Journal of the Arkansas Academy of Science

Volume 37 Article 8

1983

Comparison of Two Year Classes of Hybrid Grass Carp and Grass Carp for Aquatic Plant Control

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A COMPARISON OF TWO YEAR CLASSES OF HYBRID GRASS CARP AND GRASS CARP FOR AQUATIC PLANT CONTROL

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ABSTRACT

Two year classes of grass carp and F_1 hybrids resulting from bighead carp male x grass carp female were compared at various stocking densities for aquatic plant control. One and two year old grass carp exhibited higher survival rates and better growth rates than the same age hybrid grass carp. The presence of grass carp or hybrid grass carp decreased both Secchi disc transparencies and dissolved oxygen values. Grass carp had a greater negative effect upon these measurements because they removed the vegetation quicker than the hybrid grass carp. These apparent detrimental effects on water quality are necessary trade-offs for vegetation removal by any method.

Grass carp and hybrid grass carp utilized *Chara* sp., *Potamogeton pectinatus, Hydrodicton* sp., *Rhizoclonia* sp., and *Pithophora* sp. Two year old hybrid grass carp required approximately twice as much time as the same age grass carp to eliminate dense growths of the vegetation listed above. One year old hybrid grass carp were slightly less effective than one year old grass carp at controlling these same plant species. However, it was extremely difficult for one or two year old hybrid grass carp to totally eliminate dense growths of these plant species except at high stocking densities. The use of mean vegetation heights to indirectly measure total plant biomass was unacceptable whenever unpreferred floating plant species were present. The hybrid grass carp appeared to be a poor alternative biological control for nuisance aquatic vegetation when compared directly to the grass carp.

INTRODUCTION

Problems with aquatic plant growths exist in most parts of the United States in varying degrees (Hamilton, 1977; Colle et al., 1978; Mitzner, 1978). Many problem plants are nonnative species that have spread at alarming rates in new environments. They abstruct water flow, impede drainage, interfere with recreational uses, and occasionally pose health hazards.

The four basic methods of controlling noxious aquatic plants are chemical, mechanical, physical, and biological. Chemical control is costly, results are temporary, and in many cases control is not attained (Mitzner, 1978). Chemical control is also potentially hazardous to the ecological balance of a pond, lake, or river, as well as to man himself (Kilgen and Smitherman, 1971). Mechanical control is also very temporary and extremely expensive (Bailey, 1972). Physical manipulations are restricted by economical considerations, climatic conditions and the physical parameters of certain bodies of water. When physical manipulations are implemented, they can be quite effective. Biological control can be relatively inexpensive, long lasting, and ecologically safe.

Although several species of fishes have shown promise in controlling unwanted vegetation (Kilgen and Smitherman, 1971), the grass carp *(Ctenopharyngodon idella)* was reported by Swingle (1957) as one of the most promising fish species for controlling rooted aquatics. Grass carp were first introduced into the United States in 1963 at the Fish Farming Experimental Station, Stuttgart, Arkansas and at Auburn University, Auburn, Alabama (Stevenson, 1965; Guillory and Gasaway, 1978). Although two decades have passed since this introduction, grass carp have remained a highly controversial and emotional subject among fisheries administrators and biologists. At the base of this controversy is the fear that grass carp might become established in natural waters and compete with native species for food and living space (Kilgen and Smitherman, 1971; Forester and Lawrence, 1978). Restrictions on the importation and possession of grass carp in many states (Cassani, 1981) have created a need for an alternative to the grass carp for biological control of nuisance aquatic vegetation.

Using the work of Marian and Krasznai (1978) as a base, the Arkansas Game and Fish Commission produced the F_1 hybrid of female grass carp and male bighead carp *(Aristichthys nobilis)* in May 1979. Initially, all progeny of this cross were determined to be triploid and were, therefore, assumed to be sterile (Beck et al., 1980). Since the sterility of the hybrid grass carp would allay most of the fears associated with the natural reproduction and establishment of the normal diploid grass carp, the triploid hybrid was a suitable candidate for biological control of unwanted plants in managed and unmanaged waters.

