WATER FLUCTUATION AS A FACTOR IN THE LIFE OF THE HIGHER PLANTS OF A 3300 ACRE LAKE IN THE PERMIAN RED BEDS OF CENTRAL OKLAHOMA

By

JAMES H. B. DE GRUCHY

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THESIS AND ABSTRACT APPROVED:

W. H. Irwin
Thesis Adviser

H. I. Featherly
Faculty Representative

D. C. McIntosh
Dean of the Graduate School

PREFACE

The author wishes to express his gratitude to the U.S. Soil Conservation Service Research Project OK-R-3 for the water surface elevations data. He is especially grateful to W.O. Ree of the Soil Conservation Service for his computations of the water surface elevations during periods in which water surface records were lacking.

Appreciation is expressed to the members of the Department of Forestry, Oklahoma A. & M. College for their assistance in determining the age of the trees and to Dr. H. I. Featherly for aid in the identification of plants.

The writer also extends appreciation to Dr. William H. Irwin, Dr. H. I. Featherly, Dr. Roy W. Jones, Dr. Walter Hansen, Dr. A. M. Stebler and to many others who assisted him in the completion of this work.

CONTENTS

INTRODUCTION

The study of the effects of water fluctuation on the higher plants of Lake Carl Blackwell, a 12 year old 3300 acre lake was undertaken to increase the knowledge, the income, and pleasure that man could derive directly or indirectly from the pursuit and take of fish and wildlife. Studies of the effects of permanent flooding in a river bottom timber area were made by Yeager (1949) and studies of the effects of water fluctuation on the higher plants were made by Hall, Penfound and Hess (1946) with an indication of how water level management may be applied for malarial control but to my knowledge no work has been undertaken to improve the beauty or to increase the production of fish and wildlife in our man made lakes through knowledge or control of water fluctuation.

The effects of water fluctuation on the plants during the years 1950 and 1951 in many instances were comparable with the effects of the fluctuations of the past. The effects of earlier water fluctuations were garnered from remnants of plants originally present. Moreover, this study showed that water fluctuation was an important factor in the establishment of some plants and the elimination of others.

The investigation showed how water level regulation could be used to control and produce large crops of plants. Insufficient information was gathered on the killing effects of inundation of the upland plants to assign them a definite position level in contour planting in and around the lake, but need for this information was brought out in time differences required to kill plants by flooding.

The plants at Lake Carl Blackwell, represent only a small number of the plants that should be studied for use in and around the lakes of the Arkansas River Valley System. The findings at Lake Carl Blackwell should be useful in a higher plant management program for many lakes of the Arkansas River Valley System.

MATERIALS AND METHODS

Transportation to locations of study was accomplished with a 16 foot utility type boat powered with a five horsepower outboard motor. Plants were identified in situ with the aid of the taxonomic manuals of Eyles (1944), Fassett (1940), Fernald (1950), Munscher (1944), Phillips (1950) and Rydburg (1932). Photographs for permanent record were taken with a camera fitted with a shutter with speeds up to 1/400 second. Cross sections of trees for age determination were made with an ordinary hand saw. Mean sea level was chosen as a common base datum for locating the position of the base of the plants. Positions were determined by measuring the depth of the plants' base from the water surface level and the converting by computation to heights above sea level.

At the beginning of the study a general survey of the shore line area was made to obtain an approximation of species composition and distribution of the plants about the lake. After this survey, areas were selected for making a study of individuals or groups of plants. Photographs were taken of these areas for use in determining the changes that may take place. They show the position of the water with reference to the plant and serve as a reference to the condition of the plant at an earlier date. In the analysis it was important to know whether the plants were established before, during, or after the high waters of 1944 and 1945. Time of establishment of some of the perennial plants was known from previous observation.

During the past 12 years many of the plants originally present in the lake basin have been eliminated. At the same time new species have been introduced, some by natural means and some by man. During this period the flora of the basin has been continuously changing, often leaving remnants of the original stand. Water fluctuations played their role in elimination and establishment. Fortunately no long period of inundation occurred at the higher levels of the lake until the summer of 1951. This allowed a comparison of the prolonged effect of inundation in 1951 with that of the short period inundations which occurred during the early life of the lake.

The wide variation in the effects of the water fluctuation made it necessary to treat each species separately under the heading of "Discussion of the Species Observed".

GENERAL INFORMATION

Lake Carl Blackwell, an artificial impoundment constructed under U.S. Land Utilization Project L.D. OK-1, 1937, is located eight miles west of Stillwater, Oklahoma in the center of the Arkansas River Valley System. Temperature in the region varies from below 0° in the winter to over 100° fahrenheit in the summer. The region lies between the well watered central plains and the semiarid region east of the Rocky Mountains and has an annual rainfall of about 35 inches per year. Rainfall is somewhat seasonal with most of it falling during the late spring months. These apparently seasonal rains cannot be relied upon since cloudbursts and heavy rains occur throughout the year. These interspersed with long dry periods produce broad differences in water surface level. The central section of the Arkansas River Valley consists mainly of undulating prairie land covered with Prairie Grass and Jack Oak hardwood forest. The topography and mesophytic flora surrounding Lake Carl Blackwell, typical of the region, is illustrated in figure 1, a general view of the lake.

The prevailing wind of the region is from the southwest. The effect of it on higher plant life associated with the lake is evident. Whenever the wind has a sweep across open water, it has the general effect of reducing the plant life in the water. The relatively heavy growth of Willows, Button Bushes and Cottonwoods on the west side of an arm of the lake in area 9 and an absence of the same plants on the east side of the arm is shown in figure 2. This condition is common throughout the lake. Complete lack of vegetation in the water at the northmost part of the eastern side of area 6 is shown by figure 3. The shearing effect of a wind sweep two miles in length and its resultant wave action is evidenced by the absence of plants in this location.

Deep waters also inhibit the growth of the higher aquatic plants as is evidenced by their absence in the deep water along the shore of area 7, (fig. 4). This area is protected from the southwesterly winds which eliminates wind and wave action as a factor.

The more or less narrow waters of creek beds are protected from long sweeps of wind and it is in these areas (fig. 1, A) that large masses of aquatic and semiaquatic plants have become established in the lake.

The map of the lake (fig. 5) shows the location of the different areas of the lake as investigated and described under this paragraph.

The graph (fig. 6) shows the height of the water surface levels throughout the life of the lake. Superimposed on the graph are the elevations at which the species were found. The graph can best be read by transposing mentally the block representing the vertical locations of the base of the plant horizontally through time space for the purpose of determining relationship of the plant to the rise and fall of the water in the lake. This transposing process enables the reader to visualize the time and extent of inundation and the possible time of establishment of the plant. The graph also releases information on the amount and length of inundation or aeration that a plant can endure and presents the reader with information concerning ɔe plant's ability to withstand fluctuating water levels to ɔich it was subjected. The rise and fall of the surface waters f Lake Carl Blackwell cannot be considered characteristic of ater level fluctuations in the region since man has contributed nnaturally to its change. These unnatural changes over the 12 ear period produced fluctuations that aided in this research.

Plant nomenclature and spelling are the same as used in the ight edition of Gray's Manual of Botany by M. S. Fernald (1950).

Fig. 1. General View of Lake Carl Blackwell Region from the West. Bracket (A) points out a large crop of Polygonum lapathifolium. July 1, 1951.

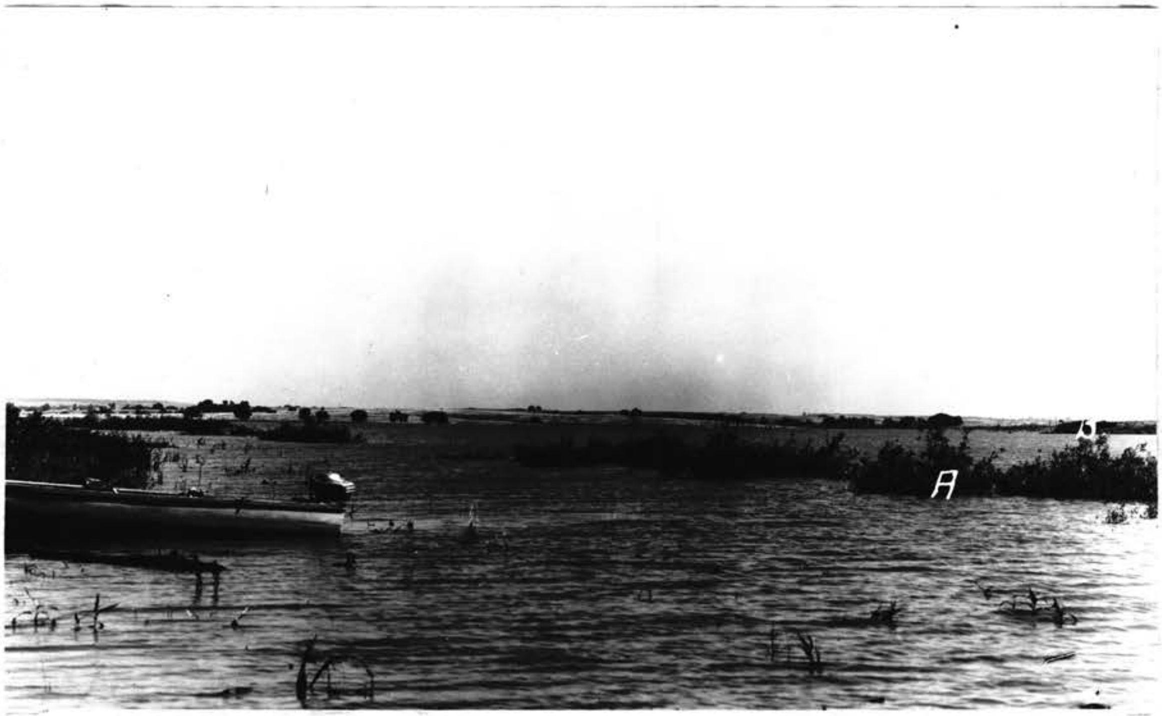

Fig. 2. Showing a comparatively heavy emergent plant population in the semi-protected west side of arm (A) and the absence of plants in relatively open east side of arm (B). Area 9, July 5, 1951.

Fig. 3. Showing the absence of emergent aquatic plants in water subjected to shearing wave action. Area 6, August 25, 1951.

Fig. 4. Showing the absence of emergent aquatic plants in deep water. Area 7, August 25, 1951.

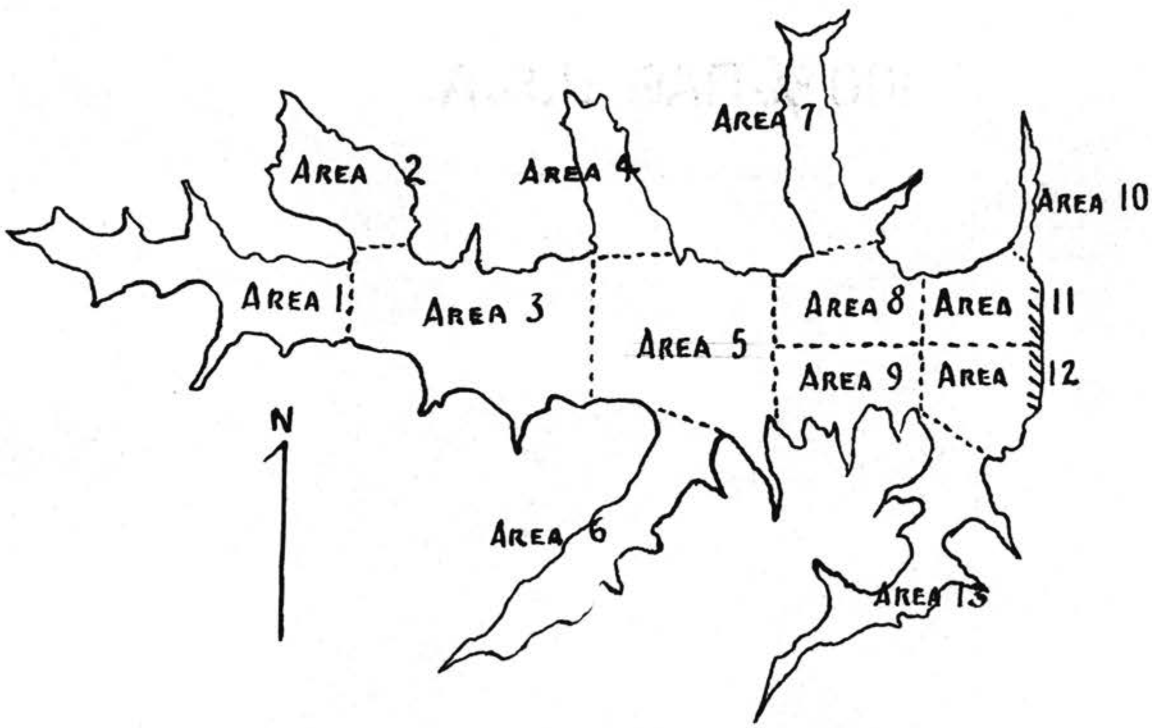

Fig. 5. Subdivisions, Lake Carl Blackwell

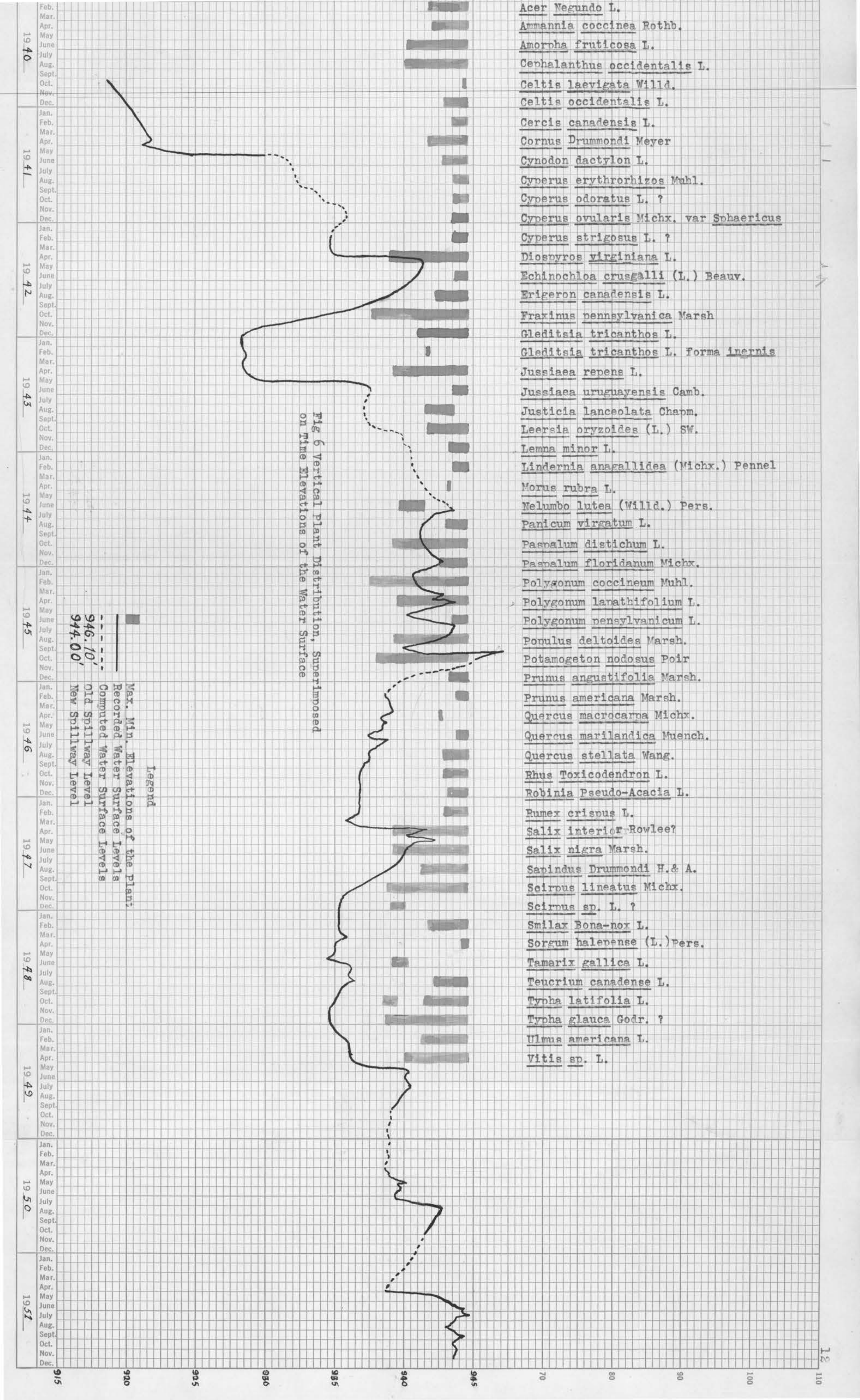

Fig 6 Vertical Plant Distribution, Superimposed on Time Elevations of the Water Surface

DISCUSSION OF THE SPECIES OBSERVED

In the following discussion the elevations given are from mean sea level. Two elevations appearing together signify that the base of the plant was found at and between the levels. The highest water level (944.60') reached during the summer of 1951 was .6' above the present spillway level of 944.00'. This information will help the reader to localize the plants with reference to what would be the normal pool level of the lake. Photographs are included to illustrate morphological and color changes produced by water coverage.

