

The Effects of varying ultraviolet-B radiation on algal growth of Douglas Lake in Northern Lower Michigan

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ABSTRACT

As UV radiation (UVR) continues to rise along with increased ozone depletion, how UVR affects primary producers is of concern. In this study, we examined the effects of UVR on algal biomass (measured by chlorophyll content) and species diversity. Algae were colonized for 12 days on a clear plexiglass grid, floating near the boat dock of Douglas Lake, Michigan. Three treatments were applied: one was UV-filtering, one received natural UVR, and one daily received 90 seconds of elevated UV-B at a wavelength of 365 nanometers. At the end of the experiment, plates were scraped and samples were analyzed for chlorophyll content and algal species biodiversity. A one-way ANOVA of chlorophyll content yielded a p-value of 0.149, meaning that we cannot reject our null hypothesis that UV-B radiation has no effect on algal growth and any observed differences are due to sampling error. Algal cell counts showed that differences in UV levels may affect the type and number of species present. Trends show a slight positive correlation between chlorophyll content and UVR. These results indicate that, with increased ozone depletion, and therefore elevated UV, no change will be observed in the first trophic level of aquatic environments.

INTRODUCTION

Since the 1970's, the depletion of the stratospheric ozone layer has increasingly altered Earth's weather patterns and ecological balance. Ultraviolet radiation (UV), a section of the electromagnetic spectrum with wavelengths shorter than visible light, is produced by the sun and split into three bands: UV-A, UV-B, and UV-C. UV-A radiation has wavelengths between 320-400 nanometers and is not captured by either the ozone layer or natural oxygen. UV-B radiation is between 280-320 nanometers and is mostly rebounded off the ozone layer, while UV-C radiation, the most harmful, is completely absorbed by the ozone layer and natural oxygen (O₂). The air space around earth can be thought as onion-like layers: the biosphere is the thin portion closest to the Earth's surface that is capable of supporting life; the troposphere extends about 10 kilometers above the surface and comprises the layer from which most of our "weather" comes;

and the stratosphere, which contains a thin ozone layer in its upper regions and extends from 10-50 kilometers above Earth's surface (United States Environmental Protection Agency 2008).

Ozone (O₃ gas) forms a band in the stratosphere, called the ozone layer that absorbs most of the harmful UV-B rays emitted by the sun. The depletion of this protective band of gas around the earth causes more UV radiation to penetrate the earth and enter the biosphere. When ozone-depleting substances like chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) float through the troposphere to the stratosphere, they are broken down by powerful ultraviolet radiation and release chlorine and bromine atoms, which deplete the ozone layer (United States Environmental Protection Agency 2008). CFCs, which are very chemically stable below the stratosphere, were developed in the 1930's for use in commercial and industrial coolants, aerosol projectors and electronic cleaning solvents. Demand for CFCs increased throughout the 20th Century until the Montreal Protocol was signed in 1987. Climate change induced by changing UV levels is predicted to radically change normal weather and growth patterns in the biosphere. The effects of our changing climate are already apparent in the mass eutrophication (increase of nutrient levels) of waters worldwide. This eutrophication occurs when an unnaturally high nutrient supply is introduced to a body of water, facilitating increased algal growth (Bi et al. 2007). When this alga begins to die and decompose, it absorbs oxygen in water, denying oxygen to other organisms, such as fish. These fish, once denied oxygen, will begin to die off as well, thus disrupting the ecological balance of that body of water (The New Hampshire Department of Environmental Services 1995).

In the Bering Sea, which is already experiencing unparalleled algal blooms and rising sea surface temperatures (SSTs), experiments were performed to simulate the effects of global warming expected in 2100 (partial pressure of CO₂ at 750 parts per million and the temperature

raised 4-5°C from the ambient temperature). Incubated phytoplankton communities were subject to elevated SSTs and CO₂ levels. The diatom population could not survive under these environmental conditions, resulting in higher numbers of nanophytoplankton. These results are significant because the diatom populations are the base upon which the enormous fishing industry in the Bering Sea rests (Hare et al. 2008).