Subsequent investigations (Drs. Beck and Biggers, pers. comm., Memphis State University, Memphis, Tennessee) have revealed that some F_1 hybrids are diploids. The percentage of diploids obtained is quite variable (near 100% to near 0%) and may be controlled by the mechanics of the hybridization production technique (Mr. J. M. Malone, pers. comm.).

Under controlled laboratory conditions, it has been reported that small triploid hybrid grass carp and grass carp have similar vegetation preferences and food consumption rates (Kilambi and Zdinak, 1980), and exhibit similar feeding behavior (Cassani, 1981). However, a comparison of these two fishes in natural conditions and at different sizes was necessary, since the food preferences and consumption rates of triploid hybrid grass carp might change with fish size and age since several investigators have reported size related food preference and consumption rate changes in grass carp (Buck et al., 1975; Meyer et al., 1975; Stanley et al., 1978). This investigation was undertaken to compare two year classes of triploid hybrid grass carp and grass carp with respect to aquatic vegetation preference and consumption.

METHODS

Ten 0.4 ha earthern ponds at the Joe Hogan State Fish Hatchery in Lonoke, Arkansas, were filled with water and innoculated with several species of aquatic vegetation in March of 1981. Species introduced were *Potamogeton pectinatus, Chara* sp., *Hydrodicton* sp., *Pithophora* sp., *Rhizoclonia* sp., and *Spirogyra* sp. These ponds averaged 0.98 m in water depth: water was periodically added to maintain equal water depths in all ponds.

Vegetation sampling was conducted at three week intervals starting on 24 April, 1981. Sampling methodology was similar to that of Buck et al. (1975), Colle et al. (1978), Mitzner (1978), and Lembi et al. (1978). This method consisted of making transects in each pond diagonally from the southeast corner to the northwest corner. Point estimates of plant species, height of vegetation, and water depth were recorded at 5 m intervals along each transect. Three 1 m vegetation samples were collected at approximately 25 m intervals along the transect in each pond, separated by species, and oven dried for 24 h at 105 C for the determination of dry weights. Dissolved oxygen and temperature were recorded at the 0.5 m water depth in the catch basin of each pond at 0900 hours for each three week period in conjunction with the vegetation sampling. Secchi disc measurements were also determined at this site.

In May of 1981, the 10 ponds were divided into four sets on the basis of preliminary vegetation sampling. Two sets of three ponds each and two sets of two ponds each were then randomly stocked with triploid grass carp hybrids, and grass carp from each of the two year classes. This grouping was done in order to insure that ponds dominated by the same plant species would be paired. One pond from each of the pond sets served as non-fish stocked controls.

On 6 May 1981, eight ponds were stocked with grass carp or grass carp hybrids utilizing two different year classes of fish at varying stocking densities (Table 1). Observed stocking mortalities were replaced during the first week of the study. Ponds were harvested upon eradication of vegetation or at the end of the study during the last week of July, 1981.

Upon harvest, ploidy determination was made on approximately 50 hybrid grass carp from each year class by Andrew J. Mitchell of the Stuttgart Fish Farming Experimental Station utilizing the red blood cell nuclear volume technique described by Beck and Biggers (1981).

Table 1. Stocking parameters of grass carp and hybrid grass carp.

