Summary: Terrestrial Ecosystems

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It is quite revealing to search the literature for studies of terrestrial plants and animals in relation to man-made lakes and find so little data on the before and after effects of an impoundment on their ecology. Thirty years ago I distinctly recall many discussions in ecological groups expressing the need for intensive studies of a new impoundment basin followed by a study of what actually happened. In the interim the talk has persisted, yet not much research has been conducted on terrestrial ecosystems before and after impoundment.

Hesse [1937] pointed out in 1924 that four fifths of the known species of animals are terrestrial despite the fact that the surface of the oceans and inland water combined amounts to about 362,250,000 km² whereas the total land surface is only 147,650,000 km². No matter where a man-made lake is developed, there is apt to be animal life affected. Of course, man-made lakes also affect plant life in a like manner. To use land for a water impoundment is justifiable only when the good to mankind (both the intangible and tangible benefits) outweighs the effect on the environment. It is not easy to weigh these considerations, and herein lies a controversy that intensifies as more people question the advisability of creating impoundments.

I take the view that benefits have to be weighed carefully in the planning stage so that the greatest good can be attained. In this discussion I do not wish to do battle with this subject; I only wish to point out that greater concern needs to be given to the terrestrial forms than has been given over the years. The present awakening of the public on these issues may very well bring about proper attention to these matters. This subject is discussed ably by *Lagler* [1969] and by *Bardach and Dussart* [this volume].

LOSS OF HABITAT

Since it was simple to recognize that man-made lakes forced stream-inhabiting animal life to move out to other niches in the surrounding territory, it likewise should have been recognized that a detailed study of these reactions was necessary. Here again, the intention for such study turned out to be mostly talk. The literature was searched only to find no evidence of any mark and recovery studies prior to impoundment. One would think that wildlife biologists or mammalogists would have tagged stream-dwelling mink (*Mustela* sp.), muskrat (*Ondatra* sp.), woodchuck (*Marmota* sp.), and other such small mammals for future recovery in order to determine their movements following flooding of their habitat. Further, tagging of deer (*Odocoieus virginianus* or *O. hemionus*) or elk (*Cervus canadensis*) would appear logical for the same reason, or the recent better method by using telemetry would also seem logical.

If, in fact, such studies were conducted, they have not been reported in literature except perhaps as an incidental part of another study. I apologize for my failure to locate these studies should they exist. In numerous discussions with colleagues in Washington, D. C., the prevailing opinion is that such studies were contemplated but were not carried out. Undoubtedly, the concept that a hopeless condition existed (a loss beyond the view of recovery) influenced many decisions for funding these studies.

The report on fish and wildlife resources affected by the proposed Rampart Canyon Dam and Reservoir Project on the Yukon River in Alaska (Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior, unpublished report, 1964) is a good example of the preimpoundment study of terrestrial life. No mark and recovery and/or telemetry studies were made. This Rampart report is an example of the type of study that should be done in great detail on any future large man-made lake.

The caring for isolated mammals during the impounding of Lake Kariba in Africa was apparently an assistance program, not a scientific

study. As far as I can determine from the literature, no extensive scientific study was conducted on the terrestrial life of that basin.

FORESTS, INSECTS, AND BIRDS

Elimination of trees and shrubs by burning, cutting, chipping, or smashing is viewed as a total loss to the ecosystem of the impounded basin except for the nutrient value that they have when they are left to rot in the water. Trees left standing can provide some benefits to fish but may be a hazard to boats.

No special studies have been noted on the determination of what happens to insect life following impoundment of a man-made lake. Birdlife is discussed later in this paper.

BENEFITS TO SURROUNDING TERRESTRIAL LIFE

No discussion of an ecosystem associated with a man-made lake is complete without pointing up the significant benefits to birdlife, especially waterfowl of the nearly 2 million man-made farm ponds in the United States and Canada. Those ponds and other man-made reservoirs located in major waterfowl breeding grounds or situated along migratory routes serve such birds well. Some biologists feel that three species of waterfowl benefit greatly in North America from man-made lakes, especially large reservoirs, namely, the mallard duck (*Anas platyrhynchos*), pin-tailed duck (*Anas acuta*), and Canada goose (*Branta canadensis*). Many species of waterfowl feed in fields and use man-made lakes for resting and refuge from man and predators. Such lakes need not furnish foods in the form of invertebrate fauna or plant life if grains are readily available not too far from the lake.

L. Compton (unpublished notes, 1971) has pointed out that there are >2 million small ponds in the United States. They are being constructed at a rate of 60,000 per year. These ponds often create new aquatic habitats in areas where natural potholes dry up in drought years. They can increase waterfowl production significantly. In Montana [*Smith*, 1952; H. A. Hansen, unpublished notes, 1971], ponds constructed in an area previously devoid of aquatic habitat increased the production of waterfowl.

There are >58,000 ponds in the state of South Dakota, about 16,000 in North Dakota, and about 5000 in Minnesota. For these three states there is a total of 79,000 ponds. These states also have many natural lakes and potholes. Compton reports that 50% of these ponds produced ducks at the rate of 10 ducks per pond, and he states, 'The farm and ranch ponds in these three states can conservatively be said to annually produce in the neighborhood of 350,000 ducks.' Stock ponds in Canada and the northern Great Plains of the United States and Canada produce upwards of 1 million waterfowl per year according to a report by *Linduska* [1964].

So much for breeding of ducks in man-made ponds. Other than the obvious resting opportunities for migrating waterfowl, ponds attract the mourning dove in great numbers [*Peters*, 1961]. Doves need a dependable source of water to produce 'pigeon milk' for feeding the young. Man-made lakes often play a vital role for doves in this respect. The annual kill of doves by hunters in the United States runs between 25 and 40 million birds. Many biologists have associated this high rate of production with the establishment of man-made lakes.