We consider an algae species to be “in bloom” when its numbers take over a local aquatic community. Blooms can be a result of a sudden surge of nutrients (natural or artificial), a change in water temperature, or the natural accumulation of a species due to pervading water currents. Algal blooms can also be a consequence of human activities such as habitat dredging, resource harvesting, and increased pollution in waterways (NOAA 1998). To determine the actual abundance of algal blooms we can look at species biodiversity and determine biomass by measuring the chlorophyll content.

In a second study centered on the effects of UV-B radiation on algal growth, ecologist Max Bothwell (1985) performed an experiment using UV-filtering and UV-transparent Saran Wrap to grow algae in the South Thompson River in British Columbia, Canada. He hypothesized that UV radiation would produce DNA sequencing errors and slow the growth of algae. This was the initial finding; however, when his experiment was left unattended for an additional two weeks, the algae colonies proliferated under the UV transparent Saran Wrap and actually showed increased growth. From this, Bothwell concluded that on a long term scale, elevated UV exposure actually facilitates algal growth (Culotta 1994).

We now know that there are two normal responses of algae to elevated UV radiation. The first response after a short burst of intense UV causes DNA sequencing errors, ultimately resulting in algal death. The second, a long-term exposure to increased UV radiation, forces the

algae to adapt methods to reduce the effects of UV, resulting in a late-life algal bloom (Xue et al. 2005). The second response is what we expected in our study. Our experimental design differed from Bothwell's in that we looked at natural UV levels, in addition to elevated and blocked UV rays. We also measured the chlorophyll biomass of all three treatments; the UV-filtering, UV-transparent (natural exposure) and enhanced UV radiation.

We expected the control, or the treatment having natural chlorophyll values of the algae in Douglas Lake in Northern Lower Michigan, to be between 0.2-1.5 micrograms/centimeter², since Douglas Lake is mesotrophic (having moderate levels of nutrients and productivity). We hypothesized that the UV-filtering algal colony would be less chlorophyll-rich and have less species diversity because algae would not have enough UV light for growth. We predicted that the UV-treated algae will show later growth as the UV radiation killed organisms that would, under normal conditions, keep algae populations in check.

METHODS

For 12 days, we grew algal colonies on two different types of acrylic plexiglass in Douglas Lake. The first type of acrylic plexiglass, Atofina Chemicals Plexiglas UF-5, was UV-filtering. The second type of plexiglass, Sparteck Solacryl SUVT Cell Cast Acrylic, was UV-transparent. Both types were three-tenths of a centimeter thick. Both types of plexiglass were cut, making 12 15-centimeter squares; four for the UV-filtering treatment and eight for the UV-transparent treatment. Three-tenths of a centimeter holes were drilled in the corners of each square, and all 12 squares were wired together in a three-by-four grid. Four UV-filtering samples were in one column, four control samples were in the second column, and four samples receiving elevated levels of UV radiation were in the third column. We attached small pieces of foam to the corners and underneath the grid for floatation. We placed the grid near the boat dock

of Douglas Lake (Michigan, USA), anchored two sides with bricks and tied a third rope to the dock for increased stabilization.

Each day, the four samples grown on UV-transparent plexiglass receiving elevated UV levels were subjected to 365 nm of UV-B by a high intensity, self-contained, battery-operated, handheld lamp for 90 seconds. The second group, acting as our control, only received natural UV and solar radiation, and the third treatment grown on UV-filtering plexiglass received no extra UV radiation, furthermore, and shielded environmental UV rays.

We allowed the colony to grow for 12 days before sampling. At this time, using a toothbrush, we scraped a seven-centimeter square from each of the plates to determine algal biomass, measured by chlorophyll a content through fluorometric chlorophyll analysis (method SM10200 H in Standard Methods for the Examination of Water and Wastewater 1998). We also collected samples from each of the plates in order to determine species biodiversity under a light microscope. Algae numbers were determined from transects across a 0.1mL counting cell slide with a cover slip. The data collected was tested for statistical significance using a one-way analysis of variance (ANOVA) through the computer interface SPSS.