Pond number	Pond set	Species	Year Class	No. fish per ha	Average total length (mm)	Average weight (g)
16	A	Grass carp	1979	951	365	426
14	A	Hybrid grass carp	1979	951	360	457
15	A	Control	---	---	---	---
1	B	Grass carp	1979	370	365	426
2	B	Hybrid grass carp	1979	370	360	457
3	B	Control	---	---	---	---
4	C	Grass carp	1980	988	122	19
5	C	Hybrid grass carp	1980	988	224	107
6	D	Grass carp	1980	494	173	52
7	D	Hybrid grass carp	1980	494	224	107

RESULTS AND DISCUSSION

Fish

Stocking rates, survival percentages and growth data of the grass carp and the F_1 hybrid are contained in Tables 1 and 2. There were no significant differences in initial stocking lengths or weights between 1979 year class grass carp and 1979 year class hybrid grass carp. However, the 1980 year class grass carp were significantly smaller (P .05) in length and weight than the 1980 year class hybrid grass carp at stocking.

Ploidy determination of 44 hybrid grass carp from the 1979 year class revealed that 43 fish were positively triploid and that the remaining fish was probably a triploid. Fifty hybrid grass carp from the 1980 year class were also examined. Forty-eight of these fish were triploids, one fish was probably a triploid, and one fish was a diploid.

Grass carp survival rates exceeded 95% and were greater than those reported by Colle et al. (1978) or Lembi et al. (1978) for similar size fish. The 1979 year class hybrid grass carp exhibited a survival rate of 88.1%, while the smaller 1980 year class hybrid grass carp experienced a 65.5% survival rate. Since dead fish were not observed in any pond after initial stocking mortalities, these losses were probably the result of predation by mink, snakes, or wading birds (Colle et al., 1978; Lembi et al., 1978; Thomas et al., 1979). Hybrid grass carp may have been more susceptible to predation, since Secchi disc transparencies (Figures 1 and 2) were generally greater in hybrid grass carp ponds than in grass carp ponds.

Table 2. Harvest parameters of grass carp and hybrid grass carp.

Pond number	Pond set	Species	Year class	Days in pond	% Survival	Average total length (mm)	Average length/day increase (mm)	Average weight (g)	Average weight/day increase (g)
16	A	Grass carp	1979	31	98.4	419	1.74	773	11.2
14	A	Hybrid grass carp	1979	110	88.1	438	0.7	720	2.4
15	A	Control	----	----	----	---	----	---	----
1	B	Grass carp	1979	150	96.0	405	2.4	1,241	16.3
2	B	Hybrid grass carp	1979	112	96.7	442	0.7	840	3.4
3	B	Control	----	---	----	---	---	---	----
4	C	Grass carp	1980	63	98.3	313	3.0	250	3.8
5	C	Hybrid grass carp	1980	117	74.0	335	1.0	515	3.5
6	D	Grass carp	1980	42	95.5	300	2.8	289	5.6
7	D	Hybrid grass carp	1980	112	65.5	347	1.1	377	2.4

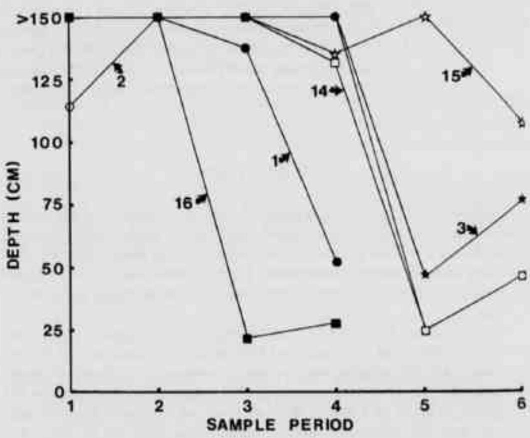

Figure 1. Secchi disc transparencies at three week intervals beginning May 3, 1981, in ponds receiving no fish (3 and 15), 1979 grass carp (1 and 16), or 1979 hybrid grass carp (2 and 14). Ponds 1 and 2 received 61 fish per ha and ponds 16 and 14 received 156 fish per ha. Ponds 16, 15, and 14 constitute set A and ponds 1, 2, and 3 constitute set B.

