Phase 3 (November to May, low flood).

This phase, which occupies the longest part of the annual cycle, consists of several consecutive stages of progressive decline in the magnitude of infestation. This decline of infestation is influenced by conditions prevailing during the long period of low flood. The factors involved are (a) the gradually subsiding water level, (b) the progressively reduced velocity of current, (c) the gentle counterclockwise shift of wind direction from southerly to northerly and, (d) the advancing season of increasingly unfavorable conditions involving low atmospheric humidity, strong desiccating cool winds, and low turbidity index of the Nile waters. The first sign of decline in the infestation is the appearance of innumerable communities that generally become cut-off from the receding width of the main course; their habitats become shallow, muddy, and eventually dry, and the vegetation is inevitably destined to lethal desiccation. Following that, and perhaps simultaneous with it, is the considerably reduced velocity of current during low flood. Hence, the massive northerly drift, maintained during high flood, relaxes, and is ultimately suspended when the current becomes sluggish. Later in the season, however, northerly winds, shifting from southerly, cause a gentle reversed drift of mid-stream free-floating waterhyacinth. The force of wind is, as a rule, variable and the influence of its southward direction is often modified by the meandering of the main course. In view of this, back-drift is generally erratic, but it eventually transports a substantial bulk of free-floating communities to various upstream locations. The destination of the back-drift is the original site of outbreaks: the Sudd-Sobat complex. There is also an obvious trend towards a much depressed vegetative vigor following the decline in infestation. This trend is evident by the reduction in vegetative reproduction, poor flowering, absence of seed regeneration, and remarkable dwarfness of individual plants.

Phase III terminates when the greater part of the White Nile system (Region II and III in particular) becomes free of infestation. The diminished swamps of region I, however, continue to sustain habitats that lodge remnants of aggregations originating from both back-drifts and from originally undischarged masses. These localized components survive in a state of vegetative dormancy until the return of the rejuvenating conditions of phase I.

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Succession Of Aquatic Vegetation In Lake Ocklawaha Two Growing Seasons Following A Winter Drawdown[1]

R. S. HESTAND and C. C. CARTER

Aquatic Botanists
Florida Game and Fresh Water Fish Commission
Eustis Fisheries Research Laboratory
Eustis, Florida 32726

ABSTRACT

Lake Ocklawaha has experienced aquatic weed problems since 1969, the year following impoundment. The lake surface elevation was lowered 1.5 m from September 1972 to February 1973. The May 1973 sampling indicated that the drawdown gave excellent control for coontail, hydrilla, southern naiad, and Brazilian elodea, but there was a substantial increase in waterhyacinth, alligatorweed, smartweed, and waterpurslane. In the November 1973 sampling, hydrilla had increased tremendously in coverage as did pickerelweed, and waterhyacinth; there was however continued control of coontail and Brazilian elodea. By

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the October 1974 sampling, hydrilla and waterhyacinth were the dominant plants, covering 1216 ha of the 2637 ha lake.

INTRODUCTION

Water level manipulation has been used for controlling aquatic plant growth in fish culture ponds, small lakes and reservoirs and recently in large hydroelectric reservoirs (2). Drawdowns have been used to control many aquatic plants in other states (1, 3, 7, 8), but the effects of a drawdown on aquatic plants had not been documented in Florida though several predictions were made in 1972 (4) concerning the drawdown of Lake Ocklawaha (Rodman Reservoir).

Lake Ocklawaha is a shallow reservoir in central Florida formed in 1968 by impounding the Ocklawaha River. Aquatic plants have flourished in the reservoir since 1970, at which time the lake level was stabilized at 5.5 m msl (mean sea level) producing ideal conditions for maximum plant growth due to central Florida's mild climate (1, 3, 4, 9). The lake surface elevation was lowered 1.5 m in August 1972, thus reducing the surface area (2,637 surface ha at 5.5 m msl to 1,643 surface ha at 4 m msl) and exposing certain plant communities. The reduced surface elevation (4 m msl) was maintained for 5 months, from September 1972 to February 1973. This schedule was similar to the winter drawdown proposed for aquatic plant control (4).