The assessing of economic values and uses to the plant are based mainly on the writers observations in this and his work on the larger aquatic plants of Oklahoma. Technical Bulletin No. 4 Experiment Station Oklahoma A. & M. College, de Gruchy (1938), "Methods of Precipitating Collodial Soil Particles from Impounded Waters of Central Oklahoma", Irwin (1945) and "Food Habits of Waterfowl Migrating through Payne County, Oklahoma", Hancock (1950) will furnish additional information that will aid in understanding assessment of values.

The following 56 species are arranged alphabetically according to their scientific names.

Acer Negundo L., Box Elder.- Elev. 944.60', 941.70'.

The Box Elder trees observed were in the age group that developed from seeds after the high waters of the fall of 1945. It is quite probable that the original plants existing below the 944.00' level were killed by the high waters of the summer of 1944 and the summer and fall of 1945.

The Box Elder tree shown in figure 7 began life in 1946. t withstood the short inundations of May and June in 1947 and he shallow inundations of August, September, and part of Octoer in 1950. At the time of the photo, August 8, 1951, the tree bowed considerable distress through yellowing of the leaves. ts ability to return to active life was doubted. The photo of he same tree (fig. 8) taken on September 16, 1951 shows almost complete loss of leaves. However the samaras remain, as a ast effort of the plant to continue its kind. The cambium ayers of plants at, and above the 942.82' level were still 'iable November 21, 1951, after a continuous shallow water inun-ation of about six months.

The Box Elder is not recommended for use as a shade tree in recreational areas which will be subjected to inundations. Nevertheless it is believed the Box Elder trees will withstand inundation periods of about one months duration during the growing season with slightly longer periods during the more or less dormant season.

Ammannia coccinea Rothb., Scarlet Ammannia.- Elev. 944.25', 942.10'.

The Scarlet Ammannia, an annual, is limited to the lake's marginal zone of shallow water. The plants sprout in shallow water or water soaked soil. They appear to follow a receding water line and in this manner cover a large area. These plants are very resistant to the erosive forces of wave action as is shown in figure 9. Note that some of the plants are growing in the water soaked soil at the waters edge while others are just

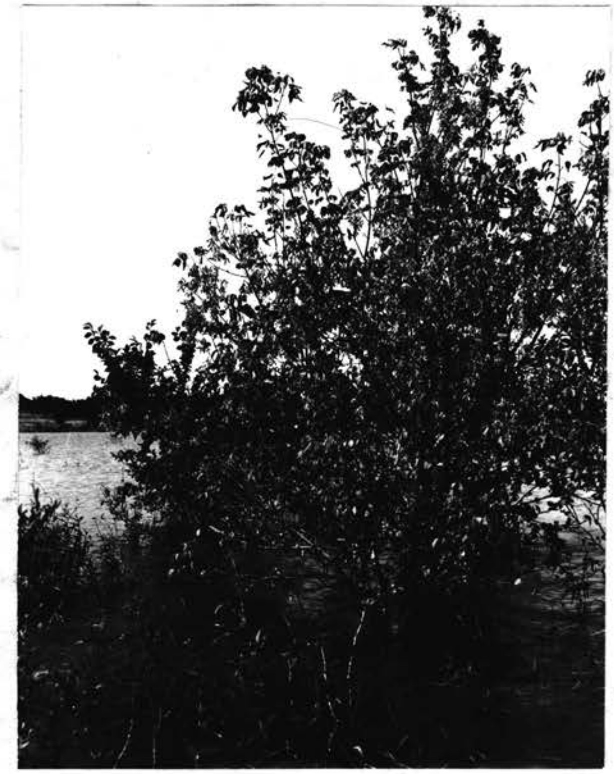

Fig. 7. Acer Negundo L., Box Elder. Showing distressed condition after two and one half months water coverage.- Elev. 941.70', Area 13, August 8, 1951.

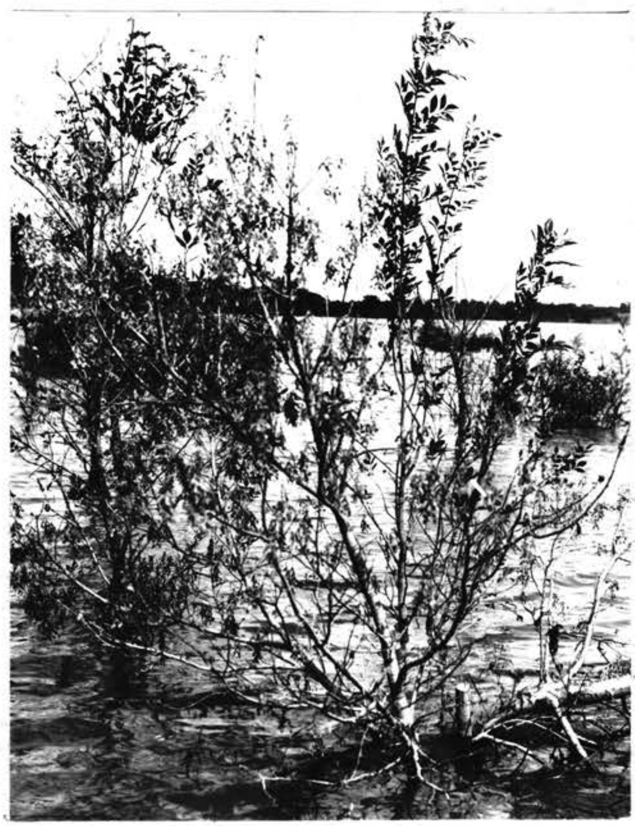

Fig. 8. Acer Negundo L., Box Elder. The same tree as shown in figure 7 after four months water coverage.- Elev. 941.70', Area 13, September 16, 1951.

Fig. 9. Ammannia coccinea Rothb., Scarlet Ammannia. Note the plant's resistance to wave action.- Elev. 944.60', 942.05', Area 7, August 28, 1951.

Fig. 10. Ammannia coccinea Rothb., Scarlet Ammannia. The Ammannia (A) and (B) are able to cope with the Cyperus (C) and the Polygonum (D).- Elev. 944.00', 942.00', Area 13, September 16, 1951.

merging from the shallow water. Figure 10, A shows the plants ate in their growing season and (B) of figure 10 shows the lants in midseason. This heavy crop of plants adds many tons f plant nutrients to the lake.

The Scarlet Ammannia will prove to be of considerable value n the lake management program, especially in lakes in which he water level can be controlled. A gradual drawdown of the ater level beginning about the middle of July should produce arge quantities of these plants once a lake is seeded. This lant is a heavy seed bearer, producing in some plants an estiated 100,000 seeds or more per plant. The plant furnishes onsiderable protection to small fish in the shallow waters. hrough the plants death and decomposition nutrients, brought up rom the soil, are added to the water. The last activity was learly demonstrated by Pond (1905) with several species of ubmerged plants.

Amorpha fruticosa L., False Indigo.- Elev. 944.60', 940.25'.

The False Indigo, normally a land plant, shows remarkable esistance to inundation by water. Considerable difference was oted between the rate of the loss of leaves from plants with nly their base covered with water and the plants that were lmost completely submerged. Figure 11 shows the leafless conition of the plants found in shallow water at the 942.68' level n August 16, 1951. In deeper water, elevation 940.25', with nly the upper branches emerged (fig. 12) the leaves remained in healthy condition until October 1, 1951 the date of the last bservation. These plants developed adventitious roots on the tem below the water line (fig. 13). The length and mass of hese roots are exibited in figure 14, photo of the plant after t had been removed from the deeper water. The upper parts of hese roots developed chlorophyll. Plants in the shallow water lso developed adventitious roots. The large masses of roots eveloped by plants in deep water may be the explanation for the rolonged viability of the plant.

Since this plant is a legume it may be valuable as a nitroen fixer. Its shrubby growth will make it valuable as cover for pland game fowl during times of low water. Additional research ill be needed before an exact inundation killing period can be scertained.

<u>Cephalanthus</u> <u>occidentalis</u> L., Button Bush.- Elev. 944.60', 40.00'.

The Button Bushes shown in figure 15, A are seven or eight ears old. These plants, established during the high waters of 944 and 1945, survived the low water levels of 1946, 1948 and 949. During the latter part of 1950 and the early part of 1951 hey were inundated continuously for a period of approximately even months and again from June 15, 1951 to October 1, 1951. Figure 16, A shows the condition of the plants on October 1, .951. Figure 17 shows the Button Bush at the 940.00' level lmost completely covered with water. The flowers of these lants shown by figure 17, A matured into seed and the plants ere in a healthy condition when observed August 25, 1951 (fig. .8). These plants produce adventitious roots in a manner simiar to that described for <u>Amorpha</u> <u>fruticosa</u>.

Fig. 11. Amorpha fruticosa L., False Indigo. The False Indigo killed early in shallow water.- Elev. 942.68', Area 13, August 16, 1951.

Fig. 12. Amorpha fruticosa L., False Indigo. Prolonged viability was common in deep water.- Elev. 940.25', Area 13, September 16, 1951.

Fig. 13. Amorpha fruticosa L., False Indigo. Plants both in shallow and deep water produced adventitious roots below the water line.- Elev. 940.25', Area 13, October 1, 1951.

Fig. 14. Amorpha fruticosa L., False Indigo. Plant removed from the water to show mass and length of adventitious roots.- Elev. 940.25', Area 13, October 1, 1950.

Fig. 15. Cephalanthus occidentalis L., Button Bush. The shrubby mass of Button Bushes (A) produce excellent cover for growing fish.- Elev. 940.68', 939.69', Area 13, August 16, 1951.

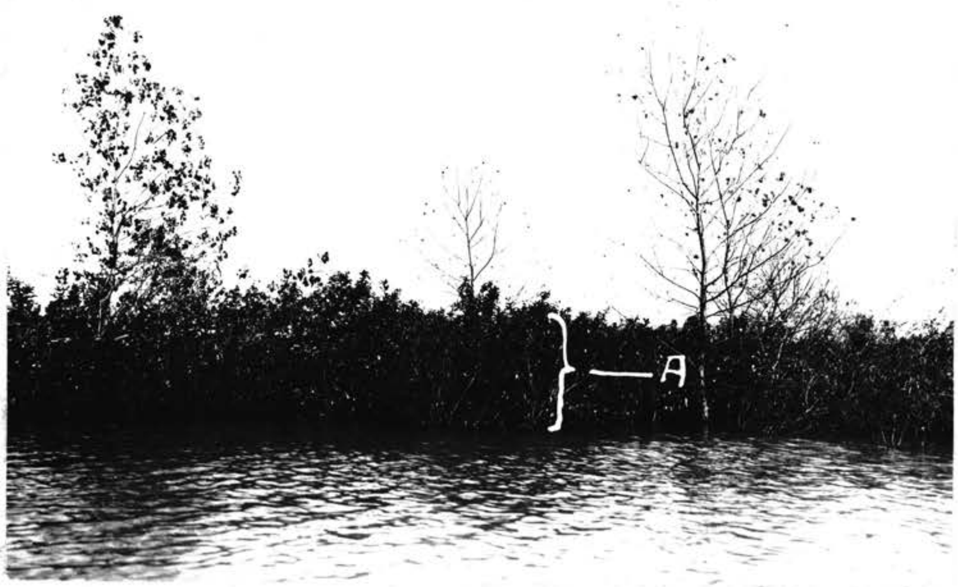

Fig 16. Cephalanthus occidentalis L., Button Bush. Same group of plants shown in figure 15 after six months water coverage.- Elev. 940.68', 939.68', Area 13, October 1, 1951.

Fig. 17. Cephalanthus occidentalis, Polygonum coccineum Study Group. The flowers of the almost completely submerged Button Bushes (A) matured into seed.- Elev. 940.00', Area 1, July 3, 1951.

Fig. 18. Cephalanthus occidentalis, Polygonum coccineum Study Group. Same group of plants as shown in figure 17. The seeds of both plants matured.- Elev. 940.00', Area 1, August 25, 1951.

The Button Bush is well adapted to the changing conditions of a fluctuating water surface zone. It is a shrubby plant and when not covered with water will furnish excellent cover for upland game. When it is covered with water it can serve as excellent cover for young fish.

Celtis laevigata Willd., Mississippi Hackberry.- Elev. 943.83'.

Only one individual of Mississippi Hackberry was observed at or below the 944.60' level. This plant was dead when observed July 28, 1951. The only reason the author can give for its establishment is its location at the side of a steep creek bank. Here the roots on the bank side of the creek could rise above the water saturated soil. This plant evidently is not well adapted to the fluctuation zone.

Celtis occidentalis L., Western Hackberry.- Elev. 944.60', 942.82'.

The Western Hackberry is similar to Celtis laevigata in its reaction toward inundation. However it remains alive after inundation a little longer than C. laevigata. It was found frequently around the edges of the old creek banks of the lake.

