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Effective Control of Waterhyacinth Using *Neochetina* and Limited Herbicide Application

KIM H. HAAG[1]

ABSTRACT

A small (0.4 ha) private pond was completely covered in August 1984 with a dense stand of large waterhyacinths, *Eichhornia crassipes* (Mart.) Solms. Waterhyacinth weevils (*Neochetina eichhorniae* Warner and *N. bruchi* Hustache) were present but at very low densities. A floating barrier was placed across one end of the pond, enclosing 20% of the plants ("reservoir area"). The remaining plants (80% of pond surface) were sprayed with 2,4-D (2.2 kg/ha) in monthly increments of 25%, beginning in August at the end of the pond farthest from the reservoir area. As sprayed plants died and decayed, weevil density slowly increased in the reservoir area. By February, all sprayed plants had disappeared and weevil densities were very high on the reservoir plants. These plants showed signs of extensive damage from heavy weevil feeding. By May, no waterhyacinth plants remained in the reservoir area. Implications for integrated pest management of waterhyacinth are discussed.

Key words: Biocontrol, *Eichhornia crassipes,* waterhyacinth weevils, integrated pest management, 2,4-D.

INTRODUCTION

Waterhyacinth, *Eichhornia crassipes* (Mart.) Solms, is a serious aquatic weed problem in the southern United States, as well as in many parts of the world. Mechanical control is often infeasible and prohibitively expensive. Chemical control using herbicides may have undesirable side effects, and pollution of ground water supplies is a significant concern. Biological control, utilizing two species of waterhyacinth weevils (Coleoptera: Curculionidae) was first suggested as an alternative to mechanical and chemical control in the early 1970's. These weevils feed and develop only on waterhyacinth, and were imported from Argentina solely for this purpose.

The weevils are now distributed throughout Florida in areas of waterhyacinth infestation. The effects of weevil damage have been documented in several studies worldwide (Cofrancesco 1983; DeLoach and Cordo 1983; Goyer and Stark 1984; Irving and Bashir 1984; Wright 1984), and results suggest that under certain circumstances *Neochetina eichhorniae* Warner and *Neochetina bruchi* Hustache can reduce and achieve control of waterhyacinth populations. These data are primarily from unmanaged sites where no herbicides are routinely used. At many field sites in Florida, densities of waterhyacinth weevils remain too low to provide effective control.

Chemical control, which typically involves spray application of the herbicides 2,4-D or diquat, is widely used in Florida and causes a relatively rapid decline in the waterhyacinth weed mat. Some of the chemical formulations used may have a harmful effect on the weevils themselves. An additional concern to biocontrol researchers is the resulting loss of habitat for the immature stages of the weevils. The eggs, larvae and pupae all live within the waterhyacinth plant itself and cannot migrate away from plants that die and decay. Furthermore, adult weevils, which live on the surface of the plant, appear to be capable of flight and migration only at certain times during their life span. Therefore, at highly managed sites where frequent spraying is employed, weevil populations may be reduced drastically as a secondary effect of spray programs.

Weevils mate and produce a new generation no more than 3 or 4 times a year. Thus weevil populations increase at a much slower rate than waterhyacinth, which can double in biomass in as little as 10 days. As a result, regrowth of the weed mat after spraying will remain unchecked by weevil feeding until the insect population can once again reach an adequate level. A cycle of repetitive large scale spraying may in this way preclude effective biocontrol by the weevils.

Florida's surface waters serve many functions including recreation, transportation and commerce, power generation, irrigation and drainage. Consequently economic, aesthetic, environmental and political concerns necessitate the inclusion of all available tactics in a successful program of integrated aquatic weed management.

This project was designed to implement a program of integrated pest management of waterhyacinth, in which biological control was promoted and the chemical control component was limited. The objectives were to:

1) slowly reduce the waterhyacinth cover on a pond by 80% while conserving the remaining 20% of waterhyacinths as a potential "reservoir" for waterhyacinth weevils;
2) monitor weevil population density on reservoir plants and document any decline in plant quality due to increased weevil feeding;
3) continue observation for a full year to determine whether a long-term steady state can be maintained between a reduced plant population and an increased weevil population.

[1]Postdoctoral Research Associate, Department of Entomology, Bldg. 339, University of Florida, Gainesville, FL 32611.

