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NORRIS RESERVOIR FERTILIZER STUDY

I. EFFECTS OF FERTILIZER ON FOOD CHAIN ORGANISMS AND FISH PRODUCTION

CARL E. WOOD AND TOMMY L. SHEDDAN

Tennessee Valley Authority

Norris, Tennessee 37828

ABSTRACT

The ability of inorganic fertilizer to increase production and survival of fish food organisms and game fish, thereby increasing sporting fish, in localized cove areas of Norris Reservoir, Tennessee, was studied from April to October 1967.

Increasing fishing and nutrients in localized areas of a reservoir in one growing season by fertilization does not appear practical.

Fertilization increased the numbers of bottom organisms and zooplankton, but there was no significant change in numbers, size, species, composition, or survival of fish. Temperature and oxygen profiles, coupled with the physical characteristics (directional axis of coves in relation to main creek and cove depth and length) suggest that the age of the water may be very significant in increasing production in coves.

INTRODUCTION

Norris Reservoir, filled in 1936, impounds 34,000 acres of the Clinch and Powell Rivers in east Tennessee. Compared to other tributary reservoirs in the Tennessee Valley, it is intermediate in fish production, supporting only about 131 pounds of fish per acre.

Increasing production by adding chemical fertilizer to such a large impoundment is not economically practical. However, small areas within the reservoir may lend themselves to fertilization as practiced in farm pond management.

During 1967 the Fish and Wildlife Branch of TVA fertilized coves in Norris Reservoir to (1) test and measure the effects of inorganic commercial fertilizer on production and survival of fish food organisms and game fish in localized reservoir areas, and (2) determine whether fertilization would be a practical way for boat dock operators, sportsman's clubs, or other to improve sport fishing in specific areas.

A simultaneous basic productivity study (carbon 14 incubation tests and chlorophyll tests) to determine the effects of fertilization on primary production was conducted by the TVA Division of Health and Safety. Those results are reported separately by Taylor and Welch (1968). The only similarity between the two studies was the way the fertilizer was originally selected and applied.

METHODS AND MATERIALS

Rates of fertilizer were selected by a preliminary bioassay conducted by the Water Quality Branch of TVA in August of 1966 to determine the concentration of nitrogen and phosphorous that limited productivity in Norris Reservoir. This study showed that at 95 percent confidence limits additions of 50 ug/1 of P and 100 ug/1 of N significantly increased phytoplankton productivity in bottles incubated in the reservoir. Higher levels of artificial enrichment did not cause a further significant increase. Purpose of the field study, therefore was to

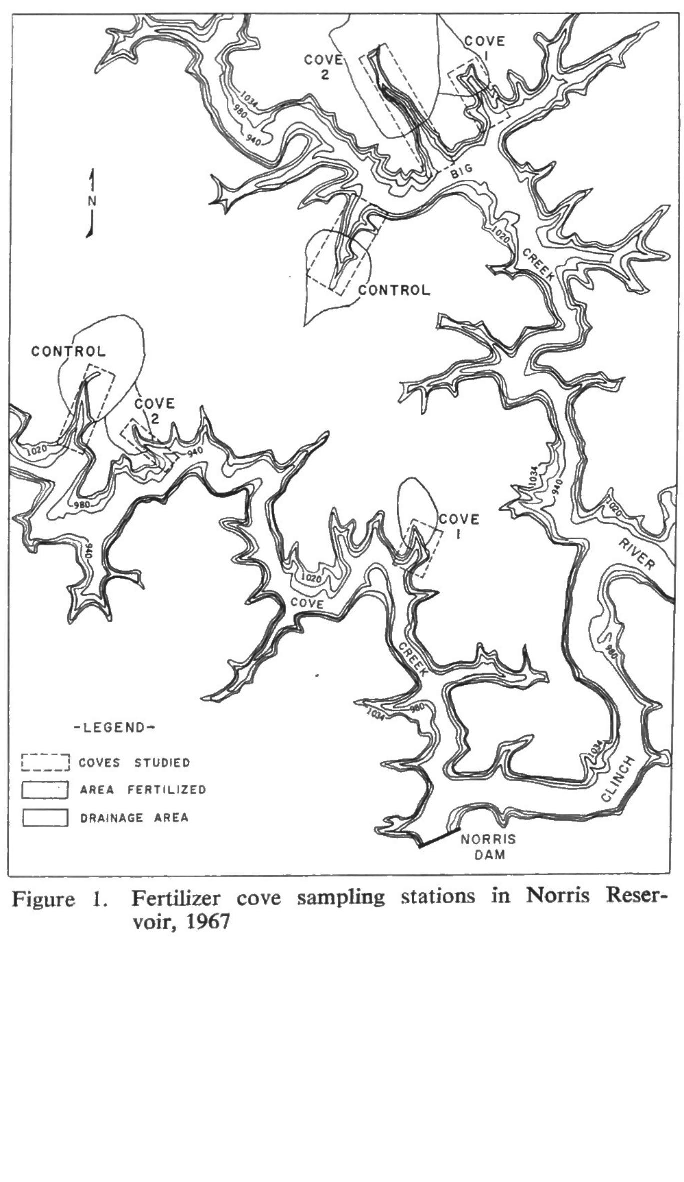


Figure 1. Fertilizer cove sampling stations in Norris Reservoir, 1967

TABLE I. Physical Characteristics of Six Study Coves

Item	C-1	C-2	C-3	B-1	B-2	B-3
Drainage area (square miles)	.20	.19	.51	.25	.71	.43
Size (acres) at lake elevation 985 feet	4.54	4.88	5.49	5.38	6.31	5.44
Size (acres) at lake elevation 1,005 feet	6.26	6.58	8.82	7.40	8.43	6.93
Volume (cubic feet) at lake elevation 1,000 feet	16.50X10^6	5.60X10^6	4.12X10^6	11.84X10^6	11.20X10^6	13.44X10^6
Depth (feet) 1/3 from head end at elevation 1,005	57	38	39	57	36	47
Depth (feet) 2/3 from head end at elevation 1,005	87	48	49	65	51	64
Depth (feet) at cove mouth at elevation 1,005	122	73	72	81	73	85
Directional orientation moutn to head	N 5°W	N65°W	N10°E	N40°W	N25°W	S10°W
Cove length (feet) at elevation 1,005 feet	1,050	975	1,600	1,050	2,275	1,425
Cove length (feet) at elevation 985 feet	900	900	1,250	1,000	1,750	1,150

determine if the nutrient concentration that was optimum in the bottles was also optimum in the natural environment. Factors such as nutrient loss from the epilimnion, movement and exchange of water, and variability in the seasonal growth cycles of phytoplankton were not operative in the bottle bioassay and would probably modify the effect of the nutrients added to the open coves.

After the rates of fertilizer were determined, six coves on Norris Reservoir were selected for study, three in Cove Creek and three in Big Creek (Figure 1). Factors in selection were (1) availability of water year around, (2) size under 10 surface acres, and (3) nearness to each other. All of the cove areas are characterized by steep slope basins surrounded by a heavily wooded drainage area. Table 1 describes their physical characteristics. Cove 2, Big Creek, has the greatest surface and drainage area. Cove 1, Cove Creek, has the greatest volume and mean depth. The Control Cove on Cove Creek has the smallest volume and mean depth. The amounts of fertilizer applied to give the theoretical concentrations are shown in Table 2. Cove 1 in each creek has enough fertilizer applied to theoretically increase the nitrogen and phosphorus concentrations to those which should cause maximum production based on the 1966 bioassay results. Half of this amount was applied to Cove 2 in each creek. The control coves got none.

