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Biological Control Of *Hydrilla verticillata* Royle With Grass Carp (*Ctenopharyngodon idella Val.*)

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ABSTRACT

Grass carp (*Ctenopharyngodon idella* Val.) were stocked into a 5.42 ha central Florida lake to determine if they could control hydrilla (*Hydrilla verticillata* Royle). Two stockings in October, 1976 and 1977, consisted of 32 and 15 fish/ha, respectively. Selective removal of grass carp by rotenone at the end of two years provided a population estimate (13 fish/ha) and a biomass measurement (90.13 kg/ha). Hydrilla biomass was monitored bimonthly throughout the study. The grass carp were effective in reducing the annual mean hydrilla biomass by 45.7% and decreasing the net primary productivity by 63.0% between the study years of October, 1976-77 and October, 1977-78.

INTRODUCTION

The grass carp (*Ctenopharyngodon idealla* Val.) was introduced into Florida in 1970 for its potential as a control of hydrilla (*Hydrilla verticillata* Royle) (14). There has been extensive research in Florida over the past several years to evaluate the biology, feeding, and environmental effect of grass carp. Aspects of vegetational feeding by the grass carp have been described in the literature. These reports range from grass carp held in small enclosures (6, 13), in experimental ponds (7, 12), in small ponds (2, 3, 15, 16), and in large lakes (1, 10, 11). Advisability of the use of grass carp for weed control has been adequately summarized by Rottman (9), Greenfield (4), and Sutton (14). Presently, several studies are underway to determine physicochemical and biological features of freshwater systems stocked with grass carp (17, 18).

In this study, our objective was to determine the efficacy of using grass carp to control hydrilla by (1) monitoring hydrilla biomass through time and by (2) determining the number of grass carp in the lake at the end of the study.

METHODS AND MATERIALS

Little Lake Barton, Orange County, Florida, is a 5.42 ha solution basin which has had an infestation of hydrilla for approximately seven years (Fig. 1). Its circular shape and

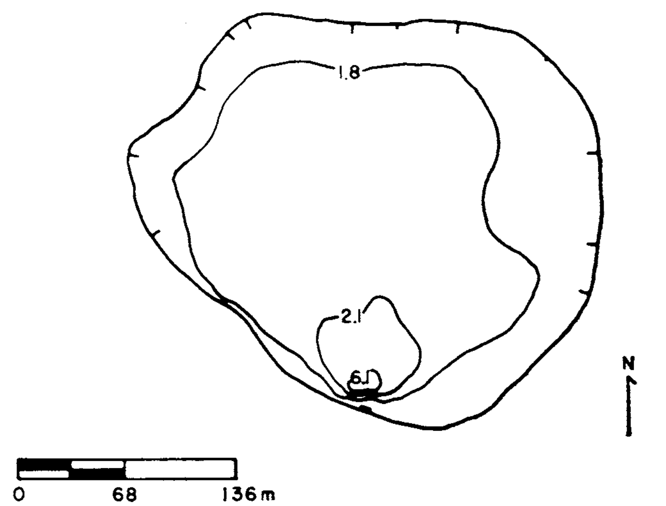

Figure 1. Bathymetric map of Little Lake Barton, Florida, September 27, 1978.

gradual sloping bottom provides it with a shoreline development of 1.04, a volume development of 0.76, and a mean depth of 1.63 m. The lake is located in an urban drainage area of somewhat excessively drained to moderately well drained soils (5); nearly 90% of its shoreline is occupied by homes and short grass lawns. Control of hydrilla growth in Little Lake Barton had not been attempted prior to this study.

