

## Final Technical Report

## Toward Describing the Effects of Ozone Depletion on Marine Primary Productivity and Carbon Cycling

NAGW-4717

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Bigelow Laboratory for Ocean Sciences

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\$228,954; 5 mo/yr PI effort; about 6 mo/yr technician services

This project was aimed at improved predictions of the effects of UVB and ozone depletion on marine primary productivity and carbon flux. A principal objective was to incorporate a new analytical description of photosynthesis as a function of UV and photosynthetically available radiation (Cullen et al., 1992, *Science* 258: 646) into a general oceanographic model. We made significant progress: new insights into the kinetics of photoinhibition were used in the analysis of experiments on Antarctic phytoplankton to generate a general model of UV-induced photoinhibition under the influence of ozone depletion and vertical mixing. The way has been paved for general models on a global scale.

## Refereed publications

Neale, P.J., M.P. Lesser and J.J. Cullen. 1994. Effects of ultraviolet radiation on the photosynthesis of phytoplankton in the vicinity of McMurdo Station (78oS). "Ultraviolet Radiation in Antarctica: Measurements and Biological Effects." C.S. Weiler and P.A. Penhale, eds. *Ant. Res. Ser.* 62: 125-142.

Lesser, M.P., J.J. Cullen and P.J. Neale. 1994. Carbon uptake in a marine diatom during acute exposure to ultraviolet B radiation: Relative importance of damage and repair. *J. Phycol.* 30: 183-192.

Cullen, J.J. and P.J. Neale. 1994. Ultraviolet Radiation, Ozone Depletion, and Marine Photosynthesis. In: "Photosynthesis and Global Changes in the Environment" *Photosynthesis Research* 39: 303-320 (Invited Review Article).

Pena, M.A., M.R. Lewis and J.J. Cullen. 1994. New production in the warm pool of the tropical Pacific Ocean. *J. Geophys. Res.* 99: 14,255-14,268.

Cullen, J.J. and M.R. Lewis. 1995. Biological processes and optical measurements near the sea-surface: some issues relevant to remote sensing. *J. Geophys. Res.* 100 (C7): 13,255-13,266.

Smith, R.C. and J.J. Cullen. 1995. Effects of UV radiation on phytoplankton. U.S. National Report to the International Union of Geodesy and Geophysics 1991-1994, *Rev. Geophys. Suppl.*, 1211-1223. (Invited)

Cullen, J.J. 1995. Status of the iron hypothesis after the open-ocean enrichment experiment. *Limnol. Oceanogr.* 40: 1336-1343. (Invited)

Lesser, M.P., P.J. Neale, and J.J. Cullen. 1996. Acclimation of Antarctic phytoplankton to ultraviolet radiation:

UV absorbing compounds and carbon fixation. *Mol. Mar. Biol. Biotech.* 5: 314-325.

Cullen, J.J. and P.J. Neale. 1997. Biological weighting functions for describing the effects of ultraviolet radiation on aquatic systems. "The Effects of Ozone Depletion on Aquatic Ecosystems," D.-P. Häder, ed. p. 97 - 118.

Neale, P.J., J.J. Cullen and R.F. Davis. 1997. Inhibition of marine photosynthesis by ultraviolet radiation: Variable sensitivity of phytoplankton in the Weddell-Scotia Sea during austral spring. *Limnol. Oceanogr.* (accepted).

Submitted:

Neale, P.J., R.F. Davis and J.J. Cullen. 1997. Interactive effects of ozone depletion and vertical mixing on photosynthesis of Antarctic phytoplankton. *Nature* (submitted).

Conference proceedings, etc.:

Cullen, J.J., R.J. Geider, J. Ishizaka, D.A. Kiefer, J. Marra, E. Sakshaug and J.A. Raven. 1993. Toward a general description of phytoplankton growth for biogeochemical models, In G.T. Evans and M.J.R. Fasham [eds.], *Toward a Model of Biogeochemical Ocean Processes*. Springer. 153-172. (NATO Working Group)

Cullen, J.J., and P.J. Neale. 1993. Quantifying the effects of ultraviolet radiation on aquatic photosynthesis. "Photosynthetic Responses to the Environment." H.Y. Yamamoto and C.M. Smith (eds.), *American Society of Plant Physiologists*. pp. 45-60. (Invited)

Neale, P.J., J.J. Cullen, M.P. Lesser and A. Melis. 1993. Physiological bases for detecting and predicting photoinhibition of aquatic photosynthesis by PAR and UV radiation. "Photosynthetic Responses to the Environment." H.Y. Yamamoto and C.M. Smith (eds.), *American Society of Plant Physiologists*. pp. 60-77.

Cullen, J.J. A. M. Ciotti and M.R. Lewis. 1994. Observing biologically induced optical variability in coastal waters. *Proc. SPIE Ocean Optics XII Vol. 2258*: 105-115.

Cullen, J.J. and P.J. Neale. 1997. Effect of ultraviolet radiation on short-term photosynthesis of natural phytoplankton. *Photochem. Photobiol.* 65: 264-266. (Invited minireview)

Cullen, J.J. 1997. Quantifying the Influence of UV-B on Biological Processes in Natural Waters. *Proceedings of the Ontario Climate Advisory Committee Workshop on Atmospheric Ozone*. Downsview, Ontario. p. 166-174.

Cullen, J.J., Á.M. Ciotti, R.F. Davis and P.J. Neale. 1997. The relationship between near-surface chlorophyll and solar-stimulated fluorescence: biological effects. In: *Ocean Optics XIII*, S.G. Ackleson and R. Frouin, eds. *Proc. SPIE 2963*: 272-277.