A two phase study was initiated to determine the effects of a fall and winter drawdown on macrophyte communities within the lake basin. The first phase involved the preparation of vegetation maps depicting the entire reservoir before, during, and after drawdown. A general overall view of effects and control of aquatic plants could be observed and compared to the predictions made in 1972 (4). The second phase consisted of documenting the response of selected aquatic macrophytes to water level fluctuations.

METHODS AND MATERIALS

An airboat was used to make vegetation maps depicting distribution of aquatic plants in August 1971, May 1972, August 1972, November 1972, May 1973, November 1973, May 1974 and October 1974. The reservoir was mapped each time in the following manner. First, the perimeter of the lake was observed, followed by open-water areas being transected at 46 to 69 m intervals. In each case the obvious vegetation types were recorded and given a color code. Resulting maps were then checked against aerial photographs for accuracy. All vegetation maps were prepared with a scale of 2.54 cm equal to 244 m.

The area in ha occupied by each plant species was computed from the maps using an area calculator, that employs an electrical grid which was placed over the map. The color coded area was traced and the resulting number converted to ha (Table 1) for that particular plant. The maps facilitated the selection of suitable areas within the reservoir for documenting responses of certain aquatic plants to water level fluctuation. A detailed study was conducted to reflect changes more subtle than those derived from mapping.

Five sites were carefully selected which would be partly or completely dewatered with the 1.5 m drawdown. The following eight aquatic plants were selected for a detailed study: hydrilla, coontail, Brazilian elodea, spatterdock, pickerelweed, alligatorweed, southern naiad, and eelgrass. Modified line transects were run through each site with permanent markers placed every 30.5 m. A steel tape was stretched between each marker and at each 1.5 m interval a pole was lowered through the water and plants that touched the pole were recorded. Since this method records multistory community composition, the resulting frequency of occurrence can be more than 100%. At each 6 m interval a floating square (1 m^2) was lowered to the water or ground and the coverage of each species was

TABLE 1. COMPARISON OF HA COVERED IN LAKE OCKLAWAHA BY AQUATIC PLANTS AT EACH SAMPLE SITE.

Plant Species	August 1971	May 1972	August 1972	November[a] 1972	May 1973	November 1973	May 1974	October 1974
Coontail	184.1	415.6	308.8	214.9	57.5	61.9	86.6	40.1
Southern naiad	138.0		26.8	11.3	1.2	32.0	4.5	12.5
Waterhyacinth	259.8	279.2	251.7	128.7	359.9	535.0	230.3	655.6
Brazilian elodea	55.4	157.8	155.0	39.7	44.5	68.8	81.7	36.4
Cattail	19.0	81.7	64.8	117.4	46.5	56.3	70.8	45.3
Spatterdock	20.6	25.5	28.3	37.6	55.8	37.6	76.9	34.8
Hydrilla	0.8	4.5	10.1	23.9	2.8	102.0	252.1	660.9
Eelgrass	4.5	8.9	16.2	11.3	4.5	17.8	30.4	29.9
Water lettuce	—	—	58.3	36.8	—	64.8	67.2	189.8
Alligatorweed	0.4	0.4	0.4	0.4	13.8	1.2	1.2	1.2
Pickerelweed	26.8	11.3	20.2	—	8.9	72.8	66.4	40.1
Pigweed	—	—	—	—	30.4	10.5	10.1	—
Smartweed	—	—	—	—	44.5		—	—
Waterpurslane	—	—	—	—	71.6	59.9	61.5	18.6
Water pennywort	—	—	—	—	—	27.9	117.8	17.4
Total Ha	709.8	985.0	940.9	622.0	741.4	1148.5	1157.5	1782.6

[a] During Drawdown

sketched on a data sheet and a color photograph taken.

