Report on studies related to the ecological implications of ozone depletion on the antarctic environment

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Annual springtime ozone depletion over Antarctica has resulted in an increase in the intensity and spectral distribution of solar ultraviolet-B (UV-B) radiation reaching the Earth's surface (Frederick and Snell 1988). UV-B is known to have many harmful biological effects (Harm 1980). This range of wavelengths (280–320 nanometers) is absorbed by DNA and proteins, causing conformational changes in molecular structure that interfere with the normal functioning of these molecules in cell metabolism. The antarctic ozone hole has been in existence for over a decade, and ecological changes that could be caused by increased UV-B have already been initiated. Long-term effects have yet to be identified, but the consequences of increased UV-B levels in the antarctic marine environment are a primary concern.

The project described here examined several aspects of ultraviolet radiation related to the photobiology of antarctic organisms. Field studies and collections were made in the vicinity of Palmer Station (64°46'S 64°03'W) at Arthur Harbor, Anvers Island, on the Antarctic Peninsula.

Quantification of UV-B in the aquatic environment. Biological dosimetry, actinometry, and radiometry were used to study the vertical transmission of UV-B within the water column of Arthur Harbor from September to December 1988. This period coincided with the opening and closing of the 1988 ozone hole (October to November). The biological dosimeter used a DNA repair-deficient bacterial cell line to measure relative levels of biologically active UV-B within the water column. Actinometry is based on the UV photolysis of specific compounds. Paranitroanisole was used as an actinometer (Dulin and Mill 1982) in conjunction with the biological dosimeter. Instantaneous measurements of UV-B were made with a waterproofed broad-band UV-B photodetector. An example of results obtained with these three methods is presented in figure 1.

Atmospheric factors such as the angle of the Sun, ozone concentration, and cloud cover affect the spectral distribution and intensity of UV-B that reaches the Earth's surface. Hydrographic factors such as dissolved matter, particulates, and phytoplankton concentration affect the transmission of UV wavelengths through the water column. Chlorophyll concentrations and total DNA content of the waters of Arthur Harbor were determined during this study. Complete analyses of light and hydrographic data are under way.

DNA repair in antarctic organisms. Eight species of planktonic diatoms isolated from Arthur Harbor and maintained in culture were studied to characterize DNA repair mechanisms and the effects of UV-B exposure on population development (figure 2). Preserved samples from additional experiments conducted during the 1988 season are being analyzed to determine specific molecular characteristics of DNA damage and repair in antarctic phytoplankton species.