Growth of grass carp and hybrid grass carp cannot be directly compared since the ponds were harvested at different times. However, average daily growth increments can be compared, since ample vegetation for fish growth was always present prior to harvest. The 1979 year class carp exhibited average daily length increments that were 2.5 and 3.4 times greater than those of 1979 year class hybrid grass carp at densities of 156 and 61 fish per ha, respectively, and average daily weight increases for 1979 year class grass carp at these respective densities were 4.7 and 4.8 times greater than those of 1979 year class grass carp (Table 2). Since the different initial sizes of 1980 year class grass carp and hybrid grass carp might distort comparisons between their daily growth rates, these comparisons are not presented. However, in all instances the 1980 year class grass carp exhibited greater daily increases in lengths and weights than the 1980 year class hybrid grass carp (Table 2).

Water Quality

Secchi disc transparencies (Figures 1 and 2) generally decreased in all ponds during the study. Decreases in Secchi disc transparencies greater than 25 cm were not noted in control ponds 3 and 15 until sample periods 5 and 6, respectively. Ponds containing fish, however, usually exhibited decreases greater than 25 cm much earlier. Lembi et al. (1978) observed increased turbidity levels in ponds containing grass carp. These increases correspond to decreased Secchi disc transparencies, since Secchi disc measurements are an indicator of visibility (Welch, 1948).

Within each set of ponds, grass carp depressed Secchi disc measurements earlier and to a greater extent than did hybrid grass carp. Since equal numbers of fish were stocked within a set, turbidity increases resulting from fish movements and activities probably would not have accounted for these differences. Although plankton populations were not monitored, it is believed that the grass carp exerted a greater negative effect upon Secchi disc transparencies than did the hybrid grass carp by stimulating plankton production through the release of nutrients from macrophytes. Decreases in total biomass of macrophytes within a pond (Figures 3, 4, and 5) were reflected by decreased Secchi disc values at the same or next sample period (Figures 1 and 2).

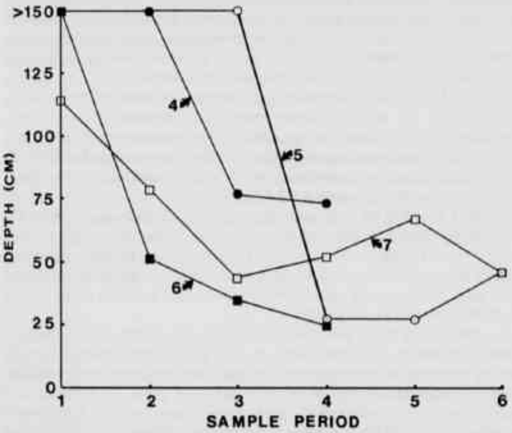

Figure 2. Secchi disc transparencies at three week intervals beginning May 3, 1981, in ponds receiving 1980 grass carp (4 and 6) or 1980 hybrid grass carp (5 and 7). Set C ponds (4 and 5) received 162 fish per ha and set D ponds (6 and 7) received 81 fish per ha.

Ranges and means of surface temperatures and dissolved oxygen levels for the ponds are illustrated in Table 3. Pond temperatures ranged from 21 to 35 C and never differed among ponds by more than 2 C at any one sampling date. Pond temperatures were always greater than 14 C which Colle et al. (1978) reported as the temperature where grass carp exhibited a marked decrease in growth.

Dissolved oxygen levels were always above 4 ppm in all ponds which is sufficient to maintain fish. Within pond sets A and B, control ponds (15 and 3) exhibited the highest mean oxygen levels, hybrid grass carp ponds (14 and 2) had intermediate mean oxygen values, and grass carp ponds (16 and 1) exhibited the lowest mean oxygen values. Hybrid grass carp ponds (5 and 7) in sets C and D, also, had mean oxygen levels greater than their respective grass carp ponds (4 and 6). Thus, the presence of grass carp or hybrid grass carp decreased dissolved oxygen values. Grass carp had a greater negative impact upon these values than did hybrid grass carp. This reduction in dissolved oxygen levels is probably a necessary trade-off for vegetation removal.