The plant marked (A) in figure 19 is at the 944.00' level. This plant, on August 24, 1951 appeared to be withstanding the killing effects of flooding. However by October 1, 1951 it had died while the American Elm (D) by its side at the same level continued to live.

This plant is not recommended for use in the fluctuation zone.

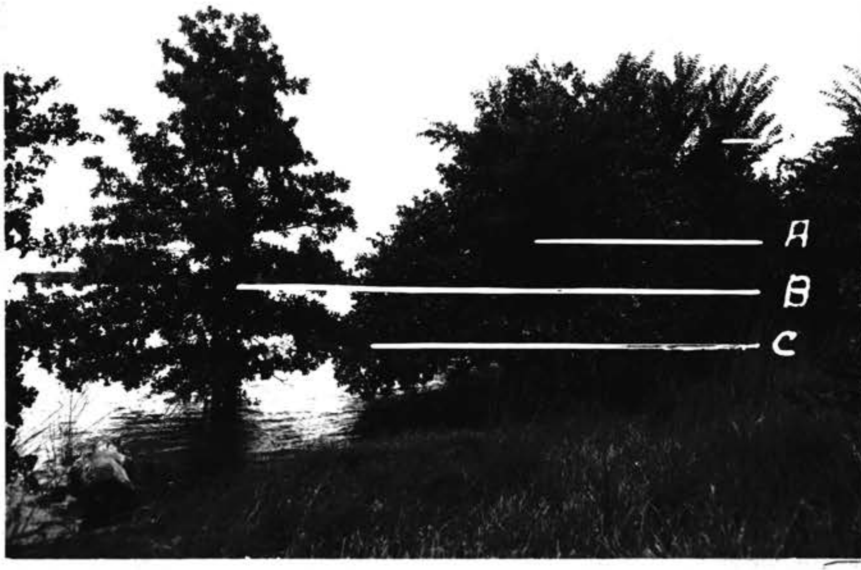

Fig. 19. Shore Line Study Group of Area 10. (A) Hackberry, (B) Post Oak, (C) Jack Oak, (D) American Elm. August 22, 1951.

Cercis canadensis L., Red Bud.- Elev. 944.60', 943.33'.

The Red Bud found only at the high levels of 943.53' and above killed soon after the inundation of its base. On July 8, 1951 after about three weeks of inundation the leaves of the plant had completely lost their green coloration. Figure 20, a photograph taken July 28, 1951 shows the killing effect of inundation of a plant at the 943.33' level. The effect is shown by comparing the drooping leaves (A) of the plant in the water with that of the turgid leaves (B) of the plant with its base above the water line.

This plant is not recommended for use in the fluctuation zone.

Cornus Drummondi Meyer, Rough leaved or Common Dogwood.- Elev. 944.60', 941.70'.

The Common Dogwood on July 8, 1951 after six weeks of water coverage at the 942.54' level showed no apparent ill effects from inundation. Nevertheless, by August 5, 1951 most of the chlorophyll had disappeared from their leaves (fig. 45, B) and by August 22, 1951 most of the leaves had dropped from the plants (fig. 46, B). On the other hand plants at the lower level (941.70') had lost most of the chlorophyll from their leaves before July 28, 1951 (fig. 21).

Since all of the plants found were along the side of the creek banks of the lake it is probable that some of the roots were able to obtain oxygen from soil above the water line and thus did not die when the water rose to the 942.50' level in 1951.

Fig. 20. *Cercis canadensis* L., Red Bud. The plant at (A) killed with only a few inches of water coverage while plants at (B) lived with its base a few inches above the water line.- Elev. 943.33', Area 2, July 28, 1951.

Fig. 21. Cornus Drummondi, Common Dogwood. Showing distressed condition of plant with less than two months water coverage.- Elev. 941.70', Area 2, July 28, 1951.

The Common Dogwood is not recommended for use in the fluctuation zone.

Cynodon dactylon L., Bermuda Grass.- Elev. 944.60', 942.65'.

Bermuda Grass, normally a land plant, was still viable on September 16, 1951 at the 942.65' level (fig. 22, A). Plants at this level were inundated from May 22 to September 16, a period of about four months.

Bermuda Grass is well known for its ability to reduce soil erosion. It will be valuable in reducing erosion by wave action. It also can be used for grazing when not covered by water. This plant will be able to withstand inundations of two to three months, especially in shallow water supplied with oxygen.

Cyperus erythrorhizos Muhl., Red-rooted Umbrella Sedge.- Elev. 944.60', 943.50'.

Cyperus odoratus L. ?, Fragrant Umbrella-Sedge.- Elev. 944.60', 943.50'.

Cyperus ovularis Michx. var. sphaericus Boeckl., Spherical Umbrella-Sedge.- Elev. 944.60', 943.50'.

Cyperus strigosus L. ?, Strigose Umbrella-Sedge.- Elev. 940.60', 943.50'.

The four species of Cyperus have been grouped together because their growth habits are similar. The seeds have been observed to sprout in the water soaked soil as the water recedes. Once established the plants are able to withstand inundation of the base of the plant. In lakes in which the water level can be controlled a drawdown of the water surface level in the spring and early summer before the middle of July would allow these

Fig. 22. Cynodon dactylon L., Bermuda Grass. Showing resistance to wave action and water coverage.- Elev. 944.60', 942.65', Area 8, August 22, 1951.

seeds to germinate before that of the competitive Scarlet Ammannia. After the middle of July a rapid drawdown of the water level would allow the two plants to germinate at about the same time and thus even their chances of survival. In either case the plants would have to compete with the larger Polygonums. In figure 10 the narrow zone of Cyperus (C) and Polygonum (D) shows plainly the potency of the Ammannia (A) as a competitor. The group shown in this photograph is a result of the slow decrease of the water level beginning about July 15, 1951. A similar plant arrangement can be seen in figure 57.

The greatest value of these plants is from the nutrients furnished to the water through their death and decomposition.

Diospyros virgiana L., Common Persimmon.- Elev. 944.60', 938.93'.

The Common Persimmon shown in (D) of figure 38 was established after the high waters of 1944 and 1945. The fact that trees six years old were found as low as the 939.91' level shows the Persimmon plant withstood inundations lasting about four months during the growing season of 1947, four months during 1949, eight or more months during 1950 and the early part of 1951, and again over four months in the summer of 1951 before dying. The viability of these plants on August 1, 1951 was considered to be such that they would have renewed their normal activity had they been returned to a land habitat. The above data establishes an inundation killing time for this group of plants of at least four months.

These trees or shrubs as in the case with the Cottonwood

Fig. 23. Diospyros virgiana L., Common Persimmon. (A) Adventitious sprouts growing vigorously a short distance above the water line.- Elev. 938.93', Area 13, August 16, 1951.

Fig. 24. Diospyros virginiana L., Common Persimmon. Showing a general distressed condition of the plant and adventitious sprouts.- Elev. 938.93', Area 13, September 16, 1951.

Fig. 25. Diospyros virgiana L., Common Persimmon. Showing complete loss of viability.- Elev. 938.93', Area 13, October 1, 1951.

and the Willow showed an inverse killing ratio with the distance of transportation of fluid to the leaves. In the case of the Willow and Cottonwood the leaves farthest from the base began dying first. In the case of the Persimmon all of the leaves gradually lost their viability but at a short distance above the water line new vigorous shoots developed from adventitious buds. Figure 23, A shows the condition of these shoots on August 16, 1951. By September 16, 1951 a large percentage of the original leaves had dropped from the plant and the leaves of the above mentioned shoots (A) of figure 24 had begun to lose their chlorophyll. By October 1, 1951 most of the leaves both from the shoots and the rest of the tree had fallen (fig. 25).

The Persimmon usually grows in thickets and as such would furnish cover for upland game fowl. The fruit is also enjoyed by man and other animals. The use of this plant should not be overlooked in planning the flora of the fluctuation zone of flood control lakes.

Echinocloa crusgallica (L.) Beauv., Barnyard-Grass.- Elev. 944.60', 943.65'.

Barnyard-Grass, normally a land plant, thrives in the rich moist soil around the edges of our lakes. Once established (fig. 26) it can withstand inundation of its base and continue to maturity in the aquatic habitat (fig. 27).

The plant, a rank grower (fig. 28) and heavy seeder, serves as food for upland game and through decomposition adds to the fertility of the water. Further knowledge is necessary before its full value in the fluctuation zone can be determined.

Fig. 26. Echinochloa crusgalli (L.) Beauv., Barnyard-Grass.- Elev. 944.60', 943.65', Area 7, August 22, 1951.

Fig. 27. Echinochloa crusgalli (L.) Beauv., Barnyard-Grass.- The same plants shown in figure 26 reach maturity with their bases covered with water.- Elev. 944.60', 943.65', Area 7, September 18, 1951.

Fig. 28. Echinochloa crusgallica (L.) Beauv., Barnyard-Grass. Illustrating the prolific growth of the plant at or above the water's edge.- Elev. 944.60', 943.67', Area 7, September 16, 1951.

Erigeron canadensis L., Mules-Tail.- Elev. 944.60', 942.85'.

This common typical land plant, as do most of the land plants, dies soon after inundation. Figure 29 shows by the drooping and withering leaves the condition of the plant after only eight days submersion of its base.

The Mules-Tail's greatest value is probably in its addition of nutrients to the water through death and decomposition. Its cultivation is not recommended in the floodable zone.

Fraxinus pennsylvanica Marsh var. subintegerrima (Vahl) Fern, Green Ash.- Elev. 944.60', 937.60'.

The Green Ash is one of the few original trees that have continued to exist throughout the life of the lake. The tree in figure 30, elevation 941.09', withstood inundations of over two months in 1942, a period of almost two years continuous shallow water inundation in 1943, 1944, and 1945, a short period in 1947, over four months in 1950 and over six months in 1951. It is believed by the author that this tree will live through the winter and again put forth leaves in 1952.

Figure 32 shows a tree that has continued to exist in the old creek bed of area 1 at the 937.60' level until after the early part of the high water flooding of 1951. The tree was cut to determine its age (43 years). The tree probably would have succumbed before 1951 had not some of its roots been able to reach aerated soil on the creek bank above the level of the water in the creek bed. This tree also survived much higher inundations during the times that flood waters entered the creek. Figure 87 shows flood-water-cut-marks one of which is approxi-

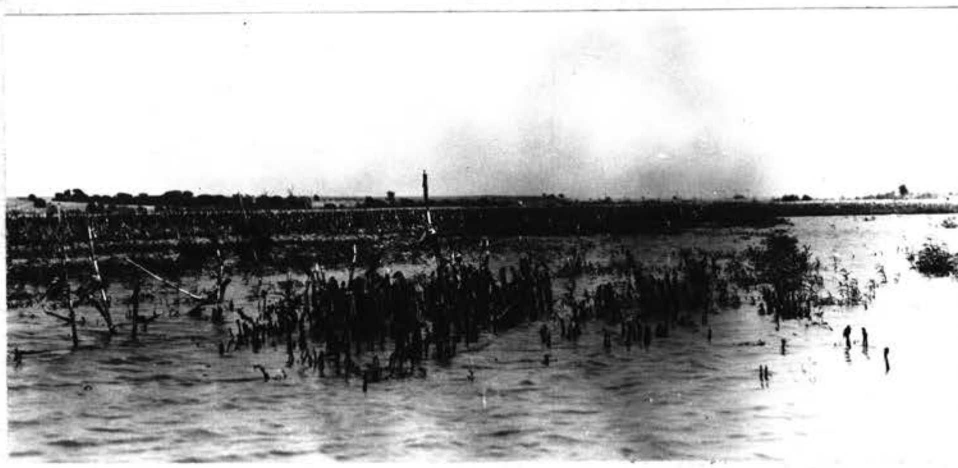

Fig. 29. Erigeron canadensis L., Mules-Tail. The Mules-Tail killed with less than eight days water coverage.- Elev. 944.60', 942.85', Area 1, June 23, 1951.

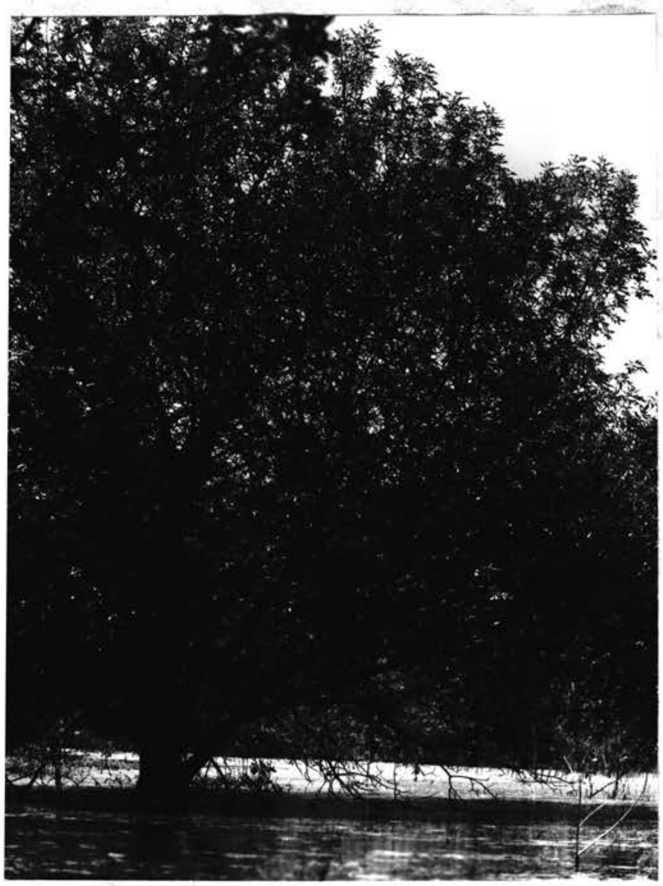

Fig. 30. Fraxinus pennsylvanica Marsh, var. subintegerrima (Vahl) Fern. Green Ash. This tree has withstood inundations of its base throughout the life of the lake.- Elev. 941.09', Area 1, June 23, 1951.

Fig. 31. Fraxinus pennsylvanica Marsh, var. subintegerrima (Vahl) Fern. Green Ash. Same tree as shown in figure 30. This tree is expected to live through the winter.- Elev. 941.09', Area 1, September 16, 1951.

Fig. 32. Fraxinus pennsylvanica Marsh, var. subintegerrima (Vahl) Fern., Green Ash. Showing depth and condition of tree. Note presence of 1951 crop of leaves which remained on the tree after death.- Elev. 937.60', Area 1, August 24, 1951.

mately eight feet above spillway level.

The author recommends this tree for plantings at or near pool levels for use as a shade tree in recreation areas.

Gleditsia *tricanthos* L., Honey Locust.- Elev. 944.60'. 941.15'.

The Honey Locust trees shown in figures 33 and 34 are trees that were present in the lake bed when the lake first started to fill. These trees withstood periods of inundation of over two months in 1944 and 1945, two short periods in 1947, and a period of over three and one half months in the late summer and fall of 1950. The leaves of the trees above the 941.65' level were still viable on September 16, 1951, though they had lost some of their chlorophyll (fig. 34). The cambium layer was still viable when examined on November 21, 1951. The tree marked (A) in figure 34 died sometime between July 8, 1951 and August 22, 1951. Using the mean between the two dates, for a complete loss of viability, would establish an inundation killing period of about four months. Furthermore, no trees were found at lower levels. Why the trees above the 941.65' level remained viable as late as November 21 is not known. It is suspected that the high oxygen content and shallowness of the almost constantly moving water are factors but no proof for this statement can be furnished.

