dividual plant species' actions and interactions with other species in stable and unstable impoundments must be understood if we are to make water level manipulation a more exacting tool for management.

I think it is evident from the information herein that documented scientific research is needed in conjunction with this important tool in aquatic weed control. We have recently begun such a project and are trying to measure and establish numerical values for the various parameters.

Looking at the future of aquatic weed control in Louisiana, it becomes obvious that no one tool or technique alone will be totally effective. Integrated management, i.e. water level manipulation, herbicides and biological agents, offers the solution to our problems.

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Water Level Fluctuation And Herbicide Application: An Integrated Control Method For Hydrilla In A Louisiana Reservoir

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ABSTRACT

Water level fluctuation of Sibley Lake in 1973-74 was very effective in controlling all serious aquatic weeds. An integrated control method combining water level fluctuation and herbicide application effectively reduced the hydrilla (*Hydrilla verticillata* Royle) population by 100%. The severe egeria (*Egeria densa* Planch.) problem in the remainder of the lake was reduced by more than 99% using water fluctuation. The rapid refilling and moderate turbidity levels placed additional stress on remaining plants, thereby increasing the degree of control. Results of this project indicate that an integrated method of water fluctuation and herbicide application can effectively control hydrilla in a Louisiana reservoir.

INTRODUCTION

Hydrilla was first discovered in the United States near Miami, Florida in 1960 (2). It has since dispersed over the entire state and into Georgia and Alabama. Hydrilla is found in canals, ditches, pools, lakes, marshes, slow streams, rivers, tidal water areas, and particularly in calcareous sites (7). It grows to depths of 6 to 7 m and commonly produces mats of vegetation so dense that birds and small animals can walk over them (2).

In July 1973, researchers working with a University of Southwestern Louisiana aquatic plant research team brought in samples of what was thought to be egeria. The samples were collected from Spanish Lake, a 502-ha impoundment located near New Iberia, Louisiana. University botanists soon identified the plant as hydrilla. This was the first positive identification of hydrilla in Louisiana.

Specimens of hydrilla were collected from Sibley Lake in Natchitoches, Louisiana by graduate students from Northwestern State University in January 1973. The absence of necessary taxonomic characters, particularly flowers or turions, prevented positive identification until August 1973.

Additional hydrilla infestations were discovered in June 1974, in Lake Theriot and Bayou Terrebonne in southeast Louisiana. Figure 1 depicts known hydrilla infestations in Louisiana.

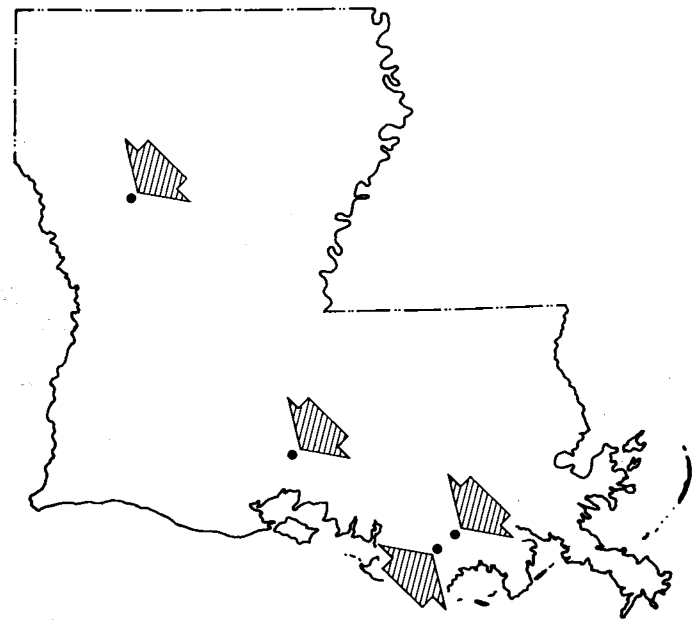

Figure 1. Reported hydrilla infestations in Louisiana as of July 1974.

Water level manipulation of reservoirs has been used for more than 30 years as a tool in managing fish populations. Fluctuated Tennessee Valley Authority reservoirs were found to produce better fishing than those with stable water levels (3).