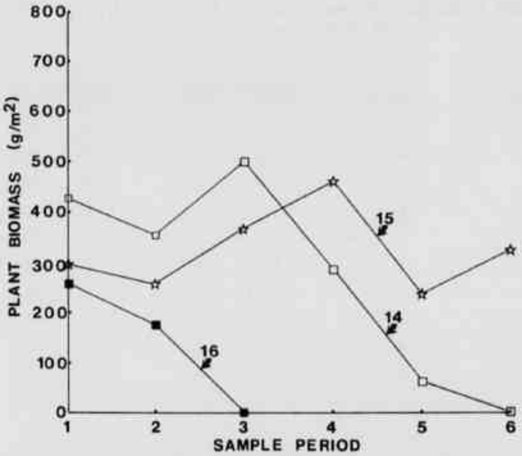

Figure 3. Plant biomass at three week intervals beginning May 3, 1981, in set A ponds receiving no fish (15, 1979 grass carp (16), or 1979 hybrid grass carp (14). Ponds 16 and 14 received 951 fish per ha.

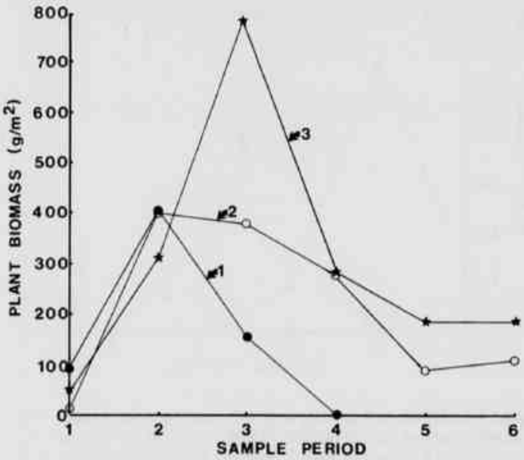

Figure 4. Plant biomass at three week intervals beginning May 3, 1981, in set B ponds receiving no fish (3), 1979 grass carp (1), or 1979 hybrid grass carp (2). Ponds 1 and 2 received 370 fish per ha.

Rottmann and Anderson (1977) observed that average dissolved oxygen concentrations were greater in ponds containing grass carp than in ponds not containing grass carp. Differences in sampling times may account somewhat for this discrepancy, since they obtained their oxygen concentrations immediately after dawn as opposed to 0900 hours when some photosynthesis would have already occurred. The stocking density utilized by Rottmann and Anderson of 233 fish per ha was lower than our minimum stocking density of 370 fish per ha. However, this difference in fish stocking rates should have only a minor effect on dissolved oxygen levels.

Table 3. Ranges and means recorded for dissolved oxygen and temperature values of the pond waters.

Pond number	Set designation	Dissolved oxygen range	Dissolved oxygen mean	Temperature (C) range	Temperature (C) mean
16	A	4.2-9.2	6.7	21-35	28.1
14	A	4.0-12.0	7.3	21-35	27.0
15	A	4.4-10.0	7.4	21-34	27.0
1	B	5.9-7.5	6.7	21-35	28.1
2	B	6.0-11.0	8.5	21-34	28.0
3	B	6.5-13.0	9.6	21-34	26.5
4	C	6.0-9.8	7.9	21-34	26.5
5	C	5.0-16.0	9.0	21-35	25.7
6	D	5.75-8.0	6.6	21-35	26.5
7	D	6.0-9.0	7.2	21-35	25.8

