Comparative Effects Of Grass Carp And Selected Herbicides On Macrophyte And Phytoplankton Communities

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ABSTRACT

Test pools containing varied populations of aquatic macrophytes were stocked with grass carp (*Ctenopharyngodon idella* Val.) or treated with Hydrothol 191 Mono(N, N-dimethylalkylamine-7-oxabicyclo (2.2.1 (heptane-2, 3-dicarboxylic acid), or Diquat (6.7-dihydrodiphyrdo [1, -2-a:2;1′-C] pyrazinediium ion) combined with Cutrine Plus (triethanolamine complex of copper sulfate) to compare the effects of the fish and herbicides on the macrophyte population and water quality. The herbicide treatments killed all of the plants quickly, releasing nutrients which triggered dense phytoplankton blooms. The grass carp slowly consumed the macrophytes with no noticeable effect on the phytoplankton community.

INTRODUCTION

The grass carp has become the subject of wide interest due to its potential for biological control of aquatic macrophytes. Its ability to consume large quantities of aquatic plants is well documented (5, 6, 9). The grass carp must consume large amounts of plant material since it can only utilize the highly digestible portion of the plants (7) due to the absence of enzymes for cellulose digestion and a short gut. Hickling (5) reported that it takes approximately 8 hours at 28 C for the fish to process its food completely and that only about half of the food is digested and utilized with the remainder egested.

Since aquatic macrophytes act as a reservoir for inorganic nutrients, their rapid destruction results in the recycling of nutrients into solution making them available for increased phytoplankton production (1, 2, 3) which could be more damaging to water quality than dense stands of macrophytes (2).

Several investigators have indicated that a major advantage of using the grass carp for aquatic plant control is the fertilization or "green manuring" of the ponds caused by the fish (8)[1,2]. Prowse (8) reported that plankton blooms invariably develop in waters where grass carp are introduced. Stanley (10) reported that large quantities of phosphorus and nitrate were excreted back into the water column when grass carp were kept in aquaria.

Stimulation of the phytoplankton community generally results in an increase in the number of individuals, changes in phyla, and the numbers of phyla present. One symptom of eutrophication is the shifting of the phytoplankton association towards one which contains large numbers of a few undesirable species such as blue-green algae. Thus it would appear that the introduction of grass carp into an aquatic ecosystem could cause major changes in that system. The objective of this study was to document the effect of the grass carp on macrophyte and phytoplankton communities, and to compare this effect to that of selected herbicides on the same communities.

METHODS AND MATERIALS

This paper represents the second phase of a two phase study initiated in 1972. The first phase concerned the effect of herbicides on plant succession, water quality, and phytoplankton populations. Portions of that study were reported earlier (3, 4). The second phase studying the effects of grass carp on the same parameters was initiated in August 1976 using the same experimental design. Information obtained from the herbicide study will be compared to the grass carp study.

Forty-five plastic pools (91 cm in depth by 366 cm in diameter) were filled with washed sand to a depth of 15 cm. Six species of aquatic macrophytes, hydrilla (*Hydrilla verticillata* Royle), Eurasian watermilfoil (*Myriophyllum spicatum* L.), chara (*Chara* sp.), vallisneria (*Vallisneria americana* Michx.), southern naiad (*Najas quadalupensis* (Springel) Magnus), and common coontail (*Certatophyllum demersum* L.) were planted in equal amounts in each pool and allowed to establish for approximately one year.

Water levels were stabilized at 90 cm and continuously maintained through an irrigation system connected to the Eustis city water supply. In phase II eighteen pools were selected and nine were stocked with one grass carp per pool, representing a stocking rate of 950 fish per ha. The fish averaged 240 mm in total length and had an average weight of 190 g at stocking. The balance of the pools were used as controls.

The percent cover of each plant species was determined by using a ring divided into tenths. The ring was placed over the pool and the approximate cover of each species in each tenth was visually estimated and recorded. The final figure represented total percent cover for each species.

From the above pools, four (two experimental and two control) were randomly selected for intensive phytoplankton and water quality analysis. Quantitative phytoplankton analyses were determined with a Palmer counting cell and the resultant counts extrapolated to number of cells per liter. Numbers of sulfur bacteria and chemical analysis of ortho-phosphate, total organic nitrogen, nitrate nitrogen, turbidity (Jackson Units, JU), pH, potassium, magnesium, and calcium were determined accordng to Standard Methods (11). Expermental data were plotted as devations (positive or negative) from the control as indicative of changes in water quality. Data from phase I (herbicide treatments) were graphed in the same manner for comparison. Samples were taken before treatment, after treatment weekly for four weeks, and monthly thereafter for eight months.

RESULTS AND DISCUSSION

MACROPHYTES: The percent cover of southern naiad decreased steadily and was virtually eliminated 130 days following stocking (Figure 1). There was a corresponding decrease in control pools (data not shown) due to competition from hydrilla.

