Spatial variation in Lake Michigan phytoplankton composition during sediment resuspension events


Introduction

Large-scale sediment resuspension is an annual and episodic event during the isothermal period in coastal waters of south-eastern Lake Michigan (Mortimer 1988, Eadie et al. 1996). The resuspended silt and clay are thought to be eroded material from the lake’s western shore that has been hydrodynamically transported to the resuspension sites. Resuspension is initiated by late winter storms and may last for up to 2 months. Within sediment-impacted waters, light scattering and absorption are significant and light attenuation is mostly attributable to particulate matter (Millie et al. 2002).

The resuspension event typically coincides with the spring phytoplankton bloom. This basin-wide bloom mostly consists of large net diatoms (e.g. Aulacoseira islandica (Müller) Simonsen, Aulacoseira italica (Ehrenberg) Simonsen) with lesser amounts of cryptophytes, and contributes up to half of the lake’s total annual primary production (Brooks & Edgington 1994). Light and nutrient availability appear to be the factors controlling phytoplankton growth and biomass, respectively, during this period (Fahrenstiel & Scavia 1987, Fahrenstiel et al. 2000).

The approximate juxtaposition of the resuspension event with the spring bloom suggests that the abundance of diatoms within the water column may be attributable to populations of viable, benthic cells and/or resting cells and cysts resuspended from the sediments (meroplankton). Meroplankton may dramatically influence the composition and abundance of planktonic assemblages in shallow systems (Carrick et al. 1993, Schelske et al. 1995) and significant resuspension of diatoms occurs following wind events within Lake Erie (Hartig 1987). However, the role of the resuspension event as a ‘seeding’ mechanism for the planktonic assemblages of Lake Michigan has not yet been identified. Here, phytoplankton assemblages were characterized from selected sites within sediment-impacted and surrounding waters and the contribution of these assemblages related to the spring bloom.

Methods

Sampling stations located within sediment-impacted and surrounding waters were established along transects within south-eastern Lake Michigan from 16 to 19 March 1998 and from 23 to 26 March and 13 to 18 April 1999 (Fig. 1). Niskin bottles were used to collect near-surface (less than 10 m depth) water for assessment of phytoplankton and suspended particulate matter (SPM). SPM concentrations were determined gravimetrically after drawing aliquots under vacuum onto rinsed, tared Whatman 47 mm GF/F (0.6 μm pore size) and/or Poretics 0.4 μm polycarbonate filters. Samples for phytoplankton were preserved immediately using the Utermöhl technique and the species composition within all samples was enumerated. Composition data for 20 stations (representing sites within sediment-
impacted and surrounding waters) were subsequently selected for statistical analysis.

A similarity matrix was constructed (using Euclidean distances) for the 20 sampling stations, based on relative abundance distributions for all observed phytoplankton (see Results). A dendrogram, illustrating the similarity (dissimilarity) among stations, based on the relative similarity of their phytoplankton assemblages, was derived by hierarchical cluster analyses and Wards linkage algorithm (PIELOU 1984, MANLY 1986). A second matrix then was constructed containing the relative abundance of common taxa (>5% of total relative abundance and/or observed in more than one sample) for the sampling stations. A dendrogram, illustrating the similarity (dissimilarity) among taxa based on the sum of their relative abundance among stations, was then derived.

The strengths of association between SPM concentrations and a sampling station's distance from shore, and among SPM concentrations and total phytoplankton relative abundance of each cluster group, were determined by Pearson Product Moment Correlation. Relative abundance and SPM data were transformed (square-root arcsine and natural logarithms, respectively) prior to statistical analysis to increase the variance and to meet the homogeneity of normality within data sets. Statistical analyses were performed using SYSTAT (version 8.0) and SigmaStat (version 2.03) software.

Results

Sediment resuspension events were observed along the south-eastern coast of Lake Michigan during 1998 and 1999. The intensity and spatial extent of sediment resuspension differed greatly between years; resuspension extended from the extreme southern portion of the lake to north of the Muskegon transect and a significant distance offshore in 1998, whereas resuspension only extended as far north as the St. Joseph transect and was mostly nearshore in 1999 (refer to Fig. 1). SPM concentrations ranged from 0.72 to 35.28 and 0.82 to 6.30 mg L⁻¹ during 1998 and 1999, respectively, and displayed a negative association with the distance of sampling stations from shore (Fig. 2).

Cluster analysis classified sampling stations into four groups based upon the relative abundance of the phytoplankton assemblages they support (Fig. 3). Phytoplankton assemblages at nearshore, mid-transect and mid-transect/offshore stations in 1998 and almost all stations in 1999 were classified together in Groups 1–4, respectively. The phytoplankton assemblage at the most nearshore station along the New Buffalo transect in 1999 was more similar to assemblages at certain mid-transect stations in 1998 (Group 2), than to assemblages at stations in 1999 (Group 4).

