Management of an Undisturbed Water Ecosystem Containing Old Growth Hemlock, as a Model System of Clear Lake Reserve, Ontario

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Abstract

Since 1969 Trent University researchers have been investigating the chemistry and biotic part of a small undisturbed lake near Minden, Ontario. Clear Lake is surrounded by old growth hemlock stands, some 400 years old. The research was later joined by personnel of the Ontario Ministry of the Environment, and the educational program in the Frost Centre. We are going to discuss changes in pH, phosphorus content and the reaction of two aquatic macrophytes, *Eriocaulon* and *Lobelia dortmana*, to simulated acid rain conditions and increased ultraviolet radiation.

Introduction

Why was it important to establish the Clear Lake Reserve area? The answer would be different depending on whether you are a scientist, tourist or government employee, or a cottager living in the area. For academic scientists the area around Clear Lake has been the oldest site where we and our government colleagues together have done experimental work since the late 1960s, almost from the founding of Trent University. Since then it has become a model system for many investigators working on acidification of that area caused by acid rain. The work started at almost the founding of Trent University, by Schindler and Nighswander, and was published in 1970. The other point of view, of the "users" of the area, will be addressed in the Discussion section.

Clear Lake and several smaller ones are surrounded by forests containing 400-year-old hemlock stands which, in addition to old growth, have all the younger ages of hemlock, thus being an almost unique example of an undisturbed ecosystem, in which we can investigate medicinal plants, and the processes of succession of plants, as well as the inter-reaction between flora and fauna. Nowadays we have realized that plant ecology involves many chemicals, and the influence of the environment on changes in phytochemistry has begun to arouse the interest of plant ecologists (Plant Ecology, 1999). The reactions involve extrusion to the plant surface of phytochemicals (Zobel and Brown, 1988), which are then chemically modified by such environmental factors as oxygen and ultraviolet, and the influence of microbes in the soil. We have investigated the influence of different kinds of radiation on hemlock seedlings growing on the debris of fallen logs of old hemlock trees. We have also chosen to investigate the sponge and the two macrophytes, because they have been influenced to the greatest extent both by changes in ph and by radiation.

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Materials and Methods

Hemlock seedlings were collected from the area surrounding Clear Lake (Fig. 1), and water plants from the lake itself, of which the bottom is visible because of the great clarity of the water (Fig. 2). We collected *Meyenia fluriatilis* (freshwater sponge) and two macrophytes, *Eriocaulon septangulare* and *Lobelia dortmanna*, and kept in lake water until the treatment. Plants were irradiated with 366 nm radiation for seven days, or kept in light on a window sill. The seven-day period was chosen because in earlier experiments we had found that this was long enough for plants to produce compounds in amounts sufficient for high performance liquid chromatography (HPLC) analysis. Parallel samples were taken after the plant had been exposed to UV and HCl solutions of pH 5.8, which was the current prevailing value (report of the Ontario Ministry of Natural Resources, 1990). Additionally, the influence of another ion was studied, because cadmium was found in high concentrations in lakes of the Sudbury region some 250 km northwest of this site. Novaspec UV/visible spectrometers were used to measure total absorption of compounds whose peaks approximated 325 nm, and thus was suitable for evaluating coumarins as well as many flavonoids (Harborne, 1967), both groups being well known as phytoalexins — compounds synthesized under stress (Zobel, 1999a; Zobel, 1999).

Results

After exposure to 366 nm radiation these three species investigated reacted differently in the production of phenolic compounds absorbing at 325 nm — most likely coumarins and many flavonoids. *Meyenia* contained more phenolic compounds absorbing at 325 nm than the macrophytes, already while growing in the lake (Fig. 3, field samples), as well as after the seven-day experiment of keeping the sponge under laboratory conditions when the amount still increased by over 30%. After UV irradiation the amounts decreased by 80% when the radiation was the only stress, but the second stress decreased the values less intensely. For instance, acidification plus UV irradiation lowered the phenolics concentration by 60%, and when exposure was to cadmium as well as UV it was lowered only 30%.