The grass carp eliminated chara 130 days following stocking. Chara reappeared at the 180 day sampling, but was eliminated by the next sampling for the duration of the study. In the control, the percent cover (35%) of chara remained the same throughout the study.

Coontail was a very poor competitor. It was eliminated in the grass carp pools after 200 days; however, in the control pools, cootail had disappeared by the beginning of the study.

Eurasian watermilfoil was not eliminated until 265 days following stocking (Figure 1). In the control pools this plant increased slightly during the study.

Hydrilla was the principal target plant because of its ability to quickly dominate aquatic systems. Hydrilla decreased steadily in percent cover until it was eliminated 205 days following stocking. The controls fluctuated slightly but were relatively constant (50% cover) throughout the study.

Vallisneria in the grass carp pools increased steadily until day 240 when it started to decline, indicating the fish began feeding on the vallisneria prior to that sample date (Figure 1). In the control, vallisneria increased through the duration of the experiment with an initial recording of 12% cover increasing to 35% at termination.

All the plant species tested except vallisneria and Eurasian watermilfoil were eliminated approximately 200 days following grass carp stocking. Vallisneria was the only plant present in the grass carp pools at the conclusion of the study indicating it was the least preferred food species. In comparison, at the conclusion of phase I (herbicides),

[1]Singh, S. B., S. C. Banerjec, and P. C. Chakrabart. 1969. Observations on the efficiency of grass carp (*Ctenopharyngodon idella* Val.) in controlling and utilizing aquatic weeds in ponds in India. Proc. of the Indo-Pacific Fisheries Council. 12:220-235.

[2]Stroganov, N. S. 1963. The food selectivity of the amur fisheries, p. 181-191. *IN* Problems of Fisheries Exploitation of Planteating fishes in Water Bodies of the U.S.S.R. Ashkhabad Academy of Sci. Turkman, U.S.S.R.

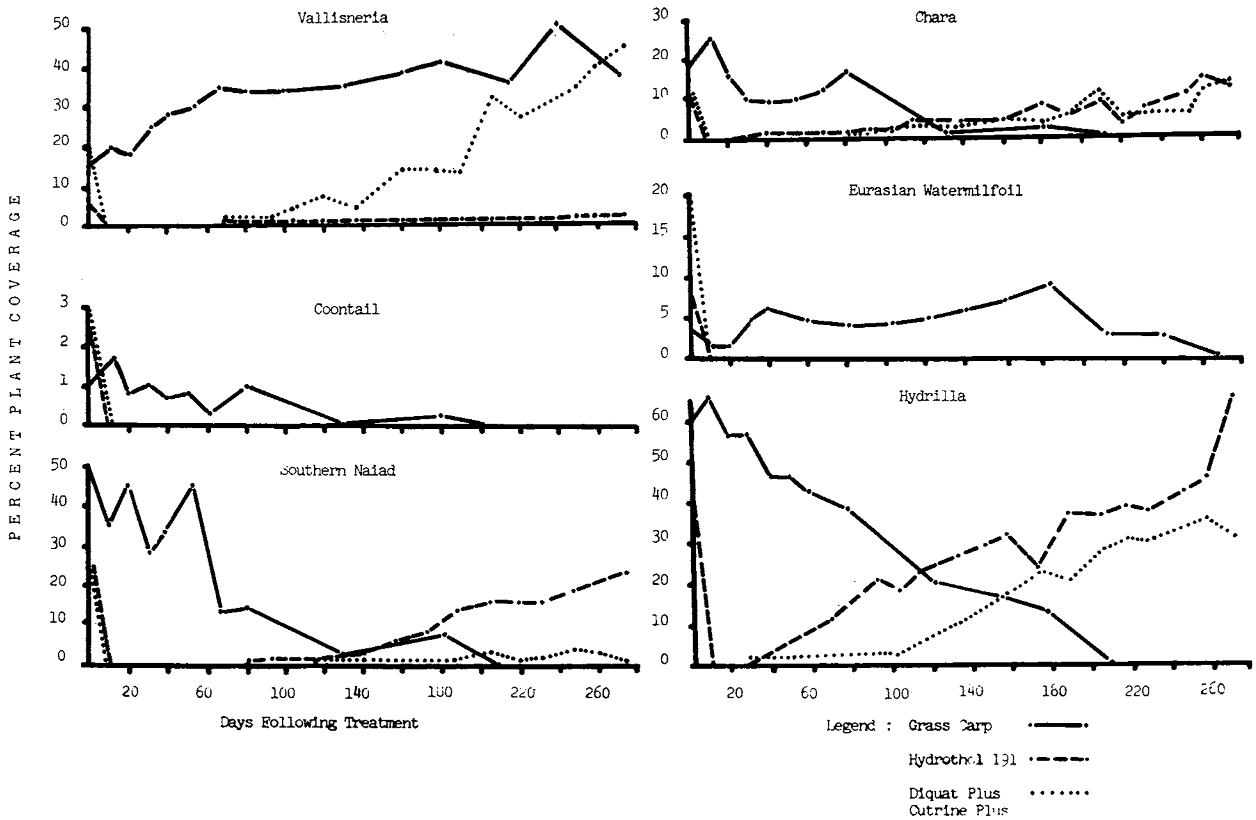

Figure 1. Succession of aquatic plants after treatment with Hydrothol 191. Diquat—Cutrine Plus and grass carp.

