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FERTILIZATION OF OBED RIVER, TENNESSEE

JOHN W. PARSONS[1]
Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service
Ann Arbor, Michigan
and
NORMAN G. BENSON[2]
Bureau of Sport Fisheries and Wildlife, U. S. Fish and Wildlife Service
Logan, Utah

INTRODUCTION

The construction of U. S. Army Engineer and TVA reservoirs in Tennessee has increased available fishing waters to the extent that sport fishing has become a major industry. These impoundments have, however, inundated many miles of valuable fishing streams. In the Cumberland Plateau area in east-central Tennessee 462 miles of fishing streams have been impounded. In addition, more than 118 miles of streams have been destroyed by coal mine wastes. These two factors have reduced the available mileage of fishing streams in the area by almost 50 percent. Thus the possibility for effective fishery management of the remaining streams by fertilization was investigated to compensate for stream fishery losses.

Preliminary observations and investigations of Cumberland Plateau streams indicated that, although physical characteristics appeared excellent for the production of fish, the waters were infertile and fish were scarce. Furthermore, large numbers of non-sport fish that had migrated from impounded waters downstream appeared in several of the streams.

Obed River, a typical plateau stream, appeared ideal for experimental addition of commercial fertilizers to increase fish production. This paper describes the preliminary investigations, two years of fishery management, and evaluation of the management.

DESCRIPTION OF THE CUMBERLAND PLATEAU AND OBED RIVER

Obed River is located on the Cumberland Plateau in east-central Tennessee. The elevation of the Plateau generally ranges from 1,500 to 1,800 feet. Elevations over 2,000 feet are common on mountain ridges and elevations less than 1,000 feet occur in stream gorges or canyons. The Plateau averages approximately 50 miles in width and extends across Tennessee from Kentucky south to Alabama.

[1]Formerly with the Tennessee Game and Fish Commission.
[2]Formerly with the Tennessee Game and Fish Commission.

Much of the area is in forest although agriculture is common in some areas. Soils are slightly acid and infertile. Underlying strata consist primarily of sandstone, slate, coal, and some conglomerates. Annual rainfall average nearly 50 inches.

The streams of the Plateau have many common characteristics. Headwaters usually are in the flatter agricultural lands. The streams then flow into deep canyons and gorges. Sheer cliffs at the water's edge are sometimes 300 feet high. Large boulders lie on stream beds and bank areas; bottoms are stable; shoals have rapid flow; and access is limited to only a few roads.

Obed River, which is characteristic of Plateau streams, has approximately 35 miles of fishing waters. It flows into Emory River, a tributary of Watts Bar reservoir 10 miles downstream.

Although water flows of several thousand cubic feet per second occur frequently during late winter and spring, flows at midsection normally fall to less than 10 cubic feet per second about the first of July. In 1955 when summer rainfall averaged slightly above normal, Obed River near its midsection had average flows as follows (cubic feet per second): 150, June; 12, July; 4, August; 0.2, September. In 1954, an exceptionally dry year, water flows at the same location averaged 55 cubic feet per second in June, and less than 1 cubic foot per second from mid-July to November.

Water temperatures of Obed River usually reach 33° F. in early winter and may exceed 80° F. in late July and August. Occasionally slack waters may freeze over when water flows are low in late fall. Except for periods immediately following heavy rains, Obed River is clear (turbidity less than 5 p.p.m.). Methyl-orange alkalinity usually ranges from 10 to 20 p.p.m.

A physical survey of Obed River was made during low water flow (less than 5 cfs) in August and September 1954. The survey was made from River Mile 34.4 downstream to Emory River. At the time of the survey, Obed River had a surface area of 190.8 acres and a volume of 623.5 acre feet. The 394 pools had an average area of 0.5 acres and a mean depth of 3.3 feet. The largest pool was 7 acres. Thirty-four percent of the river distance was shoals. Stream gradient was 23 feet per mile.

