# SOME PHYSICO-CHEMICAL AND BIOLOGICAL ASPECTS OF THREE COLD TAILWATERS IN NORTHERN ARKANSAS [1]

JAMES D. BROWN,[2] CHARLES R. LISTON,[3] AND RONALD W. DENNIE [4]
*Department of Zoology, University of Arkansas*
Fayetteville, Arkansas
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## ABSTRACT

Physico-chemical factors, plankton, benthic macroinvertebrates, and fishes occurring in cold tailwaters below Beaver, Bull Shoals, and Norfork dams in northern Arkansas, were sampled regularly from July, 1965, through December, 1966.

Physico-chemical conditions were similar in the three tailwaters throughout the study. The older tailwaters below Bull Shoals and Norfork dams were more productive than the Beaver tailwater in both phytoplankton and zooplankton. The greatest number of genera of plankton occurred in the Beaver tailwater, and the Bull Shoals tailwater had the least number.

The majority of the benthic macroinvertebrates was comprised of only a few taxa. Samples from the Norfork tailwater contained more organisms and a higher average wet weight per square foot than did samples from the other two localities. Tendipedidae and Oligochaeta made up 91.0% of the total number of benthic macroinvertebrates in the Beaver tailwater; Tendipedidae and Amphipoda comprised 70.1% in the Bull Shoals tailwater. Isopoda and Tendipedidae accounted for 87.9% in the Norfork tailwater.

Lists of fishes for the three tailwaters include 38 species. Five of these (*Campostoma anomalum, Notropis galacturus, Notropis pilsbryi, Etheostoma caeruleum,* and *Cottus carolinae*) were common to all three tailwaters. Cyprinids and sculpins were abundant below Bull Shoals and Norfork dams. The ichthyofauna below Beaver Dam exhibited a scarcity of cyprinids, with the exception of *Campostoma anomalum,* and an abundance of darters. Sculpins were rare below Beaver Dam.

## INTRODUCTION

In many areas of the United States, natural free-flowing streams have been impounded for the purposes of flood control, hydroelectric power production, and recreation. The impoundment of a stream drastically alters the ecological conditions. The upper White River system, located in northern Arkansas and southern Missouri, has been impounded at several locations changing this natural stream habitat into a series of reservoirs with cold tailwaters.

Investigations in Arkansas showed that native warm-water fisheries were destroyed for many miles below these reservoirs. A trout stocking program initiated below Norfork and Bull Shoals dams produced such excellent fishing that the area became nationally famous within a short time (Baker, 1959). The Norfork Trout Hatchery, located near Norfork Dam, was constructed for the purpose of providing trout for White River tailwaters. At the present, trout have not been stocked below Beaver Dam; but there is considerable local interest in establishing a trout fishery in this tailwater.

All factors in food chains contributing to the production of fish in streams must be understood in order that proper management practices can be applied. This investigation was concerned with the following

[1] Financial support for this investigation was provided by the Water Resources Research Center at the University of Arkansas.
[2] Present Address: Department of Zoology, University of Florida, Gainesville, Florida.
[3] Present Address: Department of Biology, University of Louisville, Louisville, Kentucky.
[4] Present Address: School of Medicine, University of Arkansas, Little Rock, Arkansas.

links in such food chains in cold tailwaters below Beaver, Bull Shoals, and Norfork dams: physico-chemical factors, plankton, benthic macroinvertebrates, and fishes.

## DESCRIPTION OF STUDY AREAS

All stream sections studied lie in the Ozark Plateau. The most abundant rocks in this region are limestone, dolomite, sandstone, and shale with the first two predominating (Branner, 1927). River basins are narrow, steep-sided, and meandering. Stream beds consist primarily of bedrock, boulders, rubble, and gravel with sand and silt occurring in areas of slight current. The riffle-pool association is prevalent.

The upper White River system was originally composed of clear, spring-fed streams that were subject to extreme seasonal variation in temperature and flow. It presently bears little resemblance to its original condition as a result of five impoundments (Figure 1). Beaver Dam, located in Carroll County, Arkansas, is the uppermost and most recent dam on the White River. It was completed in 1963. Its efferent flow enters Table Rock Reservoir less than four miles below the dam. Table Rock and Taneycomo dams are located in Missouri. Bull Shoals and Norfork dams are located in Baxter County, Arkansas. Bull Shoals Dam, completed in 1951, is the lowermost dam on the White River. Norfork Dam, completed in 1944, is located on the North Fork of the White River about 4.5 miles above its confluence with the White River.

Bull Shoals Dam, the largest dam on the White River system, has eight hydroelectric units and is 258 feet high. Minimum and maximum discharges are 50 cfs and 20,000 cfs. Beaver and Norfork Dams have two hydroelectric units each. Beaver Dam is 228 feet high, and minimum and maximum discharges are 60 cfs and 6,000 cfs. The 222-foot high Norfork Dam has a minimum discharge of 20 cfs and a maximum of 5,000 cfs.