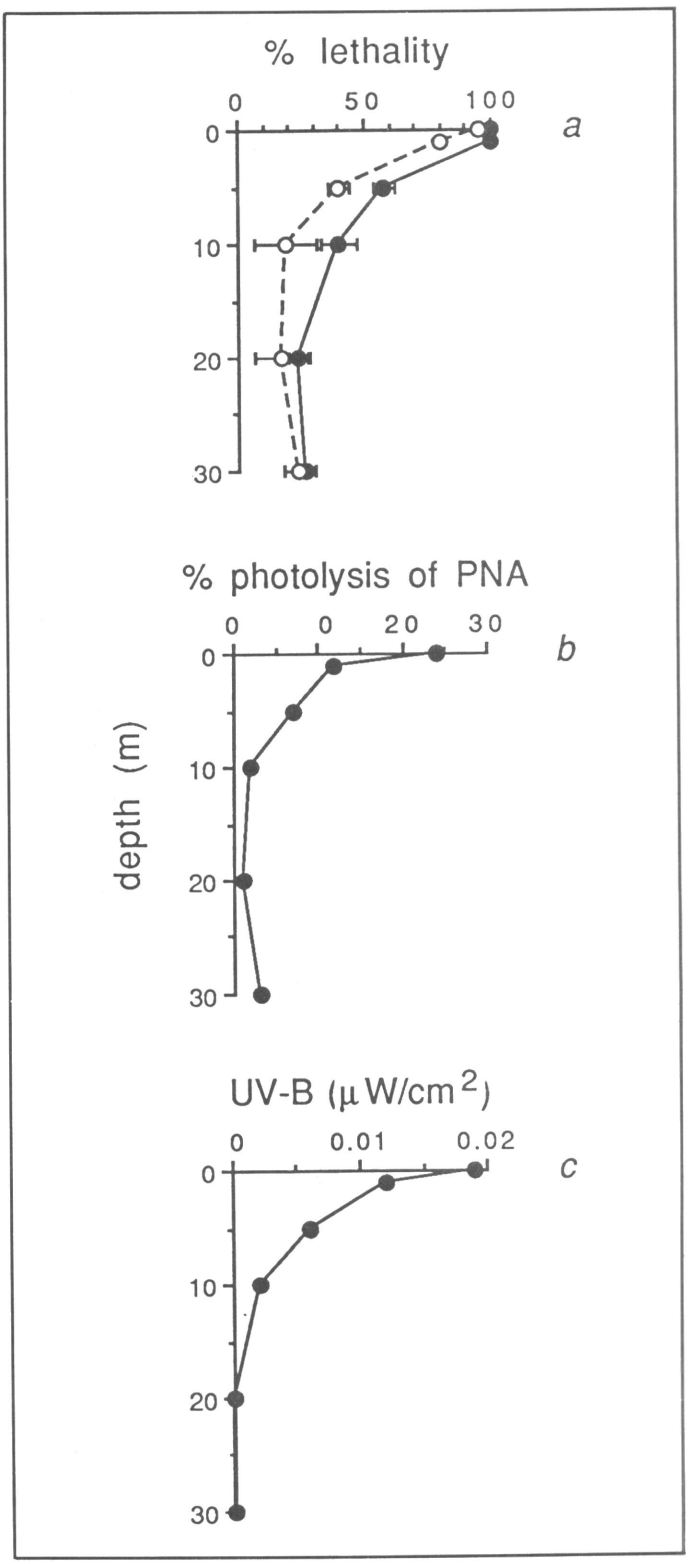

Figure 1. Measurements of in-water ultraviolet-B (UV-B). A. Biological dosimetry: Lethal effects of ambient in-water UV radiation exposure to a bioassay organism. Filled circles denote full-light incubations; open circles denote samples exposed to ambient light from which UV-B wavelengths were filtered out; and bars denote mean ± SE. Cells were exposed at the indicated depths for 3 hours on 6 October 1988. B. Actinometry: Photolysis of paranitroanisole (PNA) caused by UV-B exposure within the water column. Incubation conditions were the same as for A. C. Radiometry: Instantaneous UV-B measurements made with a broad-band photodetector at local noon. (m denotes meter. μ W/cm² denotes microwatts per square centimeter.)

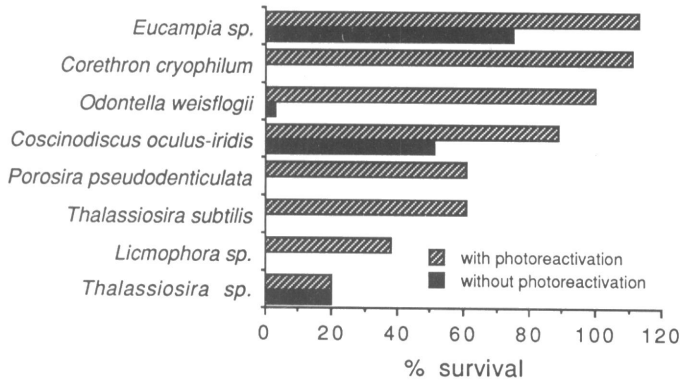

Figure 2. Survival of cultured diatom cells after irradiation by 1,000 joules per square meter of UV-B light (peak emission 313 nanometers) and 8 days of growth under light conditions that supported or prevented photoreactivated repair of DNA.

Identification of UV-B-absorbing compounds. During the spring of 1988, eight macroalgal species, 34 lichens, seven mosses, and 114 invertebrates were screened for the presence of UV-B absorbing compounds. Eighty-five percent of these samples showed distinct absorbance peaks in the UV-B wavelength range (figure 3). These samples are being analyzed by high-pressure liquid chromatography to identify specific compounds and relate their structure to those of UV-B-absorbing compounds that have been found in tropical and temperate species (Dunlap and Chalker 1986). This work is being completed in collaboration with Walter Dunlap of the Australian Institute of Marine Science.

Conclusions. Results from this project have demonstrated that biologically significant fluxes of UV-B radiation occur down to 10 meters and can reach to 30 meters in antarctic coastal waters during the ozone hole. Photoreactivation may be the predominant pathway for DNA repair in antarctic diatoms and observed differences in cell division rates support previous conclusions that the major effect (if any) of increased UV-B in the antarctic in the antarctic environment may be changes in the taxonomic structure of plankton communities. It also appears that many antarctic species are able to synthesize compounds that act as natural "sunscreens," providing protection from UV-B exposure.

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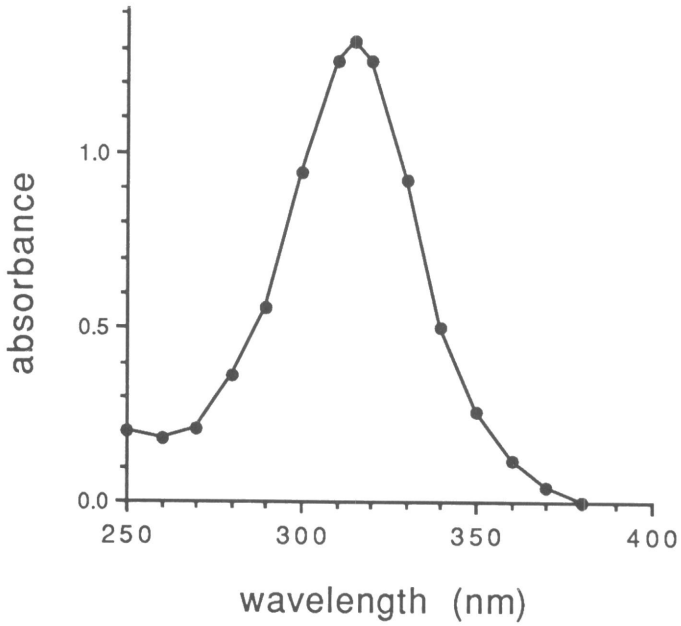

Figure 3. Example of a spectrophotometric scan of a cell extract (1:100 dilution) that has UV-absorbing properties. These data are from a red algal species (*Curdiea racovitzae*). (nm denotes nanometer.)

References

Dulin, D., and T. Mill. 1982. Development and evaluation of sunlight actinometers. *Environmental Science and Technology*, 16, 815–820.

Dunlap, W.C., and B.E. Chalker. 1986. Identification and quantitation of near-UV absorbing compounds (S-320) in a hermatypic scleractinian. *Coral Reefs*, 5, 1–5.

Frederick, J.E., and H.E. Snell. 1988. Ultraviolet radiation levels during the Antarctic spring. *Science*, 241, 438–440.

Harm, W. 1980. *Biological Effects of Ultraviolet Radiation.* (IUPAB Biophysics Series I.) Cambridge, UK: Cambridge University Press.