Hydrilla was sampled from twenty random stations in Little Lake Barton, bimonthly, from October, 1976-78. The stations were chosen from a grid overlay; a station was deemed any point within a 0.13 ha grid square. Samples of hydrilla were collected using a submersed aquatic plant sampler (Fig. 2). The 110 kg sampler was operated by winch driven cables from a pontoon boat. The falling sampler would cut and collect hydrilla on its descent through the water column before it penetrated the lake bottom. The sampler was closed and returned to the pontoon boat deck where the hydrilla was removed. Hydrilla samples consisted

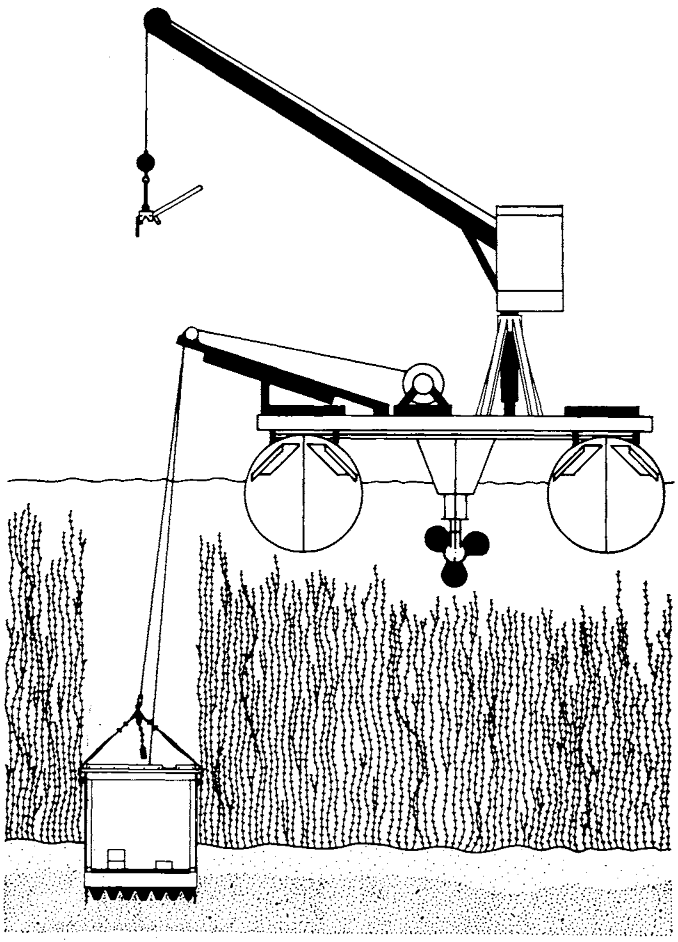

Figure 2. Operational sketch of the submersed aquatic plant sampler used to collect hydrilla samples from Little Lake Barton, Florida.

of all the vegetation (leaves, stems) within the water column (area = 0.25 m^2) as well as roots from the hydrosoil.

Hydrilla samples were washed in nylon mesh bags to remove sediment, spun in a garment washer at 540 rpm for 4 minutes to remove excess water, and weighed to the nearest 0.001 kg to determine fresh weight per unit area (kg/m^2). Net primary productivity of hydrilla was determined by substracting biomass at time (1) from biomass at time (2) and dividing by days.

Water depth was measured with a lead weight and line at each station. Mean water temperature at 1.0 m below the surface was determined for each sampling day.

The initial stocking of grass carp by the Florida Department of Natural Resources into Little Lake Barton on October 10, 1976, consisted of 174 fish (32 fish/ha) with an approximately mean weight of 0.08 kg (2.6 kg/ha). During August, 1977, a fish kill resulted in the loss of 42 grass carp. Their mean weight was estimated at nearly 4.5 kg. The grass carp were the principal fish species affected; no positive explanation as to the cause of the kill could be determined from physicochemical measurements (pH, specific conductivity, dissolved oxygen, oxidation-reduction potential) although predawn dissolved oxygen concentrations were found to be near 0.0 ppm below 3 m during that month.

Since the loss of grass carp from the original stocking was assumed high, 80 grass carp (15 fish/ha) were placed into the lake on October 13, 1977, by the Florida Department of Natural Resources. This second stocking consisted of small fish near 0.05 kg each. At the beginning of the second year, 39 fish/ha were presumed alive in the lake.

Electrofishing for grass carp was conducted in Little Lake Barton during February, 1978.

