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.

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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 egeria, but enhanced the spread of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms.) and alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.).

The major objective of this study was to quantitatively assess effects of water level fluctuation on vegetation of Black Lake, Louisiana. This lake, located in north central Louisiana, is a 5460-ha impoundment created in 1932 by placement of a dam downstream from the confluence of Black Lake and Saline bayous. Until 1960, periodic flooding of Black Lake by Red River backwaters created a relatively unstable water level which was unfavorable for establishment and persistence of aquatic plant populations. Significant flooding has not occurred since 1960, thereby creating a stable lake water level. As a result, Black Lake has experienced severe infestations of cabomba, floating bladderwort (*Utricularia inflata* Walt.) and egeria.

METHODS AND MATERIALS

The water level of Black Lake (Figure 1) was lowered 1.8 m beginning 20 July 1972 at a rate of approximately 10 cm per day. The drawdown was interrupted due to low dissolved oxygen concentrations in September 1972. The lake level was lowered an additional 0.6 m beginning 1 October 1972, making the total drawdown 2.4 m below normal pool stage. The 2.4-m drawdown was scheduled to be maintained until 15 January 1973. Abnormally heavy rainfall, beginning in November 1972 and extending through the Spring months of 1973, produced a rapid rise in the water level to a maximum of 2.1 m above normal pool stage in May 1973. This produced a total water level fluctuation of 4.5 m within a 10-month period.

Two methods were used to sample vegetation of Black Lake. Eight transects, scattered throughout the lake, were established. A second sampling procedure involved vegetational analysis of 24 permanent 0.4-ha plots located at various depth intervals.

Vegetative samples were collected at 30.5-cm depth intervals along each transect with the first sample being taken at a depth of 15 cm. Samples were collected using a 61 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 V-hull 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 quadrat top

