Relationship of Regrowth of Aquatic Macrophytes after Treatment with Herbicides to Water Quality and Phytoplankton Populations[1]

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ABSTRACT

The relationship of aquatic macrophyte regrowth after treatment with four herbicides to water quality and phytoplankton development and inhibition was evaluated in test pools in central Florida. A combination of various aquatic macrophytes reestablished to within 35 ± 5% of their original 100% cover after a total herbicidal treatment. At this percent cover these plants exhibited a capacity to regulate and maintain a stable ecosystem comparable to that of the control. The herbicides used were: Mono (dimethytridecylamine) oxide-7-oxabicyclo (2.2.1) heptane-2, 3-dicarboxylic acid (TD-1874); Mono (N, N-dimethylalkylamine-7-oxabicyclo (2.2.1) heptane-2, 3- dicarboxylic acid (Hydrothol 191); Dihydroxy aluminum salt of 7-oxabicyclo (2.2.1) heptane-2, 3-dicarboxylic acid (System E); and 6,7-dihydrodipyrido (1,2-e; 2′, 1′c) pyrazinediium dibromide (Diquat) plus triethanolamine complex of copper sulfate (Cutrine Plus).

INTRODUCTION

Aquatic macrophytes serve many functions in a lake basin. They provide food, shelter and attachment surfaces for other organisms, produce dissolved oxygen under favorable light conditions, serve as a temporary removal and storage bank for nutrients, and provide spawning and nursery areas for various economically valuable sportfish species. On the other hand plant populations such as that produced by the submersed exotic hydrilla (*Hydrilla verticillata* Royle) may become so dense that they limit or restrict recreational and agricultural use by causing physical obstruction, removing large quantities of water through evapo-transpiration, and contributing to the stunting of fish populations (5). As decomposition occurs following chemical treatment, stored nutrients are released with potentially undesirable effects on the lake's biological system, such as a temporary increase in biological oxygen demand, an increase in algal populations and the threat of related fish mortality (9).

As submersed and emergent vegetation assume greater dominance in a lake ecosystem, and eventually spreads through a majority of the lake basin, an exceedingly productive combination of littoral macrophytes and attendant microflora develops. Attached, largely epiphytic, eulittoral algae and metaphyton develop in strong association with the aquatic macrophytes. Previous investigations on the inhibition of phytoplanktonic development in heavy stands of submersed and emergent macrophytes implied that excreted organic compounds functioned in an inhibitory, antibiotic way on the growth of phytoplankton (3,4,6,8,10). Other inhibiting influences attributed to macrophytes such as competition for light and nutrients cannot be ignored. In other studies, phytoplankton production was markedly reduced when phytoplankton were taken from the pelagial zone and incubated among macrophytes, and increased when they were incubated at the same depth in open water (1).

The purpose of this study was to monitor the effects of reestablishing aquatic plant communities, after various herbicide applications, on water quality and phytoplankton populations and to establish an acceptable percent of macrophyte cover relative to these parameters that can be applied to actual weed control programs. Observations were conducted over a 9-month period (August 1974 to May 1975) after application of the following herbicides: TD-1874; Hydrothol 191; System E; and Diquat combined with Cutrine Plus.

METHODS AND MATERIALS

Forty-five plastic pools (91 cm in depth by 366 cm in diameter) were filled with washed sand to a depth of 15 cm and planted with the following aquatic macrophytes in various combinations: Hydrilla; Eurasian watermilfoil (*Myriophyllum spicatum* L.); coontail (*Ceratophyllum demersum* L.); muskgrass (*Chara* sp.); eelgrass (*Vallisneria americana* Michx.); and southern naiad (*Najas guadalupensis* (Sprengel) Magnus). Water levels were stabilized and continuously maintained through an irrigation system connected to the Eustis city water supply. These plants were allowed to establish for approximately 1 year. Nine replications of each of the following treatments were randomly selected and herbicides applied (total volume) at the following rates: TD-1874[2], 3 mg per liter; Hydrothol 191, 3 mg per liter; System E, 0.93 kg/ha (3.3 mg per

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[2]A coded experimental compound made by Pennwalt Corp.

liter); 1 mg per liter of Diquat combined with 0.33 mg per liter Cutrine Plus, respectively; and the control. From each treatment series two pools were randomly selected to be used throughout the study for extensive phytoplankton and chemical analysis. All nine replications per treatment were used for visual macrophyte reaction determinations.

