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The Effects of Sediment Toxicity on the Growth Rates of *Skeletonema* sp.

Lewis F. Affronti, Jr. and **B. Thomas Duquette**
Departments of Science and Mathematics, Norfolk Academy,
Norfolk, VA 23502-5591

ABSTRACT

Skeletonema sp. was exposed to elutriate prepared from sediment known to be contaminated with high concentrations of heavy metals and semivolatile organic compounds. Significant differences were observed in specific growth rates of *Skeletonema* sp. over the three experimental conditions tested ($P < 0.001$), and *post hoc* multiple comparison tests showed significant differences ($P < 0.5$) between a control (no contaminants) and Site B (high contaminants) as well as between Site A (low contaminants) and Site B. The growth rate of *Skeletonema* sp. was directly influenced by sediment contaminants. Results of this work and its implications for ecosystem dynamics are discussed.

Keywords: sediment toxicity, sediment elutriate, ecosystem dynamics

INTRODUCTION

Studies on the effects of sediment toxicity to both marine and freshwater systems are widespread (Thomas et al., 1987; Cheung et al., 1997). Conditions which influence the movement of chemical constituents across the sediment--water interface are unique, dynamic and include physical, chemical and biological processes (Tessier and Campbell, 1987; Wood, 1987). Sediment quality can impact aquatic ecosystem dynamics through bioaccumulation, trophic transfer and bioturbation (Reynoldson, 1987; Tessier and Campbell, 1987; Severn et al., 1989). This study investigated the influence of contaminated sediment on the specific growth rates of *Skeletonema* sp., a genus of significant importance within the lower Chesapeake Bay ecosystem (Marshall and Affronti, 1992).

MATERIALS AND METHODS

Sediment samples were collected using a ponar dredge and stored in plastic bottles at 4°C. One sediment sample was taken from a lower Chesapeake Bay estuary known to contain significant levels of heavy metals and semivolatile organic compounds. A second estuarine site was selected where this contamination was less severe. These locations are designated as Site A (without contamination) and Site B (with contamination). Metals analysis and organic scans were performed using standard EPA approved methodologies (EPA, 1997).

A control was prepared to establish a standard growth curve for the *Skeletonema* sp. used in this study. Control samples were made by partitioning 39.0 ml of filter sterilized (0.2 μm Nucleopore filter) water from the Chesapeake Bay (salinity = $22^{0/00}$) into three 18 mL culture tubes (final volume 13.0 mL). Guilliard's f/2 media with silica (0.26 mL) was added to each tube to prevent the possibility of limiting nutrient condi-

tions. Treatment samples (Sites A and B) were prepared in the same manner using sediment elutriate rather than bay water.

Elutriate preparation followed a modified technique of Daniels et al. (1989). Sediment water combinations were prepared using the method of volumetric displacement (USEPA, 1977). Bay water and sediment samples were mixed for one hour at 4 rpm using a ferris wheel rotary tumbler. Sediment mixtures were filtered using a 0.2 μm Nucleopore filter rather than a 0.45μ m Millipore filter as recommended by Daniels et al. (1989). All tubes were inoculated with a stock culture of *Skeletonema* sp. (0.25 mL) (CCMP 792) (cell diameter of 3.0 to 5.0 μm) resulting in an initial concentration of approximately 3.50×10^4 cells/mL and incubated under a 15 W Sylvania Gro-Lux light on a 12:12 light:dark cycle.

To ensure accuracy in enumerating cell abundance, a nested sampling design was employed. An initial subsample (0.06 mL) was taken from each tube during incubation and placed in two separate chambers of a Neubauer Bright Line Counting Slide. A randomly chosen sector of each chamber was scanned at 400X for cell abundance using a Zeiss Axiolab Microscope and phase contrast objective. To replicate cell enumeration, a second subsample was acquired and the above counting procedure repeated. Cell abundance was counted daily until a stationary phase was established in the control sample.