In order to selectively remove grass carp with minimal effect on largemouth bass (*Micropterus salmoides*) and bluegill sunfish (*Lepomis macrochirus*), bioassay experiments were performed on October 21, 1978. The procedures used by Colle, et al. (1) to selectively remove grass carp from a Florida lake were followed. Duplicate test concentrations of 0.075, 0.100, 0.125, and 0.150 ppm of 5% emulsified rotenone in lake water were used to determine stress and death of largemouth bass, bluegill sunfish, and grass carp. Largemouth bass and bluegill sunfish were taken from the lake by electrofishing, while the grass carp were obtained from rearing ponds; for the most part, the test fish were less than 10 cm total length. Eighty liter volumes of the test concentrations were placed into plastic bags and strung along a rope in the lake. Three individuals of each fish species were placed in the test concentrations and monitored for stress or death after 3, 5, and 8 hrs.

A bathymetric map of Little Lake Barton (Fig. 1) was made on September 27, 1978, in order to calculate the amount of fish toxicant needed to treat the lake. Twenty-nine marked (pelvic fin clipped) grass carp were placed into the lake on September 28, 1978, to provide a ratio of marked to unmarked fish for a population estimate. Rotenone was applied on October 29, 1978, to the lake by herbicide pump and airboat to produce a 0.100 ppm concentration. The lake was entirely treated by 1100 hrs.

RESULTS AND DISCUSSION

No grass carp were taken during the February, 1978, electrofishing trial, however, many largemouth bass were observed; the sample included 24 greater than 3.6 kg, thus indicating a reasonably high resident population of large fish in the lake.

The selectivity experiment revealed that largemouth bass were most susceptible to the rotenone, while bluegill sunfish were least affected. After eight hours, 16.7% of the grass carp survived at 0.100 ppm, however none of the largemouth bass survived. Survival for bluegill sunfish was 50% after eight hours in 0.100 ppm rotenone. These results differ from those obtained by Colle, et al. (1) for Lake Baldwin; they found grass carp least affected by rotenone at 0.100 ppm. At this point, it was doubtful if grass carp could be removed from Little Lake Barton without seriously affecting the population of largemouth bass.

With the exception of one grass carp netted dead on the morning of the second day, all grass carp were taken before 1600 hrs on the day rotenone was applied to the lake. Fourteen unmarked and 5 marked grass carp were obtained (Table 1). By using the adjusted Petersen estimate (8), the number of grass carp in the lake was determined at 71 (13 fish/ha) with a biomass of 90.13 kg/ha. Reasonably small numbers of largemouth bass and bluegill sunfish were taken; the largest largemouth bass obtained was 2.25 kg.

Annual mean hydrilla biomass was 1.700 kg/m^2 fresh

TABLE 1. LENGTH-WEIGHT RELATIONSHIPS OF GRASS CARP TAKEN FROM LITTLE LAKE BARTON, OCTOBER 29, 1978.

	Weight (kg)	Total length (cm)	Standard length (cm)
Marked fish	1.20	45.8	37.8
	1.45	46.2	38.5
	1.60	50.0	41.0
	1.10	44.6	36.5
	1.40	46.1	38.0
	$\bar{x}$ 1.35	46.5	38.4
	S_x 0.09	0.9	0.7
Unmarked fish	5.80	74.5	61.0
	5.70	74.5	62.0
	11.20	87.0	72.0
	5.45	72.0	61.0
	7.65	79.0	67.0
	5.85	72.0	60.0
	6.45	76.0	63.0
	10.50	90.3	77.0
	9.40	88.6	74.5
	2.50	63.7	49.5
	4.60	70.3	57.7
	6.80	78.0	66.0
	6.00	77.0	64.2
	8.40[a]	83.8[a]	69.9[a]
	$\bar{x}$ 6.88	77.6	64.6
	S_x 0.63	2.0	1.9

[a] Second day pick up.

weight for 1976-77 and 0.923 kg/m² fresh weight for 1977-78. This represents an annual decrease in biomass between years of 45.7%. Net primary productivity was –8.0 gm/m²/day (–433.0 kg/lake/day) for 1976-77 and –22.0 kg/m²/day (–1,193.0 kg/lake/day) for 1977-78 or approximately threefold lower during the second year of the study. Monthly mean biomass values for the second year were generally much lower than in the previous year (Table 2). For example, biomass of hydrilla in October, 1977, was 22.1% lower than in October, 1976, and hydrilla biomass in October, 1978, was 55.5% lower than in October, 1977 (Table 3). The percent frequency of occurrence of hydrilla (percent of stations having hydrilla) in Little Lake Barton was much greater during the first year than during the second year. While the percent frequency of occurrence was generally greater than 85% during the first year, it was found to be as low as 15% (April, 1978) during the second year (Table 2).