The principal native fishes[2] of Obed River are smallmouth bass, rock bass, spotted bass, longear sunfish, muskellunge, channel catfish, flathead catfish, hogsucker, and golden redhorse.

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[2] Scientific names of fishes mentioned in the text are: Smallmouth bass, **Micropterus dolomieu**; Largemouth bass, **Micropterus salmoides**; Spotted bass, **Micropterus punctulatus**; Rock bass, **Ambloplites rupestris**; Warmouth, **Chaenobryttus gulosus**; Longeared sunfish, **Lepomis megalotis**; Bluegill, **Lepomis machrochirus**; Muskellunge, **Esox masquinongy**; Walleye, **Stizostedion vitreum**; Channel catfish, **Ictalurus punctatus**; Black bullhead, **Ictalurus melas**; Flathead catfish, **Pilodictus olivaris**; Carp, **Cyprinus carpio**; Smallmouth buffalo, **Ictiobus bubalus**; Freshwater drum, **Aplodinotus grunniens**; Gizzard shad, **Alosa cepedianum**; Silver redhorse, **Moxostoma anisurum**; Spotted sucker, **Mynitrema melanops**; Golden redhorse, **Moxostoma erythrurum**.

Species that may have been introduced into Obed River from farm pond overflow are largemouth bass, bluegill, warmouth, and black bullhead. These fish spawn successfully in the river.

Fish that appeared to migrate into Obed River from downstream waters are carp, smallmouth buffalo, freshwater drum, gizzard shad, silver redhorse, spotted sucker, and walleye. None of these fish are known to spawn successfully in Obed River.

METHODS

Preliminary studies revealed that Obed River consisted of three well-defined physical segments. These segments differed primarily in gradient, surface area of water, and volume flow. For investigational and comparative purposes these segments were classified as zones and were used in identifying stations and sampling areas. (Fig. 1).

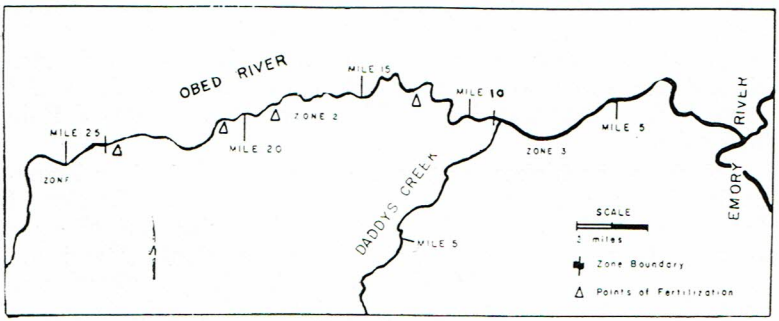

Figure 1. Sketch depicting the zones of Obed River and points of fertilization.

Zone 1, the upper segment of the river, was established as a check for the evaluation of management in downstream areas. Evaluation of fertilization was made in Zone 2. Zone 3, the lowermost segment, was excluded from the study primarily due to its large water volume. Lengths of zone 1, 2, and 3 were 11, 16, and 8 miles, respectively.

The agricultural fertilizer used in this investigation had a 9-6-3 nitrogen, phosphorous, potassium, content. Inert material consisted primarily of crushed limestone. This tpye of fertilizer was selected since it was known to be effective in increasing fish populations in farm ponds in the vicinity. The cost was $40 per ton delivered. The fertilizer was dumped from sacks onto the shoal areas where dilution with the water was complete within a few days. In July 1954, 40 tons of fertilizer were applied at the rate of about 266 pounds per acre to Obed River in three areas of Zone 2. In July 1955, 31 tons were added.

A flow of 5-10 cubic feet per second at the upper limit of Zone 2 was determined to provide optimum distribution and

use of the fertilizer. This usually occurred by July 1 when water volume in Zone 2 would be replaced by inflow every 30 days.