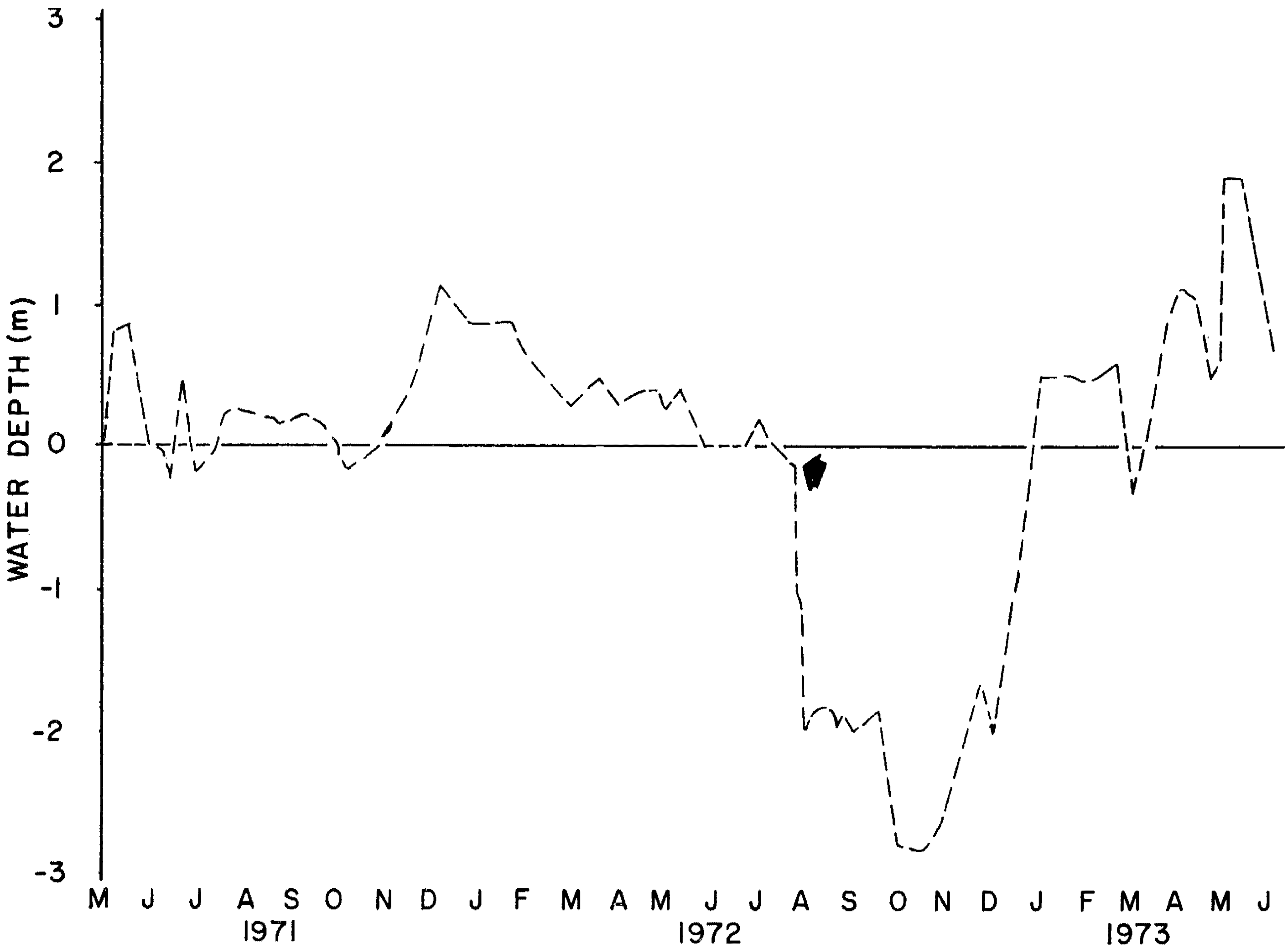

Figure 1. Water level above or below normal pool stage of Black Lake from May 1971 to June 1973 taken at weekly intervals. The arrow indicates initiation of drawdown.

to retain severed vegetation. A cutter inserted in a slot near the quadrat bottom was used to sever stems at the hydrosol surface. The unit containing vegetation was then raised above water and lowered into the boat where all vegetation inside the unit was removed and placed into a plastic bag. Plant samples collected each day were placed in a refrigerator until laboratory analysis. In the laboratory, plant samples were washed and sorted according to species, spun in a centrifuge at 1200 rpm for 2 min to remove excess water, and weighed.

Each transect was sampled in July 1972, and in June and August 1973. Control for each species at each depth interval for both sampling dates in 1973 was determined using the following formula:

$$\frac{\text{FW species A in 1972} - \text{FW species A in 1973}}{\text{FW species A in 1972}} \times 100 = \text{Control } (\%)$$

where FW equals freshweight. Data collected from the eight transects were combined for purposes of analysis and can be considered as representative of vegetative changes in Black Lake during the study period.

The permanent plot study provided a means of checking the reliability of the transect sampling method. Six permanent 0.4 ha plots were established in each of four depth zones: 0 to 1.8 m, 1.8 to 2.4 m, 2.4 to 3.1 m, and 3.1 to 3.7 m. Frequency values for species found in the plots were determined for the summers of 1971, 1972 (prior to drawdown), and 1973. Frequency was calculated by dividing the number of samples containing a species by the total number of samples (60). The bottom was checked for presence of vegetation using SCUBA (Self Contained Underwater Breathing Apparatus) prior to 1973 sampling, and no samples were taken in plots without vegetation.

RESULTS AND DISCUSSION

Average freshweights of aquatic plant species (g/m^2) per plot are shown in Table 1. Egeria, which had a high freshweight average at all depths in 1972, decreased 99.9% by August 1973. The only remaining egeria at that time was found at 0 to 1.2 m depths and probably represented fragments which washed into shallow areas and became rooted. A similar response was noted in small Georgia impoundments for several species (7).

Cabomba, the second most important species in Black Lake prior to drawdown, decreased 99.4% by August 1973, and showed essentially the same response as egeria with reference to depth distribution. The slight increase in

TABLE 1. AVERAGE FRESHWEIGHT (g/m^2) AND CONTROL (%) OF AQUATIC PLANTS IN EIGHT TRANSECTS, ARRANGED ACCORDING TO DEPTH BEFORE AND AFTER WATER FLUCTUATION.