The most critical factors governing the success of water level manipulation of Louisiana reservoirs were found to be proper timing and extent of drawdown (6). The Louisiana Wild Life and Fisheries Commission has utilized water level manipulations since 1946 to assist in controlling aquatic weeds and balancing fish populations. This was found to be the only economically feasible method of controlling aquatic plant populations in public reservoirs. Abundance of two aquatic plant species was reduced by an estimated 90% by use of 1.5 to 2.4-m drawdowns in two Louisiana reservoirs (6). Several aquatic weed species were controlled in Arkansas using fluctuations (5). The fluctuation of the water level of Rodman Reservoir in Florida gave excellent control of egeria, coontail (*Ceratophyllum demersum* L.), hydrilla, and naiad (*Najas guadalupensis* (Sprengel) Magnus), but there was a substantial increase in waterhyacinth (*Eichhornia crassipes* (Martius) Solms), alligatorweed (*Alternanthera philoxeroides* (Martius) Grisebach), smartweed (*Polygonum punctatum* Ell.), and water purslane (*Ludwigia palustris* (L.) Ell.) (4). The major objective of this project was to achieve maximum control of hydrilla in Sibley Lake utilizing a combination of water level manipulation and herbicide applications. Although essentially a management project, quantitative research data were collected and evaluated for possible use in future management efforts.

Sibley Lake, located in Natchitoches, Louisiana, is a 810-ha impoundment completed in 1962 to be used as the water reservoir for the city of Natchitoches. Sibley Lake has 61 km of shoreline and an average depth of 2.75 m. By an act of the State Legislature, the water body was declared to be within the Natchitoches city limits to allow the city control over use and management of the lake.

Immediately following positive identification of hydrilla from Sibley Lake in August 1973, a survey was made by Louisiana Wild Life and Fisheries aquatic plant control biologists and Northwestern State University aquatic plant research personnel. Underwater inspection with SCUBA (Self Contained Underwater Breathing Apparatus) revealed dense stands of hydrilla from the end of the northwest arm to a depth of 2 m. Hydrilla was found mixed with egeria beyond this point to a depth of 2.9 m. Inspection of north and south banks of the infested arm to the point of confluence with the main lake body revealed sparsely scattered plants to a depth of 1.4 m. A few scattered hydrilla plants were found at two boat launching ramps. A severe infestation of egeria was found along the shore and in the shallow end of the southwest arm.

In early October 1973, core samples were taken in hydrosoil beneath dense hydrilla mats to determine if subterranean turions were present. No turions were found; however, the area of topmatted hydrilla had more than doubled in only 6 weeks.

In October 1973, Commission biologists met with the Natchitoches City Council and presented recommendations for control of hydrilla in Sibley Lake. The Natchitoches City Council agreed to a 2.13-m drawdown to begin 31 October 1973. The lake would be maintained at this lowered level until 15 January 1974, at which time it would be allowed to refill.

METHODS AND MATERIALS

The water level of Sibley Lake was lowered 2.13 m at an average rate of 10.7 cm per day beginning 31 October 1973. The gates were shut on 15 January 1974 to allow the lake to return to normal pool stage. Very heavy rains caused the lake to rise from 2.13 m below pool stage to 0.61 m above pool stage in 11 days. This produced a total water fluctuation of 2.74 m.

Four transects were established to gather data to describe the submersed vegetation in Sibley Lake. Two transects were established in the hydrilla infested northwest arm and two were established in the egeria infested southwest arm. Vegetative samples were collected at 30.5-cm depth intervals along each transect, with the first sample being taken at a depth of 30.5 cm. Samples were taken using a 61 cm by 61 cm sheet metal quadrat possessing cutting edges along the bottom. The unit was designed to be hoisted above water level by a boom attached to a 4.3-m aluminum boat. A quick-release device allowed the sampling unit to free-fall through the water, severing all vegetation in its path. A nylon net sack was placed over the top of the quadrat to retain vegetation inside the unit. A cutter inserted in a slot near the quadrat bottom was used to cut stems at the top of the hydrosoil. The unit containing vegetation was then raised above the water and lowered into the boat and all vegetation inside the unit was removed and placed into a labeled plastic bag for transporting to the laboratory. At the laboratory, they were washed and sorted by species, spun in a variable-speed centrifuge at 1200 rpm for 2 min to remove excess water, and weighed.

Each transect was sampled in October 1973 and June 1974. Percent control for each species at each depth interval was determined using the formula:

$$\text{Percent control} := \frac{\text{Species A (1973)} - \text{Species A (1974)}}{\text{Species A (1973)}} \times 100$$

Data collected from the two transects in the northwest arm of the lake were combined for purposes of analysis and the same procedure was used in data analysis in the southwest arm. These data can be considered as representative of vegetational changes in Sibley Lake during the water fluctuation period.