Although the fertilizing of Obed River was scheduled on normal water flows, water flows varied in both 1954 and 1955 to the extent that application of the fertilizer varied considerably. Water flows lowered to 5 cubic feet per second in 1954 at the gauging station by the first of July, and rapidly lowering water flow thereafter required complete application of the fertilizer during the first two weeks of July to assure satisfactory distribution.

Fertilizer was not applied until the tenth of July in 1955 when flow was about 10 cubic feet per second. Flow did not drop to less than 5 cubic feet per second until after fertilization was completed on August 1.

Biweekly chemical measurements were taken at sampling stations during the summer in all 3 zones during 1954. All water temperatures, carbon dioxide, total alkalinity, and hydrogen-ion concentrations were determined by standard methods. All reagents were prepared by the Tennessee Department of Public Health.

Work on the higher aquatic plants was conducted by Franklin Robinson, a botany graduate student of the University of Tennessee. Both taxonomic and ecological observations were included. General observations were made on plankton and bottom filamentous algae. Major changes in phytoplankton concentration were measured with a platinum wire turbidimeter.

Fish populations were sampled with 5-percent emulsifiable rotenone before (1953) and after (1956) fertilization. All samples were taken in late summer or early fall during low water flow. The rotenone was applied to each pool and when possible, waters were disturbed with an outboard motor and boat.

Several pools of each size group in Zones 1 and 2 were sampled for fish in 1953 and 1956 (Table 1). About 10 percent of the pool areas were sampled both years. Fish population estimates were adjusted to include all pools in each size group. Population estimates for the entire zone were then easily obtained. In order to adequately sample pools of all sizes, sampling areas were chosen (but not randomly) from a map or from the physical survey data.

All fish were picked up, identified, and measured. Pools were checked for 2 days following treatment. In 1955 a 1.5-acre pool was sampled for fish with an electrical seine and all fish captured were fin-clipped and released. Two days later the pool was treated with rotenone and all fish removed. Although conditions at the time were not ideal for recovery of fish, 90 percent of the fin-clipped fish by weight were recovered.

For this study largemouth bass and smallmouth bass longer than 8.5 inches, other sunfishes longer than 5.5 inches, and muskellunge longer than 25 inches (legal length), were considered to be of angling size.

For comparative purposes the fishes of Obed River were broken down to the following groups: sport fish – smallmouth bass, spotted bass, largemouth bass, rock bass, bluegill, and longear sunfish; non-sport fish – freshwater drum, channel catfish, flathead catfish, carp, smallmouth buffalo, and various suckers (*Catostomidae*); and forage fish – minnows and darters.

Table 1.—Size and number of pools sampled for fish with rotenone in Zones 1 and 2, Obed River

Range of pool sizes (surface acres)	Number	Number of pools sampled 1953	1956
Zone 1			
0.05- .10	66	5	2
0.11- .49	38	2	3
0.49- over	8	2	1
Total	112	9	6
Zone 2			
0.10- .24	73	4	3
0.25- .49	53	3	5
0.50- .99	39	3	2
1.00-1.99	16	2	3
2.0 -over	8	1	1
Total	189	13	14

Since Zone 2 of Ober River is entirely within the Catoosa Wildlife Management Area of the Tennessee Game and Fish Commission, fishing was easily controlled and measured. Lower Daddy's Creek, also in the management area, was used as a check for fishing success.

Daily permits were required by the Commission to fish in the management area. The permit card was also a form upon which the fish catch was recorded. These cards were self-addressed and stamped and the fishermen, upon completion of his fishing trip, filled out the card and turned it over to the area manager or dropped it in a mail box. Cards that were not filled adequately were returned to the fishermen for completion. Spot checks in the field verified the validity of the data collected by the permit card census. Seventy-six percent of the cards were returned during the census and adjustments were made for unreported fishing trips. Data were compiled to determine the rate of cropping and fishing pressure for each stream.