The specially prepared commerical grade fertilizer was a monobasic ammonium phosphate $(NH_4)_2SO_4$ in an N-P-K ratio of 16-20-0. The fertilizer, in a tapwater solution was applied to the test coves once every two weeks from May through October. Distribution to the various coves was by boat with the solution being pumped into the propeller wash in a crisscross pattern at approximately the same speed each time. Each application should have increased the nutrients in the coves to the concentrations shown in Table 2. The listed poundage is the amount of fertilizer added to each cove every two weeks and the total amount applied during the study period.

Biweekly samplings to determine basic biological and chemical differences between the coves were begun on April 1 and continued until October 24. Samples taken at a point one-third the distance from back end to mouth of the cove included the following:

a. Zooplankton—100 gallons of water were pumped from two feet below the surface and filtered through a No. 20 Wisconsin plankton net.

b. Limnetic macroivertebrates—one Dendy two-plate sampler was located one to two feet above the bottom in eight feet of water.

TABLE II. Biweekly Fertilizer Application Rates

Cove	Initial*	May-July	August-October	Total Pounds Applied May-October	Increased Concentrations (Theoretical) µg/l N	P
	----------pounds--------------------					
C-1	163.0	68.0	123.0	1,377	100	50
C-2	86.5	35.5	61.0	701	50	25
B-1	192.5	80.5	146.0	1,440	100	50
B-2	111.0	46.0	85.0	943	50	25
Total	553.0	230.0	415.0			

* Rate applied to compensate for increase in water volume in coves from the original volume when fertilizer recommendations were made.

c. Bottom organisms—two 6-inch Ekman dredge samples were sieved through a No. 30 U. S. standard sieve.

All these samples were preserved in the field. In the laboratory, bottom and limnetic macroinvertebrate samples were separated from debris by Anderson's (1959) sugar flotation technique and then stored in 5-percent formalin solution for final identification under a dissecting microscope. Zooplankton samples were concentrated to 20 ml; a 1-ml subsample was then examined in a Sedgwick-Rafter counting chamber under a 50X dissection scope. Plankters were enumerated by family.

Chemical differences were determined from surface water samples taken at the same time as biological samples. They were then taken to the TVA Engineering Laboratory at Norris, Tennessee, for measurements of silica, iron, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chlorides, nitrate, phosphate, dissolved solids, color, and turbidity according to *Standard Methods for the Examination of Water and Waste Water* (1965).

Additional water chemistry and hydrological measurements taken two-thirds of the way from the back end of the cove included temperature to the nearest degree Fahrenheit every five feet from top to bottom, dissolved oxygen to the nearest 1 ppm every 10 feet and pH and carbon dioxide to the nearest 1 ppm on the surface and one foot from bottom. Temperature was measured with a Fixboro or Applied Research Corporation resistance thermometer. Dissolved oxygen, pH, and carbon dioxide were measured with a Hach chemical kit.

One soil sample taken one-third the way from the back end of each cove before the first application of fertilizer was analyzed for nitrates and phosphates by the Tennessee Extension Service Soil Testing Laboratory in Nashville, Tennessee. A second sample from each of the same spots after termination of the test was analyzed by the TVA Division of Agricultural Development in Muscle Shoals, Alabama.

Fish populations in each cove were sampled biweekly with a boat-mounted 220V-DC electroshocker delivering 2.5 amps at 180 cps. Game fish were measured for total length and fin clipped. Nongame fish were counted and the length of the largest and smallest recorded.

Results and Discussion

First analysis of data compared coves in Big and Cove Creeks to see if equal treatments produced the same response. No statistically significant differences were found in numbers of zooplankton, limnetic macroinvertebrates, bottom fauna, or fish; therefore, averages of these parameters were used to interpret these data. However, significant hydrographic differences were found between coves. The effects of treatment and time on each of these parameters is described.

Physcial topography and the above biological characteristics are used to assess the effects of nutrient enrichment on the cove habitats. Some physical and chemical features of the test environments are given.

Zooplankton

Zooplanton counts indicate three significant blooms in each cove within the observation period (Table 3). A time lag of three to four weeks occurred between the first application of fertilizer on May 1 and the first bloom, which began in late May and extended into early June. A second bloom occurred in late July and early August, and a third in early October. The first bloom coincided with increasing water temperatures (Figure 3 to 5), while the second coincided with increasing rainfall and a sharp rise in reservoir elevations.

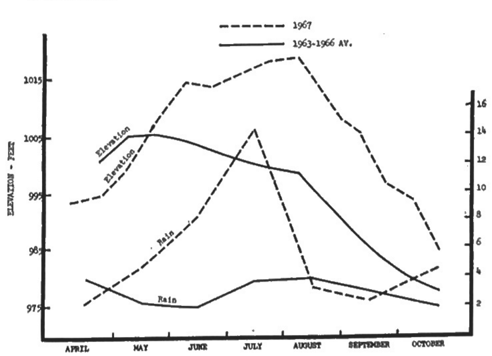
All blooms occurred when the reservoir was in a mixed or nonstratified condition. The second bloom is of special interest in that it occurred approximately three weeks after a period of heavy rainfall. This numerical increase in plankters, especially rotifers, after heavy rainfall is similar to what Jones (1939) found in his study of Norris Reservoir. The effects of nutrients added by the rain and runoff are not known. The third bloom occurred in October and followed a significant increase in primary productivity and numbers of the diatom *Nitzchia* sp. (Taylor and Welch, 1968). Jones also observed three major zooplankton blooms at approximately the same time of year.

From the standpoint of zooplankton seasonal abundance (Table 3), the rotifers (mainly *Keratella* sp.) were the most numeous plankter in all coves, followed by copepods (mainly *Limnocalanus* sp.), cladocerans (mainly *Daphnia* sp.), and ostracods in that order. There was a highly significant (5-percent level) differ-