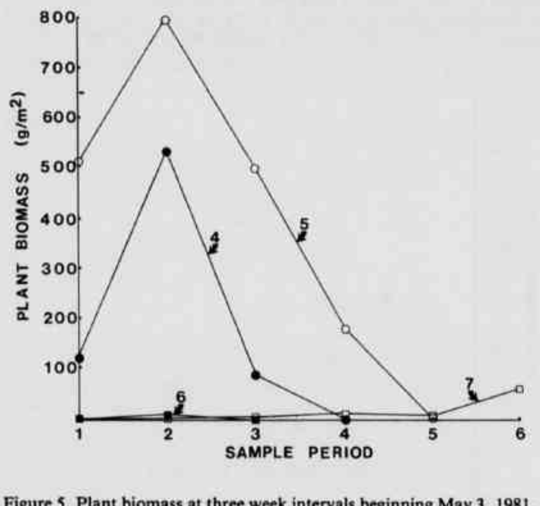

Figure 5. Plant biomass at three week intervals beginning May 3, 1981, in ponds receiving 1980 grass carp (4 and 6) or 1980 hybrid grass carp (5 and 7). Set C ponds (4 and 5) received 988 fish per ha and set D ponds (6 and 7) received 494 fish per ha.

Biomass Reduction

Plant biomass of all ponds utilized during the study is illustrated in Figures 3, 4, and 5. Fish were added to all ponds approximately one week prior to sample period two on 6 May, 1981. Thus, any noticeable effects upon plant biomass probably would not be evident until four weeks later at sample period three (three week intervals between sample periods).

Species composition of plants within set A ponds varied from pond to pond as time progressed (Figure 3). At sample period one (24 April, 1981) *Hydrodicton* sp. dominated all set A ponds comprising at least 62.4% of the initial plant biomass in each pond. Ponds 14 and 16 in set A received 1979 year class fish at 951 fish per ha prior to sample period two. By sample period two *Hydrodicton* sp. and *Potamogeton pectinatus* were co-dominants in ponds 16 (51.1% and 48.9% respectively) and 14 (27.3% and 72.7% respective), while *Hydrodicton* sp. still dominated control pond 15 (87.8% of plant biomass). Thereafter, *Potamogeton pectinatus* comprised at least 64.2% of the plant biomass in pond 14 with *Rhizoclonia* sp. making up the remaining biomass present. *Pithophora* sp. accounted for at least 55.2% of the plant biomass in control pond 15 after sample period two. *Potamogeton pectinatus* and *Chara* sp. were also present in control pond 15, which exhibited the greatest species diversity of set A ponds.

All of the plant species present in set A ponds were readily consumed by grass carp and hybrid grass carp. Various studies have documented that grass carp will utilize *Hydrodicton* sp. (Lewis, 1978), *Potamogeton pectinatus* (Singh et al., 1967; Mehta et al., 1976), *Pithophora* sp. (Singh et al., 1967; Lembi et al., 1978; Lewis, 1978) and *Chara* sp. (Kilgen et al., 1978). The only information available concerning hybrid grass carp utilization of the plant species present in set A ponds was that *Chara* sp. was a preferred food (Cassani, 1981).

Species diversity of plants within set B ponds was quite complex. At sample periods one and two, ponds 1 and 2 were dominated by *Potamogeton pectinatus,* which comprised at least 61.7% of the biomass in each pond. At sample period two, pond 1 also contained significant amounts of *Hydrodicton* sp. (31.4%) and *Chara* sp. (6.9%) while pond 2 contained significant amounts of *Rhizoclonia* sp. (11.8%) and *Chara* sp. (10.3%). By sample period three in pond 1 and by sample period four in pond 2 only *Potamogeton pectinatus* and *Rhizoclonia* sp. remained as co-dominants in each pond. *Hydrodicton* sp. comprised 87.2% and 72.0% of the plant biomass in control pond 3 at sample periods one and two, respectively. However, by sample period three, *Hydrodicton* sp. was no longer present in control pond 3 which contained 42.8% *Rhizoclonia* sp., 36.2% *Potamogeton pectinatus,* and 20.9% *Chara* sp. By sample period six, *Pithophora* sp. made up 66.1% of the plant biomass in control pond 3 with *Potamogeton pectinatus* accounting for the remaining 33.9%.

