ANGLER ORIENTED OBJECTIVES OF AN AQUATIC WEED CONTROL PROGRAM[1]

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ABSTRACT

Chickahominy Reservoir, Virginia, was treated with a mixture of herbicides diquat and endothall to control obnoxious growths of *Egeria densa* Planchon. Herbicides were undetectable in water by the 16th day after treatment. Herbicides accumulated in plant tissue at levels higher than those in the water. Only diquat accumulated in hydrosoils. Diquat levels in hydrosoils increased as levels in plants and water decreased. All diquat had dissipated from hydrosoils after two years. Neither herbicide concentrated in edible fish flesh. Aerial photographic monitoring revealed the amount of surface acreage and fishable shoreline was increased substantially following treatment. Weed regrowth was greater in shallow areas than in deeper areas after one year. Seventy-two percent of the anglers polled to determine the sportsmen's opinion of the weed control project believed that the treatment alleviated the weed problem and increased fishing and boating enjoyment.

INTRODUCTION

Sport fishing is enjoyed by millions of Americans. Seventy-six percent concentrate their fishing effort on freshwater lakes, ponds, and reservoirs (U. S. Dept. Int., 1970). However, a major limiting factor to increasing recreational use of such impoundments is the growth of nuisance aquatic weeds (Corning, 1969). The extent of this problem has been well documented and is especially important in the southeastern United States (Holm *et al.*, 1969; Gangstad, 1971). Dense growths of the aquatic macrophyte egeria (*Egeria densa* Planchon) severely limited the recreational potential of Chickahominy Reservoir, a high-use warmwater fishery located in the populated eastern corridor of Virginia between Richmond and Norfolk.

This reservoir alone supplied 24,500 days of recreational fishing (computed on a 20 week season) to Virginia's fishermen in 1969 (U. S. Army, 1969). Fishermen complained that the thick mats of plants seriously detracted from their fishing experience by reducing the amount of fishable water, fouling tackle, and inhibiting navigation. The Virginia Commission of Game and Inland Fisheries and the U. S. Army Corps of Engineers jointly sponsored a chemical weed control project in response to the sportsmen's requests for improvement of the reservoir's recreational capacity. This report evaluates the efficacy of the control program with respect to meeting the objectives of the angler. Safety factors and accumulation of the chemicals in the environment are considered.

MATERIALS AND METHODS

A 1:1 mixture of diquat dibromide [6,7-dihydrodipyrido-(1,2-a: 2′, 1′-c)-pyrazinediium dibromide] and potassium endothall [7-oxabicyclo-(2,2,1) heptane-2,3-dicarboxylic acid] was applied at an application rate of 2.83 liter of each chemical per surface 0.4 ha. This application rate was calculated to yield 0.11 mg/liter active ingredient of diquat and 0.17 mg/liter of endothall at a depth of 144cm. Herbicide was applied to the eastern half of the reservoir as a surface spray from an airboat; the western half was treated using a siphon arrangement from an outboard motor boat. The treatment was completed in one week (July 9-13). The lake was closed to fishing for 14 days to allow for dissipation of the chemicals from the water.

Intensive monitoring was conducted in two quadrants chosen to represent deep and shallow areas of the reservoir. These quadrants covered 11.3 ha and 14.2 ha, respectively (Figure 1). Water samples were collected from the surface of each quadrant daily before treatment at intervals of 4, 12, 20, 28, and 40 h after treatment and then on a daily basis for one month. Sediment samples were collected once a week for six weeks following treatment, then approximately every two months for one year and

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a final collection two years after treatment. Samples were collected with a stainless steel core sampler (Daniel, 1972). The top 5cm of sediment was separated for analysis after freezing the core and extracting the core from the tube. Grab samples of egeria were collected daily for 10 days immediately after treatment and then every two days for the next 10 days and finally weekly until the egeria had disintegrated. Fish were collected 3, 10, 14, 44 and 76 days after treatment and then approximately every other month for one year. Fish were collected by electrofishing and hook and line, eviscerated, scaled and frozen. Fillets were analyzed for herbicide contents. Chemical analysis for diquat was carried out employing a spectrophotometric method. Endothall analysis was conducted using a gas-liquid chromatographic technique (Van Horn *et al.*, 1974, Van Horn, 1975).