A comprehensive survey utilizing SCUBA was made 1 November 1973, to determine the exact extent of hydrilla infestation. Three days after drawdown initiation, two airboats began daily overspray operations on freshly exposed hydrilla, spraying (2,4-dichlorophenoxy)acetic acid (2,4-D) at a rate of 2.7 kg active ingredient per 0.41 ha mixed with 0.5 liter of surfactant (Active Plus) and 757 liters of water. The airboats were equipped with drums and air-cooled driven 41.6 liters per min Hypro pumps. This operation continued daily until the lake reached 2.13 m below pool stage on 19 November 1973.

The second phase of the herbicide treatment began 20 November 1973. The remaining 24.3 ha of hydrilla infested waters were marked off into 0.41 ha plots using plastic jugs as markers. A treatment of 1 ppm of 6,7-dihydrodipyrido[1,2-*a*:2′,1′-*c*]pyrazinediium ion (diquat) and 4 ppm copper sulfate pentahydrate was applied. A large barge was towed to the application site to be used as a platform for mixing and transferring the herbicides to the airboats. Two airboats, each equipped with three stern nozzles to inject the herbicides approximately 15 cm below the water surface were used to treat each plot.

RESULTS AND DISCUSSION

Treated Area

Figures 2, 3, 4, and 5 show results of surveys made of hydrilla infestation in Sibley Lake. Infestation increased from less than 0.8 ha in January 1973 to approximately 216 ha in November 1973. This clearly demonstrates the ability of this plant to spread rapidly and infest new areas. Any water body can be choked with vegetation in a relatively short time (1). Therefore, effective control is essential if the water body is to be used for man's purposes. The survey in June 1974, (Figure 5) shows the small area where plants produced from axillary and subterranean turions were found.