Growth data was transformed (cell abundance +1) to account for scans where no cells were observed. Best fit exponential curves were calculated using the following:

$$N = N_0 e^{\mu(t - t_0)}$$

where N = the number of cells/mL in culture at time t, N_0 = number of cells/mL at the beginning of incubation, μ= the specific growth rate constant, t = time in days and t_0 = 0 (Stanier et al., 1979). A one-between, one-within Analysis of Variance (ANOVA) was performed on the calculated growth rates to determine if there was a significant difference in growth rates across the three experimental conditions.

RESULTS

Table 1 reveals selected metals and semivolatile organic compounds present in collected sediments. The sediment at Site B contains high concentrations of heavy metals and semivolatile organic compounds. Many of these contaminants are known to be toxic to marine biota (NOAA, 1991). In contrast, the concentrations of contaminants at Site A are much lower. Lead and Zinc concentrations were over 25 times higher at Site B compared to Site A and many semivolatile organic compounds identified in Site B were not detected in Site A.

Cell growth reached stationary phase in the control samples on the sixth day of incubation (incubation began on day 0). Changes in cell abundance over the first six days of incubation for both control and treatment samples are shown in Fig. 1. Specific growth rates (μ) varied from 0.788 to 1.00 (d^{-1}) in the control samples, from 0.837 to 0.972 (d^{-1}) at Site A and 0.453 to 0.656 (d^{-1}) at Site B. Average specific growth rates (μ) for both control and treatment sites are shown in Table 2. The ANOVA showed a significant difference in specific growth rates across the three experimental conditions ($P < 0.001$). Scheffé *post hoc* multiple comparison tests showed significantly different ($P < 0.05$) growth rates between the control and Site B as well as beween Site A and Site B.

TABLE 1. Comparison of selected chemical constituents within collected sediment samples. "ND" indicates no detection and "*" indicates an Effects Range-Low (ER-L) rating as determined by NOAA, (1991).

Contaminant	SITE A (ppm)	SITE B (ppm)
Arsenic	0.683	2.44
Beryllium	0.013	0.050
Cadmium	0.013	0.043
Chromium	0.69	10.34
Lead	0.56	19.69
Nickel	0.42	5.56
Selenium	0.062	0.242
Zinc	5.16	128.88 *
Anthracene	ND	0.40 *
Benzo(a)anthracene	ND	0.34 *
Benzo(a)pyrene	ND	0.44 *
Chrysene	ND	0.54 *
Fluoranthene	ND	0.89 *
Nonadecane	0.27	3.22
Phenanthrene	ND	0.36 *
Pyrene	ND	0.80 *

DISCUSSION

In this study, specific growth rates of *Skeletonema* sp. were directly influenced by contaminated sediment elutriate resulting in less phytoplankton production. These findings have important implications considering the potential influence contaminated sediment has on estuarine trophodynamics. Contaminated sediment can decrease phytoplankton productivity and indirectly influence species diversity as conditions favor more tolerant phytoplankton species.

In studies of phytoplankton species common to the Chesapeake Bay, metal contaminants (even at low levels) have been shown to influence species composition and succession where normally dominant algal species were replaced with more resistant forms (Sanders and Cibik, 1988). Likewise, Brand et al. (1986) found the introduction of cadmium inhibits the reproduction of phytoplankton species with cyanobacteria being most sensitive and diatoms the least sensitive. Cheung et al. (1997) reported that the growth of *Skeletonema costatum* was inhibited when exposed to sediment elutriate containing similar metals and semivolatile organic compounds identified in this study. Phytoplankton are an integral part of food web dynamics within estuarine ecosystems and any change in phytoplankton composition may cause significant shifts at higher trophic levels decreasing ecosystem productivity and efficiency.