Table 3. ESTIMATED NUMBER OF ZOOPLANKTERS PER 100 GALLONS OF WATER

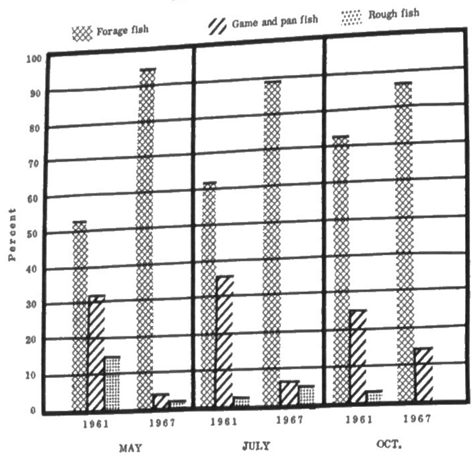
Treatment	Taxa	May 9-10	May 23-24	June 5-6	June 19-20	July 3	July 18	July 31 Aug. 1	Aug. 14	Aug. 28-29	Sept. 11-12	Sept. 25-26	Oct. 9-10	Oct. 23-24	Average number
		- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - thousands	- - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
100 µg/l N 50 µg/l P	Rotifera	3,593	7,925	78,408	20,923	9,299	3,487	9,299	16,590	1,691	1,691	1,268	5,706	3,064	12,534
	Cladocera	317	317	528	106	423	0	317	317	423	740	317	1,585	845	480
	Copepoda	951	2,959	39,415	2,113	634	106	740	634	211	845	528	1,479	106	3,902
	Ostracoda	0	106	0	0	0	0	106	106	106	0	0	0	0	33
50 µg/l N 25 µg/l P	Rotifera	2,113	21,451	10,461	12,575	3,698	1,796	5,706	1,796	740	1,374	1,374	5,495	2,747	5,487
	Cladocera	0	317	2,113	211	0	0	211	0	211	211	211	1,374	528	414
	Copepoda	211	4,491	2,430	951	0	106	528	317	211	845	211	1,374	211	914
	Ostracoda	0	106	106	0	0	0	53	0	0	0	0	0	0	20
Control	Rotifera	845	13,420	10,673	2,166	1,902	2,853	2,589	423	4,650	2,642	3,910	7,820	3,698	4,430
	Cladocera	106	1,162	2,325	106	0	0	106	0	106	211	106	1,479	211	455
	Copepoda	0	2,959	2,008	53	317	1,057	528	0	106	2,853	317	1,268	740	939
	Ostracoda	0	106	106	0	0	0	53	106	0	0	0	0	0	29

Figure 2. MONTHLY RAINFALL AND ELEVATION AVERAGES FOR NORRIS RESERVOIR, 1967 AND 1963-66.



ence in abundance of these four groups and between treatments for total numbers. The latter significance is strongly indicated in Table 3 where the total number collected in coves treated with 100 μg/1 P and 50μg/1 P accounted for 57 percent of all the organisms collected in all coves. The other percentages compared to

Figure 3. SEASONAL VARIATIONS IN THE MAJOR FISH GROUPS, NORRIS LAKE, 1961 AND 1967



were 23 for treatment with 50 μg/1 N and 25 μg/1 P and 20 for the control coves. These results are similar to those found by McIntire and Bond (1962) in Oregon where number of crustaceans and rotifers increased proportional to the amount of nitrogen and phosphorus fertilizer applied.

Phytoplankters were not enumerated; however, great numbers of *Ceratium hirundinella* were observed in the July-September samples. With this addition to the zooplankters, the species composition during this period was similar to that found by Smith (1967) and Jones (1939) on Norris Reservoir.

Limnetic Macroinvertebrates

The abundance of each of the macroinvertebrates groups are shown in Table 4. Cladocerans (mainly *Daphnia* sp.) and tendipes larvae predominated. Higher than usual rainfall, and probable influx of organic material, into the coves in July (Figure 2) suggests a probable cause of the sharp decrease in cladocerans and increase in tendipes larvae. The assumption that an influx of organic material occurred is based on the fact that tendipes larvae are used as indicators of organic pollution (Reid, 1961). Neither treatment made statistically significant differences in macroinvertebrate abundance. Differences between sampling dates were significant.

FIGURE 4. TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN COVES FERTILIZED WITH 100 μg/1N-50μg/1P

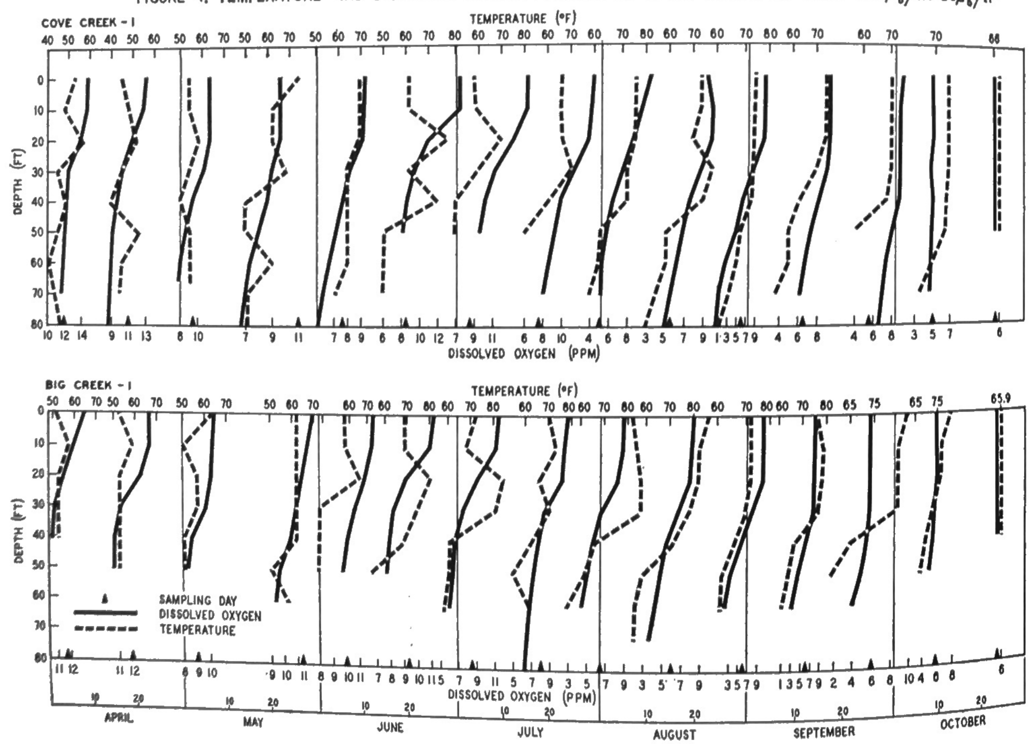


FIGURE 5. TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN COVES FERTILIZED WITH 50μg/1N-25μg/1P

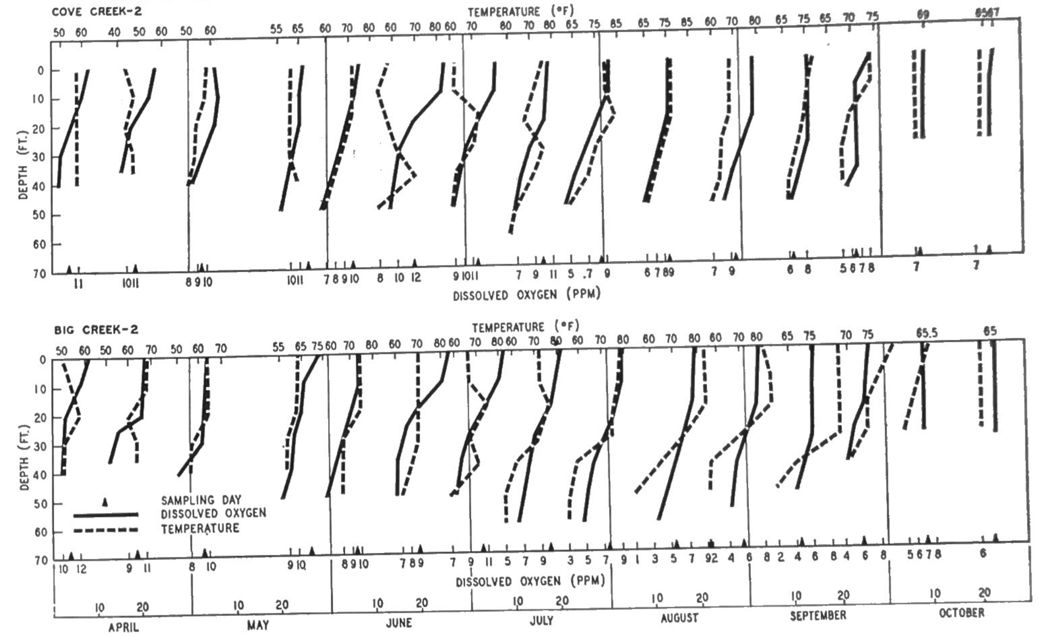


FIGURE 6. TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN THE CONTROL COVES