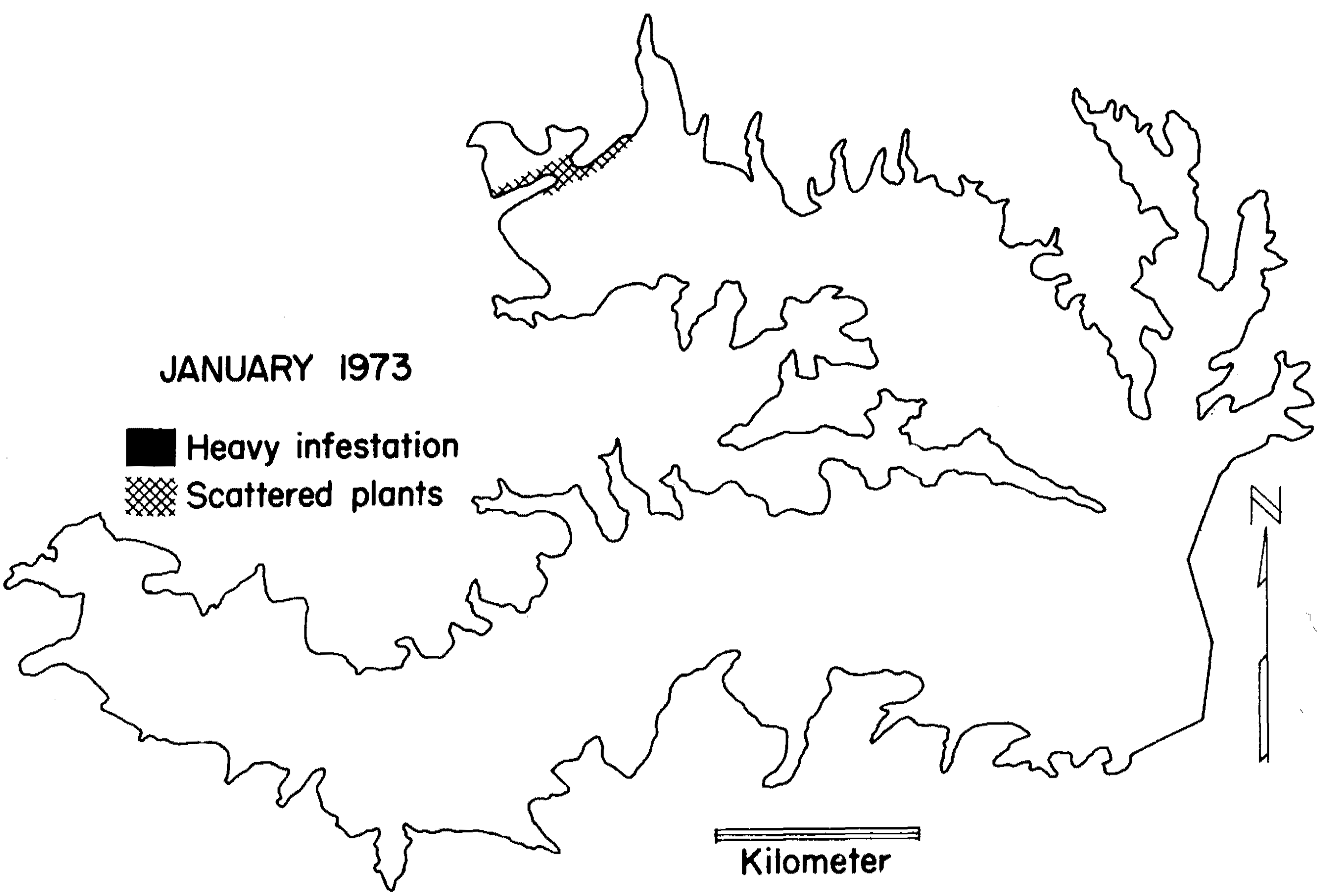

Figure 2. Sibley Lake hydrilla infestation during January 1973.