Values for *Lobelia* showed a similar trend, although the absolute values were much smaller, not reaching even 20% of the values for the sponge. *Eriocaulon* reacted differently. It showed the smallest concentration of phenolic compounds at the start, while the values for the control, UV alone and UV plus acidification were similar, and only UV plus cadmium caused an increase over threefold.

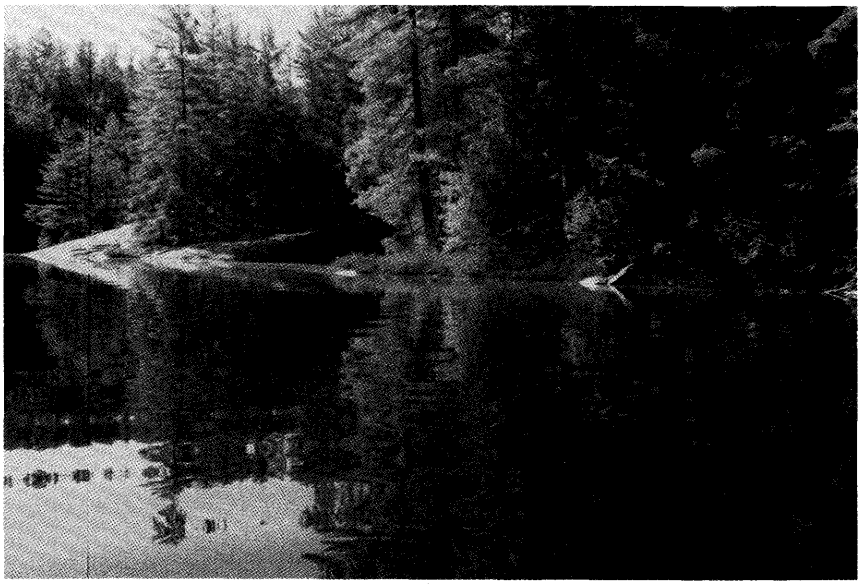

Figure 1.—The bottom of the lake, where the macrophytes grow. Arrow points to the underwater log on whose branches the *Meyenia* grows.

Figure 2.—The great transparency of the water several metres deep at a distance of 50-100 m from the shore. Between the rocks grow macrophytes.

The pH changes in the Clear Lake Reserve (Fig. 4) oscillated around 5.8. The highest measured was in 1994, 5.95, and the lowest in 1992, 5.73. The trend of decline over the 30 years was stable, lowering but not much. Total phosphorus concentration (Fig. 5) seemed to decrease steadily between 1980 and 1994, by half — from 5.5 to 2.8 AU.

Discussion

Meyenia (a symbiotic organism) had the most compounds absorbing UV, the amount being five times that of *Lobelia* and over 20 times that of *Eriocaulon*. This fact is difficult to explain, and we can only speculate that the macrophytes could have evolved additional different protective mechanisms against UV radiation. The inflorescences of these two macrophytes extend above the surface of the water, and are thus exposed to UV, and indeed the whole plant can be exposed to radiation when water levels are low, so they would need protection against UV at least for part of the period of their ontogenesis. It is thus strange that both have low concentrations of phenolic compounds, and there must be some factor other than UV that is responsible for the low phenolics level.