A table was compiled of all plants encountered (Table 2). Data analyzation included the frequency of occurrence (percent composition) and the percent coverage of the plots. The reason for the employment of both can be best illustrated in Figure 1. Frequency represents percent composition within a certain period. Hydrilla was found often, but as indicated by the percent coverage, not in great quantities until the second growing season. Due to the large amount of data compiled only the dominant plants were graphed (Figure 1). Since the eight primary aquatic plants were studied in areas which would be partly or completely dewatered, data from all transects were combined and analyzed as if they were one long transect to facilitate data presentation. Due to bias introduced by site selection, the resulting transect data is applicable only to areas which were dewatered, not the entire lake.

TABLE 2. PLANT SPECIES ENCOUNTERED DURING THE STUDY PERIOD.

Scientific Name	Common Name
Alternanthera philoxeroides (Martius) Grisebach	Alligatorweed
Amaranthus australis (Gray) Sauer	Pigweed
Axonopus affinis Chase	Carpet grass
Azolla caroliniana Willd.	Mosquito fern
Bacopa monnieri (L.) Pennell	Waterhyssop
Bacopa caroliniana (Walter) Robinson	Waterhyssop
Bidens laevis (L.) BSP.	Beggar ticks
Boehmeria cyclindrica (L.) Swartz	False nettle
Caphalanthus occidentalis L.	Button bush
Ceratophyllum demersum L.	Coontail, hornwort
Cicuta maculata L.	Water hemlock
Cicuta mexicana C. & R.	Water hemlock
Cynoctonum mitreola (L.) Britt	Miterwort
Cyperus sp.	Sedges
Digiteria serotina (Walter) Michaux.	Crab grass
Diodia virginiana L.	Virginia buttonweed
Dyschoriste humistrata (Michaux) Kuntze	—
Eclipta alba (L.) Hasskarl	—
Echinochloa walteri (Pursh) Heller	Millet
Egeria densa Planchon	Brazilian elodea
Eichhornia crassipes (Martius) Solms	Waterhyacinth
Elocharis acicularis (L.) R. & S.	Spike rush
Eleusine indica (L.) Gaertner	Goose grass
Erachtites hieracifolia (L.) RAF	Fireweed
Eupatorium capillifolium (Lam.) Small	Dog fennel
Hibiscus sp.	Hibiscus
Hydrilla verticillata Royle	Hydrilla
Hydrochloa caroliniensis Beauvois	Southern watergrass
Hydrocotyle bonariensis Lam.	Water pennywort
Lemna sp.	Duckweed
Ludwigia palustris (L.) Ell.	Waterpurslane, false loosestrife
Mikania scandens (L.) Willd.	Climbing hempweed
Myriophyllum heterophyllum Michx.	Variable milfoil
Najas quadalupensis (Sprengel) Magnus	Southern naiad
Nuphar macrophyllum (Small) E.O. Beal	Spatterdock, cow-lily
Panicum sp.	Panic grass
Phytolacca americana L.	Pokeweed
Pistia stratiotes L.	Water lettuce
Pleucheae purpurascens (Swartz) D.C.	Marsh-fleabane
Polygonum punctatum Ell.	Smartweed, knotweed
Pontederia lanceolata Nutt.	Pickerelweed
Potamogeton illinoensis Morong.	Pondweed
Rhyncospora sp.	Beak rush
Rumex verticullatus L.	Swamp dock
Sacciolepsis striata (L.) Nash	—
Sagittaria lancifolia L.	Arrowhead
Sagittaria subulata Buch	Eelgrass
Salvinia rotundifolia Willd.	Salvinia
Sambucus simpsonii Rehder.	Southern-elderberry
Scirpus californicus (C.A. Mey.) Stead.	Bullrush
Scirpus validus (Vall.)	Bullrush
Typha latifolia L.	Cattail
Utricularia sp.	Bladderwort
Vallisneria americana Michaux.	Eelgrass, tapegrass

RESULTS AND DISCUSSION

Prior to the drawdown (August 1972), those species having the greatest frequencies of occurrence were coontail, Brazilian elodea, and hydrilla, respectively (Figure 1). This was also found to be true in percent coverage of plants occurring in the plots (Figure 1). The frequency of occurrence of hydrilla was much greater than its coverage (Figure 1). This finding was corroborated by field observations which showed that the plant was sparsely scattered and not in dense mats like coontail. It was found from the vegetation map analysis that coontail, waterhyacinth, Brazilian elodea, cattails, and water lettuce constituted the dominant plants throughout the reservoir (Table 1).