RESULTS

We analyzed our results by using the SPSS one-way ANOVA statistical test to compare our treatments. Our null hypothesis stated that UV-B radiation had no effect on algal growth, and that any differences that do appear are due to sampling error alone. The alternative hypothesis stated UV radiation had an effect on algal growth, as the differences are too great to be due to sampling error alone. The differences in chlorophyll content were not statistically significant (p -value = 0.149). We ran a Principle Component Analysis (PCA) on the species

diversity. Although minor trends in species variation between treatments was observed, the PCA (Fig. 2) indicated that there were no significant differences between the treatments.

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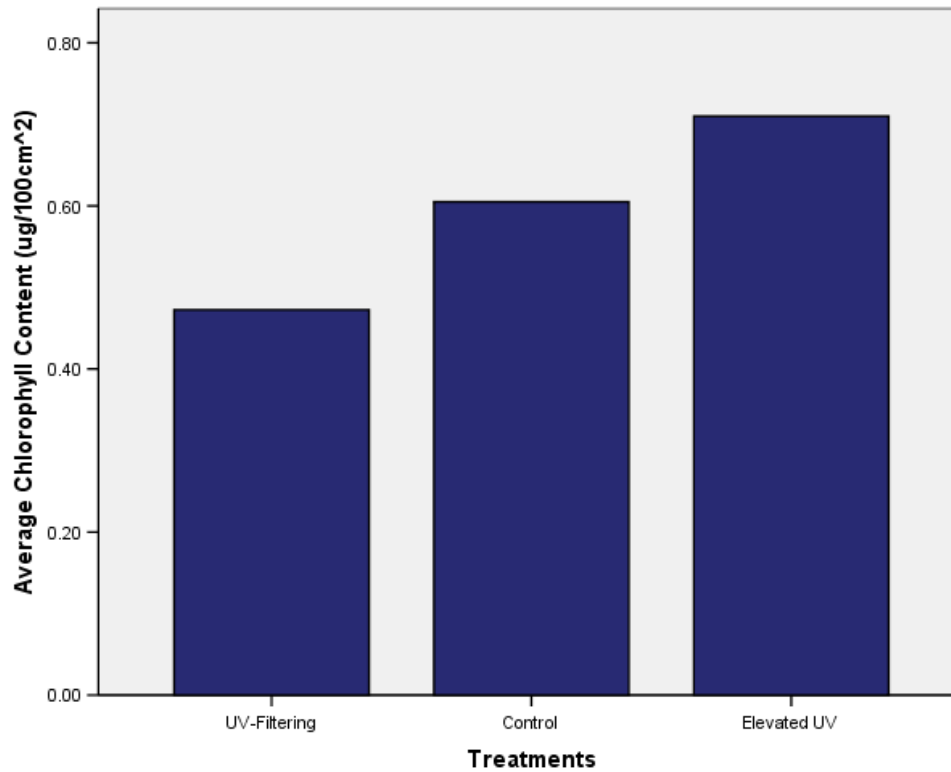


Fig. 1 Average chlorophyll content in ug/100 cm².

This graph displays a trend in increasing biomass measured in our three treatments beginning with the lowest level of chlorophyll content: UV filtering treatment (.47 ug/100cm²), control group (.60 ug/100cm²), and elevated UV (.71 ug/100cm²).

