<td>Amphora</td>
<td>Cymbella</td>
<td>G. olivaceum</td>
<td>N. rhynchocepha</td>
<td></td>
</tr>
<tr>
<td>A. aequalis</td>
<td>C. affinis</td>
<td>var. germanii</td>
<td>S. smithii var. incisa</td>
<td></td>
</tr>
<tr>
<td>A. normani</td>
<td>C. amphiocphala</td>
<td>G. parvulum var.</td>
<td>S. phoenicenteron</td>
<td></td>
</tr>
<tr>
<td>A. ovalis</td>
<td>C. aspera</td>
<td>micropus</td>
<td>S. minuta</td>
<td></td>
</tr>
<tr>
<td>A. pediculus</td>
<td>C. hebrida</td>
<td>G. sphaerophorum</td>
<td>S. ovata</td>
<td></td>
</tr>
<tr>
<td>A. persusailla</td>
<td>L. lunata</td>
<td>G. subclavatum</td>
<td>S. tenera</td>
<td></td>
</tr>
<tr>
<td>A. muelleri</td>
<td>C. muellera</td>
<td>G. tenellum</td>
<td>S. turgida</td>
<td></td>
</tr>
<tr>
<td>A. naviculiformis</td>
<td></td>
<td></td>
<td>Synedra</td>
<td>S. delicatissima</td>
</tr>
<tr>
<td>A. prostrata</td>
<td></td>
<td>Gyrosigma</td>
<td>Neidium</td>
<td>S. angusta</td>
</tr>
<tr>
<td>A. sileica</td>
<td></td>
<td>G. exile</td>
<td>N. hercyicum</td>
<td>S. linears</td>
</tr>
<tr>
<td>A. sinuata</td>
<td></td>
<td>G. poisonis</td>
<td>N. iridis var.</td>
<td>S. linears var.</td>
</tr>
<tr>
<td>A. tumida</td>
<td></td>
<td>G. scheloroides</td>
<td>amphigonomphus</td>
<td>S. helvetica</td>
</tr>
<tr>
<td>A. arcuata</td>
<td></td>
<td>G. spenceri</td>
<td></td>
<td>S. minuta</td>
</tr>
<tr>
<td>A. islandica</td>
<td>Deformed Pennate</td>
<td>Hannaea arcus</td>
<td>N. acurialis</td>
<td>S. ovalis</td>
</tr>
<tr>
<td>A. articla</td>
<td></td>
<td></td>
<td>N. amphibia</td>
<td>S. ovata</td>
</tr>
<tr>
<td>A. lirata</td>
<td>Diatoma</td>
<td>Hantzchia</td>
<td>N. coartata</td>
<td>S. turea</td>
</tr>
<tr>
<td>A. muzzanensis</td>
<td>D. niemale var.</td>
<td>H. amphioxys</td>
<td>N. commutata</td>
<td>Synedra</td>
</tr>
<tr>
<td>Brachysira neoexilis</td>
<td>D. moniliformis</td>
<td>H. sigmoidida</td>
<td>N. dissipata</td>
<td>S. delicatissima</td>
</tr>
<tr>
<td>D. vulgaris</td>
<td></td>
<td>Luticula mutica</td>
<td>N. hungarica</td>
<td>S. ulna</td>
</tr>
<tr>
<td>Caloneis</td>
<td>D. vulgaris var. breve</td>
<td>Melosira</td>
<td>N. inconspicua</td>
<td></td>
</tr>
<tr>
<td>C. amphisbaena</td>
<td>D. vulgaris var. linearis</td>
<td>M. varians</td>
<td>N. laevis</td>
<td></td>
</tr>
<tr>
<td>C. bacilum</td>
<td></td>
<td>M. sp.</td>
<td>N. linears</td>
<td>Tabellaria</td>
</tr>
<tr>
<td>Capartogramma</td>
<td>Diploneis oblongella</td>
<td>Meridion</td>
<td>N. microcephala</td>
<td>T. fenestrata</td>
</tr>
<tr>
<td>Crucicula</td>
<td>Epithemia adnata</td>
<td>M. circulare</td>
<td>N. palea</td>
<td>T. flocculosa</td>
</tr>
<tr>
<td>Cocconeis</td>
<td>Eurola</td>
<td>M. circulare var.</td>
<td>N. pseudofonticola</td>
<td>Thalassiosira</td>
</tr>
<tr>
<td>C. pediculus</td>
<td>E. bilunaris</td>
<td>constrictum</td>
<td>N. reversa</td>
<td>fluvistatilis</td>
</tr>
<tr>
<td>C. placenta</td>
<td>E. monodon</td>
<td>Navicula</td>
<td>N. subtiloides</td>
<td>Tryblionella</td>
</tr>
<tr>
<td>C. placenta linea</td>
<td>E. pectinalis var. recta</td>
<td>N. capitata</td>
<td>N. suchlandtii</td>
<td>T. levendens</td>
</tr>
<tr>
<td>Coscinodiscus</td>
<td>E. vanheurckii var. intermediate</td>
<td>N. capitatoradiata</td>
<td>N. valdeadcosta</td>
<td>T. levendens var.</td>
</tr>
<tr>
<td>Tacustris</td>
<td></td>
<td>N. capitellata</td>
<td>N. vitrea</td>
<td>victoriae</td>
</tr>
</tbody>
</table>

Norse Scientist 33
Amanda Trout works with algal toxins