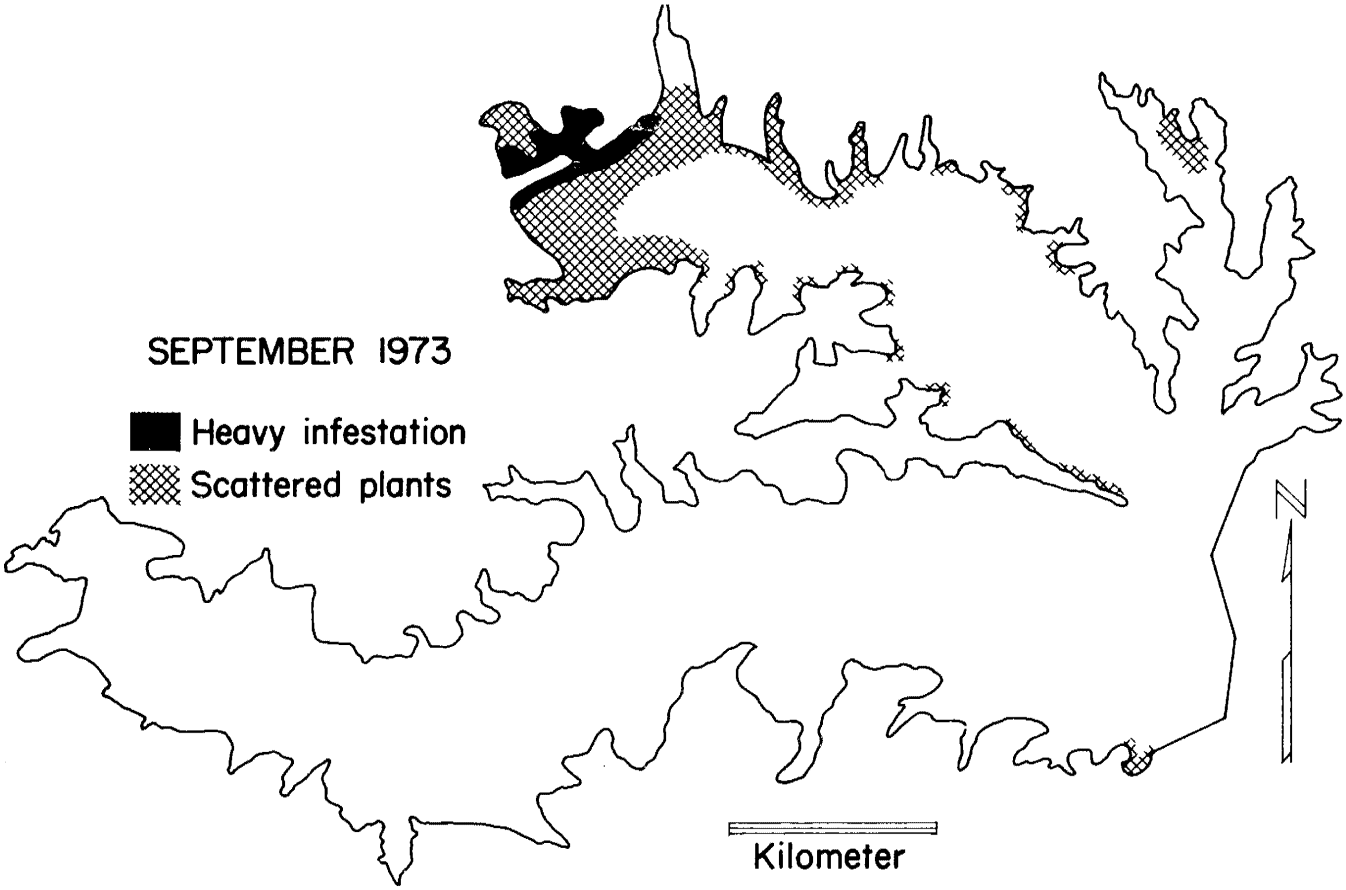

Figure 3. Sibley Lake hydrilla infestation during September 1973.

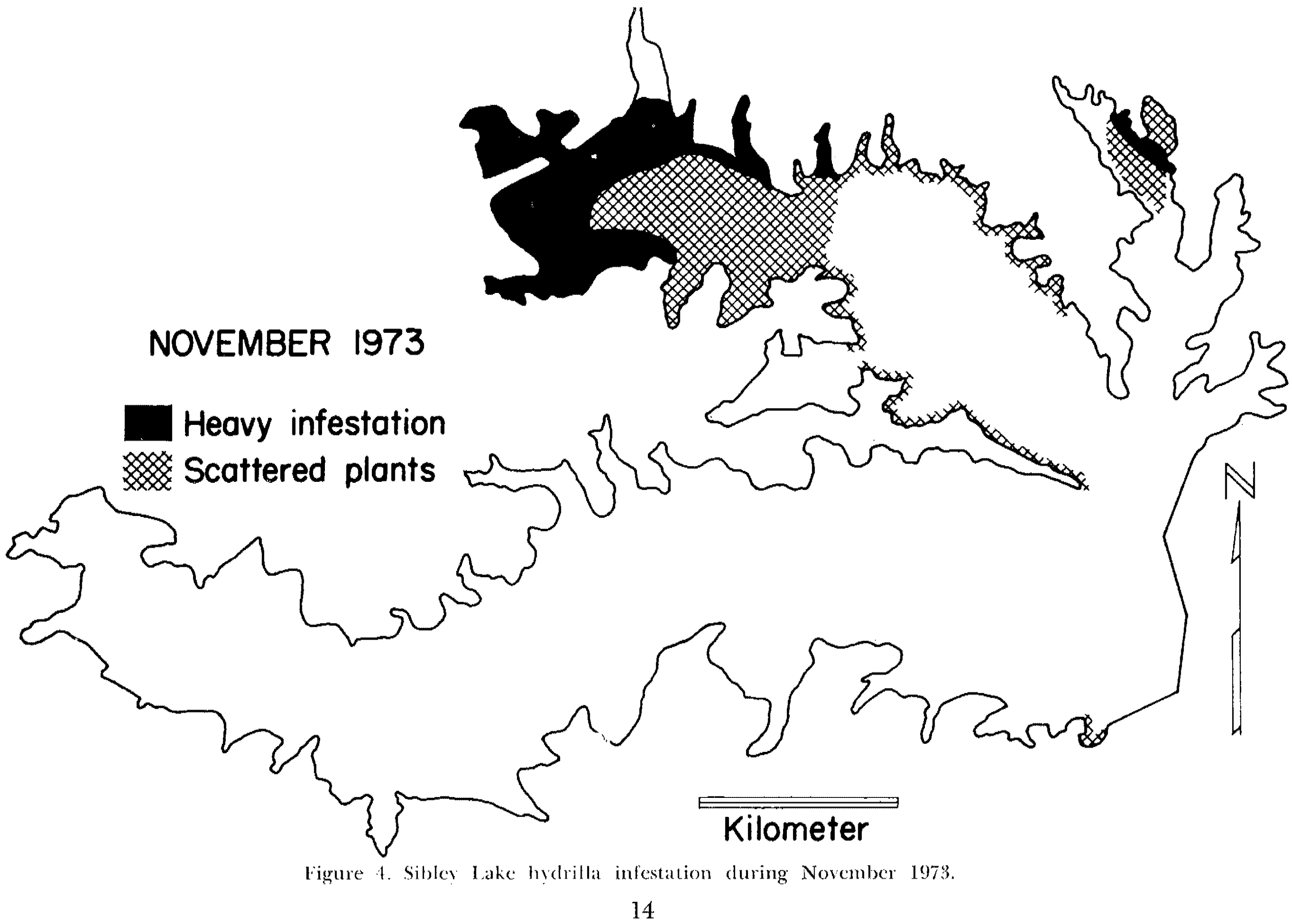

Figure 4. Sibley Lake hydrilla infestation during November 1973.