Most of the transect sites were dry or had very shallow water during the drawdown, and several changes in dominance occurred. Dominant species during drawdown were sedges, alligatorweed, beak rush, and waterpurslane. Lakewide data illustrated that coontail, waterhyacinth, cattails, Brazilian elodea, and spatterdock were the dominants. The ha of hydrilla also increased (Table 1).

The first year post drawdown transect sampling (May, August, November 1973) yielded yet another combination of dominant species. Waterpurslane became the new dominant, followed by coontail, hydrilla, Brazilian elodea, smartweed, and waterhyacinth. Total percent plant coverage for the entire reservoir increased through the sampling period until after the drawdown (Table 3), when in May 1973, the percent coverage decreased 9.5%. However, by November 1973 the highest percent coverage was reached (43.5%). At this time a complete shift in the dominant plants occurred and waterhyacinth became the new dominant (Table 1). This corresponds to data from other studies which demonstrated that water level fluctuation encourages proliferation of this plant (3). A large decrease in coontail, and Brazilian elodea occurred, however, southern naiad and eelgrass changed little in coverage (Table 1). Pickerelweed, waterhyacinth, and spatterdock exhibited a moderate increase in coverage while hydrilla exhibited a dynamic proliferation matched temporarily by alligatorweed. Several semiaquatic plants invaded the area exposed during the drawdown and were among the dominants after the drawdown was complete. Beak rush and pigweed were found in all sections of the reservoir as subdominants. Smartweed and waterpurslane, which formed the dominant submerged vegetation (Table 1), in May 1973 were replaced by hydrilla, Brazilian elodea, and coontail by November 1973.

The second year post drawdown transect sampling (April and September-October 1974) revealed hydrilla to be the new dominant, followed by waterhyacinth, coontail, Brazilian elodea, and waterpurslane. The percent plant coverage for the entire reservoir during 1974 increased to a new high of 67.6% (Table 3) with hydrilla the new dominant plant followed closely by waterhyacinth (Table 1).

TABLE 3. COMPARISON OF PERCENTAGE OF AQUATIC PLANTS IN LAKE OCKLAWAHA AT EACH SAMPLE DATE.

	August 1971	May 1972	August 1972	November[a] 1972	May 1973	November 1973	April 1974	October 1974
Coverage (%)	26.9	37.4	35.4	37.9	28.4	43.5	43.9	67.6
Pool Level meters (msl)	5.5	5.5	5.5	4.0	5.5	5.5	5.5	5.5

[a] During Drawdown

A continued decrease in Brazilian elodea and coontail along with southern naiad and pickerelweed was documented (Table 1). The semi-aquatic plants (pigweed, smartweed, waterpurslane, and water pennywort) which had invaded the exposed and shallow areas during the drawdown were replaced by submerged or floating aquatic vegetation and thus became incidental to the total plant community (Table 1). The largest increases in coverage were exhibited by hydrilla, water lettuce, and eelgrass.

Frequency of occurrence and percent coverage of coontail were reduced by 30% following the drawdown, by 48% at the end of the first growing season and stabilized at 47% by the end of the second growing season (Figure 1). Control of coontail has been previously obtained by drawdown in Louisiana (7), Arkansas (6), and Wisconsin (1). The reduction in coontail which occurred in the transects and plots reflects the lake-wide trend, 80% in November 1973 and 87% in October 1974.

Southern naiad was not present in the post drawdown samples in either plots or transects and had been reduced 96% (Table 1) over the lake in May 1973. It had increased slightly from the predrawdown sampling (August 1972) by November 1973 but decreased again by October 1974.