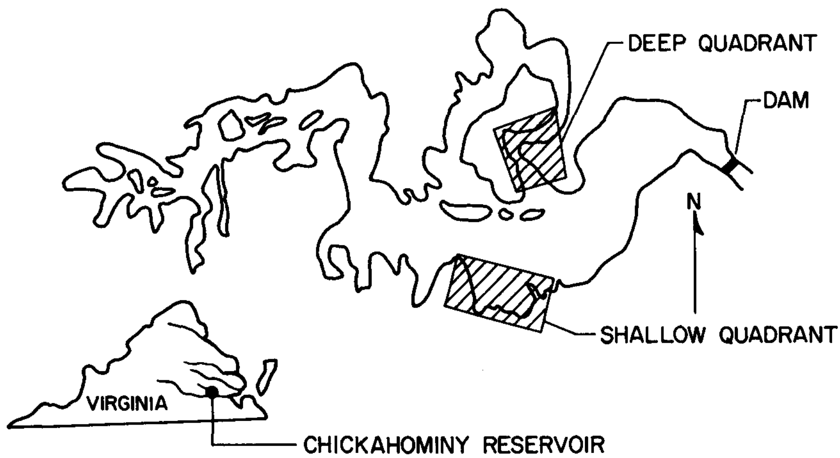

Figure 1. Map of Chickahominy Reservoir showing deep and shallow water study quadrants.

Aerial photography of the study quadrants was also conducted to monitor the decline of the egeria population (Berry *et al.*, 1974). Photography was conducted using a hand-held 35mm Minolta SRT 101 camera. Infrared film (Kodak Ektachrome Infrared, IE 135-20, ASA 100) was exposed through a minus-blue filter (Hoya YK2). Photoreconnaissance was conducted from a Piper Cherokee-6 aircraft at an altitude of 150m along designated transects over the reservoir. Ground measurements were made between fixed objects within each quadrant to establish the actual photographic scale which was later used to calculate the length of shoreline and amount of open and weed-choked water. Photographs were taken one week before, 4 weeks after and 50 weeks after treatment.

One year after treatment, an "angler acceptance survey" was conducted to determine the anglers' opinion of various aspects of the project. A questionnaire (Table 1) was distributed at four principal marinas. Personal interviews were also conducted. Only anglers with pretreatment knowledge of the lake were included in the survey. Respondents were separated into two groups: 1) those who visited the lake less than once a week, and 2) those who visited the lake once a week or more. The latter group included residents of the area. Where several answers were possible (questions 2, 4, and 5) the total number of responses was determined and each separate answer expressed as a percentage of this total.

RESULTS

Average endothall concentration in water the first day after treatment was 0.2 mg/l and 0.02 mg/l in the shallow and deep quadrants respectively (Figure 2). The average value for diquat was 0.07 mg/l in the shallow and 0.02 mg/l in the deep quadrant one day after treatment (Figure 3). Both herbicides dropped to very low levels 3 days after treatment and were undetectable within 16 days in the shallow and 10 days in the deep quadrant. The first two points for each quadrant represent averages of all samples collected on these days and include samples possibly collected in "hot spots" prior to uniform mixing. These values should not be interpreted as initial values in the reservoir. Each point thereafter represents an average of three days' values.

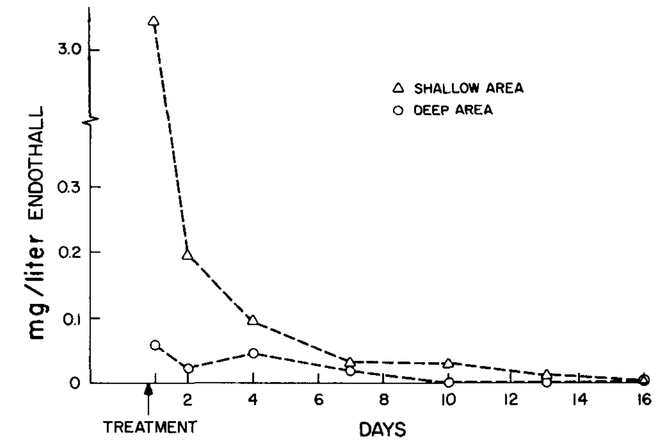

Figure 2. Dissipation of endothall from water in shallow and deep water study quadrants.