Room temperature and laboratory light conditions, after seven days, caused the concentrations of compounds absorbing at 325 nm to increase in the sponge, but to decrease in both of phenolic concentrations by 50-80%,

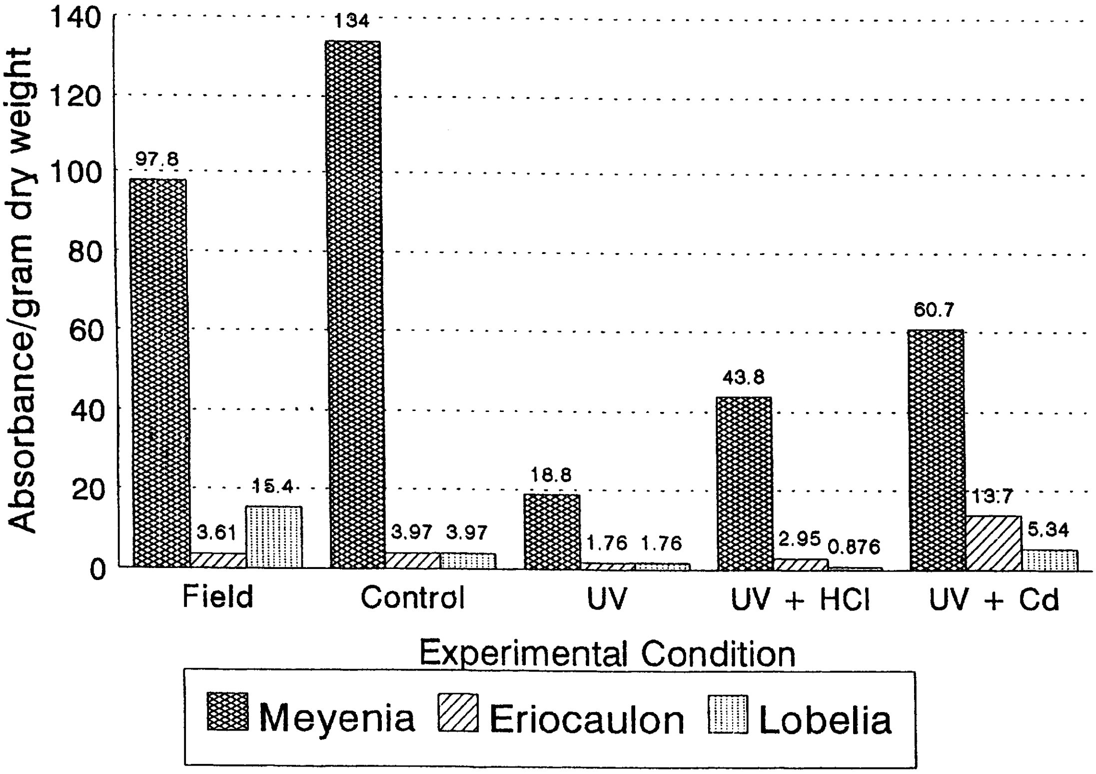

Figure 3.—UV absorbance of *Loeblia dortmanna, Eriocâulon septangulare,* and *Meyenia fluviatilis* under various conditions. (UV spec. wavelength of 325nm, experimental wavelength of 366nm).

compared to the control, and by this criterion the stress caused by UV alone (i.e., 80%) was the strongest, showing the lowest concentration of phenolics. However, with acidification, and even more with added cadmium, the lowering of the phenolics concentrations was less pronounced. As stresses in higher plants have been found to increase these concentrations, as in the case of two species of pine (Zobel and Nighswander, 1990, 1991) our present results are unexpected and difficult to explain without further investigation. We suggest that it could be caused by retardation of biochemical pathways or destruction of compounds already produced by the action of UV, as has been found for many photo-inhibited and photo-stimulated drugs (Zobel, 1999b). The fact that UV alone caused the greatest diminution of absorption suggests how important shortwave radiation is.

It is important from the scientific point of view to have a lake as a model system that is relatively undisturbed, on which both academic and government researchers can conduct studies with base comparisons dating from 1967, a period covering much of the progressing acidification. After the papers of Schindler and Nighswander published in 1970, including the analysis of acidification, and zoological and botanical observations, Clear Lake became the model system for ensuing studies (Banks, 1981; MNR report, 1990). Recently macrophytes have been investigated (Sandstrom, 1990; Zobel et al., 1996), and most recently the freshwater sponge was added to the investigation (Cybulski, 1997).