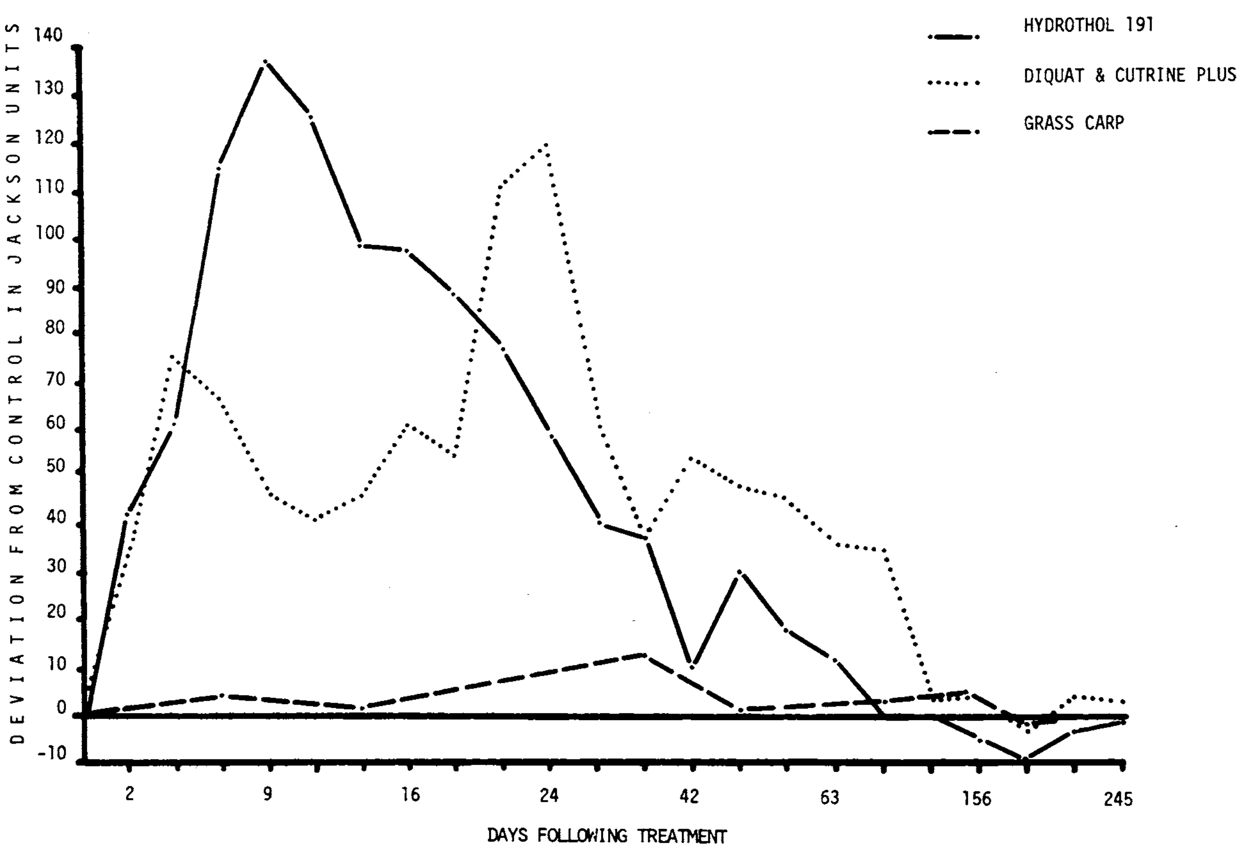

Figure 2. Comparison of turbidity changes in pools treated with Hydrothol 191, Diquat—Cutrine Plus and grass carp.

the pools were completely covered and the entire water column filled with plants. Treatment with Hydrothol 191 resulted in hydrilla dominating (75% cover) while treatment with Diquat—Cutrine Plus resulted in vallisneria and hydrilla dominating at 50 and 35% cover respectively (Figure 1).

WATER QUALITY: The highest turbidities (maximum, 144 JU) occurred in the Hydrothol 191 and Diquat—Cutrine Plus treatments (Figure 2). The water in these pools was very septic and had a reddish scum on the surface soon after treatment. These pools returned to control levels as the plants regrew (3). Little or no effect was noted in the grass carp pools, where the highest turbidity reading was 18 JU (Figure 2). However, the grass carp pools did become tannin stained.