The percent cover of each species was determined by using a ring divided into tenths. The ring was placed over the pool and the approximate coverage for a species in each tenth was visually estimated and recorded. The total resulted in the percent cover for each species (7). Quantitative phytoplankton analyses were determined with a Palmer counting cell; the resultant counts were extrapolated to number of cells per liter.[3] Numbers of sulfur bacteria and chemical analyses of ortho-phosphate, total organic nitrogen, turbidity (Jackson Units—JU), and pH were determined by standard methods (11). Samples for chemical analysis of ortho-phosphate, total organic nitrogen, turbidity and pH were taken prior to treatment from all pools, and a mean was determined to establish a baseline. Experimental data from the control and TD-1874 were then plotted as deviation from the baseline (positive or negative) as indicators of changes in water quality. Data from the pools to which the herbicide TD-1874 was applied were graphed since they illustrated the greatest deviation from the control during this study (Figures 1 and 2) (2). Actual readings are given throughout the text. Samples were taken before treatment; after treatment three samples were taken per week for 4 weeks, then weekly for 6 weeks, and monthly thereafter.

RESULTS AND DISCUSSION

In general, the effects of Diquat and Cutrine Plus were quite similar to liquid endothall products (TD-1874 and Hydrothol 191). By the 9th day following application, all

[3]Wilbur, Robert L. 1971. Habitat manipulation. Annual Report. Fla. Game and Fresh Water Fish Comm., Federal Aid Project F-26-2, Job 6, Limnological Sampling. pp. 1-3.

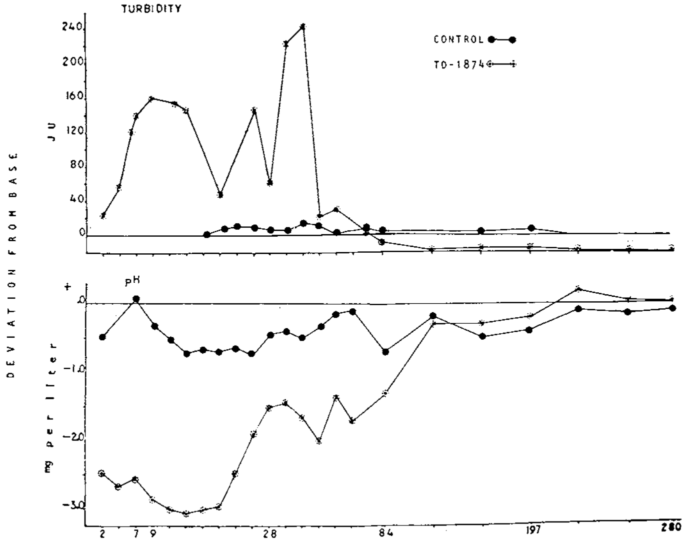

Figure 1. Comparison of Water Quality in Treated and Untreated Pools for Analysis of Turbidity and pH.

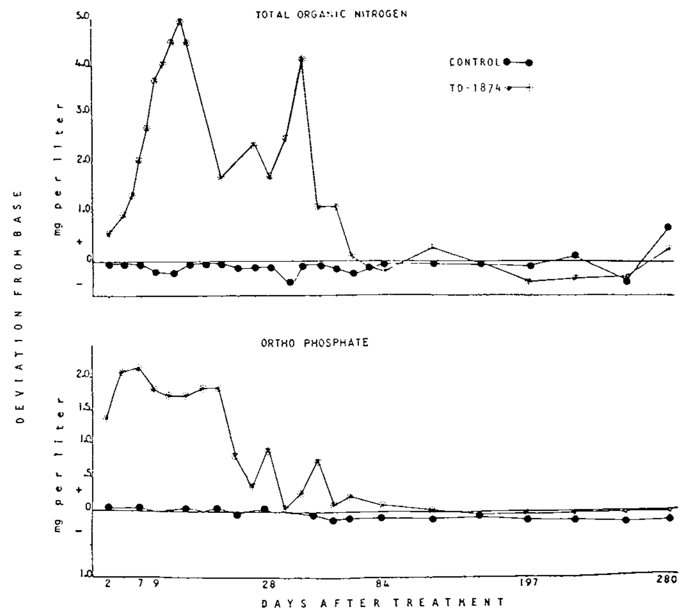

Figure 2. Comparison of Water Quality in Treated and Untreated Pools for Analysis of Total Organic Nitrogen and Ortho-Phosphates.