Besides scientists, other groups of people with different interests have been benefiting from formation of this Clear Lake Reserve area. Tourists appreciate the beautiful undisturbed ecosystem, and by learning about the existence of 400-year-old hemlock they appreciate and admire more the beauty of Nature, and the need to preserve it for future generations. Leaving a protected and undestroyed pool of genes of such unique old trees is our responsibility. It is also necessary to protect the surrounding area containing 120-year-old pine forests, as their existence is a necessary precondition for development of the next hemlock old growth. Since a succession of pine and hemlock takes centuries, and since it is important for it to be undisturbed for the next generation, there needs to be very careful planning of future management in that area.

The pH changes in the Clear Lake Reserve were not dramatic over the past 30 years of research, but increased from 1992 until the present. The large changes in pH could be followed by changes in phosphorus availability over that period. The decrease in pH occurred over two periods: 1981-83 and 1990- 94. The pH changes followed the phosphorus concentration except during the 1992-94 period, an unexpected finding, as increased pH lowers phosphorus concentration.

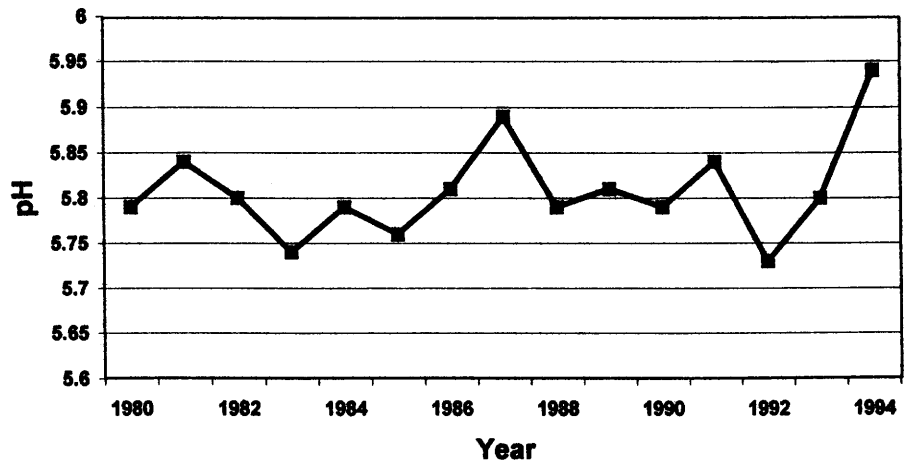

Figure 4.—Clear lake pH 1980 to 1999.

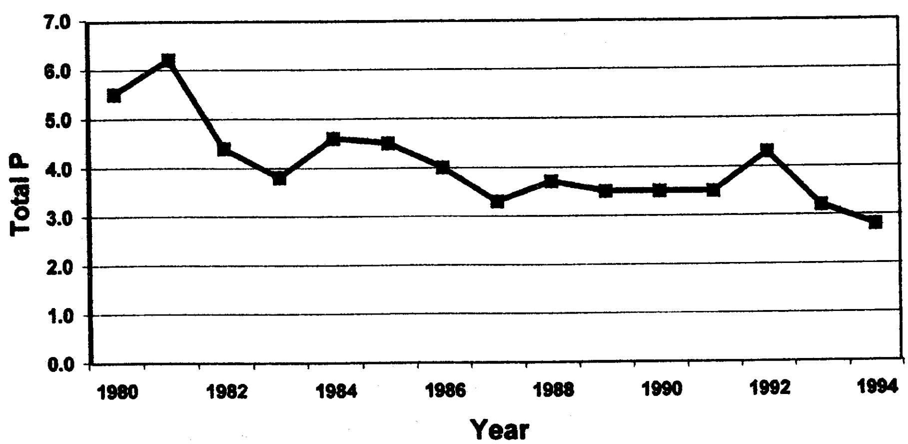

Figure 5.—Clear lake total phosphorus.

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