[2]Mention of a tradename or a proprietary product does not constitute a guarantee or warranty of the product by the University of Florida and does not imply its approval to the exclusion of other products that also may be suitable. The University of Florida, Center for Aquatic Weeds, has not tested all the herbicides mentioned and does not warrant, expressly or implied, the fitness of any products. Any product tradenames that are listed are for the benefit of the reader and list may not contain all products available due to changes in the market. Be sure to read and follow herbicide label directions.

MATERIALS AND METHODS

Richardson Pond, located in southwestern Alachua Co., is a small private pond with a surface area of approximately 0.4 ha. It is a sinkhole pond, and receives water from Hogtown Creek. It lies adjacent to Hogtown Prairie, a wetlands area also supporting scattered mats of waterhyacinth. In the summer of 1984 the pond itself was completely covered with very large, densely-packed waterhyacinth plants, and no open water was visible. Waterhyacinth weevils were present but at low densities.

A floating barrier, constructed of nylon rope and capped 3.8 cm diameter PVC pipes, was placed across one end of the pond. The area behind the barrier, termed "the reservoir", represented approximately 20% of the pond surface (Figure 1). This area was never sprayed during the course of the experiment.

Plants in this area were sampled at 5 m intervals along each of 3 transect lines extending from shore to shore. At each sampling interval, 3 floating frames (0.25 m^2) were thrown at random into the weed mat. All plants within each frame were counted. Of these plants, 5 were chosen at random, and all weevil adults on them were collected and preserved in ethyl alcohol.

Beginning in late August and continuing at 3-4 week intervals through November, approximately 20%-30% of the waterhyacinth-covered pond surface was sprayed with herbicide. The formulation included 2,4-D (2,4-dichlorophenoxy acetic acid) (2.2 kg/ha), Kover[2] (0.25% v/v) and Submerge[2] (.012 % v/v), in a total spray volume of 934 l/ha. Spraying began at the end of the pond farthest from the reservoir area. An area of live waterhyacinth was always maintained adjacent to the reservoir area until the final spraying date.

Weevils and plants were sampled, as described above, at monthly intervals from August 1984 through April 1985, and always at least 10-14 days after the most recent herbicide application. Sampling was suspended in December and January because frost damage and plant decay made it virtually impossible to delineate and collect individual plants. Plant quality and condition were assessed in the reservoir area in November 1984, prior to any frost damage. Water samples were also collected in November and analyses included measurements of pH, hardness, alkalinity, conductivity and levels of nitrogen and phosphorus.

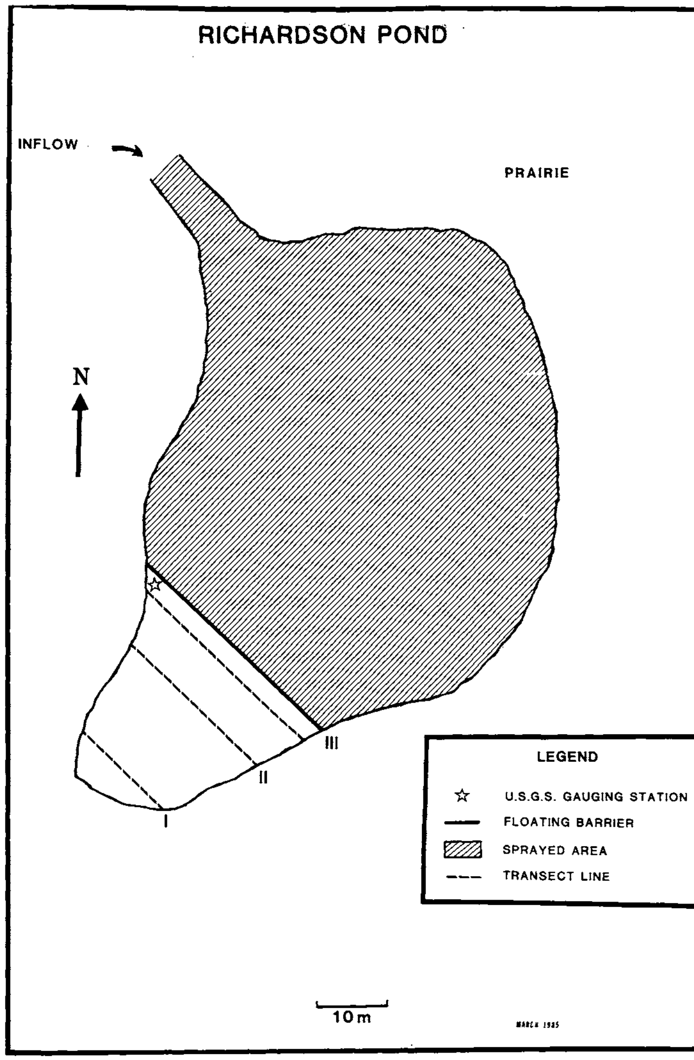

Figure 1. Map of Richardson Pond, showing location of sampling transect lines, floating barrier and sprayed area.