SPECIES	0 to 1.2 m			1.2 to 2.4 m			2.4 to 3.7 m		
	7/72	6/73	8/73	7/72	6/73	8/73	7/72	6/73	8/73
Egeria	618.4	7.3 (98.8)[a]	1.1 (99.8)	815.3	0.3 (99.7)	— (100.0)	1073.0	10.2 (99.7)	1.1 (100.0)
Floating Bladderwort	60.8	50.6 (16.8)	82.6 (−35.8)[c]	111.1	T[b] (100.0)	17.5 (84.3)	7.3	3.2 (55.6)	T (100.0)
Cabomba	11.0	1.6 (85.4)	2.4 (78.0)	102.8	T (100.0)	T (100.0)	275.2	1.6 (99.4)	— (100.0)
Snailseed Pondweed	7.0	— (100.0)	3.2 (54.0)	10.2	— (100.0)	— (100.0)	—	—	— —
Coontail	1.6	5.6 (−350.0)	21.5 (−1333.0)	14.8	T (100.0)	T (100.0)	182.4	4.6 (97.5)	— (100.0)
Stonewort (Chara)	T	—	105.4	T	—	4.3	—	—	—
Southern Naiad	T	—	T	—	—	—	—	—	—
Slender Spikerush	—	0.8	0.5	T	T	3.5	—	—	—
Eastern Bladderwort	—	T	T	3.8	— (100.0)	— (100.0)	1.6	— (100.0)	— (100.0)
Arrowhead	—	0.8	3.2	—	T	—	—	—	—
Water Primrose	—	8.3	—	—	—	—	—	—	—
Southern Water Grass	—	3.5	T	—	—	—	—	—	—
Roundleaf Bacopa	—	0.3	—	—	—	—	—	—	—
Variable Leaf Milfoil	—	T	—	—	—	—	—	—	—
Smartweed	—	T	—	—	—	—	—	—	—
Frogbit	—	T	—	—	—	—	—	—	—
Average for all species	699.4	78.8 (88.7)	220.0 (68.5)	1058.0	0.3 (100.0)	25.3 (97.6)	1539.5	12.1 (99.2)	0.0 (100.0)

[a] Each number in parentheses represents degree of control achieved relative to 1972 values.
[b] T means that at least one plot contained the species, but less than 1g was found.
[c] The negative value indicates an increase over the initial weight.

abundance from June to August 1973 was due primarily to growth of cabomba seedlings which germinated after the lake refilled.

Although coontail increased by 1300% at the 0 to 1.2 m depths, freshweights before and after drawdown were low, and the total weight increase was slight. Coontail was not abundant at the 0 to 1.2 m depths prior to drawdown; therefore, the increase could be partially explained by the fact that coontail was not anchored in hydrosol and drifted into shallow areas when the lake level returned to normal. Coontail was successfully eliminated as a problem species in deeper lake areas.

The response of floating bladderwort to water fluctuation was similar to that of coontail. The increase in bladderwort was related to surviving individuals in downlake areas being blown into shallow uplake areas where they became anchored. It is possible that the population of floating bladderwort will increase in years immediately following completion of the water fluctuation program. Indications are that floating bladderwort represents an earlier stage of aquatic plant succession than egeria or cabomba.

Stonewort (*Chara vulgaris* L.) and slender spikerush (*Eleocharis acicularis* (L.) R. & S.) increased in abundance in shallow lake areas following water fluctuation. This also is indicative of a successional shift in lake vegetation. It is generally accepted that these species cannot compete favorably with more aggressive species such as egeria and cabomba under stable water conditions.

Several primarily marginal species which were not present in samples taken prior to drawdown were found at the 0 to 1.2 m depths in June 1973. These included arrowhead (*Sagittaria subulata* (L) Buchenau), water primrose (*Ludwigia repens* Forst.), southern water grass (*Hydrochloa caroliniana* Beauv.), roundleaf bacopa (*Bacopa rotundifolia* (Michx.) Wettst.), variable leaf milfoil (*Myriophyllum heterophyllum* Michx.), smartweed (*Polygonum amphibium* L.) and frogbit (*Limnobium spongia* (Bosc.) Steud.). However, only arrowhead and southern water grass were found 2 months later. Presumably, other species were not able to successfully compete with more aggressive species such as coontail and floating bladderwort, which were blown into shallow lake areas from deeper areas.