plants in these treatments were dead and decomposing. The water was very septic with a reddish scum on the surface (2), as anaerobic sulfur bacteria liberated H_2S byproducts. These herbicides had caused a fast kill of the plants, fish, and invertebrates, which resulted in a rapid release of nutrients and an explosive growth rate of bacterial and phytoplankton populations (Figure 3).

As plants decomposed, the rapid release of nutrients was recorded as follows: ortho-phosphates increased from 0.39 mg per liter to 2.45 mg per liter; total organic nitrogen increased from 0.77 mg per liter to 6.15 mg per liter; turbidity increased from 11 JU to 245 JU; and pH dropped from 9.0 to 6.6 (Figures 1 and 2).

In the granulated endothall treatment (System E) all plants except muskgrass were dead and decomposing within 9 days after treatment (dat). Muskgrass was unaffected and grew vigorously, crowding out the affected plants apparently utilizing the nutrients released from decomposing plants. Throughout the duration of the study, water quality and phytoplankton populations in the System E pools closely followed those of the control.

Phytoplankton: In pools treated with Diquat and Cutrine Plus, TD-1874, and Hydrothol 191 the water clarity was severely affected as phytoplankton and sulfur bacteria populations vacillated, imparting either a dark red or green coloration.

Sawyer, et al (1944) arbitrarily defined a bloom as 0.5 x 10^6 cells per liter but observed that large numbers of extremely small algae, such as *Gloeocapsa* (blue-green), though quantitatively considered a bloom, showed no evidence of water discoloration nor nuisance problems in some instances.[4] We found a similar situation in the control and the System E treatments where moderate levels of

[4]Sawyer, C. N., J. B. Lackey and H. T. Lenz. 1944. Investigations of the odor nuisance occurring in the Madison Lakes Monova, Waubesa, Kegonsa, from July, 1943 to July, 1944. Part II. Biological Rept. for the Gov's. Comm. of the State of Wisc., Madison, Wisc.