Results of Fertilization

Success of angling

The number of annual fishing trips recorded for Zone 2 of Obed River from 1954-1956 increased from 280 to 747 (18 to 47 fishing trips per mile) for a 167-percent increase in fishing pressure (Table 2). Fishermen catch increased from 1,680 to 4,856 fish (16 to 47 fish per acre) for the same period, an increase of 189 percent. Fishing success increased from 6.0 to 6.5 fish per fishing trip, an increase of 9 percent.

Table 2.—Fishery records for the 16 miles of Obed River (Zone 2) and 6 miles of Daddy's Creek in the Catoosa Wildlife Management Area, Tennessee, 1954 to 1956.[1]

Stream	Item	Year 1954	1955	1956
Obed River	Number of fishing trips	280	490	747
	Fishing trips per mile	18	31	47
	Number of fish caught	1,680	2,842	4,856
	Number of fish caught per mile	105	178	304
	Number of fish caught per acre	16	27	47
	Average number of fish per trip	6.0	5.8	6.5
Daddy's Creek	Number of fishing trips	103	138	163
	Number of fishing trips per mile	19	23	27
	Number of fish caught	810	1,432	1,108
	Number of fish caught per mile	147	239	185
	Average number of fish per trip	7.9	8.9	6.8

[1]Daily catch limit: smallmouth, largemouth, and spotted bass — 10; bluegill, rock bass, and other sunfishes 25; walleye and muskellunge — 5; no limits on other species.

Similar records compiled from Daddy's Creek, which flows into Obed River at the lower limit of Zone 2, indicates only slight increases in fishing pressure and catch (Table 2). During the period 1954-1956, fishing pressure on Daddy's Creek increased only 58 percent and total catch 24 percent.

The increase of fishing pressure on Daddy's Creek during 1955 and 1956 was a direct result of the increased fishing on Obed River. Although Daddy's Creek absorbed the increased fishing in 1955, fishing success and total catch dropped substantially in 1956. Fish catch from Obed River was 304 fish per mile in 1956; 185 fish per mile on Daddy's Creek.

The catch of fish from Obed River from 1954-1956 reveals substantial increases of bluegill and largemouth bass each year (Table 3). In 1956 smallmouth bas sand rock bass showed a marked increase over previous years. The catch of catfish was relatively unaffected. Catch from Daddy's Creek for the same period was variable and no important trends were apparent (Table 3).

The residual sport fish crop (those fish present after the major fishing season) was determined from fish samples taken with the use of rotenone in Zone 2 of Obed River during the fall of 1953 and 1956.

Table 3.—Angler's catch of fish from Obed River and Daddy's Creek 1954-56 (Numbers in parentheses represent percentage of catch).

Stream	Species	Number of fish caught 1954	1955	1956
Obed River	Smallmouth bass	706 (42)	654 (23)	1428 (28)
	Rock bass	622 (37)	530 (38)	1345 (26)
	Bluegill	67 (4)	115 (8)	1641 (32)
	Largemouth bass	67 (4)	284 (10)	442 (9)
	Catfish	218 (13)	255 (9)	287 (6)
Daddy's Creek	Smallmouth bass	340 (42)	467 (34)	310 (25)
	Rock bass	300 (37)	530 (38)	573 (47)
	Bluegill	32 (4)	115 (8)	133 (11)
	Largemouth bass	32 (4)	43 (3)	110 (9)
	Catfish	105 (13)	229 (17)	100 (8)

Angler's catches were computed for 1954-1956. The availability of sports fish to the angler, including recruitment, was then determined from these data for pre- and post-fertilization periods.

From table 4 it is noted that the residual crop of principal angling-sized sport fish in Zone 2 increased from 34 to 57 fish per acre from 1954-1956. Angler's catches increased from 15 to 47 fish per acre. The available numbers of angling-sized smallmouth bass, rock bass, bluegill, and largemouth bass increased 90, 126, 110, and 133 percent, respectively. The increase in numbers of these fish available to the angler increased from 49 to 104 fish per acre, or 112 percent. The rate of exploitation of sport fish increased from 31 to 45 percent of fish available.