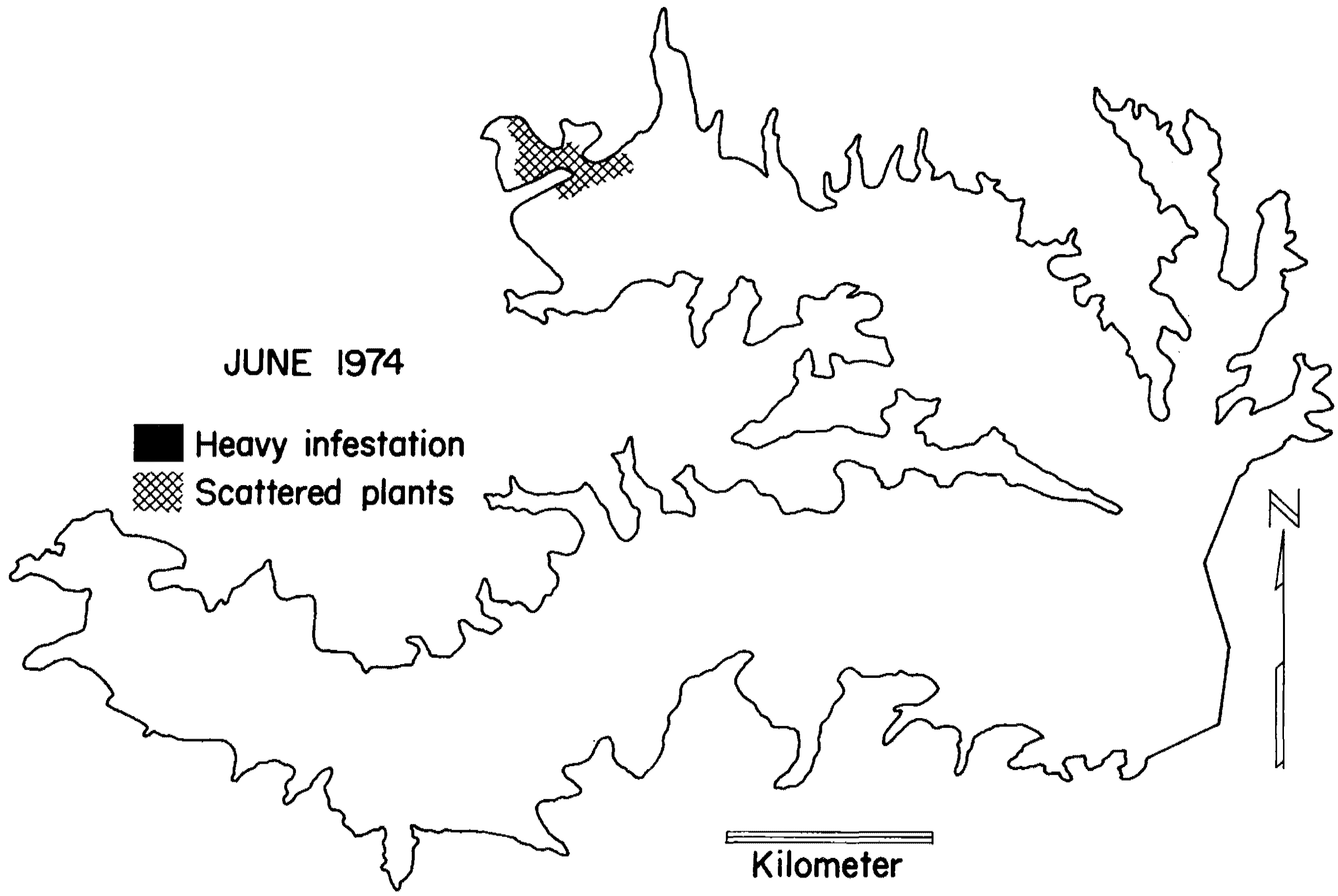

Figure 5. Sibley Lake hydrilla infestation during June 1974.