In all chemical treatments pH initially dropped to 6.8 and increased slowly as the systems recovered. The pH in the grass carp pools decreased slowly, reaching a minimum of 7.8 after 245 days, as the grass carp consumed the plants (Figure 3).

The highest amount of total organic nitrogen was observed in the Hydrothol 191 and Diquat—Cutrine Plus treatments (5.0 and 2.8 mg/l respectively) 11 days following treatment. Total organic nitrogen content in the grass carp pools fluctuated slightly throughout the study with a high reading of 1.0 mg/l 148 days after grass carp were stocked (Figure 4). The largest amount of nitrate nigrogen (0.9 mg/l) was found in the Diquat—Cutrine Plus treatment 7 days following treatment. The grass carp pools and the control pools had a maximum reading of 0.02 mg/l.

The highest quantities of ortho-phosphate (2.40 mg/l) were found in the Diquat—Cutrine Plus treatment pools 11 days following treatment. The Hydrothol 191 pools contained 1.65 mg/l two days following treatment. The grass carp pools were lower than, or the same as, the controls throughout the study with concentrations of 0.05 and 0.07 mg/l, respectively (Figure 4). The same trend was true of total phosphate with Diquat—Cutrine Plus, reaching a maximum of 3.00 mg/l total phosphate 16 days following treatment and Hydrothol 191, 2.00 mg/l four days following treatment. The grass carp pools and controls had 0.02 and 0.08 mg/l, respectively, during the latter part of the study.

Potassium reached a maximum content of 10.0 mg/l in both herbicide treatments 22 days following treatment. The grass carp pools reached a maximum content of 3.4 mg/l at day 214. More magnesium was freed into the system (4 day sampling to conclusion) with grass carp (22.8 mg/l) than with herbicides (12.8 mg/l). The drop in magnesium at day 156 in the grass carp pools occurred during cold weather (December). The magnesium content decreased in the herbicide pools as plant regrowth occurred, indicating the magnesium was utilized by the plants (Figure 5). The grass carp treatment also liberated more calcium than the herbicides (Figure 5). The maximum reading in grass carp pools was