The tree could be recommended for use in the fluctuation zone for recreational use if it were not for the heavy thorns on its branches.

Gleditsia *tricanthos* L. forms *inernis* (Pursh) Schneid,

Fig. 33. Gleditsia tricanthos L., Honey Locust. These trees have lived throughout the life of the lake.- Elev. 942.65', 941.15', Area 7, July 8, 1951.

Fig. 34. Gleditsia tricanthos L., Honey Locust. Same group of trees shown in figure 33. Tree shown by (A) killed early at the 941.15' level.- Elev. 942.65', 941.15', Area 7, September 16, 1951.

Thornless Honey Locust.- Elev. 941.81'.

Only one Thornless Honey Locust tree was observed and it reacted in the same manner to water inundation as the afore mentioned Honey Locust. Figure 35, A shows the plant on August 3, 1951. Figure 36 shows the same tree on September 16, 1951. The cambium layer of this tree was still viable when it was examined on November 21, 1951.

The Thornless Honey Locust though not an ideal shade tree would survive relatively long periods of inundation and could be used for shade at or near pool levels in flood control lakes.

Jussiaea repens L. Creeping Primrose-Willow.- Elev. 944.60', 939.32'.

The seeds of the Creeping Primrose-Willow sprout at or slightly above the water line. At times of high water the plant is able to withstand considerable inundation. The plants under these flooded conditions developed to their maximum growth around the first of August. After fruiting, the stems sank to the bottom. This development can be seen by noting the changes at the 939.32' level in the study group photos (see (A) of figure 37, 38 and 39). The plant was found more often in quiet waters than in open waters subject to heavy wave action. Figure 40 shows the plant in a semi-sheltered inlet on the east side of area 6. It is doubtful whether the plants in this deeply inundated zone will live through another season.

The practical value of this plant can not be fully estimated until more work has been done on its habits. The plants with their floating leaves have been observed to completely

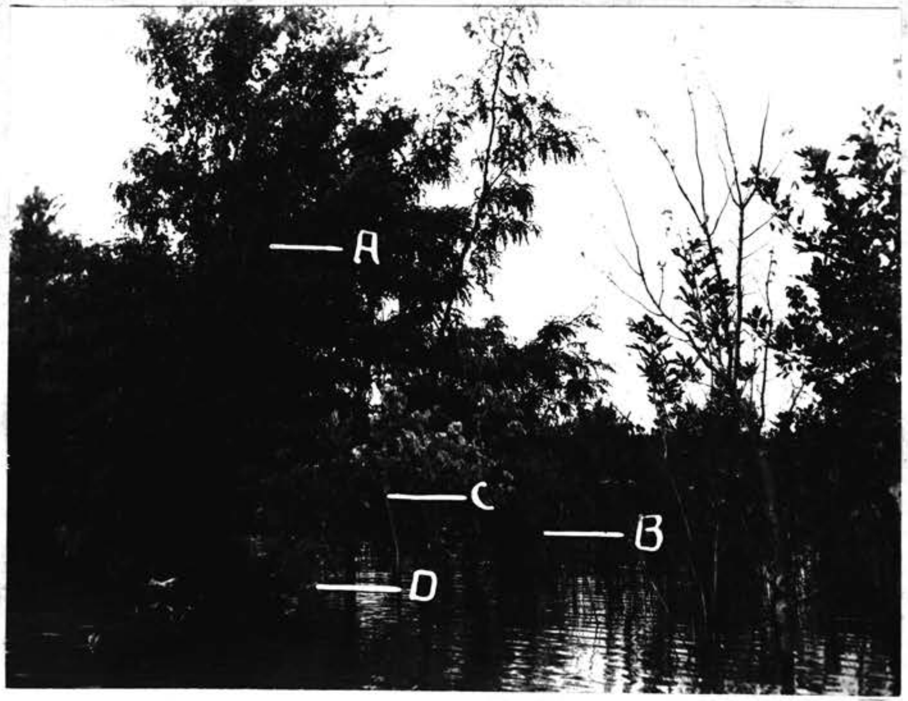

Fig. 35. Plant Study Group. (A) Thornless Honey Locust, (B) Poison Ivy, (C) Box Elder, (D) Green Ash.- Elev. 943.31', 941.31', Area 13, August 8, 1951.

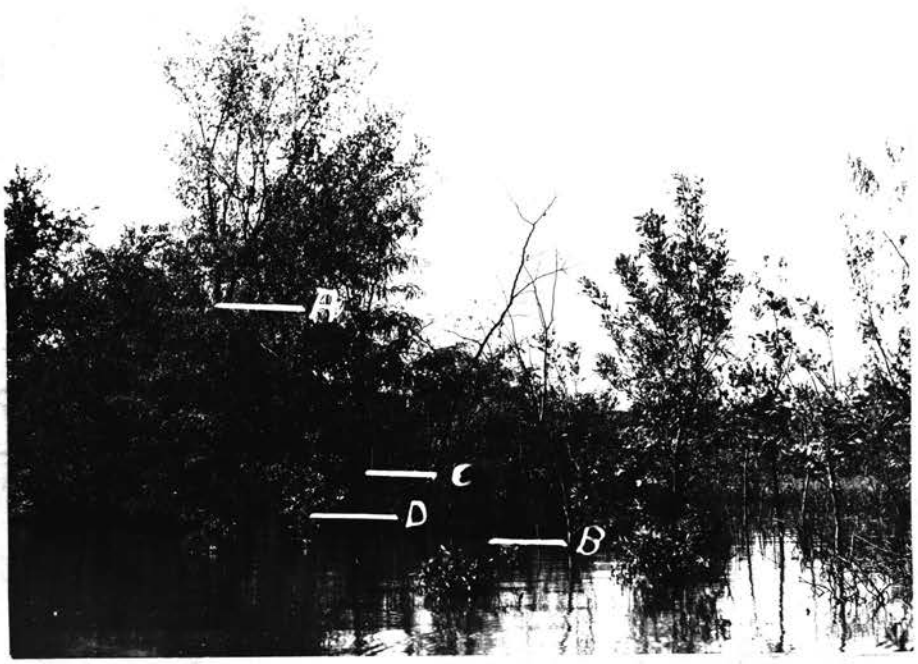

Fig. 36. Same Group shown in figure 35. Note morphological changes.- Elev. 943.31', 942.31', Area 13, September 16, 1951.

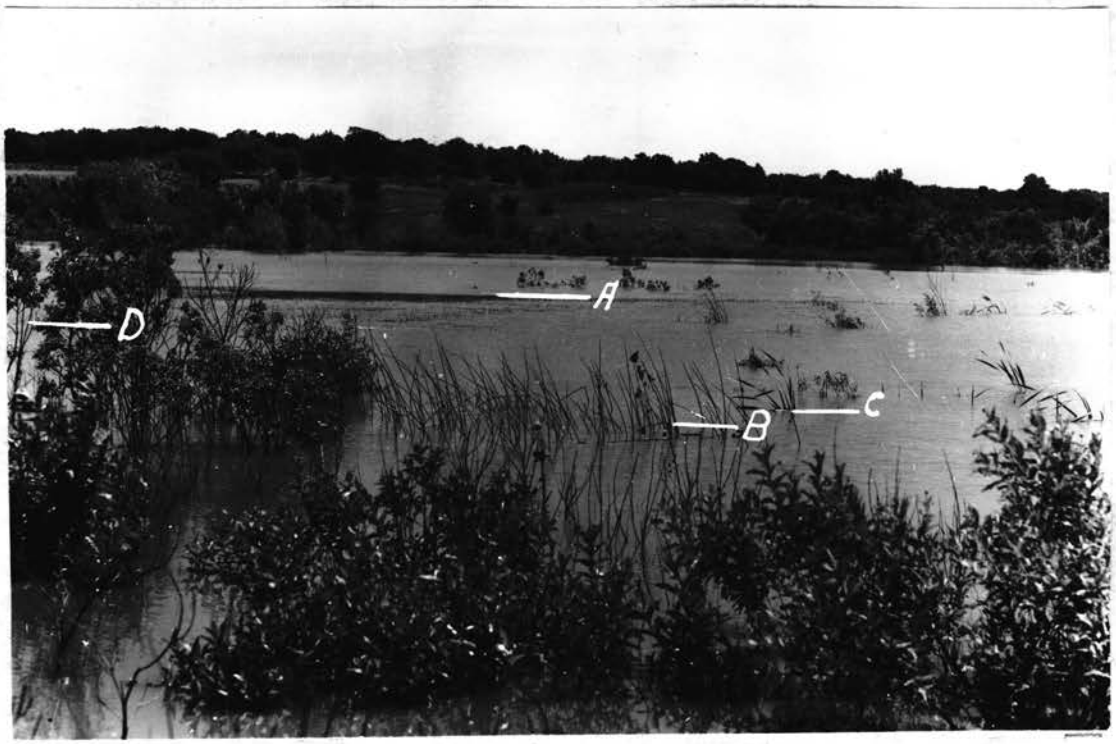

Fig. 37. Study Group of the Semi-open Water of Area 13. (A) Jussiaea repens (B) Scirpus lineatus (C) Typha latifolia (D) Diospyros virginiana. June 15, 1951.

Fig. 38. Study Group of the Semi-open Water of Area 13. Note morphological changes. August 8, 1951.

Fig. 39. Study Group of the Semi-open Water of Area 13. Note morphological changes. September 16, 1951.

Fig. 40. Jussiaea repens L., Creeping Primrose-Willow. These plants were found to be prevalent only in quiet waters of small inlets.- Elev. 941.50', 940.50', Area 6, July 5, 1951.

close small inlets thus reducing the oxygen content of the water. In the more or less open and deep waters the plants would be inhibited in their outward growth. These plants, as do all rooted aquatics, add to the nutrients of the water through death and decomposition.

<u>Jussiaea</u> <u>uruguayensis</u> Camb., Uruguayan Primrose-Willow. -Elev. 944.60', 943.30'.

The Uruguayan Primrose-Willow was found only in area 2 of the lake. The plants were found growing on decaying floating logs and in the narrow marginal zone at the waters edge. This species of plant originally from Uruguay, has not been observed except during the summer of 1951. Several years study will be necessary to determine the part is will play in the life of lakes.

<u>Justica</u> <u>lanceolata</u> Chapm., Water Willow.- Elev. 944.00', 942.54'.

The Water Willow probably established itself (fig. 41) in its present location by seeds during the high waters of 1944 or 1945. Normally a marginal aquatic plant, it survived the dry period from 1946 to 1950 without water coverage. The usefulness of this valuable plant in fluctuating waters will not be fully known until it has been studied for several years.

<u>Leersia</u> <u>oryzoides</u> (L.) S.W., Rice-Cutgrass.- Elev. 944.60', 941.79'.

This perennial was first observed in the inundated condition during the high waters of 1951. The plant (fig. 42) at the

Fig. 41. Justica lanceolata Chapm., Water Willow. The Water Willow spreads from under-water rootstalks.- Elev. 941.60', Area 1, September 18, 1951.

Fig. 42. Leersia oryzoides (L.) S.W., Rice-Cutgrass. The Rice-Cutgrass grew to maturity from submerged rootstalks.- Elev. 941.79', Area 13, September 26, 1951.

941.79' level developed to maturity from rootstalks below the surface of the water. It is beleived that this plant will continue to live through the season of 1952 though it remains in the inundated condition.

The seeds of Rice-Cutgrass are used by upland and aquatic wildfowl. The plant furnishes protection for fry and fingerlings when covered with water. Additional research is needed to determine the plants full value.

Lemna minor L., Minor Duckweed.- Elev. 944.60', 943.30'.

The Minor Duckweed is a free floating plant that follows the rise or fall of the surface of the lake or may become stranded on the shore by wave action. This plant has a tendency to accumulate in the quiet waters or protected areas of the lake (fig. 43). The mass of Duckweed in this inlet was one half inch thick.

The plant is found frequently in the ponds and streams of this region. It is doubtful whether man could successfully apply control measures to its growth.

The full extent of its value is not known.

Lindernia anagallidae (Michx.) Pennel, False Pimpernel. -Elev. 944.60', 943.50'.

Sprouting at the waters edge this small flowering False Pimpernel (fig. 44) grows rapidly to maturity. So rapidly does it develop that it can compete, though not wholly successfully, with the larger Ammannia, Cyperus and Polygonum that grow in the marginal area at the same time.

Its greatest value is probably in its appeal to the esthetic

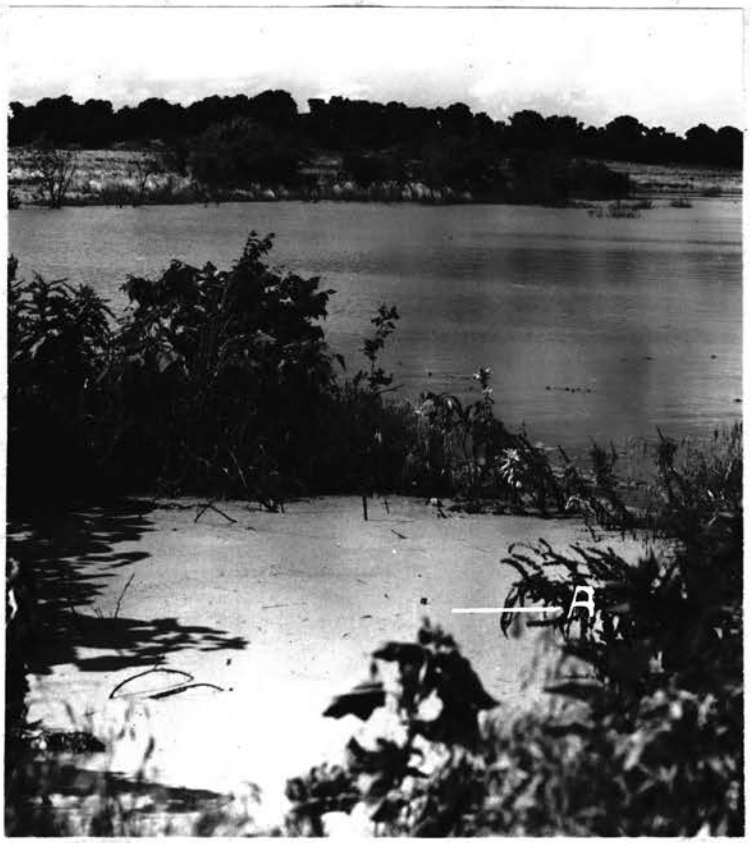

Fig. 43. Lemna Minor L., Minor Duckweed. The Minor Duckweed accumulated in the sheltered area (A).- Elev. 943.63', Area 7, June 14, 1951.