Spatterdock indicated a slight increase in the transects and plots throughout the study (August 1972 to October 1974) while lake-wide there was a 23% increase in ha (Table 1). Beard (1) found, during a Wisconsin winter drawdown, that there was a large reduction in spatterdock. During a spring-summer drawdown on Lake Tohopekaliga in central Florida, coverage of spatterdock remained about the same (5).

Waterhyacinth and alligatorweed have increased in Louisiana during drawdown (3) and the same trends held in Florida. Figure 1 illustrates the 333% increase in frequency of waterhyacinths (transects) and the 622% in coverage (plots, August 1972 to November 1973). This general increase was also evident over the lake, which experienced a 133% increase in ha but was only 23% from November 1973 to October 1974. Waterhyacinth seedlings were abundant on the newly exposed area and were immune to biological control by "root-rot"[2] that was containing them before the drawdown.

Alligatorweed exhibited a much smaller increase in the transects and plots (62% and 47%, respectively) than over the entire lake (3,300%) in the May 1973 sample. The large increase in population of alligatorweed was mainly located along the shoreline and had died out and stabilized by November 1973 (Table 1). The flea beetle (*Agasicles hygrophila* Selman & Vogt) was not effective in controlling alligatorweed initially following the drawdown but was effective by November 1973.

The two main plants of concern during the drawdown were hydrilla and Brazilian elodea since these noxious plants are capable of choking the entire water column of a reservoir. One growing season following the drawdown the percent frequency of occurrence for hydrilla increased 71% (Figure 1), while the percent coverage decreased 59% (Figure 1). Lake-wide, there was a 908% increase in ha (Table 1). The discrepancy in the data is caused by two factors: (1) the transect site was completely out of the water and thoroughly dried and (2) edaphic conditions of the site may be atypical. By the end of the second growing season (October 1974) the percent frequency of hydrilla had increased 152% (Figure 1), while the percent coverage had increased 194% (Figure 1). Lake-wide, there was a 6,440% increase in ha from predrawdown (August 1972) to October 1974, two growing seasons later.

Brazilian elodea decreased after the first growing season 70% in percent frequency of occurrence and 85% in percent coverage at the study site (Figure 1). Over the lake there was a decrease in ha of 56% (Table 1). Brazilian elodea still exhibited a decrease by the end of the second growing season in percent frequency of 38% and percent coverage of 56%. Over the entire lake there was a large decrease in ha of 77% (Table 1). This decrease was caused by the solid covering of the area it inhabited by water lettuce and waterhyacinths. If the area is cleared, the Brazilian elodea should quickly recover. Table 1 shows the large increase in water lettuce and waterhyacinths from the May to October 1974 sampling and a correlated decrease in Brazilian elodea.

From this study, it is evident that most of the previous predictions made were correct (4). It was thought that coontail, hydrilla, and Brazilian elodea would overgrow the reservoir. This did occur during the drawdown, but upon refilling coontail and Brazilian elodea disappeared. However, hydrilla by the end of the first growing season (November 1973) had increased 908%, and by October 1974, 6,440%. It appears that the drawdown gave very good control of Brazilian elodea and coontail, especially in areas that were completely dried. It is also evident that a drawdown will give only temporary control of hydrilla unless the area is thoroughly dried.

It was also predicted that waterhyacinth possibly could be controlled, depending on the winter. The winter of

[2] The agent of this disease is unidentified and currently under study by D. R. Charudattan, Dept. of Plant Pathology, Univ. of Fl., Gainesville, Fl.