Average freshweights of aquatic plant species per m² for the northwest arm of Sibley Lake are shown in Table 1. These values are arranged by depth intervals. Hydrilla, which averaged 1330 and 1100 g freshweight in the first and second depth intervals in 1973, decreased 100% by June 1974. The only remaining hydrilla was found in two sample plots, one at 0.9 m and the other at 2.7 m. Plants from both of these plots weighed less than 1 g and were probably propagated from turions produced in 1973. Egeria, which had high average freshweights at all depth intervals, decreased 100% by June 1974. Coontail was effectively reduced 100%, the only fragment found being in the first depth interval. Coontail was effectively eliminated as a problem species.

Stonewort (*Chara vulgaris* L.) was found only in the first depth interval on both sample dates. The data show a 72% reduction in 1974, which is opposite of what was expected. This species normally increases in abundance in

TABLE 1. AVERAGE CALCULATED FRESHWEIGHT (g/m²) AND CONTROL (%) OF AQUATIC WEEDS IN TWO HYDRILLA INFESTED TRANSECTS ARRANGED ACCORDING TO DEPTH BEFORE (10/73) AND AFTER (6/74) WATER FLUCTUATION.

SPECIES	0 to 1.2 m		1.2 to 2.1 m		2.1 to 3.0 m	
	10/73	6/74	10/73	6/74	10/73	6/74
Egeria	954.6	— (100%)	644.2	— (100%)	151.8	— (100%)
Hydrilla	1329.8	T[a] (100%)	1100.5	— (100%)	33.3	T (100%)
Coontail	202.9	T (100%)	402.0	— (100%)	49.2	— (100%)
Stonewort	9.7	2.7 (72%)	—	—	—	—
Pondweed	—	T	—	—	—	—
Slender Spikerush	—	T	—	—	—	

[a] T: indicates that at least one plot contained the species, but less than 1.0 g in the plot.

shallow waters of Louisiana lakes following drawdown. The 2,4-D overspray could possibly have affected the abundance of this species.

Pondweed (*Potamogeton capillaceus* Poir.) and slender spikerush (*Eleocharis acicularis* (L.) R. and S.) were not present in 1973 samples but were present in 1974. This represents a shift in the vegetational composition of the lake to an earlier successional stage. These species were not present in 1973 probably because they could not compete with other species such as egeria and hydrilla.

During the 2,4-D overspray, several instances of possible herbicidal damage were observed for hydrilla stranded in small, shallow, isolated pools. No positive proof exists that the 2,4-D overspray was effective in killing the stranded plants. This part of the operation was undertaken to produce additional stress upon exposed hydrilla and thereby enhance the drawdown effects.

High winds and scattered rainfall produced an average turbidity level of 25 JTU (Jackson Turbidity Units) which caused much concern preceding the diquat plus copper sulfate application. It is generally thought that moderate turbidities may adversely affect diquat uptake. Despite turbidity, treatment was carried out due to the late date. Severe herbicide damage was observed within 2 weeks after application. Water temperature during application averaged 18.3 C. Turbidity levels increased after application to a high of 80 JTU in late January 1974. Hydrilla fragments were not found after rewatering until the June 1974 survey when all plants found were determined to be propagated from turions. The June 1974 survey revealed no plants in the diquat plus copper sulfate treated waters.

Untreated Area

The average freshweights of aquatic plant species per m^2 in the southwest arm of Sibley Lake are shown in Table 2. Egeria, which had a very high freshweight average in 1973, decreased 100% in the first and second depth intervals and 99.3% in the third depth interval. Reduction was to be expected in the 0 to 2.1 m depths because egeria is usually easily reduced by drawdown in Louisiana. The very interesting results is the degree of control achieved in the 2.1 to 3 m depths. This area was not subjected to drying but experienced turbidity levels of 80 JTU for a lengthy period after the lake refilled.

Stonewort increased by 8330% in the 1974 samples. This great increase in stonewart substantiates the conclusion that the repeated application of 2,4-D during the overspray operation significantly reduced the growth of stonewort in the treated northwest arm of Sibley Lake.