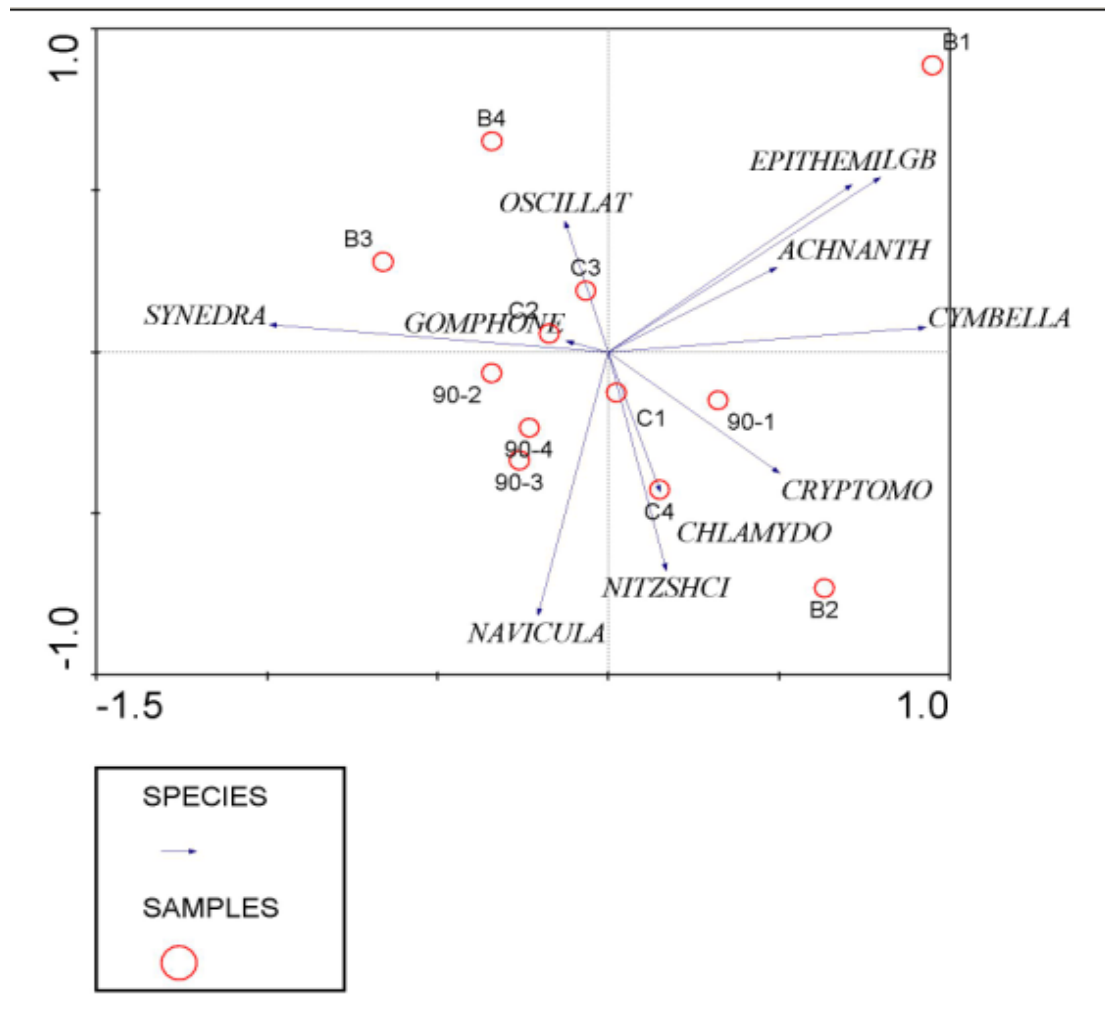


FIGURE 2: PCA OF ALGAE TREATMENT COMPOSITIONS

Each red circle above represents the analysis of one of the four samples in each treatment. Seventy-five percent of the variation is described by the x-axis and an additional 10% is described by the y-axis. Species with vectors at right angles to each other represent two species which vary independently. For example, *Oscillatoria* and *Epithemia* vary independently from each other. Three of the 4 UV Blocking (B) samples form an arc in the upper half of the graph. The species most prominent in the upper quadrants are *Oscillatoria*, *Epithemia*, and LGBs. This suggests that these species may be more UV sensitive than the species represented in the lower half of the graph. *Synedra* and *Cymbella* are inversely related and do not seem to be as effected by UVR as *Oscillatoria* or *Epithemia*. In general, the elevated UV and the control group had similar species composition.