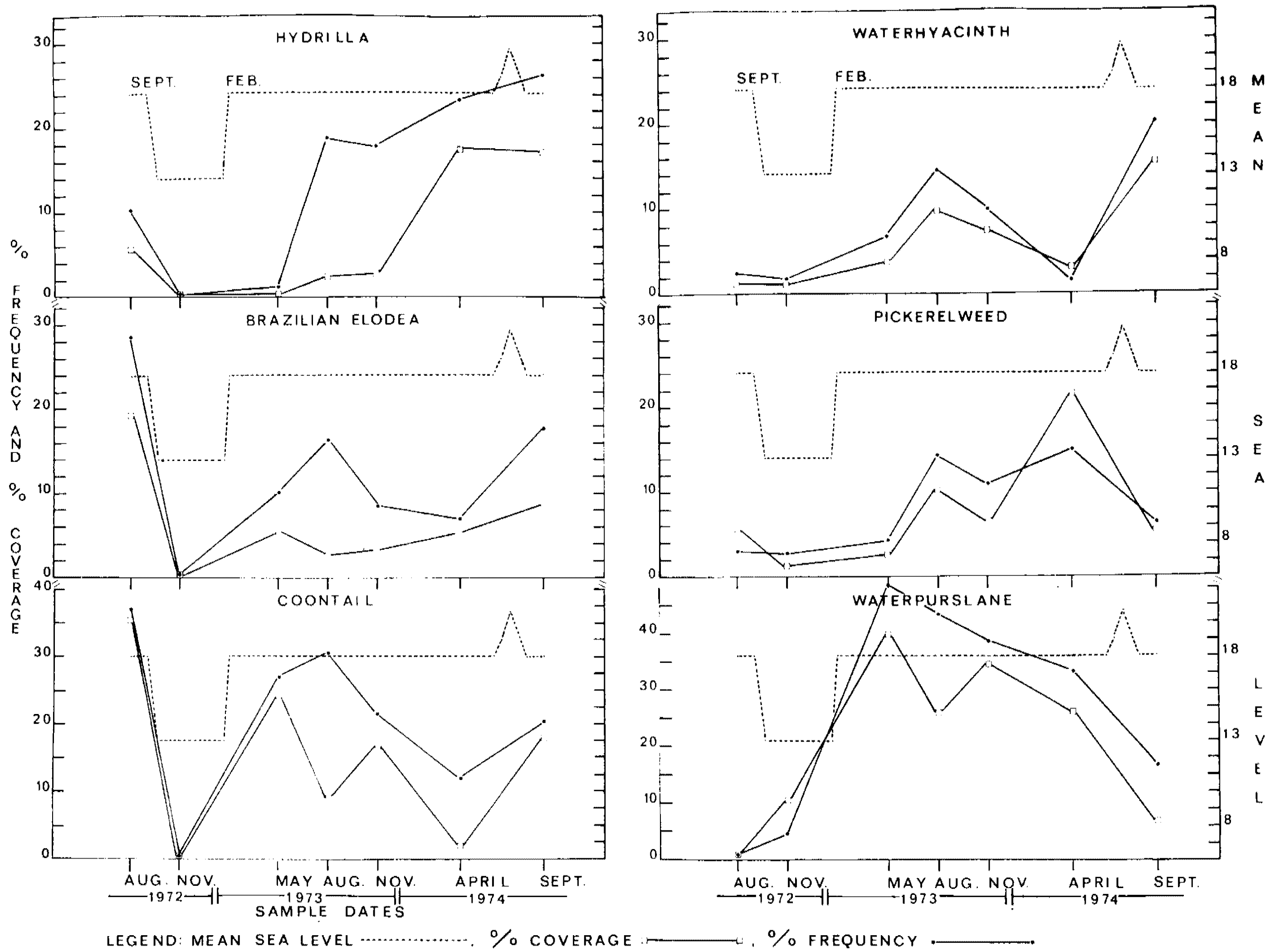

Figure 1. Comparison of Percent Frequency and Percent Coverage of The Dominant Plants Recorded On The Transect Sites During The Study Period.

1972-73 was mild (no frost), allowing the waterhyacinth and alligatorweed to proliferate and colonize many new areas. The increase had been expected, but not to the degree to which it occurred.

It is evident that drawdowns can be useful in controlling certain species of noxious aquatic vegetation but care should be exercised since under certain conditions dewatering may actually encourage the proliferation of some noxious species.

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