Several primarily marginal plant species present before the drawdown did not reappear after the drawdown. These included southern water grass (*Hydrochloa caroliniensis* Beauv.), water primrose (*Ludwigia repens* Forst.), naiad, arrowhead (*Sagittaria subulata* (L.) Buchenau), and burhead (*Echinodorus* sp.). Conditions favorable for growth of these plant species apparently do not exist at this time. Sibley Lake has been refilled less than 5 months and these species possibly have been unable to compete with stonewort in shallow water areas.

Pondweed and slender spikerush were found in trace amounts in the first depth interval in 1974. Slender spikerush was not found in 1973 which indicates a successional

TABLE 2. AVERATE CALCULATED FRESHWEIGHT (g/m^2) AND CONTROL (%) OF AQUATIC WEEDS IN TWO EGERIA INFESTED TRANSECTS ARRANGED ACCORDING TO DEPTH BEFORE (10/73) AND AFTER (6/74) WATER FLUCTUATION.

SPECIES	0 to 1.2 m		1.2 to 2.1 m		2.1 to 3.0 m	
	10/73	6/74	10/73	6/74	10/73	6/74
Egeria	1080.6	— (100%)	1295.9	T[a] (100%)	1415.2	10.2 (99.3%)
Coontail	50.5	— (100%)	30.6	— (100%)	30.6	T (100%)
Southern Water Grass	25.5	— (100%)	—	—	—	—
Water Primrose	8.9	— (100%)	—	—	—	—
Burhead	T	—	—	—	—	—
Stonewort	T	83.3 (-8330%)[b]	—	—	—	—
Naiad	34.1	— (100%)	T	—	—	—
Arrowhead	T	—	—	—	—	—
Pondweed	T	T	—	—	—	—
Slender Spikerush	—	T	—	—	—	—

[a]T: indicates that at least one plot contained the species, but less than 1.0 g in the plot.
[b]: indicates a net increase in vegetation.

change in plant composition. This plant probably could not compete with the heavy concentrations of egeria.

The integrated control method combining water level fluctuation and herbicide application was very effective in controlling all serious aquatic plants in Sibley Lake. The rapid refilling (11 days) and moderate turbidity levels placed additional stress on remaining plants, thereby increasing the degree of control.

ACKNOWLEDGMENT

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Effects Of Water Fluctuation On Vegetation In Black Lake, Louisiana

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ABSTRACT

Water level fluctuation of Black Lake, Louisiana in 1972 successfully reduced the standing crop of egeria (*Egeria densa* Planch.) and cabomba (*Cabomba caroliniana* Gray) by more than 99%, and effective control was achieved over other species. Exposure of plants to drying and temperature extremes during the drawdown, an extended period of high water following refilling, and cold temperatures during the Spring months following drawdown were prime factors in eliminating the plant populations. The degree of control achieved was probably maximal under ideal weather conditions. Results clearly indicate the potential value of water fluctuation as an aquatic plant management tool.

INTRODUCTION

Water level fluctuation of reservoirs has been used as a tool in fish population management for more than 30 years. Fluctuated Tennessee Valley Authority reservoirs were found to produce better fishing than those with stable water levels (2). Drawdown has been utilized in Arkansas to bring about a balance between predator fish populations and their food supplies and to maintain expanding fish populations (4). The largemouth bass (*Micropterus salmoides* Lacepede) and bluegill (*Lepomis macrochirus* Rafinesque) populations of small Georgia impoundments were brought into balance with the aid of water level fluctuation (7). The most critical factors governing success of water level manipulation of Louisiana reservoirs were found to be proper timing and extent of drawdown (5).

Drawdowns have also been used in several instances as a means of checking growth of troublesome aquatic plants. Louisiana has used drawdown for a number of years as the only economically feasible method of controlling aquatic plant populations in public reservoirs. Although quantitative studies of effects of fluctuation on plant populations were not conducted, the abundance of pondweed (*Potamogeton* sp.) (1) and southern naiad (*Najas guadalupensis* (Spreng.) Magnus) was reduced by an estimated 90% by using 1.5 to 2.4 m drawdowns in two Louisiana reservoirs (5). Several aquatic weed species were controlled in Arkansas using fluctuation (4). A 1-m Fall and Winter drawdown of Lake Catherine in Arkansas, followed by stocking 118 Israeli carp (*Cyprinus carpio* L.) per ha, gave excellent control of coontail (*Ceratophyllum demersum* L.) and egeria (6). Fluctuation of the water level of Rodman Reservoir in Florida (3) resulted in excellent control of