Fig. 44. Lindernia anagallidae (Michx.) Pennel, False Pimpernel. The flowering False Pimpernel survives the competition of Ammannia and Cyperus.- Elev. 944.60', 944.00', Area 10, August 22, 1951.

sense. Its diminutive size keeps it from becoming a major factor in the economy of the lake.

Morus rubra L., Red Mulberry.- Elev. 943.25'.

Only one plant of Red Mulberry could be found in the lake. The plant lived through four periods of inundation of about six weeks each during 1944 and 1945, but succumbed in 1951 after a period of a little over two months inundation. Figure 45, A shows the healthy condition of the plant on August 5, 1951. By August 22, 1951 the plant (fig. 46, A) had lost the greater percentage of its chlorophyll and at that time was not considered able to resume normal activity if returned to its normal land habitat. By September 16, 1951 the plant (fig. 47, A) had lost all of its foliage. The foliage seen in the tree is that of Smilax Bono-nox which has proved to be more resistant to inundations.

The Red Mulberry is not recommended for use in the lower levels of the floodable zone.

Nelumbo lutea (Willd.) Pers., Water-Chinquapin, Wonkapin.- Elev. 941.43', 939.93'.

The floating leaves of Nelumbo lutea were first noted coming to the water's surface on August 8, 1951 (fig. 48). By October 1, 1951 many of the leaves had reached the surface (fig. 49). It is quite probable that the actively growing leaves of this plant came from rootstocks that established themselves during the high waters of 1944 and 1945. If the supposition is true the plants existed through the dry years of 1946 and 1948.

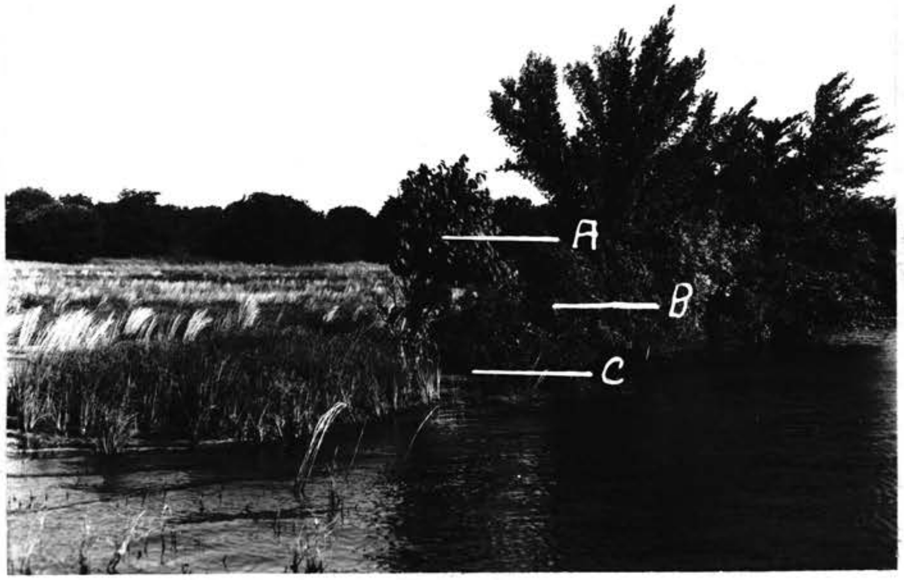

Fig. 45. Plant Study Group. (A) Mulberry, (B) Dogwood, (C) Smilax. Area 7, August 5, 1951.

Fig. 46. Plant Study Group. (A) Mulberry, (B) Dogwood, (C) Smilax. Note morphological changes. Area 7, August 22, 1951.

Fig. 47. Plant Study Group. (A) Mulberry, (B) Dogwood, (C) Smilax. Note morphological changes. Area 7, September 16, 1951.

Fig. 48. Nelumbo lutea (Willd.) Pers., Water-Chinquapin, Wonkapin. First leaves of the Water-Chinquapin reach the surface.- Elev. 941.43', 939.93', Area 13, August 8, 1951.

Fig. 49. Nelumbo lutea (Willd.) Pers., Water-Chinquapin, Wonkapin. Same location as figure 48 showing increase in surface leaves.- Elev. 941.43', 939.93', Area 1, October 1, 1951.

his would make it a plant that is quite adaptable to fluctuat-ng water conditions.

The Water-Chinquapin can become a nuisance by completely losing the fishing waters of shallow inlets. It is doubtful hether this plant should be used in lake management.

<u>Panicum</u> <u>virgatum</u> L., Switchgrass.- Elev. 944.60', 943.07'.

Switchgrass grows well with its base covered with water. 'igure 50 shows the plant at the 943.07' level after its base ad been covered with water for a period of approximately four onths. The time of its establishment could not be determined.

The practical use of Switchgrass in lake management should e investigated.

<u>Paspalum</u> <u>distichium</u> L., Knotgrass.- Elev. 944.60', 939.15'.

Knotgrass was found in the lake as low as the 939.15' evel (fig. 51). It continued to exist at this level throughout he summer but did not produce fruit. However plants from the 44.60' level down to the 942.09' level did produce fruit. It s not likely that the plants from the 942.09' level down to the 39.15' level will survive deep water through another year. ven the plants in shallow water may die if they remain submer-ed.

Sufficient information is not available to assess this plant value in our lake management programs.

<u>Paspalum</u> <u>floridanum</u> Michx., Florida Paspalum.- Elev. 944.60', 42.58'.

The Florida Paspalum, a perennial, probably established

Fig. 50. Panicum virgatum L., Switchgrass. Switchgrass reaches maturity with water covering its base.- Elev. 943.07', Area 7, August 22, 1951.

Fig. 51. Paspalum distichium L., Knotgrass. Surface characteristics of the plant after three and half months inundation.- Elev. 939.15', Area 13, August 16, 1951.

tself in the lake bed sometime during the dry years from 1946 ɔ 1950. Plants at the 942.58' level reached maturity with their ases covered with water. Figure 52 shows a plant at the 942.58' evel reaching maturity after four months inundation of the base f the plant.

Sufficient information is not available to assess it a lace in the economy of lake management.

Polygonum coccineum Muhl., Water Smartweed.- Elev. 944.60', 37.50'.

Water Smartweeds have become established spottedly throughıt about one half of the shoreline area of the lake. The preence of these plants in the lake was noted as early as 1945. lants, especially at the higher levels had to endure the dry easons of 1946 and 1948, but quickly rejuvenated during the ate summer of 1950 and summer of 1951. Figure 53 shows a aracteristic group of the plants in area 2 at the 938.10' evel. Figure 54 shows the modification of the plant to meet e wind and wave swept conditions found at the southern edge f area 4.

Water Smartweed should not be overlooked in our lake anagement program. Its wide range of habits enables it to surive in our widely fluctuating lakes. Its use at or near pool evel of our flood control lakes should be investigated.

The seeds of this plant furnish food for migratory water owl besides the many benefits that can be derived indirectly rom it by fish.

Polygonum lapathifolium L., Dock-leaved Smartweed.- Elev.

Fig. 52. Paspalum floridanum Michx., Florida Paspalum. Illustrating the ability of the plant to reach maturity after four months inundation of its base.- Elev. 942.68', Area 13, August 16, 1951.

Fig. 53. Polygoneum coccineum Muhl., Water Smartweed. A characteristic group.- Elev. 937.70', Area 2, July 28, 1951.

Fig. 54. Polygoneum coccineum Muhl., Water Smartweed. Showing plant modification to meet conditions in a wind swept area.- Elev. 938.10', Area 4, July 9, 1951.

44.60', 939.35'.

The heaviest crop of plants found in the lake was that of his annual Dock-leaved Smartweed. Two crops of this plant were roduced during the season of 1951. In the early spring before he first of May seeds of the first crop sprouted in the exposed oil of the shore line area. These seeds had probably been rought into the shoreline area by the high water (942.90') of ugust 1950. Plants were found established in the lake down to he 939.35' level which is only six inches from the calculated owest water level (938.75') reached on April 30, 1951. Figure 5 shows the lower limit of establishment of the plants at the 39.35' level (A) near the edge of the old creek bed.

The second crop germinated in the marginal soil around the 44.00' level as the water started down during the latter part f July (see graph figure 6). At this time of year the Scarlet mmannia begins to germinate in shallow water. Thus, in an area ith a receding water line the Scarlet Ammannia attains suffi- ient growth to offer competition to the seedlings of Cyperus nd Polygonum which sprout after the water has receded. The yperus and Polygonum are thus prevented from establishing hemselves in the area where the Ammannia seedlings are thick. ompare area (A) figure 56 and area A figure 57. The Polygonum eedlings and the Cyperus seedlings (fig. 56, B) developed only in n area where the Ammannia was scarce. The extremely high level reas, 944.60' down to the 944.00' was not covered with water ong enough to sprout the seeds of the Ammannia with the excep- ion of wave swept shores (fig. 9). Figure 56 shows the high evel area to be void of Ammannia seedlings. In this high level

Fig. 55. Polygonum lapathifolium L., Dock-leaved Smartweed. The establishment of plants ceased sharply at the 937.35' level along the edge of the old creek bed.- Elev. 940.35', 939.35', Area 1, July 28, 1951.

Fig. 56. Shore Line Study Group. Showing areas of seedlings. (A) Ammannia, (B) Cyperus and Polygonum, (D) Potomogeton.- Elev. 944.60', 943.60', Area 7, August 5, 1951.

Fig. 57. Shore Line Study Group. Same group as figure 56 showing growth. (A) Ammannia, (B) Polygonum and Cyperus, (C) Cyperus, (D) Potomogeton.- Elev. 944.60', 943.60', Area 7, September 16, 1951.

rea the seedlings of the *Cyperus* and the *Polygonum*, shown by he bracket (B) figure 57, grew to maturity. Where the stand of olygonum was heavy the *Cyperus* plants were stunted or even illed. Where the stand of *Polygonum* was light the *Cyperus* grew o maturity (fig. 57, C).

P. lapathifolium is exceptionally valuable as a heavy crop roducer and is well adapted to lakes in this region. A draw-own of the water surface level of about six feet in the spring ould allow the seeds, if present, to germinate. The water, fter germination of the seeds, could again be raised three ourths of the distance of drawdown for the remainder of the rowing season. This would enable the plants to serve as pro-ection for young fish. In late summer or fall the plants hould be flooded (figs. 58 and 59) to allow decomposition and elease of nutrients to the water. The seeds of these plants re used as food by aquatic and upland game fowl. The plants an be used by aquatic birds if covered with water or by upland ame birds if exposed.

Polygonum pensylvanicum L., Pinkweed.- Elev. 944.60', 43.50'.

The Pinkweed has become established at high elevations in a ew of the swale areas of the lake. In general this plant is ore common at elevations above spillway level. Nevertheless his plant is associated with and may become useful in our flood ontrol lakes. A period of several years study would be re-uired before the full extent of its usefulness could be deter-ined.

Fig. 58. Plant Study Group. Cottonwood trees in the Polygonum filled water of the old creek bed.- Elev. 944.60', 940.00', Area 1, October 8, 1950.

Fig. 59. Plant Study Group. Same group as shown in figure 59 illustrating the early killing of the Cottonwood trees in the quiet detritus filled water.- Elev. 944.60', 940.00', Area 1, August 25, 1951.

Its esthetic value is high and it serves as food for both quatic and upland game fowl.

Populus deltoides Marsh., Cottonwood.- Elev. 944.60', 39.35'.

The study of the Cottonwoods during the summer of 1951 resented some unusual data which the writer could not explain.

In the relatively quiet waters of area 1 (fig. 58) the ottonwoods and Willows from the 942.90' level to 940.00' level ithstood periods of inundation ranging up to seven months or ore during the summer and fall of 1950. These plants produced eaves in the spring of 1951 but had lost most of them by July ., 1951 and by August 25, 1951 all their leaves had been shed fig. 59).

In contrast the Cottonwoods in the open waters of area 1 fig. 60 and fig. 61) at the 940.35' to the 939.35' level were till viable on August 1, 1951. By August 25, 1951 the taller rees in the open waters began to lose their leaves (fig. 61,A). y September 16, 1951 the taller trees had lost nearly all of heir leaves (fig. 62) but the leaves and branches of the young rees (fig. 63) with only a small portion of their branches out f the water continued to live. Some of these young trees etained their leaves in a living condition as late as October 5, 1951.

Possible explanations for the difference in killing time of he plant in the open and the closed water might be placed on ifferences in the oxygen content of the water. The large amount f organic debris in the water around the trees shown in figure

Fig. 60. Populus deltoides and Salix nigra Study Group. Cottonwood and Willow trees in open water.- Elev. 939.85', 939.35', Area 1, October 8, 1950.

Fig. 61. Populus deltoides and Salix nigra Study Group. Same area as shown in figure 60 showing the prolonged viability of the trees in open water.- Elev. 939.85', 939.35', Area 1, August 25, 1951.

Fig. 62. Populus deltoides Marsh., Cottonwood. Tall two and three year old Cottonwood trees died earlier than the short two and three year old trees.- Elev. 940.09', 939.59', Area 1, September 18, 1951.

Fig. 63. Populus deltoides Marsh., Cottonwood. Same area as above showing prolonged viability of short two and three year old trees.- Elev. 940.09', 939.59', Area 1, September 18, 1951.

3 suggest a high oxygen demand on the water. This area is also
otected from wind and wave action that would normally stir
d mix the oxygen absorbed at the surface into the lower layers.
e low amount of oxygen in this water could have been the cause
r the early killing of the trees. The absence of decaying or-
nic material and active wind and wave action characterize the
nditions surrounding the trees shown in figure 60. Here the
evailing southwesterly wind has fully a one half mile sweep
ich can by the creation of water turbulence stir considerable
ygen into the lower layers of the water.

A possible explanation for the difference in killing time
tween the tall and the short trees shown in figure 62 and
gure 63 could be the greater transpiration rates of the taller
ees. Whatever the cause may be the fact remains that there
an inverse ratio between killing time and the surface area
the plant exposed to the air. This is especially true in
e two and three year year old group.

The trees shown in figure 64 are in their fifth and sixth
ars of life. They began life after the high waters of 1944
d 1945 and were found only above the 940.18' level (dotted
ne figs. 64 and 65). At the 940.18' level inundations of a
ttle over two months duration occurred in 1947 and in 1949.
ese occurred during the early months of the summer when oxygen
mand of the plant was high. It is highly probably that most
the plants which may have started in 1946 below the 940.18'
vel were killed by the more than two months inundation which
ey would have received.

Younger trees were found at the slightly lower levels of

Fig. 64. Six year old Study Group. Dotted line marks limit of establishment at the 940.18' level.- Elev. 944.60', 940.18', Area 13, August 16, 1951.