By computing the average lengths of the angling-sized sport fish taken in the fish samples in the fall of 1953 and 1956, differences in sizes of each species were determined. Smallmouth bass, largemouth bass, and bluegill were substantially longer in 1956 (Table 5). The average angling-sized sport fish in Zone 2 was 20 percent larger in 1956 than in 1953.

Fish species composition and abundance. – The pre-fertilization standing crop of sport fish of Obed River in Zone 2 compares favorably with other Plateau streams. For the four streams sampled, standing crops of sports fish per acre were quite similar, ranging between 20.7 and 26.1 pounds (Table 6). There were, however, considerable differences in the abundance of angling-sized sport fish, and non-sport fish. For instance, 75 percent of the fish weight of the 1952-1953 Obed River fish samples consisted of fish (carp, smallmouth buffalo, freshwater drum)

Table 4. — Catch and abundance of principal sports fish of angling size per acre in Zone 2, Obed River, 1954 and 1956.

Species	1954 Number of fish			Percentage of fish caught	1956 Number of fish			Percentage of fish caught
	Angler's catch	Residual crop	Total available		Angler's catch	Residual crop	Total available	
Smallmouth bass	7	3	10	70	13	5	18	72
Rock bass	6	9	15	40	12	21	33	36
Bluegill (and other sunfish)	1	20	21	5	17	28	45	38
Largemouth bass (spotted bass included)	1	2	3	33	4	3	7	57
Total	15	34	49	31	46	57	103	45

Table 5.—Average lengths on angling size sport fish taken from population samples in 1953 and 1956, from Zone 2, Obed River

Species	Average length (inches) 1953	1956
Largemouth bass	11.4	12.1
Smallmouth bass	9.7	10.8
Rock bass	6.1	6.2
Bluegill	6.8	7.3

Table 6.—Estimated standing crop of fish (pounds per acre) for several streams of the Cumberland Plateau, 1953
(Estimated from 38 pools totalling 16 acres)

Stream	Sport Fish			Non-sport fish	Total
	Angling-sized	Small	Total		
Obed River (Zone 2)	12.6	13.5	26.1	65.5	91.6
Clear Fork River	9.5	11.2	20.7	55.5	76.2
Daddy's Creek	7.7	17.1	24.8	24.8	49.6
Otter Creek	4.7	16.3	21.0	10.2	31.2

that had migrated from other waters, whereas none of these fish appeared in Daddy's Creek where natural rock barriers restricted fish movement upstream.

General observation of the effects of fertilization upon the fishes of Obed River strongly indicated that best results were obtained in 1954 when the observed abundance and growth of both young largemouth bass and bluegill was far above average for past years. By fall, minnows were extremely abundant in all areas of Zone 2. Fishermen likewise observed and explained that some "great phenomenon" was taking place in Obed River.

Small samples of fish taken with the use of rotenone in the fall indicated young minnows, bluegill, longear sunfish, and largemouth bass were in much greater abundance than in 1952 or 1953. However, these large numbers of small fish were not evident the next spring.

Few young fish of any species appeared in particular abundance in Zone 2 before or after fertilization in 1955. Summer water flows were above average and water temperatures did not exceed 75° F. until August. The sunfishes did not spawn successfully until the water temperatures reached 80° F. whereas in 1954, many young sunfishes were evident as early as June.

Estimates of standing crops of fish in Zone 1 in 1953 and 1956 revealed a marked decrease in the abundance of all groups of fish (Table 7). The estimated standing crops of fish in Zone 2 during the same period indicated an increase from 98.2 to 136.2 pounds of fish per acre; however, carp and smallmouth

buffalo comprised most of the increase. Sport fish increased slightly from 26.1 to 28.7 pounds of fish per acre and forage fish decreased from 6.6. to 6.3. pounds per acre.

Table 7.—Estimated standing crops of fish (pounds per acre) for Obed River, 1953 and 1956.