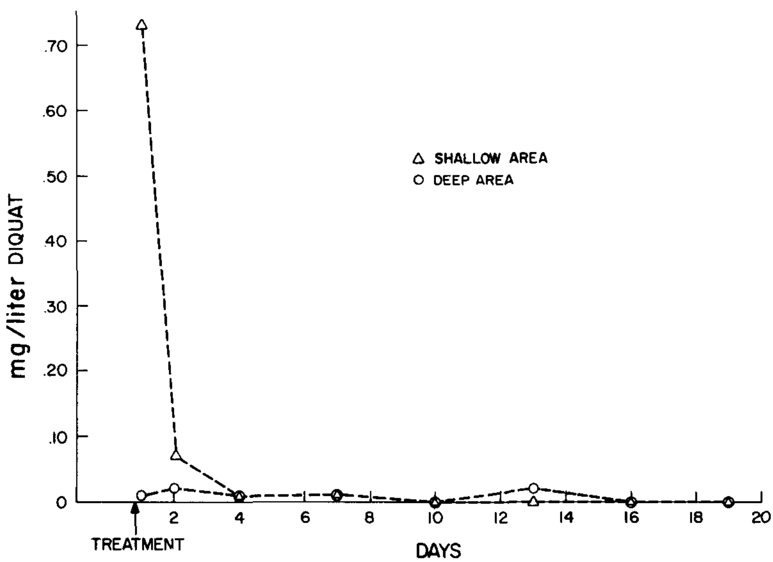

Figure 3. Dissipation of diquat from water in shallow and deep water study quadrants.

Concentrations of diquat in egeria tissue fluctuated (Figure 4). High concentrations of diquat were found in plant tissue until approximately 14 days after treatment when levels began to decline. Diquat was still present when plant sampling was discontinued. There appeared to be generally more diquat accumulated in egeria tissue in the shallow water quadrant than in the deep water quadrant.

Concentrations of endothall in egeria tissue were much lower than those of diquat and endothall dissipated to undetectable levels 22 to 25 days after treatment (Figure 5). Endothall accumulative levels in egeria tissue were similar in the shallow and deep water quadrants.

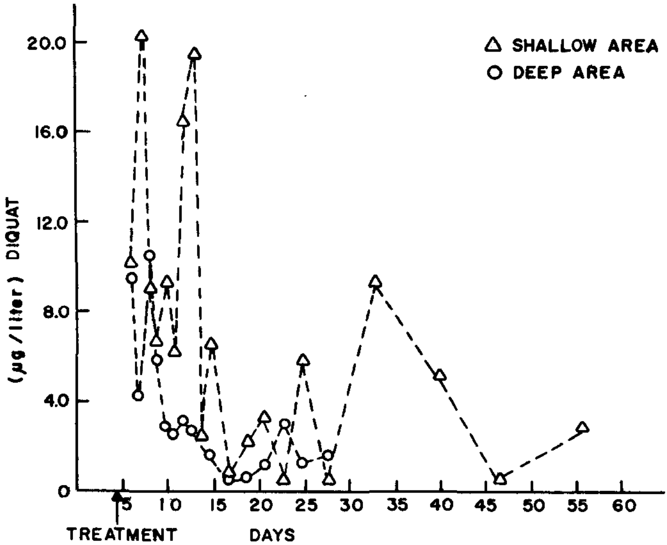

Figure 4. Diquat accumulation in egeria tissue in shallow and deep water study quadrants.