## MATERIALS AND METHODS

Established stations, shown in Figure 1, were sampled regularly for a period of several months in 1965 and 1966. Stations $B_1$, $B_2$, and $B_3$ were 0.25, 1.9, and 3.5 miles, respectively, below Beaver Dam. Station $B_t$ marked the headwaters of Table Rock Reservoir at high water levels. Stations $BS_1$ and $BS_2$ were located 0.75 and 20.0 miles, respectively, below Bull Shoals Dam, and stations $N_1$ and $N_2$ were 0.25 and 3.5 miles, respectively, below Norfork Dam.

Physico-chemical, plankton, and benthic macroinvertebrate samples were taken weekly, when feasible, in the tailwater below Beaver Dam from July, 1965, through December, 1966; and similar collections were made monthly in tailwaters below Bull Shoals and Norfork dams from September, 1965, through November, 1966. Standardized fish collections were made monthly in all three tailwaters from October, 1965, through November, 1966.

Free carbon dioxide, dissolved oxygen, and hydrogen ion determinations were made in the field. Free carbon dioxide and methyl orange alkalinity analyses followed methods described in APHA, AWWA, and WPCF (1960). A Hach field version of the Winkler method was used for dissolved oxygen analyses. Hydrogen ion concentrations were determined with a Hellige color comparator. Ortho- and meta-phosphate, nitrate-nitrogen, and silica determinations were made in the laboratory with Hach field kits.

Plankton samples were taken in riffles with a standard cone-shaped number 25 silk bolting cloth plankton net. These were obtained by concentrating 20 liters of water to 20 milliliters. Two direct counts were made from each sample with a Sedgewick-Rafter counting cell. When a single genus exceeded 2,000 cells per liter, the random counting technique of Serfling (1949) was employed.

Benthic macroinvertebrates were collected in riffles using a Surber square foot sampler as described by Lagler (1956). The samples were sorted and counted in the laboratory and wet weights were determined.