Area	Year	Sport fish	Non-Sport fish	Forage fish	All
Zone 1	1953	78.2	25.0	26.8	130.0
	1956	60.3	10.4	18.5	89.2
Zone 2	1953	26.1	65.5	6.6	98.2
	1956	28.7	101.2	6.3	136.2

Estimated standing crops of sport fish in Zone 2 indicate little change except for an increase in the abundance of rock bass from 6.2 to 9.4 pounds per acre, and a decrease of small bluegill from 3.0 to 1.3 per acre (Table 8).

Since approximately 88 percent by weight of all non-sport fish are of migratory descent and do not reproduce in Obed River, changes in standing crops of non-sport fish in Zone 2 from 1953 to 1956 are difficult to interpret. The pounds of non-sport fish per acre increased from 65.5 to 101.2 between 1953 and 1956. Carp and golden redhorse showed the greatest increase in the composition of non-sport fish (Table 9).

Length-weights.—The length-weights of 2,586 rock bass, 798 smallmouth bass, and 1,947 bluegill collected before and after fertilization were used to determine changes in condition. Those fish examined in 1956 generally displayed slight increases in weight by one-inch size groups. Since fish taken in 1956 were examined the year following fertilization, length-weight data are not entirely comparable.

Measurements of 74 freshwater drum, 246 carp, and 182 smallmouth buffalo from Zone 2 showed an increase in lengths and weights from 1953 to 1956. The lengths of the drum examined ranged from 9 to 21 inches (average 15.3); carp 12 to 27 inches (average 20.2); and buffalo 13 to 23 inches (average 17.4). The average-sized drum, carp, and buffalo were 3.9, 2.7, and 2.2. inches larger respectively, in 1956 than in 1953 (Table 10). Average weight increases were 1.2, 1.6, and 1.2 pounds for drum, carp and buffalo, respectively.

In every instance all inch groups of each species portrayed an increase in weight. Drum, carp, and buffalo, averaged 0.16, 0.69, and 0.24 pounds heavier for each one-inch group.

Measurements of 111 golden redhorse indicated an average increase of 0.12 pounds for each inch group from 1953 to 1956.

Table 8.—Standing crops of sport fish (pounds per acre) before (1953) and and after (1956) fertilization, for Zone 2, Obed River

Species	Angling size		Small		All	
	1953	1956	1953	1956	1953	1956
Rock bass	1.5	2.3	4.7	7.1	6.2	9.4
Bluegill	5.7	7.2	3.0	1.3	8.7	8.6
Smallmouth bass	1.6	2.9	2.7	2.3	4.3	5.2
Largemouth bass	1.8	1.9	0.5	0.7	2.3	2.6
Other sport fish	2.0	1.2	2.6	1.7	4.6	2.9
All	12.6	15.5	13.5	13.2	26.1	28.1

Table 9.—Composition by weight of principal non-sport species before (1953) and after (1956) fertilization in Zone 2, Obed River (Expressed as percentages)

Species	1953	1956
Carp	44	54
Buffalo	45	32
Hogsucker	6	4
Golden redhorse	4	9
Other	0	1

Table 10.—Length and weight increases of principal non-sport fish in Obed River from Zone 2, from 1953-1956

Species	Average weight increase (pounds)		Average length increase (inches)
	Each inch group	Each fish	
Carp	0.69	1.55	2.7
Smallmouth buffalo	0.24	1.22	2.2
Drum	0.16	1.17	3.9

Lengths of fish examined ranged from 11 to 21 inches and averaged 14.4 inches.

Limnology. — In 1955 a detailed study of the aquatic vascular plants was made in Obed River (Robinson, 1960). Observations, coupled with photographs of designated areas, indicated that between 1953 and the fall of 1955 there was no visual increase in the abundance of aquatic vascular plants. The most common species in Zone 2 of Obed River were *Callitriche heterophylla, Podosteum ceratophyllum, Juncus debilis, Nuphar advena, Eleocharis obtusa, Justicia americana, Sparganium americanum,* and *Lobelia cardinalis.*

The most notable effect of the fertilizer upon Obed River was the great increase of filamentous algae on the stream bottom, particularly for a distance of 3 or 4 miles downstream from points of fertilization. This influence was also noticed by Huntsman in a cold-water stream in Nova Scotia (1948). A great increase in the abundance of snails and certain zooplankton (*Cyclops* and *Daphnia*) was readily evident along pool edges in the summer and fall.