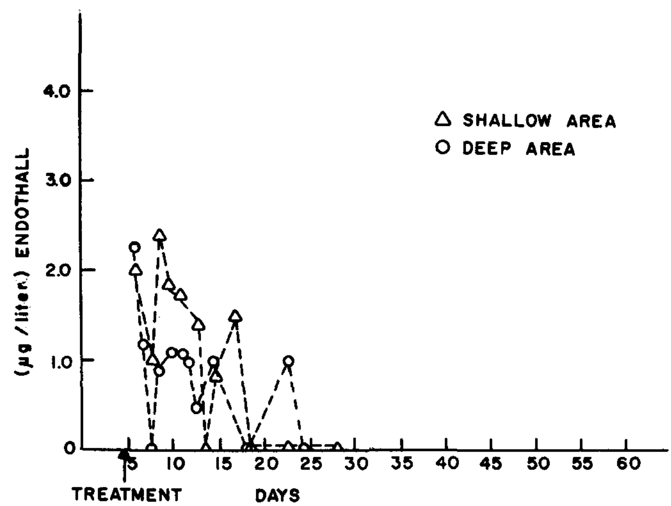

Figure 5. Endothall accumulation in egeria tissue in shallow and deep water study quadrants.

Table 1. Results of the angler survey conducted one year after herbicide application.

Question	*Answer*	*Group Response (percent)* Persons angling less than once a week	Persons angling more than once a week	Total
1. The lake was closed last summer from July 10 to July 24. Are you aware that during that time the lake was treated to control weeds?	Yes	77	95	87
	No	23	5	13
2. How did you become aware of this fact?[a]	Newspapers	37	17	27
	Signs	5	19	12
	Marina Oper.	27	40	34
	Word of mouth	30	22	26
3. Did the two week closing inconvenience you?	Yes	11	46	29
	No	89	54	71
4. Do you fish for[a]. . .	Bass	27	27	27
	Sunfish	27	22	24
	Crappie	21	19	20
	Catfish	10	8	9
	Pickerel	11	16	14
	Other	4	6	5
5. Do you usually use[a]. . .	Live bait	46	37	42
	Flies	24	25	25
	Plugs	29	37	33
6. Do you enjoy fishing more, less, same, now than before treatment	More	71	57	63
	Less	9	21	16
	Same	19	22	21
7. Do you catch more fish now than before treatment?	Yes	46	38	41
	No	27	28	27
	Same	26	34	32
8. Do you enjoy boating more, less, same now than before treatment?	More	60	60	60
	Less	11	15	13
	Same	29	25	27
9. For your overall use of the lake, do you think the weed control project helped, hurt, or made no difference?	Helped	81	65	72
	Hurt	3	11	7
	No. diff.	16	24	21
10. Do you agree with state and federal agency use of chemicals to control aquatic weeds?	Yes	97	87	91
	No	3	13	9

[a] Responses for each answer summed and divided by total responses for the question.

Concentration of diquat in hydrosoils was also variable with more herbicide found in sediment from the shallow water quadrant than from the deep water quadrant (Table 2). The time of maximum herbicide accumulation in hydrosoils roughly corresponded to the disintegration of the killed plants. Diquat persisted in hydrosoils for one year after treatment but was not found two years after treatment. No endothall was found in any hydrosoil sample.

Table 2. Diquat persistence (μg/g) in hydrosoils from Chickahominy Reservoir study stations.

Date	*Deep Quadrant*	*Shallow Quadrant*
1973		
VII - 11	3.77	3.80
		1.26
16	1.81	3.40
20	3.26	3.40
VIII - 8		17.37
15	3.32	11.09
22	0.90	4.84
IX - 20	5.45	0.39
X - 14	0.00	15.86
XII - 14	2.08	1.72
1974		
I - 25	1.16	*
III - 14	0.76	*
V - 9	5.54	*
VI - 24	0.00	*
1975		
VII - 10	0.00	0.00

* Inadequate Analysis.

Analysis of muscle tissue of 8 largemouth bass, *(Micropterus salmoides)*, 22 bluegills *(Lepomis macrochirus)*, 4 golden shiners *(Notemigonus crysoleucas)*, and one alewife *(Alosa pseudoharengus)*, revealed no evidence of herbicide accumulation in edible portions of the fish.