Ciotti, Á.M., J.J. Cullen, C.S. Roesler and M.R. Lewis. 1997. The influence of phytoplankton size structure on the spectral attenuation coefficient in the upper ocean. In: *Ocean Optics XIII*, S.G. Ackleson and R. Frouin, eds. *Proc. SPIE 2963*: 380-385.

Invited Presentations

1993: Group for Aquatic Primary Productivity (GAP VI), Saskatoon, Canada, Keynote presentation on modelling.

- 1994: Trondheim Biological Station, Norway, "Influence of UV Radiation and Ozone Depletion on the Photosynthesis of Antarctic Phytoplankton."
- 1994: Workshop on the Ecology and Oceanography of Harmful Algal Blooms, Winter Park, Colorado, "Detection and Assessment of Harmful Algal Blooms with In Situ Optical Instruments."
- 1994: Workshop: "The Interactions of Climate Change, Increasing UV-B Exposure, and Dissolved Organic Carbon, and Their Implications for Aquatic Ecosystems," Jasper, Alberta. "Penetration of Biologically Effective UV Radiation in Different Aquatic Systems."
- 1995: University of Southern Mississippi, Center for Marine Science, "Effects of Ultraviolet Radiation on the Photosynthesis of Antarctic Phytoplankton."
- 1995: American Society of Limnology and Oceanography Summer Meeting, "Penetration of UV Radiation in Aquatic Systems and the Potential Ecological Effects of Ozone Depletion."
- 1995: Workshop: "Atmospheric Changes in Atlantic Canada," Halifax, Nova Scotia. "Quantifying the Potential Effects of Ozone Depletion on Aquatic Systems."
- 1996: American Geophysical Union / American Society of Limnology and Oceanography Ocean Sciences Meeting, "Optical Observation Technologies and Harmful Algal Blooms."
- 1996: Mount Allison University, Sackville, New Brunswick, "Optical Observation of Biological Variability in Surface Waters."
- 1996: Woods Hole Oceanographic Institution. "Effects of ultraviolet radiation and ozone depletion on water-column primary production in the context of vertical mixing."
- 1996: Guest lecturer for a course on Systems Approach to Biological Ocean Science, University of New Hampshire, Durham.
- 1996: Hargis Memorial Lecture, "Effects of ultraviolet radiation and ozone depletion on water-column primary production in the context of vertical mixing." University of Minnesota, Duluth.
- 1996: Conference: Remote Sensing for Marine Resource Users, Managers, and Educators, Rockport, Maine. "Optical observation technologies for long-term marine monitoring."
- 1996: NATO Advanced Study Institute on "The Physiological Ecology of Harmful Algal Blooms," Bermuda. "Special modalities of macronutrient assimilation" and "Behavior, physiology and the niche of depth-regulating phytoplankton."
- 1996: American Society for Photobiology, 24th Annual Meeting, Atlanta. "Effect of UV on short-term photosynthesis of Antarctic Phytoplankton." *Photochem. Photobiol.* 63: 12S - 13S.
- 1996: Inter-American Institute for Global Change Research. Workshop, Ensenada, Mexico. Keynote presentation, "Effects of UV on Phytoplankton."
- 1996: Ontario Climate Advisory Committee, Workshop on Atmospheric Ozone, Downsview, Ontario, "Quantifying the influence of UV radiation and ozone depletion on biological and photochemical processes in natural waters."

Other Presentations at Conferences:

Cullen, J.J., P.J. Neale, R.F. Davis and D.R.S. Lean. 1994. Ultraviolet radiation, vertical mixing, and primary productivity in the Antarctic. AGU/ASLO Ocean Sciences Meeting, Feb. 1994

Pena, M.A., M.R. Lewis, J.J. Cullen, and W.G. Harrison. 1994. The effect of fluctuation in the input of nitrate on phytoplankton biomass and new production. AGU/ASLO Ocean Sciences Meeting, Feb. 1994; EOS 75 (3, Suppl): 95.

Cullen, J.J., A. M. Ciotti and M.R. Lewis. 1994. Observing biologically induced optical variability in coastal waters. Proc. SPIE Ocean Optics XII, Bergen, Norway.

Neale, P.J., J.J. Cullen and R.F. Davis. 1994. "Biological weighting functions for UV inhibition of photosynthesis: assessing the effect of ozone depletion on primary productivity of Antarctic phytoplankton." Scientific Committee on Antarctic Research, 6th Biology Symposium, Venice, 30 May - 3 June 1994.

Service as a reviewer: 1993-96: AGU Antarctic Series, American Chemical Society, Aquat. Microb. Ecol., CalCOFI Reports, Can. J. of Fish. Aquat. Sci., Cytometry, Deep-Sea Res., Int. J. Env. Sci., J. Geophys. Res., J. Mar. Res., J. Photochem. Photobiol. B: Biology, J. Phycol., J. Plankton Res., J. World Aquacult. Soc., Limnol. Oceanogr., Mar. Biol., Mare Nor, Mar. Ecol. Prog. Ser., Nature, Photosyn. Res., Polar Biol., Science. Proposal reviewer for: NSF (Biol. Oc., Chem. Oc., Polar Programs, DEB, SBIR), NASA (Oceanic Processes, Global Change, EOS), NOAA (Sea Grant, Global Change, NURP), USDA, Australian Research Council, NERC (UK), and NSERC Canada. Multiple reviews have been prepared for several of the above journals and agencies.

Recognition:

Editor's Citation for Excellence in Refereeing, Journal of Geophysical Research - Oceans. 1993

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