Ponds 1 and 2 in set B (Figure 4) received 1979 year class fish at 370 fish per ha. The two year old grass carp eliminated the vegetation in pond 1 by sample period four but vegetation was still present at project termination in pond 2 which contained the two year old hybrid grass carp. After sample period two, control pond 3 exhibited the highest plant biomass of set B ponds.

By examining peak biomass occurrences for each plant species in ponds containing fish compared to fish free control ponds, certain feeding selectivities were observed. At the lower stocking density utilized in set B ponds (370 fish/ha) the two year old grass carp exhibited a preference for *Potamogeton pectinatus* and *Chara* sp. over *Rhizoclonia* sp. Menta et al. (1976) also observed a similar preference by small grass carp for *Chara* sp. and *Potamogeton pectinatus.* The two year old hybrid grass carp at the same stocking rate selected *Potamogeton pectinatus* over *Rhizoclonia* sp. and *Chara.* This was contrasted to the observations of Cassani (1981) who reported that *Chara* sp. was preferred by hybrid grass carp over six other submersed plant species. The higher stocking density utilized in set A ponds (971 fish/ha), prevented feeding selectivities from being observed since biomass reduction occurred quickly.

Ponds 4 and 5 in set C were dominated throughout the study by *Chara* sp. which comprised at least 73.6% of the biomass present. Both ponds received the higher stocking density of 1980 fish at 988 fish per ha. The one year old grass carp eliminated all vegetation in pond 4 by sample period four (Figure 5) and the one year old hybrid grass carp eliminated all vegetation in pond 5 by sample period five. As previously stated, *Chara* sp. is utilized by both grass carp (Kilgen and Smithermen, 1971; Willey et al., 1974; Mehta et al., 1976; Lembi et al., 1978) and hybrid grass carp (Cassani, 1978).

Ponds 6 and 7 in set D (Figure 5) were stocked with one year old fish at the rate of 494 per ha. These two ponds developed dense plankton blooms immediately after fish stocking as measured by Secchi disc transparencies (Figure 2). Dense growths of aquatic macrophytes did not occur prior to or after fish introduction, so little can be stated concerning their reduction.

Vegetation Height

Average heights of vegetation in all ponds utilized in the study are depicted in Figures 6, 7, and 8. Vegetation heights were greatly influenced by the plant species present, since the occurrence of floating species resulted in increased heights. Wind direction and intensity, also, affected vegetation heights by windrowing the floating species along pond edges.

Vegetation heights in set A (Figure 6) and set B (Figure 7) ponds which contained the 1979 year class of fish stocked at 951 and 370 fish per ha generally reflected the same trends as the plant biomasses in these ponds (Figures 3 and 4). Set A ponds always contained large amounts of the floating species: *Hydrodicton* sp., *Pithophora* sp. and *Rhizoclonia* sp. Pond 2 which contained the lower stocking density of 1979 hybrid grass carp showed an increase in vegetation height at each period until sample period six. An inverse relationship occurred in pond 2 between vegetation height and plant biomass (Figure 4) due to a sparse covering of *Rhizoclonia* sp. in pond 2 during the study.

Mean vegetation heights of set C and D ponds (Figure 8), which received the 1980 year class of fish at 988 and 494 fish per ha reflected the plant biomasses of these ponds (Figure 5). The similarity in trends between mean vegetation height and plant biomass in these ponds probably resulted from the fact that their biomasses were comprised primarily of the submerged plant species: *Chara* sp. and *Potamogeton pectinatus*. Mean vegetation height does not adequately reflect plant biomass when unpreferred floating plants comprise a larger portion of the plant biomass present.