Fifty-three taxa were observed among the 20 sampling stations. Diatoms and cryptophytes dominated the phytoplankton assemblages. Diatom assemblages were composed of the large-sized centrics (A. islandica, A. italicca), various small-sized centrics (Cylindrospermopsis spp., Cyclotella spp., Stephanodiscus spp.) and various pennates within the genera, Diatoma, Syedna, Navicula, Nitzschea, and Tabellaria. Cryptophyte assemblages included Cryptomonas erosa Ehrenberg and various Rhodomonas spp. (Rhodomonas minuta Skuja, Rhodomonas lens Pascher et Ruttner). Numerous small (< 6 μm) phytoflagellates were also observed.

Cluster analysis classified common taxa into four groups based on the similarity among distribution patterns of phytoplankton relative to abundance (Fig. 4). Moreover, the association of the groups of taxa had distinct associations with SPM concentrations (Table 1). Small centric diatoms (Cylindrospermopsis spp., Cyclotella spp.) and phytoflagellates (Group 1) and large, net diatoms and cryptophytes (Group 2) dis-
played positive and negative associations with SPM concentrations, respectively. Large, pen- nate diatoms, considered benthic in origin (Group 4), also displayed a positive association with SPM concentrations, whereas various pen- nate taxa considered planktonic in origin (Group 3) had no association with sediment resuspension.

Discussion

The classification of sampling stations based on phytoplankton relative abundance indicated a spatial dissimilarity among assemblages that closely mirrored the extent and intensity of sediment resuspension. In 1998, the most near- shore stations for all transects were impacted by sediment resuspension. The similarity among phytoplankton assemblages enabled these stations to be subsequently classified together. Phytoplankton assemblages at mid-transect and the farthest offshore stations in 1998 were classified similarly, most likely representing the decreased sediment resuspension with increased distance offshore. In 1999, sediment resuspen-
Fig. 4. Wards-linkage dendrogram for distances (dissimilarity) of common taxa based on their collective relative abundance among sampling stations.

Table 1. Pearson Product Moment Correlation values (n = 19) between suspended particulate matter concentration (SPM) and the collective relative abundance of phytoplankton within each of the four groups derived using cluster analysis (for listing of taxa within each group, see Fig. 3). Probability values are in parentheses.

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>In [SPM]</td>
<td>0.863 (&lt; 0.0001)</td>
<td>−0.595 (0.0073)</td>
<td>−0.271 (0.261)</td>
</tr>
<tr>
<td>Group 1</td>
<td>−0.476 (0.0392)</td>
<td>0.017 (0.9440)</td>
<td>0.473 (0.0409)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.604 (0.0062)</td>
<td>−0.171 (0.4840)</td>
<td></td>
</tr>
</tbody>
</table>

ally are directed offshore. Consequently, these events could provide a mechanism for transporting meroplanktonic taxa from nearshore to offshore regions. However, the negative association of SPM with large, net diatoms, and cryptophytes typically comprising phytoplankton of the spring bloom and of optically clear offshore waters (Scavia & Fahnenstiel 1987, Millie et al. 2002) indicated little association between resuspension and the occurrence of planktonic taxa within the spring bloom.

One group of assorted phytoplankton (Group 3) displayed no association with sediment resuspension. This group generally was comprised of the centric and pennate diatoms representative of offshore, planktonic assemblages. Furthermore, because many of these taxa display greatest relative abundances in lake waters during late spring and summer (Stoermer & Ladeveze 1976), they represent a source of transitional taxa for phytoplankton assemblage development within Lake Michigan, with the warming of the water column later in the year.

Millie et al. (2002) noted no impact of sediment resuspension events on instantaneous accumulation of phytoplankton biomass (as chlorophyll a). However, resuspension did influence the spatial distribution of phytoplankton composition in Lake Michigan waters and resuspension of benthic diatoms greatly influenced the taxonomic composition of nearshore phytoplankton assemblages. Resuspension events appear to have little, if any,
relationship with the compositional development of the annual spring diatom bloom.

Acknowledgements

This work is a portion of the research program, Episodic Events – Great Lakes Experiment (EEGLE): “The Impact of Episodic Events on the Nearshore–Offshore Transport and Transformation of Biogeochemically Important Materials in the Great Lakes”, funded by the National Oceanic and Atmospheric Administration, Coastal Ocean Program and the National Science Foundation, Coastal Ocean Processes. References to proprietary names are necessary to factually report on available data; however, the Florida Institute of Oceanography, the Florida Fish & Wildlife Conservation Commission, the National Oceanic and Atmospheric Administration, the State University of New York at Buffalo, the University of Southern Mississippi, and Rutgers University neither guarantee nor warrant the standard of a product and imply no approval of a product to the exclusion of others that may be suitable.

References


Authors' addresses:

D. E. MILLIE, Florida Institute of Oceanography & Florida Marine Research Institute, Fish & Wildlife Conservation Commission, 100 Eighth Avenue S. E., Saint Petersburg, FL 33701, USA.

G. L. FAHNENSTIEL, Lake Michigan Field Station, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, 1431 Beach Street, Muskegon, MI 49441, USA.

H. J. CARRICK, School of Forest Resources – Fisheries & Wildlife, Pennsylvania State University, University Park, PA 16802, USA.

S. E. LOHRENZ, Institute of Marine Science, University of Southern Mississippi, Stennis Space Center, MS 39529, USA.

O. M. E. SCHOFIELD, Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901, USA.