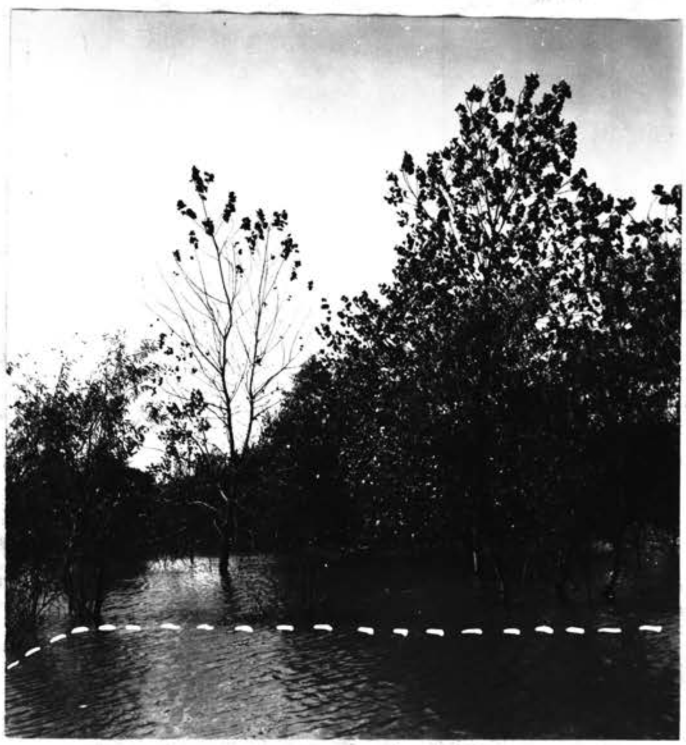

Fig. 65. Six year old Study Group. Same group as figure 64 but taken from the opposite direction.- Elev. 944.60', 940.18', Area 13, October 1, 1951.

40.09' to 939.59' elevation (fig. 62 and fig. 63). These young-
r trees began their life after the water rise in 1947. No
lants were found below the 939.35' level. Trees above the
39.59' level lived through the long period of inundation begin-
ing the latter part of July and extending through the winter
onths of 1950-51 probably because they had passed or nearly
assed their active growing season when the rise came.

Trees older than six years were found only above the 942.50' evel and these near the waters edge particularly near a high reek bank (fig. 66). In such cases some of the roots of the ree could reach the aerated soil above the water line. Follow-ng the 942.50' level back through the years on the graph one an see that trees at this level must have withstood inundation eriods of about two months during the years of 1944 and 1945. From this data it is beleived that a period of inundation greater han two months especially during the growing season will gener-lly produce a kill of these trees, but longer periods of inun-ation without a kill are possible during the more or less ormant period of the plant.

Killing time behavior of the five and six year old and lder trees was quite erratic and in some instances could not be xplained. Figure 65, the same area as shown in figure 64 shows two six year old Cottonwood trees side by side, one of the two rees had succumbed, but the other was still living on October ., 1951. The cambium layer of the living tree was still viable on November 21, 1951. The large Cottonwood tree shown in the Willow, Cottonwood Study Group at the 942.70' level (figs. 77 and 78) succumbed, losing its leaves by October 25, 1951. The

Fig. 66. Populus deltoides Cottonwood. One of the older Cottonwood trees near the shoreline.- Elev. 942.50', Area 2, October 25, 1951.

ree shown in figure 66 photographed from the same position as hat of figure 77 retained its leaves in a chlorophyllaeceous ondition until frost. It is beleived that this tree will put 'orth leaves in the spring of 1952.

The relatively short inundation killing period of the ottonwood tree would keep it from being recommended for use at he lower contour levels in recreational areas of our flood ontrol lakes though longer periods of viability in the shallower reas are in evidence.

<u>Potamogeton</u> <u>nodosus</u> Poir, American Pondweed.- Elev. 944.60', 38.10'.

The American Pondweed was found in abundance at two general evels in the lake, the 940.10' to 938.10' level (fig. 68, A) nd the 942.67' to the 941.67' level (fig. 68, B). The graph fig. 6) shows two high water periods during the past two years. 'he first rising to the 940.65' level in the midsummer months of .949; the second rising to the 942.90' level during the late summer months of 1950. The presence of the majority of the plants at these two levels suggest that these plants began their ctive life in the shallow water areas during these two high aters periods. The well established plants of the 940.10' to 938.10' level reached the water's surface about the middle of une while the plants of the 942.67' to 941.67' level did not each the surface until August. The appearance of the latter group of plants at the surface can be noted by examining area D) of figures 56 and 57.

These observations suggest that the proper control of water

Fig. 67. Potamogeton nodosus Poir, American Pondweed. Floating characteristics of leaves and fruiting bodies. -Elev. 940.10', 938.10', Area 13, July 9, 1951.

Fig. 68. Potamogeton nodosus Poir, American Pondweed. The American Pondweed had established itself at two different levels.- Elev. A; 940.10', 938.10', Elev. B; 942.67', 941.67', Area 7, August 22, 1951.

evels might produce large crops of this plant in a lake once it s seeded. However, more investigation is needed to prove this ssumption. The possible use of the American Pondweed should ot be overlooked in the fluctuation zone area.

Prunus angustifolia Marsh., Chickasaw Plum.- Elev. 944.60', 43.05'.

Only one thicket of Chickasaw Plums (fig. 69) was found in he lake bed and that above the 943.05' level. The plants lived hrough the inundation of the high waters of 1944 and 1945, ossibly because the inundation occurred at a time of the year n which the plant was more or less dormant. Plants at the 43.05' level and above were not again inundated until May of 951. These plants killed soon after inundation but exact time s not known. The plants had lost all of their leaves and most f their fruit by August 22, 1951.

The short duration of the inundation killing period pre- ents the recommendation of this plant for use in a lake manage- ent program.

Prunus americana Marsh, var. lanata, American Wild Plum. Elev. 944.60', 944.09'.

American Wild Plums were found along the old creek banks nd above the 944.09' level. The leaves of the tree shown in igure 70 had lost most of their chlorophyll before July 28, 951. At that time it was considered that this tree had already ost its ability to resume normal activity. Figure 71 shows the ondition of the tree on September 16, 1951.

Fig. 69. Prunus angustifolia Marsh., Chickasaw Plum. These Chickasaw Plum trees lived through the high water inundation of the fall of 1945 but were killed quickly by water coverage during the summer months of 1951.- Elev. 944.60', 945.05', August 25, 1951.

Fig. 70. Prunus americana Marsh, var. lanata, American Wild Plum. Registrating the flaccid condition of the leaves.- Elev. 944.09', Area 2, July 28, 1951.

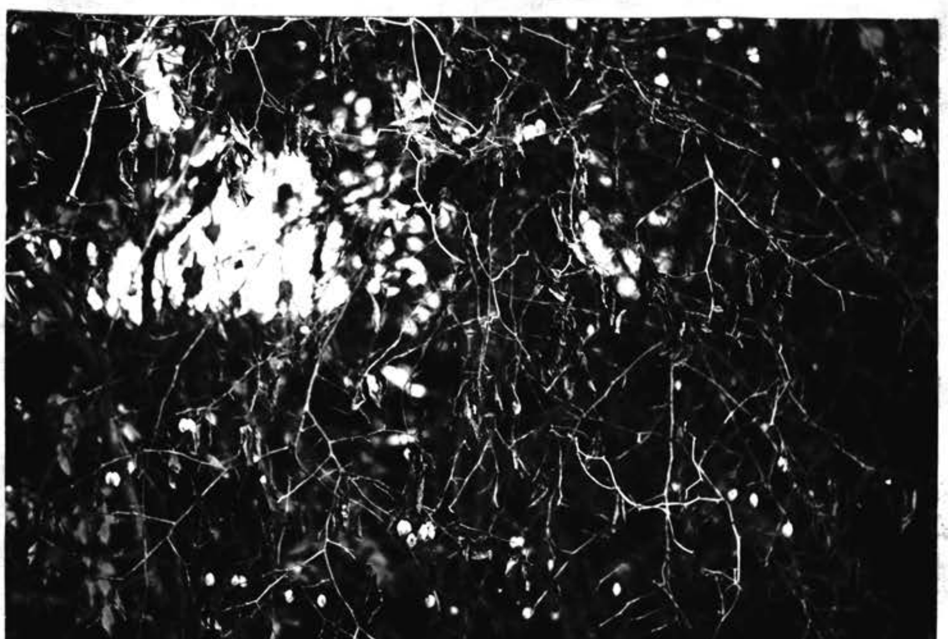

Fig. 71. Prunus americana Marsh, var. lanata, American Wild Plum. Same tree as shown in figure 70, Area 1, September 16, 1951.

The short inundation killing period prevents it from being recommended for use in a lake management program.

Quercus macrocarpa Michx., Mossy-cup Oak.- Elev. 942.50'.

One tree of the Mossy-cup Oak was found in the lake. The tree (fig.72) was first observed on July 28, 1951, at which time the writer assumed that it would be able to resume normal activity if returned to a land environment. The leaves of the tree remained in a chlorophyllaceous condition until September 1, 1951. However, the tree was not considered able to resume its normal activity if returned to a land habitat. By September 16, 1951 the tree had lost all of its leaves (fig. 73).

Since only one tree of this species was observed it would be difficult to arrive at an inundation period killing time. It is believed, however, that this tree will survive an inundation period of over two months duration.

This tree has possibilities for use as a shade tree in the recreation areas at or above pool level in our flood control lakes but cannot be recommended until further observations are made.

Quercus marilandica Muench., Black Jack, Jack Oak.- Elev. 944.60', 943.60'.

Many original Jack Oaks were found around the edge of the lake basin in locations such that their roots could reach aerated soil above the water line. The plant shown by (A) in figure 74 at the 943.10' is one of the Jack Oaks present when the lake started to fill. This tree survived over a month of inundation late in the year of 1945, but killed with less than

Fig. 72. Quercus macrocarpa Michx. This Mossy-cup Oak showed little sign of distress after two months water coverage of its base.- Elev. 942.40', Area 1, July 28, 1951.

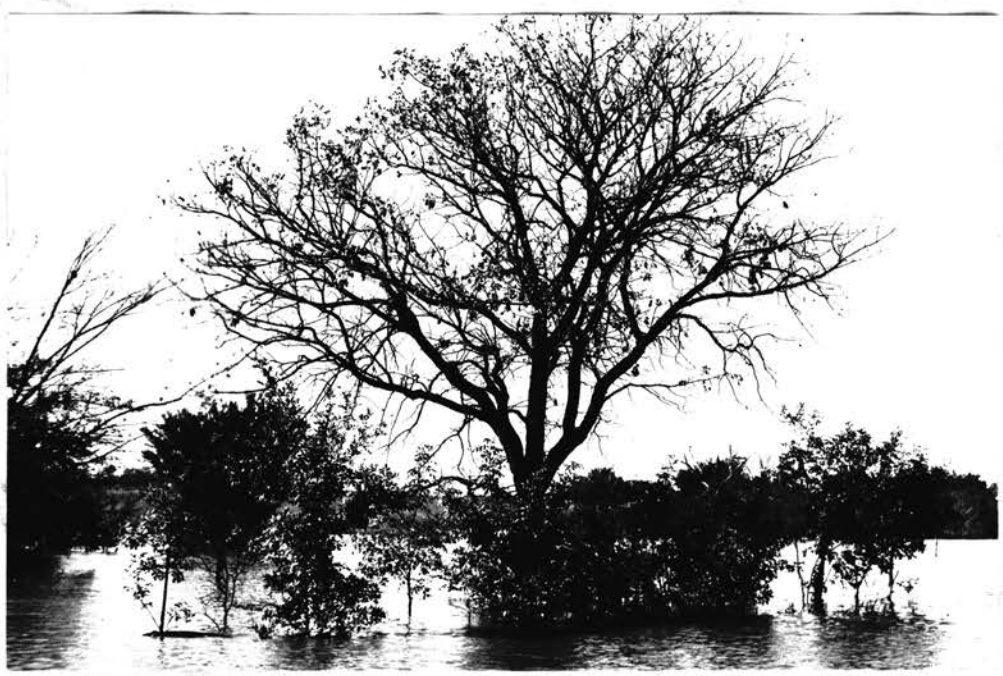

Fig. 73. Quercus macrocarpa Michx. The same tree shown in figure 72 succumbed after three months inundation. Note the viability of the young Green Ash trees in the foreground.- Elev. 942.40', Area 1, September 18, 1951.

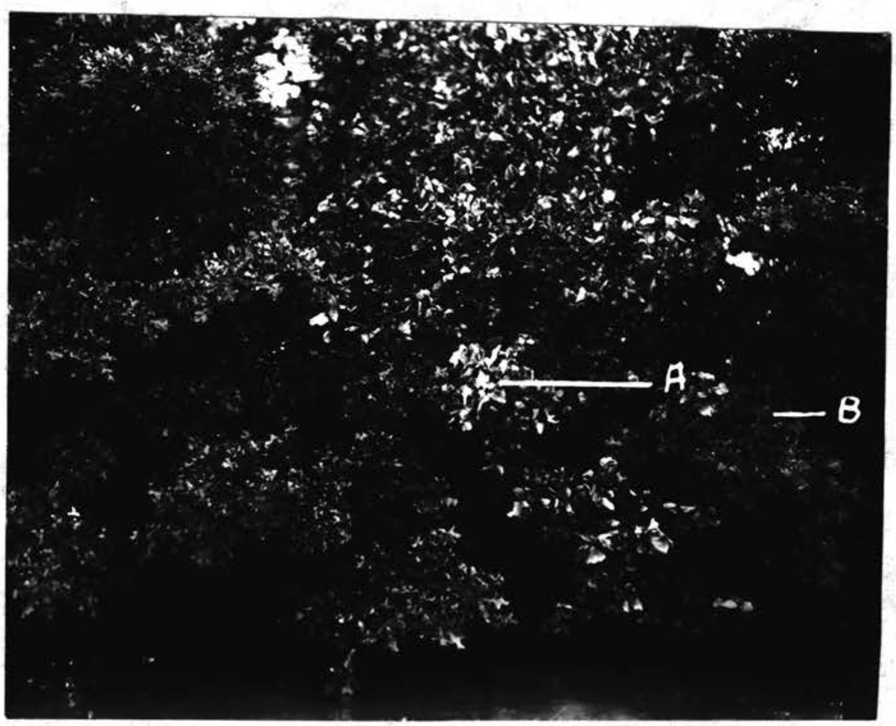

Fig. 74. *Quercus marilandica* Muench and Quercus stellata Wang. The Jack Oak (A) is less resistant to water coverage than the Post Oak (B).- Elev. 943.60', Area 13, July 8, 1951.

month of inundation during the early summer of 1951. A comparison can be made with the more resistant Quercus stellata (B) nearby.

This tree because of its short inundation killing period cannot be recommended for use in lake management.

Quercus stellata Wang., Post Oak.- Elev. 944.60', 942.73'.

The presence of the original indigenous Oaks only at levels of 942.73' or higher indicates that Post Oak trees were able to survive inundation periods of about six weeks but succumbed if the inundation period reached two months.

Figure 19, B shows a tree of this species at the 942.73' level at a time when it is just beginning to lose the chlorophyll from its leaves. It must also be remembered that the tree was near the shore line and that some of its roots may have extended to the aerated soil on the shore. However, its resistance to inundation is much greater than that of the Jack Oak tree shown by (C) of figure 19 at the 944.00' level which had already lost the chlorophyll from its leaves.

Q. stellata with an indicated inundation killing period of about two months cannot be recommended for use in the lower levels of the fluctuation zone of flood control lakes.