Studies of man-made ponds in Missouri [*Greenwell*, 1948] showed a high use by muskrat, rabbits, raccoon, and bobwhite quail. *Shanks and Arthur* [1951] studied 40 farm ponds in Missouri and stated the following in regard to muskrat use: 'Without question, the thousands of farm ponds throughout the midwest (U.S.) provide an additional habitat type of importance.'

Antelope, deer, raccoon, opossum, skunk, and other small mammals have been attracted to small ponds, and many upland game birds such as prairie chickens have benefited from these impoundments. In studies in South Dakota, *Bue et al.* [1952] found 90 species of songbirds using small ponds.

Elsewhere in this volume, attention is given to various studies of Kainji and Kariba lakes in Africa. *Halstead* [this volume] has presented data on the evolution of the shoreline features of these two lakes. Halstead believes that large inland bodies of water lead to local climatic changes and states that all erosional features along the shores of man-made lakes can be attributed to storm action. *Bardach and Dussart* [this volume] do not agree with this climate effect. They feel there is inadequate data, as they put it, to permit firm judgment on whether man-made lakes have induced climatic changes.

Halstead's remarks on the inundated termite mounds in Lake Kainji are interesting. He describes the impounded termite mounds as novel microenvironments on the muddy lake

floor. The sand and grit from the mounds was very evident in comparison to the thin layer of mud and silt elsewhere in the exposed drawdown areas. Halstead states,

> Erosion was confined to the vicinity of obstacles, such as houses, trees, and termite mounds . . . . The spreading of termite mound sediments together with the fine sands heralded the first stage of the establishment of a genuine lacustrine regime.

One of the problems of man-made lakes is the damage that takes place to soils that are exposed at drawdown or eroded at the waters' edge even under nonfluctuating water levels. The Soil Conservation Service of the U.S. Department of Agriculture is testing a series of plants, grass, sedges, and shrubs for establishing across-the-waterline slopes of lakes. *Young* [this volume], a regional plant materials specialist, has determined that a native grass, maiden cane (*Panicum hemitomon*), shows promise of being suitable for this purpose. It is limited, however, to the humid section of the southeast United States. Yet, good results are noted when this grass is used north and west of its normal range. Additional research is needed to further expand its natural range.

In the arid regions of the United States, plant growth is needed on exposed drawdown banks where blowing dust is a problem. It is hoped that Young's future research will include these areas for testing.

One of the better designed and managed man-made lakes in an urban area is Lake Burley Griffin, Canberra, Australia. Terrestrial ecological problems were taken into account during the planning stages of this lake, and intelligent management followed during construction and later operation of the waters impounded on the Molonglo River. *Minty* [this volume] has reported on this lake. He points out that great concern was raised prior to establishment of this lake over the possible pollution problems, mosquito breeding, water quality, meteorology (fog), fish, aquatic plants, and so forth. Each of these topics was investigated carefully in the design stage. Steps were taken to minimize these problems, and none proved insurmountable. Over 55,000 trees have been planted in the lake's shoreline and vicinity.

Various environmental problems were ironed out by construction of a hydraulic model. Lake Burley Griffin is a good example of successful integration of the various professional disciplines working together in the design, construction, and operation of a man-made lake. Scientists, engineers, and landscape architects worked hand in hand on this project.

ADJUSTMENTS IN ECOLOGICAL MANAGEMENT

Certain techniques, or adjustments, are being made at man-made lakes to satisfy needs of terrestrial plants and animals. Browse improvement for deer and elk can be improved by controlled burning techniques, as applied, for example, at Dworshak Reservoir in Idaho, which is now under construction (Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior, unpublished report, 1970). These actions are taken to mitigate (replace in kind) the loss of 6,070 ha of terrestrial wildlife habitat in the reservoir. The measures are designed to increase the big-game carrying capacity of the existing habitat nearby.

Wildlife food plots (such as grains and grasses) are often developed for deer, turkey, and waterfowl. Where it is permitted, grazing for cattle and sheep is controlled by fences when that grazing is destructive to native vegetation.

Where endangered plant and animal species exist in the vicinity of a man-made lake, steps are often taken to establish a refuge for their preservation. Where possible, water level fluctuation is controlled in order not to jeopardize terrestrial forms.

NEEDS FOR PRESERVATION AND MANAGEMENT OF TERRESTRIAL FORMS

The need for funding more ecological research is great. Although the Food and Agriculture Organization and other organizations are spending considerable sums on certain large lakes (such as Volta, Kariba, Kainji, and Nasser), there is no doubt that more intensive investigations are essential. The tendency is to place most of the attention on the aquatic ecosystems, whereas terrestrial research is less intensive.

Bardach and Dussart [this volume] have limited their discussion to large man-made lakes, roughly those 4000 man-made lakes in the world used for hydroelectric power generation, flood control, and agricultural irrigation purposes. At this point I want to express my feeling, shared by *Mermel* [1958], that a world registry of man-made lakes with dams of >15.24 meters in height should be established (see also *Fels and Keller* [this volume]).

I would like also to point out that, here in the United States, Public Law 91-190, The National Environmental Policy Act of 1969, requires an environmental impact statement to be filed with the Council on Environmental Quality on all major federal actions that significantly affect the environment. To adequately prepare such a statement, preimpoundment studies must also be taken to properly assess the impact the new reservoir will have on the environment in the area. Effects upstream, downstream, and adjacent to the reservoir should also be studied. The terrestrial ecosystem is an important part of this study that should be covered as well as the other environmental parameters discussed in this volume.

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