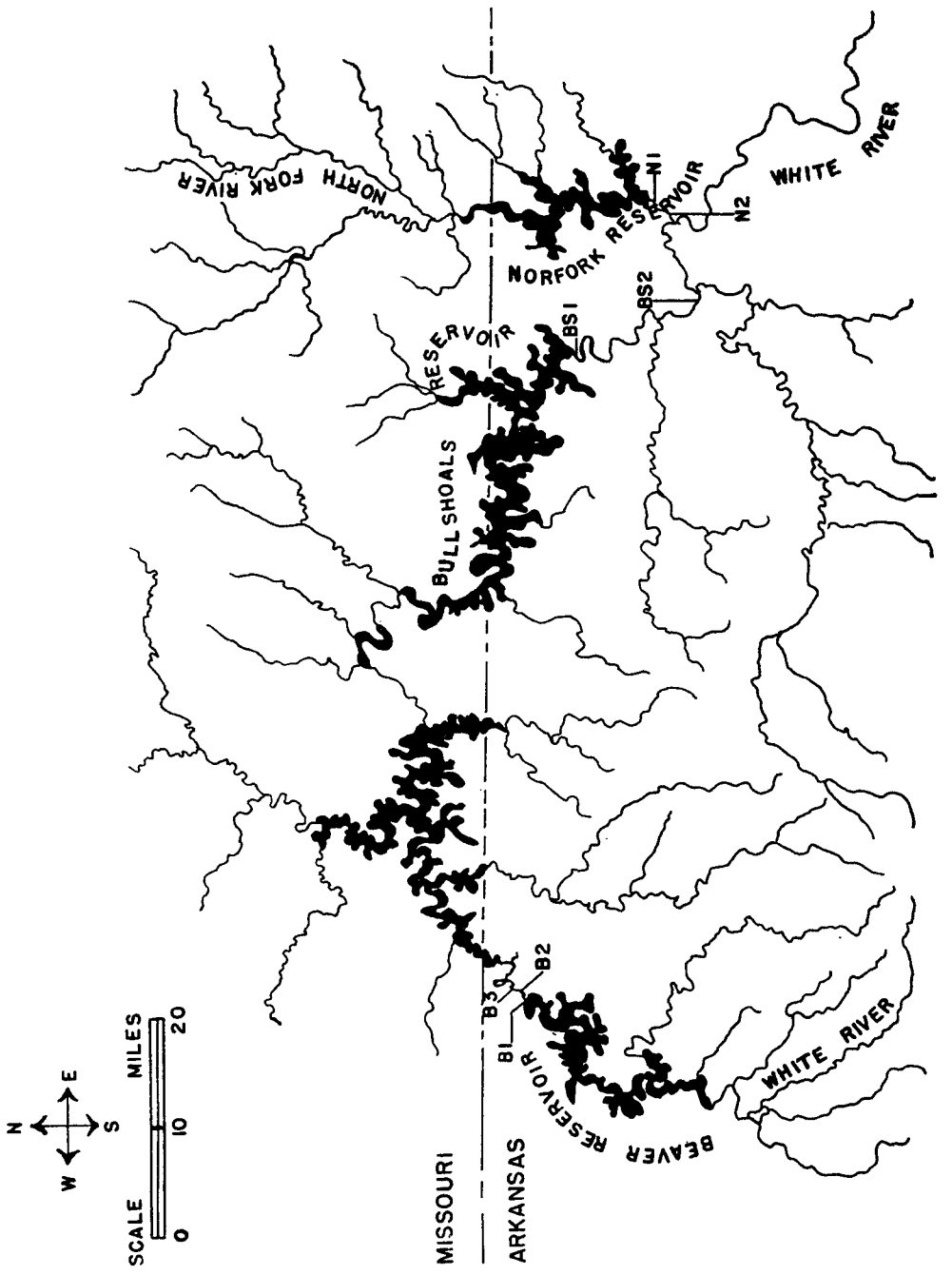


Figure 1. — Map of the upper White River system showing collecting stations below Beaver, Bull Shoals, and Norfork dams.

Fishes were collected by two methods. Pools were seined with a 6 x 20-foot straight seine with one-eighth square inch mest. A variation of the electroseining procedure was used to collect in riffles. Two crew members, using the 20-foot seine, blocked the lower end of the riffle being sampled while two other members worked electrodes back and forth across the upper part of the riffle. A gasoline-powered generator with 115 volt, 1,000 watt capacity supplied electrical power. Stunned fish were washed into the seine by the current and were removed after cessation of the electrical current. Each collection was separated, and the various species identified, counted, and recorded. The nomenclature used followed that recommended by the American Fisheries Society (1960) with certain modifications. All specimens collected were placed in the Tulane University Museum.

## PHYSICO-CHEMICAL FACTORS

Averages and ranges of physico-chemical data are presented in Table I. One of the more striking differences between a cold tailwater and a natural free-flowing stream is temperature. Generally, cold tailwaters exhibit much less seasonal variation than do natural streams. The tailwater below Beaver Dam is colder than those below Norfork and Bull Shoals dams. The power outlets are deeper in Beaver Dam than in the other dams which may account for these lower temperatures. In accordance with mean yearly atmospheric temperature, the temperatures of the three tailwaters increases as the water moves downstream.

Average amounts of dissolved oxygen increased slightly downstream from the dams. Summers (1954) concluded that dissolved oxygen would be a limiting factor in the Illinois River below Tenkiller Dam in summer months. Moffett (1942) found that dissolved oxygen was abundant at all times in a study of the Colorado River below Boulder Dam. Throughout the course of this investigation, dissolved oxygen was always abundant. Current tends to keep carbon dioxide from accumulating (Welch, 1952); consequently, free carbon dioxide decreased as the water moved downstream, and pH increased slightly. Methyl orange alkalinity varied widely directly below the dams. Methyl orange alkalinity values in the Beaver tailwater were lower than values reported by Horn and Garner (1965) in a pre-impoundment study of Beaver Reservoir. Silica was relatively constant below all three dams, but slight increases occurred at downstream stations. The average nitrate-nitrogen values were highest immediately below Beaver Dam; this area also exhibited the greatest variation. While Beaver Reservoir was filling, organic matter was abundant (Applegate and Mullan, 1967). The high nitrate-nitrogen values obtained in the Beaver tailwater can be attributed to decomposition of this organic matter. Average ortho- and metaphosphate values did not appear to differ significantly among the tailwaters studied.

## PLANKTON

The average numbers of cells and organisms per liter and percentages of net phytoplankton and zooplankton are presented in Table II. The tailwaters below Bull Shoals and Norfork dams were more productive than the tailwater below Beaver Dam in phytoplankton and zooplankton.

A total of 91 genera of phytoplankton occurred in all three tailwaters. The tailwater below Beaver Dam exhibited the largest number of genera (82), and the Bull Shoals tailwater had the least number (68). A total of 75 genera occurred in collections made below Norfork Dam. Phytoplankton comprised 99.9% of the net plankton collection in the Bull Shoals and Norfork tailwaters and 99.8% in the Beaver tailwater. The numerically dominant phylum in the Bull Shoals and Norfork tailwaters was Chrysophyta; Cyanophyta was dominant in the Beaver tailwater. Diatoms comprised the majority of Chrysophyta in all tailwaters. Abundant genera of diatoms included *Achnanthes*, *Asterionella*, *Fragilaria*, and *Melosira*. *Lyngbya*, *Oscillatoria*, and *Phormidium* were the predominant genera of Cyanophyta. Green algae were most abundant in the Beaver tailwater and least abundant in the Nor-