Rhus Toxicodendron L., Poison Oak.- Elev. 944.60', 943.83'.

The plants of this species shown by (B) of figure 35, had lost all of the chlorophyll from their leaves by August 8, 1951 and apparently had been dead for sometime.

Since this plant is poisonous to man its presence in the lake or the area surrounding is not desired. Flooding might be considered as a means of eliminating the plant from the recreational areas surrounding a lake.

Robinia Pseudo-Acacia L., Black Locust.- Elev. 944.60', 943.30'.

The study of the Black Locust grove (fig. 75) in area 3 illustrates the inability of this species to cope with water covering its root system. The base of the large trees shown by (A) of figure 75, is at the 943.30' level. This tree and the large barren tree in the back ground probably were killed by the high waters of the summer of 1944 and 1945. The younger trees six years and less seen in the water and at about the same level, put forth leaves in 1951 as a last effort of survival but did not reach full foliage status. The trees shown by (B) of figure 75, at the 944.25' level reached full foliage but killed with less than three weeks inundation. The trees seen at the higher levels above the water line withstood inundation of their bases for periods of at least a month in 1945. This inundation occurred at a time when the plants had passed their active growing season.

This plant can not be recommended for use in the fluctuation zone.

Rumex crispus L., Yellow Dock.- Elev. 944.60', 942.90'.

Yellow Dock as well as most of the herbaceous upland plants succumbed quickly after inundation. Figure 76, A shows the plant in water at the 942.90' level on July 3, 1951.

Its chief value in the fluctuation zone area would be in

Fig. 75. Robinia Psuedo-Acacia L., Black Locust. The lack of resistance to inundation is shown by the dead tree (A) and the dying tree (B) which is above the water line.- Elev. 944.60', 944.00', Area 3, July 8, 1951.

Fig. 76. Rumex crispus L., Yellow Dock. The Yellow Dock soon after inundation.- Elev. 944.60', 942.90', Area 1, July 3, 1951.

e addition of organic matter and nutrients to the water through ath and decomposition. This is true of most of the herbaceous land plants found in the fluctuation zone.

Salix interior Rowlee, Sandbar Willow ?- Elev. 944.60', 39.10'.

The Sandbar Willow was found in conjunction with the Black llow in nearly all areas of the lake. Its diminuitive size d smaller leaf distinguished it from the larger fast-growing ack Willow. It was more commonly found along the old creek nks in the upper reaches of the lake. Many of these plants re killed by August 1, 1951. All plants found were less than x years old.

It is believed that these plants cannot withstand prolonged iundation.

Salix nigra Marsh., Black Willow.- Elev. 944.60', 939.10'.

The Black Willow was found in every section of the lake. ts presence in numbers indicates its adaptability to lake shore nvironment. A few trees still exist that were present in the ld creek bed before the lake was built. Figure 77 shows one of hese trees at the 940.20' level. This tree withstood inundations f its base in 1943, all of 1944 and 1945, a short period in 947, 1949, and 1950 and was still alive on October 25, 1951 fig. 78). This tree and all of the other trees older than six ears were found next to a shore possessing a high bank. The op of the tree shown in figure 78 started losing its leaves ong before the leaves near the base. This again suggests as in he case of the Cottonwood that the distance of transportation

Fig. 77. Plant Study Group. Populus deltoides.- Elev. 942.70', Salix nigra.- Elev. 940.20', Area 2, July 28, 1951.

ig. 78. Plant Study roup. Same group as bove. The Cottonwood nd the top branches f the Willow died hile the lower branches f the Willow remained live.- Populus deltoi- es Elev. 942.70', Salix igra Elev. 940.20', rea 2, October 25, 1951.

f water to the leaves might be a killing factor. The tall .llow trees illustrated in figure 80 also showed an earlier .scoloration and killing than the shorter trees. The Black .llow as was the case with the Cottonwood tree did not live as ong after inundation in the quiet detritus filled waters of the llets (fig. 79) as they did in the open waters (fig. 80).

The endurance to inundation of some of the young trees as hown in figure 80 would indicate a rather long inundation kill- ng period time especially in shallow water. The fact that none f the trees older than six years were found in the lake except t the higher levels or near the bank indicates that the killing .me is much shorter. The Willow has the ability to put forth lventitious roots from the stem below the water line. These irnish succor to the plants, thus giving a false impression as killing time. The inundation killing time of this plant will .ry considerably with its age and with its location in the lake. s normal inundation killing period appears to be well over two nths and for this reason it is recommended for use as a shade ee at or near pool levels. The young trees when covered with .ter serve as protection to small fish and add considerably to e esthetic value of a lake.

<u>Sapindus</u> <u>Drummondi</u> H. and A., Soapberry,- Elev. 944.60', 1.25'.

The Soapberry tree was found only at very high levels cept in the case of a very young tree (fig. 81, C). This ung tree at the 941.25' level died before July 28, 1951. At is time trees at the 943.75' had already started losing their

Fig. 79. Salix nigra, Populus deltoides. These trees lived only a short time in the quiet detritus filled waters.- Elev. 944.60', 939.10', Area 1, June 23, 1951.

Fig. 80. Salix nigra. Showing prolonged viability of the Black Willow in open water.- Elev. 944.60', 939.10', Area 13, October 1, 1951.

Fig. 81. Sapindus Drummondi, Soapberry. Color differentiation is exibited by the leaves of the plants at the different levels.- Elev. A- 944.60', B- 943.75', C- 941.25', Area 1, July 28, 1951.

Fig. 82. Sapindus Drummondi, Soapberry. Early discoloration of the leaves was noted in this group of Soapberry trees.- Elev. 943.70', 942.80', Area 1, July 3, 1951.

green color (fig. 81, B) while those at the 944.60' level retained their full color (fig. 81, A). The reduction of chlorophyll in the leaf was noticed as early as July 3, 1951 (fig. 82). The leaves of the Soapberry trees at the 943.60' to the 943.20' level gradually lost their green color and by August 6, 1951 nearly all of the leaves had turned yellow (fig. 83). By September 16, 1951 the plants had lost most of their leaves (fig. 84). Compare the color of the Sapindus leaves with that of the more resistant American Elm at the extreme left of the picture.

The Soapberry can not be recommended for use in the lower levels of the lake flucuation zone because of its short inundation killing period.

Scirpus lineatus Michx., Bulrush.- Elev. 944.60', 938.60'.

Scirpus lineatus had become well established in several of the small inlets of the lake at the 939.81' to the 938.81' levels. The plants probably established themselves at these levels during the high waters of 1947 or 1949. They then had lived through the dry periods of 1948 and 1949-50, which would show them to be quite versatile as far as requirements of habitat are concerned. The stems of the plants at the above mentioned levels were not husky though they protruded through the water surface. Most of these especially at the deeper levels did not produce fruit and before the summer was over the stems died and fell into the water. The above mentioned phenomena of these plants at the 939.30' level is illustrated in (B) of figures 37, 38, 39. This data places the plant's maximum depth limit at about four to five feet. Plants found at the higher

Fig. 83. Sapindus Drummondi, Ulmus americana. Leaf color differentiation.- Elev. 943.60', 943.20', Area 7, August 6, 1951.

Fig. 84. Sapindus Drummondi, Ulmus americana. Same group as shown in figure 83 illustrating the difference in viability of the American Elm and the Soapberry.- Elev. 943.60', 943.20', Area 7, September 16, 1951.

levels were in a healthy growing condition.

The plant grows rapidly in shallow water and in water soaked soil. Its full value in a lake management program is not known. Its appeal to the aesthetic sense is high and through death and decomposition it will add nutrients to the water. It also will serve as protection to small fish. Further studies should reveal other values.

Scirpus sp. ? L., Bulrush.- Elev. 940.10', 939.10'.

Scirpus sp. probably introduced by man, was found only in area 13 at the location shown in figure 85. The plant was noted at its present site by the writer while fishing in the lake during the summer months of 1945. Apparently, the plants have persisted in dry soil through the summers of 1946 and 1948.

The plant appears to be quite versatile as far as habitat requirements are concerned and is recommended for use in lakes with a widely fluctuating water surface level.

Smilax Bona-nox L., Greenbrier,- Elev. 944.60', 941.71'.

The Greenbrier was found to be quite resistant to inundation. Plants at the 942.79' level, with their bases continually under water remained viable from June 6, 1951 to October 1, 1951 (fig. 85). Others were found that were still viable on October 25, 1951 at the 941.71' level. The Greenbrier (C) of figures 45, 46, and 47 of the, "Plant Study Group, Area 7", shows the plant at the 942.79' level and allows a comparison of its viability with that of the other plants in the group; namely, the Red Mulberry, the Dogwood and the Elm.

Fig. 85. Scirpus sp. ? General growth characteristics of the plants.- Elev. 940.10', 939.10', Area 13, September 16, 1951.

Smilax Bona-nox provides good cover for quail and other pland game. Since its resistance to flooding is high it should e considered in experimental plantings in the fluctuating zone rea of our flood control lakes.

Sorgum halepense (L.) Pers., Johnson Grass.- Elev. 944.60', 44.23'.

Johnson grass was observed only at one place in the lake ed below the 944.60' level though it is quite prevelant at igher levels. The Johnson grass shown in figure 87 extends ownward to the 944.23' level and forms a definite line at that evel. The line was probably produced by the inflowing waters f the creek which were higher than spillway level.

More work needs to be done before the value of this plant 1 the fluctuation zone can be assessed.

Tamarix gallica L., French Tamarisk, Salt Cedar.- Elev. 40.40', 939.40'.

The Salt Cedar was found between the levels of 940.40' and 39.40' and only in one location (fig. 88). The plants in this rea were in their fifth and sixth years, having started life in 946 and 1947. The plants which started in 1946 lived through aree months inundation in 1947 and 1949, more than seven months 1 1950 and more than five months in 1951. Their prolonged via-lity in the long inundation periods of 1950 and 1951 is parti-ly attributed to the plants ability to produce adventitious oots below the surface of the water. The cambium layer of the em below the origin of the adventitious roots died during the

Fig. 86. Smilax Bona-nox L., Greenbrier. This Greenbrier remained viable late in the season.- Elev. 943.20', Area 7, September 16, 1951.

Fig. 87. Sorgum halepense, Johnson Grass. Showing lower limit of growth at the 944.23' level. Note the high-water-cut-marks in the old creek bank.- Elev. 944.60', 944.23', Area 1, August 24, 1951.

Fig. 88. Tamarix gallica, Salt Cedar. This plant remained viable through the development of adventitious roots just below the water line.- Elev. 940.40', 939.40', Area 11, August 25, 1951.

ummer of 1951.

The fact that these plants withstood inundations of over hree months during the years of 1947 and 1949, places them in class suitable for use in the fluctuation zone of flood control akes.

<u>Teucrium</u> <u>canadense</u> L., American Germander.- Elev. 944.60', 42.14'.

Plants of <u>Teucrium</u> <u>canadense</u> withstood inundation in 1951 ong enough to produce flowers and fruits. Figure 89 shows the ondition of the plants on August 5, 1951, at the 942.14' level. t is doubtful whether these plants will send forth shoots in 952 especially if the water remains at a high level.

Sufficient knowledge is not available to assess this plant value in a lake management program.

<u>Typha</u> <u>latifolia</u> L., Common Cat-tail.- Elev. 944.60', 941.35' nd 939.50', 938.50'.

The Common Cat-tails were probably established at the lower evels by the germination of the seeds in the water soaked soil ollowing the midsummer rises of 1947 and 1949. The plants ived through the medium high waters of 1950 but failed to re-ppear in 1951. One relatively large bed was found in area 13 uring the fall of 1950 at the 938.50' to 939.50' level. Few f the plants reached the surface of the water in 1951. Two f the plants reached the surface but died before the end of ummer (fig. 37,C). It is possible that depth of water is the nly factor involved in the death of the plants. If so then one

Fig. 89. Teucrium canadense, American Germander. The American Germander remained alive after water coverage but failed to produce normal growth.- Elev. 942.14', Area 7, August 5, 1951.

ould conclude that continuous inundations of four feet or more s a limiting factor to their growth. However, further obser- ation on the depth limitations of this plant should be made.

Only the plants found at the higher levels of the fluctua- ion zone were in a healthy growing condition. Figure 90 shows lants from the 941.85' to the 941.35' level in area 1. The bove observation indicates that the plant is probably better ited for use in lakes with a stable rather than a fluctuating ter level. The data even suggest that control of water level ght be used to kill the plants should they become a nuisance.

Typha glauca Godr. ?, Cat-tail-Elev. 944.60', 938.60'.

This rank growing plant remained viable in the relatively ep waters between the 940.40' and 938.60' levels during the gh waters of 1951. Some of the plants were observed by the iter in their present locations as early as the summer of 1945. e plants were able to withstand the dry years of 1946 and 1948. uiting bodies were not found as late as October 1, 1951, the me of the last observation (fig. 91).

Its ability to withstand both the submerged and the emerged nditions make it suitable for use in widely fluctuating lakes. re needs to be known about the habits of this plant before its al value can be assessed.

Ulmus americana L., American Elm.- Elev. 944.60', 941.02'.

Several of the original American Elms present when the water s first impounded were found around the edge of the lake basin. roadside group in area 7, (fig. 92) was selected for continued udy throughout the summer of 1951. Figure 92 shows the condition

Fig. 90. Typha latifolia, Common Cat-tail. The Common Cat-tails grew vigorously in shallow waters.- Elev. 941.85', 941.35', Area 1, June 23, 1951.

Fig. 91. Typha glauca Godr. ? Cat-tail. These plants failed to produce seed in 1951 but remained viable in the deep waters.- Elev. 938.90', 940.40', Area 7, October 1, 1951.

f the trees on June 15, 1951 at which time the trees at the owest level had been inundated for a period of approximately ix weeks and the trees at the higher levels approximately four eeks. All of the trees put forth foliage though some of he trees had undergone an inundation period of more than three onths during the late summer of 1950. However, leaves of the rees at the 941.02' and 941.17' level were stunted and did not each full size. These leaves as well as the leaves of the rees at the 941.32' level dropped from the tree before August 5, 951 (fig. 93). At the same time the leaves of the trees at ne 941.67' level turned yellow and dropped from the trees before eptember 14, 1951. By September 14, 1951 the leaves of the rees at the 942.42' level turned yellow (fig. 94) and these rees in turn began losing their leaves before October 1, 1951 fig. 95). Trees at the 943.17' level and above held their eaves until frost. Examination of the cambium layer of these rees on November 21, 1951 showed the trees to be in viable ondition.

Reconstructing the history of inundation of American Elms rom the time of impounding of the water in the lake one finds eriods of inundation lasting about two months in 1942, three r more months in 1944, three periods of over two months uration in 1945, two short periods of a month or less in 1947, period as long as four months in 1950 and a period of more han seven months in 1951.