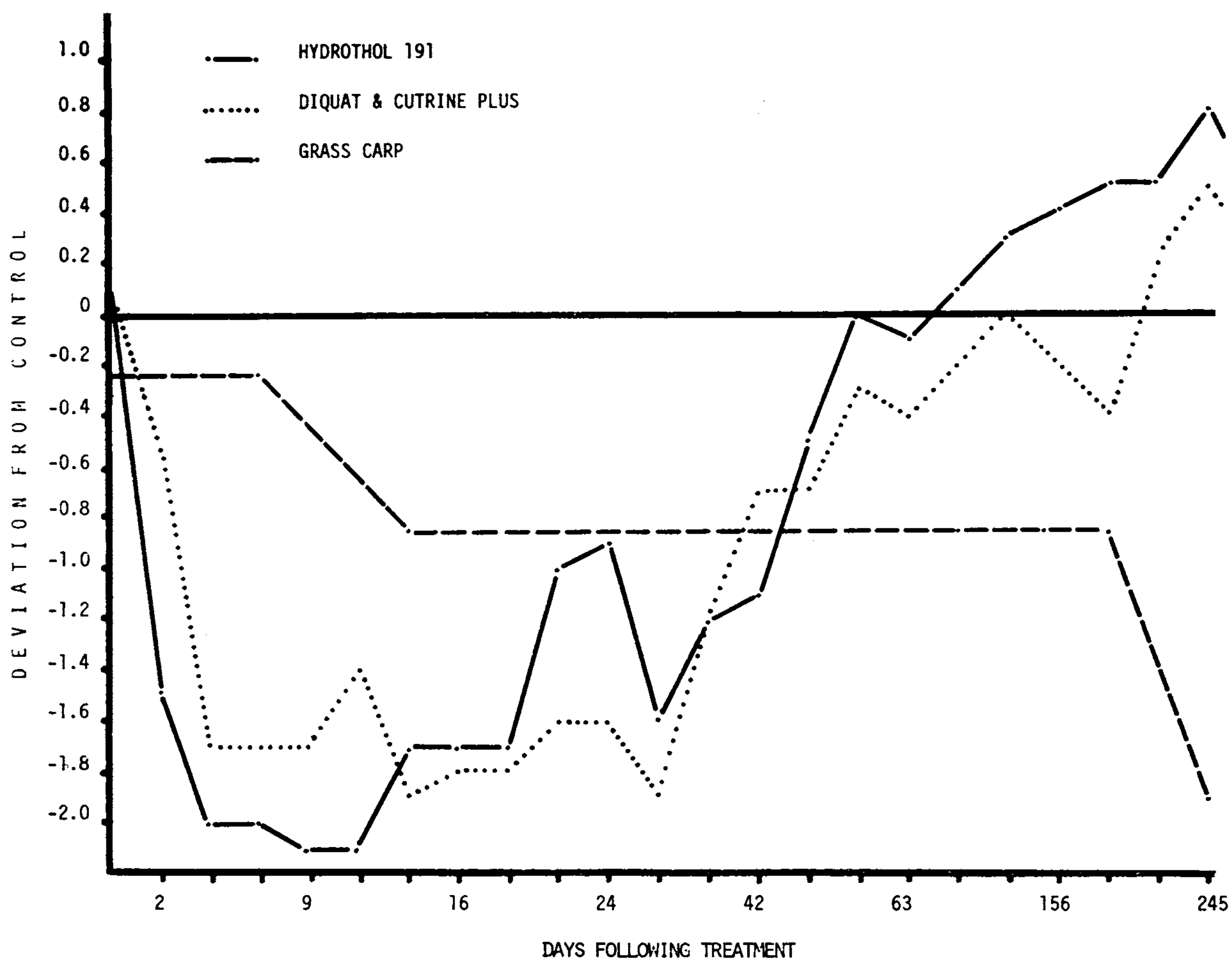

Figure 3. Comparison of pH changes in pools treated with Hydrothol 191, Diquat—Cutrine Plus and grass carp.

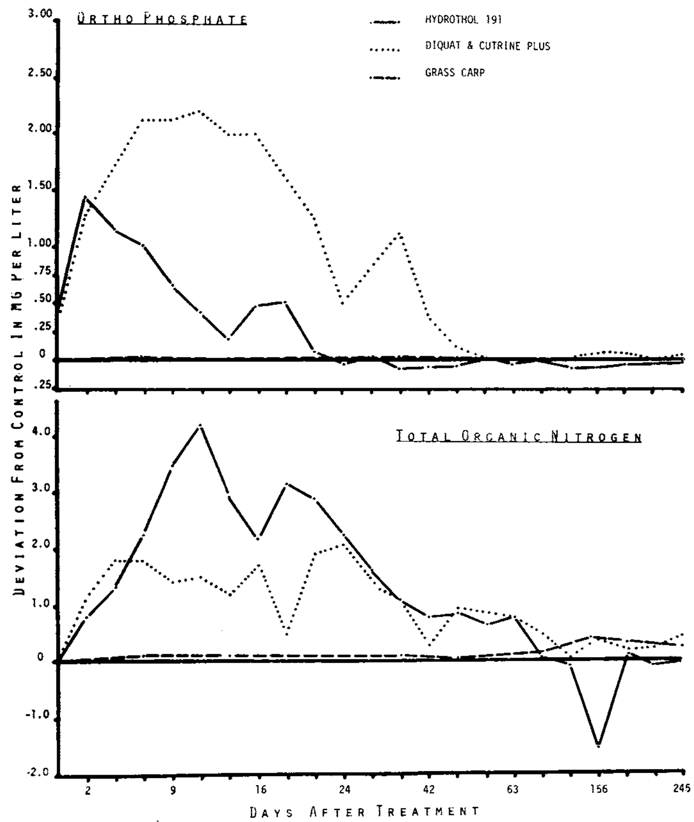

Figure 4. Comparison of ortho-phosphate and total organic nitrogen changes in pools treated with Hydrothol 191, Diquat—Cutrine Plus and grass carp.

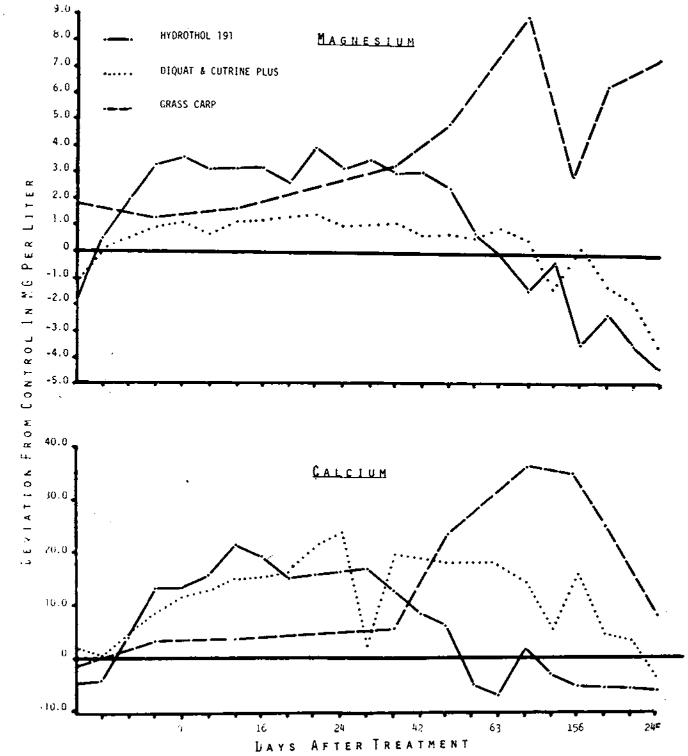

Figure 5. Comparison of magnesium and calcium changes in pools treated with Hydrothol 191, Diquat—Cutrine Plus and grass carp.