Aerial infrared photography was found to be useful for monitoring the response of the aquatic plant community to the herbicide treatment. Mats of egeria encroached on the channel of the deeper quadrant leaving only a small path for boats one week before treatment. Sixty-four percent of the open water was covered with egeria, and the amount of fishable shoreline was reduced by 30%. The egeria mats formerly lining the channel were cleared four weeks after treatment. All of the shoreline was reopened to angling, and the fishable shoreline was still clear one year after treatment.

Dense stands of egeria choked three small inlets within the shallow quadrant before treatment. Seventy-two percent of the open water was covered and 76% of the fishable shoreline had been eliminated. The three small inlets were cleared and most of the available open water and fishable shoreline were opened one month after treatment. Regrowth of egeria in nearly half of this quadrant was found one year after treatment.

Responses to the angler survey were collected from 235 anglers; 103 visited the lake less than once a week and 132 fished (or observed) the lake more than once a week (Table 1). Eighty-seven percent of the anglers knew that the lake had been closed the previous summer in order for the lake to be treated. Most respondents indicated that they learned of the weed control program from marina operators. Newspapers, word-of-mouth, and posted signs were cited in decreasing order as other sources of this knowledge. When asked if the 2 week closing inconvenienced them, 71% indicated that it did not. This figure was less (54%) for more frequent visitors and residents than for less frequent visitors (89%).

The most sought after game fish was the largemouth bass *(Micropterus salmoides)* with sunfish (*Lepomis* spp.), crappie (*Pomoxis* spp.), and pickerel (*Esox* spp.) following in that order of popularity. Most fishermen indicated they fished for more than one species. Fishermen usually employed more than one type of fishing tackle, but hook and line with live bait was favored by most. Fishermen were approximately equally divided in response to the question whether they caught more, less or the same amount of fish following treatment.

When asked how the treatment affected fishing and boating, 63% indicated that they enjoyed fishing more and 60% indicated that they enjoyed boating more following treatment. In general, 72% thought that the weed control project helped the recreational aspects of the lake. Frequent visitors and residents responded less favorably than infrequent visitors. The same trend was noted in response to the question about the enjoyment of fishing.

An overwhelming majority (91%) favored the use of chemicals to control nuisance aquatic weeds. Nearly everyone appended the condition that chemicals employed should not be harmful to fish or the reservoir ecosystem in general.

DISCUSSION

The decline rate of both herbicides from the water was rapid; the levels declined to the limits of assay detectability by 3 days. Our data supports other authors' findings that these herbicides are not persistent in water (Yeo, 1967, 1970; Hiltibran *et al.*, 1962, 1972; Frank and Comes, 1967; Van Horn, 1975). The rapid decline may be due to adsorption onto soil particles, plants and plant materials, active uptake by macrophytes and other biota, and by phytochemical decomposition. The magnitude of herbicide accumulation in egeria tissue found in our study was generally similar to that found by other authors (Coats *et al.*, 1964; Newman and Way, 1966; Calderbank, 1973). We did not find that the chemicals were released back into the water as the weeds decomposed, a possibility suggested by Yeo (1967).

The magnitude of diquat accumulation in hydrosoils found in our study generally agreed with that found by other authors (Haven, 1969; Frank and Comes, 1967; Gilderhaus, 1967). Our data, showing the persistent nature of hydrosoil-bound diquat, also supports the findings of others (Frank and Comes, 1967; Newman, 1970; Way *et al.*, 1971). Knight and Thomlinson (1967) and Hiltibran *et al.* (1972) have shown that diquat is strongly adsorbed to soil particles at cation exchange sites and desorption is not likely. On the other hand, endothall is not a persistent herbicide in bottom sediments owing to its rapid biological degradation (Montgomery and Freed, 1974; Sikka and Rice, 1973; Sikka and Saxena, 1973). Keckemet (1969) showed that the metabolic breakdown products of endothall were harmless and did not accumulate in the environment.

Higher levels of both herbicides were found in the shallow water quadrant compared to the deep water quadrant. This disparity can be attributed to an unequal application rather than quadrant depth.