Hydrilla biomass dropped in a nearly linear fashion between October, 1976, and April, 1977 (Fig. 3). Water temperature was lowest during February (Table 2). With the onset of increasing water temperature during the spring of 1977, hydrilla growth was nearly exponential through October, 1977 (Fig. 3). Hydrilla biomass leveled off when it reached nearly 2.2 kg/m² fresh weight in August, 1977, and remained near that value through December, 1977. In February, 1978, water temperature dropped to a low for the study of 12 C following two months of unseasonally cold temperatures. During February, 1978, hydrilla biomass was found to be much reduced from the December, 1977, value and was even lower than during April, 1977 (Fig. 3). While an early spring decline in hydrilla was common to both study years, it occurred two months earlier during the second year. The decrease in hydrilla biomass between December, 1977, and February, 1978, was the largest change between any two consecutive sampling dates and is represented as having the largest negative change in net primary productivity (Table 4). Late spring and early summer growth in 1977 did not recover to the previous year's values (Fig. 3). Hydrilla biomass only reached 1.012 kg/m² fresh weight by October, 1978.

TABLE 2. MONTHLY MEAN HYDRILLA BIOMASS, FREQUENCY OF OCCURRENCE, AND WATER TEMPERATURE IN LITTLE LAKE BARTON, FLORIDA, FROM OCTOBER, 1976 TO OCTOBER, 1978.

Month	Hydrilla fresh weight (kg/m²)	Frequency of occurrence (%)	Temp. (C)
October, 1976	2.919	95	26.0
December	2.020	90	17.0
February, 1977	1.061	90	14.5
April	0.382	70	25.0
June	1.712	85	31.0
August	2.112	85	30.0
October	2.275	95	20.0
December	2.201	100	18.0
February, 1978	0.323	75	12.0
April	0.134	15	25.0
June	0.210	35	29.0
August	0.392	40	27.5
October	1.012	60	17.5

TABLE 3. PERCENT DIFFERENCE IN HYDRILLA BIOMASS BETWEEN SIMILAR MONTHS OF DIFFERENT YEARS FOR LITTLE LAKE BARTON, FLORIDA.

Month	Percent difference in monthly mean biomas 1976-77	1977-78
October	–22.06	–55.52
December	+8.96	
February		–69.56
April		–64.92
June		–87.73
August		–81.44

Although the lowest water temperature occurred during the second year, seasonal trends were similar between study years. While water temeprature can not be dismissed altogether as a factor affecting the growth of hydrilla, especially during the second year, we feel that it did not play a major role. We conclude that the grass carp were the major contributor to the decline in hydrilla over the two year period in Little Lake Barton.

TABLE 4. NET PRIMARY PRODUCTIVITY OF HYDRILLA FRESH WEIGHT IN LITTLE LAKE BARTON, FLORIDA.

Time interval[a]	1976-77 gm/m²/day	1976-77 kg/lake/day	1977-78 gm/m²/day	1977-78 kg/lake/day
Oct.-Dec.	–11*[b]	–596	–1	–54
Dec.-Febr.	–20*	–1084*	–33*	–1789*
Febr.-Apr.	–10	–542	–3	–163
Apr.-June	+24*	+1301*	+1	+54
June-Aug.	+6*	+325*	+3	+163
Aug.-Oct.	+3	+163	+11	+596

[a] Time interval varied between 54 and 81 days.
[b] Hydrilla biomass between months was significantly different ($P = 0.05$).