49.0 mg/l at day 214, and compared to 40.3 mg/l at day 24 with Diquat—Cutrine Plus. The decline of calcium in the grass carp pools corresponded to the drop in magnesium at 156 days. However, the decline in calcium continued after 156 days, indicating it was being utilized and/or bound into the sediments.

PHYTOPLANKTON: Table 1 lists the succession of green and blue-green algae in the control and grass carp pools. Green algae (Chlorophyta) exhibited similar successional patterns in both the control and grass carp pools. *Tetraedron, Cosmarium* and *Gloeocystis* were the dominant genera in both; the controls supported higher concentrations. This was in contrast to the herbicide tests (Hydrothol 191 and Diquat—Cutrine Plus) where shifts in families, orders, and concentrations occurred within short periods of time, often resulting in moderate to heavy blooms.

The sucession of representative blue-green algae (Cyanophyta) was basically similar to the green algae. *Anacystis* and *Dactylococcopsis* dominated the control as compared to *Anacystis* and *Agmenellium* in the grass carp pools. These genera are in the family Chroococcaceae and were found in low concentrations. Herbicide applications (Hydrothol 191 and Diquat—Cutrine Plus) caused family, order, and concentration shifts within short periods of time (3).

Yellow-green algae (Chrysophyta) were found in only trace amounts in the grass carp pools during the first 180 days. However, there were successional changes since *Opephora, Coscinodiscus* and *Amphipleura* belong to different orders (Table 2). A definite shift was observed at day 199, when the algae in grass carp pools shifted from a dominant green to around 44% composition yellow-green algae (*Frustulia*). Although the control increased in this manner the increase was short term. In the herbicide treatments, these genera were also recorded in trace amounts.

The flagellate populations consisted of trace amounts of *Euglena* in the control and grass carp pools. This was in direct contrast to the herbicide treated pools which contained moderate to heavy blooms of Euglinoids (3).

Table 3 is a synopsis of the percent composition of the various algae phyla found in the treatments throughout the experiment. The control, in the grass carp study, was dominated by green algae until the last sampling period when there was a shift to 56% green and 43% blue-green. Grass carp pools were composed of about 60% green and 40% blue-green until day 199 when a shift occurred to about 45% yellow-green, which persisted to the end of the study.

In the pools treated with Diquat—Cutrine Plus, and Hydrothol 191 water clarity was severely affected as large phytoplankton and sulfur bacteria populations alternated, imparting either a dark red or green coloration (3). In pools treated with Hydrothol 191, phytoplankton levels of 1.73 X 10^8 cells per liter and sulfur bacteria counts of 1.71 X 10^8 cells/l were recorded at 24 and 11 days after treatment, respectively. This explosive growth rate was also observed in the Diquat—Cutrine Plus treatments where phytoplankton levels of 2.36 X 10^8 cells/l and sulfur bacteria counts of 1.861 X 10^9 per liter were recorded at 22 and 24 days following treatment. Highest counts for the control with herbicides was 7.14 X 10^7.

The plankton community did not respond in this manner with the introduction of the grass carp, in fact, rather

TABLE 1. SUCCESSION OF GREEN (CHLOROPHYTA) AND BLUE-GREEN (CYANOPHYTE) ALGAE IN POOLS STOCKED WITH GRASS CARP.

Days after Treatment	Green		Blue-Green	
	Control	Grass Carp	Control	Grass Carp
0	Tetraedron	Tetraedron	Anacystis	Anacystis
			Dactylococcopsis	
6	Tetraedron	Tetraedron	Anabaena	
12	Tetraedron	Tetraedron	Dactylococcopsis	Agmenellum
	Cosmarium	Cosmarium		Anacystis
		Crucigenia		
35	Tetraedron	Tetraedron	Dactylococcopsis	Agmenellum
	Cosmarium	Cosmarium		Anacystis
		Crucigenia		
48	Tetraedron	Desmatractum		
		Crucigenia		
87	Tetraedron	Tetraedron		Anacystis
	Cosmarium	Gloeocystis		
142	Tetraedron	Tetraedron		
	Gloeocystis	Gloeocystis		
199	Tetraedron	Tetraedron		Anacystis
	Cosmarium			
240	Tetraedron		Anacystis	Anacystis
	Cosmarium		Agmenellum	

TABLE 2. SUCCESSION OF YELLOW-GREEN ALGAE (CHRYSOPHYTA) AND FLAGELLATES IN POOLS STOCKED WITH GRASS CARP.