Rather than the 0.45 μm Millipore filter recommended by Daniels et al. (1989), a 0.2 μm Nucleopore filter was used in elutriate preparation. The smaller pore size resulted in a more conservative concentration of chemical constituents within the elutri-

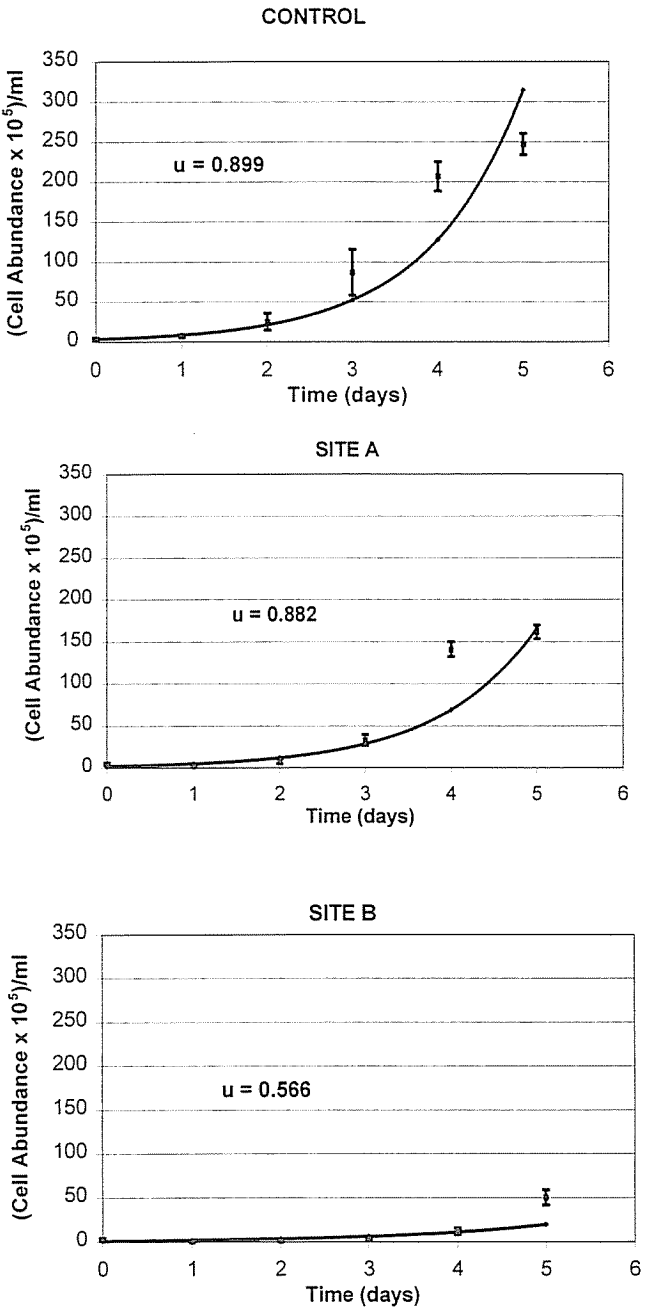

FIGURE 1. Average *Skeletonema* sp. growth (abundance + 1) and best fit lines over six days of incubation for control and treatment samples. Error bars indicate standard error of three replicate samples. Average specific growth rate (μ) for each treatment is indicated.

TABLE 2. Average specific growth rates and standard deviations for both control and treatment samples.

	CONTROL	SITE A	SITE B
Average Specific Growth Rate (d^{-1})	0.899	0.882	0.566
Standard Deviation	0.080	0.050	0.087

ate given that chemical contaminants tend to bind to a variety of particulate matter (Tessier and Campbell, 1987). In addition, the smaller pore size removed the picoplankton (0.2 μm - 2.0μ m) component from the elutriate thereby reducing competition for nutrients.

This study has demonstrated the influence of sediment contaminants on the growth rates of a primary producer common to the Chesapeake Bay. Though beyond the focus of this study, a more detailed experimental design may identify individual chemical constituents and their inhibition of specific phytoplankton species. Results of this study emphasize the importance of sediment quality and the need to consider water resource utilization when evaluating and modeling estuarine ecosystems.

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