RESULTS AND DISCUSSION

Richardson Pond is a deep sinkhole lake, with an average depth of 10 meters and a maximum depth exceeding 35 meters. It is slightly acidic (pH 6.9) with a total alkalinity of 49 mg/l (as $CaCO_3$), and a total hardness of 91 mg/l (as $CaCO_3$). Conductivity at 25°C was 207 mho/cm. This pond is rather eutrophic compared to many north-central Florida lakes (Shannon and Brezonik 1972), containing 4.0 mg/l total nitrogen and 0.7 mg/l total phosphorus (N/P = 5.7). These nutrient levels exceed the minimum levels of nitrogen and phosphorus needed for waterhyacinth growth (Boyd 1970, 1976; Haller *et al.* 1970; Knipling *et al.* 1970), and are primarily responsible for the large size

TABLE 1. SUMMARY OF PLANT CONDITION ALONG 3 SAMPLING TRANSECTS (MEAN OF VALUES) AT RICHARDSON POND IN NOVEMBER 1984.

Meter #	Plants[a] per m^2	Ht. Tallest[b] Leaf (cm)	Root[b] Length (cm)	# Live[b] Leaves Per Plant	# Dead[b] Leaves Per Plant	Dry Plant[b] Wt (g)	Dry Root[b] Wt (g)	Feeding[c] Scars/Leaf	# Weevils[b] per Plant
0 (shore)	77.2 ± 8.2	65.8 ± 11.4	65.9 ± 8.2	4.2 ± 0.7	7.2 ± 1.2	17.0 ± 4.8	4.1 ± 1.4	88.9 ± 28.1	1.2
5	54.8 ± 4.9	75.6 ± 2.8	67.6 ± 8.1	6.2 ± 0.7	4.2 ± 0.7	21.8 ± 6.4	6.1 ± 1.7	116.4 ± 52.2	1.5
10	97.2 ± 3.8	69.6 ± 2.8	58.4 ± 15.7	5.8 ± 0.7	7.4 ± 2.0	27.1 ± 10.9	6.5 ± 2.5	126.3 ± 56.8	1.2
15	53.2 ± 4.9	77.2 ± 5.5	64.0 ± 9.9	6.0 ± 0.6	5.6 ± 1.4	26.3 ± 4.5	6.1 ± 1.0	158.7 ± 36.9	1.5
20	96.0 ± 11.8	66.4 ± 3.4	54.6 ± 15.5	6.0 ± 0.6	4.6 ± 1.2	20.6 ± 9.3	5.7 ± 2.9	98.5 ± 27.7	1.5
25 (shore)	53.2 ± 6.8	73.9 ± 3.2	48.3 ± 8.3	6.4 ± 0.8	5.4 ± 1.0	24.0 ± 8.2	5.6 ± 1.2	121.7 ± 54.4	3.7

[a]Values are means of 3 separate counts ± standard deviation.
[b]Values are means of 5 randomly chosen plants ± standard deviation.
[c]Based on means from 5 randomly chosen plants ± standard deviation; 3 leaves per plant examined.

and high density of waterhyacinth in this pond. The source of the nutrients is presumably Hogtown Creek, which flows through Gainesville and into the pond (Huber *et al.* 1981).

The results of the November 1984 assessment of plant quality are shown in Table 1. Plant density ranged from 53 to 97 plants/m^2, whereas height of the longest leaf on each plant ranged from 66 to 77 cm. Individual plants had from 4 to 6 live leaves and 4 to 7 dead leaves at the time of sampling. Dry plant weight (petioles and leaf blades) ranged from 17 to 27 g/plant, whereas the combined dry weight of roots (roots and stem) ranged between 4 and 6 g/root. It is interesting to note that values for all these parameters agree closely with those reported by Center and Spencer (1981) for waterhyacinth plants in nearby Lake Alice in late fall.