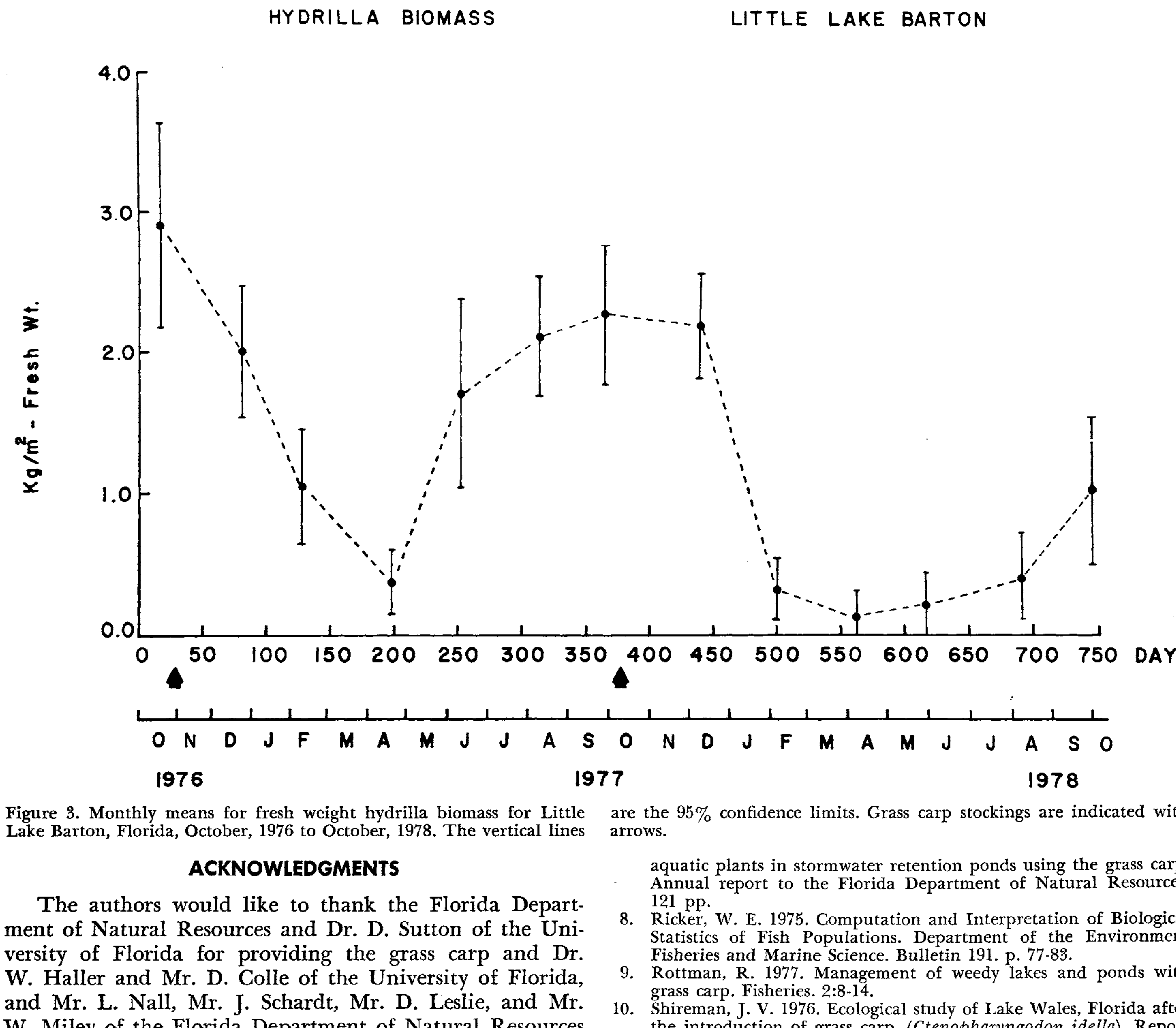

Figure 3. Monthly means for fresh weight hydrilla biomass for Little Lake Barton, Florida, October, 1976 to October, 1978. The vertical lines are the 95% confidence limits. Grass carp stockings are indicated with arrows.

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