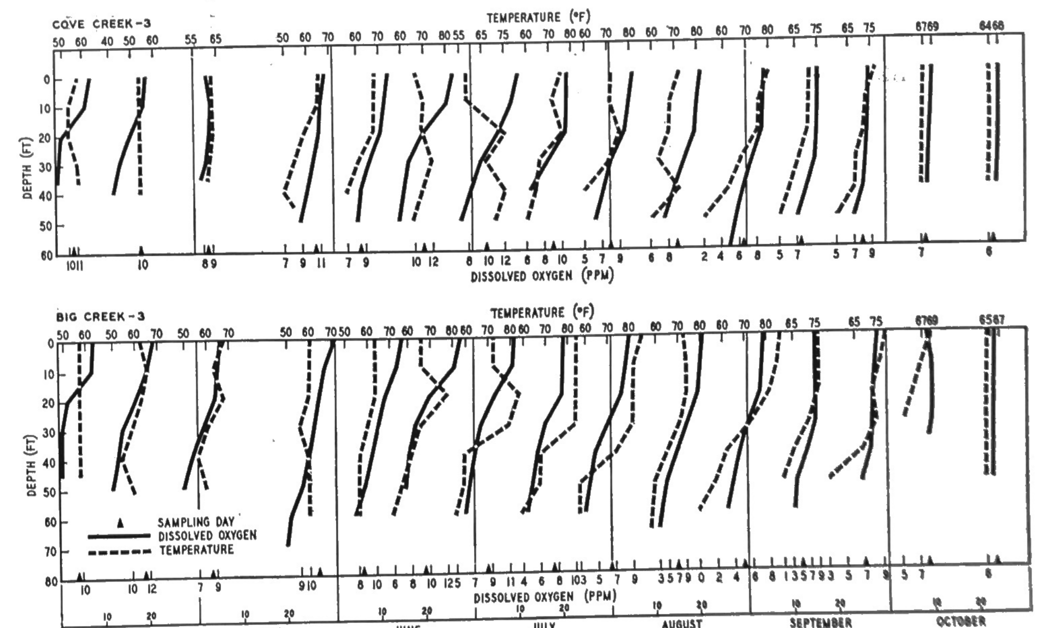


Table 4. NUMBER OF LIMNETIC MACROINVERTEBRATE ORGANISMS PER SQUARE FOOT OF BOTTOM

Treatment	Taxa	April 18-19	May 2-3	May 9-10	May 23-24	June 5-6	June 19-20	July 3	July 17-18	July 31 Aug. 1	Aug. 14-15	Aug. 28-29	Sept. 11-12	Sept. 25-26	Oct. 9-10	Oct. 23-24
100 $\mu g/l$ N 50 $\mu g/l$ P	Crustacea Cladocera	-	1,010	1,716	1,560	2,640	230	-	4	-	-	-	6	2	2	-
	Diptera Culicidae	-	-	-	-	-	10	-	-	10	12	-	-	2	-	-
	Diptera Tenipedidae	-	-	48	14	12	2	64	34	188	60	128	50	20	-	6
	Ephemeroptera Ephemeridae	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
	Mollusca Gastropoda	-	-	-	-	-	-	2	-	-	-	4	-	-	-	-
	Oligochaeta Opisthocystidae	-	-	4	-	2	-	-	-	-	6	2	-	-	-	-
	Oligochaeta Tubificidae	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-
50 $\mu g/l$ N 25 $\mu g/l$ P	Crustacea Cladocera	680	1,046	212	386	3,090	250	2	4	4	-	6	2	-	-	2
	Diptera Culicidae	-	-	-	-	-	8	2	2	2	8	-	10	-	-	-
	Diptera Tenipedidae	6	4	2	-	10	48	148	68	96	196	34	58	20	-	2
	Ephemeroptera Ephemeridae	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-
	Oligochaeta Opisthocystidae	8	-	-	-	-	-	2	28	2	-	-	2	-	-	8
Control	Crustacea Cladocera	788	480	320	654	2,006	96	-	4	6	-	2	6	-	-	-
	Diptera Ceratopogonidae	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-
	Diptera Culicidae	-	-	-	-	-	4	-	-	8	8	-	4	-	-	8
	Diptera Tenipedidae	8	2	2	-	14	12	26	12	64	78	28	20	-	-	-
	Mollusca Gastropoda	-	-	-	-	-	-	-	2	4	-	-	-	-	2	-
	Oligochaeta Opisthocystidae	-	-	-	-	10	-	2	2	-	-	-	-	-	2	-
	Turbellaria Planariidae	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-

Dashes indicate absence in both replicates.

Bottom Fauna

Tendipes larvae were dominant in all coves (Table 5). Tubifex worms (mainly *Tubifex* sp.) and biting midge larvae also contributed significantly to this community. The dominance of tendipe larvae is similar to what Ball and Tanner (1951) and Ball (1949) found in fertilized Michigan lakes and Howell (1941) found in fertilized ponds in Alabama.

midge larvae and tubifex worms but not for total organisms (Table 5).

Fish

Forage fish dominated the electrofishing samples. A large catch of threadfin shad occurred on May 18 (Table 7), but a significant difference between kinds of fish still remains when they are deleted from the analysis. Statistical tests indicate fertilizer did not increase the number of game fish. The total number of fish taken on different sampling dates was significantly different, but much of this difference was due to the increased population of threadfin shad taken on May 18. Also contributing was the rise of water into the trees, which made sampling difficult, and then the recessions which caused large numbers of fish to be located in peripheral sampling areas. Numbers of fish collected by electrofishing are summarized in Tables 6 and 7. When the electrofishing results are compared to the results obtained in the 1961 Norris Reservoir Fish Inventory (Tennessee Valley Authority and Tennessee Game and Fish Commission, 1961), the difference in ratios of each group of fish for each season (Figure 3) indicates strongly that the electroshocker is not a valid sampling technique in deep reservoirs with steep sloping bottoms. This was especially true in the July 1967 sample when the fish were among the trees around the edge of the cove and the electroshocker was ineffective.