Table 1. Averages and Ranges of Physico-Chemical Data

| Tailwater | Station | $CO_2$ (ppm) Avg. | $CO_2$ (ppm) Range | D.O. (ppm) Avg. | D.O. (ppm) Range | pH Avg. | pH Range | M.O. Alk. (ppm) Avg. | M.O. Alk. (ppm) Range | Water Temp. (°C.) Avg. | Water Temp. (°C.) Range |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Beaver | $B_1$ | 2.2 | 1.0-4.0 | 9.0 | 4.0-14.0 | 7.2 | 6.9-7.8 | 84.1 | 73.2-103.0 | 8.2 | 6.2-10.0 |
| | $B_2$ | 2.0 | 0.0-4.0 | 9.0 | 4.5-13.0 | 7.3 | 6.9-8.2 | 87.3 | 68.9-109.2 | 9.8 | 5.1-16.2 |
| | $B_3$ | 1.7 | 0.0-3.0 | 9.5 | 4.5-13.0 | 7.4 | 6.9-8.5 | 99.0 | 76.8-171.6 | 11.2 | 4.2-23.0 |
| Norfork | $N_1$ | 2.4 | 0.0-6.0 | 8.3 | 4.0-13.0 | 7.4 | 7.2-8.1 | 178.6 | 147.5-205.0 | 11.1 | 6.1-15.4 |
| | $N_2$ | 1.0 | 0.0-2.5 | 12.0 | 9.0-17.0 | 8.0 | 7.3-8.4 | 193.7 | 182.4-204.0 | 13.0 | 8.0-16.5 |
| Bull Shoals | $BS_1$ | 1.4 | 0.0-3.5 | 9.9 | 7.0-13.5 | 7.6 | 7.3-8.4 | 149.6 | 127.2-160.8 | 10.6 | 7.1-15.4 |
| | $BS_2$ | 1.1 | 0.0-2.5 | 10.8 | 9.0-13.0 | 7.7 | 7.3-8.2 | 155.8 | 140.5-167.2 | 12.5 | 5.7-17.3 |



| Tailwater | Station | Silica (ppm) Avg. | Silica (ppm) Range | Nitrate (ppm) Avg. | Nitrate (ppm) Range | Ortho-phos. (ppm) Avg. | Ortho-phos. (ppm) Range | Meta-phos. (ppm) Avg. | Meta-phos. (ppm) Range |
|---|---|---|---|---|---|---|---|---|---|
| Beaver | $B_1$ | 2.2 | 1.1-2.8 | 0.24 | 0.00-2.00 | 0.08 | 0.00-0.25 | 0.25 | 0.05-0.50 |
| | $B_2$ | 2.2 | 1.0-3.2 | 0.17 | 0.00-0.90 | 0.08 | 0.00-0.20 | 0.28 | 0.05-0.65 |
| | $B_3$ | 2.4 | 1.8-3.5 | 0.18 | 0.00-0.80 | 0.08 | 0.00-0.20 | 0.26 | 0.05-0.45 |
| Norfork | $N_1$ | 3.0 | 1.3-4.5 | 0.20 | 0.00-0.60 | 0.08 | 0.05-0.15 | 0.29 | 0.10-0.45 |
| | $N_2$ | 3.1 | 1.5-4.2 | 0.21 | 0.00-0.50 | 0.07 | 0.05-0.10 | 0.35 | 0.20-0.50 |
| Bull Shoals | $BS_1$ | 2.2 | 1.2-3.2 | 0.14 | 0.00-0.45 | 0.06 | 0.05-0.15 | 0.23 | 0.15-0.45 |
| | $BS_2$ | 2.3 | 1.3-3.3 | 0.13 | 0.00-0.40 | 0.08 | 0.05-0.15 | 0.22 | 0.10-0.45 |

Table 11. Average Standing Crops and Percentages of Net Phytoplankton and Zooplankton at Selected Stations

| Taxon | $BS_1$ | | $N_1$ | | $B_1$ | | $B_2$ | | $B_3$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. Per Liter | % | No. Per Liter | % | No. Per Liter | % | No. Per Liter | % | No. Per Liter | % |
| **Phytoplankton (cells per liter)** | | | | | | | | | | |
| Chlorophyta | 1,210 | 8 | 705 | 5 | 3,057 | 37 | 526 | 15 | 480 | 9 |
| Euglenophyta | 1 | T[1] | 13 | T | P[2] | T | P | T | P | T |
| Chrysophyta | 11,206 | 78 | 11,010 | 75 | 2,146 | 26 | 712 | 20 | 682 | 13 |
| Pyrrophyta | 2 | T | 12 | T | 2 | T | 1 | T | 2 | T |
| Cyanophyta | 1,706 | 12 | 3,004 | 20 | 3,063 | 37 | 2,282 | 64 | 3,914 | 77 |
| Rhodophyta | 202 | T | 29 | T | 61 | 1 | 25 | 1 | 22 | T |
| Totals | 14,327 | 98 | 14,773 | 100 | 8,329 | 101 | 3,546 | 100 | 5,100 | 99 |
| **Zooplankton (organisms per liter)** | | | | | | | | | | |
| Protozoa | 1.5 | 10 | 1.5 | 8 | 3.0 | 23 | 1.7 | 19 | 1.8 | 17 |
| Rotifera | 6.8 | 46 | 7.8 | 42 | 5.1 | 40 | 3.9 | 43 | 5.5 | 50 |
| Cladocera | 1.8 | 12 | 2.8 | 15 | 1.8 | 14 | 1.3 | 14 | 1.1 | 10 |
| Copepoda | 4.7 | 32 | 6.3 | 34 | 3.0 | 23 | 2.1 | 23 | 2.5 | 23 |
| Totals | 14.8 | 100 | 18.4 | 99 | 12.9 | 100 | 9.0 | 99 | 10.9 | 100 |