Days after Treatment	Yellow-Green		Flagellate	
	Control	Grass Carp	Control	Grass Carp
0		Opephora		
6		Coscinodiscus		
12				
35				
48			Euglena	Euglena
87		Amphipleura	Euglena	
		Navicula		
142	Amphipleura	Amphipleura		
199	Navicula	Frustulia		
240		Rhopalodia		Euglena
				Dinobryon

than stimulating the plankton community as predicted, its introduction actually had either no effect (Figure 6) or reduced the plankton community. The highest counts recorded during phase II of the study were as follows: control grass carp 1.78 X 10^7 cells/l, 190 days following treatment and grass carp 2.01 X 10^7 cells/l, 190 days following treatment. Pools receiving herbicide treatments had approximately 10 times the number of algae found in the grass carp pools.

The results indicate that nutrients resulting from the control of macrophytes by grass carp were not available to phytoplankton since no appreciable change in water quality was found. It is theorized that nutrients in the grass carp pools were not available for planktonic growth as a result of two factors. Terrell[3] found that even though large quantities of nutrients are released into the water by grass carp, they are not available to the phytoplankton community. Terrell found that sediments in ponds containing grass carp had significantly higher quantities of ortho-phosphate, iron and magnesium than in the sediments of control ponds. These nutrients were released by the grass carp and were precipitated by, or with, organic acids. Once in the sediments, the nutrients became bound in complex organic molecules not available to phytoplankton, however, rooted macrophytes could utilize these nutrients. By elimination of the macrophyte "nutrient pumps", grass carp caused an increase in the sediment nutrient concentration and thus indirectly decreased phytoplankton production.

The second factor that effected the availability of nutrients was the conversion of plant material to fish flesh. During this study the stocked grass carp gained an average of 1832 grams. They were stocked at an average total length of 240 mm, and weighed 190 grams; at the conclusion of the study they averaged 529 mm in total length and weighed an average of 2022 grams.

Preliminary literature investigations did not reveal the need to include sediment soil analysis thus base line data of these parameters were not taken. However, data reported here parallel those of, and were in agreement with the results of Terrell pointing out the need to consider sediment soil analysis in any future nutrient budget experiments.

This investigation was conducted in pools permitting replication and elimination of many naturally uncontrollable variables, such as run off and wind caused currents. Due to this it was determined that stimulation of the plankton community did not occur after vegetation removal by the grass carp as predicted, indicating that plankton depend on macrophytes or other nutrient inputs as a source of nutrition. In phase I, chemical erradication of plants resulted in nutrients being released directly into the water column resulting in dense plankton blooms. In phase II, however, nutrients released by the control of macro-

[3]Terrell, Terry T. 1975. Response of plankton communities to the introduction of grass carp in some Georgia ponds. Ph.D. Disseration, University of Georgia. pp. 23.

Table 3. Percent composition of algae phyla in pools treated with herbicides and stocked with grass carp.[1]

Treatment	Days after treatment								
	0	6	12	35	48	87	142	199	240
Green (%)									
Control-grass carp	62	97	100	100	—	90	100	67	57
Grass carp	65	100	59	59	78	80	100	56	—
Control-herbicides	60	66	50	40	86	62	53	98	100
Hydrothol-191	83	56	—	20	98	73	—	84	24
Diquat & Cutrine Plus	—	—	—	62	98	—	86	72	80
Blue-green (%)									
Control-grass carp	38	—	—	—	—	—	—	—	43
Grass carp	35	—	33	33	22	20	—	—	50
Control-herbicides	—	33	—	60	12	26	13	1	—
Hydrothol-191	17	44	1	79	1	—	3	8	76
Diquat & Cutrine Plus	—	—	14	14	1	—	11	24	20
Yellow-green (%)									
Control-grass carp	—	—	—	—	—	—	—	33	—
Grass carp	—	—	8	8	—	—	—	44	50
Control-herbicides	—	—	25	—	1	—	13	1	—
Hydrothol-191	—	—	—	—	—	24	87	8	—
Diquat & Cutrine Plus	—	—	29	—	—	—	3	6	—
Flagellates (%)									
Control-grass carp	—	—	—	—	100	10	—	—	—
Grass carp	—	—	—	—	—	—	—	—	—
Control-herbicides	40	—	25	—	1	12	21	—	—
Hydrothol-191	—	—	99	1	1	3	10	—	—
Diquat & Cutrine Plus	—	—	57	24	1	—	—	—	—

[1] Each value is average of 2 determinations.