It has been shown that diquat and endothall may enter a fish's body but are not accumulative since the herbicides are metabolized or voided soon after they disappear from water (Freed and Gauditz, 1961; Newman, 1970; Sikka, 1973; Calderbank, 1972; Beasley *et al.*, 1975). Gilderhaus (1967) and Cope (1966) found diquat residues in bluegills 6 weeks after treatment with 1.0 ppm. Calderbank (1972) and Hiltibran *et al.* (1972) showed that most if not all diquat residues in fish were located in skin, gills and viscera and not in edible flesh. Our data partially supports this generalization since we found no herbicide accumulation in edible flesh.

The toxic levels of these herbicides to mammals, birds and fish are many times higher than found at any time in the reservoir (Akhavein and Linscott, 1968; Keckemet, 1969; Clark and Hurst, 1970). Both diquat and endothall have been recommended for use in fish cultural operations as treatment for disease (Snieszko, 1975) and for weed control (Armstrong, 1974). No fish kills were observed following treatment. The possibility of unwanted effects on fish due to chronic toxicity was reduced due to the rapid decline rate of the herbicides. The two week closure was suitable time to allow the chemicals to dissipate. The suspension of fishing activities was acceptable to sportsmen, causing only minor inconvenience.

Plants beneath the surface could not be detected by infrared photographs, but egeria mats reaching the surface were well documented. Duckweed (*Lemna minor* L.) and watermeal (*Wolffia* sp.), both small free-floating plants, were frequently trapped by these mats and served to delineate the distribution of the egeria stands. The aerial photographs readily revealed that the amount of water available for fishing and boating increased after treatment.

One month after treatment, the weeds had completely disappeared from both quadrants. One year after treatment regrowth was much more evident in the shallower of the two study areas. Egeria can spread quickly within a lake by lateral growth from roots and by fragmentation. Unaffected plants remaining after treatment coupled with the plant's high proliferation potential account for rapid repopulation of herbicide-cleared waters. In shallow areas, this repopulation is expedited due to the increased light incident on the substrate. Regrowth such as found in the shallow study area was also typical of other areas of the reservoir, especially in portions treated with the siphon and outboard motor boat indicating that surface spray from an airboat is a more effective means of herbicide application than siphoning. Riemer (1964) found that low and high treatment rates of diquat achieved equal plant kill but regrowth was more rapid in low treatment cases. In our study, the regrowth prompted 21% of the anglers polled to indicate that the treatment made no difference in the reservoir's recreational capacity.

Approximately 30% of the sportsmen thought that the treatment either hurt the lake or made no difference and thought that they enjoyed fishing and boating the same or less after treatment. A common reason for these feelings was the belief that the filamentous algae (*Lyngbya* sp.), an oscellatoriatious bluegreen algae indigenous to the reservoir, had increased in quantity following treatment. Quantitative plant sampling and visual observations confirmed this contention (Berry *et al.*, 1975). Fishermen reported that mats of this algae, which rise and fall in the water column depending on climatological conditions are actually more difficult to contend with than egeria. Fortunately, *Lyngbya* had proliferated only in limited areas. Another reason expounded by anglers that the treatment hurt the lake or made no difference was that afterward there were more boats and fishermen, thus decreasing their enjoyment of the total fishing experience.

Residents and frequent visitors responded less favorably to the success of the treatment than infrequent visitors. The difference can be explained by the distribution of anglers on the lake. Most residents and frequent visitors are located or confine their activities to the western half of the lake where the treatment was carried out by siphoning and was less effective. Conversely, the eastern half of the lake, the part more thoroughly treated with the airboat, is used most by infrequent visitors.

CONCLUSIONS

Aerial photographs showed that a majority of surface water in two study quadrants remained open for angling one year after treatment. Repopulation of egeria was more rapid in shallow areas than in deeper areas. The herbicides have environmental advantages in that they dissipate from the water quickly and are not extensively accumulated. A great majority of anglers agree with the use of herbicides to control aquatic weeds and most people are willing to refrain from fishing while such a program is being carried out. A smaller majority believed that the weed control project on the Chickahominy helped the weed problem and increased fishing and boating enjoyment. Reoccurrence of stands of egeria in some places and increased abundance of *Lyngbya* were cited by some fishermen who believed that the project was not beneficial or made no difference.

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