[1] T = less than 1%.

[2] P = less than one per liter.

fork tailwater. Oganisms with holdfast organelles constituted the majority of green algae collected. Euglenophyta, Pyrrophyta, and Rhodophyta were scarce in all three tailwaters.

Thirty-nine genera of zooplankton were identified from the three tailwaters. In addition, nauplii and rotifers of the order Digononta occurred in all tailwaters. As with the phytoplankton, the Beaver tailwater had the largest number of genera (36) and the Bull Shoals tailwater the least number (25). Twenty-seven genera were taken below Norfork Dam. Rotifers were the most abundant group of zooplankton in the three tailwaters. *Keratella* was the predominant rotifer and the most commonly observed metazoan in all localities. Copepods were more abundant below Bull Shoals and Norfork dams than below Beaver Dam. Nauplii were the most commonly taken copepods. Protozoans were the least abundant group in the Bull Shoals and Norfork tailwaters; whereas cladocerans were the least abundant group below Beaver Dam. *Difflugia* was the most abundant protozoan, and *Bosmina* and *Daphnia* were the most abundant cladocerans.

A river plankton community is augmented by lake plankton just below the outlet of an impoundment, but these lake plankton soon decrease under river conditions (Chandler, 1937). The phytoplankton below Beaver Dam exhibited a 67% decrease in the average number of

cells per liter from station B1 to B2 and a 38% decrease from station B1 to B3. A 30% increase occurred from station B2 to B3. Blue-green algae were primarily responsible for the increase from station B2 to B3. The zooplankton exhibited similar results.

Seasonal cycles of abundance of both phytoplankton and zooplankton varied considerably among the tailwaters studied. The maximum average number of cells of phytoplankton per liter in the Beaver tailwater appeared in summer, 1965, and the minimum in summer, 1966. The maximum in the Bull Shoals and Norfork tailwaters occurred in the winter and spring of 1966, and the minimum occurred in summer, 1966.

The average number of zooplankton per liter in the Beaver tailwater reached a maximum in winter, 1966, and a minimum in summer, 1965. The maximum in the Bull Shoals and Norfork tailwaters appeared in the winter and spring of 1966.

Many factors influence the seasonal abundance of plankton below dams, but the nature of the reservoir plankton and the amount of water discharge are two of the most obvious. In general, zooplankton were more abundant during periods of daily generation, and phytoplankton were more abundant during periods of irregular or no generation. Summer, 1965, when zooplankton were least abundant and phytoplankton most abundant in the Beaver tailwater, was a period of minimal discharge. Blue-green and green algae comprised the majority of phytoplankton present at this time. Power was generated daily at Beaver Dam in the summer and fall of 1966, and phytoplankton density declined. In contrast to this, the maximum for phytoplankton in the Bull Shoals and Norfork tailwaters corresponded with a period of unusually high discharge (winter and spring, 1966). Generation frequently took place on a 24-hour basis during this time; consequently, many collections made in winter and spring were taken during high-water conditions. Phytoplankton were generally more abundant in samples taken during highwater conditions than in those taken during low-water conditions. Collections usually were not made during high-water conditions except in the Bull Shoals and Norfork tailwaters in the winter and spring of 1966. The maximum of zooplankton in the Bull Shoals and Norfork tailwaters corresponded with this period of frequent discharge.

## BENTHIC MACROINVERTEBRATES

The abundant taxa of benthic macroinvertebrates and their percentage compositions are shown in Figure 2. The group designated as "other" includes taxa that appeared irregularly throughout the samples.

The Beaver tailwater yielded four dominant groups. These were as follows: Tendipedidae (50.2%), Oligochaeta (40.8%), Isopoda (3.6%), and Turbellaria (1.3%). The three stations studied in the Beaver tailwater differed in both number of organisms and wet weight per sample, but dominant groups were similar. Some seasonal differences were apparent since more organisms were collected in the months of October, 1965, May, 1966, and August, 1966.

Amphipoda (37.6%), Tendipedidae (33.1%), Isopoda (13.6%), and Oligochaeta (11%) were the abundant groups in the Bull Shoals tailwater. Consistently higher numbers of organisms were collected directly below Bull Shoals Dam (station $BS_1$) than at station $BS_2$ located twenty miles downstream from the dam.