There was a very wide range in the mean number of feeding scars per leaf lamina. This variation occurred both between plants, as well as among leaf laminae on the same plant. Values ranged from 88.9 ± 28.1 to 158.7 ± 36.9. Counts of feeding scars on petioles were not included since these scars were so dense, particularly at the leaf isthmus, that they could not be individually counted. The mean number of adult weevils per plant ranged from 1.2 to 3.7 on this sampling date, and weevil density did not appear to be related to plant distance from shore along any sampling transect.

When this study was initiated, similar assessments of plant condition were planned at 3 month intervals. The assumption was that while increased weevil densities might not extirpate the waterhyacinth population, there would be at least an overall reduction in plant density, size and vigor, as well as growth rate of the weed mat. The precipitous decline in plant quality by early spring precluded subsequent assessments of this type.

Changes in weevil density are presented in Table 2. Ambient weevil density in August (prespray) was low, with a mean density of 0.7 weevils per plant. A value for weevil intensity, calculated using the formula[3] developed by

TABLE 2. MEAN WEEVIL DENSITY ON UNSPRAYED PLANTS AT RICHARDSON POND FROM AUGUST 1984 TO APRIL 1985.

Date	Mean number of weevils per plant along sampling transects[a,b] I	II	III	Mean
August 1984				
(pre-spray)	0.8 ± 0.5	0.6 ± 0.3	0.7 ± 0.4	0.7
September	1.3 ± 1.1	1.0 ± 0.4	0.5 ± 0.2	0.9
October	0.6 ± 0.3	1.2 ± 0.5	0.8 ± 0.5	0.9
November	0.8 ± 0.4	1.1 ± 0.9	2.9 ± 0.9	1.6
Dec-Jan	—	—	—	—
February	1.7 ± 0.4	3.4 ± 1.0	7.3 ± 2.9	4.1
March	3.5 ± 0.7	5.9 ± 1.6	4.3 ± 1.9	4.6
April	0.9 ± 0.3	no plants	no plants	0.9

[a]Transects extended from shore to shore and were 25 to 40 meters in length. Samples were taken at 5 meter intervals. Each sample consisted of 3 separate counts.

[b]Values are means ± standard deviation of 3 separate counts. Each count consisted of the total number of weevil adults on 5 randomly selected plants.

[3]Intensity = weevil mass (mg) × m^{-2} / plant mass (kg) × m^{-2}.

T. Center and W. Durden (unpublished data), was found to be 94.6 in August. As spraying of the pond proceeded, mean weevil density increased slightly in the reservoir area (0.9 weevils per plant in September and October), as did weevil intensity (121.6 in both months). At the time of the November sample, all herbicide spraying had been completed. Weevil density averaged 1.6 weevils per plant in the reservoir area, and weevil intensity was found to be 216.3.

By late November, when all herbicide spraying had been completed, weevil density was highest along Transect III, moderately elevated along Transect II, and had not increased from August levels along Transect I. Transect III was closest to the sprayed area, and would include the first healthy plants to be encountered by the weevils if they were indeed migrating from sprayed to unsprayed plants. This pattern was still evident in February.

Plant samples were not collected in December and January since the frost damaged plants were partly submerged and difficult to handle. Weevil density was again assessed in February when regrowth began, and was found to have increased to 4.1 weevils per plant. Weevil intensity was estimated at 1662.9. This 8-fold increase in weevil intensity over the November samples was due both to increased weevil numbers and to the much smaller biomass of early spring plants. Mean weevil density (4.6 weevils per plant) and intensity (1865.3) also increased in March. By March, plant density and quality had declined along Transect III and peak weevil density was seen along Transect II. Increased densities were also evident at this time along Transect I, suggesting further movement of weevil adults towards healthy plants. Weevil density and intensity declined in April samples, when value of 0.9 weevils per plant and a weevil intensity of 604.0 were found. As plants continued to decline in size and number, numbers of weevils fell also. It is not known whether these weevils died due to loss of habitat and food source or whether they emigrated for similar reasons. A relatively high proportion of the adult weevils from Richardson Pond possessed wing muscles in late March and April (67%), suggesting that the capability for flight was present at that time.

Figure 2 shows the increase in weevil density in the reservoir area, along with the decrease in waterhyacinth density which accompanied it. Weevil densities are presented as numbers of weevils per plant. Although not shown in Figure 2, a similar pattern was observed when density was calculated as numbers of weevils per m^2. These values range from 80.7 weevils per m^2 in August, to a high of 282.5 weevils per m^2 in February. By April, weevil density fell to a value of 23.5 per m^2, following the decline in plant density.