A measurable increase in phytoplankton concentration occurred only in 1954 immediately downstream from points where fertilizer was added. Turbidity in these areas ranged from 8 to 20 p.p.m. All other readings in Obed River were less than 5 p.p.m. A heavy bloom of phytoplankton occurred on the water's surface in several areas in 1954; however, water below the surface was clear.

Chemistry. — The addition of fertilizer to Obed River made no measurable change in total alkalinity which was generally constant at all times above and throughout waters affected by the fertilizer. A slight increase in free CO_2 and lower pH readings were recorded from waters immediately below shoals where fertilizer was added. Free CO_2 ranged from 2 to 8 p.p.m. and averaged about 4 p.p.m. in all areas of Obed River from June to September in 1954 and 1955. During the same period total alkalinity in p.p.m. ranged from 10 to 18 and pH 6.7 to 7.0. No differences were apparent in the alkalinity and pH of waters in Zones 1 and 2 when taken at about the same date.

EVALUATION OF FERTILIZATION

Major changes in the fishery of Obed River between pre- and post-fertilization periods were: the number of fishing trips per mile increased from 18 to 47 (167 percent); the number of fish caught per mile increased from 105 to 304 (189 percent); rate of cropping increased 45 percent; individual angling catch increased 9 percent; and average length of the fish caught increased 20 percent. Furthermore, increased fishing success and fishing pressure resulted in more specific angling for the relatively abundant bluegill and largemouth bass — species that were insufficiently cropped previous to fertilizing.

The effect of the fertilizing on the growth of sports fish was not well demonstrated. Since calculated growths of sport fish taken in population studies in 1956 were seriously biased by the high rate of cropping, comparisons of growth in 1953 and 1956 were inconsistent and not included in the text. However, increases in growth of young smallmouth bass, largemouth bass, and bluegill suggested that these species grew to angling size at a younger age by 1956. The great increase in fishing pressure, fish catch, and rate of cropping made comparison of standing crops a poor measure of changes in sport fish populations. Non-sport fish, not subject to exploitation, strongly increased in numbers, length, and weight between 1953 and 1956.

Since the study did not consider benefits that may have occurred downstream from Zone 2, nor were the increases in fish populations or angling catches from 1953 to 1954 determined, the net results of the fertilization may have been much higher than demonstrated. Furthermore, if a portion of the fertilizing was done in Zone 1, the test area, greater over-all benefits surely would have been obtained.

Results of the work on Obed River reveal fertilizing, where applicable, is a feasible method of fishery management. The study was not designed to experiment with improved methods or techniques or delve into the fundamentals of aquatic production; it is here that opportunity is greatest for development. Improvements in fertilizing streams over that completed will require: (1) development of methods to easily determine the nutrient requirements in any stream waters and the best fertilizer to use; (2) less laborious methods of adding fertilizer to streams, which may involve liquid fertilizers dispensed by the rate of stream flow; and (3) a better understanding of the dispersion of fertilizer nutrients downstream and its effect upon aquatic life.

The success of fertilizing warm-water streams in any area is largely dependent upon the chemical properites of the water, fish species present, the relationship between the rate of flow and displacement volume of the stream during the summer, and the general size and length of the stream.

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Free University of Berlin, Germany, and for the past four years has been associated with the Max Planck Institut fur Vergleichende Erbbiologie und Erbpatholigie, Berlin-Dahlem, Germany.

Menachem B. Lion, who received the Ph.D. in Organic Chemistry from the Hebrew University, Jerusalem, Israel in June, 1959, will be associated with Mammalian Recovery Group for the coming year.