Four dominant groups were collected in the Norfork tailwater. These were as follows: Isopoda (57.8%), Tendipedidae (30.1%), Oligochaeta (5.2%), and Turbellaria (2.5%). This tailwater appeared to be somewhat uniform at all stations with respect to the abundance of organisms.

Presumably, several factors, including large and frequent fluctuations in water level and cold water temperatures throughout the year, restrict the benthic fauna to those organisms capable of withstanding these conditions. Moffett (1936) reported that abnormally high water levels reduced productivity by their scouring action upon the bottom and that rapid recovery was not present when streams were flooded periodically. The bottom fauna of a constant cold-water habitat, such

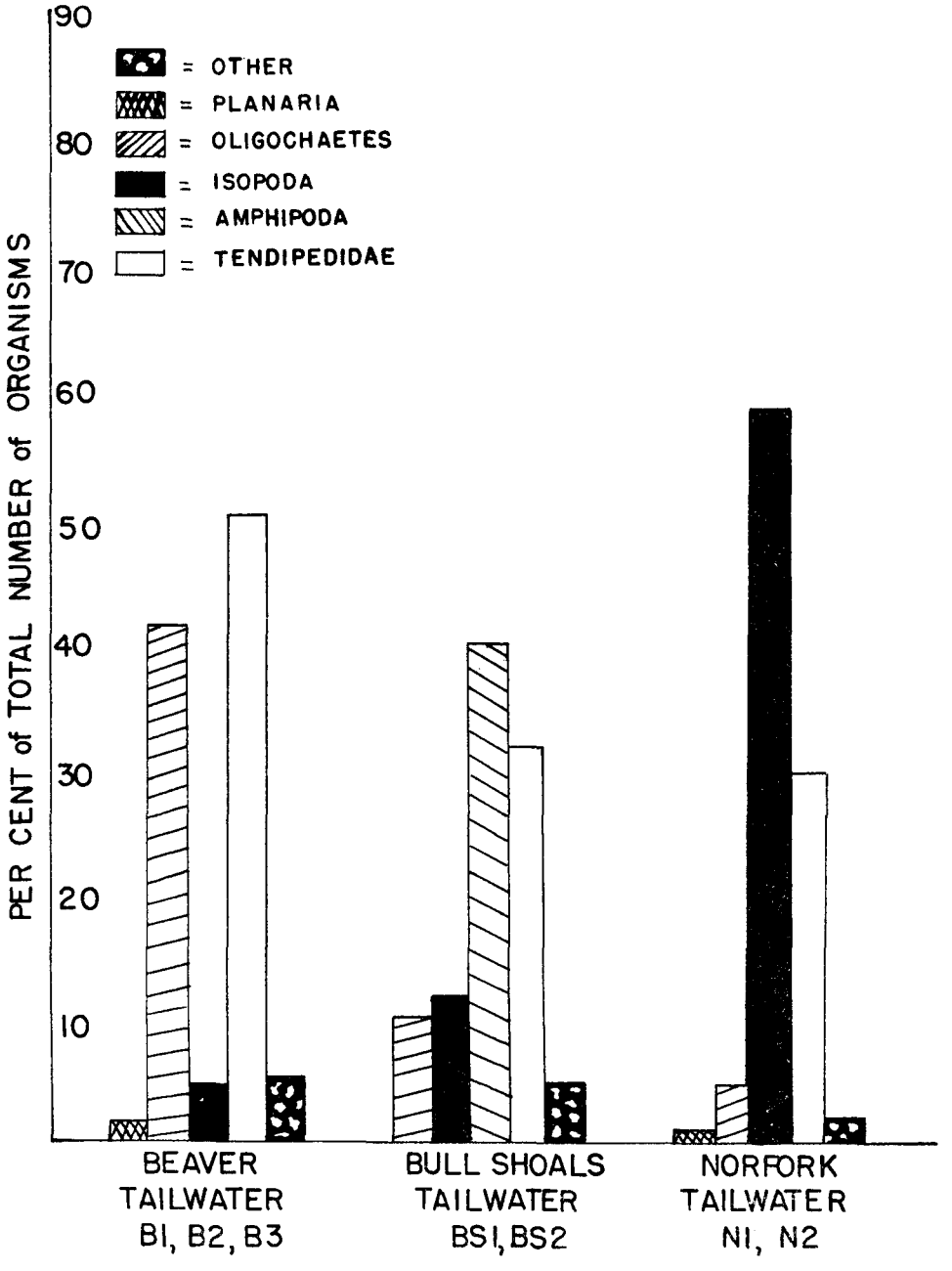


Figure 2. Percentages of dominant taxa of benthic macroinvertebrates occurring in the Beaver, Bull Shoals, and Norfork tailwaters.

as a cold spring, consists of few taxa; and two or more species are usually numerically dominant (Pennak, 1953).