The changes in waterhyacinth density can also be seen in the photographs in Figure 3. In Figure 3a, taken shortly after spraying had begun, the pond is completely covered with large densely-packed waterhyacinths. Application of 2,4-D outside the reservoir area resulted in death of sprayed plants, seen as brown areas. These plants did not sink for several months because they were supported by the dense surrounding waterhyacinth growth. In early spring (3b) the frost damaged plants in the reservoir area showed signs of regrowth. New shoots emerged but were immediately fed upon by weevils. All new growth was heavily damaged (3c), and the weight of the dead tissue began to sink areas of the mat. By mid-April few waterhyacinth

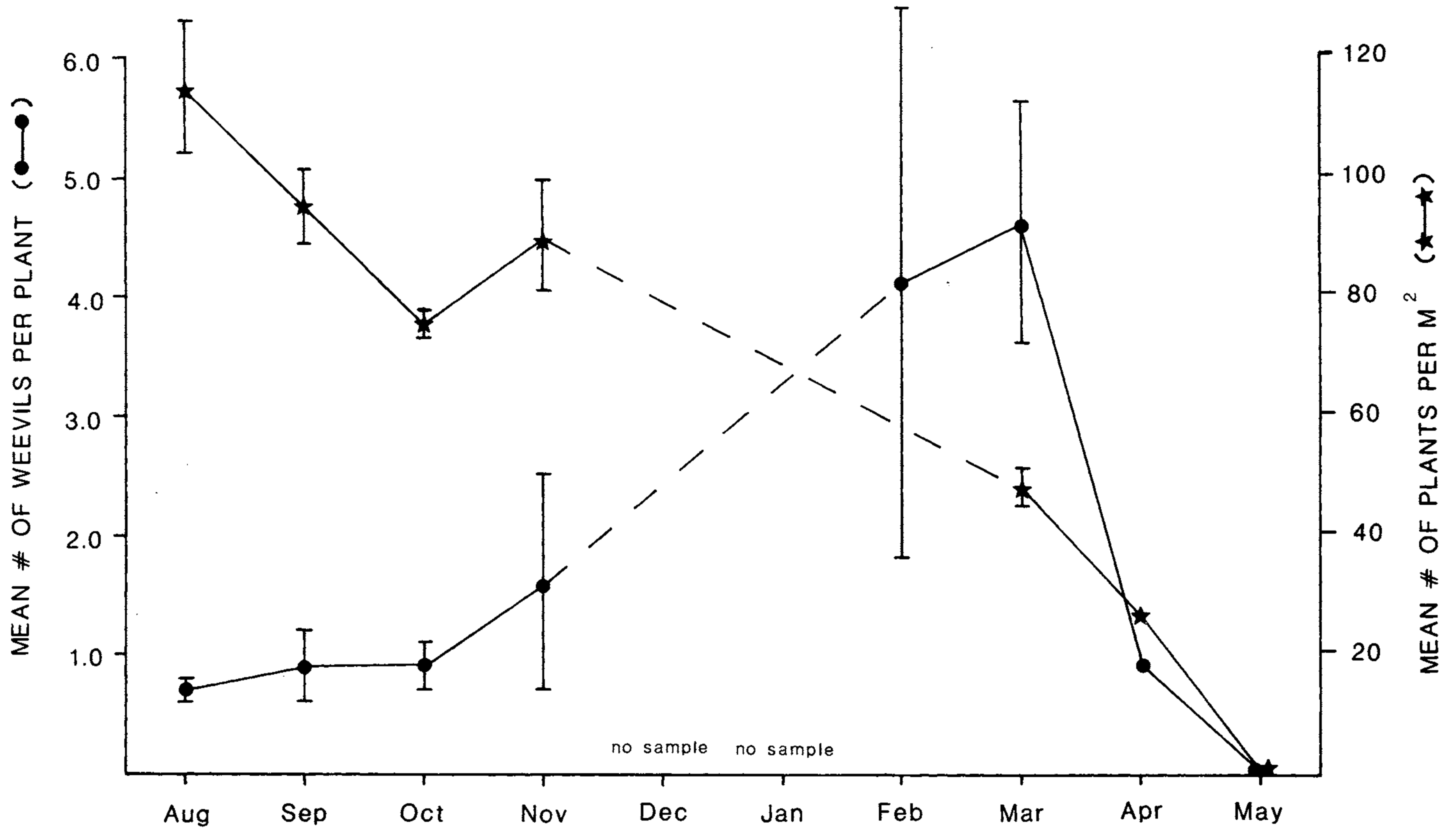

Figure 2. Density of waterhyacinth plants and waterhyacinth weevils in Richardson Pond from August 1984 to May 1985. Vertical lines represent +/- one standard deviation.

plants remained. Most petioles were so heavily damaged that they could not stand erect and were floating on the water surface (3d). Single petioles were often separated from roots and stems, and were found floating individually prior to sinking. The last waterhyacinth plants disappeared from the reservoir area by the end of April.