Table 5. AVERAGE NUMBER OF BOTTOM ORGANISMS PER SQUARE FOOT

Treatment	Taxa	April 7	April 18-19	May 2-3	May 9-16	May 23-24	June 5-6	June 19-20	July 3	July 18	July 31 Aug. 1	Aug. 14	Aug. 28-29	Sept. 11-12	Sept. 25-26	Oct. 9-10	Oct. 23-24
100 $\mu g/l$ N 50 $\mu g/l$ P	Bryozoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Crustaceae Cladocera	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-
	Crustaceae Copepoda	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	Diptera Ceratopogonidae	3	5	5	-	-	-	-	-	1	-	-	-	-	-	1	-
	Diptera Culicidae	-	2	-	-	-	-	-	-	-	1	2	-	-	-	-	1
	Diptera Tendipedidae	5	2	2	1	1	1	-	2	7	3	15	-	4	8	4	1
	Ephemeroptera Ephemeridae	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mollusca Pelecypoda	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
	Oligochaeta Opisthocystidae	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
	Oligochaeta Tubificidae	3	3	2	-	3	-	4	5	-	1	18	-	4	9	4	11
50 $\mu g/l$ N 25 $\mu g/l$ P	Coleoptera	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Diptera Ceratopogonidae	9	9	4	1	2	-	-	-	-	1	1	-	1	1	-	1
	Diptera Culicidae	-	-	1	-	-	-	2	-	1	3	-	-	-	-	-	-
	Diptera Tendipedidae	5	5	3	1	5	3	6	-	31	30	44	46	38	26	7	2
	Ephemeroptera Ephemeridae	-	-	-	-	1	-	1	-	-	-	-	-	-	-	1	1
	Hydracarina	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-
	Mollusca Pelecypoda	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	Oligochaeta Tubificidae	-	-	1	-	20	1	6	2	-	1	3	8	4	-	-	8
	Trichoptera	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-
Control	Bryozoa	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	Crustaceae Cladocera	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
	Crustaceae Copepoda	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
	Diptera Ceratopogonidae	2	7	-	-	1	-	-	-	-	-	-	-	-	1	1	3
	Diptera Culicidae	1	-	-	1	-	-	-	-	23	3	-	-	-	1	-	-
	Diptera Tendipedidae	-	2	-	-	6	-	3	6	3	14	7	1	3	7	1	6
	Ephemeroptera Ephemeridae	-	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-
	Mollusca Pelecypoda	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oligochaeta Opisthocystidae	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
	Oligochaeta Tubificidae	1	-	-	5	4	-	1	2	1	1	3	2	3	6	16	2
	Trichoptera	-	-	-	-	-	-	1	-	-	-	-	-	-	4	-	1

Bottom organisms were significantly more abundant in coves treated with 50 $\mu g/1$N-25 $\mu g/1$ P than in those treated otherwise. This was due to the increased number of tendipes larvae, nearly five times greater here than in either the higher treatment or the controls. This magnitude of increase in tendipes is similar to Ball's (1949) findings in lakes in Michigan.

In treatment 50 $\mu g/1$ N - 25 $\mu g/1$ P (C-2 and B-2), a significant difference in numbers was found between the two coves but not for total organisms. Seventy-three percent of the tendipes larvae in this treatment were found in B-2. This will be discussed in detail in relation to basin morphology. The probable significance of rainfall is again borne out by the significant increase in numbers in July. Significant differences were found between sampling dates for numbers of

Table 6. GAME FISH CAPTURED BY ELECTROSHOCKING, BY SPECIES AND TYPE OF FERTILIZER TREATMENT

Species	May 18			June 1			June 15			June 28			July 13			July 26		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Largemouth bass	2	15	6	2	4	-	-	-	-	2	-	2	-	2	6	1	-	-
Smallmouth bass	3	5	1	-	3	1	1	-	-	-	2	3	-	-	-	-	-	2
Bluegill	7	20	4	6	5	3	-	1	-	13	3	10	-	-	2	1	-	2
Spotted bass	8	17	26	2	4	4	1	1	3	-	7	10	1	-	-	-	-	2
Rock bass	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Sauger	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White crappie	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White bass	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	24	59	39	10 (1)	16	8	2	2	4	15	12	25 (2)	1	2	8	2	-	6

Species	Aug. 10			Aug. 23			Sept. 7			Sept. 21			Oct. 5			Oct. 9		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Largemouth bass	2	-	-	6	16	7	9	9	8	-	3	3	2	1	-	-	-	-
Smallmouth bass	1	1	-	1	7	10	4	7	6	1	2	-	7	2	-	1	3	4
Bluegill	2	1	-	7	88	234	10	19	53	2	7	19	2	3	1	-	3	-
Spotted bass	1	-	3	9	22	21	8	11	13	7	1	2	4	1	1	-	-	-
Rock bass	-	-	-	-	-	-	1	-	4	-	-	-	1	-	-	-	-	-
Sauger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White crappie	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	6	2	3 (1)	23	133 (2)	272 (1)	32 (3)	46 (3)	84 (4)	10	13 (1)	24 (1)	16	7	2	1	6	4 (2)

Treatments: A=100 $\mu g/l$ N and 50 $\mu g/l$ P, B=50 $\mu g/l$ N and 25 $\mu g/l$ P, C=Control.
Numbers in parentheses indicate recaptures from previous markings.

Only 21 of the 919 marked game fish (2.28 percent return) were recaptured (Table 6). This indicates that the small game fish do not remain in the same shallow peripheral regions of the coves.

Table 7. TOTAL FISH TAKEN BY ELECTROSHOCKING

Date	Game fish			Rough fish			Forage fish		
	A	B	C	A	B	C	A	B	C
May 18	17	29	20	4	22	7	341	409	772
June 1	5	12	4	8	8	4	42	32	10
June 15	1	1	2	-	-	1	1	-	-
June 28	8	6	12	1	1	1	18	8	220
July 13	1	1	4	1	2	-	4	17	6
July 26	1	-	3	1	1	1	1	1	52
Aug. 10	3	1	1	-	-	-	1	1	8
Aug. 23	12	68	136	-	-	2	-	15	34
Sept. 7	18	24	40	2	2	1	8	12	38
Sept. 21	5	6	12	-	1	-	18	16	12
Oct. 5	8	2	2	-	-	-	12	5	18
Oct. 19	1	3	2	-	-	-	6	12	20
Total	80	153	238	17	37	17	446	528	1,190

Treatments: A = 100 $\mu g/l$ N and 50 $\mu g/l$ P, B = 50 $\mu g/l$ N and 25 $\mu g/l$ P, C = Control.
Each figure is the mean of two coves treated alike.

Hydrography

Biweekly temperature-oxygen profiles (Figures 4 to 6) show thermal stratification in all coves throughout June, July, August, and September. In each instance an established epilimnion, thermocline, and hypolimnion were evident. Generally, dissolved oxygen maxima occurred at depths of approximately 10 to 35 feet from June to early August. During April and late October, oxygen values corresponded closely to the temperature trends in that they were homogeneous from the surface to the bottom.

Average dissolved oxygen values varied from 1.0 to 9.0 ppm at the bottom of the coves during June, July, and August, depending on whether the water of the epilimnion reached the bottom. Values below 4.0 ppm were found only where water depth was 65 feet or more.

During June, July, and early August oxygen profiles in all coves showed a pronounced deviation. The dissolved oxygen maxima occurred at 10 to 35 feet, with averages of 8.0 ppm at 10 feet and 11.5 ppm at 20 feet. These findings differ from the temperature-oxygen profiles described by Wiebe (1939). In 1937-38 he found oxygen minima in Norris Reservoir at depths of 15 to 40 feet. High turbidity, caused by heavy rain, occurred at that time, and changes in reservoir operations since then have produced different flow patterns.