The numbers of organisms and wet weights per sample from the collecting areas studied are presented as averages (Table III). The

TABLE III — AVERAGE NUMBER AND WET WEIGHT OF BENTHIC MACROINVERTEBRATES PER SAMPLE FROM EACH TAILWATER

| Tailwater | Avg. Number Per Sq. Ft. | Avg. Weight Per Sq. Ft. (grams) |
|---|---|---|
| Beaver | 78.2 | 0.136 |
| Bull Shoals | 73.5 | 0.327 |
| Norfork | 201.6 | 0.883 |

Norfork tailwater samples produced more organisms and a higher average wet weight per square foot than did other samples. The older age of the Norfork tailwater may be related to this, but aquatic vegetation is probably the important factor. Attached filamentous algae are present in large masses sometimes concealing the substrate. This provides both a place of attachment and a source of nutrients for benthic organisms. The Bull Shoals tailwater samples exhibited a considerably higher average wet weight but a lower average number of organisms than did the Beaver tailwater samples. This reflects the difference between the dominant taxa of the two tailwaters.

Several genera have been tentatively identified from the family Tendipedidae. These are *Cardiocladius, Cricotopus, Paratendipes,* and *Tendipes. Lirceus* and *Asellus* have been keyed from the Isopoda. *Gammarus* has been identified from the group Amphipoda.

## FISHES

Over 8,000 fishes, representing 38 species, were collected in the three tailwaters during the study. The species, their numbers, and percentages of the total number taken in each tailwater are given in Table IV. The species lists and percentages are more useful for making comparisons since unequal numbers of collections were made in each tailwater.

The species lists for the Beaver and Norfork tailwaters include 18 species each, and the list for the Bull Shoals tailwater includes 24 entries. Rainbow trout *(Salmo gairdneri)* can be added to the species lists for the Norfork and Bull Shoals tailwaters. The capture of trout was avoided in the interest of good public relations. Species that might be added to the list for the Beaver tailwater include carp *(Cyprinus carpio),* white bass (*Roccus chrysops*), and walleye (*Stizostedion vitreum*). Carp were observed in this tailwater in summer 1965, preceding the initiation of the study; but none has been encountered since then. Reports of local fishermen suggest that white bass and walleye move into the Beaver tailwater in late winter and spring even though none was collected in this investigation.

The ichthyofauna of each tailwater was distinct, but the fauna below Beaver Dam was the most unique. The fauna was characterized by a scarcity of cyprinids, with the exception of stonerollers *(Campostoma anomalum*), and an abundance of darters. Centrarchids appeared seasonally, having apparently moved upstream from Table Rock Reservoir. *Cottus bairdi* and *Notropis pilsbryi* were the more abundant species below Norfork Dam, and these two species plus *Notropis rubellus* comprised a large portion of the ichthyofauna below Bull Shoals Dam. *Cottus bairdi* has been reported in the vicinity of the Beaver Dam tailwater (Knapp, 1958; Keith, 1964), but it does not presently occur in this stream section. The restriction of *Cottus Bairdi* to cold-water situations (Robins, 1955) and its abundance below Norfork and Bull Shoals dams indicate that it is well suited for this type of environment.

Table IV. Species, Numbers, and Percentages of Fishes Taken in Each Tailwater

| Species | Beaver Tailwater | | Bull Shoals Tailwater | | Norfork Tailwater | |
|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % |
| Ichthyomyzon sp. | - | - | - | - | 1 | T[1] |
| Dorosoma cepedianum | 9 | 0.7 | - | - | - | - |
| Campostoma anomalum | 599 | 50.2 | 361 | 8.9 | 102 | 3.6 |
| Chrosomus erythrogaster | - | - | 2 | T | 90 | 3.2 |
| Dionda nubila | - | - | 173 | 4.2 | 5 | 0.2 |
| Hybopsis amblops | - | - | 20 | 0.5 | - | - |
| Hybopsis biguttata | - | - | - | - | 1 | T |
| Hybopsis dissimilis | - | - | 1 | T | - | - |
| Notemigonus crysoleucas | - | - | - | - | 1 | T |
| Notropis ariommus | - | - | 15 | 0.4 | 21 | 0.7 |
| Notropis boops | - | - | 272 | 6.7 | 3 | 0.1 |
| Notropis chrysocephalus | - | - | 5 | 0.1 | 3 | 0.1 |
| Notropis galacturus | 1 | 0.1 | 190 | 4.7 | 4 | 0.1 |
| Notropis greenei | - | - | 34 | 0.8 | - | - |
| Notropis pilsbryi | 3 | 0.3 | 892 | 21.9 | 667 | 23.8 |
| Notropis rubellus | - | - | 722 | 17.7 | 54 | 1.9 |
| Notropis whipplei | 1 | 0.1 | - | - | - | - |
| Pimephales notatus | - | - | 75 | 1.8 | - | - |
| Pimephales promelas | - | - | - | - | 3 | 0.1 |