There is a possibility that three factors have contributed o the killing of the trees by inundation, namely, duration,

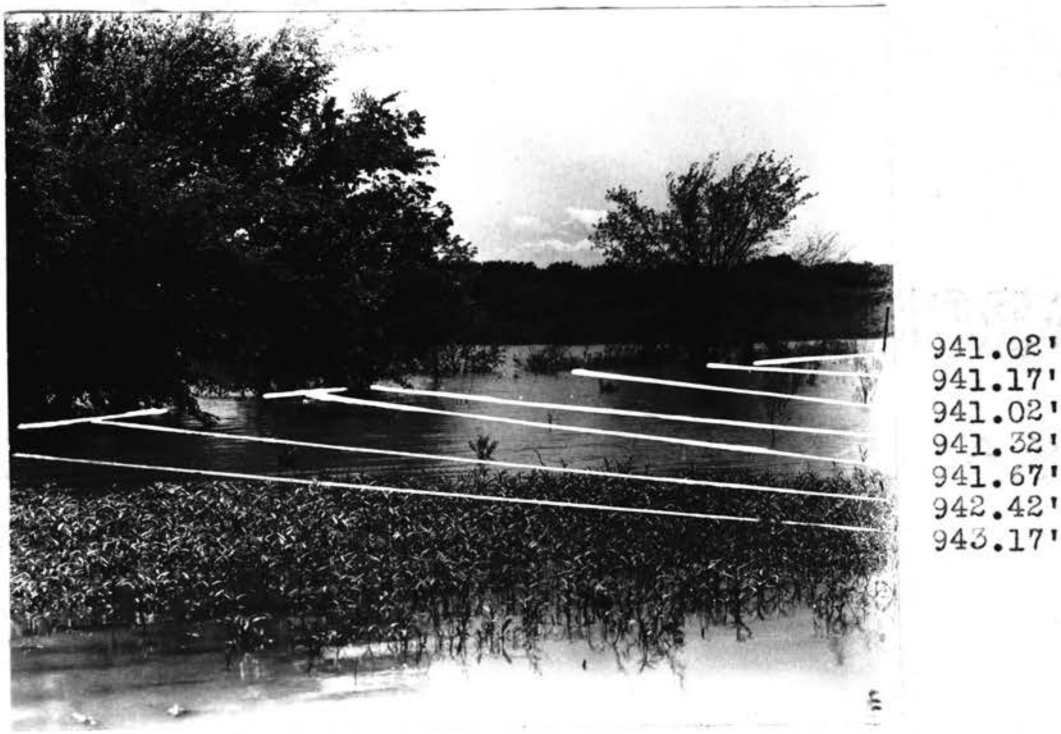

Fig. 92. Polygonum lapathifolium, Ulmus americana. Illustrating the growth of P. lapathifolium and the morphological changes in U. Americana.- Elev. indicated, Area 7, June 15, 1951.

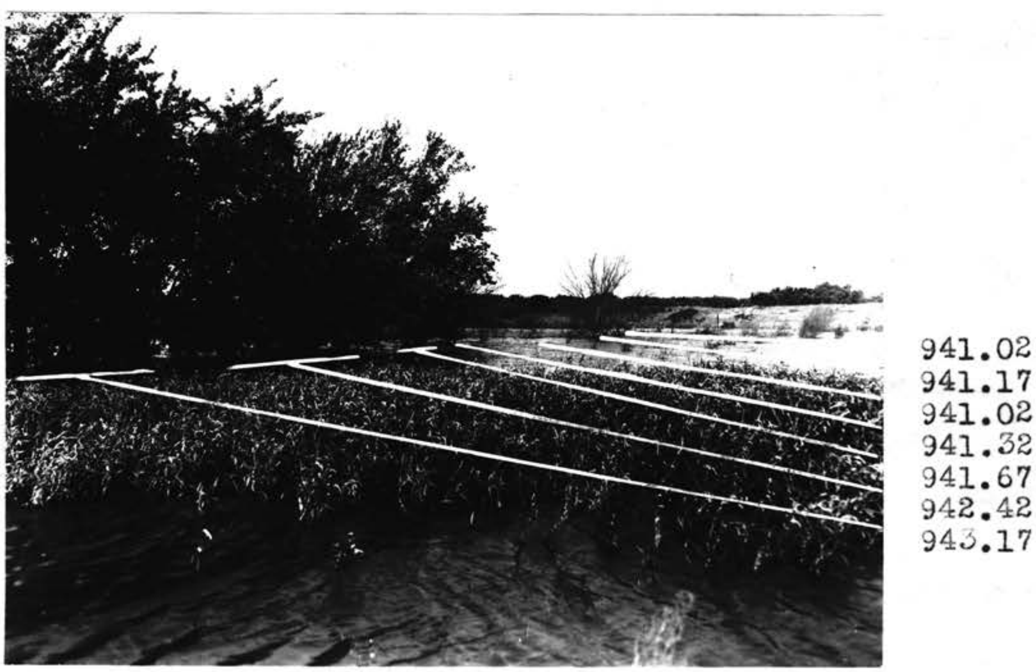

Fig. 93. Polygonum lapathifolium, Ulmus americana. Illustrating the growth of P. lapathifolium and the morphological changes in U. americana.- Elev. indicated, Area 7, August 5, 1951.

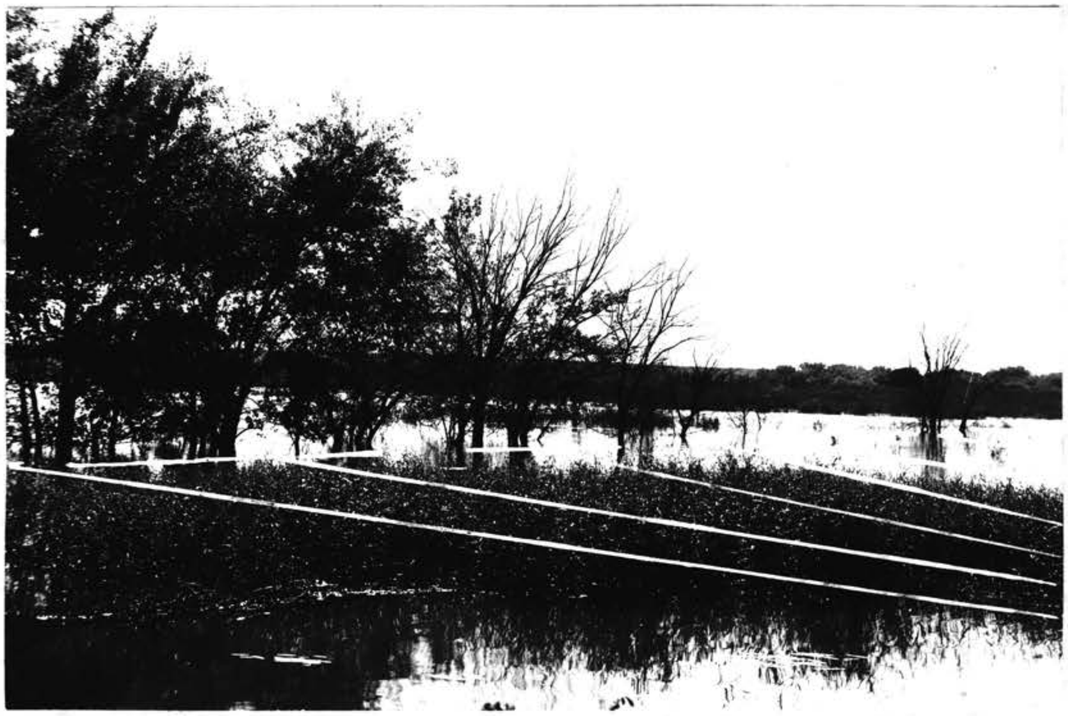

Fig. 94. Polygonum lapthifolium, Ulmus americana. Illustrating the growth of P. lapathifolium and the morphological changes in U. americana.- Elev. indicated, Area 7, September 14, 1951.

Fig. 95. Polygonum lapathifolium, Ulmus americana. Illustrating the growth of P. lapathifolium and the morphological changes taking place in U. americana. -Elev. indicated, Area 7, October 1, 1951.

epth of water and time of the year. Trees at the 941.17' o 941.67' level were inundated about May 1, 1951 which was early n the growing season. Trees at the 941.67' to 942.42' levels ere inundated from May 10, 1951 to May 15, 1951. Trees above he 942.67' level were not inundated until after June 1, 1951 t which time the rapid growing period of the trees was well dvanced. Trees above the 943.17' level remained alive through he six months of inundation in 1951 and it is believed that hese trees will put forth leaves in 1952. These trees withtood known inundation periods of about three months in 1944 nd 1945 even during their periods of rapid growth and still onger periods in the year of 1951. Present data seems to show he trees to have a minimum viability period after inundation f about three months for the spring four or more months for the te summer and possibly longer if the trees are dormant. The ong viability period of the trees at the 943.17' level can rdly be explained by the time of year alone since these trees re continually inundated from the latter part of May to November 21, 51, a period of approximately six months. Shallow inundation st also play a role by permitting the trees to live longer an if covered by deep water. This hypothesis was strengthened the discovery on November 21, 1951 in area 13 of additional ees living in the shallow water above the 922.81' level. The ses of these trees were too far away from the shore line for e roots to reach aerated soil.

The American Elm with an inundation killing period of about ree months is recommended for use as a shade tree in the recreaonal areas of our flood control lakes.

Vitis sp L., Wild Grape.- Elev. 944.60', 940.00'.

Wild Grape plants of this species were found growing along he banks of the creek in area 2 between the levels of 944.60' nd 940.00'. They were first observed on July 28, 1951 (fig.96) t which time their viability was considered excellent. They ere not again observed until October 25, 1951 (fig. 97) at hich time they were about the only plants remaining in a viable ondition in the area. However, some of the vines with bases elow the 941.71' level had succumbed.

This plant though observed only twice by the writer appears o be quite resistant to inundation and should fit into a lake luctuation zone management program. The trailing matted vines f this plant could serve as cover to upland game fowl.

Fig. 96. Vitis sp., Wild Grape.- Elev. 944.60', 940.00', Area 2, July 28, 1951.

Fig. 97. Vitis sp., Wild Grape. This Wild Grape (A) remained viable until frost.- Elev. 944.60', 940.00', Area 2, October 25, 1951.

GENERAL DISCUSSION

An important result of this investigation was that it ıggested a wide range of vegetative control possibilities that ɔuld be obtained by systematically regulating the water level f a lake. This regulation is possible to a certain extent in our ɩood control lakes and could be more fully utilized in recrea-.onal impoundments that have installed in them outlet control ılves. Plants such as the Scarlet Ammannia, the Knotweeds and ɔe Umbrella Sedges require a changing water level during the .ants seeding and germination season if large crops are to be ·oduced. The large area marked by the bracket (A) of figure 1 ıows one of the many areas that was covered with <u>Polygonum</u> <u>ıpathifolium</u>. This large crop was possible only by the rise of ıe water to the 942.90' level in July of 1950, followed by the ·adual decrease of the water to the 938.75' level. The rise ·obably helped to move the seeds into position. The decrease ı the water level exposed the seeds allowing them to germinate ɪring the spring of 1951. The plants were covered with water 'ter germination and grew to maturity. Other examples can be ɪund under, "Discussion of The Species Observed", i.e., the <u>ımannia</u>, the Cattails, the <u>Cyperus</u> and others; each with its 'n peculiar reaction to a changing or stable water line.

The differences in resistance to water coverage shown by ɪe different species of upland plants suggest that a form of ɪntour planting should be taken into consideration when intro-.cing plants into temporarily flooded areas. The use of the

lant and the length of time it can survive inundation should be
ie basis for plant selection. The plants should be planted on
contour at their proper elevation above the normal pool level.
ie length of time a particular contour is likely to be inundated
.so should be considered. The approximate length of inundation
or the different levels can be calculated from the expected
infall, the runoff and the drawdown contemplated for a particu-
r lake. Further investigation is needed in this relatively
w field to determine more accurately the individual resistance
flooding under varying conditions. The descending order of
sistance to inundation shown by plants was, for the trees;
een Ash, Black Willow, American Elm, Honey Locust, Cottonwood,
r the shrubs; Button Bush, Persimmon, Tamerisk, False Indigo
d for the grasses; Knotgrass, Rice-Cutgrass, Florida Paspalum
d Bermuda grass.

By the creation of a marginal fluctuation zone our flood
ntrol projects have opened a new field useable in the produc-
on of fish and wildlife. Today very little is known about the
riculture and aquiculture of this zone. Development of the
oodable zone surrounding our lakes will not only increase the
come to man but provide an area useful for his recreation.

SUMMARY

1. The effects of water fluctuation on the higher plants bserved in this work agree in the main with the findings of all, Penfound and Hess, 1946 in their investigations in the ennessee Valley and the findings of Yeager, 1949 in his investiation in the Upper Mississippi Valley.

2. In general the elevations of the remnants of the oriinal stand of hardwood trees aided in determining the killing eriods which corresponded to the observed killing period during ie prolonged inundation of 1951.

3. Variation in resistance to water coverage suggests the eed for contour planting based on the length of time a partilar level of the fluctuation zone is apt to be flooded.

4. Besides the duration of inundation the depth of water overage proved to be a killing factor. This was exhibited most trongly in the study of the American Elm which withstood seven onths shallow water coverage but died in deeper water after iree months inundation.

5. The short time during July of 1951 required to kill ack Locust and Jack Oak trees that had withstood more than a onths water coverage during October of 1945 indicates that ason of flooding is a factor.

6. Water fluctuation is not only necessary but the proper ming of its rise and fall is necessary if large crops of the emi-aquatic plants are to be grown. Large crops of plants are eded to add nutrient salts to the water. The amount of nutrient lts in a lake is a criterion of its productivity (Hotchkiss,

941; Allee, 1949).

7. The need of water fluctuation for the establishment f some species was disclosed in the study of the American Pond-eed which was found to be established at only two general levels.

8. Generally the taller Willow and Cottonwood trees under ıe same condition of water coverage were killed more quickly ıan the shorter trees.

9. A longer period of water coverage was required to kill illow and Cottonwood trees in water open to wind and wave action ıan in protected waters.

10. Willow and Cottonwood trees killed more quickly from ıundation in the detritus filled water than in water free from etritus.

11. Adventitious roots developed on the submerged stems of ıe Willow, Salt Cedar, Button Bush and the False Indigo.

12. The killing period of Amorpha fruticosa with only ıeir bases covered with water was shorter than for plants .most completely submerged. Adventitious roots were developed plants in shallow and in deep water with large masses of ›ots on the stems of plants in deep water. These large masses f roots may be the explanation for prolonged viability of the .ants in deep water.

13. The Common Persimmon developed shoots from adventitious ıds on the stems of the plant a short distance above the water .ne. Explanations for this and other morphological or color ıanges resulting from flooding have not been attempted but amer (1951) believes that injury to the shoots of flooded .ants is complex in origin and has several causes rather than

esulting simply from interference with water absorbtion.

14. Flooding can be used to eradicate or limit the growth f undesirable plants.

15. The uses of the plants for fluctuation zones are iscussed under the topic, "Discussion of the Species Observed".

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Gwendolyn de Gruchy

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AUTHOR: MARVIN TIPTON EDMISON

THESIS ADVISER: O. C. DERMER

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TYPIST: MRSa SAMUEL SIEGEL