Data gathered by Taylor and Welch (1968) on primary productivity (C^{14} and chlorophyll methods in the test coves) show a sharp increase in chlorophyll at 15 to 30 feet, indicating an increase in phytoplankton. The cause of this increase is not known, but two hypotheses have been advanced: (1) negative phototaxis or light inhibition for the phytoplankters in the upper 10 of the water caused the marcroinvertebrates to be crowded into the lower reaches of the epilimnion; (2) organisms near the thermocline were receiving nutrients from the nutrient-rich upper hypolimnion. Disappearance of the oxygen maxima from all coves in mid-July may have been caused by rain and the associated increase in water mixing (Figures 4 to 6). These maxima reappeared in mid-August in coves C-1 and B-1 but disappeared again in late August. The possible effect of fertilizer on this increase in dissolved oxygen is indicated. Both coves were treated at the rate of 100 $\mu g/1$N-50 $\mu g/1$, and in both cases the oxygen maxima appeared approximately 2 weeks earlier than in the other coves (Figures 4 to 6).

Fall mixing began in September. Temperatures and dissolved oxygen levels were more homogeneous and there was a definite reduction in the amount of stratification.

Table 8. CHEMICAL ANALYSES OF SURFACE WATER IN COVES FERTILIZED WITH 100 μg/l N AND 50 μg/l P

	April		May			June		July		July 31 August 1	August		September		October	
	4-7	18-19	2-3	9-10	22-23	5-6	19-20	3	17-18		15	28-29	11-12	25-26	9-10	23-24
	ppm															
Cove Creek 1																
Carbonate	-	-	-	-	-	3.00	2.00	2.00	-	1.00	-	-	-	1.00	-	-
Bicarbonate	105.00	108.00	103.00	104.00	104.00	98.00	102.00	96.00	94.00	93.00	95.00	93.00	93.00	91.00	96.00	99.00
Sulfate	15.20	14.80	13.40	14.40	12.80	11.80	13.00	13.80	10.40	12.50	13.20	13.20	13.00	-	15.00	15.20
Chloride	2.50	2.00	2.50	2.50	3.00	3.00	2.00	2.00	2.50	2.00	2.00	2.00	2.50	2.00	2.00	2.00
Nitrate	1.50	1.50	1.40	1.60	1.00	1.20	0.40	0.90	0.60	0.10	0.20	0.30	0.60	0.20	0.50	0.70
Phosphate	-	-	0.10	-	-	-	-	-	-	-	-	-	-	-	-	-
Color	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.00	3.00	5.00	5.00	5.00	5.00	5.00
Turbidity	4.00	5.00	2.09	3.00	2.00	1.00	1.00	2.00	-	1.00	1.00	-	-	-	-	3.00
Specific conductance (Micromhos at 25°C)	220.00	200.00	200.00	203.00	205.00	198.00	193.00	195.00	187.00	180.00	180.00	180.00	182.00	178.00	178.00	185.00
Silica	4.10	3.10	2.00	1.90	2.50	2.60	2.20	1.90	1.50	1.50	1.40	1.30	1.10	1.10	1.00	1.30
Iron	0.01	0.01	-	0.01	-	-	-	-	-	0.01	-	-	-	-	-	-
Calcium	28.00	28.00	27.00	28.00	27.00	26.00	26.00	25.00	22.00	24.00	24.00	23.00	24.00	24.00	24.00	26.00
Magnesium	8.30	7.50	7.50	7.30	7.30	6.80	7.10	6.90	7.90	6.70	6.90	6.80	6.60	6.50	7.10	7.20
Sodium	2.50	2.40	2.50	2.50	2.20	2.10	2.00	1.90	1.90	2.20	2.20	2.30	2.30	2.30	2.40	2.40
Potassium	1.20	1.20	1.40	1.60	1.20	1.20	0.80	1.20	1.50	1.30	1.60	1.40	1.40	1.40	1.20	1.30
Dissolved solids upon evaporation	113.00	112.00	102.00	103.00	105.00	105.00	101.00	91.00	96.00	106.00	122.00	96.00	107.00	95.00	100.00	112.00
Hardness as $CaCO_3$	105.00	100.00	100.00	99.00	97.00	94.00	94.00	92.00	88.00	88.00	88.00	86.00	88.00	86.00	90.00	94.00
pH	8.20	8.20	8.00	7.70	7.70	8.50	8.40	8.50	7.60	8.30	8.20	8.20	8.10	8.30	7.80	7.80
Big Creek 1																
Carbonate	-	-	2.00	-	-	3.00	2.00	-	1.00	-	1.00	-	1.00	1.00	-	-
Bicarbonate	115.00	112.00	102.00	106.00	100.00	101.00	104.00	100.00	100.00	96.00	96.00	94.00	95.00	97.00	104.00	103.00
Sulfate	15.40	14.80	12.20	13.00	14.00	12.80	12.20	13.00	9.80	11.50	12.40	13.60	13.60	13.20	12.40	14.00
Chloride	2.50	3.00	2.50	2.00	3.00	3.00	2.50	2.00	2.00	2.00	2.00	2.00	2.00	1.50	2.00	2.50
Nitrate	2.00	1.10	1.20	1.40	1.20	1.00	0.50	0.90	0.70	0.10	0.20	0.40	-	-	0.40	0.40
Phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Color	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.00	2.00	5.00	5.00	5.00	5.00	5.00
Turbidity	5.00	5.00	4.00	1.00	3.00	2.00	1.00	1.00	2.00	1.00	1.00	-	-	-	2.00	1.00
Specific conductance (Micromhos at 25°C)	210.00	215.00	203.00	201.00	202.00	201.00	197.00	199.00	186.00	180.00	185.00	185.00	185.00	185.00	185.00	188.00
Silica	3.30	0.90	0.50	0.70	1.60	1.70	1.70	1.40	1.00	1.30	1.30	1.20	1.00	1.00	0.90	0.90
Iron	0.01	0.01	0.01	0.01	-	-	0.01	-	-	0.01	-	-	-	-	-	-
Calcium	29.00	28.00	27.00	28.00	27.00	26.00	26.00	25.00	22.00	24.00	24.00	24.00	24.00	25.00	25.00	26.00
Magnesium	8.30	8.00	7.80	7.10	7.80	7.80	7.20	7.30	8.30	6.90	7.10	6.90	7.40	6.90	7.80	7.70
Sodium	2.50	2.40	2.30	2.30	2.20	2.20	2.00	1.90	1.70	2.00	2.20	2.30	2.30	2.30	2.40	2.40
Potassium	1.20	1.20	1.40	1.60	1.20	1.20	1.20	1.20	1.30	1.60	1.60	1.20	1.40	1.40	1.30	1.30
Dissolved solids upon evaporation	116.00	113.00	102.00	99.00	102.00	101.00	98.00	109.00	94.00	106.00	115.00	91.00	94.00	98.00	101.00	103.00
Hardness as $CaCO_3$	107.00	104.00	100.00	100.00	98.00	96.00	95.00	94.00	90.00	88.00	90.00	89.00	90.00	90.00	95.00	96.00
pH	8.10	8.20	8.40	7.90	8.10	8.50	8.40	8.20	8.00	8.10	8.40	8.20	8.40	8.40	7.80	7.80

Amounts of bicarbonate, silica, magnesium, and calcium were significantly different in the two creeks (Tables 9 to 11). Sampling data were significant for color and all mineral ions except phosphate, potassium, and sodium. Nitrate was the only ion affected significantly by fertilizer treatment. The amount of nitrate was always higher in treated coves than in control coves. Regardless of the differences between test areas, dates, treatments, etc., none of the parameters seem to be limiting acording to the literature (Lund, 1966). The zero ppm values for phosphate are probably not valid. No phosphate preservative was added to the samples in the field to counteract the slow phosphate uptake by chemical and biological reactions when stored for future analysis. We later learned that samples were stored for a considerable period (1 to 8 weeks) before being analyzed, and under such conditions a preservative is required.

