Studies for the Wichita and Caddo tribes, but the work should be greatly extended before it is too late. Even now only the oldest members of the tribes remember much of the ancient culture. Such work involves the co-operation of anthropologists, linguists, and historians.

Many of the important Indian sites are soon to be covered with water by the Federal River Basin Reservoir projects. It is extremely important to beat the bulldozer to these sites, and to excavate them before they are lost forever. We have been doing this on a small scale, but greatly increased funds are imperative to complete the work in time. It will be many years' work to classify and analyze the recovered material.

Public Health

We have just started a Graduate School of Public Health on a minimal budget. No funds are available for research in this important field. If our School of Public Health is to take its place with the better schools, we must immediately initiate reasearch in this area.

Government

Our Bureau of Government Research is likewise operating on a pitifully small budget. We should be investigating new and better methods of procedure for state, county, and local governments; supervision of tax assessments, public personnel practices, debt limitations, and many similar governmental problems which state and local governments have requested that we study. The fine work which our competent staff has already done under its very small budget indicates what could be done with adequate funds. The constitutional studies made by our Bureau for the State Legislative Council received wide acclaim.

The problems listed above represent just a few of the many important basic researches that we should be doing. Not only should the University be attacking such problems, but it is anxious to do so, and has a staff capable of carrying out the investigations. What is needed is the money for equipment, research assistants to do the routine work involved, travel where necessary, and similar items. The annual expenditure of $50,000 to $100,000 would do much to put the University of Oklahoma in the forefront of research. It would help to prevent the rapid loss of the state and national pool of fundamental research findings on which must be based the industrial, business, governmental, economic, social, cultural, and military advances which are so vital to the preservation of the state and the nation in these times of crises.

Management of State Lakes

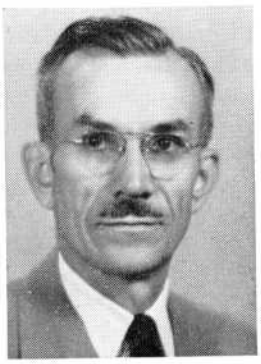
By WILLIAM T. PENFOUND

In a recent article in this magazine, Professor Riggs states, "At the present time, Oklahoma has approximately 225 lakes and 100,000 farm ponds with the total surface area of more than 300,000 acres." This list of lakes and ponds is based on an area of ten acres as the dividing line between lakes and ponds. Oklahoma's lakes are man-made, with a few exceptions: the ox-bows along the lower reaches of the Arkansas and Red Rivers in eastern Oklahoma and the playas of the Oklahoma Panhandle. The greatest period of construction of artificial lakes and ponds occurred from 1931 to 1940. At the end of that period Oklahoma ranked eighteenth of the forty-eight states in per cent of total area covered by inland water. It should be pointed out, however, that the position of the state in this respect should have improved somewhat in the last decade with the recent completion of a number of large impoundments.

The lakes of Oklahoma have been studied by investigators from various organizations. Workers from Oklahoma A. and M. College have investigated sedimentation, turbidity, fish populations, and the effect of flooding on plants. The U. S. Corps of Engineers has contributed much data on stream flow, types of rock, sedimentation and other physical facts on flood control reservoirs. The Oklahoma Game and Fish Department has investigated physical, chemical, and biotic factors of lakes with reference to fish production. In addition, the department has conducted many fishery surveys of specific lakes and have formulated excellent investigative and utilization programs for the future. The University of Oklahoma, especially through the Biological Survey and the Biological Station, has contributed much to our knowledge of Oklahoma lakes. Members of the survey and the faculty and students at the station have conducted studies similar to those of the Oklahoma Game and Fish Department. In addition, they have initiated studies on parasitism in fishes and frogs, on populations of algae, turtles, and birds at Lake Texoma, the effect of lakes on climate, and the plant populations of Oklahoma lakes.

The most important climatic factors in determining the distribution of higher aquatic plants in our lakes are precipitation, evaporation, wind, and temperature. As is well known by most Oklahomans, the amount of the rainfall decreases, but the rate of evaporation and wind velocity increases from eastern Oklahoma westward to the tip of the Panhandle. Furthermore, the rainfall in western Oklahoma is more unevenly distributed and less dependable than in eastern Oklahoma. As a result, the water levels in the westward lakes fluctuate more rapidly than in the eastern lakes.

In general, Oklahoma lakes are full in the spring and decrease gradually throughout the late summer and early autumn. If heavy rains occur during the summer, however, the lakes are refilled to or above the summer pool elevation. If the water is re-



ABOUT THE AUTHOR

Dr. Penfound is a distinguished ecologist and has published in scientific journals many articles resulting from his research in this field. From 1937 *to* 1941, *he worked in the Malaria Control Division of TVA and is at present a Consultant in Malaria Control for the Authority. He joined the faculty in* 1947 *after having taught for six years at Tulane. The Quarterly is happy to publish this article.*

tained above the normal pool level, all the terrestrial and even many of the wetland (growing on wet soil) plants are destroyed. A notable example of this occurred during the summer of 1951 at the Fort Supply Reservoir, in which not only the terrestrial plants such as sand plum, skunkbrush, and sand sage were killed, but also nearly all the wetland cottonwood (up to 40 feet tall), black willow, and sandbar willow trees were destroyed. If the water level falls much below summer pool level (marked by wetland plants) for more than a few weeks, the exposed aquatic plants may be eliminated. The result of such a wide range of water levels in lakes is a relatively barren shore-line. All the flood control lakes (Altus, Canton, Fort Supply, Grand, Salt Plains, Texoma, and Wister) have shorelines of this nature.