**Table IV** continued

| Species | Beaver Tailwater | | Bull Shoals Tailwater | | Norfork Tailwater | |
|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % |
| Hypentelium nigricans | 4 | 0.3 | 1 | T | - | - |
| Ictalurus punctatus | 1 | 0.1 | - | - | - | - |
| Pylodictis olivaris | - | - | 1 | T | - | - |
| Fundulus catenatus | 2 | 0.2 | 17 | 0.4 | - | - |
| Fundulus olivaceous | 7 | 0.6 | - | - | - | - |
| Lepomis cyanellus | 1 | 0.1 | - | - | - | - |
| Lepomis macrochirus | 3 | 0.3 | - | - | - | - |
| Lepomis megalotis | - | - | 12 | 0.3 | - | - |
| Micropterus salmoides | 23 | 1.9 | - | - | - | - |
| Etheostoma blennioides | - | - | 6 | 0.1 | 1 | T |
| Etheostoma caeruleum | 391 | 32.8 | 93 | 2.3 | 2 | 0.1 |
| Etheostoma juliae | 4 | 0.3 | 1 | T | - | - |
| Etheostoma punctulatum | 1 | 0.1 | - | - | - | - |
| Etheostoma spectabile | 48 | 4.0 | - | - | - | - |
| Etheostoma zonale | - | - | 1 | T | - | - |
| Percina caprodes | 92 | 7.7 | - | - | 1 | T |
| Cottus bairdi | - | - | 1167 | 28.6 | 1840 | 65.7 |
| Cottus carolinae | 3 | 0.3 | 5 | 0.1 | 2 | 0.1 |
| Labidesthes sicculus | - | - | 10 | 0.2 | - | - |
| Totals | 1193 | 100.1 | 4076 | 99.7 | 2801 | 99.7 |

[1] T = less than 0.1% .

Previous faunal studies have shown that the upper White River has a rich and diverse ichthyofauna. Knapp (1958) collected 70 species and 2 hybrid combinations in a pre-impoundment survey of Table Rock Reservoir. A pre-impoundment survey of Beaver Reservoir yielded 72 species and 5 hybrid combinations (Keith, 1964). Direct comparisons are impossible since no collections were made in stream sections covered in this study, but a reduction of species below Beaver, Norfork, and Bull Shoals dams seems likely. Hogsuckers *(Hypentelium nigricans)*, redhorse suckers (*Moxostroma sp.*), green sunfish (*Lepomis cyanellus*, bluegill sunfish (*Lepomis macrochirus*), and longear sunfish (*Lepomis megalotis*) occurred in rotenone samples made below Norfork Dam in 1950 (Baker, 1959). These fishes may have disappeared from the tailwater.

The ichthyofaunas of the Beaver and Bull Shoals tailwaters exhibited a type of longitudinal succession. Species and average number of fish per collection increased downstream from the dams (Table V). This

TABLE V — NUMBER OF COLLECTIONS, FISH, AND SPECIES AND AVERAGE NUMBER OF FISH PER COLLECTION AT EACH STATION

| Tailwater | Station | No. of Collections | No. of Fish | No. of Species | Av. No. of Fish Per Collection |
|---|---|---|---|---|---|
| Beaver | $B_1$ | 30 | 113 | 8 | 3.8 |
| | $B_2$ | 45 | 237 | 11 | 5.3 |
| | $B_3$ | 42 | 843 | 14 | 20.1 |
| Bull Shoals | $BS_1$ | 20 | 188 | 6 | 9.4 |
| | $BS_2$ | 52 | 3,888 | 24 | 74.8 |
| Norfork | $N_1$ | 20 | 1,600 | 12 | 80.0 |
| | $N_2$ | 18 | 1,201 | 13 | 66.7 |

succession was more striking below Bull Shoals Dam. Only six species *(Campostoma anomalum, Notropis boops, Notropis pilsbryi, Etheostoma blennioides, Cottus bairdi,* and *Cottus carolinae)* were collected at station $BS_1$. Station $BS_2$ was 20 miles below the dam; the general increase in temperature and the leveling out of daily fluctuations in water level probably account for this increase in species and numbers.

Inadequate sampling in winter and spring somewhat obscured seasonal cycles. The appearance of centrarchids below Beaver Dam corresponded with an increase of both species and number in March, April and May. This was apparently a result of spawning movements from Table Rock Reservoir. Ripe stonerollers and darters were collected in March and April, and the young of these fishes appeared in May and June. Ripe cyprinids, darters, and sculpins were collected in the other two tailwaters in April and May with young appearing in June.

It is impossible to make absolute quantitative comparisons with available data, but the Beaver tailwater is the most sparsely populated. Differences in species composition and abundance among the tailwaters studied are probably due to complex ecological relationships. The ichthyofauna below Beaver Dam may come to resemble those of the Norfork and Bull Shoals tailwaters as it grows older.

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