This experiment was begun in August simply because the field site became available at that particular time. It now appears that this was a fortuitous circumstance, since it resulted in the highest possible density of weevils on waterhyacinth plants early in the following spring, when plant biomass is typically at its lowest point for the year (Center and Spencer 1981). Weevils were "herded" to healthy plants during the fall, and either these adults or their progeny overwintered on unsprayed plants. A new spring generation of weevil adults and larvae was available to attack the spring plant growth, including apical buds and new petioles. With their winter reserves of energy depleted, this early spring reduction in photosynthetic capacity was extremely detrimental to individual plants. Sanders (1984) made a similar observation at field sites in Louisiana, suggesting that the key to significant reduction in waterhyacinth populations seems to be a dense weevil population on the small plants of early spring, followed by maintenance of or increase in insect population density as the growing season progresses. Data gathered by Center and Spencer[4] from Lake Alice also seem to support this theory.

[4]Center, T. D. and N. R. Spencer. 1985. The effects of *Neochetina eichhorniae* Warner (Coleoptera: Curculionidae), an introduced biological control agent, upon a waterhyacinth population in north-central Florida. (Unpublished Report).

Two additional factors may have contributed to increased weevil density in the reservoir area. The first was a period of drought. Rainfall was well below average through the winter and early spring of 1984-1985. The level of the pond fell at least 5 feet from August levels. The shrinking shoreline left plants stranded on the banks in the reservoir area and may have contributed slightly to the increase in weevils per plant seen during the study. The other factor, unique to this site, was the proximity of Hogtown Prairie. When the study began, there were large areas of waterhyacinths on the Prairie. The ensuing drought left these plants dry and dying, and removed habitat for any weevils present. It is conceivable that these weevil adults also migrated to the healthy plants in the reservoir area, thereby increasing weevil densities even further.

It was clear that a change in water quality or the influx of some toxic material was not responsible for the demise of the waterhyacinth weed mat. As the waterhyacinth population declined, alligatorweed (*Alternanthera philoxeroides*) spread rapidly and by May covered half of the reservoir area. Such succession, which indicated that water quality had not changed appreciably, is frequently seen at field sites when the dominant weed is controlled. By June, feeding damage from *Agasicles hygrophila*, the alligatorweed flea beetle, was evident and the spread of alligatorweed slowed. The flea beetle subsequently checked the growth of alligatorweed at Richardson Pond, and this weed is no longer present at the site. The pond has remained clear of waterhyacinth, and other aquatic weed infestations, as of February, 1986.

Figure 3. Richardson Pond. a. (upper left) October 1984. The pond is completely covered with waterhyacinths. Reservoir area is in the foreground, area to be sprayed is in the background. Brown dead plants in the background area are a result of initial herbicide application. b. (upper right) March 1985. New spring growth of waterhyacinth plants in the reservoir area. Brown plants are due to winter frost damage. c. (lower left) Close-up of 3b. Leaf shows very large numbers of feeding scars due to high density of adult weevils. d. (lower right) April 1985. Sprayed area in background is completely free of waterhyacinths. Foreground shows reservoir area with severely damaged spring growth of waterhyacinths. Waterhyacinth mat is almost completely gone. Green areas are due to encroaching mat of alligatorweed.

In summary, in the fall of 1984 approximately three-fourths of a waterhyacinth weed mat was sprayed with herbicide, in increments of 20%. The remaining waterhyacinths were allowed to overwinter, providing a habitat and food source for those waterhyacinth weevils present at the site. By early spring, waterhyacinth regrowth was severely damaged by high densities of weevils, and all plants were dead by late April. Efforts are now being directed towards repeating this experiment at larger lakes with mobile, floating mats of waterhyacinths and no other nearby sources of weevils. This will yield information on the feasibility of the design for use in larger lakes, and also determine whether the technique will give consistent results.

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