Southern naiad and eastern bladderwort (*Utricularia gibba* L.), found in trace amounts in August 1973, were not eliminated by the water fluctuation. However, eastern bladderwort was restricted to shallow areas following fluctuation.

Frequency data obtained by sampling permanent plots (Table 2) show the same trends among plant species as was shown by transect analysis. The permanent plots were established 2 years prior to the decision to use water fluctuation; therefore, plot selection could not have biased results of this study. This is important because the transect method described in this paper is a new method and additional data from the permanent plot study corroborate findings of the transect study, even though different parameters were estimated.

It is impossible to assess effects of the 2.4-m drawdown independently of high water levels experienced following drawdown. However, other area lakes which experienced similar water levels were still heavily infested with a variety of aquatic plants in 1973. Therefore, it is probable that high water levels alone could not have produced the degree of control obtained in Black Lake. It is also unlikely that the degree of control achieved could be attributed solely to drawdown. Excellent control of egeria and cabomba was achieved even at depths where water was not completely removed. This suggests that additional stress was placed on plants in these areas which could not be attributed to drawdown alone. High water levels and cold temperatures during Spring months could have been responsible for some of the additional stress placed upon these species. A plankton bloom during late May and early June also could have been a contributing factor. All of these factors would have affected the date of regrowth initiation.

As has been pointed out previously (4,5), proper timing is of great significance in determining success of water level fluctuation. It appears that a Fall-Winter drawdown is the most effective type of drawdown for this area. Degree of success is also related to weather conditions present during and immediately following completion of drawdown. Conditions outlined above appeared to be ideal for placing additional stress on existing plant populations. It is impossible to predict the degree of control a particular drawdown will yield. Further study should make possible more reliable predictions concerning degree of control which can be expected under a given set of post-drawdown environmental conditions.

TABLE 2. AVERAGE FREQUENCY (%) OF AQUATIC PLANTS IN TWENTY-FOUR PERMANENT 0.4 HA PLOTS DURING A 3-YEAR PERIOD.

	0 to 1.8 m			1.8 to 2.4 m			2.4 to 3.1 m			3.1 to 3.7 m		
SPECIES	1971	1972	1973	1971	1972	1973	1971	1972	1973	1971	1972	1973
Floating Bladderwort	49.7[a]	37.5	63.7	36.7	11.4	2.5	0.0	18.3	1.7	0.0	0.3	0.0
Egeria	42.0	71.1	1.7	22.2	58.3	0.0	14.7	25.3	0.0	2.5	10.3	0.0
Cabomba	16.7	16.3	8.9	31.6	32.6	0.0	49.7	42.8	0.0	40.6	43.8	0.0
Coontail	0.8	0.0	27.5	0.6	4.4	0.8	1.7	2.5	1.7	0.3	10.0	0.0
Stonewort	0.0	0.0	36.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Southern Naiad	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Each value is the mean of 60 samples in each of six plots.

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Improved Application Techniques For Aquatic Herbicides

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ABSTRACT

Two gallons of 6,7-dihydrodipyrido(1,2-*a*:2′,1′-*c*) pyrazinediium dibromide (diquat) were used with either copper sulfate pentahydrate (copper sulfate) or copper triethanolamine complex (cutrine-plus) in an invert carrier to control hydrilla (*Hydrilla verticillata* Royle), eelgrass (*Vallisneria neotropicalis* Marie Vict), coontail (*Ceratophyllum demersum* L.), and southern naiad (*Najas guadalupensis* (Spreng.) Morong.) in Florida. Herbicide efficacy was evaluated in each test area, and water residue samples were collected and analyzed for diquat content. The submersed weed population was reduced 80% or more within 28 days after application. Residual levels of diquat were below the EPA interim tolerance of 0.01 ppm 3 days after application.

INTRODUCTION

Aquatic weed control with herbicides is only a part of water management, but a very vital part if our waterways are to continue to be useful. Allowed to grow unchecked, aquatic weeds can interfere with irrigation, drainage, fish production, transportation, and recreation.