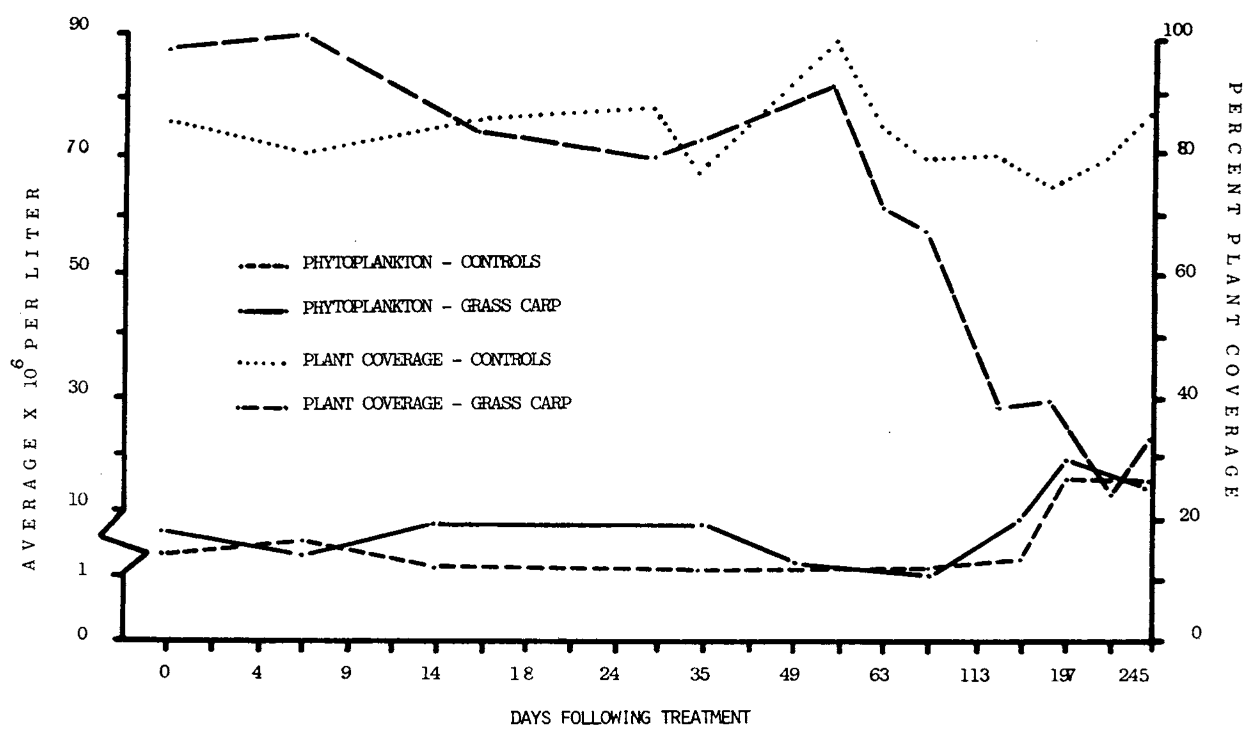

Figure 6. Comparison of percent plant coverage and phytoplankton changes in control and grass carp pools.

phytes with the grass carp were not available to the planktonic community.

LITERATURE CITED

1. Boyd, C. E. 1968. Some aspects of aquatic plant ecology. Reservoir Fisheries Symposium, Athens, Georgia 1967. p. 114-129.
2. Burton, A. M. 1971. Eutrophication of the St. Lawrence Great Lakes, p. 233-243. *IN* T. R. Detwyler. Man's Impact on Environment. McGraw-Hill Book Co., New York.
3. Carter, C. C. and R. S. Hestand. 1977. The effects of selected herbicides on phytoplankton and sulfur bacteria populations. J. Aquatic Plant Manag. 15:47-56.
4. Hestand, R. S. and C. C. Carter. 1977. Succession of various aquatic plants after treatment with four herbicides. J. Aquat. Plant Manage. 15:60-64.
5. Hickling, C. F. 1965. On the feeding process of the white amur, *Ctenopharyngodon idella* Val. Proc. of the Zoological Society of London. 148:408-419.
6. Kilgen, R. H. and R. O. Smitherman. Food habits of white amur stocked in ponds alone and in combination with other species. Prog. Fish-Cult. 33(3):123-127.
7. Michewicz, J. E., D. L. Sutton, R. D. Blackburn. 1972. The white amur for aquatic weed control. Weed Sci. 20:106-110.
8. Prowse, G. A. 1969. The role of cultured pond fish in the control of eutrhophication in lakes and dams. Verh. Internat. Verein. Limnol. 17:714-718.
9. Prowse, G. A. 1971. Experimental criteria for studying grass carp feeding in relation to weed control. Prog. Fish-Cult. 33(3):128-131.
10. Stanley, J. G. 1974. Nitrogen and phosphorus balance of grass carp, *Ctenopharyngodon idella,* fed elodea (Egeria densa). Trans. Am. Fish. Soc. 103(3):587-592.
11. Taras, M. J., A. E. Greenbury, R. D. Hook, and M. C. Rand. 1971. 13th Ed. Standard methods for the examination of water and wastewater. Am. Pub. Health Assn., N.Y. 10010. pp. 874.

J. Aquat. Plant Manage. 16: 50-52