Table 9. CHEMICAL ANALYSES OF SURFACE WATER IN COVES FERTILIZED WITH 50 μg/l N AND 25 μg/l P

	April		May			June		July		July 31 August 1	August		September		October	
	4-7	18-19	2-3	9-10	22-23	5-6	19-20	3	17-18		15	28-29	11-12	25-26	9-10	23-24
	ppm															
Cove Creek 2																
Carbonate	-	-	-	-	-	4.00	2.00	2.00	-	-	-	-	1.00	1.00	-	-
Bicarbonate	101.00	101.00	101.00	100.00	102.00	97.00	99.00	94.00	92.00	92.00	94.00	90.00	91.00	90.00	90.00	91.00
Sulfate	16.20	16.20	14.00	15.00	13.20	12.20	14.20	13.40	11.60	13.60	13.20	13.40	13.20	13.00	17.00	14.80
Chloride	2.00	2.00	2.50	2.00	3.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.50	2.00
Nitrate	1.60	1.50	1.20	1.40	1.20	1.10	0.40	0.90	0.60	-	-	0.30	0.30	0.10	0.10	0.40
Phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Color	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	3.00	5.00	5.00	5.00	5.00	5.00
Turbidity	4.00	4.00	-	2.00	1.00	2.00	1.00	2.00	-	1.00	1.00	-	-	-	1.00	3.00
Specific conductance (Micromhos at 25°C)	210.00	200.00	200.00	201.00	203.00	198.00	191.00	192.00	186.00	180.00	178.00	180.00	178.00	175.00	172.00	175.00
Silica	3.90	3.10	1.60	2.30	2.60	2.30	1.80	1.70	1.60	1.40	1.60	1.50	1.30	1.30	1.00	1.20
Iron	0.01	0.01	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-
Calcium	27.00	27.00	27.00	27.00	26.00	26.00	26.00	26.00	23.00	24.00	23.00	22.00	23.00	23.00	23.00	24.00
Magnesium	7.50	7.30	7.40	6.90	7.40	7.30	7.20	6.60	7.30	6.60	7.10	7.20	6.80	6.80	6.80	6.30
Sodium	2.40	2.30	2.50	2.30	2.20	2.20	2.20	2.20	1.70	2.30	2.20	2.30	2.20	1.40	2.30	2.40
Potassium	1.20	1.20	1.60	1.40	1.20	1.20	1.20	1.30	1.30	1.20	1.60	1.40	1.40	-	1.20	1.30
Dissolved solids upon evaporation	108.00	106.00	108.00	108.00	103.00	104.00	100.00	98.00	92.00	105.00	106.00	90.00	105.00	83.00	96.00	109.00
Hardness as $CaCO_3$	98.00	96.00	98.00	96.00	97.00	94.00	94.00	92.00	87.00	87.00	86.00	85.00	85.00	85.00	86.00	87.00
pH	8.10	8.20	7.80	8.00	8.00	8.50	8.50	8.40	8.00	8.20	8.20	8.10	8.40	8.40	7.80	7.80
Big Creek 2																
Carbonate	-	-	-	-	-	3.00	-	-	2.00	-	2.00	-	-	1.00	-	-
Bicarbonate	115.00	110.00	105.00	104.00	101.00	101.00	100.00	100.00	100.00	94.00	97.00	95.00	96.00	97.00	102.00	103.00
Sulfate	15.20	15.40	13.60	13.40	14.00	12.80	13.20	12.80	8.60	11.70	11.60	14.80	12.00	13.00	14.60	15.00
Chloride	2.50	3.00	2.00	2.00	3.00	3.00	2.00	2.00	2.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Nitrate	1.90	1.20	1.40	1.40	1.30	1.00	0.30	0.80	0.60	-	-	0.30	0.30	0.10	0.40	0.20
Phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Color	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.00	2.00	5.00	5.00	5.00	5.00	5.00
Turbidity	6.00	4.00	3.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	-	-	-	2.00	2.00
Specific conductance (Micromhos at 25°C)	220.00	210.00	202.00	204.00	205.00	201.00	195.00	199.00	187.00	180.00	182.00	185.00	185.00	185.00	185.00	188.00
Silica	3.80	0.80	0.80	1.00	1.50	1.80	1.70	1.50	1.70	1.40	1.30	1.30	1.10	1.00	1.20	1.00
Iron	0.01	0.01	-	0.01	-	0.01	-	-	-	-	-	-	-	-	-	-
Calcium	29.00	28.00	27.00	27.00	27.00	26.00	27.00	26.00	24.00	24.00	24.00	24.00	23.00	24.00	25.00	25.00
Magnesium	8.30	8.00	8.20	7.50	7.80	7.30	7.20	7.20	7.30	7.30	7.20	7.50	7.50	7.00	7.80	8.00
Sodium	2.50	2.40	2.30	2.30	2.30	2.20	2.20	2.20	1.80	2.20	2.20	2.30	2.30	2.30	2.40	2.40
Potassium	1.20	1.20	1.40	1.60	1.30	1.30	1.20	1.30	1.30	1.30	1.60	1.20	1.40	1.20	1.30	1.30
Dissolved solids upon evaporation	114.00	111.00	101.00	98.00	105.00	106.00	95.00	105.00	95.00	108.00	115.00	91.00	90.00	102.00	105.00	112.00
Hardness as $CaCO_3$	107.00	102.00	100.00	100.00	98.00	96.00	96.00	94.00	90.00	89.00	90.00	90.00	90.00	90.00	95.00	96.00
pH	8.10	8.20	8.20	8.10	7.80	8.50	8.00	8.30	8.10	8.20	8.40	8.20	8.20	8.40	7.80	7.80