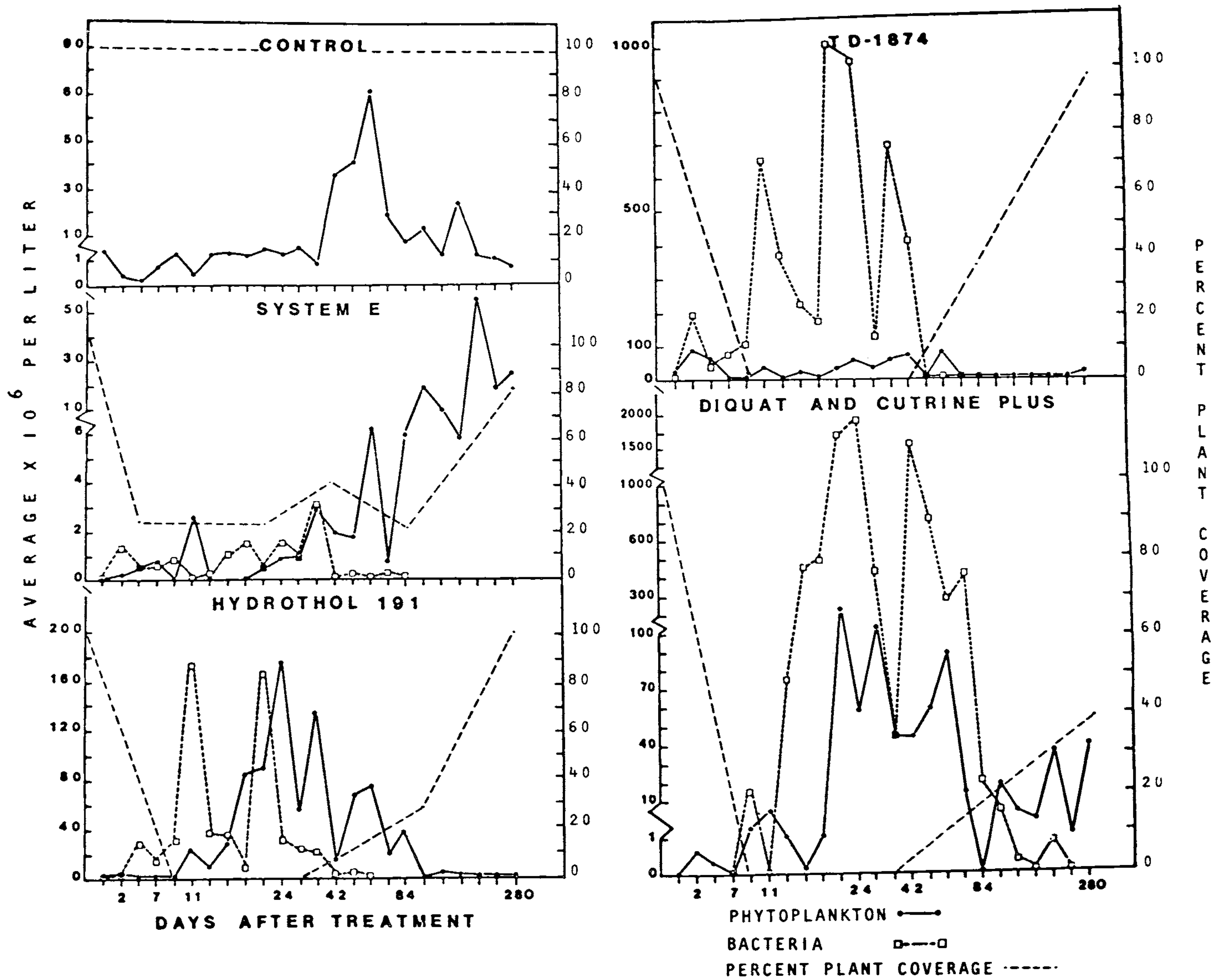

Figure 3. Percent Plant coverage, Phytoplankton, and Bacteria Populations of Pools treated with Aquatic Herbicides.

Selenastrum minutume (green algae) were recorded several times without affecting the water quality or its clarity.

In pools treated with Hydrothol 191, however, phytoplankton levels of 1.73 x 10^8 cells per liter and sulfur bacteria counts of 1.71 x 10^8 per liter were recorded. This explosive growth rate was also observed in TD-1874 and Diquat and Cutrine Plus treatments where phytoplankton levels of 9.9 x 10^7 and 2.36 x 10^8 cells per liter and sulfur bacteria counts of 1.027 x 10^9 and 1.861 x 10^9 per liter were recorded, respectively (Figure 3).

During this period of heavy phytoplankton activity the following species composition was recorded: green algae represented 75% of the total population with *Selenastrum*, *Gloeocystis*, and *Cosmarium* the dominant genera; blue-green 12% with *Anacystis* and *Oscillatoria* the dominant genera; flagellates comprised 10% of the population with *Euglena* the dominant genus; and yellow-green 4% with *Opephora* and *Navicula* the dominant genera. Green algae were found in 87% of the samples; blue-green, 75%; flagellates, 46%; and yellow-green, 36%.

Macrophyte Regrowth: The recovery pattern of macrophytes is shown in Figure 3. In the pools treated with Hydrothol 191, hydrilla and muskgrass regrowth was recorded 28 dat with a concomitant decline in phytoplankton and sulfur bacteria, sulfur bacteria had subsided 56 dat. Southern naiad and vallisneria regrowth occurred 68 dat. By 116 dat, phytoplankton population had returned to normal, percent cover was 29% and the water was clear.

In the TD-1874 treatment, hydrilla regrowth was recorded 40 dat; vallisneria, southern naiad, and muskgrass were recorded 65 dat; sulfur bacteria subsided 84 dat; and Eurasian watermilfoil regrowth was recorded 92 dat. By 116 dat, phytoplankton populations returned to normal, percent plant cover was 37% and the water was clear.

In the Diquat-Cutrine Plus treatment, hydrilla regrowth was recorded 38 dat; vallisneria and muskgrass, 68 dat; and sulfur bacteria subsided 245 dat. By 280 dat, phytoplankton populations had markedly decreased, percent plant cover was 40% and the water was fairly clear.