On the other hand, lakes with a relatively constant water level are characterized by an abundance of plants. These are usually arranged in concentric zones from the land to the deeper water as follows: terrestrial, wetland and emergent, floating leaf, and submerged aquatics. If free-floating plants (e.g., duckweeds) and floating mat plants (e.g., primrose willow) are present, they are usually distributed among or over the other aquatic plants. Sometimes, as at the lakes of the Wichita Mountain Wildlife Refuge, these plants become so abundant that they present a serious impediment to boating, fishing, and swimming.

The question has often been raised as to whether an abundance of higher aquatic plants in lakes is desirable. The answer lies partly in the kind of utilization planned for the lake. If the water is to be utilized for recreation and for wildlife production, the presence, types, and quantity of plants are very important. The important wildlife in Oklahoma lakes, from an economic and recreational standpoint, include fish, migratory waterfowl, and aquatic mammals.

The relation of higher aquatic plants to fishing is still uncertain. The practice of the Chinese, over 2000 years ago, was to grow fish in a pond for about two years, then to empty the pond and start over again in a basin largely devoid of plants. In this country, until very recently, the practice of planting shallow ponds with submerged plants (moss) has been recommended. It has been shown, however, that abundant aquatic plants decrease fishability and promote the production of small fish by providing them hiding places from larger, predaceous fishes. Experience in Oklahoma suggests that the relatively barren lakes provide fishing as good as those with an abundance of aquatic plants. Fishery experts in Oklahoma are in general agreement that higher aquatic plants usually do more harm than good in a pond or lake designed primarily for fish production.

If ponds and lakes are to be utilized for migratory waterfowl, an abundance of plants with edible vegetative parts or relatively large fruits or seeds is necessary. This may include terrestrial and wetland as well as aquatic plants, such as ragweeds, smartweeds, and pondweeds. Attempts to establish various aquatic plants failed completely at Grand Lake, undoubtedly because of the wide annual range of water levels occurring therein. No single factor is more potent, probably, in preventing the development of waterfowl food plants than extreme or irregular fluctuations in water level. Because of this it is believed that the planting of aquatic food plants for waterfowl will never be successful in any of the flood control lakes in Oklahoma. Even in relatively constant level lakes the practice is rarely profitable unless the plantings are made in a relatively new lake before the native plants invade.

Aquatic mammals are relatively unimportant in Oklahoma, although mink, muskrat, and racoon furnish 17.86 per cent of the annual value of pelts. Since ponds and lakes are compartively recent on the Oklahoma scene, a considerable natural increase in aquatic mammals will no doubt take place. Apparently the most important factor in providing a good habitat for muskrats is a stable water level, because this favors the establishment of muskrat food plants (bulrushes, sedges, and cattails) and favors the home activities of the species. The production of racoon and mink is also favored by stable water levels. Wildlife experts believe that a tremendous increase in aquatic mammals would be effected if reasonable management practices could be instituted.

The presence of terrestrial and wetland trees is very desirable in the development of recreational areas around lakes. If the hunting of migratory waterfowl and trapping of aquatic mammals are considerations, an abundance of aquatic food plants is desirable. For boating, fishing, and swimming, a minimum of aquatic plants is the ideal. Emergent aquatic plants interfere with bank fishing and easy access to the lake by boat. Floating leaf and submerged plants interfere with boating and make fishing almost impossible. Swimming is very unsatisfactory among emergent and floating leaf plants and very dangerous in areas with submerged plants. One is forced to conclude that lakes utilized by the public for recreational purposes should possess few or no aquatic plants.

How can we get rid of undesirable wetland and aquatic plants in a recreational lake? Fortunately, most Oklahoma lakes are artificial impoundments whose water levels can be controlled. It will be recalled that lakes with a wide range of water levels possess few or no aquatic plants. By raising the water level above the summer pool level (wetland fringe), any undesirable terrestrial and wetland plants can be destroyed through flooding; by lowering the water level to the lakeward edge of the aquatic plants (about 5 feet vertically below the wetland fringe), most or all of the aquatic plants will be eliminated by exposure and subsequent desiccation. Thus it is possible to maintain a reservoir with few or no aquatic plants merely by the manipulation of water level, and with virtually no cost to the management.

In natural lakes, or in artificial lakes where a constant water level is desired, other means of plant control must be employed. These methods include direct attack on the plants, such as removal, underwater cutting, crushing, and burning. One unusual method is the employment of black, aniline dyes to kill submerged plants by preventing the penetration of light. Chemicals used in plant control include ammonium sulfamate, sodium arsenite, sodium chlorate and 2, 4-dichlorophenoxyacetic acid (2,4-D) and related compounds. To date, 2,4-D has proved to be the chemical of choice in the control of all except submerged plants, which are impossible to control by any of the known chemicals. An interesting development in very recent years is the control of submerged plants by fertilization. This increases the microscopic plants and animals in the water to such an extent that the rooted, submerged plants are shaded out.

The future of the development and utilization of Oklahoma lakes appears very favorable. Several flood control lakes are under construction and others are in the planning stage. With continuing increases in urban population, new municipal reservoirs are being constructed. The development of recreational areas on flood control lakes has proceeded at a phenomenal rate, particularly on Lake Texoma. That the state looks with favor on the use of lakes as recreational areas is shown by the superb facilities constructed at Lake Murray. The state has ample scientific personnel to insure proper lake management. As has been indicated above, it is relatively simple to control the plants in most Oklahoma lakes since their water levels can be controlled. The progress in fishery research has been phenomenal to date and the prospect for improved fishing appears bright indeed. With the natural increase in fishes, migratory waterfowl, and aquatic mammals being aided by research and regulated by our current personnel, it is not too much to hope that Oklahoma may become the leader in the Southwest in the production of aquatic wildlife resources.