Table 10. CHEMICAL ANALYSES OF SURFACE WATER IN CONTROL COVES

	April		May			June		July		July 31 August 1	August		September		October	
	4-7	18-19	2-3	9-10	22-23	5-6	19-20	3	17-18		15	28-29	11-12	25-26	9-10	23-24
	ppm															
Cove Creek 3																
Carbonate	-	-	-	-	-	2.00	-	2.00	-	-	2.00	-	2.00	2.00	-	-
Bicarbonate	98.00	97.00	99.00	102.00	96.00	99.00	101.00	93.00	96.00	89.00	88.00	88.00	88.00	87.00	91.00	92.00
Sulfate	16.20	16.20	14.80	14.00	14.00	13.20	14.60	13.80	8.40	13.60	14.80	13.40	14.00	13.60	14.40	14.80
Chloride	2.00	2.00	2.50	2.00	3.00	3.00	2.50	2.00	2.00	2.00	1.50	2.00	1.50	2.00	2.00	2.00
Nitrate	1.50	1.40	1.40	1.40	1.10	1.10	0.40	0.80	0.50	-	-	0.20	0.40	0.10	0.20	0.30
Phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Color	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	3.00	5.00	5.00	5.00	5.00	5.00
Turbidity	12.00	5.00	7.00	2.00	2.00	1.00	1.00	2.00	-	1.00	1.00	-	-	-	1.00	1.00
Specific conductance (Micromhos at 25°C)	200.00	200.00	201.00	202.00	201.00	198.00	190.00	194.00	185.00	180.00	175.00	176.00	175.00	175.00	172.00	175.00
Silica	3.50	2.90	2.20	2.10	2.70	1.90	1.50	1.30	1.90	1.60	1.70	1.40	1.40	1.30	1.00	1.20
Iron	0.01	0.01	0.01	-	-	-	0.01	-	-	0.02	-	-	-	-	-	-
Calcium	25.00	25.00	27.00	26.00	26.00	26.00	26.00	25.00	23.00	23.00	23.00	23.00	23.00	23.00	25.00	25.00
Magnesium	7.40	7.20	6.90	7.30	7.20	6.70	6.80	6.70	7.20	6.70	7.10	6.60	6.60	6.60	5.80	6.30
Sodium	2.30	2.30	2.30	2.50	2.20	2.20	2.20	2.20	1.80	2.00	2.20	2.30	2.20	2.30	2.30	2.40
Potassium	1.20	1.20	1.40	1.40	1.20	1.20	1.30	1.20	1.00	1.30	1.60	1.40	1.40	1.40	1.20	1.30
Dissolved solids upon evaporation	117.00	106.00	110.00	108.00	99.00	100.00	94.00	101.00	91.00	103.00	104.00	93.00	98.00	90.00	100.00	104.00
Hardness as $CaCO_3$	94.00	92.00	100.00	96.00	94.00	92.00	93.00	90.00	86.00	86.00	86.00	84.00	84.00	84.00	86.00	92.00
pH	8.00	8.20	7.80	8.10	8.00	8.40	8.10	8.50	8.20	8.20	8.40	8.00	8.40	8.40	7.80	7.80
Big Creek 3																
Carbonate	-	-	-	-	-	2.00	2.00	2.00	3.00	2.00	3.00	-	1.00	1.00	-	-
Bicarbonate	113.00	110.00	104.00	107.00	104.00	102.00	102.00	99.00	97.00	92.00	97.00	94.00	97.00	98.00	104.00	102.00
Sulfate	17.00	15.00	14.20	14.60	15.20	12.20	13.80	13.00	8.80	12.10	11.80	12.80	13.00	-	13.40	15.00
Chloride	2.50	2.50	2.50	2.50	3.00	3.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.50
Nitrate	1.80	1.00	1.20	1.20	1.00	1.20	0.40	0.90	0.60	-	-	-	0.10	0.10	0.20	0.50
Phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Color	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.00	2.00	5.00	5.00	5.00	5.00	5.00
Turbidity	3.00	5.00	2.00	2.00	2.00	1.00	1.00	1.00	-	1.00	1.00	-	-	-	4.00	3.00
Specific conductance (Micromhos at 25°C)	210.00	215.00	203.00	203.00	201.00	200.00	195.00	199.00	188.00	180.00	182.00	185.00	185.00	185.00	185.00	188.00
Silica	3.30	0.80	0.80	0.80	1.40	1.70	1.50	1.40	1.30	1.30	1.30	1.10	1.10	1.00	1.00	0.90
Iron	0.01	0.01	-	-	0.01	0.01	-	-	-	-	-	-	-	-	-	-
Calcium	29.00	28.00	28.00	28.00	28.00	26.00	26.00	25.00	23.00	24.00	24.00	24.00	23.00	25.00	25.00	26.00
Magnesium	8.20	8.00	7.70	7.20	7.90	7.30	7.30	7.50	7.80	7.30	7.20	6.80	7.80	7.20	7.90	7.50
Sodium	2.50	2.40	2.50	2.30	2.20	2.20	2.20	1.90	1.80	2.00	2.20	2.30	2.30	2.30	2.40	2.40
Potassium	1.20	1.20	1.40	1.40	1.30	1.30	0.80	1.30	1.30	1.20	1.60	1.40	1.40	1.40	1.30	1.20
Dissolved solids upon evaporation	113.00	118.00	113.00	94.00	106.00	104.00	100.00	106.00	90.00	103.00	114.00	104.00	98.00	101.00	103.00	111.00
Hardness as $CaCO_3$	107.00	102.00	101.00	100.00	101.00	96.00	96.00	94.00	90.00	89.00	90.00	88.00	90.00	91.00	95.00	95.00
pH	8.20	8.20	8.10	8.20	8.10	8.50	8.50	8.50	8.20	8.50	8.50	8.10	8.30	8.10	7.80	7.80

On September 18, fluorescent dye was mixed with the fertilizer in an attempt to determine the pattern of distribution. Several papers (Hepher, 1958; Reich, 1950; Fisher and Rashkes, 1951; Nisbet, 1951; Zeller, 1952) confirmed our finding that much of the fertilizer sank to the bottom within a few hours and that what was left in the water column was concentrated and moved about by the wind. This is also supported by bottom soil analyses (Table 11) before and after the experiment. Orientation of coves to wind direction and reservoir current relationships were not adequately considered when the test coves were selected. The amount of fertilizer that may have been sluiced out of the coves by wind and reservoir currents is unknown. Basin morphology of both creeks seems to indicate that C-2 and B-2 have the oldest or most stagnant water. The heavy growth of Bryozoa in B-2 from June to September strongly suggests this since Bryozoans favor habitats with little or no water movement (Pennak, 1953).

Table 11. BOTTOM SOIL ANALYSIS OF SIX COVES BEFORE AND AFTER FERTILIZATION

Item	C-1	C-2	C-3	B-1	B-2	B-3
P (ppm) Before	2	2	2	2	2	2
P After - Extractable	183	330	230	170	225	183
Organic	68	107	-	20	64	34
Total N (%) After	.08	.08	.07	.09	.13	.09

CONCLUSIONS

Increasing sport fishing in selected coves of a deep reservoir through application of inorganic fertilizer during one growing season does not appear to be practical. The fertilizer produced little lasting increase in nutrients in the water of the coves. Most of it presumably sank into the mud or was sluiced out of the coves.

Fertilization increased the numbers of bottom organisms and zooplankton, but there was no significant change in numbers, size, species composition, or survival of fish. Temperature and oxygen profiles, coupled with the physcial characteristics (directional axis of coves in relation to main creek and cove depth and length) suggest that the age of the water may be very significant in increasing production in coves.

The exact effect of fertilizer still remains unknown since the amount of fertilizer loss to sinking and sluicing could not be measured. But one thing seems clear: the measured increase in production was due to only a small fraction of the total application.

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