In the System E treatment, the percent cover of muskgrass reached 40% of the pool area before stabilization, at which time several aquatic macrophytes reappeared. The presence of muskgrass seemed to moderate the undesirable effects of this herbicide treatment as these pools containing muskgrass had exceptional water clarity which is obviously beneficial unless large populations of muskgrass occur and reduce the utility of the water.

We noted a similarity in water quality with plant reestablishment and phytoplankton activity 116 dat. As the percent cover of plants increased, turbidity decreased and returned to normal, the pH stabilized, and ortho-phosphate and total organic nitrogen decreased to levels comparable to the control (Figures 1, 2, and 3).

In essence, a combination of various aquatic macrophytes reestablished to within 35 ± 5% of their original 100% cover after a total herbicidal treatment. At this percent cover, these plants exhibited a capacity to regulate and maintain a stable ecosystem comparable to that of the control. However, the relationship between desirable vs. undesirable plants as stabilization occurred was quite different.

When pools treated with Hydrothol 191 stabilized 116 dat at 29% of the original cover, hydrilla was the dominant (60%) followed by muskgrass and southern naiad (40%). When pools treated with TD-1874 stabilized 116 dat at 37% of the original cover, hydrilla again was the dominant plant (60%) followed by muskgrass, southern naiad, and vallisneria (40%). When pools treated with the Diquat plus Cutrine Plus combination stabilized 280 dat at 40% of the original cover, muskgrass, southern naiad, and vallisneria represented 100% of the reestablished plants. However, hydrilla had reestablished and later dropped out again 84 dat in these pools. Monitoring of other pool studies with this treatment indicated moderate to heavy reinfestation of hydrilla (7).

Overall this indicates the efficiency and competitiveness of hydrilla, but this also indicates that desirable macrophytes, though taking longer to stabilize the system, did so with only 40% of their original cover (Table 1).

If a multiple-use recreational lake has to be treated with herbicides, test results indicate that at least 30 to 40% of the vegetation should be left to support the lake's biological system and keep bacterial and phytoplankton populations in check while the remaining 60 to 70% will still provide adequate areas for varied recreational useages. Florida Game and Fresh Water Fish Commission fishery biologists[5] prefer to have a 50% vegetated to 50% open water ratio for best fish production; however, if with careful management desirable plants such as muskgrass, spatterdock *Nuphar* sp.), vallisneria, southern naiad, panic grass (*Panicum* sp.), bullrush (*Scirpus* sp.), etc. can be either thinned out if too dense or introduced as competitors with less desirable species, a minimum of 40% vegetated to 60% open water ratio appears to be acceptable.

Macrophyte regrowth in test pools did not form a surface mat at 30 to 40% cover, indicating that the density of desirable plants necessary for adequate regulation need not interfere with recreational use. Systems which need total herbicidal treatment will not achieve natural control of phytoplankton and water quality until the aquatic macrophytes reestablish a 30 to 40% cover.

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[5]Smith, S. and V. Williams. 1976. Personal communication.

TABLE 1. RELATIONSHIP BETWEEN WATER QUALITY, PHYTOPLANKTON LEVELS, ANP PERCENT COVERAGE OF REESTABLISHED PLANTS AT STABILIZATION TIME IN POOLS TREATED WITH HERBICIDES.

Treatment	Original Plant Coverage (%)	Plant Regrowth (%)	Stabilization Time	Phytoplankton Levels	Water Quality	Dominant Plants (%)	
Control	100			Normal[a]	Normal		
Hydrothol 191	100	29	116 days	Normal	Normal	Hydrilla	60
						Chara and Naiad	40
TD-1874	100	37	116 days	Normal	Normal	Hydrilla	60
						Chara, Naiad Vallisneria	40
Diquat and Cutrine Plus	100	40	280 days	Normal	Normal	Chara, Naiad[c] Vallisneria	100
System E	100	NA[b]	NA	Normal	Normal	NA	
Average	100	35 ± 5					

[a] Within limits similar to control.
[b] Not applicable since chara was not affected by this herbicide.
[c] Hydrilla 0% 84 dat.

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