CONCLUSIONS

The hybrid grass carp, while not as effective as the grass carp in controlling aquatic macrophytes, appears to be an alternative biological control for nuisance aquatic vegetation. Stocking rates for the hybrid grass carp will have to be higher than for grass carp to obtain the same degree of control as with the grass carp. The effectiveness of hybrid grass carp at lower stocking densities over longer time periods needs to be further evaluated.

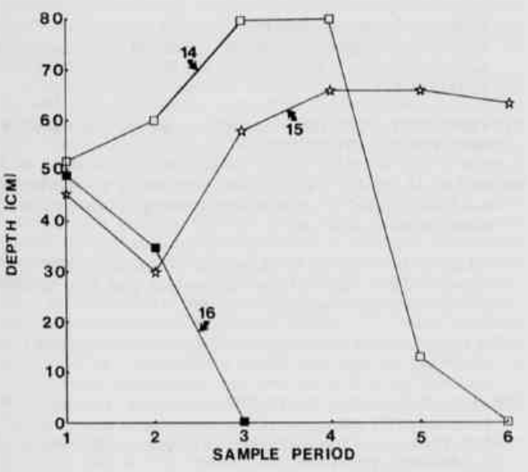

Figure 6. Mean vegetation height at three week intervals beginning May 3, 1981, in set A ponds receiving no fish (15), 1979 grass carp (16) or 1979 hybrid grass carp (14). Ponds 16 and 14 received 951 fish per ha.

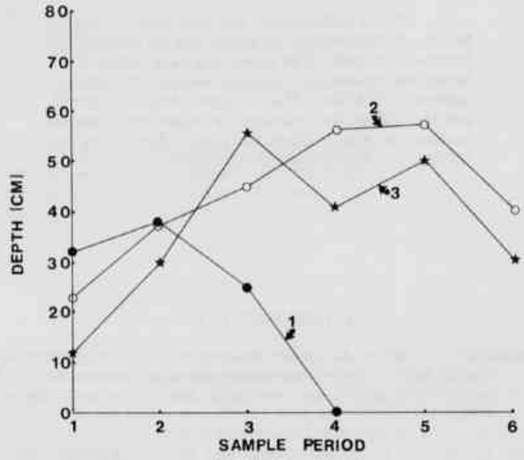

Figure 7. Mean vegetation height at three week intervals beginning May 3, 1981, in set B ponds receiving no fish (3), 1979 grass carp (1), or 1979 hybrid grass carp (2). Ponds 1 and 2 received 370 fish per ha.

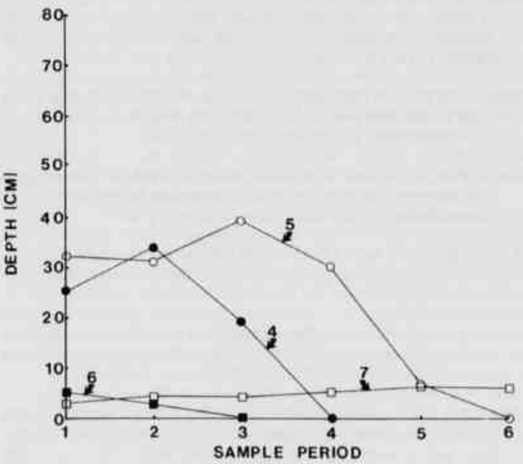

Figure 8. Mean vegetation height at three week intervals beginning May 3, 1981, in ponds receiving 1980 grass carp (4 and 6) or 1980 hybrid grass carp (5 and 7). Set C ponds (4 and 5) received 988 fish per ha and set D ponds (6 and 7) received 494 fish per ha.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Andrew Mitchell in determining fish ploidy and the assistance of Tommie Crawford, Mike Verser, and Jana Collins in collecting and processing vegetation samples. We also are indebted to Bill Keith, Harry Dupree, Andrew Mitchell, and Jim Collins for reviewing the manuscript. Last but not least, we wish to thank Kay Hester, Rita Corley and Bobbie Pack for typing the manuscript.

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